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DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

POTENTIAL FOR USING THE UPPER COACHELLA VALLEY GROUND-WATER BASIN, CALIFORNIA, FOR STORAGE OF ARTIFICIALLY RECHARGED WATER

By Michael J. Mallory, Lindsay A. Swain, and Stephen J. Tyley

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TABLES

CONVERSION FACTORS

The inch-pound system of units is used in this report. For readers who prefer metric units, conversion factors for the terms used in this report are listed below.

Multiply	By	To obtain
acre-feet	0.4047	hectares
inches	25.4	millimeters
feet	0.3048	meters
gallons per day per foot	0.01242	square meters per day
miles	1.609	kilometers
square miles	2.589	square kilometers

National Geodetic Vertical Datum of 1929 is a geodetic datum derived from the average sea level over a period of many years at 26 tide stations along the Atlantic, Gulf of Mexico, and Pacific Coasts and as such does not necessarily represent local mean sea level at any particular place. To establish a more precise nomenclature, the term "NGVD of 1929" is used in place of "Sea Level Datum of 1929" or "mean sea level."

POTENTIAL FOR USING THE UPPER COACHELLA VALLEY GROUND-WATER BASIN, CALIFORNIA, FOR STORAGE OF ARTIFICIALLY RECHARGED WATER

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ABSTRACT

The California Department of Water Resources, through the Future Water Supply Program, is investigating the use of ground-water basins for storage of State Water Project water in order to help meet maximum annual entitlements to water project contractors.

This report presents a preliminary evaluation of the geohydrologic factors affecting storage of water by artificial recharge in the upper Coachella Valley, Calif. The ground-water basin of the upper Coachella Valley seems to be geologically suitable for large-scale artificial recharge. A minimum of 900,000 acre-feet of water could probably be stored in the basin without raising basinwide water levels above those that existed in 1945. Preliminary tests indicate that a long-term artificial recharge rate of 5 feet per day may be feasible for spreading grounds in the basin if such factors as sediment and bacterial clogging can be controlled.

INTRODUCTION

As the demand for water in California approaches the available supply, it is becoming increasingly necessary to develop comprehensive plans to avert shortages and assure adequate supply to meet future demands. By the mid-1980's, availability of water supplies from northern California through the State Water Project (SWP) may not be sufficient to meet the anticipated demand of SWP contractors. For this reason, the California Department of Water Resources has been evaluating alternative sources of supply in order to develop a plan to make maximum use of existing resources so that the long-range water-supply obligations of the SWP can be met.

At times in the future, there may be extra water available from northern California and sufficient power to deliver this water to southern California. Thus, suitable places are needed to store such water in anticipation of alleviating future deficiencies.

When the SWP was designed, the Coachella Valley (fig. 1) was recognized as one of the areas that would ultimately be served with water from the California Aqueduct. A 1979 study completed by the California Department of Water Resources concluded that it is feasible from an engineering standpoint to extend the California Aqueduct to the upper Coachella Valley by either a "desert route" or a "pass route" for delivery of SWP water to meet the State's contractual commitments. The "desert route" and the "pass route" describe the two engineering alternatives evaluated in the California Department of Water Resources study. Available storage space in the Coachella Valley ground-water basin could be optimized by importing additional SWP water for storage during periods when supplies in northern California and capacity in the California Aqueduct are both available. Stored SWP water could then be withdrawn from the Coachella Valley and used during periods when the surface delivery of SWP water is not possible. Before a ground-water storage program in the Coachella Valley is planned, however, it must be determined if such a program is economically and hydrologically feasible.

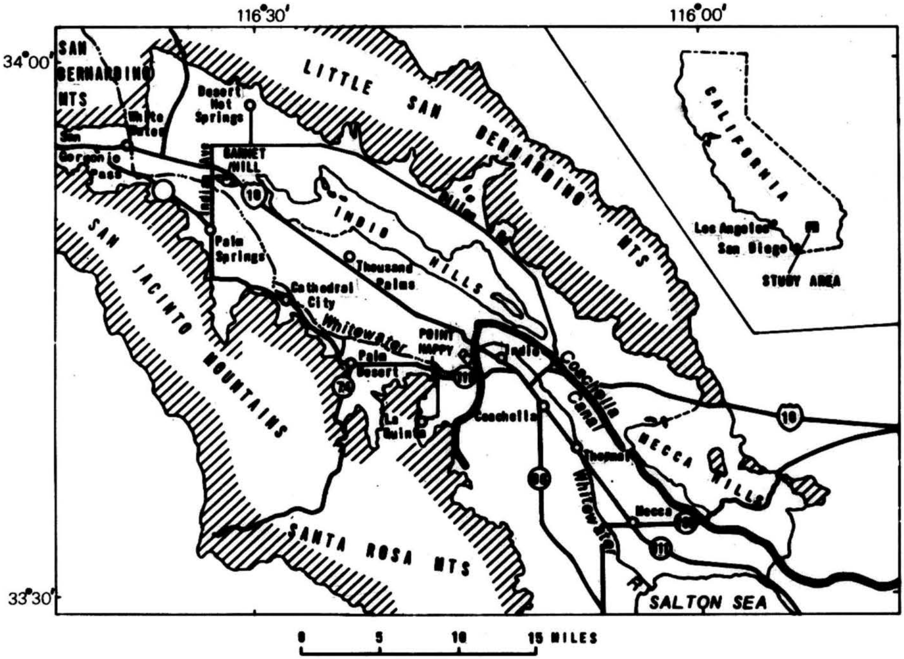


FIGURE 1.--Coachella Valley, California.

Purpose and Scope

This study is part of a reconnaissance-level investigation of the engineering, economic, and environmental considerations of using the Coachella Valley ground-water basin as a SWP conservation reservoir. The scope of this study is limited to a preliminary investigation of the physical characteristics and hydrology of the basin. The engineering, financial, legal, and institutional impacts will be evaluated by the California Department of Water Resources. The results of the combined studies will then be summarized in a "Technical Information Record" to be published by the Department of Water Resources. The specific objectives of the present study are to determine (1) the storage capacity available in the basin and (2) how much SWP water could be feasibly stored.

A previous report by Swain (1978) described the results of finite-element digital models of ground-water flow and quality. These models are available as tools to evaluate specific proposed modes of operation of a ground-water recharge program.

Regional Setting

The Coachella Valley (fig. 1) is a long, narrow desert valley in the central part of Riverside County, Calif., about 100 miles southeast of Los Angeles and 90 miles northeast of San Diego. The valley extends southeastward from the east end of San Gorgonio Pass along a structural depression known as the Salton Trough. It is bordered on the north and east by the San Bernardino and Little San Bernardino Mountains and on the southwest by the San Jacinto and Santa Rosa Mountains. The Salton Sea forms the southeastern boundary of the valley.

Drainage is southeast via the Whitewater River and its tributaries into the Salton Sea. Air temperatures often exceed 100°F in summer and drop below freezing in winter. Average annual rainfall on the valley floor is about 3 inches (Hely and Peck, 1964). At the crests of the San Jacinto and San Bernardino Mountains, however, rainfall may be as much as 40 inches per year.

Within the valley are the cities of Palm Springs, Cathedral City, Palm Desert, Indio, Coachella, Thermal, Mecca, and Desert Hot Springs. The upper Coachella Valley is famous for its desert resort communities, and the lower valley is a major center for irrigated agriculture. The valley has a surface area of about 690 square miles.

GEOHYDROLOGY

The geology of the area is described in detail by Bechtel (1967), California Department of Water Resources (1964), Dutcher and Bader (1963), Proctor (1968), and Vaughn (1922). The various geologic units described in these reports can be generalized in three categories: Consolidated rocks, partly consolidated deposits, and unconsolidated deposits.

The consolidated rocks form the basement complex of Coachella Valley. They consist of granitic intrusive and metamorphic rocks, of Precambrian and Tertiary age. These rocks contain little or no water and generally form a no-flow boundary.

The partly consolidated deposits of Pliocene and Pleistocene age, which underlie the Indio Hills and Garnet Hill, generally have low permeability and yield only small quantities of water to wells. Characteristically, these units consist mainly of poorly bedded sandstone and conglomerate. Many of the units have been warped or faulted, further limiting their effectiveness as aquifers.

The unconsolidated deposits, of late Pleistocene and Holocene age, constitute the valley fill and are the main water-bearing units. In the deeper parts of the valley these deposits are more than 3,000 feet thick (Biehler, 1964), generally have moderate to high permeability, and yield large quantities of water to wells.

Practical sites for artificial recharge of SWP water to the ground-water basin are limited to the upper Coachella Valley. The upper Coachella Valley, as used in this report, refers to the part of the valley north of the Coachella Canal. Thus, the southern boundary of this area is an arbitrary line from Point Happy northeast to the Little San Bernardino Mountains (fig. 1). South of this line, water imported from the Colorado River by the Coachella Canal is the major source of irrigation water, and water levels have been rising since 1949. North of the boundary ground water pumped by wells is the major source of irrigation water, and water levels have been declining. South of the boundary the ground-water system is characteristically confined or partly confined and contains numerous perched ground-water bodies that limit the suitability of this area as a site for large-scale artificial recharge. Also, storage space available for ground-water recharge is less because the water table becomes more shallow as it approaches the Salton Sea. Water in the shallow aquifer underlying the lower valley has a high dissolved-solids concentration because of agricultural wastewater recharge above the confined zone.

In the upper Coachella Valley, ground-water movement in the unconsolidated deposits is affected by the San Andreas fault system. This system includes the Mission Creek, Banning, Garnet Hill, and Indio Hills faults and associated folds (fig. 2).

The Mission Creek fault extends southeast from Mission Creek, crosses the east side of the Indio Hills, and joins the Banning fault just north of Indio. This fault is an effective barrier to ground-water movement, as evidenced by the 150- to 250-foot water-level difference between the Desert Hot Springs subbasin and the adjacent Mission Creek subbasin and by the phreatophyte growth along the northeast side of the fault.

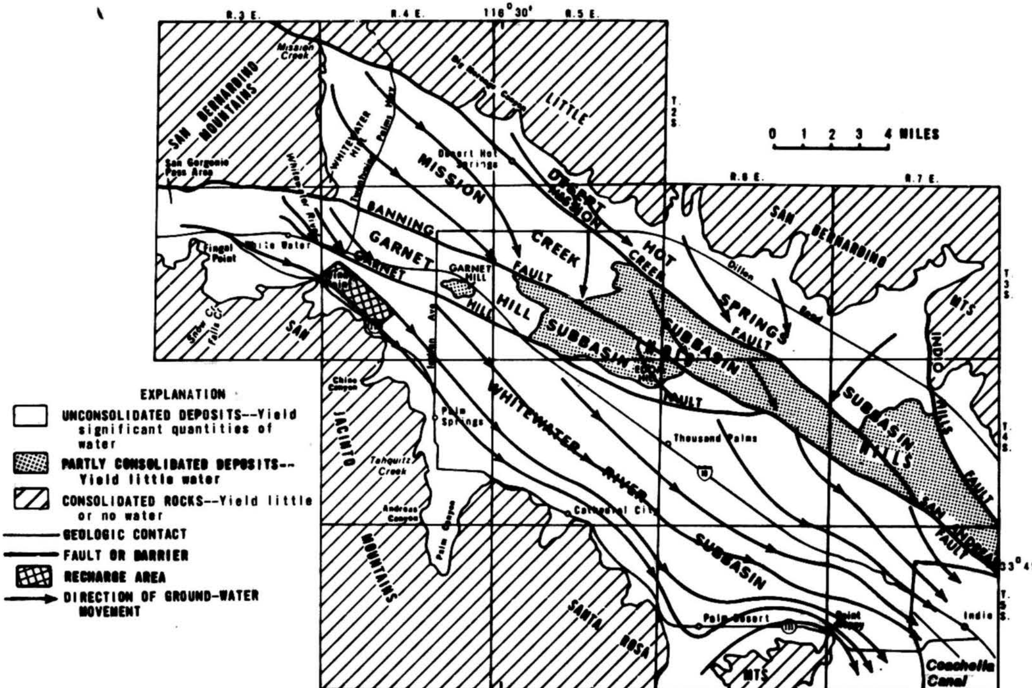
The Banning fault separates the Mission Creek subbasin from the Garnet Hill and Whitewater River subbasins. This fault is also an effective barrier to ground-water movement as evidenced by a 100- to 200-foot water-level drop between the Mission Creek subbasin and the Garnet Hill subbasin and also by the phreatophyte growth along the east side of the fault.

The Garnet Hill fault acts as a ground-water barrier, creating about a 100-foot water-level difference between the Garnet Hill subbasin and the Whitewater River subbasin. The fault is difficult to locate accurately, although Proctor (1968) reported that a major oil company has gravity data that places the fault approximately as shown in figure 2. The few measurements of water levels in wells in the area generally confirm that location.

The Indio Hills fault acts as a partial barrier to ground-water movement where it crosses the valley fill between the Indio Hills and the Little San Bernardino Mountains. The sparse data indicate that a water-level drop of 30 to 50 feet is probable from the west side to the east side of the fault.

Other faults (not shown) exist in the area, but for the scope of this report they are not considered hydrologically significant. These faults include the Morongo reverse fault (Proctor, 1968) and the Palm Springs fault (Dutcher and Bader, 1963).

Ground-water movement is also affected by folding that resulted from compression and drag associated with fault displacements. The three main areas of folding are topographically expressed by Whitewater Hill, Garnet Hill, and the Indio Hills (fig. 2). In each of those areas the permeability and the storage capability have been altered, and in most places this alteration has reduced the permeability and storage capacity of the original unaltered formations.



From S. J. Tyley, 1974

FIGURE 2.--Generalized ground-water flow lines.

Fault barriers, constrictions in the basin profile, and changes in permeability of the water-bearing units have compartmentalized the upper Coachella Valley into four ground-water subbasins: Desert Hot Springs, Mission Creek, Garnet Hill, and Whitewater River (fig. 3).

The Desert Hot Springs subbasin is composed mainly of coalescing alluvial fans from the Little San Bernardino Mountains. The Indio Hills fault on the southeast, the Mission Creek fault on the southwest, and the Little San Bernardino Mountains on the northeast are the boundaries of this subbasin.

The Mission Creek subbasin is bounded on the north by the Mission Creek fault and on the south by the Banning fault. Partly consolidated deposits of the Indio Hills are of low permeability and act as a partial barrier to ground-water movement to the southeast.

The Garnet Hill subbasin is bounded on the north by the Banning fault and on the south by the Garnet Hill fault. At the southeast corner there is a grading into the Whitewater River subbasin where the Garnet Hill fault is not an effective barrier to ground-water movement.

The Whitewater River subbasin is the largest of the four subbasins and contains the most significant aquifer. This subbasin is bounded on the northwest by the San Gorgonio Pass subbasin (west of area shown in fig. 2, Bloyd, 1969) and on the northeast by the Garnet Hill, Banning, and San Andreas faults. On the west this subbasin is bordered by the generally impermeable San Jacinto and Santa Rosa Mountains. The southern boundary is the arbitrary line extending from Point Happy northeast to the Little San Bernardino Mountains.

The Whitewater River subbasin is further divided into four subareas on the basis of population centers and water use. These subareas are Palm Springs, Thousand Palms, Palm Desert, and Indio (fig. 3).

Water-table conditions prevail in most of the study area, but there are artesian conditions near the southern boundary. Ground water generally flows from the recharge areas of the surrounding mountain fronts southeastward through the center of the valley to the Salton Sea.

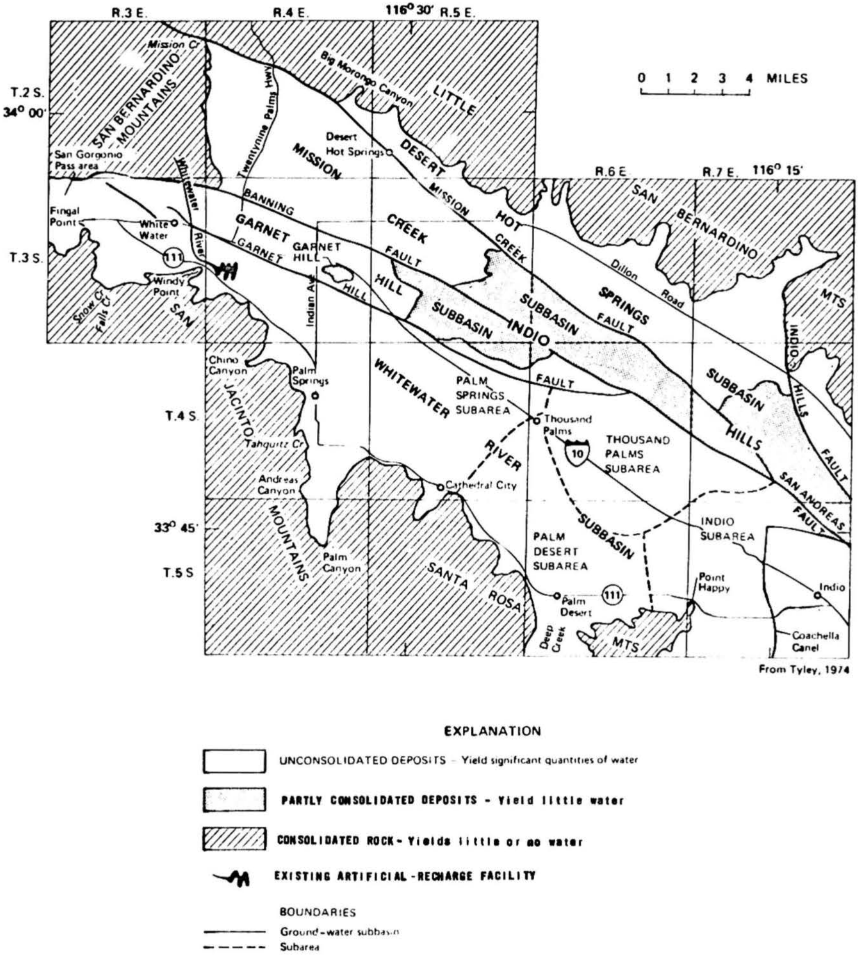


Figure 3.--Ground-water subbasins of the upper Coachella Valley, Calif.

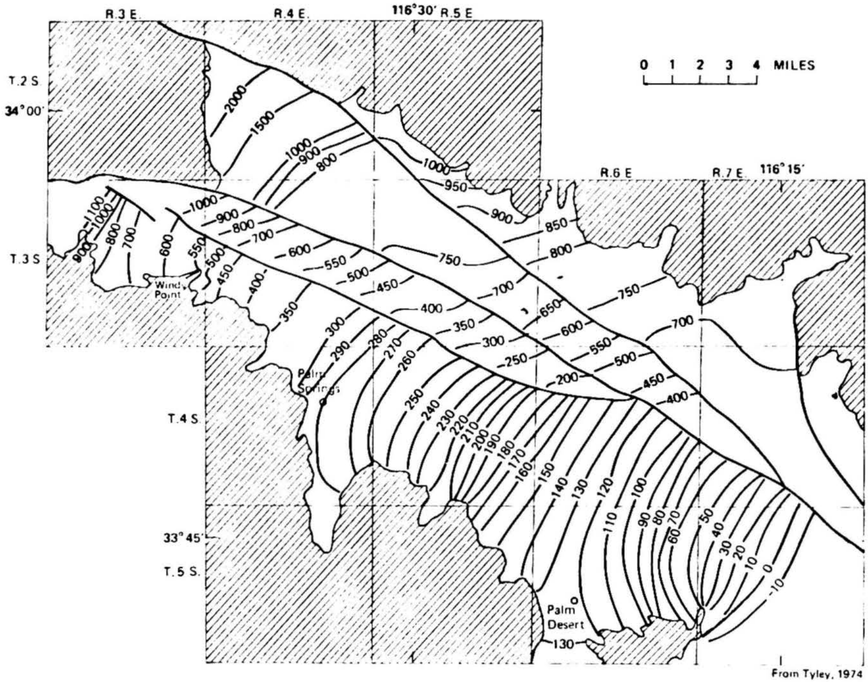
Because the average rainfall over the valley floor is slightly less than 3 inches per year and potential evaporation can be as much as 9 feet per year, there is no significant recharge to the ground-water basin from rainfall on the valley floor itself. Average ground-water recharge to the basin as of 1974, however, was approximately 42,000 acre-feet per year (Swain, 1978). The recharge occurs as underflow from the San Gorgonio subbasin on the west and from runoff infiltration through the beds of the streams that enter the valley from the surrounding mountains.

Discharge from the upper Coachella Valley ground-water basin is principally from pumping, ground-water underflow across the southern boundary of the study area, and some evapotranspiration along the Mission Creek and Banning faults. Net annual pumpage, which ranged from 5,000 acre-feet in 1936 to 53,000 acre-feet in 1973, and consumptive use were estimated and discussed by Tyley (1974). Annual underflow across the southern boundary was estimated by Tyley (1974, p. 24) to be 30,000 acre-feet in 1967.

The altitude of water levels in the upper Coachella Valley is highest at the northwest end of each subbasin (figs. 4, 5); ground-water flow is from the northwest to the southeast in the valley.

Although water levels have been declining in most of the basin since 1945, water levels southeast of the study area have been rising because of increased percolation of imported irrigation water and decreased pumpage in that area.

Comparison of the 1936 water-level map (fig. 4) and the 1973 water-level map (fig. 5) shows that water levels declined more than 100 feet in parts of the Palm Springs subarea and more than 70 feet in parts of the Palm Desert subarea during the 37-year period (fig. 6). This significant decline, which in recent years has averaged 5 feet annually in the Palm Springs area, has been the cause of great concern to the local water purveyors and prompted the artificial recharging of the ground-water basin.



EXPLANATION

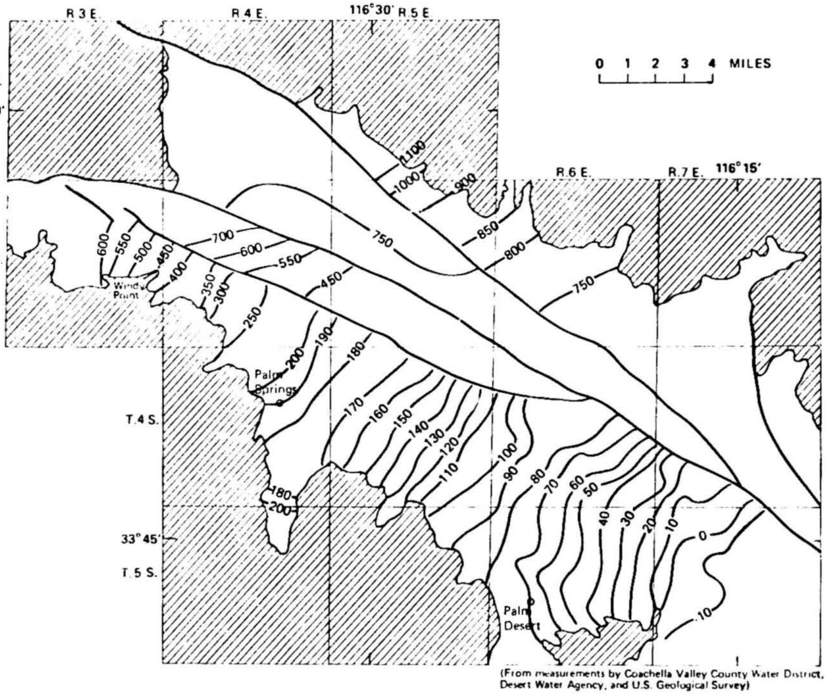
UNCONSOLIDATED AND PARTLY CONSOLIDATED DEPOSITS

CONSOLIDATED ROCK

—500— WATER-TABLE CONTOUR – Shows altitude of water table, in feet. Contour interval variable. National Geodetic Vertical Datum of 1929

GROUND-WATER SUBBASIN BOUNDARY

FIGURE 4.—Water-table contours, 1936



EXPLANATION

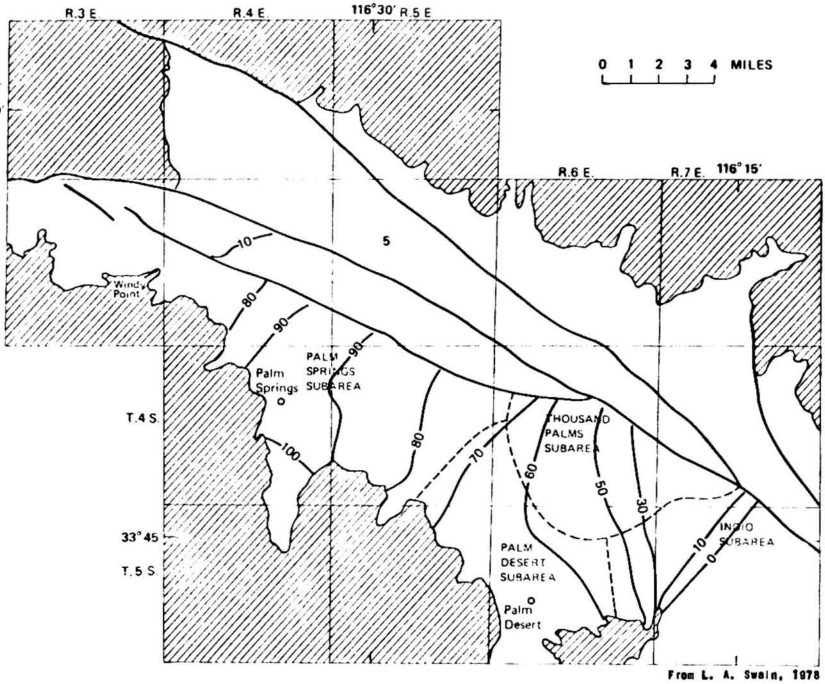
UNCONSOLIDATED AND PARTLY CONSOLIDATED DEPOSITS

CONSOLIDATED ROCK

—200— WATER-TABLE CONTOUR – Shows altitude of water table, in feet. Contour interval variable. **National Geodetic Vertical Datum of 1929**

——— GROUND-WATER SUBBASIN BOUNDARY

FIGURE 5. –Water-table contours, autumn 1973.



EXPLANATION

UNCONSOLIDATED AND PARTLY CONSOLIDATED DEPOSITS

CONSOLIDATED ROCK

—50--- LINE OF EQUAL WATER LEVEL DECLINE - Interval 10 and 20 feet

BOUNDARIES

Ground-water subbasin

Subarea

FIGURE 6. —Water-level decline 1936-73.

Ground-Water Storage Capacity

Table 1 shows the estimated usable storage for each of the subbasins. Tyley (1974) calculated the net change in storage between 1945 and 1967 to be about 600,000 acre-feet. Tyley (1974) also estimated that the average annual decrease in storage was 33,000 acre-feet per year for the period 1953-67 and that this annual figure was increasing with increasing consumptive use. It is conservatively estimated that an additional 340,000 acre-feet of net storage depletion has occurred between 1967 and 1978. It, therefore, seems reasonable that 900,000 acre-feet of water could be stored in the upper Coachella Valley without water levels rising above those that existed in 1945 if the recharge is uniformly distributed throughout the upper valley. Most of the depletion of storage in the valley has occurred in the Whitewater River subbasin. In some respects this is fortunate, because many of the most favorable sites for artificial recharge in the basin occur in the highly permeable river-channel deposits of the Whitewater River in this subbasin.

TABLE 1. - Summary of ground water in storage, as of 1967[1]

(From Tyley, 1974)

Subbasin	Depth[2] (feet)	Storage (acre-feet)
Desert Hot Springs	300	779,000
Mission Creek	500	2,630,000
Garnet Hill	500	1,520,000
Whitewater River	700	10,200,000
Total (rounded)		15,100,000

[1]Ground water in storage is the area times the saturated depth times the storage coefficient.

[2]Depth is an arbitrary choice that represents the most reasonable thickness of saturated deposits that can be economically and hydrologically utilized.

Quality of Ground Water

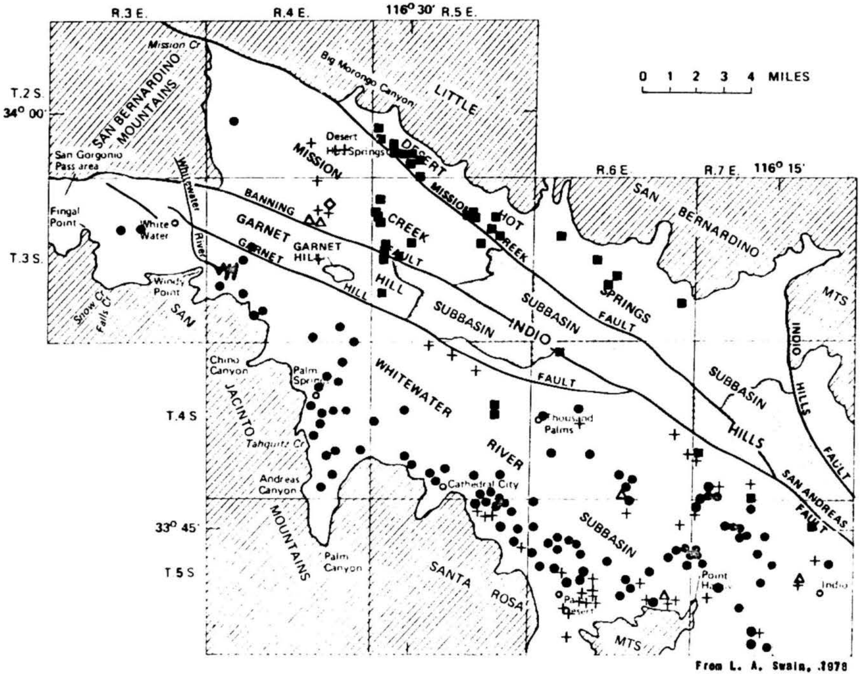
Swain (1978) collected more than 1,000 chemical analyses from the numerous agencies that analyze or monitor the chemical quality of the ground water in the upper Coachella Valley. These water analyses cover the period 1968-74. After the analyses were examined, selected ones were used to determine the areal distribution of selected chemical constituents and water-quality types.

Water-quality types may be distinguished by the predominance of a specific chemical constituent expressed as a percentage of the total anions or cations. For example: (1) A calcium bicarbonate water is one in which calcium amounts to more than 50 percent of the cations and bicarbonate to 50 percent or more of the anions in milliequivalents per liter, and (2) a mixed-type water in which no anion or cation comprised more than 50 percent of the total anions or cations in milliequivalents per liter.

The areal distribution of the water-quality types is shown in figure 7. The three subbasins north of the Garnet Hill fault contain water that is predominantly of the sodium sulfate type. Southwest of the fault in the Whitewater River subbasin, the water is predominantly of the calcium bicarbonate type. Streams that recharge the Whitewater River subbasin are also of the calcium bicarbonate type.

In the areas adjacent to the Garnet Hill fault and near the southeast end of the Banning fault, zones of mixing occur where water of varied water-quality types exists. This situation supports Tyley's contention (1974) that the faults are not as effective as barriers to ground-water flow in the southeast as they are in the north. Thus, seepage through the fault on the southeast results in mixing of water-quality types.

Since 1973, water from the Colorado River Aqueduct has been recharged to the ground-water basin through the Whitewater River channel into the artificial-recharge area near Windy Point (fig. 7). This water fluctuates from a sodium sulfate to a calcium sulfate type at times.



EXPLANATION

UNCONSOLIDATED DEPOSITS — Yield significant quantities of water

PARTLY CONSOLIDATED DEPOSITS - Yield little water

CONSOLIDATED ROCK — Yields little or no water

EXISTING ARTIFICIAL-RECHARGE FACILITY

WATER-QUALITY TYPES, BASED ON 1968-74 CHEMICAL ANALYSES

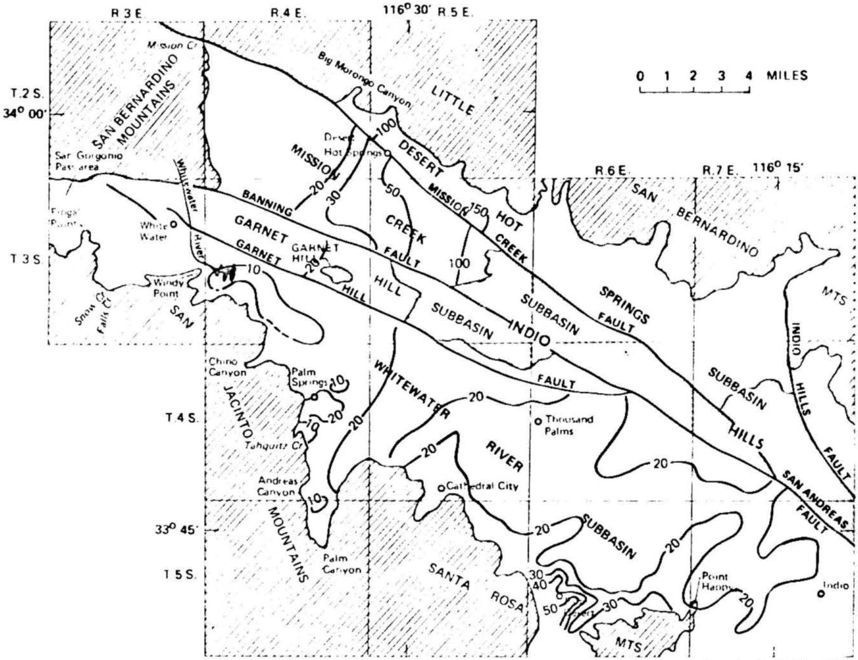
■ Sodium sulfate
● Calcium bicarbonate
◇ Calcium sulfate
△ Sodium bicarbonate
+ Mixed--No predominant cation or anion

FIGURE 7.—Water-quality types.

Figure 8 shows the variations in chloride concentrations that exist between and within the subbasins. The water of highest chloride concentration, more than 150 mg/L (milligrams per liter), is in the Desert Hot Springs subbasin. The water of lowest concentration, less than 10 mg/L, is in the Whitewater River subbasin.

Figure 9 shows the variations in sulfate concentrations. The highest concentrations of sulfate, more than 500 mg/L, are in the Desert Hot Springs subbasin and the lowest concentrations, less than 20 mg/L, are in the Whitewater River subbasin.

Dissolved-solids concentration shows more distinctive differences for the various subbasins in the area than any of the individual chemical constituents examined in this phase of the study. Figure 10 shows the areal distribution of dissolved-solids concentration in the ground water of the upper Coachella Valley. As with the individual chemical constituents, the greatest concentrations, more than 1,000 mg/L, occur in the northern part of the Desert Hot Springs subbasin. The water of lowest concentration, less than 200 mg/L, is in some areas of the Whitewater River subbasin.



From L. A. Swain, 1978

EXPLANATION

UNCONSOLIDATED DEPOSITS - Yield significant quantities of water

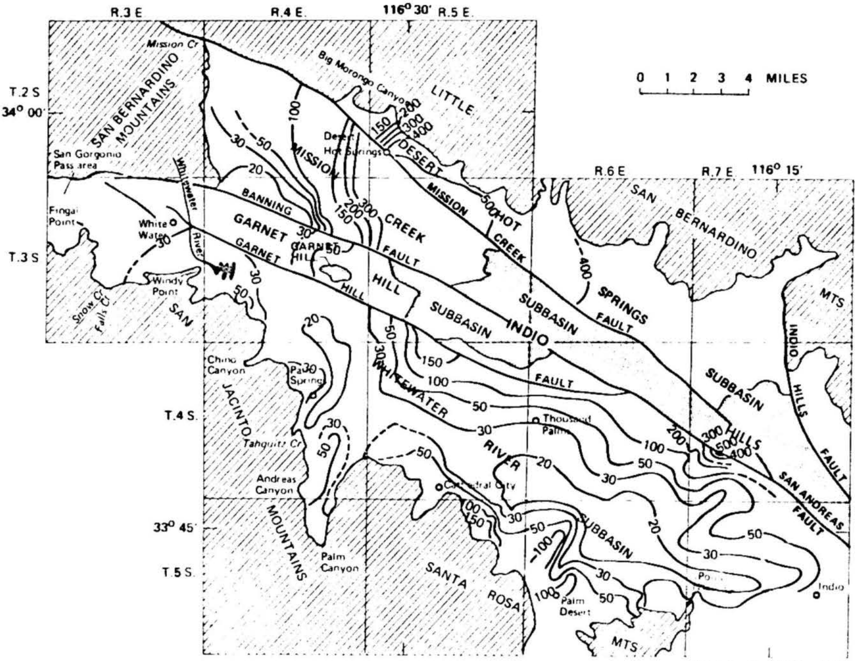
PARTLY CONSOLIDATED DEPOSITS - Yield little water

CONSOLIDATED ROCK - Yields little or no water

EXISTING ARTIFICIAL-RECHARGE FACILITY

—20— LINE OF EQUAL CHLORIDE CONCENTRATION, BASED ON 1968-74 CHEMICAL ANALYSES - Dashed where approximately located. Interval 10, 20, and 50 milligrams per liter

FIGURE 8.—Chloride concentration.



From L. A. Swain, 1978

EXPLANATION

UNCONSOLIDATED DEPOSITS - Yield significant quantities of water

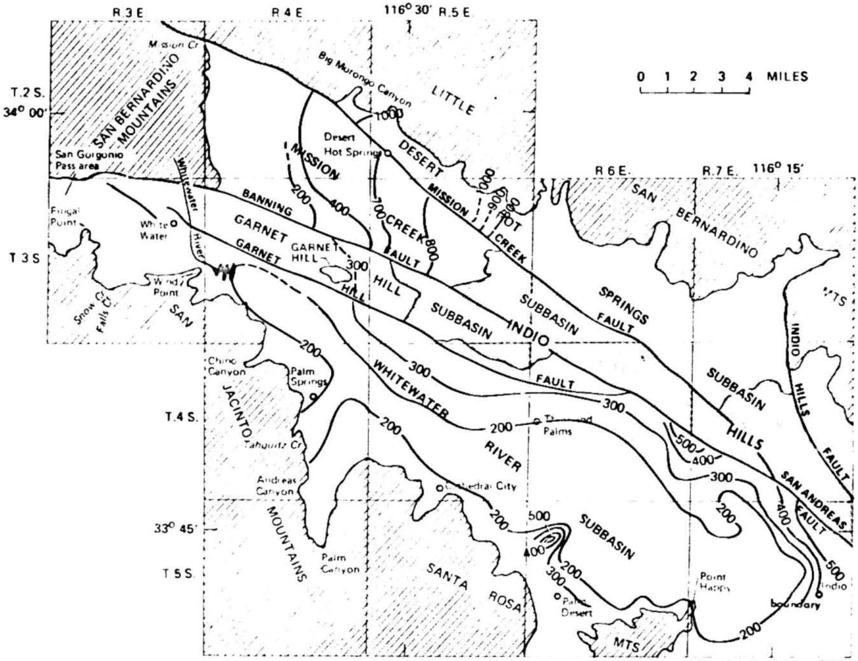
PARTLY CONSOLIDATED DEPOSITS - Yield little water

CONSOLIDATED ROCK Yields little or no water

EXISTING ARTIFICIAL-RECHARGE FACILITY

—30— LINE OF EQUAL SULFATE CONCENTRATION, BASED ON 1968-74 CHEMICAL ANALYSES
Dashed where approximately located. Interval variable, in milligrams per liter

FIGURE 9.—Sulfate concentration.



From L. A. Swain, 1978

EXPLANATION

UNCONSOLIDATED DEPOSITS - Yield significant quantities of water

PARTLY CONSOLIDATED DEPOSITS - Yield little water

CONSOLIDATED ROCK - Yields little or no water

EXISTING ARTIFICIAL-RECHARGE FACILITY

—200— LINE OF EQUAL DISSOLVED-SOLIDS CONCENTRATION, BASED ON 1968-74 CHEMICAL ANALYSES - Dashed where approximately located. Interval 100, 200, and 300 milligrams per liter

FIGURE 10.—Dissolved-solids concentration.

ARTIFICIAL-RECHARGE POTENTIAL

The selection of an artificial-recharge site and the evaluation of its probable effectiveness require detailed knowledge of the geologic characteristics of the ground-water basin. Physical properties of surface and subsurface deposits determine to a large extent the sustained infiltration rates and volumes of water that can be successfully recharged into the ground-water basin. The effectiveness and suitability of a recharge site are related to subsurface geologic features that might form a complete or partial barrier to percolation of recharge water to the water table. The depth to the water table and the hydraulic gradient must be defined to estimate the distribution of recharge water once it reaches the water table. The total thickness of unsaturated deposits ultimately limits the available storage capacity.

Tyley (1974) concluded that the unconsolidated deposits east and south of Windy Point (fig. 2) probably provide the most suitable sites for artificial recharge. The surficial deposits in this area are generally alluvial sand derived from the metamorphic rocks drained by the upper reaches of the Whitewater River in the San Bernardino Mountains. A large percentage of the surface deposits is windblown-sand and river-channel deposits ranging in size from fine sand to boulders 9 feet in diameter. The Pleistocene Cabezon Fanglomerate (local usage) which underlies the surficial alluvium, consists of poorly sorted, massive, conglomeratic arkosic sandstone.

Hydrologic suitability criteria for artificial recharge of a ground-water basin and suitability of the basin under study were discussed in the report on the electric-analog model study by Tyley (1974). Briefly, these criteria include the following:

1. The storage capacity of the ground-water basin in the proposed recharge area must be adequate to accommodate the anticipated quantities of imported water. Because the depth to water in much of that area is now nearly 500 feet, the storage is probably more than adequate.

2. The ground-water basin must readily transmit the recharged water to the intended areas of extraction.

Figure 2 shows that ground-water movement is southeastward through the center of the valley; thus, water recharged in the Windy Point area will move toward Indio. The transmissivity of the aquifer is high throughout the Whitewater River subbasin, ranging, according to Tyley (1974), from 50,000 to 300,000 gallons per day per foot, and from 200,000 to 300,000 gallons per day per foot in the vicinity of the proposed recharge site.

Tyley (1974) noted that drillers' logs for existing wells in the Whitewater River subbasin indicated that highly permeable deposits occur above the water table. The logs revealed no significant layers of silt or clay to impede the downward movement of recharge water. Results of test drilling and coring reported by Tyley (1973) also support the conclusion that no significant layers of silt or clay exist in the Wind Point area.

The major problem associated with evaluation of a recharge site or a method of recharge is the determination of probable long-term infiltration rates. Such rates are critical for determining the method of recharge, the size of the recharge site, and the techniques of operation and maintenance.

Many factors affect infiltration rates, but most are difficult to analyze separately. The composition of surface soils and the hydrologic conditions discussed above are important factors affecting infiltration rates. The quality of the recharge water and the procedures used in the construction, operation, and maintenance of a recharge project can also affect the long-term infiltration rates. These latter factors can generally be controlled to maintain favorable rates.

Tyley (1973) reported that in pilot recharge site tests, using a pit 150 feet long by 60 feet wide by 4 feet deep, the infiltration rates were initially as high as 24 feet per day and stabilized at about 5 feet per day after about 40 days. If silt and bacterial clogging can be controlled, it should be possible to maintain an infiltration rate of about 5 feet per day in a large-scale system.

SUMMARY OF CONCLUSIONS

Based on preliminary evidence, the upper Coachella Valley seems to be a hydrologically feasible site for inclusion in the Future Water Supply Program of the Department of Water Resources. The area of the Whitewater River subbasin east and south of Windy Point seems to be particularly well suited to accepting artificial recharge in relatively large quantities. Preliminary tests indicate that an infiltration rate of as much as 5 feet per day might be maintained if such factors as sediment and bacterial clogging can be controlled. Digital flow and water-quality models are available to test specific projected operational modes.

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