

WHEELER RIDGE-MARICOPA WATER STORAGE DISTRICT
Kern County, California

REPORT
ON
INVESTIGATION
OF
PLANNED OPERATION AND MANAGEMENT
OF THE
WHITE WOLF GROUND WATER BASIN

BOOKMAN-EDMONSTON ENGINEERING, INC.
Bakersfield, California
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INTRODUCTION

Presented in this report are the results of an investigation of the planned operation and management of the White Wolf ground water basin. The study was conducted in accordance with a letter proposal by Bookman-Edmonston Engineering, Inc., dated June 6, 1974, and pursuant to subsequent authorization by the District Board of Directors on July 10, 1974.

The Wheeler Ridge-Maricopa Water Storage District has contracted through the Kern County Water Agency for water from the California Aqueduct. This contract provides for a buildup in deliveries to the year 1990, after which 263,200 acre-feet of firm water and 39,700 acre-feet of surplus water are provided. The District has in turn entered into contracts with its landowners for a total of 274,300 acre-feet. These landowner contracts provide for both Schedule 1 and Schedule 2 water, the former being each landowner's share of the District's firm water entitlement and the latter being each landowner's share of the surplus water.

The objective of this investigation was to develop, on a reconnaissance level, information on the practicability of operating the White Wolf basin through a program of ground water replenishment and subsequent recovery of stored water by pumped extraction through wells. The accomplishments of such a program of basin operation could include the provision of supplemental water to:

- (1) Meet a possible projected deficiency in the summer peaking capacity of the California Aqueduct and the District system
- (2) Firm up the District's existing surplus water entitlement and possibly additional surplus water
- (3) Meet a portion of the District's delivery demand in the event of an emergency curtailment of deliveries from the California Aqueduct.

The investigational activity reported upon herein was performed by the firm of Bookman-Edmonston Engineering, Inc. in cooperation with, and assisted by, the staff of the Wheeler Ridge-Maricopa Water Storage District. Information on land use, water requirements and imported water deliveries was provided by the Arvin-Edison Water Storage District. It should be noted that a portion of lands overlying the White Wolf basin is within the Arvin-Edison District and activities of that District and its land-owners must be recognized in formulating a program of planned basin operation.

This report does not provide a definite plan, but the factors involved and possible alternatives for achieving the desired objectives are discussed and costs are estimated on a reconnaissance basis.

Results of this investigation are presented in the ensuing sections of this report under the following headings:

- Summary

- Ground Water Geology and Hydrology

- Surface Soils

- Water Quality

- Water Requirements

- Water Supply

- Hydrologic Balance

- Formulation of Plans for Basin Operation

- Considerations for Implementation of Basin Operation

SUMMARY

Presented following is a summary of the principal findings and conclusions of this investigation:

1. The White Wolf basin constitutes a ground water storage reservoir overlain by about 52,000 acres of valley floor land, of which about 33,000 acres are presently irrigated.
2. Permeable water-bearing deposits occur to a maximum depth of 2,000 feet and wells penetrating the aquifers within these deposits are highly productive, yielding water of satisfactory chemical quality for the continued irrigation of agricultural crops.
3. The basin is estimated to have contained over four million acre-feet of ground water in storage prior to agricultural development of lands overlying the basin. During the 30-year period 1945-1975, ground water storage has been depleted by about 1.5 million acre-feet, or an average of 50,000 acre-feet per year.
4. Surface soils in the basin are generally sandy and gravelly with little or no subsoil profile development. They exhibit rapid moisture absorption, good subsoil drainage and low water-holding capacity, all of which factors are favorable for relatively rapid infiltration of surface water for ground water replenishment.
5. It is estimated that delivery of full contractual quantities of imported surface water by both the Wheeler Ridge-Maricopa and Arvin-Edison Water Storage districts and completion of all planned agricultural development in the basin by 1980 will result in the elimination of ground water overdraft and should further result in a continuing accumulation of an estimated

13,000 acre-feet per year of ground water in storage.

6. California Aqueduct capacity allocations to the Kern County Water Agency and Wheeler Ridge-Maricopa Water Storage District are anticipated to constitute a restraint on delivery of water to the District during the three peak summer months, possibly by the early or mid-1980's and thereafter. A further possibility exists that surplus water may not be available in sufficient quantity during a series of dry years to allow the District to meet its Schedule 2 water commitments beyond about 1990.
7. Operation of the White Wolf basin through a program of ground water replenishment and subsequent pumped extractions of stored ground water could provide sufficient water to meet peak demands and "firm up" existing Schedule 2 water or possibly increase the level of firm water service.
8. Use of spreading basins constitutes the most practical and efficient of several methods available for ground water replenishment. Spreading facilities could be located adjacent to either the California Aqueduct or 850 Canal.
9. Deep wells for recovery of ground water could be located adjacent to or northerly of the 850 Canal. Wells drilled to an average depth of 1250 feet and equipped with properly sized pump and motor equipment would be capable of producing about four cubic feet per second of water each.
10. Costs associated with imported water charges and construction and operation of recharge and recovery facilities, rather than physical limitations imposed by geological or hydrological conditions, would appear to determine the feasibility of operating the White Wolf basin.
11. As an illustrative example of alternatives considered in this report, water spreading at a rate of 126 cfs and extraction of ground water at a maximum rate of 96 cfs would be

required to meet peak demands and maintain firm water service under existing Schedule 1 and Schedule 2 contract commitments (274,300 acre-feet per year). Total capital costs are estimated to be about \$3.3 million and annual costs to maintain this level of service, including operation and maintenance of facilities, are estimated to be \$175,000.

12. Variable (pumping) costs for surplus water available from the Kern County Water Agency are estimated to average about \$13 per acre-foot (reflecting both Agency and District variable charges) canalside at either Reach 16 of the California Aqueduct or the District's 850 Canal.

GROUND WATER GEOLOGY AND HYDROLOGY

The occurrence and availability of ground water is governed by subsurface geologic conditions, by the replenishment, movement and storage of ground water within permeable geologic deposits and by the pattern and magnitude of extractions. Presented following is a discussion of the geologic and hydrologic conditions which determine the character of the ground water supply in the White Wolf basin.

Geology

Geologic units associated with the White Wolf basin consist of three principal groups: (1) crystalline basement rocks; (2) consolidated marine and continental sedimentary deposits; and (3) unconsolidated to semi-consolidated continental deposits. Shown on Plate 1 are two generalized geologic sections extending through the White Wolf basin in a northwest to southeast alignment.

Rocks of the basement complex and the consolidated continental

and marine sedimentary deposits are relatively impermeable and are of little or no hydrologic significance as they are generally deeply buried and contain connate water of unusable chemical quality. In areas around the periphery of the White Wolf basin where marine deposits are found at shallow depths, saline connate water in these materials has often been flushed out and replaced with fresh water; however, owing to the low permeability of these deposits, well yields are generally too low to be a factor in ground water production. The top of the marine deposits is marked by the generally oil-bearing sands of the Santa Margarita formation and an overlying transition zone within the Kern River-Chanac formation.

Continental deposits of Tertiary and Quaternary age constitute a ground water reservoir within the White Wolf basin. The older continental deposits of the Kern River-Chanac formation were deposited primarily on alluvial fans bordering the mountain areas similar to the manner in which alluvial fan deposition occurs today. Thus, an accurate differentiation between older Tertiary continental deposits of the Kern River-Chanac formation and Quaternary alluvium cannot be made on the basis of well log reports. However, the older and usually deeper deposits are generally more consolidated, less permeable and often exhibit the effects of structural deformation resulting from fault activity more prominently than shallower alluvial deposits.

The Kern River-Chanac formation consists generally of lenticular strata of slightly consolidated sand, silt, clay and gravel extending to a maximum depth of 6,000 feet within the basin. The lower portion of the formation exhibits a predominance of sandy siltstone and clay with lenses of sand and gravel, thus the permeability of the deeper materials is greatly reduced. Available electrical logs show a rather abrupt change in lithologic character and permeability of deposits within the Kern River-Chanac formation. Shown on Plate 2 are contours of equal depth to the base of permeable deposits which comprise the principal aquifer system in the

White Wolf basin. As indicated, these aquifer materials reach a maximum depth below ground surface of over 2,000 feet in the extreme northwest portion of the basin near the White Wolf fault.

Surface and near-surface younger alluvial deposits underlying much of the White Wolf basin consist of interstratified and discontinuous beds of gravel, sand, silt and clay derived from the granitic and metamorphic rocks in the adjacent Tehachapi Mountains. The deposits are coarsest near the apexes and on the upper slopes of the alluvial fans of Salt, Tecuya, Grapevine, Pastoria, Tunis, El Paso and Tejon creeks.

The White Wolf ground water basin is separated from the main San Joaquin Valley ground water basin by the White Wolf fault which, as shown on Plate 2, extends southwesterly from Comanche Point to Wheeler Ridge. As further shown on the geologic sections (Plate 1), the White Wolf fault plane dips steeply to the southeast and has displaced and offset the basement complex, consolidated marine deposits and most probably the deeper Tertiary and Quaternary continental deposits. Displacement of permeable strata has created a barrier to the movement of ground water, and as such constitutes a convenient hydrologic boundary. A boundary condition has also been created by the Springs fault along the east side of the basin. The boundary for the remaining portion of the White Wolf ground water basin is delineated by the extent of alluvial deposits around the periphery of the basin. The area of the basin as delineated covers about 52,000 acres.

Occurrence of Ground Water

As stated, permeable continental deposits comprising the upper portion of the Kern River-Chanac formation and overlying alluvial deposits constitute the water-bearing materials of the White Wolf basin. The base of fresh water occurs at depths ranging from about 1200 to 2500 feet, below which brackish or saline water is normally encountered.

Ground water is unconfined or semiconfined to depths penetrated

by existing water wells. Most water wells are constructed and perforated in a manner that provides a composite hydraulic response from all aquifer systems penetrated by the well. However, water level information available from test wells and wells of varying depths indicates a substantial degree of vertical hydraulic continuity between different depth zones. No continuous confining clay strata in either the shallow alluvium or deeper permeable deposits of the Kern River-Chanac formation can be traced from existing well log information.

Production characteristics of water wells in the White Wolf basin indicate a relatively high permeability of water-bearing strata. The uniform water level response in wells and the relatively flat hydraulic gradient throughout the basin provide further indication of moderate to high aquifer permeability. Presented on Plate 3 are contours of equal elevation of ground water in wells as measured during January 1975. Shown on Plate 4 are contours of equal depth to ground water in wells for the same period of time.

Recharge and Movement of Ground Water

Natural recharge to ground water in the White Wolf basin is obtained primarily as percolation from several streams flowing onto the alluviated valley floor from the tributary watershed areas. Very little replenishment to ground water is considered to occur from precipitation falling on the valley floor area, since most of the available "effective precipitation" is consumed to satisfy soil moisture deficiencies or to meet agricultural consumptive use requirements.

Previous estimates of runoff reaching White Wolf basin prepared by this firm indicate an average of 7,000 acre-feet per year is available for ground water replenishment. The foregoing value was derived from analyses of partial gaging station records available for Grapevine, Pastoria, and El Paso creeks and from comparison and correlation of watershed

characteristics of the aforementioned streams with other ungaged streams tributary to the basin.

Although small amounts of subsurface inflow may enter the basin across the Springs fault, the magnitude of this source of ground water replenishment is not considered to be significant. Possible small quantities of subsurface flow from adjacent basement or consolidated marine rocks are similarly of insufficient magnitude to be considered.

As demonstrated by contours of equal ground water elevation depicted on Plate 3, ground water moves generally northward to the White Wolf fault. Water levels in wells show that the White Wolf fault acts as a barrier to the continued northward movement of ground water into the main San Joaquin Valley basin. Ground water levels in deep wells south of the fault zone are in excess of 100 feet higher than those north of the fault. This barrier effect, as previously stated, appears to have resulted from displacement of permeable aquifers along the fault and possible cementation of fine-grained materials within the buried fault zone. Very little water moves across the barrier, and in subsequent analyses presented in this report it was assumed that there is no subsurface flow across the White Wolf fault.

Ground Water Storage

Estimates were made of the volume of ground water contained in the principal aquifer system within the Kern River-Chanac formation and overlying alluvial deposits. Storage capacity of unconfined water-bearing deposits can be estimated by multiplying the total volume of deposits by the specific yield of those deposits. Specific yield, expressed as a percentage, is the ratio of the volume of water that can be drained by gravity from the deposits to the total volume of the deposits.

A ground water storage unit covering nearly 28,000 acres within the White Wolf basin was defined for the purpose of estimating the volume

of unwatered storage and of remaining ground water in storage. The boundaries of the storage unit as shown on Plate 2 encompass a substantially smaller area than the edge of surficial alluvial deposits which marks the ground water basin boundary as conventionally established. Two factors require a reduction in the area of the basin for evaluation of ground water storage: (1) water bearing deposits around the periphery of the basin are normally thin and are usually dewatered; and (2) ground water in peripheral deposits is generally of marginal to unsuitable chemical quality. Accordingly, the storage unit is bounded by the White Wolf fault on the north, Interstate 5 on the west and by the California Aqueduct on the south. The easterly boundary is established to generally coincide with the depth contour which represents a 750-foot depth to the base of the principal aquifer system as shown on Plate 2.

Prior investigations by the U. S. Geological Survey and California Department of Water Resources on the character of water-bearing deposits in the San Joaquin Valley included classification of these deposits according to their specific yield. There is summarized in Table 1 the weighted average specific yield of water-bearing deposits in the White Wolf basin for depth intervals of 100 feet below the historic high ground water level experienced during the mid-1940's prior to initial construction of wells and extraction of ground water to provide irrigation of newly developed agricultural lands. As shown, averages vary from a maximum of 17.6 percent to a minimum of less than ten percent, with the weighted average for all depth zones throughout the entire storage unit estimated to be 13.3 percent.

Application of appropriate specific yield values to the computed volume of water-bearing materials which have been unwatered since the mid-1940's indicates that the White Wolf basin has experienced a depletion in ground water storage on the order of 1.5 million acre-feet during the approximate 30-year period, 1945-1975, or an average of 50,000 acre-feet per year.

The total volume of fresh water remaining in storage within the principal aquifer system was computed to be about 2.5 million acre-feet. Thus, it is indicated that nearly 40 percent of the total available storage of about 4.0 million acre-feet has been utilized at the present time.

TABLE 1

ESTIMATED AVERAGE SPECIFIC YIELD
FOR DEPTH ZONES IN WHITE WOLF BASIN

Depth Zone Below Ground Surface (feet)	Weighted Average Specific Yield (percent)
200-300	11.8
300-400	16.1
400-500	15.4
500-600	17.6
600-700	15.4
700-800	10.3
800-900	15.2
900-1,000	13.2
1,000-1,250	9.9
Below 1,250	8.8
Weighted Average for all Depth Zones	13.3

SURFACE SOILS

Soils developed on the extensive alluvial fans in the White Wolf basin have been largely included in the San Emidio series as reflected in surveys conducted by the U. S. Department of Agriculture and University of California. A less extensive area of the basin is covered with soils included in the Cajon series. The remaining soils types include Hesperia-Hanford, Tehachapi-Placentia, Panoche, Riverwash and Rock Land associations, most of which cover relatively small areas along the easterly and southerly edges of the basin.

San Emidio and associated Hesperia soils occur generally adjacent to the Pastoria Creek channel and extend northward to the White Wolf fault as shown on Plate 5. These soils are loose, normally sandy and gravelly, light-colored with no subsoils development and are derived from mixed granitic and sedimentary rock materials which occur in the southern Tehachapi Mountain watershed areas tributary to the basin. San Emidio soils exhibit rapid moisture absorption, good subsoil drainage and low water-holding capacity; thus, their infiltration characteristics appear to be highly favorable for consideration as possible sites for ground water recharge facilities.

Cajon soils similarly include light-colored soils accumulated on alluvial fans and in stream channels but are derived only from granitic rock sources. Cajon and associated soils, as shown on Plate 5, occur adjacent to Grapevine Creek generally south of Laval Road and adjacent to Tunis and El Paso creeks in the easterly portion of the basin. These soils exhibit no profile development, have a very low water-holding capacity and good internal drainage, thus providing favorable infiltration rates for ground water replenishment from surface water.

Panoche soils are medium-textured, well-drained alluvial materials developed from sedimentary rocks. A thin strip of Panoche occurs along the easterly portion of the basin but is not sufficiently widespread

to be a factor in possible plans for operation of the basin to maximize its ground water production potential. Hesperia-Hanford and Tehachapi-Placentia soils associations similarly are found along the easterly edge of the White Wolf ground water basin, but since both are located outside of the ground water storage unit boundary neither is considered significant with respect to ground water replenishment activities.

The coarsest-grained and, therefore, most permeable surface soils occur as riverwash material along banks and channels of tributary streams entering the basin, principally Grapevine and Pastoria creeks. The principal source of ground water recharge occurs from seepage of streamflow in the upper reaches of these stream channels. Occasional overflow from these channels allows water to spread out onto adjacent permeable soils and provides additional infiltration. Any plan to conjunctively operate the White Wolf ground water basin should recognize the locations of riverwash materials as representing natural intake areas, and, as such, would be the most desirable sites for ground water replenishment.

WATER QUALITY

Sources of water supply presently or potentially available for use in the White Wolf basin include: (1) tributary surface inflow; (2) ground water; (3) the California Aqueduct; and (4) the Kern River through a proposed intertie with the California Aqueduct near Tupman. Presented in the following sections of this report are brief summaries of the chemical quality of those water supplies.

Tributary Surface Inflow

Ground water in the White Wolf basin reflects the quality of surface water entering the basin as tributary surface inflow. El Paso, Tunis, Pastoria, Grapevine and Tecuya creeks are considered transitional streams, with respect to chemical composition of water, between those flowing from

the Sierra Nevada and those from the San Emigdio and Temblor ranges to the west. Presented in Table 2 are available mineral analyses of tributary surface flows entering the basin. As shown, the concentrations of dissolved solids increase from east to west, ranging from an indicated 288 parts per million (ppm) for El Paso Creek to 2,440 ppm for Tecuya Creek. By comparison, waters from Sierra Nevada streams to the north show dissolved solids concentrations generally less than 100 parts per million.

Ground Water

Recently completed samplings of privately-owned wells in the White Wolf basin indicate total dissolved solids concentrations are less than 500 ppm and electrical conductivity values are less than 700 micromhos (micromhos = mhos $\times 10^6$) over a large area of the basin. However, dissolved solids concentrations of ground water in the southwesterly portion of the basin exceed 1,000 ppm, reflecting the influence of more highly mineralized surface flows from Tecuya and Salt creeks which recharge the ground water. The area of relatively high salinity is reflected by contours of equal electrical conductivity as shown on Plate 5, and is indicated to extend a substantial distance east of Interstate 5.

It should be noted that most laboratories report water salinity in terms of both total dissolved solids (TDS) and electrical conductivity (EC). EC values are often more readily available since they can be conveniently and rapidly determined. The relationship between TDS and EC is: $EC \times 10^6 \text{ (micromhos)} \times K = \text{TDS (ppm)}$, where K has a value between 0.55 and 0.75 unless the water has an unusual chemical composition.

In accordance with criteria developed by the U. S. Department of Agriculture, water with an electrical conductivity value in excess of 750 micromhos would be classed as having a salinity hazard of high to very high. Sufficient data are not available with which to determine the rate of

TABLE 2

CHEMICAL ANALYSES OF SURFACE FLOWS
ENTERING WHITE WOLF BASIN
(values in ppm except as noted)

Name of Stream	El Paso Creek	Tunis Creek	Pastoria Creek	Grapevine Creek	Tecuya Creek
Date of Test	3/60	7/52	7/52	3/62	10/56
Flow in cfs	6	-	-	2	-
<u>Constituent</u>					
Calcium	51	78	57	56	304
Magnesium	16	22	22	61	106
Sodium	16	23	36	112	362
Potassium	1.6	2.8	3.2	0.4	-
Bicarbonate	192	220	218	386	940
Sulfate	56	80	100	243	1080
Chloride	8.5	23	26	48	55
Nitrate	1.2	2.3	2.5	1.9	1.6
Boron	-	0.3	0.9	-	1.0
EC (micromhos)	497	-	-	1154	3120
TDS	288	370	400	790	2440
Sodium percentage	16	15	25	38	39
pH	8.3	-	-	7.9	-

ground water movement in the Salt-Tecuya Creek area; however, maintenance of the prevailing hydraulic gradients in the basin will cause this body of more highly mineralized ground water to continue its northeasterly migration.

Presented in Table 3 are selected chemical analyses of water from wells in the White Wolf Basin. Concentrations of individual mineral constituents considered critical with respect to the suitability of water for agricultural application include chloride, sodium and boron. None of the foregoing are indicated to occur in concentrations which would render ground water in the basin unsuitable for agriculture.

California Aqueduct

Records of the quality of water available from the California Aqueduct are available for the four full calendar years 1971 through 1974. Presented in Table 4 are the average annual concentrations of mineral constituents as monitored on a monthly basis near the Buena Vista Pumping Plant (Check 29) for each of the four years.

It should be noted that the quality data shown for California Aqueduct water supplies are historical and that the mineral quality of these waters in future years cannot be precisely predicted. The water service contract between the Kern County Water Agency and the State of California contains provisions, in Article 19, to the effect that the State will make all reasonable effort to control the mineral constituents in the Aqueduct water at or below the limits indicated in Table 4.

It will be further noted that the long-term average TDS of 220 ppm shown in these objectives is generally lower than what has been experienced as shown previously for sampling at the Buena Vista Pumping Plant. The State and supporting organizations are currently expending extensive effort to obtain favorable resolution of the Delta diversion rights and also to implement construction of the Peripheral Canal. Favorable resolution

TABLE 3

SELECTED CHEMICAL ANALYSES OF WATER
FROM WELLS IN THE WHITE WOLF BASIN
(values in ppm except as noted)

Location	10/20-1	10/19/8A1	11/19-24M	11/19-27Q	12/19-35R
Date of Test	9/63	11/63	8/74	8/74	8/74
<u>Constituent</u>					
Calcium	134	64	50	60	45
Magnesium	35	34	12	15	10
Sodium	190	159	43	55	29
Bicarbonate	120	366	246	251	185
Sulfate	695	288	49	89	54
Chloride	50.3	31.9	12	30	4
Nitrate	4.2	1.25	3.7	1.8	10.6
Boron	0.25	0.36	0.31	0.3	0.09
EC (micromhos)	1780	1080	530	670	440
TDS	1532	828	299	381	249
Sodium percentage	46	54	35	36	29
pH	7.2	7.0	7.9	7.9	7.8

TABLE 4

CHEMICAL QUALITY
OF CALIFORNIA AQUEDUCT WATER

	Average Annual Concentrations of Mineral Constituents in California Aqueduct Water at Buena Vista Pumping Plant				State Contract Limits (Article 19)	
					Average for	
	1971	1972	1973	1974	Monthly Average	any 10-Yr. Period
EC (micromhos)	404	400	506	352	-	-
TDS (ppm)	232	240	297	197	440	220
Chlorides (ppm)	53	57	72	43	110	55
Sulfates (ppm)	41	35	55	34	110	20
Sodium (%)	45	48	51	46	50	40
Boron (ppm)	0.2	0.2	0.3	0.2	0.6	-

of these matters should make it possible for the State to meet the stated water quality objectives for the long-term future.

Although California Aqueduct water is of generally excellent quality for irrigation of crops, it has been demonstrated that infiltration of water through surface soils is greater with water having a relatively high salt content as compared to waters of very low salinity. Water from the California Aqueduct would provide an "intermediate" infiltration capability as compared with, for example, the poor soil penetration characteristic of Friant-Kern Canal water (TDS = 50 ppm) and good penetration achieved with local well water (TDS = 300⁺ ppm).

An evaluation of water quality with respect to ground water replenishment must include consideration of turbidity levels of surface supplies to be recharged. Suspended solids content of water in the California Aqueduct at Mile 243.00 (near Tupman) have been monitored by the Department of Water Resources at monthly intervals since September 1973. Five locations within the Aqueduct prism at Mile 243.00 are sampled in order to accurately reflect

a representative condition throughout the section. The average monthly values of suspended solids concentrations are tabulated following:

<u>Date</u>	<u>Suspended Solids in PPM</u>
9/18/73	34
10/16/73	21
11/13/73	21
12/18/73	29
1/15/74	11
2/19/74	31
3/19/74	16
4/16/74	16
5/14/74	21
6/18/74	42
7/16/74	76
8/20/74	37
9/17/74	26
10/15/74	16
11/19/74	25
12/17/74	18

The fluctuations in suspended solids content appear to be related to flow rates in the Aqueduct. The indicated high values can be attributed to increased scouring action occurring during high flow months. Continued operation of the Aqueduct should be expected to reduce the level of suspended solids to a maximum value of 30 ppm or less. Levels above this value are unacceptable for the successful conduct of water spreading activities.

Kern River

A proposed intertie between the California Aqueduct and the Kern River near Tupman provides an opportunity for flood waters from the Kern River to be introduced into the Aqueduct and eventually into the distribution system of the Wheeler Ridge-Maricopa Water District. There is presented in Table 5 a summary of the mineral quality of Kern River water near

TABLE 5

CHEMICAL QUALITY OF KERN RIVER WATER
(values in ppm except as noted)

<u>Constituent</u>	<u>Range</u>	<u>Average</u>
Calcium	7-64	15
Magnesium	1-24	3
Sodium	5-34	15
Potassium	1-3	2
Bicarbonate	6-125	71
Sulfate	0-33	19
Chloride	1-22	7
Boron	0.0-1.2	0.2
EC (micromhos)	63-308	167
TDS	21-189	107
Sodium percentage	14-51	38

Bakersfield, including both the average and the range in values of the various mineral constituents as determined from sampling and testing performed by the California Department of Water Resources.

As shown, Kern River water is of excellent chemical quality, although its relatively low salinity may result in reduced penetration into the soil. Results of tests conducted by the U. S. Department of Agriculture, Agricultural Research Service, at Minter Field near Shafter during 1953 and 1954 clearly indicated a major difference between infiltration rates using Kern River water and well water of substantially higher salinity. The ratio of the average infiltration rate of Kern River water to the average infiltration rate of well water was about 0.53 early in the tests and declined to about 0.42.

A second factor which may restrict the use of Kern River water for ground water replenishment is the occurrence of large quantities of suspended material. Quantitative measurements of Kern River water

turbidity are available during the high flow periods experienced during 1969. These observations indicate that flows in the river channel during rain floods and heavy releases of snowmelt runoff from Isabella Reservoir, which is the only time the intertie would be operated, carry total suspended solids concentrations substantially higher than would be acceptable for spreading operations. Measured values peaked at 490 ppm during periods of maximum river flow and concentrations were frequently observed to reach 100 ppm of suspended solids.

WATER REQUIREMENTS

Lands within the White Wolf basin are extensively developed to irrigated agriculture and are included within the boundaries and service areas of the Arvin-Edison Water Storage District as well as the Wheeler Ridge-Maricopa Water Storage District. Land use and crop surveys conducted by both districts during the summer of 1974 indicate the following areas of irrigated agriculture within the basin:

	<u>Gross Ac</u>
A-E WSD	21,680 (incl. overlap)
WR-MWSD	25,170 (incl. overlap)
Subtotal	<u>46,850</u>
Less Overlap	<u>-13,580</u>
Total	33,270

In addition to the presently irrigated area, approximately 14,000 acres in the southerly portion of the basin not now developed are scheduled to be placed under irrigation by 1980. Therefore, the total irrigated area in the White Wolf basin is anticipated to reach about 47,000 acres by 1980 and remain at that figure thereafter.

Unit values of consumptive use of applied water for crops in the southern San Joaquin Valley have been developed by the State Department of Water Resources and Agricultural Extension Service, University of California. Presented in Table 6 are the estimates of annual unit and total consumptive use of applied water for present crops and net irrigated acreages thereof in the White Wolf basin.

A rough check of the weighted average unit consumptive use of applied water was developed from records of surface water deliveries from both districts to landowners within the basin. These data indicate an average of 3.2 acre-feet of water per net acre per year is being applied to crops. A consumptive use value of 2.3 acre-feet per acre, as derived in Table 6, and a unit applied water value of 3.2 acre-feet per acre would indicate a present irrigation efficiency of 72 percent. Sprinkler irrigation is widespread and expectations have been expressed that irrigation efficiencies of up to 80 percent could ultimately be attained.

The present net water requirement in the White Wolf basin is estimated to be the consumptive use of applied water of 67,000 acre-feet per year. Development of an additional 14,000 acres to deciduous tree crops by 1980 would increase the future net water requirement to an estimated 108,000 acre-feet per year.

WATER SUPPLY

Water supplies to meet the indicated present and future water requirements in the White Wolf basin are presently and will continue to be available from pumped ground water supplemented by imported surface water delivered through the existing and proposed distribution systems of the Arvin-Edison and Wheeler Ridge-Maricopa Water Storage districts.

TABLE 6

PRESENT ANNUAL CONSUMPTIVE USE
OF APPLIED WATER BY IRRIGATED CROPS

<u>Irrigated Crop</u>	<u>Unit (feet)</u>	<u>Net Irrigated Area (acres)</u>	<u>Total (acre-feet)</u>
Alfalfa	3.3	310	1,020
Potatoes	1.5	3,360	5,040
Cotton	2.5	6,810	17,030
Barley	1.6	900	1,350
Sugar Beets	2.0	110	220
Deciduous Orchard	3.0	5,450	16,050
Grapes	2.4	8,800	21,120
Misc. Truck	1.5	3,740	5,610
Fallow	-	2,180	-
Weighted Ave. or Total	2.3	31,560	67,440

Presented in the following tabulation is a summary of contractual amounts of water to be delivered within the basin by each District under full project development.

	<u>Acre-feet per year</u>	<u>Percent of total</u>
A-E WSD	25,560	22.4
WR-MWSD	88,390	77.6
Total	113,950	100.0

It is assumed that the foregoing quantities of water will be delivered by 1980, although present water service contracts allow for a more extended development period. It should be noted that the total surface water supply of nearly 114,000 acre-feet includes both Schedule 1 and full Schedule 2 contract entitlements to be delivered by the Wheeler Ridge-Maricopa Water Storage District. If only firm water (Schedule 1) is assumed to be available in 1990 and thereafter, the available imported water supply for the White Wolf basin would be reduced by about 5,000 acre-feet per year to a total of about 108,800 acre-feet per year.

HYDROLOGIC BALANCE

The factors of water requirements and water supply developed in the preceding sections can be summarized in a computation of hydrologic balance to determine the response of the ground water basin under long-term conditions. Set forth in the following tabulation is the computed hydrologic balance in the White Wolf basin under conditions projected to occur in 1980 and beyond:

<u>Items of water supply</u>	<u>Values in acre-feet per year</u>
Tributary surface inflow	7,000
Projects delivery	114,000
Total water supply	121,000
<u>Items of water disposal</u>	
Net water requirement	108,000
<u>Supply minus disposal</u>	13,000

The above computation indicates that ground water storage in the White Wolf basin will be increased by 13,000 acre-feet per year under conditions anticipated to prevail in 1980 and thereafter.

FORMULATION OF PLANS FOR BASIN OPERATION

Operation of the White Wolf basin as a storage reservoir would necessarily involve replenishment of ground water from surplus waters when available from the California Aqueduct or other sources, and withdrawal from storage during periods when surplus waters would not be available or when deficiencies may occur. Presented in this section is a discussion of the objectives and an evaluation of the factors to be considered in formulating a plan for conjunctive operation of the basin.

Availability of California Aqueduct Water

Current projections by District staff indicate that sufficient California Aqueduct capacity will be available to meet the District's needs until the early or mid-1980's. The Department of Water Resources has advised the Kern County Water Agency that delivery of all contract entitlement water plus Contractors' estimates of surplus water can be made until 1985 without an aqueduct capacity limitation in the joint State-Bureau reach. The Department has further advised the Agency that surplus water can be delivered in quantities larger than had been scheduled by the member units with reasonable dependability until about 1990. It should be recognized that this advice is based upon operation of the Peripheral Canal by 1980, favorable decisions by the State Water Resources Control Board regarding required release of water to the Delta during dry years and favorable resolution of pending litigation.

The quantities of water required to replenish ground water storage are dependent upon the objective to be achieved through a program of planned basin operation. Numerous hydrological operational studies have been made by the Department of Water Resources of the State Water Project to determine the amounts and time of availability of surplus water.

For purposes of this investigation, the following conditions were assumed:

- (1) The critical period with respect to water supply would include a seven-year dry period similar to that which occurred from 1927-28 through 1933-34, and that sufficient water in storage must be available to meet the program objectives during that period.
- (2) The full amount of firm water (263,200 acre-feet) would be available to the District to meet all contract commitments during the critical period although it is recognized that there could be years when overall Aqueduct supplies would be deficient as provided in the water service contracts.
- (3) A four-year sequence of wet years would provide sufficient surplus water to accumulate the required carryover storage in the ground water basin.
- (4) The quantity of surplus water available for replenishment occurs under two conditions:
 - (a) During a four-month period extending from October 15 through February 15 when surplus water is available from the Kern County Water Agency at a current rate of \$2.00 per acre-foot plus the variable charge.
 - (b) During an eight-month period when the District will have capacity available in the California Aqueduct.

Objectives of Basin Operation

As stated previously in the Introduction to this report, the accomplishments of a program of basin operation could include: (1) augment surface water supplies to meet a projected deficiency in the summer peaking capability; (2) firm up the District's surplus water entitlement; and (3) provide a partial supply in the event of emergency reduction or curtailment of water deliveries from the California Aqueduct. Each of the foregoing is discussed in greater detail.

Augmentation of Peaking Capability

In a report prepared by the District's Engineer-Manager and submitted to the Board of Directors in June 1974, it was indicated that California Aqueduct capacity allocations to the District and Kern County Water Agency are limited and would constitute a restraint on the delivery of water to the District, particularly during the three peak months. It was further indicated that adequate Aqueduct capacity appears to be available until the early or mid-1980's.

The amount of peaking capability required depends on the monthly distribution of demand, which varies from year to year depending upon cropping patterns, weather conditions and irrigation practices. Historical peaks experienced by the District during June, July and August are shown following as a percentage of the annual demand:

	<u>Summer Peak Deliveries</u> <u>(percent of annual demand)</u>			
	<u>1971</u>	<u>1972</u>	<u>1973</u>	<u>1974</u>
June	14.2	14.1	19.0	17.0
July	16.3	18.2	19.4	18.4
August	14.2	12.8	14.4	15.3
Annual Delivery in 1000 Acre-feet	102.7	149.4	174.4	195.2

As shown, the most critical year was 1973 during which the monthly percent of annual demand was 19.0 in June and 19.4 in July. Weather was a factor, with a late spring and relatively hot summer, but it is anticipated that with full development of projected irrigated crops and with a larger acreage of mature, permanent crops, the monthly peaking percentage will not be as high during the summer. Although possibly imposing a more severe condition than will occur, it was assumed that the peaks experienced during 1973 would recur.

Presented in Table 7 is a summary of peaking requirements under four levels of total system demand. Shown therein for each of four conditions are required peaking capacities to meet the 1973 demand schedule experienced during the summer months, available California Aqueduct capacity, the deficiency in capacity which would be met through pumped extraction of ground water from storage and the required rate of ground water replenishment. The four levels of system demand are described more fully in the following paragraphs.

1. This condition would provide for meeting Schedule 1 peaking requirements only (263,200 acre-feet per year) with a repetition of the 1973 summer demand schedule. This would require pumping capability from wells at a rate of 60 cfs and the extraction of about 6,760 acre-feet during June and July to meet the indicated deficiency in Aqueduct capacity. Ground water replenishment at a rate of 28 cfs during a four-month spreading period would be required.
2. This condition would provide for meeting peaking equivalents of existing Schedule 1 and Schedule 2 contractual commitments, totalling 274,300 acre-feet per year, under 1973 peaking. This would require a ground water pumping capability of 96 cfs, and the extraction of about 11,000 acre-feet during June and July. Ground water replenishment at a rate of 46 cfs during a four-month spreading period would be required.
3. This condition would provide for meeting peaking requirements with delivery of 302,900 acre-feet, which would include the entire contract entitlement of the District's firm and surplus water from the Kern County Water Agency. A pumping capability of 186 cfs would be needed to meet the deficiency, resulting in the extraction of about 22,000 acre-feet during

TABLE 7

SUMMARY OF PEAKING REQUIREMENTS

System Demand (af/yr)	Required Capacity for Summer Peaking		Available Aqueduct Capacity		Deficiency		Required Ground Water ⁽⁸⁾ Replenishment	
	(cfs)	(af)	(cfs)	(af)	(cfs)	(af)	(cfs)	(af/mo)
263,200 ⁽¹⁾	833	101,069 ⁽⁵⁾	773	94,306 ⁽⁵⁾	60	6,763 ⁽⁵⁾	28	1700
274,300 ⁽²⁾	869	105,331 ⁽⁵⁾	773	94,306 ⁽⁵⁾	96	11,025 ⁽⁵⁾	46	2755
302,900 ⁽³⁾	959	116,314 ⁽⁵⁾	773	94,306 ⁽⁵⁾	186	22,008 ⁽⁵⁾	92	5500
337,300 ⁽⁴⁾	1074	178,473 ⁽⁶⁾	773	141,459 ⁽⁶⁾	301	37,014 ⁽⁶⁾	155	9250

(1) Schedule I water as per existing landowner contracts.

(2) Schedule I plus Schedule 2 water as per existing landowner contracts.

(3) All firm and surplus water available under KCWA contract. This includes Schedule 1 and Schedule 2 water plus 28,600 acre-feet of additional surplus water.

(4) Ultimate assumed system demand.

(5) For two-month summer peak - June and July.

(6) For three-month summer peak - June, July and August.

(7) To be met by ground water extraction.

(8) During a four-month replenishment period.

June and July. The required ground water replenishment could be achieved at a rate of 92 cfs during a four-month spreading period.

4. This would provide for meeting peaking requirements with delivery of about 337,000 acre-feet per year, this being the District's rough estimate of overall water requirements for lands within the District and possible annexations thereto. This condition would require a total ground water storage accumulation of about 37,000 acre-feet per year, a pumping capability of about 300 cfs and a ground water extraction from the basin of about 37,000 acre-feet during June, July and August. The required ground water storage could be accumulated during a four-month spreading period at a rate of 155 cfs.

The foregoing considerations are based on the assumption that the total annual system demand for each condition will be available from the California Aqueduct or some other source, and the ground water basin would be called upon to meet summer peaking requirements only.

Expansion of Firm Water Service

Use of the ground water basin to allow the District to meet its Schedule 2 commitment in a series of dry years and/or to contract with additional landowners for firm water delivery are considered for the four conditions of annual system demand as set forth in the previous section of this report. The requirements for accumulation of ground water storage and spreading capability are shown in Table 8 for each of the four conditions. The previously discussed seven-year critical period was employed to determine the order of magnitude of required carryover storage, and the annual quantities of surplus water available for spreading during the assumed four-year wet period were used to determine the rate of spreading needed.

TABLE 8

SUMMARY OF GROUND WATER STORAGE AND REPLENISHMENT
REQUIRED TO MAINTAIN FIRM WATER SERVICE

<u>System Demand</u> (af/yr)	<u>Additional Schedule 1 Water</u> (af/yr)	<u>Required Ground Water Storage⁽¹⁾</u> (af)	<u>Required Ground Water⁽²⁾ Replenishment</u>		
			(af/yr)	(af/mo)	(cfs)
263,000	0	0	0	0	0
274,300	11,100	77,700	19,200	4,800	80
302,900	39,700	277,900	69,400	17,300	288
337,300	74,100	518,700	129,700	32,400	540

(1) Calculated on basis of seven-year critical period of deficient water supply.

(2) Surplus water for ground water replenishment assumed to be available during four-year wet period. Recharge facilities would be operated during a four-month period in each of four wet years.

As shown in Table 8, imposition of the most severe conditions, whereby 337,000 acre-feet of firm water would be delivered annually, could require the spreading of up to 540 cubic feet per second if carried out within a four-month period. The ground water extraction rate to "firm up" Schedule 2 water would not exceed the rate required to augment peaking capability for similar conditions as indicated in Table 7, since a portion of ground water extraction required to maintain firm water service would be delivered during other than peak periods.

Unless another means such as surface storage is developed to handle peaking capacity problems, the amount of surplus water to be spread during years when it is available could equal the sum of the amounts shown in Tables 7 and 8 for each condition. This would be the case when additional summer Aqueduct capacity is not available, but there is an adequate supply of surplus water which can be delivered during the remainder of the year.

Provision for Service During Emergencies or Aqueduct Deficiencies

A portion of the District's water requirements could be met during emergency reduction or deficiency in firm water supplies available from the California Aqueduct. It is noted that deficiencies in annual firm water entitlements from the State would not occur until after nearly full use of Aqueduct entitlements by all Contractors as well as a recurrence of very dry years as were experienced during the critical period 1927-28 through 1933-34. In this report, no additional ground water replenishment or extraction capability was assumed to provide emergency service or meet firm water deficiencies over that needed to augment peaking capability or to increase firm water service.

Ground Water Recharge

Planned replenishment of ground water in the White Wolf basin could be accomplished by: (1) introduction of surface water into existing

stream channels through turnouts installed in the California Aqueduct; (2) utilization of abandoned, currently active or newly-constructed wells; (3) over-application of water on irrigated lands; (4) interim delivery of surplus water to areas remaining on ground water service; and (5) construction of spreading basins or ponds. Each of the five alternatives listed above is discussed in greater detail in the following sections.

Utilization of Existing Stream Channels

As stated previously in this report, natural replenishment of ground water in the White Wolf basin occurs primarily as percolation of stream flow which originates in tributary watershed areas and crosses permeable alluvial fan deposits. The coarsest-grained, and, therefore, more permeable soil materials are associated with existing stream channels and it is in these areas where maximum infiltration of surface water occurs.

Several factors can be identified which would limit utilization of existing stream channels for ground water replenishment: (1) planned development of presently native grassland to irrigated crops by Tejon Ranch Company will eliminate substantial portions of the presently identifiable channels of Grapevine and Pastoria creeks, as well as those smaller channels of numerous minor streams; (2) a major portion of the available Grapevine Creek channel, in excess of 500 acres, is located southerly and upslope of the California Aqueduct in the 1980 deferred service area and would require installed pumping capacity to deliver water from the Aqueduct to this reach of channel; (3) the relatively steep slope of the land surface would require substantial channel modification, in the form of checks or drop structures, to minimize or prevent erosion of surface soil materials, and (4) available channel reaches are located in areas where depths to ground water are the greatest in the basin and are relatively large distances from potential areas of ground water recovery.

It may be possible for the District to acquire lands adjacent to those channel reaches now developed to farming and thus overcome, in part, the limitations outlined in items (1), (2) and (4) above. Although these former channel lands tend to be less suitable for agriculture and would be anticipated to produce lower crop yields, the severance and disruption of present or planned farming operations may render their acquisition economically infeasible.

It is concluded that utilization of existing or former stream channels for ground water replenishment in the White Wolf basin does appear to offer a feasible method of accomplishing the required replenishment.

Recharge Wells

Wells are used for ground water recharge, but the method is normally employed for replenishment of confined aquifer systems. The overall costs of achieving replenishment through wells, including both initial capital outlay and subsequent operation and maintenance, are usually found to be much greater than for other alternatives.

Aside from initial capital costs of well construction, continuing costs for operation include required filtration and treatment of water to be recharged. Unless the recharge water introduced into the wells is sterilized by chlorine dosages, bacterial slimes and algae will form and clog the aquifers being recharged. Removal of suspended solids from recharge water by filtration is also generally necessary in order to minimize aquifer clogging.

A rough estimate of initial capital costs required to replenish ground water through recharge wells can be derived from the following. Acceptance rates are anticipated to range from one to two cubic feet per second per well, with a long-term average of one cfs considered to be feasible. Recharge wells would be drilled to an average depth of 1,000 feet at a cost of \$50 per foot. Thus, the estimated cost of recharge wells would be on the order of

\$50,000 per each cfs of recharge capacity.

It should be noted that the foregoing does not include required pipe conveyance and manifolding systems or pumping equipment for periodic well redevelopment. It should be further noted that it may be possible to utilize existing wells or wells constructed for recovery purposes, in part, for this purpose.

Over-Application of Water on Irrigated Lands

Replenishment of ground water through over-application of water on certain permanent crops during dormancy or during pre-irrigation of annual crops may be possible through joint District-Landowner cooperation. The magnitude of such recharge may be approximated by assuming 50 percent of the irrigated land in the basin can be included in such a program. Further assuming over-application at a rate of 12 inches per year, approximately 15,000 acre-feet per year of additional recharge results.

The many limitations inherent in the implementation of this type of planned ground water replenishment are apparent. Even under the most favorable conditions, the total recharge capability would not be sufficient to provide the minimum annual requirements for meeting system demands as set forth previously herein. Furthermore, the concept of over-application is contrary to generally acceptable modern farming practices, particularly in the White Wolf basin where drip irrigation techniques are being considered for existing and future development.

Delivery of Interim Water to Lands Remaining on Ground Water

The approximately 25,000 acres of presently irrigated District land within the White Wolf basin include 9,300 acres which will continue to rely on ground water as a source of water supply. Delivery of surplus water to these lands on an interim basis would in effect provide an increment of replenishment to ground water by reducing the net ground water extraction. This increment would be equal to the consumptive use of water applied to

lands with interim service and could reach a maximum of 21,000 acre-feet per year if all irrigated lands in the District were served.

It is apparent that required extensions of existing distribution systems to serve lands not under water service contracts would present severe design problems and increased system costs to provide such interim service. However, within a portion of the existing or planned distribution systems, interim service to certain lands may be practical.

Spreading Basins

Construction of percolation basins or ponds is generally the most practical and feasible method of artificially recharging unconfined aquifer systems, primarily because of relatively efficient use of space and ease of maintenance. Many factors control the rate at which water will enter the soil, but the wetted area, soil characteristics and length of time water remains in contact with the soil are the most significant.

As described previously in this report, surface soils in the White Wolf basin exhibit generally satisfactory characteristics for ground water replenishment by infiltration of surface water. Constraints imposed by cultural development and topography would appear to govern the type of spreading basin facility which might be constructed. The availability of a water supply source in reasonable proximity to the recharge site or sites is also an important consideration.

In view of the foregoing, it would appear that areas adjacent to the California Aqueduct and 850 Canal alignments offer the most favorable locations for construction of spreading basins. The extreme depth to ground water (1,000 feet) and the extended distance to probable recovery well sites render the California Aqueduct area a less desirable recharge site than areas adjacent to the 850 Canal, although surface soils along the California Aqueduct exhibit generally higher infiltration rates. On Plate 5 are delineated several sites, covering a total area of over 1,100 acres, which appear to be favorable for location of spreading basins.

Presented in Table 9 are estimated costs for ground water recharge facilities in the White Wolf basin under four conditions of system demand. Shown therein are required rates of ground water recharge, required areas for spreading grounds construction, land acquisition costs computed at \$1,000 per acre, construction costs based on estimated current prices of \$2,500 per acre and total capital costs.

Annual costs of debt service for capital repayment are also shown in Table 9. Repayment of capital costs was assumed to occur over a 20-year period, 1980-2000, with an interest rate of eight percent per annum. As indicated, annual costs for debt service range from about \$21,000 to \$495,000. As further indicated, the total estimated capital costs of spreading grounds acquisition and construction could range from slightly over \$200,000 to a maximum of about \$4.9 million.

Estimated annual operation and maintenance costs associated with spreading basins for ground water recharge required to meet the four levels of system demand are also shown in Table 9. These estimated O&M costs are indicated to range from \$24,000 to about \$160,000 per year.

Total annual costs for ground water recharge facilities in the White Wolf basin are estimated to range from \$45,000 for the lowest level of system demand (263,200 acre-feet per year) to slightly over \$650,000 for the maximum level of system demand considered in this report (337,300 acre-feet per year).

Ground Water Recovery

Construction of deep, gravel-packed wells, or use of existing wells where available, appears to be feasible for the recovery of ground water replenished through planned operation of the White Wolf basin. The most efficient locations for the subject wells, both from the standpoint of ground water recovery and integration into the District distribution system, would be adjacent to or in close proximity to existing pipe laterals running northerly from the 850 Canal, or along the 850 Canal itself.

TABLE 9

ESTIMATED COSTS FOR
GROUND WATER RECHARGE FACILITIES
IN WHITE WOLF BASIN

System Demand (af/yr)	Required Recharge (cfs)	Required Spreading Grounds (acres)	Capital Costs in \$1000			Annual Costs in \$1000		
			Land	Construction	Total	Debt Service	O&M	Total
<u>263,200</u>								
Provide Peaking	28	60	60	150	210	21	24	45
Provide Firm Supply	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
Total	28	60	60	150	210	21	24	45
<u>274,300</u>								
Provide Peaking	46	100	100	250	350	36	29	65
Provide Firm Supply	<u>80</u>	<u>160</u>	<u>160</u>	<u>400</u>	<u>560</u>	<u>57</u>	<u>33</u>	<u>90</u>
Total	126	260	260	650	910	93	62	155
<u>302,900</u>								
Provide Peaking	92	190	190	473	665	68	35	103
Provide Firm Supply	<u>288</u>	<u>580</u>	<u>580</u>	<u>1,450</u>	<u>2,030</u>	<u>207</u>	<u>68</u>	<u>275</u>
Total	380	770	770	1,925	2,695	275	103	378
<u>337,300</u>								
Provide Peaking	155	310	310	775	1,085	110	45	155
Provide Firm Supply	<u>540</u>	<u>1,080</u>	<u>1,080</u>	<u>2,700</u>	<u>3,780</u>	<u>385</u>	<u>114</u>	<u>499</u>
Total	695	1,390	1,390	3,475	4,865	495	159	654

The foregoing criteria would require wells to be located generally within one mile of the 850 Canal. Wells would be drilled to an estimated average depth of 1,250 feet and equipped with 400 horsepower motors to produce four cfs of water. Pump settings would extend to a maximum depth of 800 feet. The total cost per well, including well construction and furnishing and installing a pump and motor, is estimated to be on the order of \$100,000 at current price levels.

The indicated deficiencies in peaking capacity for the four conditions described previously range from 60 to 301 cfs, requiring from 15 to 75 wells of four cfs capacity each. Thus, the estimated total capital cost for recovery wells would range from 1.5 to 7.5 million dollars.

Estimates were made of ground water production costs which would be experienced to meet peaking demands and maintain firm water service under the four levels of system demand. Presented in Table 10 are both annual and per acre-foot costs of ground water production. Included in these estimates were annual fixed costs of plant depreciation, interest on invested capital, operation, maintenance and replacement and variable costs (power). Wells were assumed to have a useful life of 20 years and pumps and motors 10 years, and costs would be recovered over these periods. Interest on invested capital would be eight percent per annum. The current (effective January 1, 1975) Pacific Gas and Electric Company Schedule No. PA-1 for agriculture power was used to calculate power costs.

As shown in Table 10, total annual ground water production costs range from about \$300,000 to meet peaking requirements for the District's Schedule 1 contractual commitment of 263,200 acre-feet per year, to about \$2.1 million to provide peaking and maintain firm water service under a maximum system demand of 337,300 acre-feet per year. It is further shown that unit costs of ground water production decline from an estimated \$47 per acre-foot under the minimum system demand to \$28 per acre-foot under the maximum demand considered. It should be recognized that the foregoing

TABLE 10

ESTIMATED GROUND WATER PRODUCTION COSTS
IN WHITE WOLF BASIN

	System Demand (af/yr)			
	<u>263,200</u>	<u>274,300</u>	<u>302,900</u>	<u>337,300</u>
Required Ground Water Extraction (af/yr)	6,763	11,100	39,700	74,100
Maximum Pumping Capacity (cfs)	60	96	186	301
Required Number of Wells	15	24	47	75
Total Capital Costs (\$1,000)	\$ 1,500	\$ 2,400	\$ 4,700	\$ 7,500
Annual Costs Per Well				
Fixed	\$12,000	\$12,000	\$12,000	\$12,000
Variable (Power)	9,140	9,240	14,240	16,090
Total	21,140	21,290	26,240	28,090
Total Annual Costs (x 1000)	\$317	\$511	\$1,233	\$2,107
Cost per Acre-Foot	\$47	\$46	\$31	\$28

estimates of unit ground water production costs have little significance as such, but must be evaluated in terms of their effect on the total cost of water service when integrated into the District's overall program. Such an economic analysis has not been included herein.

CONSIDERATIONS FOR IMPLEMENTATION
OF BASIN OPERATION

Although the objective of this investigation was to develop reconnaissance level information on plans for operating the White Wolf basin, certain operational factors and considerations should be recognized and

evaluated with respect to the implementation of an operational plan. Presented in this section of the report is a discussion of these considerations.

Accumulation of Ground Water Storage

As indicated previously in this report, adequate capacity is anticipated to be available in the California Aqueduct to meet the District's delivery and peaking demands until the early or mid-1980's and it appears that surplus water can be delivered in quantities greater than contractual amounts with reasonable dependability until 1990 or possibly longer.

Several alternative operational plans are available for consideration. For example, ground water replenishment activities could be initiated in the White Wolf basin and construction of wells be deferred until such time as surplus water is no longer available in sufficient quantity to meet the demands of the District. Provision of spreading grounds to replenish underground storage at a continuous rate of 100 cfs, for example, could be expected to result in the accumulation of up to 50,000 acre-feet per year, assuming surplus water would be available at a reduced cost from the Kern County Water Agency for ground water recharge during an eight-month period. This offers the obvious potential for a significant and substantial buildup in ground water storage prior to the time such storage would be required to augment available Aqueduct capacity. This level of ground water replenishment could be achieved by utilization of about 200 acres of spreading grounds and would further offer an opportunity to evaluate the response of ground water levels in the basin prior to the time when planned extractions would be required to maintain the District's firm water service commitments.

Immediate initiation of recharge operations and accumulation of ground water storage would result in some degree of economic benefit to those lands remaining on ground water, both in the Arvin-Edison and Wheeler Ridge-Maricopa Water Storage districts. It should be noted that when both

districts achieve full project deliveries, ground water in storage will increase by an estimated 13,000 acre-feet per year. It is further noted that about 3,000 acre-feet per year of the foregoing ground water storage accumulation is attributable to importations of Central Valley Project water to the White Wolf basin through the Arvin-Edison distribution system.

Utilization of Water

The 850 System service area of the Wheeler Ridge-Maricopa Water Storage District includes the 850 Canal and four main distribution laterals which provide a capability to meet the District's contractual commitment to deliver approximately 44,400 acre-feet per year of Schedule 1 and Schedule 2 water to about 14,800 acres within the White Wolf basin. The peak month demand in the 850 System, assuming a recurrence of the summer peak deliveries experienced during 1973, would be 8,400 acre-feet, or 140 cfs.

Operation of the White Wolf basin to provide more than 140 cfs for peaking capability would necessarily require the "export" of water from the 850 System service area in order to increase the peaking capability. In order to do this, it may be possible to reverse the flow from the 850 Canal into 10P Lateral and back to the California Aqueduct, thereby achieving up to about 186 cfs which is the previously estimated amount of peaking capacity necessary for the entire District system when delivering up to 300,000 acre-feet per year in the service area. It is further recognized that future development of lands in the southerly portion of the basin could provide the opportunity to develop additional capacity, but these lands overlies ground water at depths in excess of economic pumping lifts and would require facilities to convey water from recovery wells located adjacent to or northerly from the 850 Canal.

As previously indicated in Table 7, 96 cfs of additional peaking capacity would be required to meet a total system demand of 274,300 acre-feet per year and 186 cfs would be required for a system demand of 302,900

acre-feet per year. It is apparent, therefore, that 140 cfs of additional peaking capability available through operation of the White Wolf basin, without export from the 850 System service area, would be sufficient to satisfy a total system demand of about 288,000 acre-feet per year, assuming a recurrence of 1973 peaking requirements.

Cost and Availability of Water for Spreading

The complexity of the District's contract with the Kern County Water Agency and possible changes in the Agency's pricing policy for surplus water make it difficult to accurately determine the cost to deliver California Aqueduct water to the White Wolf basin for ground water replenishment. Studies required to derive these costs do not fall within the scope of this investigation; however, the following considerations serve to indicate the options which may be available to the District.

As previously stated in the Introduction to this report, the District's contract with the Agency provides for 39,700 acre-feet of surplus water after 1990. When available, this water may be taken by the District by payment of State variable (pumping) costs only. Current Agency policy provides for delivery of surplus water for ground water replenishment during a four-month period extending from October 15 through February 15 at a rate of \$2.00 per acre-foot plus variable charges. Possible modification of this policy, whereby surplus water would be available for ground water replenishment over an eight-month period, for example, would provide a substantially greater opportunity for the District to effectively implement a plan for the conjunctive operation and management of the White Wolf basin.

Presented in Table 11 are estimated variable costs for California Aqueduct water from both the District's 850 Canal and Reach 16 of the Aqueduct for the years 1975 through 1990. As shown, the variable costs are about equal through the period, indicating that it makes little difference from a cost standpoint whether ground water replenishment facilities are located along the 850 Canal or Reach 16 of the California Aqueduct.

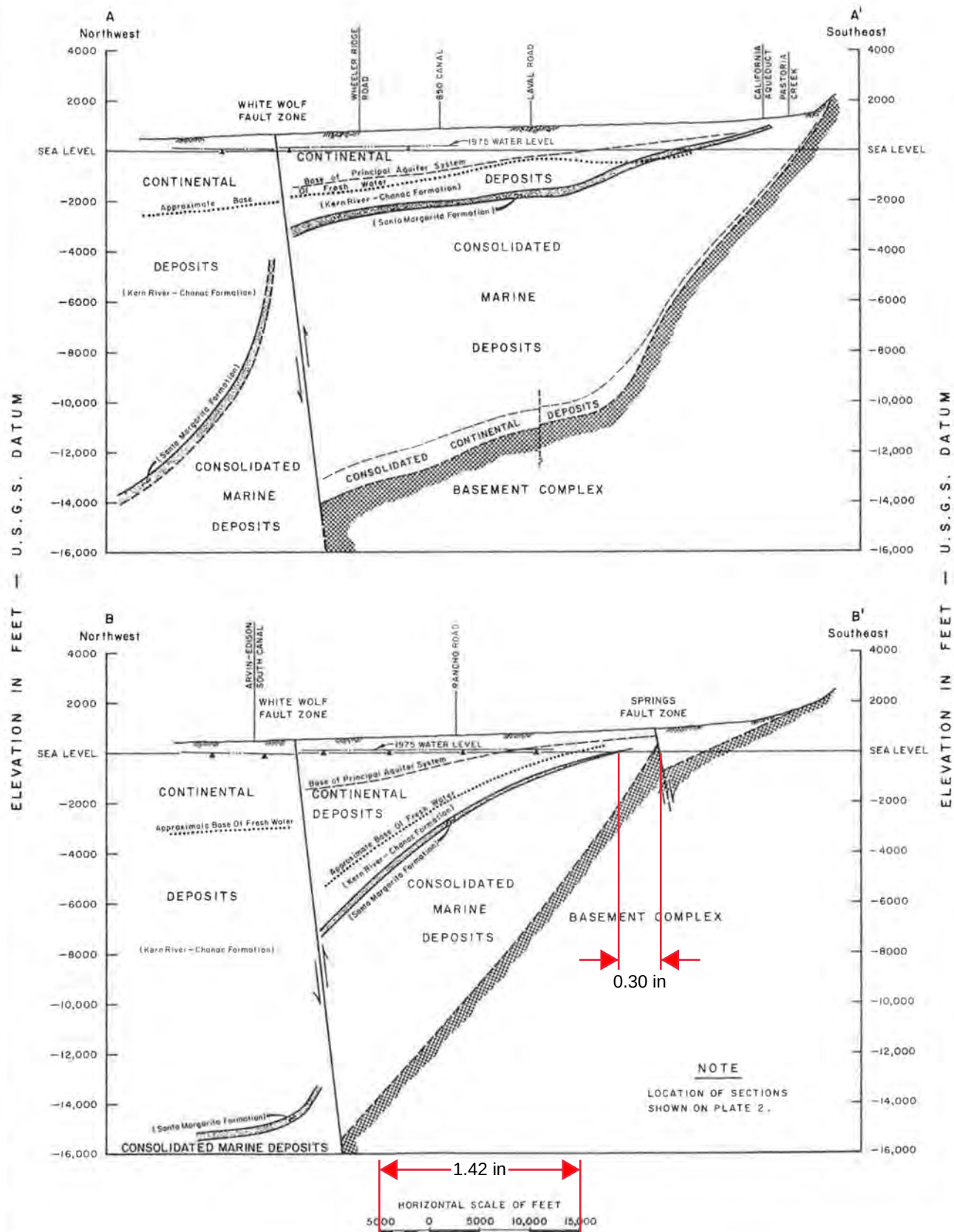
TABLE 11

ESTIMATED VARIABLE COSTS
OF CALIFORNIA AQUEDUCT WATER
IN WHITE WOLF BASIN⁽¹⁾
(values in \$ per acre-foot)

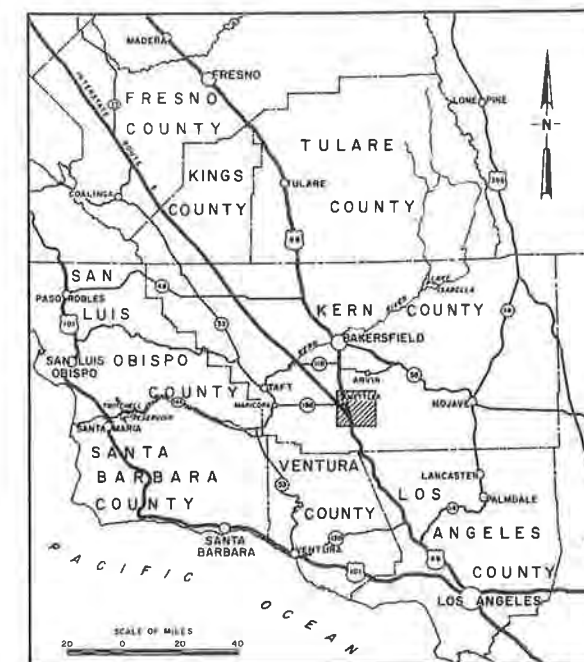
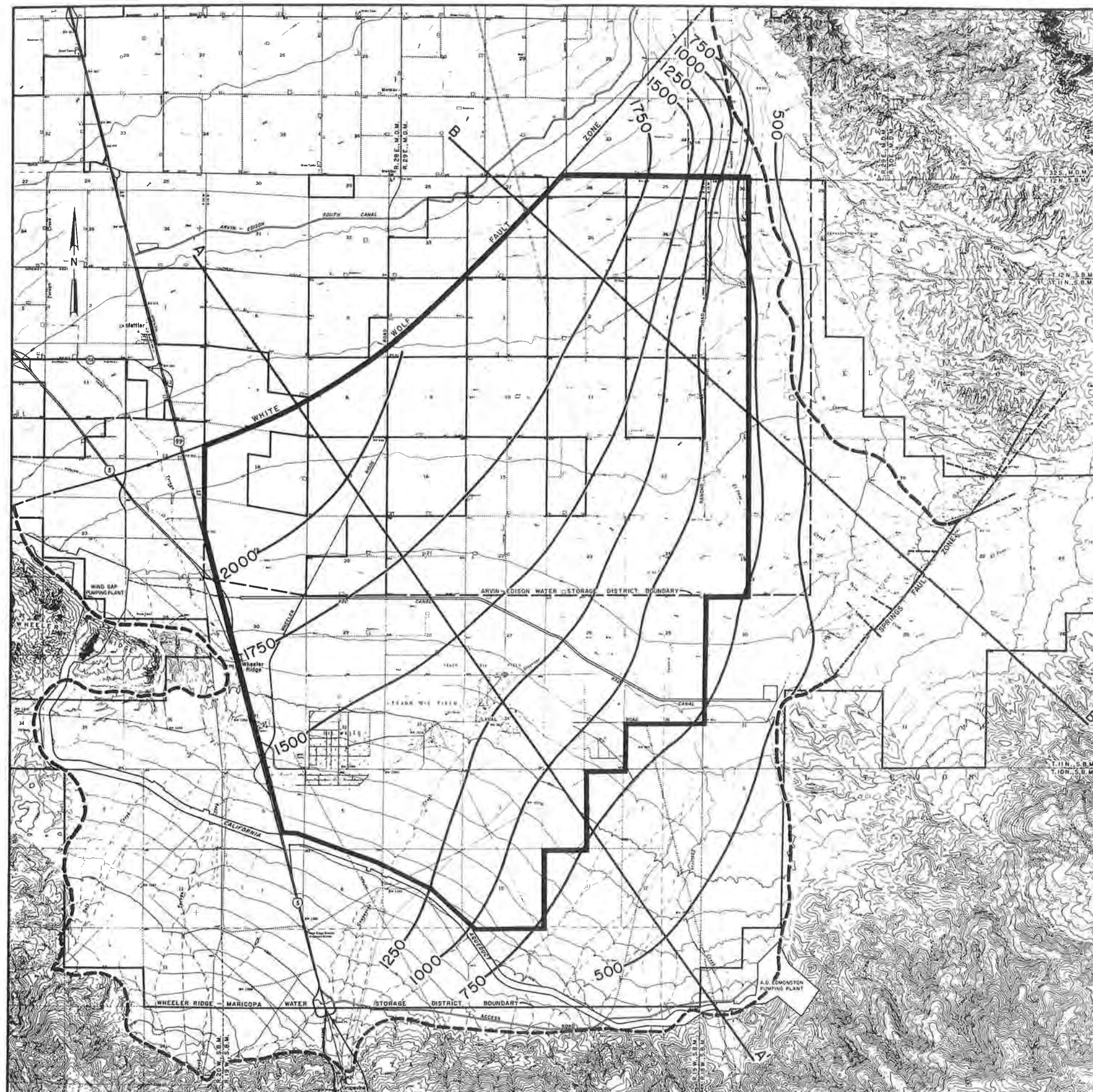
Year	Agency Variable Charges ⁽²⁾		District Variable Costs		Total Variable Costs	
	Reach 15	Reach 16	850 Canal	Reach 16	850 Canal	Reach 16
1975	5.07	7.63	4.10	0	9.17	7.63
76	5.46	8.47	4.25	0	9.71	8.47
77	5.82	9.05	4.35	0	10.17	9.05
78	6.37	9.73	4.50	0	10.87	9.73
79	6.97	10.40	4.60	0	11.57	10.40
80	6.14	9.42	4.75	0	10.89	9.42
1981	5.59	9.06	4.90	0	10.49	9.06
82	6.12	9.72	5.05	0	11.17	9.72
83	9.44	15.04	5.20	0	14.64	15.04
84	9.73	15.46	5.35	0	15.08	15.46
85	10.04	15.70	5.50	0	15.54	15.70
1986	10.48	16.45	5.70	0	16.18	16.45
87	10.31	16.02	5.85	0	16.16	16.02
88	10.62	16.88	6.00	0	16.62	16.88
89	10.34	16.48	6.20	0	16.54	16.48
90	11.12	17.33	6.40	0	17.52	17.33
Average 1975-90	8.10	12.68	5.17	0	13.27	12.68

(1) From Office Report "Estimated Contract Water Charges to 1990", dated September 1974 and prepared by Arnold S. Rummelsburg, Engineer-Manager, Wheeler Ridge-Maricopa Water Storage District.

(2) Values are increased 50% to reflect higher variable charges for surplus water.



GENERALIZED GEOLOGIC SECTIONS WHITE WOLF BASIN



VICINITY MAP

LEGEND

- 500 ——— CONTOURS SHOWING DEPTH IN FEET TO BASE OF PRINCIPAL AQUIFER SYSTEM.
- A ——— A' LOCATIONS OF GEOLOGIC SECTIONS AS SHOWN ON PLATE 1.
- EDGE OF ALLUVIAL DEPOSITS AND BOUNDARY OF GROUND WATER BASIN.
- BOUNDARY OF GROUND WATER STORAGE UNIT.

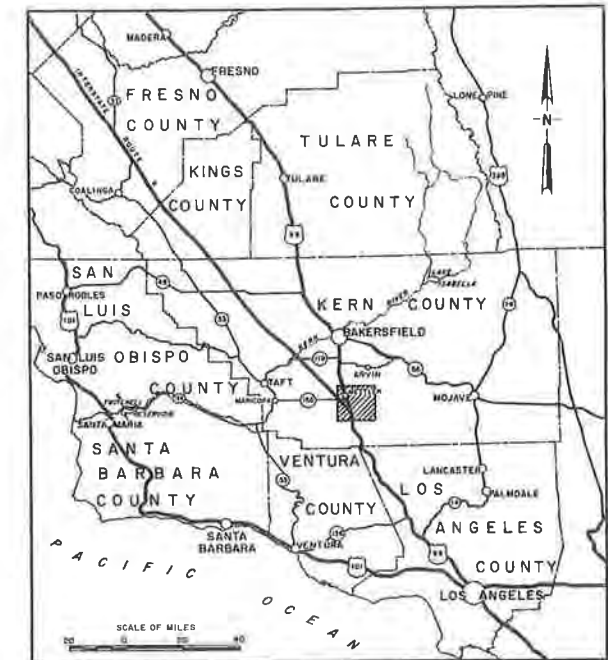
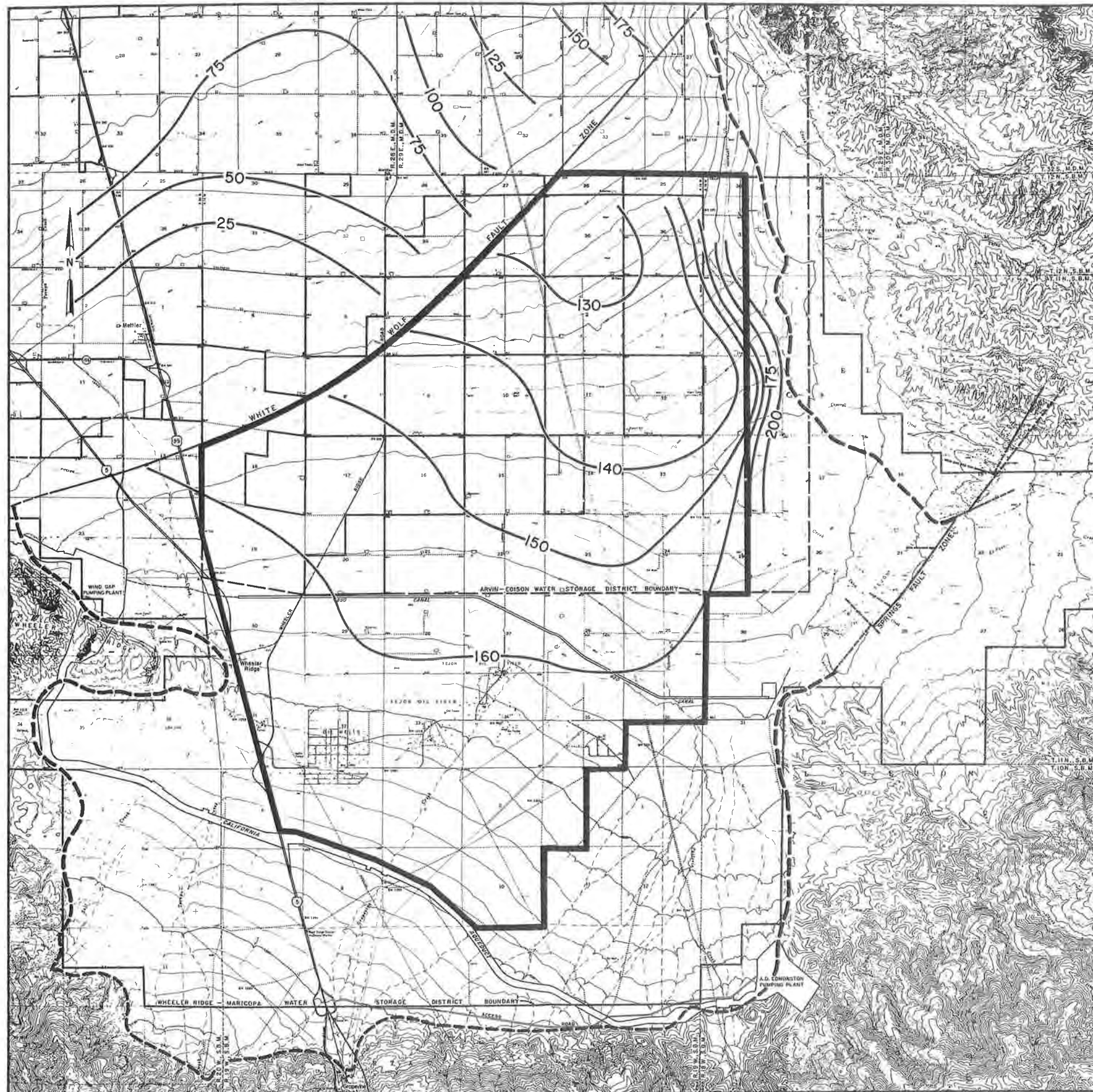
WHEELER RIDGE-MARICOPA WATER STORAGE DISTRICT

CONTOURS OF EQUAL DEPTH
TO
BASE OF PRINCIPAL AQUIFER SYSTEM
WHITE WOLF BASIN

BOOKMAN-EDMONSTON ENGINEERING, INC.
BAKERSFIELD, CALIFORNIA

JUNE 1975





VICINITY MAP

LEGEND

- 150 CONTOURS OF EQUAL ELEVATION OF GROUND WATER.
- EDGE OF ALLUVIAL DEPOSITS AND BOUNDARY OF GROUND WATER BASIN
- BOUNDARY OF GROUND WATER STORAGE UNIT.

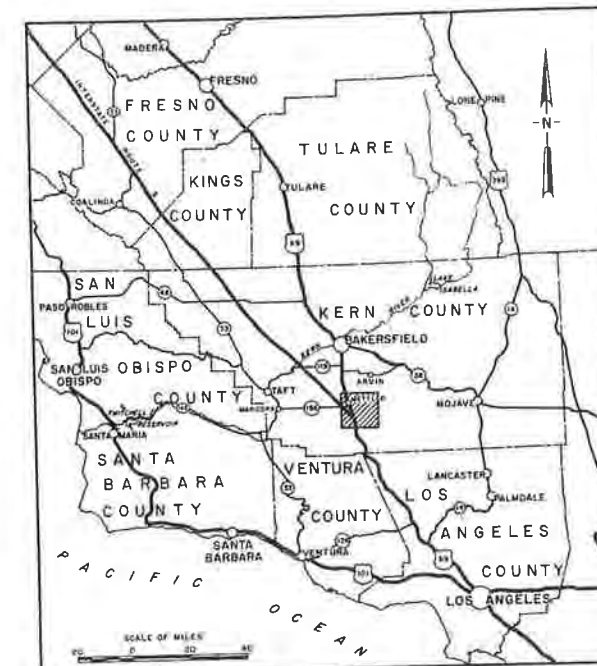
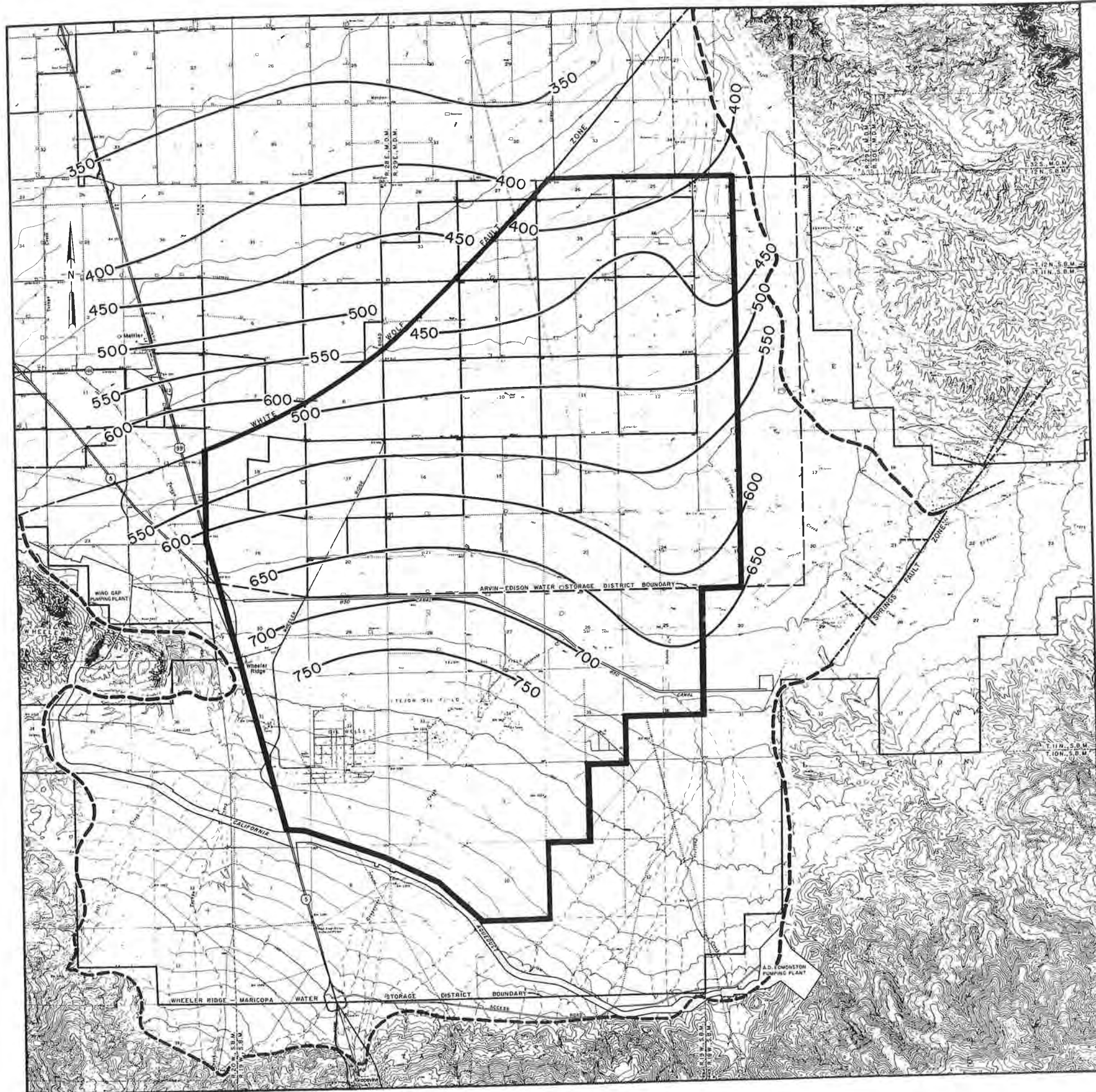
WHEELER RIDGE-MARICOPA WATER STORAGE DISTRICT

CONTOURS OF EQUAL ELEVATION OF GROUND WATER
JANUARY 1975
WHITE WOLF BASIN

BOOKMAN-EDMONSTON ENGINEERING, INC.
BAKERSFIELD, CALIFORNIA

JUNE 1975

SCALE OF FEET
4000 0 4000 8000



VICINITY MAP

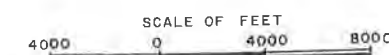
LEGEND

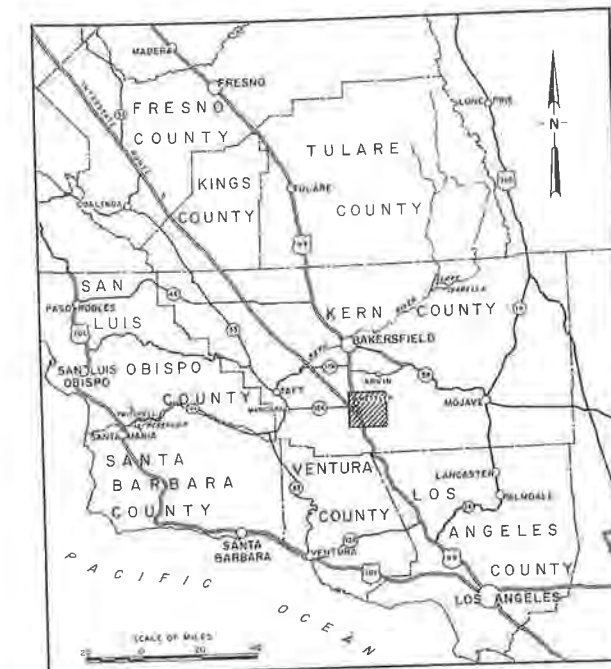
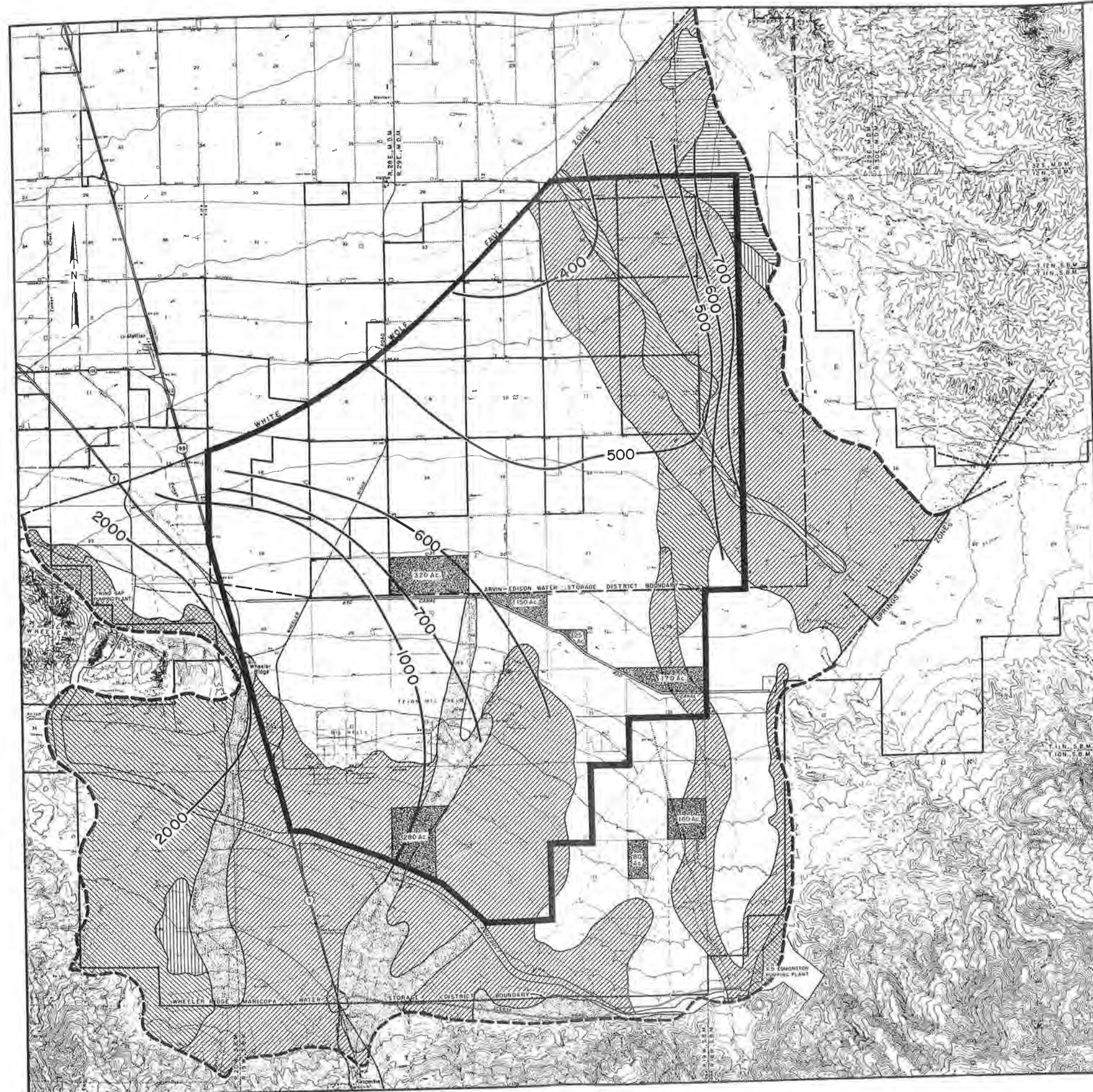
- 600 ——— CONTOURS OF EQUAL DEPTH TO GROUND WATER
- - - - - EDGE OF ALLUVIAL DEPOSITS AND BOUNDARY OF GROUND WATER BASIN
- BOUNDARY OF GROUND WATER STORAGE UNIT.

WHEELER RIDGE-MARICOPA WATER STORAGE DISTRICT
 CONTOURS OF EQUAL DEPTH TO GROUND WATER
 JANUARY 1975
 WHITE WOLF BASIN

BOOKMAN-EDMONSTON ENGINEERING, INC.
 BAKERSFIELD, CALIFORNIA

JUNE 1975





VICINITY MAP
LEGEND

- 500 CONTOURS OF EQUAL SALINITY OF GROUND WATER. VALUES SHOWN ARE $EC \times 10^6$ (MICROMHOS)
- EDGE OF ALLUVIAL DEPOSITS AND BOUNDARY OF GROUND WATER BASIN.
- BOUNDARY OF GROUND WATER STORAGE UNIT.
- LOCATIONS OF POSSIBLE SITES FOR SPREADING BASINS.

SOIL TYPES

- | | | |
|---------------------|------------------|-----------|
| SAN EMIGDIO | HESPERIA-HANFORD | PANOCHÉ |
| CAJON | RIVER WASH | ROCK LAND |
| TEHACHAPI-PLACENTIA | | |

WHEELER RIDGE-MARICOPA WATER STORAGE DISTRICT

CONTOURS OF EQUAL SALINITY OF GROUND WATER
AND
OCCURRENCE OF SURFACE SOIL TYPES

BOOKMAN-EDMONSTON ENGINEERING, INC.
BAKERSFIELD, CALIFORNIA

JUNE 1975

SCALE OF FEET
0 4000 8000