DRAFT
TECHNICAL INFORMATION RECORD
STUDY CODE NO. 1335-11-B-1

PRELIMINARY
SUBJECT TO REVISION

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES
Southern District
Planning Branch

PRELIMINARY EVALUATION OF ANNUAL RECHARGE TO THE BORREGO VALLEY GROUND WATER BASIN

by

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This Technical Information Record (TIR) was prepared to document pertinent information developed in the Borrego Valley cooperative water management investigation. The findings in this TIR have not been fully reconciled with all the technical aspects of the total investigation, which will be reviewed when all phases of the investigation have been completed. Review was limited to consideration of technical data by the writers' immediate supervisor. Hence, this TIR is for internal office use and should be considered preliminary and subject to revision.

March 1983

#4

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PRELIMINARY EVALUATION OF ANNUAL RECHARGE TO THE BORREGO VALLEY GROUND WATER BASIN

INTRODUCTION

This Technical Information Record (TIR) is intended to present the results of an analysis of ground water recharge in Borrego Valley of northeastern San Diègo County. This information was necessary for formulation of alternative plans for future operation of the basin. Estimates were made through three different procedures. The first method was based on a hydrologic balance of the saturated portion of the ground water basin. The second was based on the application of Darcy's Law to the steady state (1945) ground water level contour map and the isotransmissivity map contained in USGS Open File Report 82-855 (1). The third was the application of a mathematical model to estimate the deep percolation at each node using the values of transmissivity presented in the Open File Report.

Borrego Valley is an arid desert basin located in the shadow of the Peninsular Ranges 50 miles northeast of San Diego (Figure 1). The surface area of the ground water basin is about 65,000 acres. The basin is comprised of three aquifers - the upper, middle, and lower - with a maximum alluvial depth of 2,450 feet. (Ref. 1, P. 12).

The Geological Survey, for Phase I of the current investigation, developed ground water level contour maps for various years between 1945, when serious development of Borrego Valley ground water began, and the present. 1965 was the second most recent year for which contours were plotted, with 1980 being the most recent. The data for the period 1965 through 1980 should give a reasonable estimate of current ground water recharge since major changes in ground water pumpage patterns in the years preceding 1965 were accompanied by a substantial reduction of irrigated agriculture; since 1965, changes in agriculture have been less drastic.

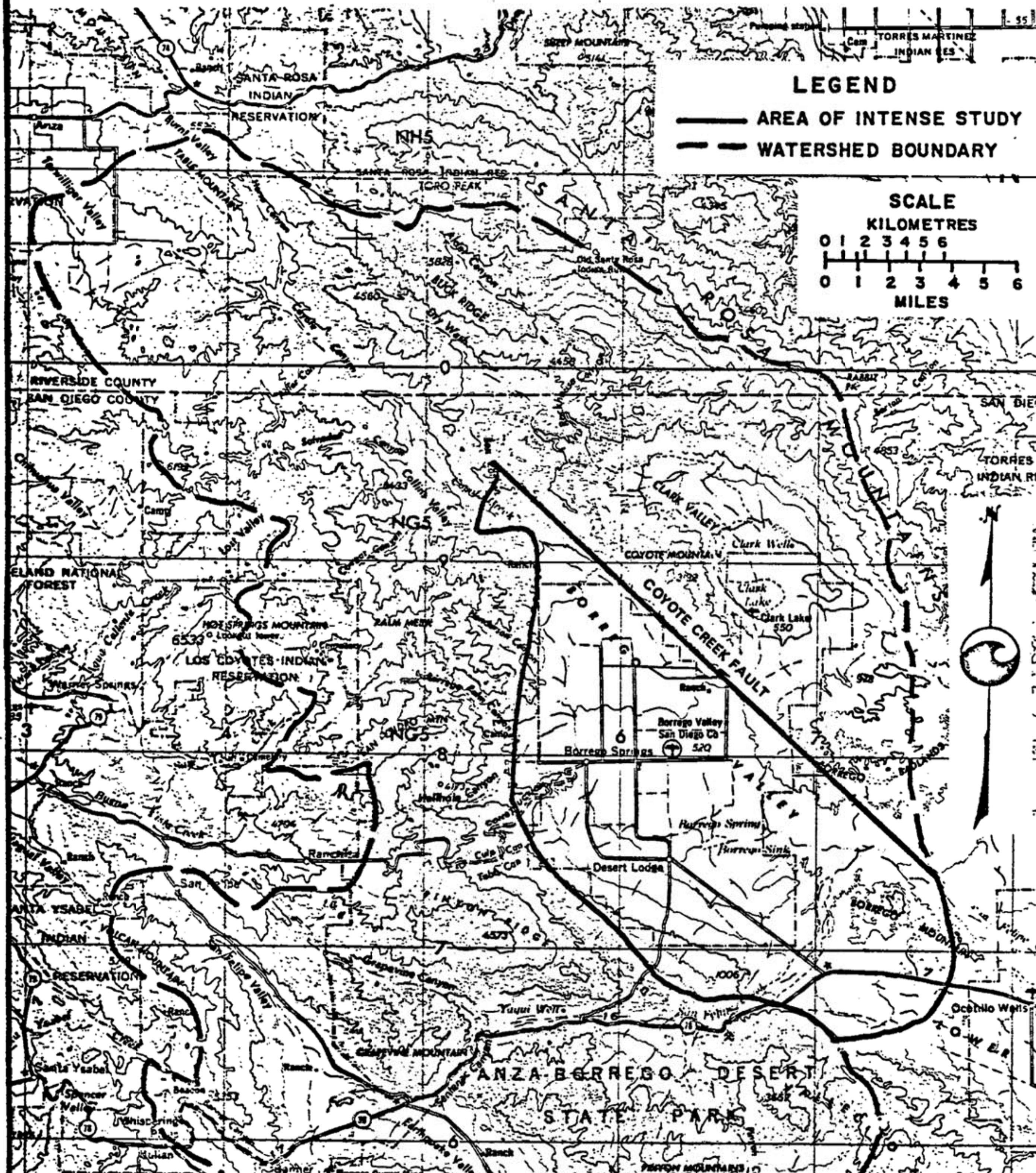

FIGURE 1. BORREGO VALLEY STUDY AREA

ESTIMATED RECHARGE USING HYDROLOGIC BALANCE

Change of Storage 1965-1980

USGS did not attempt to refine previously made estimates of the average annual recharge to the Borrego Valley. They range from 3,300 to 11,000 acre-feet per year. USGS did suggest that most of the ground water recharge is derived from: surface water percolation on Coyote, Borrego Palm Canyon, and San Felipe Creeks; ground water inflow from San Felipe Creek; and a small amount of surface water percolation from the other drainages.

A simple means of estimating recharge is by comparing the change in ground water levels between 1965 and 1980 and then applying an estimated specific yield to determine the change of ground water in storage. From this figure, the net annual change of ground water in storage, or net recharge, is easily determined.

The procedure used for determining the change of ground water in storage was as follows: first, the change in ground water level map for 1965-1980 was obtained from USGS and the weighted average decline for the period was determined to be about 7 feet; then the change of ground water in storage was computed by multiplying the average decline of water level times the area of the valley times a typical specific yield. Since ground water levels have varied mainly in the upper aquifer with a specific yield of 20% with some variation in the middle (10%) and lower (5%) aquifers, the specific yield used to compute change of ground water in storage bracketed the range between 10% and 20%.

Subsurface Outflow

An estimate of subsurface outflow from Borrego Valley was determined based on ground water basin data obtained by USGS. They transformed these data into maps of historic ground water levels and transmissivity. There is an alluvial gap between the Borrego Badlands and Borrego Mountain, east of Borrego

Sink, through which ground water apparently flows out of the valley. The formula Q = TIW, based on Darcy's Law, was used where Q = flow rate, T = transmissivity, I = hydraulic gradient, and W = width of cross-section of aquifer.

In 1945, at which time the ground water basin was being operated under steady-state conditions, the flow across the 460-foot contour was presumed to be the total outflow and was computed to be 1,900 acre-feet per year. In 1965, the flow across the 440-foot contour, which was the contour nearest the outlet to the valley, was estimated to be 3,800 acre-feet per year. Thus, it can be assumed that annual outflow is at least roughly 1,900 acre-feet per year. (Appendix A).

USGS has estimated that subsurface inflow to the valley is about 30 acre-feet per year from the San Felipe Creek drainage (Ref. 1, P. 17).

Water Budget

The annual consumptive water use figures developed by USGS are shown below. These data were combined with the change in storage estimates obtained previously to develop estimates of average recharge into the basin.

The hydrologic balance for the ground water basin is illustrated in Figure 2 and is summarized in the following equation:

Inflow - Outflow = Change in Storage
where:
Inflow = subsurface inflow + deep percolation of precipitation and applied water.
Outflow = Consumptive use by man and phreatophytes + subsurface outflow.

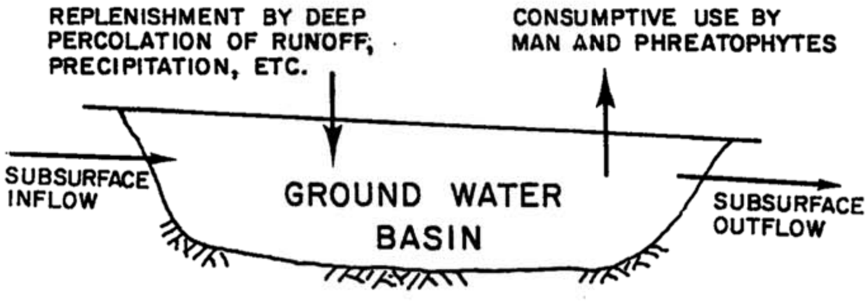

FIGURE 2. SCHEMATIC OF HYDROLOGIC BALANCE

Based on an examination of ground water levels for 1965 and 1980, the average decline in ground water levels throughout the 65,000-acre valley was about 7 feet. (See Appendix B for computations). The annual recharge for the ground water basin was estimated for specific yields of 10% and 20% since the average specific yield of the dewatered portion of the basin falls somewhere in between (probably closer to 10% than 20%); also, recharge was computed assuming that there is subsurface outflow as well as for the opposite case.

TABLE 1
ESTIMATED RECHARGE
USING CHANGE IN STORAGE

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Estimated decline in ground water levels, 1965-1980, feet	Annual consump-tive use, AF./yr.	Specific yield	Change in annual storage [65,000x(1)x(3)/15] AF./yr	Subsurface inflow, AF./yr.	Subsurface outflow, AF./yr.	Annual recharge w/o outflow, [(2)-(4)-(5)], AF./yr.	Annual recharge with outflow, [(2)-(4)-(5)+(6)], AF./yr.
7	9,870	0.10	3,000	30	1,900	6,800	8,700
		0.20	6,100	30	1,900	3,700	5,600

The annual recharge to Borrego Valley would range from 3,700-6,800 acre-feet per year, when it is assumed that there is no subsurface outflow from the valley; it would range from 5,600-8,700 acre-feet per year under the more likely situation where outflow was assumed to average 1,900 acre-feet per year. The ground water gradient near the southeast boundary of Borrego Valley gives indication that there is ground water outflow (Appendix A). Also, since average specific yield should be near 10%, the annual recharge would more likely range between 6,800 to 8,700 acre-feet per year with a tendency to favor the higher number since subsurface outflow is likely.

ESTIMATED RECHARGE USING ISOTRANSMISSIVITY MAP

An alternative means of obtaining an estimate of annual ground water recharge is to determine the subsurface flow across a centrally-placed contour of equal ground water elevation. Under steady-state conditions in which inflow to the valley equals outflow and the flow characteristics of the ground water remain constant with time, the flow calculated to be crossing the contour should represent the net amount of recharge to that portion of the basin located upgradient of the selected contour line. In this study, the year 1945 was believed to be representative of steady-state conditions and the flow across the 500-foot contour was selected as representative of basin recharge under these conditions since it lay upgradient from the areas of ground water discharge in the basin. This should give a reasonable estimate of recharge since most of the ground water recharge takes place on the alluvial fans upstream from this contours, along the mountain front. The total flow in 1945 across the 500-foot contour was estimated to be 8,900 acre-feet per year using Darcy's law. This would be the annual recharge to Borrego Valley under steady-state conditions (Appendix C).

ESTIMATED RECHARGE USING MATHEMATICAL MODEL

The linked-node type mathematical ground water model is a useful tool for investigating the various elements of a hydrologic budget including the amount and distribution of recharge to the ground water basin. To determine the amount of annual net recharge at each node, Q, the basic equation for the model was rearranged to solve for Q. Under a steady-state condition, no change of storage takes place; specific yield estimates for each node are not involved.

For this study, an isotransmissivity map and historic ground water level information for each node on a grid overlain on the valley that were developed by USGS (1) were used. These data were fed into a linked-node model of Borrego Valley to solve for Q of each node.

Using this technique it was determined that the recharge to Borrego Valley was 7,700 acre-feet per year under steady-state conditions. An additional examination was conducted to determine the sensitivity of Q at each node in relation to changes in transmissivity. Assuming that transmissivities were 15% higher throughout the valley, resulted in an estimate for annual recharge of 8,900 acre-feet (Appendix D).

COMPARISON WITH OTHER AGENCIES' RECHARGE ESTIMATES

For comparison, estimates of annual ground water basin recharge calculated by other agencies which have previously studied Borrego Valley are presented in Table 2. These estimates varied within a range from 3,300 acre-feet per year up to 11,000 acre-feet per year.

TABLE 2
BORREGO VALLEY GROUND WATER RECHARGE ESTIMATES

Source	Estimated annual recharge, AF/yr	
	1945-1964	1907-1964
Bureau of Reclamation (1968)*	6,000	11,000
County of San Diego (Lough, 1974)**	3,300	
Threet (1975)***	6,200 (174 square mile watershed) 10,000 (280 square mile watershed)	
A.A. Webb Associates (1977)†	11,000	

*U. S. Bureau of Reclamation, "Inland Basins Project, Borrego Valley, California", Reconnaissance Investigations, June 1968, p. 23.

**Lough, Charles F., "Water Budget for Borrego Valley", County of San Diego Integrated Planning Office, November 1974, p. 9.

***Threet, Richard L., "Review of Water Budget for Borrego Valley by Charles F. Lough", Correspondence to L. R. Burzell, January 1975.

†Albert A. Webb Associates, "Borrego Valley Groundwater Supply", Appendix to the "Borrego Country Club Draft General Plan Amendment Report" and "Borrego Country Club Draft Environmental Impact Report". 1977. In the report it was estimated that annual recharge was 12,100 acre-feet per year and noted that this was higher than the Bureau of Reclamation's higher estimate of 11,000 acre-feet per year. It concluded that for management purposes, 11,000 acre-feet per year is an appropriate figure.

SUMMARY

Three alternate methods were used in an effort to estimate the average annual recharge to Borrego Valley ground water basin. The first method made use of the hydrologic budget which is summarized by the equation: Inflow - Outflow = Change in Storage. The elements of the hydrologic equation, such as consumptive use by domestic users and vegetation and subsurface inflow were determined by USGS (1). The determination of subsurface outflow and change in storage were based on information developed by USGS. This method resulted in an estimated rate of annual recharge of between 6,800 and 8,700 acre-feet, with a tendency to favor the upper end of this range due to evidence of ground outflow from the valley.

The method of determining recharge using the isotransmissivity map and water level contour map for 1945 developed by USGS, resulted in an estimated annual recharge rate of 8,900 acre-feet. This was determined by calculating the flow across the elevation 500-foot contour line using Darcy's law.

The last approach used to estimate recharge was with a linked-node mathematical ground water model. Transmissivity values were obtained from the isotransmissivity map contained in USGS Open-File Report 82-855. Ground water levels were obtained from a tabulation used by USGS in its calibration effort of the Borrego Valley model. Using the USGS values resulted in an estimated annual recharge of 7,700 acre-feet.

With the three methods which utilized geohydrologic data developed by USGS, estimates of annual recharge ranged between 6,800 and 8,900 acre-feet. The low estimate of 6,800 acre-feet per year using the water budget is probably too low since there is likelihood of ground water outflow; the upper range hydrologic budget estimate of 8,700 acre-feet per year may be slightly high since average specific yield of the basin is somewhat higher than 10 percent.

The indication given by the isotransmissivity map and mathematical model methods is that the annual recharge should range between 7,700 and 8,900 acre-feet. For the purposes of this investigation, a figure of 8,000 acre-feet per year would be a reasonable estimate of annual ground water recharge, based on the estimates provided by the three methods, which ranged from 6,800 - 8,900 acre-feet per year.

After the completion of the preceding portion of this report, USGS made several revisions to the steady-state ground water map representing conditions in 1945. The major change was a smoothing out of the contours in the vicinity of San Felipe Creek, with the result that the estimated subsurface outflow rose from 1,900 acre-feet per year to 3,600 acre-feet per year. The net result was that using the hydrologic balance technique, annual recharge was estimated to be 10,400 acre-feet per year (see Appendix E).

By using the revised 1945 contour map, USGS also made two estimates of the average annual recharge to Borrego Valley ground water basin. One estimate was based on a water yield method and the amount of recharge estimated was 3,800 acre-feet per year. Another estimate was based on a chloride method and the amount was 13,000 acre-feet per year. By estimating weighting factors for each estimate, including our three estimates, and based on the variance, USGS arrived at a weighted average annual recharge of approximately 8,400 acre-feet per year. Upon completion of its calibration of the mathematical model, it is expected that USGS will prepare a summary providing details of their estimates as well as the derivation of the weighted average recharge. This estimate is adopted for use in this study as representative of average annual recharge to Borrego Valley.

Because the water consumption by phreatophytes of about 1,200 acre-feet per year estimated by USGS, and the subsurface outflow of about 3,600 acre-feet per year estimated by DWR are expected to continue at about the same magnitudes, the usable portion of the replenishment would be approximately 3,600 acre-feet per year (8,400 - 1,200 - 3,600).

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REFERENCES

1. Moyle, W.R., "Water Resources of Borrego Valley and Vicinity, California - Phase I - Definition of Geologic and Hydrologic Characteristics of Basin." United States Geological Survey Open File Report 82-855. November 1982.

2. PRC Toups Corporation. "Borrego Water District Latent Powers Authorization." Focused Environmental Impact Report. La Jolla, CA Revised November 1979.

Appendix A

OUTFLOW FROM BORREGO VALLEY

The outflow from Borrego Valley was estimated for two years, 1945 and 1965. The method was to apply Darcy's law across a ground water contour line near the outlet of the valley. The calculations and contours used are shown in the following two tables and figures. Also included is a map of transmissivity for the Borrego Valley ground water basin developed by USGS(1).

STATE OF CALIFORNIA

DEPARTMENT OF WATER RESOURCES
COMPUTATION SHEET

THE RESOURCES AGENCY

DRAFT

Project: BORREGO VALLEY

Sheet:

Feature: FLOW ACROSS EL. 460'

Designed: KH.

Date: 1/17/83

Item: CONTOUR IN 1945

Checked:

Date:

(1) Section No.	(2) Transmissivity 1,000 ft²/day	(3) Length X-Section feet, W	(4) Gradient length, feet	(5) Upper HGL feet	(6) Lower HGL feet	(7) Diff feet	(8) (7)/(4) Grad i	(9) Q=TiW (2)(3)(8) ft³/day
1	4	5,000	7,000	470	450	20	0.00286	57,000
2	5	5,000	11,000	470	450	20	0.00182	46,000
3	2	5,000	3,000	470	450	20	0.00667	67,000
4	0.8	5,000	1,500	470	450	20	0.01333	53,000
								223,000 ft³/day

$$223{,}000\ \frac{ft^3}{day} \times \frac{365\ days}{yr} \times \frac{1\ acre}{43{,}560\ ft^2} = 1{,}900\ \frac{acre\text{-}feet}{year}$$

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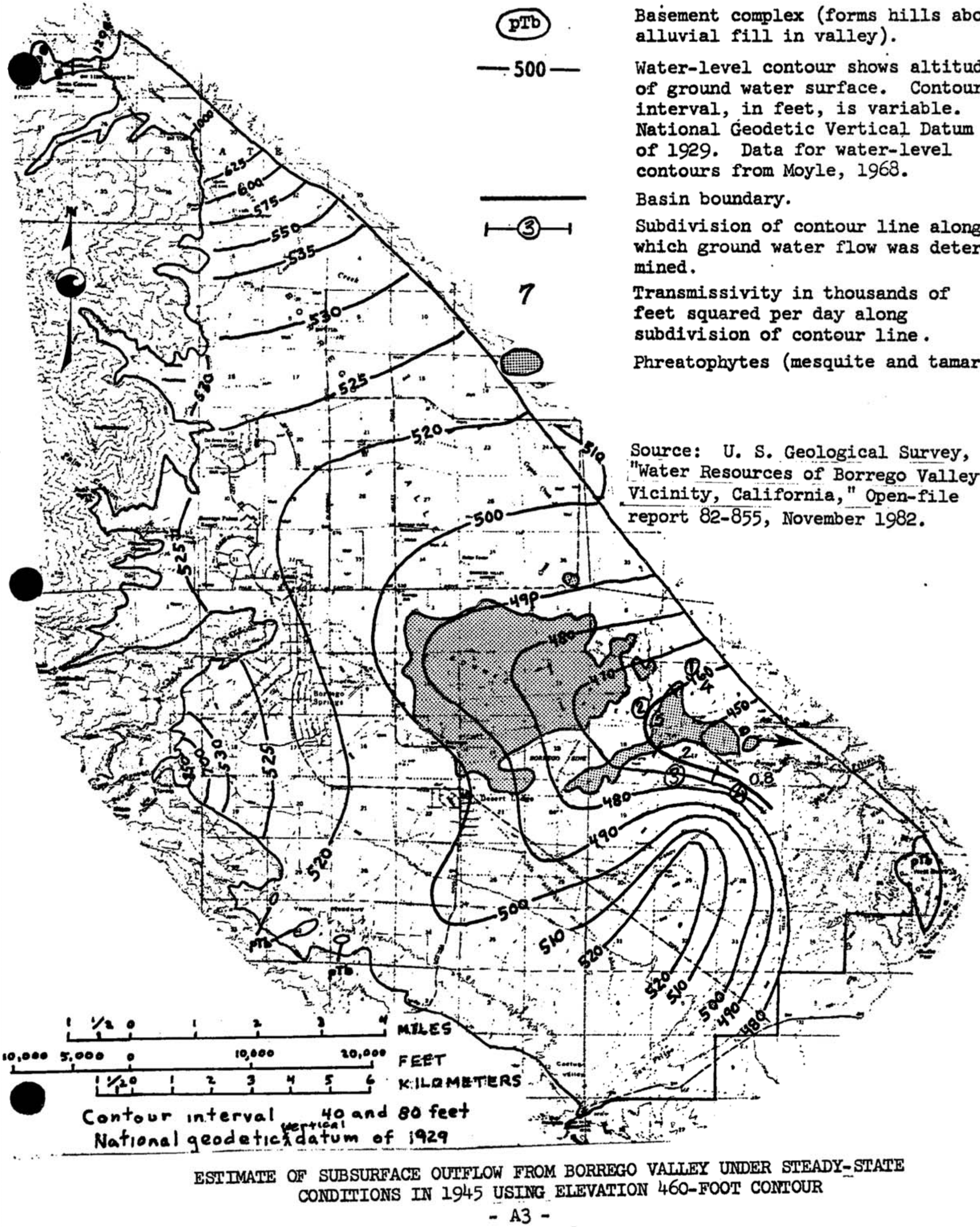

Source: U. S. Geological Survey, "Water Resources of Borrego Valley a Vicinity, California," Open-file report 82-855, November 1982.

ESTIMATE OF SUBSURFACE OUTFLOW FROM BORREGO VALLEY UNDER STEADY-STATE CONDITIONS IN 1945 USING ELEVATION 460-FOOT CONTOUR

STATE OF CALIFORNIA | DEPARTMENT OF WATER RESOURCES | THE RESOURCES AGENCY

COMPUTATION SHEET

Project BORREGO VALLEY | Sheet

Feature FLOW ACROSS EL. 440' | Designed | Date

Item CONTOUR IN 1965 | Checked | Date 1/5/83

(1) Section No.	(2) Transmissivity 1,000 ft²/day	(3) Length X-Section feet, W	(4) Gradient Length, feet	(5) Upper HGL feet	(6) Lower HGL feet	(7) Diff feet	(8) (7)/(4) Grad i	(9) Q=TiW (2)(3)(8) ft³/day
1	6	7,100	5,000	450	440	10	0.00200	85,000
2	8	5,000	3,500	450	440	10	0.00286	114,000
3	8	1,400	4,300	450	440	10	0.00233	26,000
4	6	5,500	2,900	450	440	10	0.00345	114,000
5	4	5,900	2,900	450	440	10	0.00345	81,000
6	2	4,800	3,600	450	440	10	0.00278	27,000
7	1	4,600	4,000	450	440	10	0.00250	12,000

Sections 1-3 225,000

Sections 4-7 234,000

459,000

$$459{,}000\ \frac{ft^3}{day} \times \frac{365\ days}{yr} \times \frac{1\ acre}{43{,}560\ ft^2} = 3{,}800\ AF/yr$$

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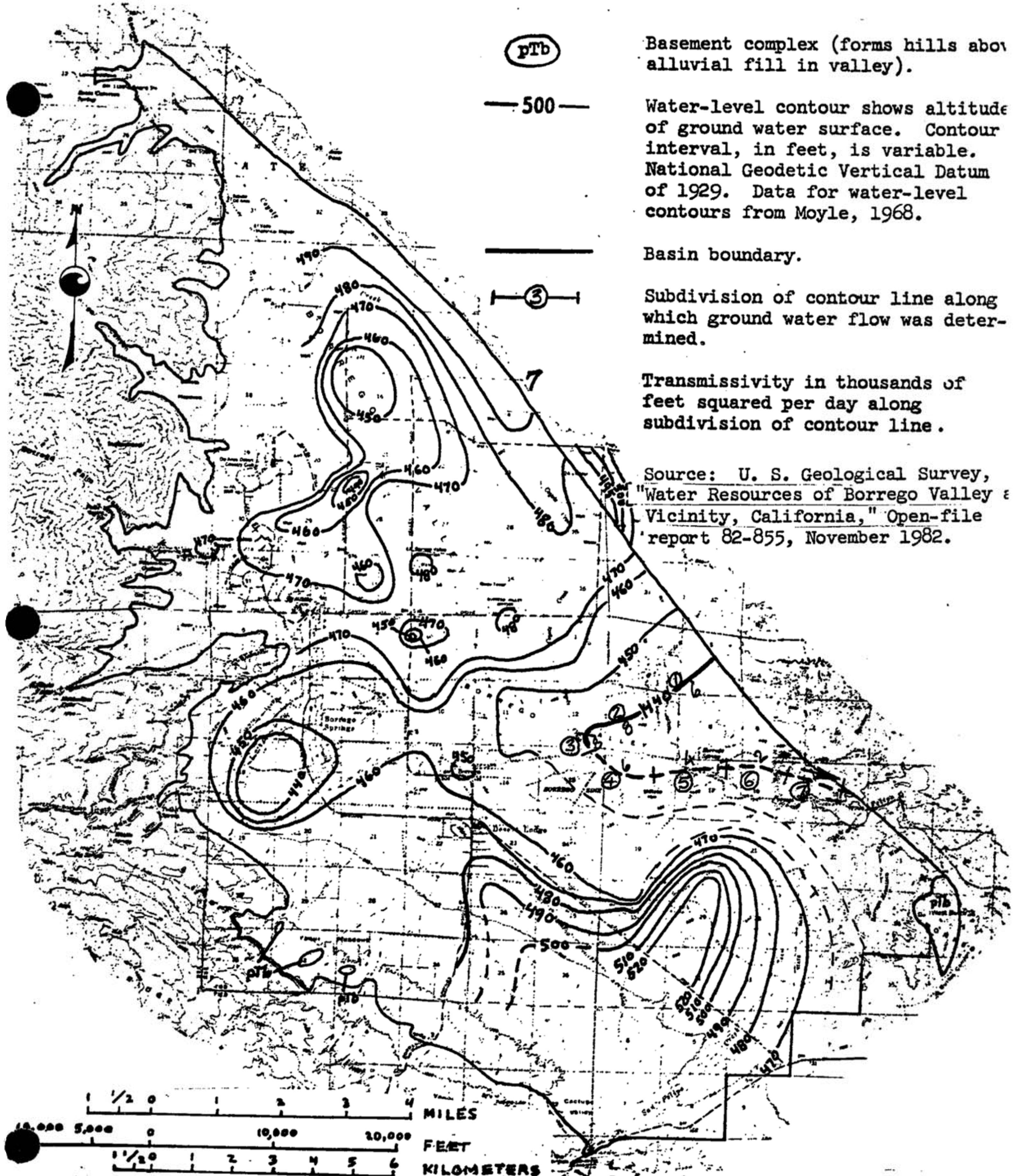


EXPLANATION

(pTb) Basement complex (forms hills above alluvial fill in valley).

—500— Water-level contour shows altitude of ground water surface. Contour interval, in feet, is variable. National Geodetic Vertical Datum of 1929. Data for water-level contours from Moyle, 1968.

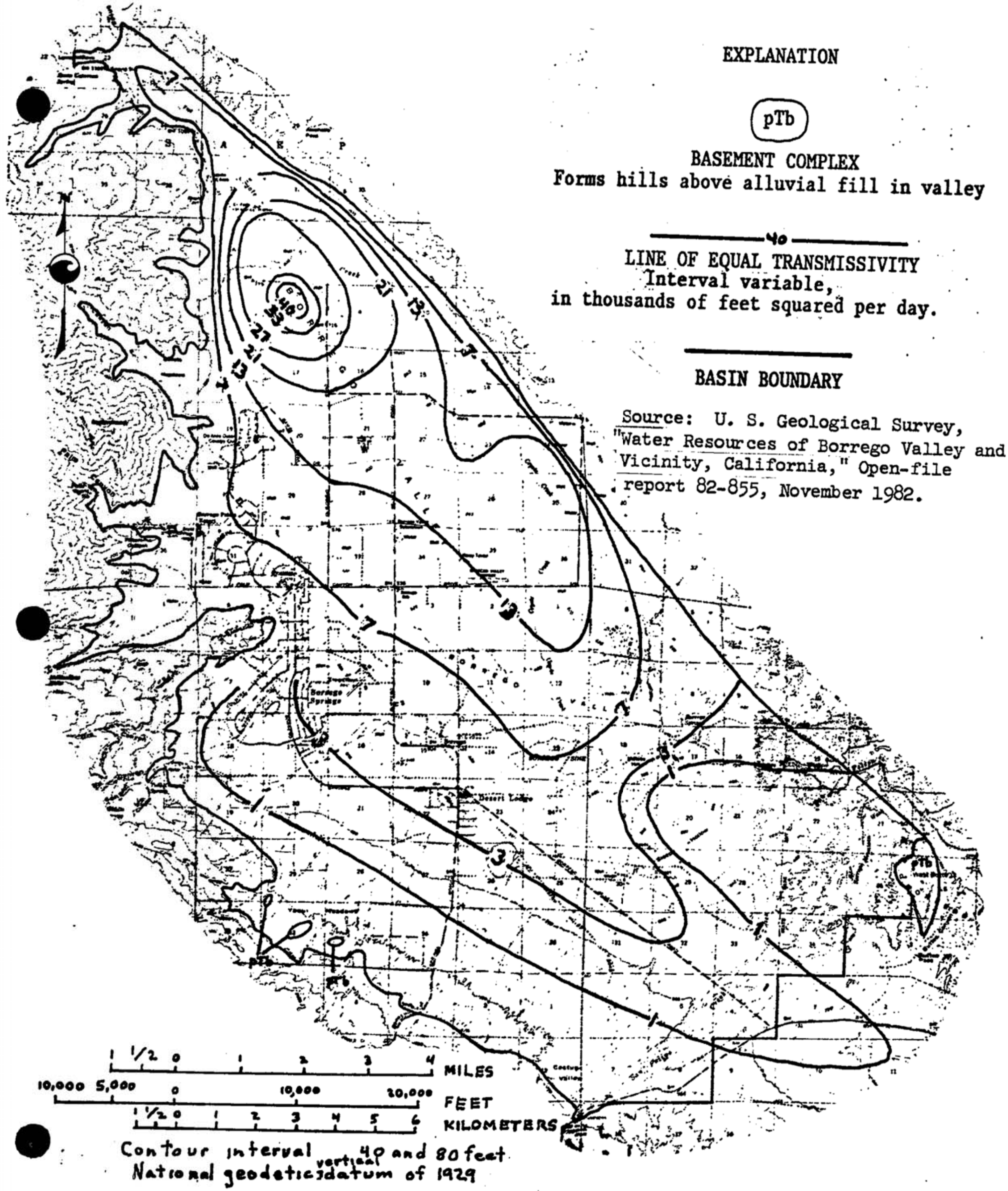
Basin boundary.

├③┤ Subdivision of contour line along which ground water flow was determined.

7 Transmissivity in thousands of feet squared per day along subdivision of contour line.

Source: U. S. Geological Survey, "Water Resources of Borrego Valley and Vicinity, California," Open-file report 82-855, November 1982.

ESTIMATE OF SUBSURFACE OUTFLOW FROM BORREGO VALLEY IN 1965
USING ELEVATION 1,440-FOOT CONTOUR

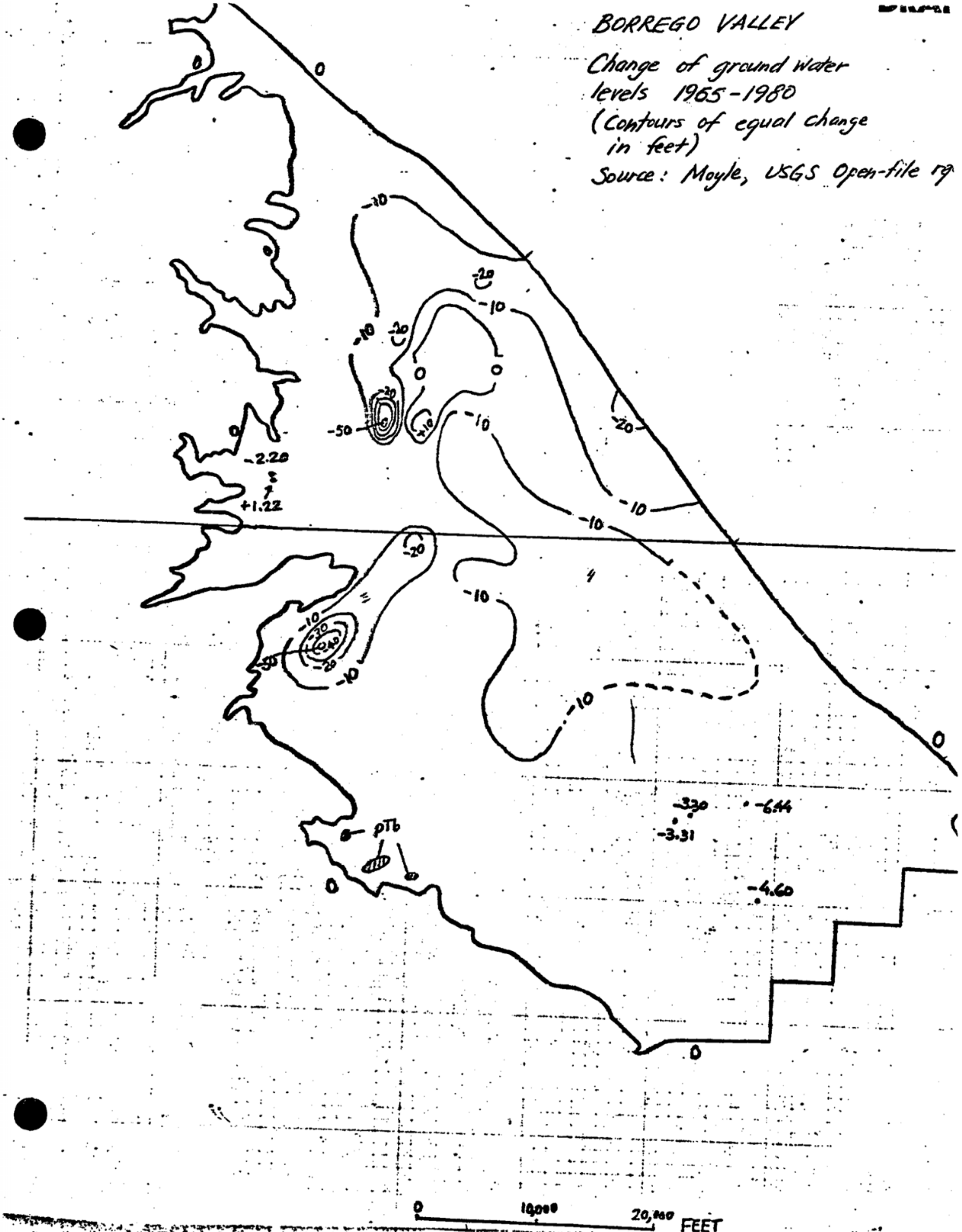


TRANSMISSIVITY MAP OF ALLUVIAL SEDIMENTS IN BORREGO VALLEY, CALIFORNIA

APPENDIX B

CALCULATIONS FOR ESTIMATING RECHARGE USING HYDROLOGIC BALANCE

In general, the procedure may be described as follows. First, a map was made of the lines of equal change of ground water elevation for the period between 1965 and 1980. From this map, the average decline in water level was obtained by taking a weighted average of the areas within each contour line. An average specific yield of between 10% and 20%, inclusive, is representative of the average specific yield in the valley. Multiplying these elements together produced the change in storage for 1965 and 1980. After introducing the elements of ground water inflow and outflow, the total annual recharge was estimated (Table 1).



BORREGO VALLEY
Change of ground water levels 1965-1980
(Contours of equal change in feet)
Source: Moyle, USGS Open-file rg
0
-10
-20
-50
+10
-2.20
+1.22
pTb
-3.30
-6.44
-3.31
-4.60
0 10,000 20,000 FEET

Change in Storage 1965-80

DWR Planimeter No. 14133

Calibrate

Initial	Final	Diff.
4.829	5.208	0.379
0.399	0.778	0.379
1.358	1.735	0.377
2.002	2.382	0.380

1.515/4 = 0.379

0.379 = 20,000 x 20,000 ft^2
= 400,000,000 ft^2
= 9,183 acres

AREA OF VALLEY FILL (0 - Ft. Change Contour)

North Half				South Half			
Initial	Final	Diff.	Area	Initial	Final	Diff.	Area
0.806	1.751	0.945	22,897	2.284	4.009	1.725	41,796
3.263	4.203	0.940	22,776	4.440	6.166	1.726	41.820
5.009	5.950	0.941	22,800	7.443	9.175	1.732	41,966

68,473 acres ÷ 3 = 22,800 acres

125,582 ÷ 3 = 41,900

Total Area (+0) contour = 64,700 acres

AREA WITHIN (+10) CONTOUR

Initial	Final	Diff.	Area
8.699	8.704	0.005	121 acres

Area = 121/3 = 40 Acres

AREA WITHIN (+0) CONTOUR

Initial	Final	Diff.	Area
9.024	9.073	0.049	1,187
9.463	9.509	0.046	1,115
0.543	0.595	0.052	1,260

Area = 3,562/3 = 1,187 acres

AREA WITHIN (-10) CONTOUR

(1) Initial	Final	Diff.	(2) Initial	Final	Diff.	(3) Initial	Final	Diff.
0.487	0.700	0.213	3.140	3.467	0.327	6.828	6.894	0.066
0.896	1.112	0.216	3.806	4.133	0.327	7.126	7.190	0.064
1.260	1.477	0.217	4.843	5.173	0.330	7.543	7.605	0.062

Avg. $= \frac{0.646}{3} = 0.215$ Avg. $= \frac{0.984}{3} = 0.328$ Avg. $= \frac{0.192}{3} = 0.064$

$0.215 \times \frac{9,183}{0.379} = 5,209$ acre $0.328 \times \frac{9,183}{0.379} = 7,947$ acre $0.064 \times \frac{9,183}{0.379} = 1,551$ acres

Total within (-10) Contour = 14,707 acres

AREA WITHIN (-20) CONTOUR

No.	Initial	Final	Diff.
1	7.324	7.327	0.003
2	7.481	7.482	0.001
3	7.400	7.408	0.008
4	7.999	8.001	0.002
5	8.318	8.319	0.001
6	8.057	8.073	0.016
			0.031

$$\text{Area} = 0.031 \times \frac{9{,}183}{0.379} = \underline{751 \text{ acres}}$$

AREA WITHIN (-30) CONTOUR

No.	Initial	Final	Diff.
1	8.220	8.226	0.006
2	8.197	8.203	0.006
			0.012

$$\text{Area} = 0.012 \times \frac{9{,}183}{0.379} = \underline{291 \text{ acres}}$$

AREA WITHIN (-40) CONTOUR

No.	Initial	Final	Diff.
1	7.950	7.953	0.003
2	8.400	8.403	0.003
			0.006

$$\text{Area} = 0.006 \times \frac{9{,}183}{0.379} = \underline{145 \text{ acres}}$$

AREA WITHIN (-50) CONTOUR

$$2 \times (500 \text{ ft} \times 500 \text{ ft}) \times \frac{1 \text{ acre}}{43{,}560} = \underline{11 \text{ acres}}$$

Change in Water Level 1965-80 (feet)	Inclusive Area Within Contour Line of Equal Change (acres)
+10	40
0	64,700
-10	14,707
-20	751
-30	291
-40	145
-50	11

Average Change (feet)	Area of Average Change (acres)	Total Volume Change within contour (acre-feet)
+10	40	400
- 5	49,993	-249,965
-11	13,956	-153,516
-25	460	- 11,500
-35	146	- 5,110
-45	134	- 6,030
-50	11	- 550
	64,740 acres	-426,271 (acre-feet)

$$\frac{-426{,}271}{64{,}740} = -6.6 \text{ feet average throughout valley}$$

APPENDIX C

CALCULATIONS FOR ESTIMATING RECHARGE USING ISOTRANSMISSIVITY MAP

Under steady-state conditions, the subsurface flow across a contour line lying downstream of the recharge area and upstream of an area of phreatophytes, should be an estimate reasonably close to the volume of annual recharge to the ground wter basin. Consequently, the flow was determined across the 500-foot contour using Darcy's equation. The procedure is shown in the following pages.

STATE OF CALIFORNIA — DEPARTMENT OF WATER RESOURCES — THE RESOURCES AGENCY

COMPUTATION SHEET

DRAFT

Project: BORREGO VALLEY — Sheet:

Feature: Flow across 500-ft contour — Designed: K.H — Date: 12/16/82

Item: 1945 Steady-state condition — Checked: — Date:

1 inch = 10,000 feet

(1) Section No.	(2) Transmissivity 1000 ft²/day	(3) Length, W X-section feet	(4) Gradient length ft feet	(5) Upper H.G.L feet	(6) Lower H.G.L. ft.	(7) (5)-(6) Diff ft	(8) (7)/(4) Grad i	(9) Q=Tiw ft³/day
1	13	10,800	14,900	520	490	30	0.00201	283,0[illegible]
2	13	4,800	15,500	520	490	30	0.00194	121,0[illegible]
3	10	4,200	16,300	520	490	30	0.00184	77,0[illegible]
4	7	4,000	11,900	520	490	30	0.00252	71,0[illegible]
5	5	4,200	8,500	520	490	30	0.00353	74,000
6	5	6,300	9,400	520	490	30	0.00319	101,00[illegible]
7	5	5,700	9,000	510	490	20	0.00222	63,000
8	3	4,000	10,000	510	490	20	0.00200	24,000
9	1	5,500	12,000	510	490	20	0.00167	9,000
10	1	7,000	10,100	510	490	20	0.00198	14,000
11	3	7,100	6,000	510	490	20	0.00333	71,000
12	3	7,800	4,100	510	490	20	0.00488	114,000
13	1	4,500	2,200	510	490	20	0.00909	41,000
								1,063,000

$$1,063,000 \frac{ft^3}{day} \times \frac{365\ days}{yr} \times \frac{1\ acre\text{-}ft}{43,560\ ft^2} = 8,900\ AF/y$$

3800

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EXPLANATION

pTb — Basement complex (forms hills abo[ve] alluvial fill in valley).

—500— Water-level contour shows altitud[e] of ground water surface. Contour interval, in feet, is variable. National Geodetic Vertical Datum of 1929. Data for water-level contours from Moyle, 1968.

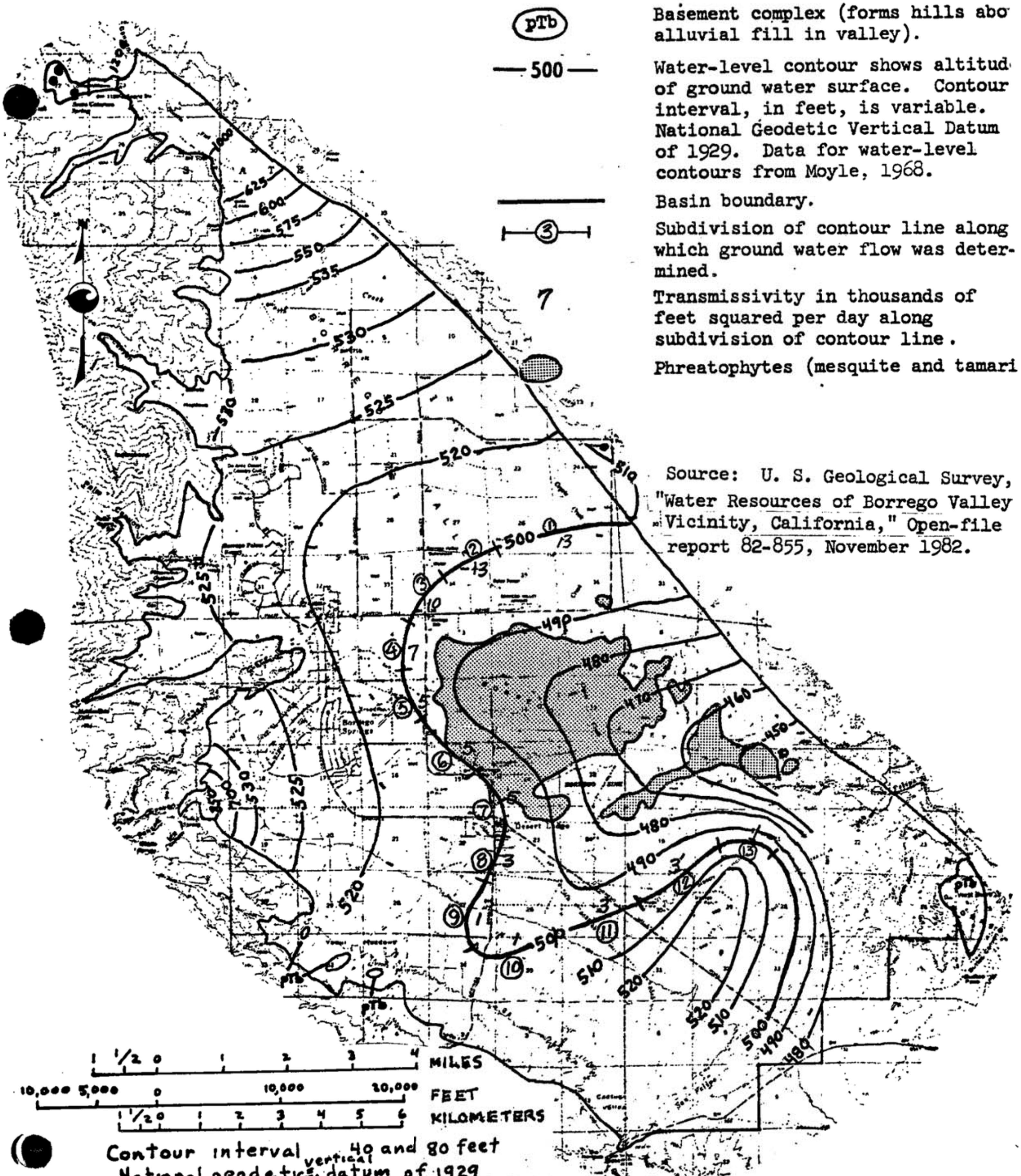
Basin boundary.

—③— Subdivision of contour line along which ground water flow was determined.

7 — Transmissivity in thousands of feet squared per day along subdivision of contour line.

Phreatophytes (mesquite and tamari[sk])

Source: U. S. Geological Survey, "Water Resources of Borrego Valley Vicinity, California," Open-file report 82-855, November 1982.



ESTIMATE OF ANNUAL REPLENISHMENT UNDER STEADY-STATE CONDITIONS IN 1945 USING ELEVATION 500-FOOT CONTOUR

APPENDIX D

RESULTS USING MATHEMATICAL MODEL TO ESTIMATE RECHARGE

A linked-node mathematical ground water model was utilized in combination with transmissivity and steady-state (1945) ground water level data to obtain an estimate of the spatial distribution of deep percolation. The set-up of the model's nodal network parallelled a preliminary network developed by USGS which was composed of rectangular elements 40 rows long and 19 columns wide.

Table 1 presents the set of transmissivities developed by USGS based on their studies (1). The mathematical model is based on the continuity equation $\Sigma(H_i - H_B) \times T + Q = 0$, for steady-state conditions where H_B is the piezometric head at node "B", H_i is the head at adjacent node "i", T is the transmissivity along the connecting link, and Q is the net deep percolation at the node. The equation is solved for Q; the set of Q's obtained using the transmissivities in Table 1 is shown in Table 2. Recharge to the valley was found to total 7,700 acre-feet per year.

In order to examine how sensitive the net recharge was with respect to changes in transmissivity, the set of transmissivities in Table 1, representing USGS values, was increased by 15 percent (Table 3). The result was that the amount of recharge increased by 15 percent to 8,900 acre-feet per year (Table 4).

Table 5 lists a set of transmissivities which were developed by USGS for an early calibration run of the USGS's ground water model. Some of the figures were greatly modified by USGS from the transmissivities given in Reference 1. Table 6 shows the results of using these transmissivities. The amount of deep percolation was found, by DWR, to be only 2,600 acre-feet, using these figures.

DRAFT

TABLE 1
TRANSMISSIVITIES BASED UPON USGS DATA*

TRANSMISSIVITY IN AF/YR/FT

ROW COL	1	2	3	4	5	6	7	8	9	10
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4	8.4	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4	16.8	25.1
10	0.0	0.0	0.0	0.0	0.0	8.4	8.4	16.8	41.9	58.7
11	0.0	0.0	0.0	0.0	0.0	8.4	8.4	16.8	33.5	58.7
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.8	33.5	58.7
13	0.0	0.0	0.0	8.4	8.4	8.4	0.0	16.8	41.9	58.7
14	0.0	0.0	8.4	8.4	16.8	16.8	8.4	16.8	33.5	58.7
15	0.0	0.0	8.4	12.6	16.8	20.9	25.1	41.9	50.3	58.7
16	0.0	0.0	8.4	12.6	16.8	25.1	33.5	41.9	50.3	58.7
17	0.0	0.0	8.4	12.6	16.8	25.1	33.5	41.9	50.3	58.7
18	0.0	0.0	8.4	12.6	16.8	25.1	33.5	41.9	50.3	58.7
19	1.7	4.2	8.4	12.6	16.8	25.1	33.5	41.9	50.3	58.7
20	1.7	4.2	6.7	8.4	12.6	25.1	33.5	41.9	50.3	58.7
21	1.7	4.2	6.7	8.4	14.2	25.1	33.5	41.9	50.3	58.7
22	0.0	4.2	6.7	8.4	16.8	25.1	33.5	41.9	50.3	58.7
23	0.0	4.2	6.7	8.4	12.6	16.8	29.3	33.5	41.9	58.7
24	0.0	3.4	6.7	8.4	12.6	16.8	25.1	29.3	33.5	41.9
25	0.0	3.4	6.7	8.4	12.6	16.8	25.1	29.3	33.5	33.5
26	0.0	3.4	6.7	7.5	10.1	16.8	25.1	29.3	33.5	25.1
27	0.0	3.4	6.7	7.5	8.4	16.8	25.1	26.8	26.8	25.1
28	0.0	0.0	6.7	7.5	8.4	16.8	25.1	26.8	26.8	16.8
29	0.0	0.0	6.7	7.5	8.4	16.8	25.1	25.1	25.1	16.8
30	0.0	0.0	6.7	7.5	8.4	8.4	20.9	25.1	25.1	16.8
31	0.0	0.0	5.9	6.7	7.5	8.4	20.9	20.9	20.9	16.8
32	0.0	0.0	5.0	5.9	6.7	7.5	16.8	16.8	16.8	12.6
33	0.0	0.0	1.7	3.4	5.0	6.7	8.4	10.1	10.1	8.4
34	0.0	0.0	1.7	3.4	5.0	6.7	7.5	8.4	9.2	9.2
35	0.0	0.0	0.0	0.0	3.4	5.9	6.7	7.5	9.2	9.2
36	0.0	0.0	0.0	0.0	0.0	0.0	4.2	4.2	4.2	4.2
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	4.2	4.2
38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	4.2	4.2
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	1.7	1.7
40	1.7	1.7	1.7	0.0	0.0	0.0	0.0	1.7	1.7	1.7

*Moyle, W. R., Jr. "Water Resources of Borrego Valley and Vicinity, California." U. S. Geological Survey Open-file Report 82-855. November 1982.
Plate 6 in this report, showing the transmissivity of the alluvial sediments in the valley was the source of the data.

TABLE 1 (continued)
TRANSMISSIVITIES BASED UPON USGS DATA*

TRANSMISSIVITY IN AF/YR/FT

ROW COL	11	12	13	14	15	16	17	18	19
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.8	16.8
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.3	41.9
4	0.0	0.0	0.0	0.0	0.0	41.9	117.3	117.3	83.8
5	0.0	0.0	0.0	0.0	142.4	176.0	234.6	217.9	142.4
6	0.0	16.8	41.9	134.1	167.6	243.0	251.4	251.4	176.0
7	0.0	25.1	83.8	167.6	226.2	335.2	276.5	226.2	176.0
8	41.9	33.5	83.8	150.8	251.4	310.0	251.4	226.2	176.0
9	50.3	83.8	108.9	150.8	217.9	251.4	251.4	209.5	108.9
10	75.4	100.6	117.3	134.1	192.7	201.1	201.1	184.3	108.9
11	75.4	100.6	117.3	142.4	184.3	209.5	209.5	201.1	0.0
12	75.4	92.2	108.9	117.3	134.1	142.4	108.9	117.3	0.0
13	83.8	83.8	108.9	108.9	117.3	108.9	100.6	83.8	0.0
14	75.4	92.2	100.6	117.3	117.3	108.9	100.6	75.4	0.0
15	75.4	83.8	100.6	117.3	117.3	108.9	108.9	0.0	0.0
16	75.4	83.8	100.6	108.9	113.1	108.9	108.9	0.0	0.0
17	75.4	83.8	108.9	113.1	113.1	113.1	108.9	0.0	0.0
18	75.4	83.8	108.9	113.1	113.1	108.9	83.8	0.0	0.0
19	75.4	92.2	108.9	113.1	113.1	108.9	83.8	0.0	0.0
20	75.4	100.6	108.9	110.6	110.6	108.9	0.0	0.0	0.0
21	67.0	83.8	104.7	108.9	100.6	83.8	0.0	0.0	0.0
22	67.0	75.4	83.8	83.8	67.0	58.7	0.0	0.0	0.0
23	67.0	71.2	75.4	67.0	58.7	50.3	0.0	0.0	0.0
24	50.3	50.3	50.3	46.1	41.9	0.0	0.0	0.0	0.0
25	41.9	41.9	41.9	41.9	41.9	0.0	0.0	0.0	0.0
26	16.8	25.1	25.1	25.1	25.1	0.0	0.0	0.0	0.0
27	8.4	8.4	8.4	8.4	16.8	0.0	0.0	0.0	0.0
28	7.5	7.5	8.4	8.4	16.8	0.0	0.0	0.0	0.0
29	8.4	7.5	7.5	7.5	8.4	0.0	0.0	0.0	0.0
30	8.4	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	8.4	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	8.4	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	7.5	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	4.2	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	4.2	4.2	4.2	0.0	0.0	0.0	0.0	0.0	0.0
38	4.2	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7
40	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 2
ANNUAL DEEP PERCOLATION BASED ON TRANSMISSIVITIES IN TABLE 1

DEEP PERCOLATION AND SUBSURFACE INFLOW IN AF/YR

RWO	COL 1	2	3	4	5	6	7	8	9	10
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.0	-5.4	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	18.9	14.2
10	0.0	0.0	0.0	0.0	0.0	2.5	.5	4.7	3.8	7.8
11	0.0	0.0	0.0	0.0	0.0	2.1	2.4	.7	-4.3	-.3
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-.0	12.6	8.4
13	0.0	0.0	0.0	-.2	-.0	-.1	0.0	-.1	9.5	7.4
14	0.0	0.0	103.1	-31.1	3.0	1.6	2.2	7.4	6.0	21.5
15	0.0	0.0	-6.2	-9.2	.8	1.7	3.0	16.2	38.8	17.4
16	0.0	0.0	-1.9	-3.4	-.3	1.9	.8	-1.5	23.9	-.9
17	0.0	0.0	-.9	-.1	-.6	.9	-2.1	-3.8	8.3	146.2
18	0.0	0.0	.1	-.5	.3	-1.0	.7	-.6	4.7	18.0
19	-.3	-1.6	-1.4	-.4	-2.5	-.3	2.3	1.3	-4.8	-72.4
20	-.0	-.5	-.7	-2.0	-1.2	2.0	2.8	3.9	-34.3	-138.4
21	.3	.6	-.5	-.2	3.0	-.0	2.3	3.9	145.9	-249.2
22	0.0	.2	-.1	-.3	.5	-2.6	3.6	6.9	-46.5	-41.1
23	0.0	-.2	-.6	.5	-1.8	-1.2	1.4	.3	-15.1	-41.4
24	0.0	.0	-.1	-.7	-.4	3.2	4.6	3.1	2.7	-6.8
25	0.0	.1	-.4	-.3	-.0	3.4	4.9	3.7	2.5	-.8
26	0.0	.2	-.1	-.7	-.7	2.2	.2	.0	-.9	-1.9
27	0.0	.5	-.6	-.3	.6	.9	1.5	.6	-.7	-1.2
28	0.0	0.0	-.6	-.8	.9	1.8	.3	-.1	-2.2	-1.5
29	0.0	0.0	-1.5	-1.5	1.0	-.5	.7	-.8	-.2	-1.9
30	0.0	0.0	26.0	-.4	4.3	4.4	13.7	12.9	13.2	9.4
31	0.0	0.0	.3	6.7	10.0	13.5	27.1	24.4	22.4	17.0
32	0.0	0.0	-3.2	-1.1	1.6	4.0	-2.2	-1.7	.4	.4
33	0.0	0.0	-4.6	-3.4	-.2	4.4	-4.7	-.7	4.3	12.3
34	0.0	0.0	-3.1	-6.3	20.9	44.2	88.9	127.8	172.8	194.3
35	0.0	0.0	0.0	0.0	-17.4	-31.3	83.1	79.4	82.8	81.8
36	0.0	0.0	0.0	0.0	0.0	0.0	-174.2	-39.3	-109.9	-139.3
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-29.3	-18.2	-15.5
38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-65.0	-61.2	-53.3
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-58.2	-59.0	-63.7
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-59.7	-59.2	-56.7

TABLE 2 (continued)
ANNUAL DEEP PERCOLATION BASED ON
TRANSMISSIVITIES IN TABLE 1

DEEP PERCOLATION AND SUBSURFACE FLOW

ROW	COL 11	12	13	14	15	16	17	18	19
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.1
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	109.8	208.5
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	675.2	479.3
4	0.0	0.0	0.0	0.0	0.0	49.0	-93.6	1256.9	787.8
5	0.0	0.0	0.0	0.0	-39.1	-81.6	-670.9	-371.9	203.0
6	0.0	2.8	-23.3	32.4	-45.7	3.2	-286.2	-493.0	1.7
7	0.0	-7.5	-39.5	-24.2	79.8	71.3	-55.5	-346.0	-206.8
8	-.4	-11.3	-24.8	-58.9	10.8	-10.4	39.6	-152.3	-237.1
9	8.3	1.2	-31.2	-6.4	-11.7	-12.8	-2.8	-25.1	-41.7
10	2.6	-1.8	.5	-6.7	-.6	6.6	-1.2	-2.0	-12.6
11	-2.6	-2.2	-10.0	-11.0	-18.6	-5.9	-11.9	-9.3	0.0
12	.8	-4.6	-7.3	-11.5	-12.7	-28.0	-20.3	24.9	0.0
13	6.2	-1.0	3.0	7.6	-5.9	3.1	48.4	29.6	0.0
14	16.5	-2.7	-3.1	13.6	10.0	-56.2	49.6	26.0	0.0
15	27.0	-8.7	2.7	-9.0	-.3	111.1	-.1	0.0	0.0
16	-.8	-3.1	8.3	-9.0	-47.1	63.6	-5.4	0.0	0.0
17	-61.4	4.0	-5.6	7.4	-28.3	-43.8	-18.8	0.0	0.0
18	108.7	22.0	26.0	21.8	125.1	81.6	-20.5	0.0	0.0
19	48.8	-31.7	14.0	-39.5	30.1	72.6	10.9	0.0	0.0
20	-29.7	-12.6	-89.5	-33.6	-71.4	-49.4	0.0	0.0	0.0
21	6.8	-22.3	-13.4	77.6	-43.3	-42.7	0.0	0.0	0.0
22	-605.8	-9.7	-4.7	47.0	-33.2	-26.2	0.0	0.0	0.0
23	3.9	-6.3	-56.7	-1.2	-23.5	-15.0	0.0	0.0	0.0
24	-.7	10.1	-25.5	-25.9	-3.0	0.0	0.0	0.0	0.0
25	-3.1	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	-1.7	-2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	-1.8	-1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	-.3	-.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	-.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	6.8	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	4.2	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	5.9	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	19.3	-11.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	164.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	103.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	-130.6	128.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	-18.2	-25.6	-35.6	0.0	0.0	0.0	0.0	0.0	0.0
38	-37.9	-138.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	-89.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	-52.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

THE AMOUNT OF DEEP PERCOLATION IS 7698.5326992 ACRE-FEET A YEAR
THE AMOUNT OF OUTFLOW IS-7698.53269921 ACRE-FEET A YEAR

TABLE 3

TRANSMISSIVITIES 15 PERCENT LARGER THAN THOSE BASED UPON USGS DATA IN TABLE 1

TRANSMISSIVITY IN AF/YR/FT

ROW COL	1	2	3	4	5	6	7	8	9	10
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6	9.6	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6	19.3	28.9
10	0.0	0.0	0.0	0.0	0.0	9.6	9.6	19.3	48.2	67.5
11	0.0	0.0	0.0	0.0	0.0	9.6	9.6	19.3	38.5	67.5
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.3	38.5	67.5
13	0.0	0.0	0.0	9.6	9.6	9.6	0.0	19.3	48.2	67.5
14	0.0	0.0	9.6	9.6	19.3	19.3	9.6	19.3	38.5	67.5
15	0.0	0.0	9.6	14.5	19.3	24.1	28.9	48.2	57.8	67.5
16	0.0	0.0	9.6	14.5	19.3	28.9	38.5	48.2	57.8	67.5
17	0.0	0.0	9.6	14.5	19.3	28.9	38.5	48.2	57.8	67.5
18	0.0	0.0	9.6	14.5	19.3	28.9	38.5	48.2	57.8	67.5
19	1.9.	4.8	9.6	14.5	19.3	28.9	38.5	48.2	57.8	67.5
20	1.9	4.8	7.7	9.6	14.5	28.9	38.5	48.2	57.8	67.5
21	1.9	4.8	7.7	9.6	16.4	28.9	38.5	48.2	57.8	67.5
22	0.0	4.8	7.7	9.6	19.3	28.9	38.5	48.2	57.8	67.5
23	0.0	4.8	7.7	9.6	14.5	19.3	33.7	38.5	48.2	67.5
24	0.0	3.9	7.7	9.6	14.5	19.3	28.9	33.7	38.5	48.2
25	0.0	3.9	7.7	9.6	14.5	19.3	28.9	33.7	38.5	38.5
26	0.0	3.9	7.7	8.7	11.6	19.3	28.9	33.7	38.5	28.9
27	0.0	3.9	7.7	8.7	9.6	19.3	28.9	30.8	30.8	28.9
28	0.0	0.0	7.7	8.7	9.6	19.3	28.9	30.8	30.8	19.3
29	0.0	0.0	7.7	8.7	9.6	19.3	28.9	28.9	28.9	19.3
30	0.0	0.0	7.7	8.7	9.6	9.6	24.1	28.9	28.9	19.3
31	0.0	0.0	6.7	7.7	8.7	9.6	24.1	24.1	24.1	19.3
32	0.0	0.0	5.8	6.7	7.7	8.7	19.3	19.3	19.3	14.5
33	0.0	0.0	1.9	3.9	5.8	7.7	9.6	11.6	11.6	9.6
34	0.0	0.0	1.9	3.9	5.8	7.7	8.7	9.6	10.6	10.6
35	0.0	0.0	0.0	0.0	3.9	6.7	7.7	8.7	10.6	10.6
36	0.0	0.0	0.0	0.0	0.0	0.0	4.8	4.8	4.8	4.8
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8	4.8	4.8
38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8	4.8	4.8
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	1.9	1.9
40	1.9	1.9	1.9	0.0	0.0	0.0	0.0	1.9	1.9	1.9

TABLE 3 (continued)

TRANSMISSIVITIES 15 PERCENT LARGER THAN THOSE BASED UPON USGS DATA IN TABLE 1

TRANSMISSIVITY IN AF/YR/FT

ROW COL	11	12	13	14	15	16	17	18	19
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.3	19.3
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.8	48.2
4	0.0	0.0	0.0	0.0	0.0	48.2	134.9	134.9	96.4
5	0.0	0.0	0.0	0.0	163.8	202.4	269.8	250.5	163.8
6	0.0	19.3	48.2	154.2	192.7	279.5	289.1	289.1	202.4
7	0.0	28.9	96.4	192.7	260.2	385.5	318.0	260.2	202.4
8	48.2	38.5	96.4	173.5	289.1	356.5	289.1	260.2	202.4
9	57.8	96.4	125.3	173.5	250.5	289.1	289.1	240.9	125.3
10	86.7	115.6	134.9	154.2	221.6	231.3	231.3	212.0	125.3
11	86.7	115.6	134.9	163.8	212.0	240.9	240.9	231.3	0.0
12	86.7	106.0	125.3	134.9	154.2	163.8	125.3	134.9	0.0
13	96.4	96.4	125.3	125.3	134.9	125.3	115.6	96.4	0.0
14	86.7	106.0	115.6	134.9	134.9	125.3	115.6	86.7	0.0
15	86.7	96.4	115.6	134.9	134.9	125.3	125.3	0.0	0.0
16	86.7	96.4	115.6	125.3	130.1	125.3	125.3	0.0	0.0
17	86.7	96.4	125.3	130.1	130.1	130.1	125.3	0.0	0.0
18	86.7	96.4	125.3	130.1	130.1	125.3	96.4	0.0	0.0
19	86.7	106.0	125.3	130.1	130.1	125.3	96.4	0.0	0.0
20	86.7	115.6	125.3	127.2	127.2	125.3	0.0	0.0	0.0
21	77.1	96.4	120.5	125.3	115.6	96.4	0.0	0.0	0.0
22	77.1	86.7	96.4	96.4	77.1	67.5	0.0	0.0	0.0
23	77.1	81.9	86.7	77.1	67.5	57.8	0.0	0.0	0.0
24	57.8	57.8	57.8	53.0	48.2	0.0	0.0	0.0	0.0
25	48.2	48.2	48.2	48.2	48.2	0.0	0.0	0.0	0.0
26	19.3	28.9	28.9	28.9	28.9	0.0	0.0	0.0	0.0
27	9.6	9.6	9.6	9.6	19.3	0.0	0.0	0.0	0.0
28	8.7	8.7	9.6	9.6	19.3	0.0	0.0	0.0	0.0
29	9.6	8.7	8.7	8.7	9.6	0.0	0.0	0.0	0.0
30	9.6	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	9.6	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	9.6	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	8.7	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	4.8	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0
38	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
40	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 4

ANNUAL DEEP PERCOLATION BASED UPON TRANSMISSIVITIES IN TABLE 3

DEEP PERCOLATION AND SUBSURFACE INFLOW IN AF/YR

RWO \ COL	1	2	3	4	5	6	7	8	9	10
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.5	-6.3	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	21.7	16.4
10	0.0	0.0	0.0	0.0	0.0	2.9	.6	5.4	4.3	8.9
11	0.0	0.0	0.0	0.0	0.0	2.4	2.8	.8	-4.9	-.4
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-.0	14.5	9.6
13	0.0	0.0	0.0	-.2	-.0	-.1	0.0	-.1	11.0	8.6
14	0.0	0.0	118.5	-35.7	3.5	1.8	2.5	8.6	6.9	24.7
15	0.0	0.0	-7.2	-10.6	.9	1.9	3.4	18.7	44.6	20.0
16	0.0	0.0	-2.2	-3.9	-.4	2.2	1.0	-1.7	27.5	-1.1
17	0.0	0.0	-1.1	-.1	-.7	1.1	-2.4	-4.3	9.5	168.2
18	0.0	0.0	.1	-.5	.4	-1.2	.8	-.7	5.4	20.7
19	-.3	-1.9	-1.6	-.5	-2.8	-.4	2.7	1.4	-5.5	-83.2
20	-.0	-.5	-.8	-2.3	-1.4	2.3	3.3	4.5	-39.4	-159.1
21	.4	.7	-.6	-.2	3.5	-.0	2.7	4.5	167.8	-286.6
22	0.0	.3	-.1	-.4	.6	-3.0	4.2	7.9	-53.5	-47.2
23	0.0	-.2	-.7	.5	-2.0	-1.4	1.6	.4	-17.3	-47.6
24	0.0	.0	-.1	-.8	-.4	3.7	5.3	3.6	3.1	-7.8
25	0.0	.1	-.5	-.3	-.0	3.9	5.7	4.3	2.8	-1.0
26	0.0	.2	-.1	-.8	-.8	2.5	.2	.0	-1.0	-2.2
27	0.0	.5	-.7	-.3	.7	1.1	1.8	.6	-.8	-1.3
28	0.0	0.0	-.7	-1.0	1.0	2.0	.3	-.1	-2.5	-1.7
29	0.0	0.0	-1.8	-1.7	1.2	-.6	.8	-1.0	-.2	-2.2
30	0.0	0.0	29.9	-.5	4.9	5.1	15.8	14.8	15.2	10.8
31	0.0	0.0	.4	7.7	11.5	15.5	31.2	28.1	25.8	19.6
32	0.0	0.0	-3.6	-1.3	1.8	4.6	-2.6	-1.9	.5	.4
33	0.0	0.0	-5.3	-3.9	-.2	5.1	-5.4	-.8	5.0	14.2
34	0.0	0.0	-3.6	-7.2	24.1	50.9	102.3	146.9	198.8	223.5
35	0.0	0.0	0.0	0.0	-20.0	-36.0	95.6	91.3	95.3	94.0
36	0.0	0.0	0.0	0.0	0.0	0.0	-200.3	-45.2	-126.3	-160.3
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-33.7	-21.0	-17.8
38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-74.8	-70.4	-61.3
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-66.9	-67.9	-73.3
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-68.7	-68.0	-65.2

TABLE 4 (continued)

ANNUAL DEEP PERCOLATION BASED UPON
TRANSMISSIVITIES IN TABLE 3

DEEP PERCOLATION AND SUBSURFACE FLOW

ROW	COL 11	12	13	14	15	16	17	18	19
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.6
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	126.2	239.8
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	776.5	551.2
4	0.0	0.0	0.0	0.0	0.0	56.4	-107.7	1445.4	905.9
5	0.0	0.0	0.0	0.0	-44.9	-93.8	-771.5	-427.8	233.4
6	0.0	3.3	-26.7	37.2	-52.5	3.7	-329.1	-567.0	1.9
7	0.0	-8.7	-45.4	-27.8	91.8	82.0	-63.8	-397.9	-237.8
8	-.5	-13.0	-28.5	-67.7	12.4	-11.9	45.5	-175.1	-272.7
9	9.5	1.3	-35.9	-7.3	-13.5	-14.7	-3.3	-28.9	-47.9
10	3.0	-2.0	.6	-7.7	-.7	7.6	-1.3	-2.3	-14.5
11	-3.0	-2.5	-11.4	-12.6	-21.4	-6.7	-13.7	-10.7	0.0
12	1.0	-5.3	-8.4	-13.2	-14.6	-32.2	-23.4	28.7	0.0
13	7.1	-1.2	3.5	8.8	-6.7	3.6	55.6	34.1	0.0
14	19.0	-3.1	-3.6	15.7	11.4	-64.7	57.1	29.9	0.0
15	31.1	-10.0	3.1	-10.4	-.3	127.8	-.1	0.0	0.0
16	-1.0	-3.6	9.5	-10.3	-54.2	73.2	-6.3	0.0	0.0
17	-70.6	4.6	-6.4	8.5	-32.5	-50.4	-21.6	0.0	0.0
18	125.0	25.3	29.9	25.1	143.8	93.9	-23.6	0.0	0.0
19	56.1	-36.5	16.1	-45.5	34.6	83.5	12.5	0.0	0.0
20	-34.2	-14.5	-103.0	-38.7	-82.2	-56.8	0.0	0.0	0.0
21	7.8	-25.7	-15.4	89.3	-49.8	-49.1	0.0	0.0	0.0
22	-696.7	-11.1	-5.4	54.1	-38.2	-30.1	0.0	0.0	0.0
23	4.5	-7.3	-65.2	-1.3	-27.0	-17.2	0.0	0.0	0.0
24	-.8	11.6	-29.3	-29.8	-3.4	0.0	0.0	0.0	0.0
25	-3.6	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	-1.9	-3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	-2.0	-1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	-.3	-.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	-.2	.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	7.8	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	4.8	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	6.7	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	22.2	-13.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	188.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	118.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	-150.2	148.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	-21.0	-29.4	-41.0	0.0	0.0	0.0	0.0	0.0	0.0
38	-43.6	-159.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	-103.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	-60.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

THE AMOUNT OF DEEP PERCOLATION IS 8853.34398 ACRE-FEET A YEAR
THE AMOUNT OF OUTFLOW IS-8853.3881715 ACRE-FEET A YEAR

TABLE 5

TRANSMISSIVITIES DEVELOPED FOR EARLY CALIBRATION RUNS OF THE USGS GROUND WATER MODEL

TRANSMISSIVITY IN AF/YR/FT

ROW \ COL	1	2	3	4	5	6	7	8	9	10
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	50.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	50.0	75.0
10	0.0	0.0	0.0	0.0	0.0	10.0	10.0	10.0	50.0	75.0
11	0.0	0.0	0.0	0.0	0.0	10.0	10.0	10.0	50.0	75.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	50.0	75.0
13	0.0	0.0	0.0	5.0	5.0	10.0	0.0	10.0	25.0	50.0
14	0.0	0.0	1.0	5.0	5.0	10.0	10.0	10.0	25.0	50.0
15	0.0	0.0	1.0	5.0	5.0	10.0	10.0	10.0	25.0	25.0
16	0.0	0.0	1.0	5.0	5.0	10.0	10.0	10.0	10.0	25.0
17	0.0	0.0	1.0	5.0	5.0	10.0	10.0	10.0	10.0	25.0
18	0.0	0.0	1.0	5.0	5.0	10.0	10.0	10.0	10.0	25.0
19	1.0	1.0	1.0	5.0	5.0	10.0	10.0	10.0	10.0	25.0
20	1.0	1.0	1.0	5.0	5.0	10.0	10.0	10.0	10.0	100.0
21	1.0	1.0	1.0	5.0	5.0	10.0	10.0	10.0	10.0	100.0
22	0.0	1.0	1.0	5.0	5.0	10.0	10.0	10.0	10.0	50.0
23	0.0	1.0	1.0	5.0	5.0	10.0	10.0	10.0	10.0	50.0
24	0.0	1.0	1.0	5.0	5.0	10.0	10.0	10.0	10.0	10.0
25	0.0	1.0	1.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
26	0.0	1.0	1.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
27	0.0	1.0	1.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
28	0.0	0.0	1.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
29	0.0	0.0	1.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
30	0.0	0.0	1.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
31	0.0	0.0	1.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
32	0.0	0.0	1.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
33	0.0	0.0	1.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
34	0.0	0.0	1.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
35	0.0	0.0	0.0	0.0	.8	.8	.8	.8	.8	.8
36	0.0	0.0	0.0	0.0	0.0	0.0	.8	.8	.8	.8
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.8	.8	.8
38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.8	.8	.8
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.8	.8	.8
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.8	.8	.8

TRANSMISSIVITIES DEVELOPED FOR EARLY CALIBRATION RUNS OF THE USGS GROUND WATER MODEL

TRANSMISSIVITY IN AF/YR/FT

ROW COL	11	12	13	14	15	16	17	18	19
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0
4	0.0	0.0	0.0	0.0	0.0	0.0	30.0	10.0	1.0
5	0.0	0.0	0.0	0.0	25.0	50.0	125.0	10.0	1.0
6	0.0	25.0	25.0	25.0	150.0	150.0	150.0	10.0	1.0
7	0.0	25.0	25.0	25.0	225.0	300.0	250.0	15.0	1.0
8	50.0	50.0	50.0	150.0	225.0	250.0	225.0	100.0	10.0
9	100.0	130.0	130.0	150.0	225.0	225.0	200.0	150.0	25.0
10	100.0	130.0	150.0	150.0	175.0	175.0	175.0	150.0	75.0
11	100.0	130.0	150.0	150.0	175.0	175.0	175.0	150.0	0.0
12	100.0	130.0	150.0	150.0	150.0	150.0	150.0	150.0	0.0
13	100.0	130.0	150.0	150.0	150.0	150.0	150.0	1.0	0.0
14	100.0	130.0	130.0	130.0	130.0	130.0	1.0	1.0	0.0
15	75.0	100.0	100.0	100.0	100.0	100.0	1.0	0.0	0.0
16	50.0	100.0	100.0	100.0	100.0	10.0	1.0	0.0	0.0
17	75.0	100.0	100.0	100.0	100.0	10.0	1.0	0.0	0.0
18	100.0	100.0	100.0	100.0	100.0	10.0	1.0	0.0	0.0
19	100.0	100.0	100.0	100.0	10.0	1.0	1.0	0.0	0.0
20	100.0	100.0	100.0	100.0	10.0	1.0	0.0	0.0	0.0
21	100.0	100.0	100.0	100.0	10.0	1.0	0.0	0.0	0.0
22	50.0	50.0	50.0	50.0	10.0	1.0	0.0	0.0	0.0
23	50.0	50.0	50.0	10.0	10.0	1.0	0.0	0.0	0.0
24	50.0	50.0	50.0	10.0	10.0	0.0	0.0	0.0	0.0
25	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	.8	.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	.8	.8	.8	0.0	0.0	0.0	0.0	0.0	0.0
38	.8	.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 6

ANNUAL DEEP PERCOLATION BASED UPON
TRANSMISSIVITIES IN TABLE 5

DEEP PERCOLATION AND SUBSURFACE INFLOW IN AF/YR

RWO COL	1	2	3	4	5	6	7	8	9	10
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54.0	-17.3	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8	27.0	17.5
10	0.0	0.0	0.0	0.0	0.0	3.0	.3	3.0	-1.6	.6
11	0.0	0.0	0.0	0.0	0.0	2.5	.3	1.8	-1.8	-.6
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-.8	4.0	2.2
13	0.0	0.0	0.0	-.1	.3	-.3	0.0	-.1	-3.5	-1.9
14	0.0	0.0	25.5	-8.7	.3	-.2	-.3	-1.4	.7	-6.6
15	0.0	0.0	2.6	-2.7	.2	-.2	-.3	-1.0	4.5	-3.8
16	0.0	0.0	.8	-.9	-.2	.3	-.3	.5	-4.3	0.0
17	0.0	0.0	.2	.1	-.3	.5	-.3	-.3	-2.0	71.8
18	0.0	0.0	.1	-.2	.1	-.4	.3	0.0	-.6	-5.6
19	0.0	0.0	-.2	.5	0.0	-.3	.3	-.3	.9	39.3
20	0.0	-.1	0.0	-.1	0.0	.4	0.0	-.3	35.6	-92.4
21	0.0	.1	.1	-.2	.4	-.4	-.3	0.0	128.0	-353.8
22	0.0	.0	.2	-.4	.4	-.4	.3	.5	16.0	-38.0
23	0.0	-.0	.1	.2	.1	-.2	0.0	-.5	9.8	-20.8
24	0.0	.0	.2	-.4	0.0	.4	.4	0.0	-.3	4.4
25	0.0	-.0	.1	-.1	0.0	-.3	-.2	-.1	.3	.2
26	0.0	0.0	.2	-.3	-.3	.3	-.3	-.1	0.0	-.1
27	0.0	.0	.1	0.0	.1	-.1	.1	.1	0.0	.1
28	0.0	0.0	.2	-.3	.1	.1	-.1	0.0	-.3	.1
29	0.0	0.0	.5	-.4	.1	-.3	.1	-.1	.1	-.3
30	0.0	0.0	6.2	1.9	2.7	2.7	3.1	2.8	3.1	3.2
31	0.0	0.0	.8	6.3	7.4	7.6	7.2	7.4	7.1	7.1
32	0.0	0.0	.7	2.9	3.5	3.2	4.3	4.2	5.0	5.0
33	0.0	0.0	.3	-.1	1.5	3.6	5.5	6.8	8.9	10.1
34	0.0	0.0	-1.4	-10.1	9.1	13.2	27.8	37.6	42.5	47.2
35	0.0	0.0	0.0	0.0	-20.3	-26.5	-21.4	-30.3	-36.2	-39.9
36	0.0	0.0	0.0	0.0	0.0	0.0	-22.3	6.2	1.6	-2.1
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-5.3	-3.3	-2.8
38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-2.4	-1.7	-.0
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-2.9	-3.2	-4.8
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-26.7	-26.5	-25.4

ANNUAL DEEP PERCOLATION BASED UPON TRANSMISSIVITIES IN TABLE 5

DEEP PERCOLATION AND SUBSURFACE FLOW

ROW \ COL	11	12	13	14	15	16	17	18	19
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	5.6
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54.1	4.2
4	0.0	0.0	0.0	0.0	0.0	19.8	169.4	178.9	16.9
5	0.0	0.0	0.0	0.0	30.3	-2.2	-144.4	138.8	9.7
6	0.0	5.6	0.0	-27.2	-4.7	88.8	-43.1	52.8	5.3
7	0.0	3.4	.9	-19.7	40.0	84.1	-10.1	25.5	8.0
8	1.9	.2	-1.3	-19.4	18.4	-10.3	12.5	-30.5	-9.5
9	9.5	2.1	-13.5	1.4	-5.6	.3	-5.9	-2.2	-1.1
10	-3.0	-6.4	6.0	3.8	-1.3	2.5	2.5	.6	-1.3
11	-3.3	.6	-5.3	.3	-2.8	5.3	4.1	1.6	0.0
12	-2.6	1.3	-5.0	3.8	6.9	-7.8	-2.5	28.3	0.0
13	8.1	-1.3	1.5	2.8	-8.5	5.8	34.0	-3.3	0.0
14	14.9	-16.8	-19.9	-10.5	-13.0	-52.6	-22.4	.3	0.0
15	.9	-18.4	-9.6	-17.5	-14.3	36.7	1.2	0.0	0.0
16	1.6	-2.5	5.0	-5.0	-17.5	-25.9	.1	0.0	0.0
17	-20.9	6.3	-7.5	5.0	-12.6	9.2	.7	0.0	0.0
18	148.8	20.0	27.5	20.0	52.6	15.5	.2	0.0	0.0
19	46.9	-45.0	17.5	-3.3	-36.3	-2.7	.0	0.0	0.0
20	-5.0	5.0	-77.5	-10.6	12.7	1.3	0.0	0.0	0.0
21	-31.9	-15.6	-15.6	65.0	4.2	.6	0.0	0.0	0.0
22	-524.4	-28.1	-18.1	-2.6	1.5	.6	0.0	0.0	0.0
23	1.3	-1.3	-16.3	-1.3	-1.7	1.3	0.0	0.0	0.0
24	-3.3	6.2	-10.5	7.3	0.0	0.0	0.0	0.0	0.0
25	1.9	-4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	-.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	.1	-.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	4.4	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	3.5	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	4.4	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	13.4	-8.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	48.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	-40.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	-6.5	23.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	-3.3	-4.6	-6.4	0.0	0.0	0.0	0.0	0.0	0.0
38	3.4	-24.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	-14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	-23.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

THE AMOUNT OF DEEP PERCOLATION IS 2568.32615 ACRE-FEET A YEAR
THE AMOUNT OF OUTFLOW IS-2568.32925 ACRE-FEET A YEAR

APPENDIX E

REVISED STEADY-STATE RECHARGE ESTIMATE USING REVISED U. S. GEOLOGICAL SURVEY GROUND WATER CONTOUR MAP FOR 1945

After the conclusion of the portion of the study presented in the previous sections of this report, USGS undertook to revise the 1945 ground water contour map representing steady-state conditions. The major revision involved a realignment of contours in the vicinity of San Felipe Creek in the southeastern Borrego Valley based on a reinterpretation of well data in the area.

New recharge estimates were made based on the revised contour map. The method of determining subsurface flow across the 500-foot contour, the same as that used in Appendix C, resulted in an estimated annual recharge of 13,100 acre-feet per year as compared to the previous 8,900 acre-feet per year.

The subsurface outflow, calculated in a manner similar to that shown in Appendix A, was estimated to be 3,600 acre-feet per year, as compared to the previous 1,900 acre-feet per year for steady-state conditions.

Finally, the hydrologic balance technique was used to estimate net recharge. As before, the annual change in storage, assuming an average specific yield of 10%, was 6,800 acre-feet per year; assuming that it is 20% made annual recharge an estimated 3,700 acre-feet per year. The same change-in-storage figures that were calculated previously are used here because the bulk of changing water levels took place away from the areas revised by USGS. Adding the estimated outflow of 3,600 acre-feet per year to these figures results in an estimated annual recharge of 10,400 acre-feet per year, assuming 10% specific yield and 7,300 acre-feet per year assuming 20% specific yield.

Borrego Valley Investigation

1 P.M.
2-24-83.

I. Estimating Recharge by 1945 Contour & Isotrans.

490 Contour (1 through 20) (Blue)	9600
Extended Contour (21 through 35)	1900
500 Contour (South East end) (3) blue	1620
	13,120

II. Subsurface Outflow.

460 Contour (Blue)	1229	
Extended	718	
	1947	
South Easterly Blue (500) (Transmissivity Value weak)	1617	
	3564	acre-feet
Say Total =	3600	" "

III. Hydrologic Balance.

Consider only Subsurface outflow change

Annual Recharge without outflow (10%) 6800 a.f.

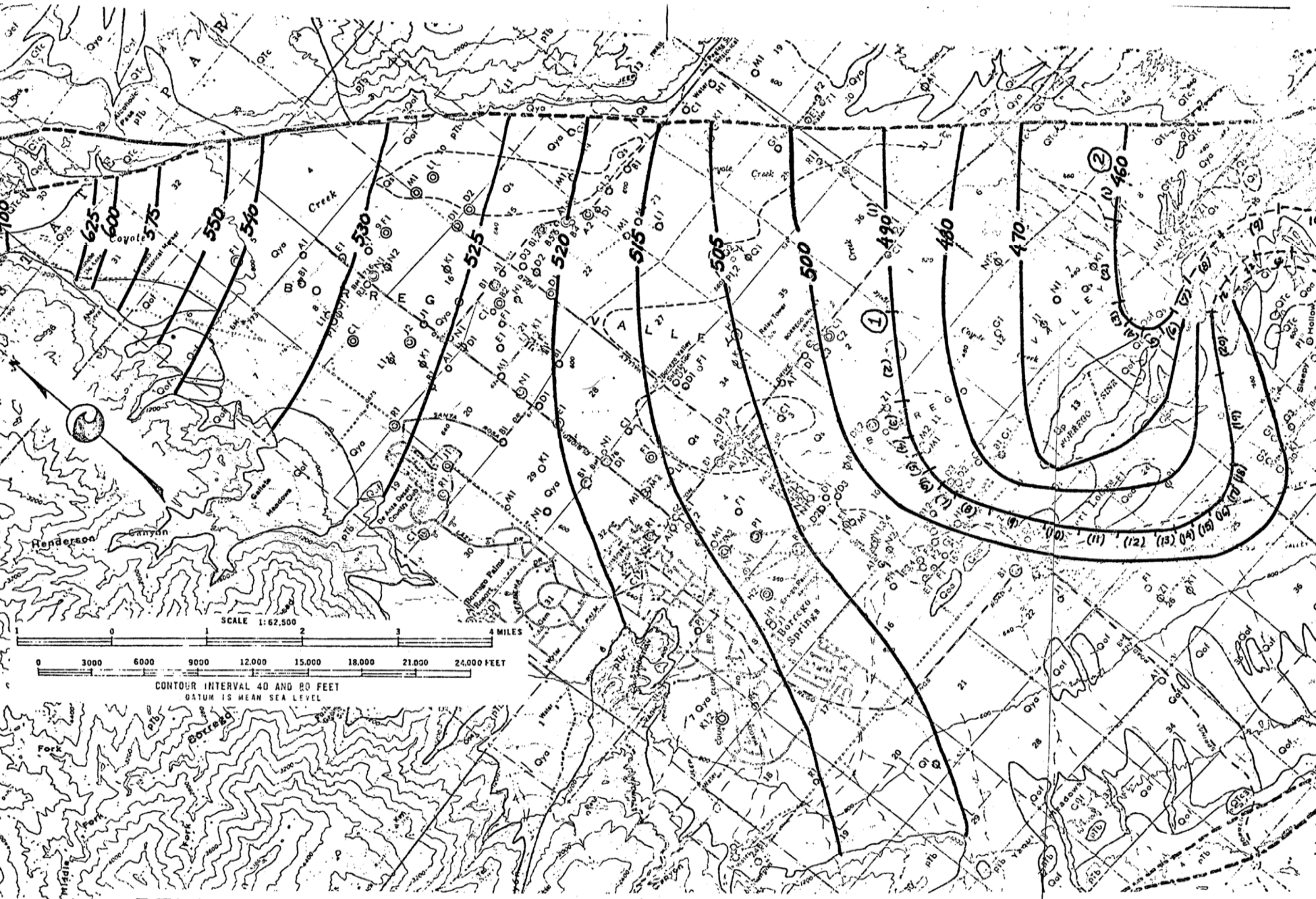
" " " " (20%) 3700 a.f.

With 3600 a.f. subsurface outflow

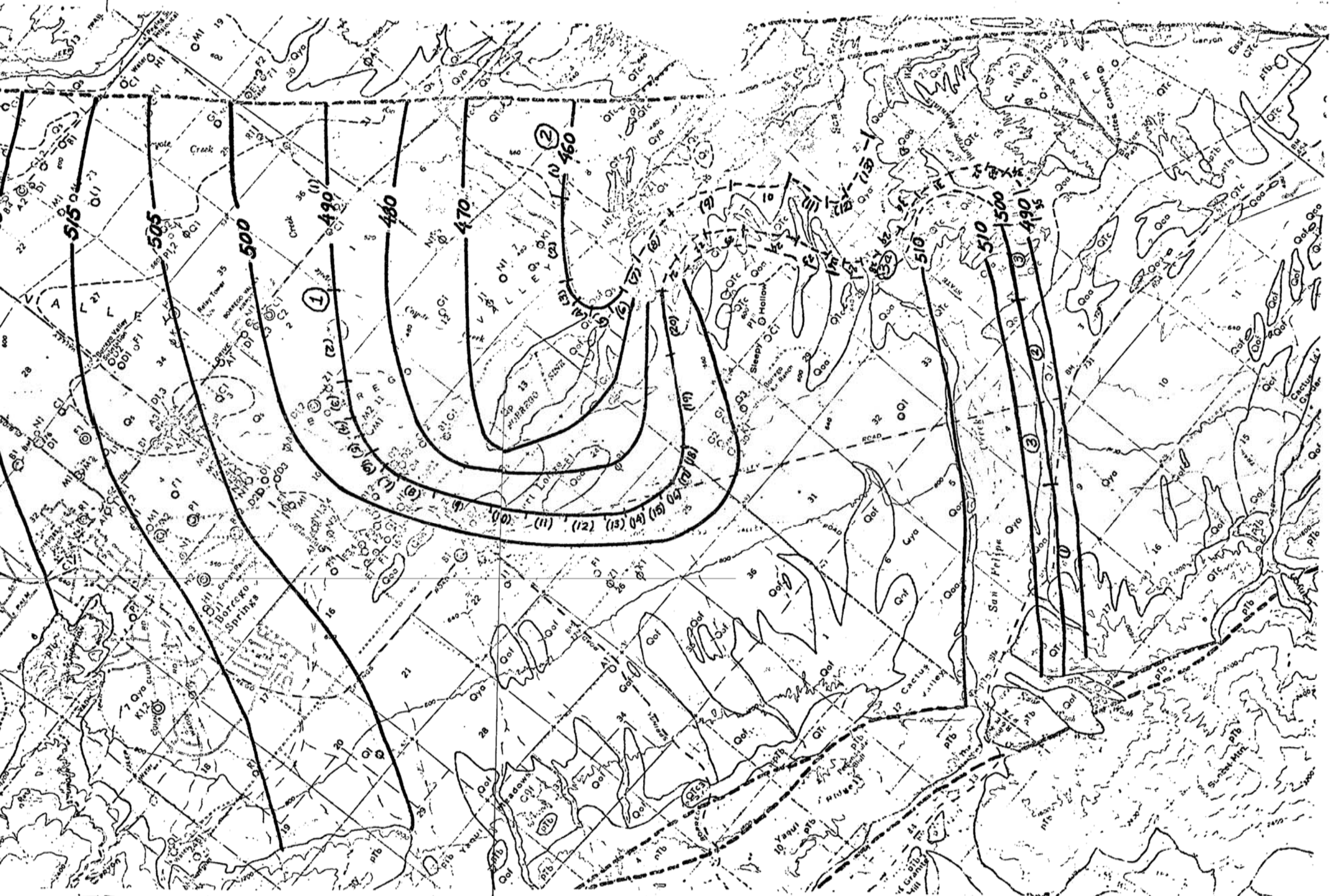
	S.Y.	An. Rech. w/t otflow		
Annual Recharge =	(10%)	6800 + 3600	=	10,400
" " =	(20%)	3700 + 3600	=	7300

inflow + Rec.

I.f − Out f = ΔS



REVISED U.S.G.S. GROUND WATER CONTOURS FOR STEADY-STATE (1945)



WATER CONTOURS FOR STEADY-STATE (1945) CONDITIONS

BORREGO VALLEY

Flow Across EL 1,460'
1945 Water Level Contours S. Johanson 2-23-8[illegible]
Steady-State Condition

(1) Section No.	(2) Transnissivity 1,000 ft²/day	(3) Length X-Section feet W	4 Gradient Length, feet	(5) Upper HGL feet	(6) Lower HGL feet	(7) Diff. feet	(8) (7)/(4) Grad i	9 Q=T·i·W (2)(3)(8) ft³/day
1	4,000	5,000	5,500	470	460	10	0.00181	36,400
2	4,000	4,500	5,000	470	460	10	0.0020	36,000
3	4,000	1,300	6,000	470	460	10	0.00166	8,700
4	4,000	1,000	9,000	470	460	10	0.00111	4,500
5	4,000	1,000	4,400	470	460	10	0.00227	9,100
6	4,000	1,300	1,000	470	460	10	0.01	52,000
								146,700 ft³/day
7	1,000	1,200	2000	490	460	30	0.02	27,000
8	1,000	3,200	1,800	490	460	30	0.02	53 000
9	1,000	3,700	1,200	490	460	30	0.03	92,500
10	1,000	3,000	2,500	490	460	30	0.01	36,000
11	1,000	2500	2,700	490	460	30	0.01	27,700
12	1,000	1,000	3,500	490	460	30	0.0085	8,500
13	1,000	3,300	2,000	490	460	30	0.02	49 500
								85,700

(2) Sections 1 thru 6 $= 146{,}700 \frac{ft^3}{day} \times \frac{365\ days}{yr} \times \frac{1\ acre\ ft}{43{,}560\ ft^2} = 1{,}229\ AF/Yr$

(3a) Sections 11 thru 13 $= 85{,}700 \frac{ft^2}{day} \times \frac{365\ days}{yr} \times \frac{1\ acre\ ft}{43{,}560\ ft^2} = 718\ AF/Yr$

7 thru 10. 208,500 ... 1747 AF/YF

DUKKEGO VALLEY

Flow across 500-ft contour

1945 Steady-state Condition S. Johnson 2-23-8

Southeast of San Felipe

(1) Section No	(2) Transmissivity 1,000 ft²/day	(3) Length W X-Section feet	(4) Gradient length feet	(5) Upper H.G.L. feet	(6) Lower H.G.L. feet	(7) Diff feet	(8) Grad i	(9) Q=TiW ft³/day
1								
1	1	10,000	2,500	510	490	20	0.008	80,00
2	1	10,000	2,500	510	490	20	0.008	80,00
3	1	4,000	2,400	510	490	20	0.008	33,00
								193,00 ft³/day

③ $193{,}000 \frac{ft^3}{day} \times \frac{365\ day}{yr} \times \frac{1\ acre\ ft}{43{,}560\ ft^2} = 1{,}617\ AF/yr$

BORREGO VALLEY

Flow Across 1490 ft. Contour

1945 WATER LEVEL   S. Johanson   2-23-8[illegible]

Steady-state condition

(1) Section No.	(2) Transmissivity 1,000 ft²/day	(3) Length W X-section feet	(4) Gradient length feet	(5) Upper H.G.L feet	(6) Lower H.G.L. feet	(7) (5−6) Diff. feet	(8) (7/4) Grad i	9. (2)(3)(8) Q=Ti W ft³/day
(1)	13,000	10,000	8,000	500	480	20	0.0025	325,00
(2)	10500	5,000	6,700	500	480	20	0.00298	156,70
(3)	7500	2,000	6,500	500	480	20	0.00307	46 20
(4)	7000	1,000	6,100	500	480	20	0.00327	23,00
(5)	7000	1,000	5800	500	480	20	0.00344	24,10
(6)	7000	1,000	5,200	500	480	20	0.00384	26,90
(7)	6000	1,000	4,700	500	480	20	0.00425	25,50
(8)	5500	2,000	4,000	500	480	20	0.0050	55,00
(9)	5500	3,000	3,500	500	480	20	0.00571	94,20
(10)	5000	2,000	3,700	500	480	20	0.00540	54,00
(11)	4500	2,000	3,900	500	480	20	0.00512	4610
(12)	4000	2,000	4,100	500	480	20	0.00487	3900
(13)	4000	1,000	4,500	500	480	20	0.00444	17,70
(14)	4000	1,000	4,800	500	480	20	0.00416	16,60
(15)	4000	1,000	5200	500	480	20	0.00384	15,36
(16)	4000	1,000	5,600	500	480	20	0.00357	14,20
(17)	4000	1,000	5,700	500	480	20	0.00350	14,00
(18)	4200	1,000	5,600	500	480	20	0.00357	15,00
(19)	3500	5000	4,000	500	480	20	0.0050	87,50
(20)	2000	3600	3,000	500	480	20	0.0066	48,00
								1,144,00 ft³/day

Section 1 thru 20

(1) $= 1{,}144000 \frac{ft^3}{day} \times \frac{365\ days}{Yr.} \times \frac{1\ acre\text{-}ft}{43{,}560\ ft^2} = 9{,}585$ or 9,600 A[illegible]

Extension of 500 contour:

	Width	L	ΔH	I.	T.	Q.
21	2000	3500	30	0.0085	1000	142.00
22	2000	"	"	"	"	142.00 ~~81.5~~
23	2000				"	142.00
24.	4000				"	284.00
25	2025				"	144.0
26	1000				"	71.1
27.	1000.				"	71.
28	1000				"	71
29	2000					142
30	2000					142
31	2000					142
32	2000					142
33	1000					71
34	1500					106
35	1500					106
					Total.	1918.
					Say	1900.

WATER RESOURCES OF BORREGO VALLEY AND VICINITY, CALIFORNIA

Phase 1--Definition of Geologic and Hydrologic Characteristics of Basin

By W. R. Moyle, Jr.

U.S. GEOLOGICAL SURVEY

Open-File Report 82-855

Prepared in cooperation with the
COUNTY OF SAN DIEGO

November 1982

CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

CONVERSION FACTORS AND ABBREVIATIONS

For this report, both inch-pound and metric units have been used. The original units of measurement have been used in all cases so that no errors will be introduced because of conversion of units or in rounding. When the data are computerized and the model is constructed, the data can be published in any units desired.

Multiply	By	To obtain
acres	0.004047	km^2 (square kilometers)
acre-ft (acre-feet)	1233.48	m^3 (cubic meters)
ft (feet)	0.3048	m (meters)
ft/d (feet per day)	0.3048	m/d (meters per day)
ft^2/d (feet squared per day)	0.0929	m^2/d (meters squared per day)
ft/mi (feet per mile)	0.1894	m/km (meters per kilometer)
gal/d (gallons per day)	0.003785	m^3/d (cubic meters per day)
(gal/d)/ft (gallons per day per foot)	0.01242	m^2/d (meters squared per day)
gal/min (gallons per minute)	0.003785	m^3/min (cubic meters per minute)
(gal/min)/ft (gallons per minute per foot)	0.2070	(L/s)/m (liters per second per meter)
inches	25.4	mm (millimeters)
mi (miles)	1.609	km (kilometers)
ton/acre-ft (tons per acre-foot)	735	Mg/hm^3 (megagrams per cubic hectometer)
µmho/cm (micromhos per centimeter)	1.00	µS/cm (microsiemens per centimeter)

Degrees Fahrenheit (°F) is converted to degrees Celsius (°C) by using the formula:

$$\text{Temp } °C = (\text{temp } °F - 32)/1.8.$$

Additional abbreviations used:

(cm/s)/s, centimeter per second per second
mGal, milligals
mg/L, milligrams per liter
µg/L, micrograms per liter
g/cm^3, grams per cubic centimeter

1 acre ft = 325 850 gal US

ALTITUDE DATUM

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

TRADE NAMES

The use of brand names is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

WATER RESOURCES OF BORREGO VALLEY AND VICINITY, CALIFORNIA

Phase 1--Definition of Geologic and Hydrologic Characteristics of Basin

By W. R. Moyle, Jr.

ABSTRACT

This report includes information needed to build a digital hydrologic model of Borrego Valley. It includes sources and amounts of recharge water to the basin, areas of water withdrawal, total ground water in storage at steady-state conditions (1945), net ground-water depletion, grid network used to determine storage and depletion, total depth of alluvial fill, transmissivity, hydraulic conductivity and specific yield of aquifers, and thickness of individual aquifers.

At steady-state water-level conditions (1945) the Borrego Valley ground-water basin contained 5.5 million acre-feet of water. Between 1945 and 1980, 330,000 acre-feet of water were withdrawn from the basin in excess of recharge. Gravity data show that the thickness of alluvial fill ranges from 0 at the edges of the basin to about 2,450 feet at its deepest part. The alluvial fill is partly saturated and partly dry, depending on location. In some areas the water level is at or near land surface, whereas in other areas it is more than 400 feet below land surface. Between 1945 and 1980 water levels have declined locally as much as 100 feet, indicating that more water is being withdrawn than is being replenished.

Of prime importance to the population of Borrego Valley is the high nitrate (NO_3) water, more than 300 milligrams per liter, being produced from some wells. The recommended upper limit for nitrate in drinking water is 44 milligrams per liter. The source of high nitrate is septic tanks and leach fields, sewage-disposal systems, irrigation-return water, and decomposition of native vegetation. High nitrate in ground water generally stays near the water table and is picked up by wells having perforations above the pumping water level. Wells with perforations below the pumping water level generally contain low nitrate water.

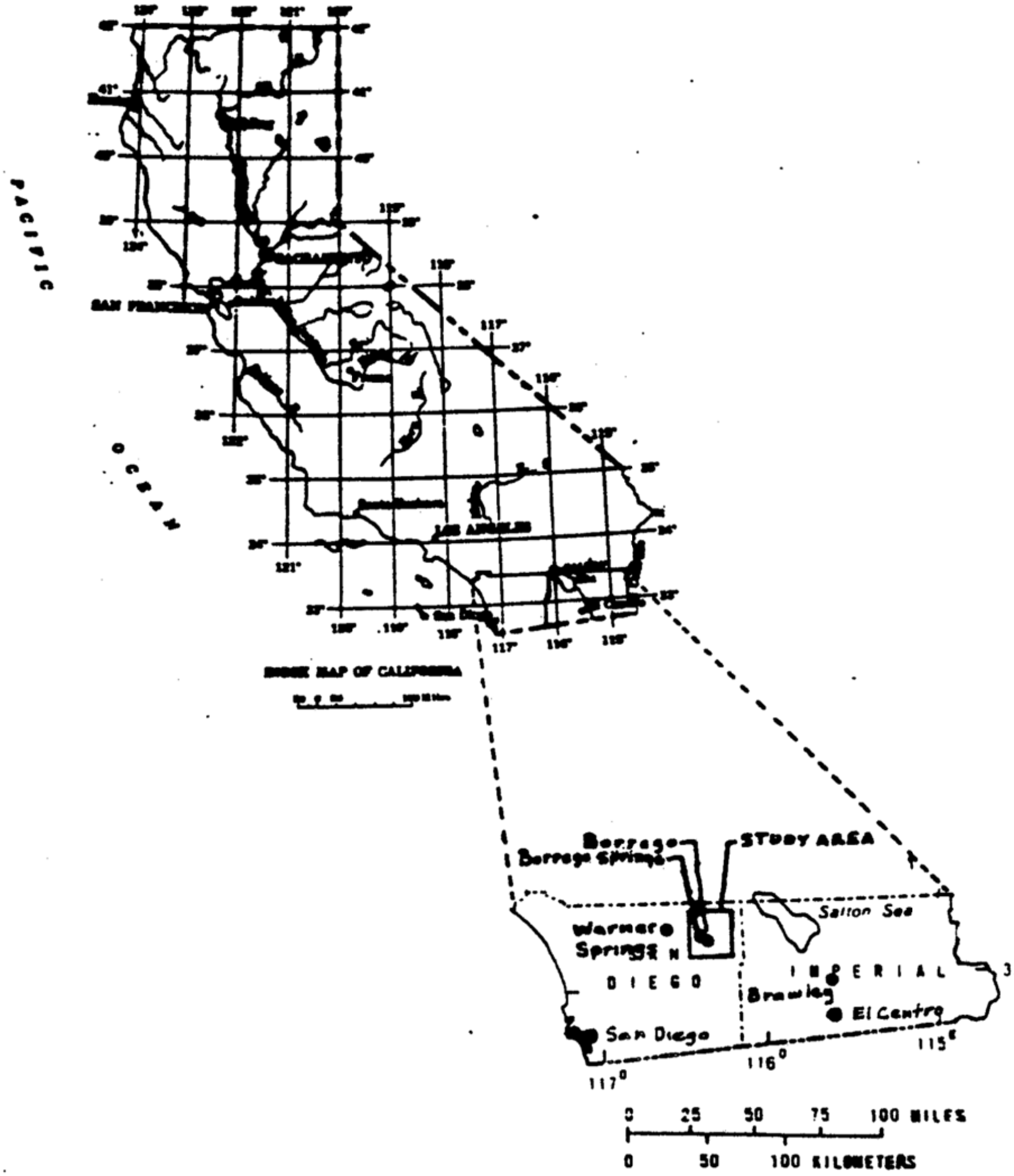


FIGURE 1.--Study area.

The Geological Survey has also measured surface-water discharge on selected streams entering Borrego Valley between 1951 and the present (1980). These data are published in various water-supply papers and data reports listed in the references.

The geology of Borrego Valley was compiled by Moyle (1968) from unpublished mapping by T. W. Dibblee, Jr., E. R. Morley, and W. R. Moyle, Jr.

Data from previous studies and reports were freely used by the author in the preparation of this report along with data supplied by the many governmental agencies, ranchers, corporations, water companies, and individuals who live or work in Borrego Valley. Without their help this study would not have been possible.

Well- and Spring-Numbering System

Wells are numbered according to their location in the rectangular system for subdivision of public land. That part of the number preceding the slash (as in 10S/6E-24K1) indicates the township (T. 10 S.); the number after the slash indicates the range (R. 6 E.); the number after the dash indicates the section (sec. 24); the letter after the section number indicates the 40-acre subdivision of the section according to the lettered diagram. The final digit is a serial number for wells in each 40-acre subdivision. Springs are numbered similarly to wells except an S is placed between the final letter and number as shown by the following spring number: 9S/5E-22KS1. The study area lies entirely in the southeast quadrant of the San Bernardino base line and meridian.

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

TABLE 1. - Annual precipitation at stations in Borrego Valley area

[Data from U.S. National Oceanic and Atmospheric Administration, (1965-80) and U.S. Weather Bureau (1878-1975)]

Year	Annual precipitation, in inches					
	Borrego	Brawley	Warner Springs	Borrego Desert Park	Borrego Springs 3NNE	Brawley 2SW
1907	--	--	18.39	--	--	--
1908	--	--	15.05	--	--	--
1909	--	3.69	29.06	--	--	--
1910	--	[1].69	11.33	--	--	--
1911	--	[1]1.76	14.21	--	--	--
1912	--	1.55	17.05	--	--	--
1913	--	2.21	13.98	--	--	--
1914	--	[1]2.94	19.09	--	--	--
1915	--	[1]3.39	25.59	--	--	--
1916	--	2.84	25.73	--	--	--
1917	--	1.84	12.43	--	--	--
1918	--	1.94	16.26	--	--	--
1919	--	1.57	13.83	--	--	--
1920	--	4.17	13.61	--	--	--
1921	--	3.57	32.02	--	--	--
1922	--	.73	22.28	--	--	--
1923	--	2.71	12.45	--	--	--
1924	--	1.23	8.89	--	--	--
1925	--	3.12	12.35	--	--	--
1926	--	6.23	24.27	--	--	--
1927	--	4.95	24.35	--	--	--
1928	--	.45	8.42	--	--	--
1929	--	.30	11.97	--	--	--
1930	--	2.03	19.66	--	--	--
1931	--	3.45	19.45	--	--	--
1932	--	5.69	22.64	--	--	--
1933	--	1.08	12.58	--	--	--
1934	--	.11	12.12	--	--	--
1935	--	3.44	13.24	--	--	--
1936	--	1.10	20.31	--	--	--
1937	--	.83	20.74	--	--	--
1938	--	2.59	23.67	--	--	--
1939	--	8.18	15.12	--	--	--
1940	--	3.18	([2])	--	--	--
1941	--	5.85	27.69	--	--	--
1942	--	1.34	9.29	--	--	--
1943	--	2.99	21.89	--	--	--
1944	[3]0.61	3.61	19.67	--	--	--
1945	10.75	3.68	25.28	--	--	--
1946	1.30	.96	15.75	--	--	--

See footnotes at end of table.

Geologic Formations

The geology of the Borrego, Carrizo, and San Felipe areas was mapped and published by the State of California in Bulletin 91-15 (Moyle, 1968). One-half the geologic map used in Bulletin 91-15 is included in this report as plate 1 to describe the geology of Borrego Valley. About 35 wells drilled between 1966 and 1980 have been added to update the map. The following geologic descriptions are quoted from Bulletin 91-15 with editorial comments in brackets.

"The geologic formations in the Borrego, Carrizo, and San Felipe Valley areas have dissimilar water-bearing characteristics, but, in general, the deposits of late Tertiary and Quaternary age are more permeable than the older rocks of pre-Tertiary and early Tertiary age. The Quaternary deposits generally underlie the valleys and contain much of the ground water stored in the area. Rocks of pre-Tertiary age form the mountains and hills, underlie the water-bearing deposits, and form the boundaries of the ground-water basin; these rocks are nearly impermeable but are important because the mountains and hills receive the major part of the precipitation within the drainage area. The runoff from the mountains and hills contributes most of the recharge to the ground-water body in the unconsolidated deposits.

"The oldest unit in the area is the basement complex composed of granite, schist, and gneiss, all of pre-Tertiary age. The basement complex is generally impermeable, but fractures and weathered zones yield small quantities of water to wells.

"The older continental rocks [Not found in Borrego Valley but may be at depth. These rocks have been described in logs of wells shown on plate 1 east of the study area], of Miocene age, are the Split Mountain Formation of Tarbet and Holman (1944) and the Fish Creek Gypsum of Dibblee (1954). The age of the Split Mountain Formation, originally considered Miocene(?) by Tarbet and Holman (1944), is now assigned to the Miocene because it underlies and overlies Miocene units. The Split Mountain Formation is composed of gray, granitic conglomerate; dioritic breccia; hard buff sandstone; and red, arkosic sandstone. The Fish Creek Gypsum, deposited mostly in playas, is composed of silt, clay, and white beds of gypsum and anhydrite. No wells penetrate this unit; it probably would not yield water of quantities usable for irrigation.

"The volcanic rocks [Not found in Borrego Valley but may be at depth], of Miocene age, consist entirely of the Alverson Andesite Lava of Dibblee (1954) which is dark-brown, andesitic lava. This unit overlies the Split Mountain Formation and underlies the Fish Creek Gypsum. No wells penetrate the volcanic rocks; they probably would not yield much water to wells.

"The playa deposits, of Recent [Holocene] age, are composed of clay with some sand and silt. Of the playas shown in figs. 2 and 3 only the Borrego Sink was a discharging playa in the recent past, having water levels at or near land surface. However, at the present time [1965 and 1980] water levels are below land surface. Where saturated, this unit yields some water to wells.

"The sand deposits, of Recent [Holocene] age, are composed of actively drifting fine to medium sand. In parts of the area this unit is saturated and yields small quantities of water, sometimes of inferior chemical quality.

"The lake deposits [Not in Borrego Valley but shown on pl. 1], of Recent [Holocene] age, are composed of alternating beds of sand and clay. These deposits presumably were laid down in ancient Lake Cahuilla which formerly covered a large part of Imperial and Coachella Valleys. Where saturated, this unit would probably yield moderate quantities of water to wells."

Faulting

The geologic map (pl. 1) shows the location of many faults. The Coyote Creek fault is the most important fault with relation to the movement of ground water in Borrego Valley. This fault has ruptured several times in the recent past and has had numerous earthquakes associated with each rupture. The most recent large earthquake on the Coyote Creek fault occurred April 9, 1968, near Borrego Mountain. This earthquake had a magnitude of 6.4 on the Richter scale, a maximum horizontal (right lateral) surface displacement of 38 centimeters, and numerous aftershocks. Data for this earthquake were published by the U.S. Geological Survey (1972).

The Coyote Creek fault is probably a barrier to the movement of ground water. Water-level contours show that ground water flows parallel to the fault in most places during steady-state conditions, and there are abnormally high gradients across the fault, as is indicated by a few water levels measured in wells. Two common explanations for the barrier effect are fault gouge in the zone of rupture causing reduced permeability and sediments with different permeabilities, adjacent but on opposite sides of the fault, impeding the ground-water flow. A third possibility is that low-permeability sediment has silted in cracks along the fault. Following the Borrego Mountain earthquake, many large cracks as much as 2 feet in width were observed along the 17-mile-long fracture. In the following 2 years many of these fractures were being filled in by silt-laden water from flash floods that occur from precipitation in the mountains. This low-permeability silt could retard ground-water flow. There are no known documented examples of such barriers, but large, deep cracks have been described in numerous desert basins elsewhere (Holzer, 1977). The measured depth of one such crack was 25 meters, and the length 3.5 kilometers; some cracks have filled with sediment (Thomas L. Holzer, oral commun., 1982). In Borrego Valley there is evidence to support each of these explanations for the ground-water barrier along the Coyote Creek fault.

HYDROLOGIC CHARACTERISTICS

Geologic and Hydrologic Sections

Geologic and hydrologic sections (pl. 4) were constructed for Borrego Valley using data from drillers' logs and specific-capacity tests of wells, water-level measurements, depth interpretations from gravity profiles, and geologic mapping. Locations of the sections are shown on plate 1. Hydraulic conductivity and specific yield of the hydrologic units and their geologic map unit equivalents are shown in the insert on plate 4. Several of the geologic map units are considered as a single hydrologic unit because of similar hydrologic properties. Other geologic map units were separated into multiple hydrologic units because of dissimilar hydrologic properties. Aquifer thickness and hydraulic properties are discussed in more detail later in this section.

Aquifer Thickness

Three aquifer-thickness maps (pl. 5) were constructed for the upper, middle, and lower aquifers for use in determining the volume of ground water in storage for the different aquifers. These maps show that the upper aquifer ranges in thickness from 0 to 1,000 feet, the middle aquifer 0 to 700 feet, and the lower aquifer 0 to 1,800 feet. The maximum thickness of each aquifer is in a different part of Borrego Valley. The maximum thickness of the upper aquifer is at the north end of the valley; the middle aquifer is thickest near the center of the valley adjacent to the Coyote Creek fault; and the lower aquifer is thickest in the south-central part of the valley.

Aquifer Characteristics

The specific capacity of a well is the rate of discharge in gallons per minute per foot of drawdown. In section A-A' (pl. 4) a decrease in specific capacity of wells is apparent from northwest to southeast. When wells 10S/6E-5F1 and 12S/7E-4J1 are compared, both with approximately equal perforated intervals, the specific capacity drops from 92 to 2. This decline in specific capacity is due to the fact that well 10S/6E-5F1 is completed and perforated in the upper aquifer, whereas 12S/7E-4J1 is completed and perforated in the lower aquifer. This is an indication that the older sediments are more compact and therefore yield less water than the younger sediments.

In general, the lower aquifer is closer to land surface at the south end of Borrego Valley than at the north end; this is a reason why wells produce less water at the south end of the valley than at the north end.

If wells were drilled in each aquifer and perforated in only one aquifer at its maximum thickness, the upper aquifer well would have an estimated specific capacity of about 100 (gal/min)/ft of drawdown, the middle aquifer about 50 (gal/min)/ft of drawdown, and the lower aquifer about 10 (gal/min)/ft of drawdown.

TABLE 3. - Average values of hydraulic conductivity of alluvial materials used in Borrego Valley, California

[From Lohman, 1972, p. 53]

Material	Hydraulic conductivity (ft/d)
Gravel:	
Coarse	1,000
Medium	950
Fine	900
Sand:	
Gravel to very coarse	800
Very coarse	700
Very coarse to coarse	500
Coarse	250
Coarse to medium	100
Medium	50
Medium to fine	30
Fine	15
Fine to very fine	5
Very fine	3
Clay	1

The middle aquifer (upper QTc) is composed of the upper part of the continental deposits. Well logs penetrating these deposits show they range in size from gravel to silt with moderate amounts of compaction and cementation. The predominant grain sizes range from medium sand to clay. These deposits are assigned a hydraulic conductivity of 5 ft/d and a specific yield of 10 percent.

The separation between the middle and lower aquifers is based on well-log descriptions of "hard, dry, red clays" that extend over the southern half of Borrego Valley at increasing depth to the north. Drillers' logs indicate sediments above the red clays are easy to drill, whereas those below the red clay are hard to drill.

The lower aquifer is composed of the lower part of the continental deposits and the marine rocks. The lower part of the continental deposits, highly compacted and cemented, is composed of sandstone, claystone, siltstone, and clay; the marine rocks are composed of sandstone, claystone, and beds of shells. Only one well (10S/5E-25R1) penetrates the marine rocks at depth in Borrego Valley. The lower aquifer is assigned a hydraulic conductivity of 1 ft/d and a specific yield of 5 percent.

The basement complex ranges from solid rock to fractured rock in fault zones. Only one well (11S/7E-36D1) in Borrego Valley is drilled entirely in a fault zone in basement complex. This well was drilled by the U.S. Geological Survey for a study of heat flow through the Earth's crust. This well yielded a small quantity of water when drilled, but because the well was constructed without a perforated casing a pump test could not be made. The assigned hydraulic conductivity of 0-0.1 ft/d and a specific yield of 0 to less than 1 percent is based on discussion with Jack Porter (U.S. Geological Survey) who was at the well when it was drilled.

The quantities from the sources of potential recharge described below are probably most but not all of the potential recharge to Borrego Valley. Other, less significant, sources may be indicated by the steady-state simulation in the modeling phase to follow this study.

Ground-Water Inflow from San Felipe Creek

San Felipe Creek has the thickest saturated alluvial sediments of any channel entering Borrego Valley from the west side of the basin; therefore, it probably contributes the largest amount of ground-water inflow. Ground-water inflow to Borrego was calculated for San Felipe Creek in T. 12 S., R. 6 E., sec. 17 through section G-G' (pls. 1 and 7) from the equation:

$$Q = TIW$$

where Q is ground-water inflow, in gallons per day,
T is transmissivity, in gallons per day per foot,
I is gradient, in feet per mile, and
W is width of the aquifer at the water table, in miles.

The transmissivity at well 12S/6E-18A1 is 2,000 (gal/d)/ft, the gradient of the water table between 12S/6E-17C2 and 18A1 is 50.7 ft/mi, and the width of the aquifer at the water table is 0.28 mi. The total ground water underflow calculated at section G-G' is 31.8 acre-ft/yr.

Most other channels entering Borrego Valley from the west contain very little alluvial sediments and do not contribute appreciable amounts of ground-water inflow to the basin. The one exception is Coyote Creek (pl. 1). However, a high spot in the bedrock at Santa Catarina Spring brings all underflow to the surface and all recharge enters the valley as surface-water flow.

Surface-Water Inflow

Three continuous water-stage recorders (pl. 7 and table 4) are presently (1980) being operated on streams entering Borrego Valley. The stations on Borrego Palm and Coyote Creeks have been in operation since 1951, and the station on San Felipe Creek has been in operation since 1959. In addition, two staff gages on Yaqui Pass and one on Pinyon Wash measured peak flow between 1960 and 1969. Approximately 65 percent of the surface-water inflow to Borrego Valley comes from the Coyote Creek drainage; most of the rest of the surface-water inflow (35 percent) is distributed between Borrego Palm Canyon and San Felipe Creek. Most of the other stream channels produce very little runoff or recharge to Borrego Valley.

Most of the streamflow occurs as intermittent runoff in the winter. Little correlation exists between stream runoff and precipitation data from sparsely located rain gages. Rainfall at the Borrego Desert Park gage during 1980 was about three times the average, while the discharge measured at the gage on San Felipe Creek for the same time period was greater than the total recorded for the previous 21 years. Surface-water inflow during 1980 totaled 21,720 acre-ft, which is the highest yearly total of record.

BASIN DEVELOPMENT

Historical Land Use and Water Development (1909-80)

1909

Mendenhall (1909) reported on desert watering places in southeastern California and southwestern Nevada to aid desert travelers. He described Borrego Springs and a nearby abandoned cabin but did not mention that any people lived in the valley at that time. The only reported use of water was by mesquite trees and other native vegetation in the area.

1917-18

Brown (1923) visted Borrego Valley in the winter of 1917-18. He described three flowing wells, one non-flowing well, Borrego Springs, and several acres of marsh surrounding the Borrego Sink. He also indicated that several homesteaders had taken up land claims in Borrego Valley mainly for grazing cattle.

1926-27

During 1926-27 approximately 40 acres of dates were planted in Borrego Valley. About 20 acres were planted in T. 11 S., R. 6 E., sec. 4 and owned by R. F. Ensign. Another 20 acres of dates were planted on the Ensign Ranch in T. 11 S., R. 6 E., sec. 9. The first harvest from these date groves was in 1939. These trees are still growing but have not been trimmed for some time and were not harvested in 1980.

1946

In March 1946 Taylor and Taylor, Engineers (written commun., 1946) of Los Angeles, produced a map showing that 36 wells had been drilled in Borrego Valley.

1951

A map produced by the DiGeorgio Corp. (written commun., June 1951), shows that vineyards covered 1,020 acres and asparagus 40 acres of its property.

1952-53

Burnham (1954) visited Borrego Valley intermittenly between 1952 and 1953 to collect various geological and hydrological data. In the process, Geological Survey personnel visited 133 wells in Borrego Valley, which indicates that about 100 wells had been drilled between 1946 and 1953 throughout the valley.

TABLE 5. - Population of Borrego Valley and water use in 1980

	Population	Water use (acre-ft/yr)
Borrego Telephone Directory (Adults)------------	1,798	--
Borrego Pre-School (under 5 years of age)-------	13	--
Borrego Elementary School----------------------	166	--
Borrego High School----------------------------	154	--
Total permanent population------------------	2,131	298
Borrego Palm Canyon Campground, 117 campsites---	[1]81,601	31
Horse Camp, 10 campsites, 40 horse corral-------	[1,2]7,300	2.2
Tamarisk Grove Campground, 25 campsites---------	[1,2]18,250	2.8
Total use--		334

[1]Total campers using facilities during 1980 on daily basis (M. H. Getty, Area Manager, Anza-Borrego Desert State Park, oral commun., 1981).

[2]Estimated (M. H. Getty, Area Manager, Anza-Borrego Desert State Park, oral commun., 1981).

TABLE 6. - Water use in Borrego Valley during 1980

Type water use	Number of acres irrigated	Consumptive water use per acre (acre-ft)	Water used (acre-ft)
Population (permanent and transient)---------		(125 [gal/d]/ person)	334
Citrus-----------------------------	940	3.26	3,064
Grass (pasture)--------------------	425	4	1,700
Alfalfa----------------------------	140	6.19	867
Tomatoes (hot house)---------------	10	2	20
Tree farm[1]------------------------	390	2	780
Grass (golf course)----------------	270	7	1,890
Mesquite and tamarisk trees (native vegetation)--------------	4,510	[2]2.7	1,218
Grapes (dead)----------------------	655	[3]0	0
Date palm--------------------------	40	40	0
Total water use (rounded)-------------------------------			9,870

[1]Tree farms are predominantly palm trees, but also include other ornamental trees such as olive.

[2]Trees cover about 10 percent of ground in 4,510 acres, or 2.7 acre-ft/yr times 10 percent.

[3]Grapes not irrigated since 1966.

[4]Not irrigated in 1980.

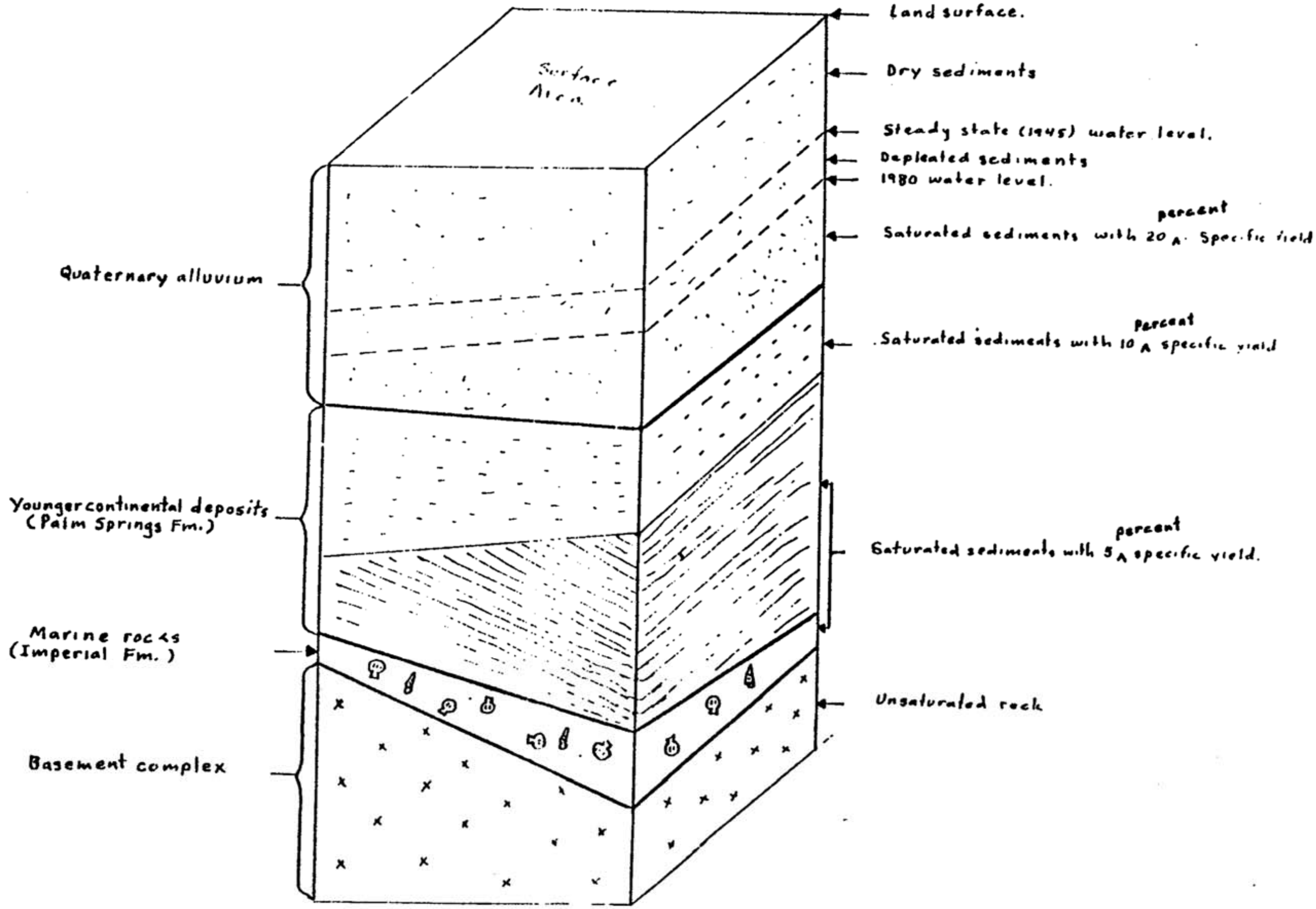


FIGURE 2.--Schematic diagram showing geologic formations, hydrologic units, specific yield, and relative positions of 1945 and 1980 water levels.

Sites where water-quality samples were collected in Borrego Valley area during 1980 are shown on plate 12 and the analyses are listed in Supplemental Data B.

Source of Nitrogen in Ground Water

Nitrogen (N) is the individual constituent in ground water in Borrego Valley of most concern to residents. Some laboratory analyses report nitrogen (N)[1]; others report nitrate (NO_3). According to the Environmental Protection Agency (National Academy of Sciences, National Academy of Engineering, 1973, p. 73) "high concentrations of nitrate (44 mg/L NO_3 or greater) in drinking water may cause infantile methemoglobinemia, especially in infants under 3 months of age. The development of methemoglobinemia is dependent upon the bacterial conversion of the relatively innocuous nitrate (NO_3) to nitrite (NO_2). Nitrite absorbed into the bloodstream converts hemoglobin to methemoglobin. The altered pigment can then no longer transport oxygen, and the clinical effect of methemoglobinemia is that of oxygen deprivation or suffocation."

Nitrate (NO_3) in water samples analyzed from Borrego Valley over the years ranged from 0 to more than 300 mg/L. Concentrations of nitrate in the same wells sampled periodically have fluctuated with time. Well 10S/6E-15D1 (fig. 3) was sampled 22 times between 1950 and 1979 for nitrate (NO_3). Nitrate values in water from this well ranged from 2 to 213 mg/L. The reason for the fluctuation in nitrate levels with time is probably contamination from septic tanks, irrigation return, well construction, and frequency and size of floods entering Borrego Valley from adjacent stream channels. Large floods sometimes inundate the sewage-dumping area in T. 10 S., R. 6 E., sec. 36. Small floods do not reach this area.

Data are presently not available to determine the areal extent of nitrate or if the nitrate concentration in water at or near the water table is increasing or decreasing with time. To collect and analyze high-nitrate water, wells must be constructed with perforations at the water table, but production wells normally are not. When water levels in wells decline to the point where the perforations are exposed at the water table, they produce high nitrate water. These wells are usually destroyed, and new wells are drilled at the same locations with deeper perforations to produce low nitrate water.

Figure 3 shows the perforated interval of the casing in well 10S/6E-15D1, the static and pumping water levels in the well during pumping tests, the pumping rate in gallons per minute, and nitrate (NO_3) concentrations in the water for various times.

The nitrate pollution in Borrego Valley comes from:

1. Individual septic tanks and leach lines.
2. Effluent from sewage-disposal systems.
3. Irrigation-return water containing fertilizer.
4. Decomposition of native vegetation.

---

[1]To convert N (nitrate-nitrogen) to NO_3 (nitrate) multiply by 4.427.

Sewage disposal in Borrego Valley is predominantly by individual septic tanks and leach fields. One small sewage-treatment plant in the northeast corner of sec. 9, T. 11 S., R. 6 E. (pl. 8) services the homes surrounding the Club Circle Golf Course (formerly Ensign Ranch). The volume of sewage treated in this plant is small. Only 12 homes were serviced by this plant from October through December 1980, according to records in the file of the California State Water Quality Control Board. Plans are presently in progress for a new 25,000 gal/d sewage-disposal plant north of the town of Borrego Springs. Phase one of this plant was scheduled to be in operation near the end of 1981.

Septic tanks at individual homes are cleaned out periodically by commerical companies using vacuum trucks to haul away the sewage sludge. Data in the California State Water Quality Control Board's files indicate that 75,000 gallons of sludge was removed from various septic tanks in Borrego Valley between October 15, 1980, and January 1, 1981, and was deposited at a dump site in the SE¼ of sec. 36, T. 10 S., R. 6 E. A sample of sewage was collected from this dump site November 21, 1980. Tables 7 and 8 show the results of this analysis.

Solid waste (trash) is trucked to the dump site in T. 11 S., R. 7 E., sec. 6 (pl. 8) and buried or burned.

High nitrate water is conducted from the land surface to the water table and generally stays within a few feet below the water table. Wells constructed with perforations above the water table, as well as wells that are in areas where declining water levels have exposed the perforations above the water table show signs of high nitrate values at various times. Similar observations of high nitrate near the water table have been made by Klein and Bradford (1979) in the Redlands area.

Several wells that contained high nitrate water have been destroyed by their owners; well 10S/6E-29K1 was destroyed by pulling the casing out of the ground and backfilling the hole. Water from 29K1 contained 30 mg/L NO_3 in 1952. A new well (10S/6E-29K2) was drilled about 50 feet east of 29K1. The new well was constructed with deeper perforations and has 3.5 mg/L NO_3 (0.8 mg/L N) (Supplemental Data B).

Floods entering Borrego Valley from the surrounding mountains also contribute to the amount and concentration of nitrate in the ground water. Small floods help transport the nitrate from land surface to the water table, as do the large floods, but the large floods may help dilute the available nitrate.

With periodic nitrate analysis of water from irrigation wells, some farmers could take advantage of the high nitrate for use on crops such as citrus trees that can tolerate high concentrations of nitrate. This would also help remove nitrate from the aquifer and lower the pollution. Water companies or farmers that raise grapes, which are less tolerant to nitrate, may wish not to use high nitrate water. Wells can be constructed with perforations some distance below the expected pumping water level to prevent high nitrate water from entering the wells. If low nitrate water is desired, wells should be constructed so that the perforations remain below the pumping water level in the well for the expected life of the well.

Water-quality samples collected from streams and wells along the west side of Borrego Valley show no evidence of high-nitrate water entering the valley from adjacent areas.

NEED FOR ADDITIONAL DATA

Additional data are needed in the area near Borrego Spring and along the Coyote Creek fault. Two test holes drilled on opposite sides of the Coyote Creek fault would help to determine the water-level decline in Borrego Valley and whether the fault acts as a ground-water barrier. A 2-inch auger hole 17 feet deep was dug at Borrego Spring during this study in an effort to measure the water level in this area. The hole was dry, indicating the water-level decline has been greater than 17 feet since 1909 when the spring was flowing.

The few data available on the vertical separation of heads in the various aquifers indicate that under present conditions of stress there is little head difference. However, future changes in pumping stress patterns or simulated stress in the digital model to be constructed may indicate head differences that could be defined by test drilling.

SUMMARY AND CONCLUSIONS

This report includes information needed to build a digital hydrologic model of Borrego Valley. It includes sources and amounts of recharge water to the basin, areas of withdrawal, a grid network used to estimate the total recoverable ground water in storage and total ground-water depletion, total depth of alluvial fill, transmissivity, hydraulic conductivity and specific yield of aquifers, and thickness of individual aquifers.

The results of this study show that at steady-state conditions (1945) the basin contained 5.5 million acre-ft of water. Between 1945 and 1980 water levels in wells have declined as much as 100 feet locally and water withdrawn from the basin exceeded recharge by 330,000 acre-ft. Interpretation of the gravity data shows that the thickness of alluvial fill in the basin ranges from 0 feet at the edges of the basin to about 2,450 feet at its deepest part. Part of this alluvial fill is saturated, and part is dry, depending on location. In some areas the water level is at or near land surface, whereas in other areas it is more than 400 feet below land surface.

In Borrego Valley some water could be salvaged that is presently being lost. During large floods, water passes through Borrego by way of San Felipe Creek. Dams on the larger creeks could hold all or part of this water until it could be recharged into the ground-water basin. In addition, some of the native vegetation that uses about half the natural basin recharge could be removed. Studies would be needed to determine the ecological and other effects of such removals.

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GEOLOGIC AND HYDROLOGIC TERMS

Complete Bouguer: A gravity anomaly calculated by allowing for the attraction effects of topography, latitude, altitude, and curvature but not for that of isostatic compensation.

Consumptive use: The difference between the total quantity of water withdrawn from a source for use and the quantity of water returned to the source. It includes mainly water transpired by plants and evaporated from the soil.

Gal: The gravity unit most commonly used in gravity surveys to measure field strength. Named after Galileo, it is equivalent to an acceleration of one centimeter per second per second. A milligal is 0.001 Gal.

Hydraulic conductivity: The rate of flow of water in feet per day under a unit hydraulic gradient, at the prevailing temperature.

Hydraulic gradient: The rate of change of static head per unit of distance in a given direction.

Net depletion: The progressive loss of water from the ground-water reservoir at a rate greater than that of replenishment.

Precipitation: The discharge of water (as rain, snow, sleet, or hail) from the atmosphere upon the Earth's surface. It is measured as a liquid regardless of the form in which it originally occurred.

Rock density: The mass divided by the volume of a rock is the density. It is generally stated in grams per cubic centimeter.

Specific capacity: The rate of discharge of a water well per unit of drawdown, commonly expressed in gallons per minute per foot.

Specific yield: The ratio of the volume of water a given mass of saturated rock will yield by gravity to the volume of that mass. The ratio is stated as a percent.

Transmissivity: The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width, under a unit hydraulic gradient. Units are given in feet squared per day.

SUPPLEMENTAL DATA A: Water-level measurements in wells during 1980

Well or spring No.	Water level (feet below land surface)	Remarks
9S/5E-5DS1	0	
22KS1	0	
9S/6E-31E1	277.30	
36A1	17.67	
9S/7E-32A1	17.25	
10S/5E-25R1	260.97	
36A1	243.98	
10S/6E-1A1	18.18	
7A1	305.76	
8B1	288.09	
8L2	270	
10M1	214.18	
14G1	141.03	
15D2	200.82	
17J2	221.65	
17K2	211.62	
17L1	221.96	
19J1	163.56	
19R1	152.5	
21A1	177.73	
21B1	184.62	
21C1	--	Dry at 178.5 ft (total depth).
21E1	175.94	
21F1	172.40	
22B2	--	Dry at 128 ft (total depth).
23M1	128.39	
23M2	127.75	
24C1	135.06	
24K2	93.54	
24L1	123.32	
25R1	89.32	
26P1	--	Dry at 58.0 ft (total depth).
26P2	--	Dry at 70.8 ft (total depth).
28D1	147.40	
28E1	139.47	

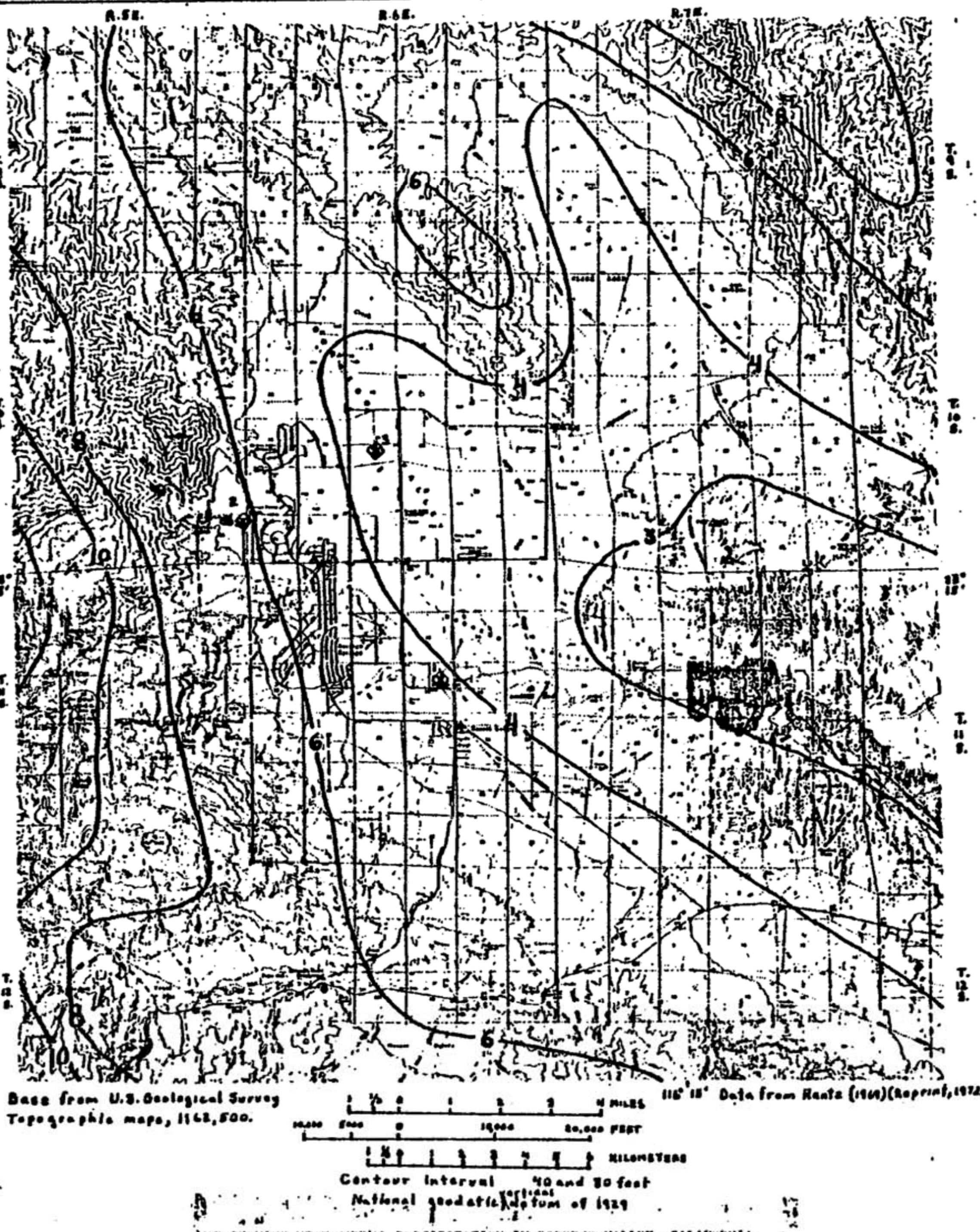
SUPPLEMENTAL DATA A: Water-level measurements in wells during 1980--Continued

Well or spring No.	Water level (feet below land surface)	Remarks
11S/6E-14D3	41.55	
15E4	67.44	
15G1	65.08	
16K1	110.00	
16M1	173.92	
18R1	325.28	
22A2	77.52	
22D1	131.22	
23E1	109.01	
23J1	52.61	
25A1	48.65	
25C1	94.96	
34A1	--	Dry at 441.6 ft (total depth).
11S/7E-29C1	77.28	
30G1	64.5	
30G2	78.39	
30G4	79.72	
30K1	72.82	
30K3	78.08	
32Q1	196.83	
12S/7E-4J1	266.47	

water from wells and streams collected in 1980

liter; except where noted]

Dissolved potassium	Alkalinity	Dissolved sulfate	Dissolved chloride	Dissolved fluoride	Dissolved silica	Dissolved solids, sum of constituents	Dissolved nitrogen, NO_2+NO_3 as N	Dissolved phosphorus, orthophosphate	Dissolved boron (µg/L)	Dissolved iron (µg/L)	Total arsenic (µg/L)	Dissolved solids (ton/acre-ft)
12	170	430	78	1.5	35	930	0.35	0.09	250	40	1	1.26
6.2	150	100	30	.4	42	373	.02	.21	40	70	1	.51
11	150	270	66	.8	29	669	.52	.03	170	10	0	.91
9.9	120	.1	290	.1	1.9	611	.00	.00	1,400	20	1	.83
7.2	140	130	43	.3	35	425	.19	.03	60	420	1	.58
11	170	310	70	.9	27	757	1.2	.00	190	10	1	1.03
10	180	240	68	1.0	25	664	.67	.06	230	20	1	.90
9.8	180	250	81	.9	25	708	1.1	.06	280	<10	1	.96
10	120	370	99	.7	20	850	2.8	.03	270	20	1	1.16
9.2	25	450	82	.5	4.6	817	.00	.00	230	30	0	1.11
10	160	310	72	.6	25	745	.95	.03	230	1,300	1	1.01
10	52	320	61	.5	14	634	.43	.03	290	10	1	.86
12	23	380	220	.5	14	947	.00	.00	290	<10	1	1.29
5.9	74	120	31.	.2	19	327	.80	.03	70	20	3	.44
10	89	360	210	.2	23	1,130	30	.03	120	20	0	1.54
5.7	48	220	62	.8	9.0	493	.11	.06	210	30	4	.67
10	38	420	270	.7	13	1,100	.04	.00	150	40	2	1.50
30	360	4.2	150	.4	3.4	624	.07	.00	290	30	0	.85
5.0	130	160	140	.2	30	605	1.3	.00	80	50	0	.82
4.8	110	110	100	1.4	26	468	.69	.03	190	10	2	.64
6.8	240	350	200	.7	64	1,150	1.3	.00	360	150	2	1.56
3.0	49	130	33	.9	17	312	.08	.06	150	20	7	.42
5.5	140	28	210	.5	26	608	11	.03	210	10	0	.83
6.8	110	110	170	.4	22	572	1.2	.00	220	10	2	.78
9.6	52	560	240	.2	17	1,260	1.1	.00	110	<10	1	1.71
6.7	29	100	83	.3	12	369	6.7	.00	70	20	1	.50
20	180	1,200	340	.5	36	2,440	.13	.00	130	40	1	3.32



EXPLANATION

PRECIPITATION STATION

Number indicates station as follows:

1. Borrego
2. Borrego Desert Park
3. Borrego Springs 3NNE

—— 4 ——

LINE OF EQUAL MEAN ANNUAL PRECIPITATION

Interval, 1 and 2 inches

Base from U.S. Geological Survey
Topographic maps, 1:62,500.

116°15' Data from Hanta (1964)(Reprint, 1972)

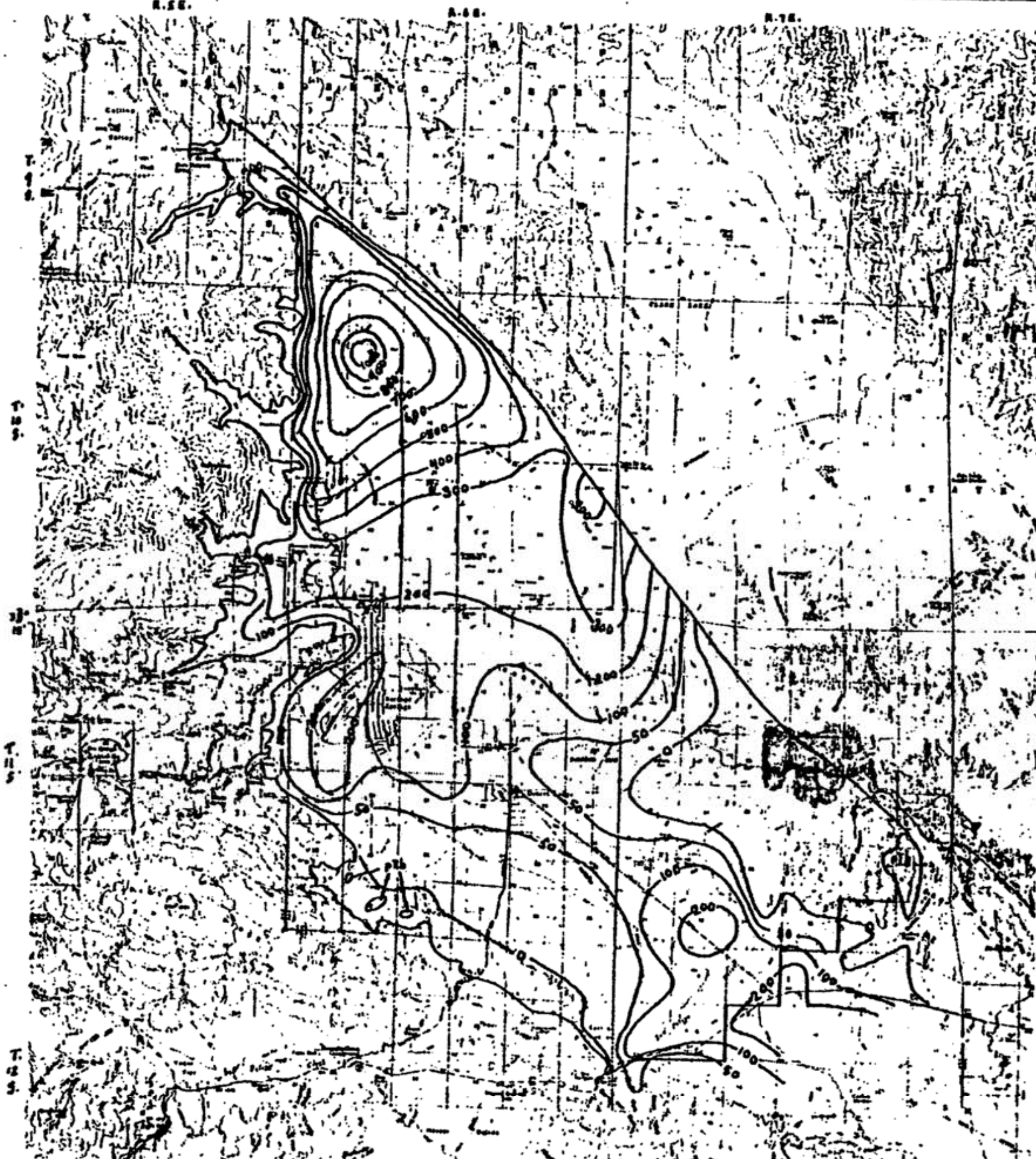
Contour interval 40 and 80 feet
National geodetic vertical datum of 1929

MAP SHOWING MEAN ANNUAL PRECIPITATION IN BORREGO VALLEY, CALIFORNIA

United St Department of the Interior
Geologic rvey

Prepared operation with the
Coun f San Diego

Open-file
Plate 5A



EXPLANATION

(pTb)

BASEMENT COMPLEX

Forms hills above alluvial fill in valley

——400——

LINE OF EQUAL THICKNESS OF UPPER AQUIFER

Interval, 50 and 100 feet. These deposits have a hydraulic conductivity of 50 feet per day and a specific yield of 20 percent.

BASIN BOUNDARY

Base from U.S. Geological Survey
Topographic maps, 1:62,500

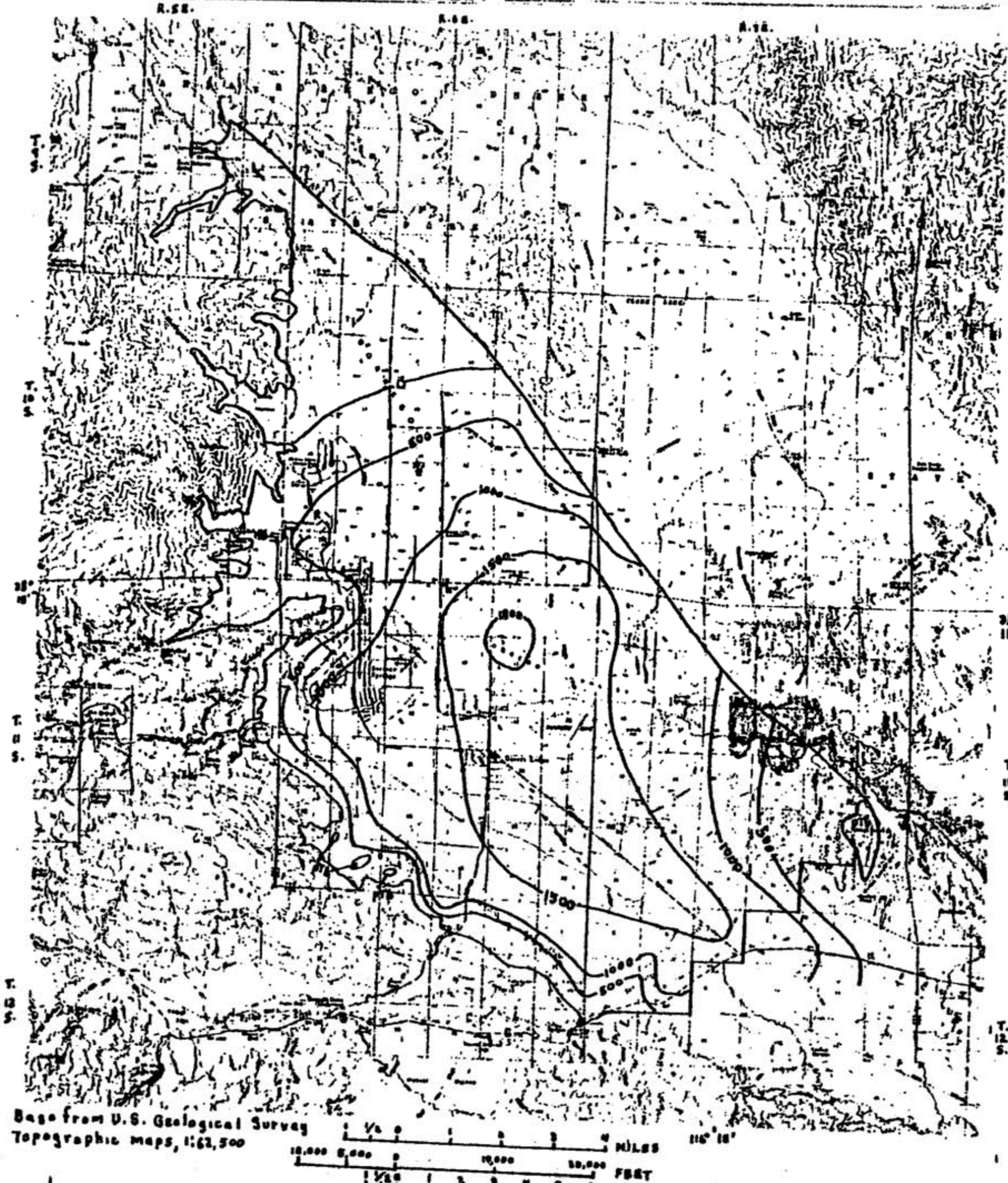
MILES 1/2 0 1 2 3 4
FEET 10,000 5,000 0 10,000 20,000
KILOMETERS 1/2 0 1 2 3 4 5 6

Contour interval 40 and 80 feet
National geodetic vertical datum of 1929

THICKNESS MAP OF UPPER AQUIFER IN BORREGO VALLEY, CALIFORNIA

United States Department of the Interior
Geological Survey

County of San Diego



Base from U.S. Geological Survey Topographic maps, 1:62,500

Contour interval 40 and 80 feet
National geodetic vertical datum of 1929

EXPLANATION

(pTb)

BASEMENT COMPLEX

Forms hills above alluvial fill in valley

——500——

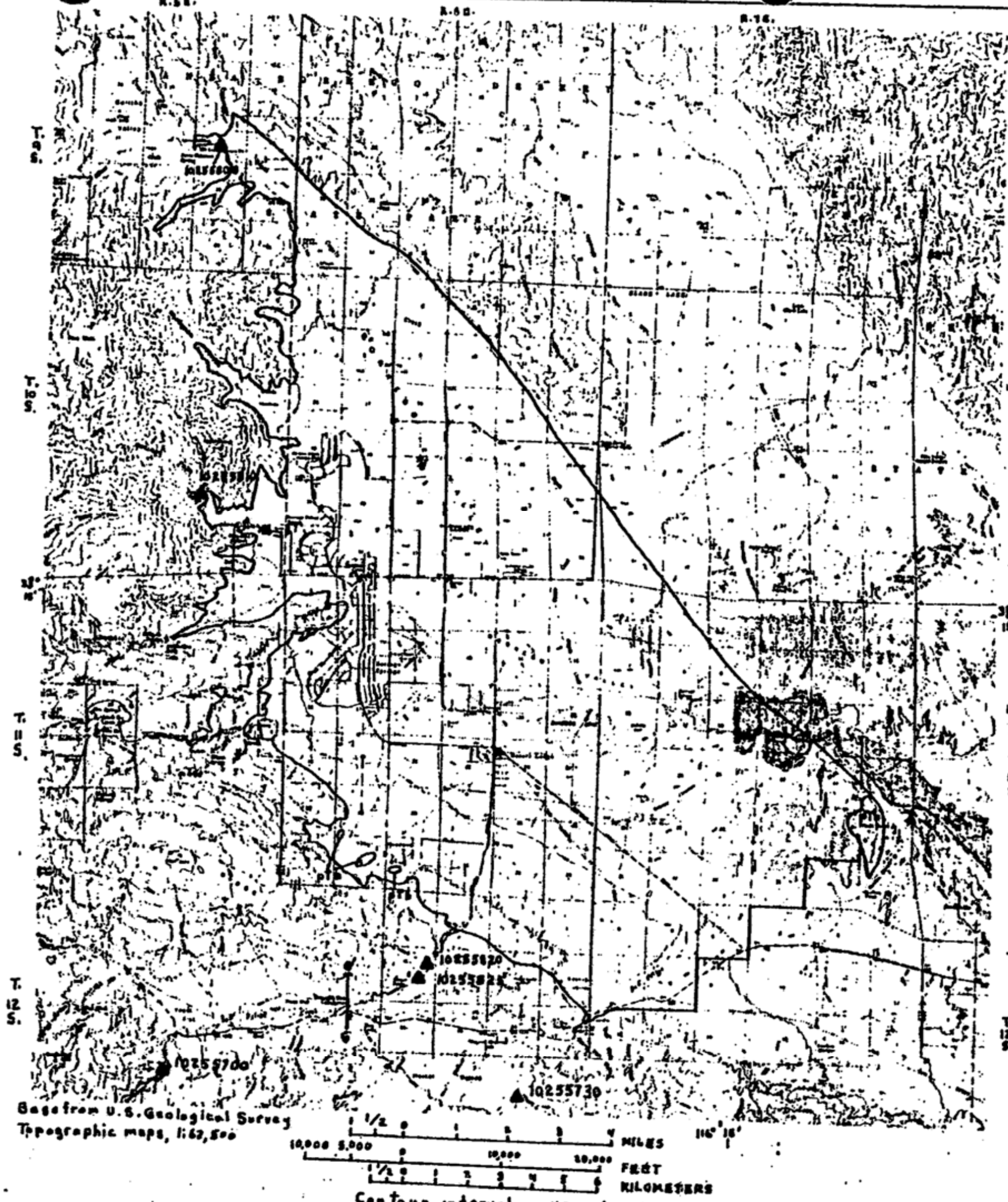
LINE OF EQUAL THICKNESS OF LOWER AQUIFER

Interval, 300 and 500 feet: These deposits have a hydraulic conductivity of 1 foot per day and a specific yield of 5 percent.

——

BASIN BOUNDARY

THICKNESS MAP OF LOWER AQUIFER IN BORREGO VALLEY, CALIFORNIA



EXPLANATION

pTb

BASEMENT COMPLEX

Forms hills above alluvial fill in valley

G ——— G'

LINE OF SECTION USED TO DETERMINE GROUND-WATER UNDERFLOW IN SAN FELIPE CREEK

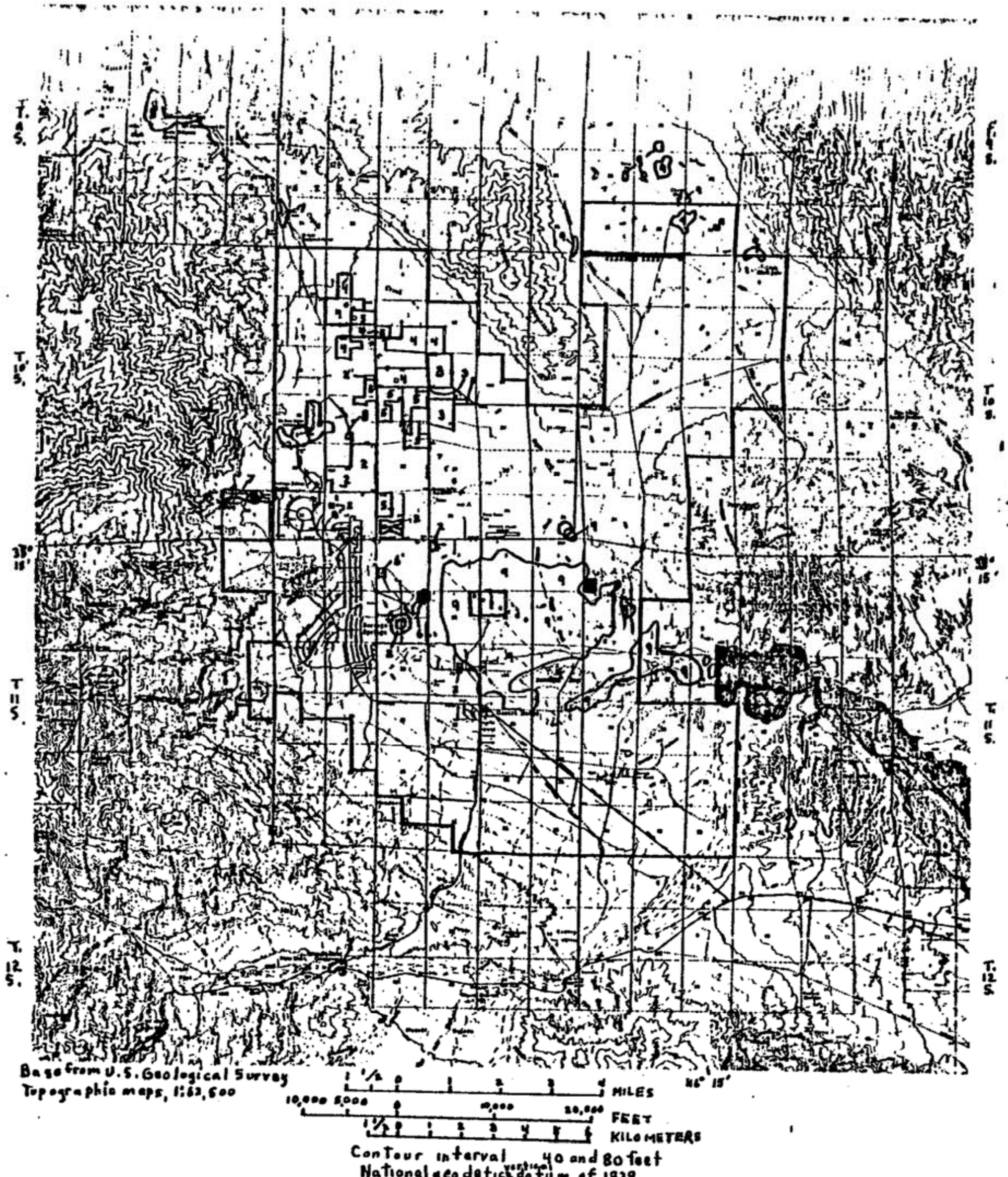
▲ 10255825

SURFACE-WATER GAGING STATION AND U.S. GEOLOGICAL SURVEY NUMBER

BASIN BOUNDARY

PLATE 7.--MAP SHOWING LOCATION OF SURFACE-WATER GAGING STATIONS AND LINE OF GROUND-WATER UNDERFLOW SECTION G-G', BORREGO VALLEY AREA, CALIFORNIA

Plate 8B



LAND-USE MAP FOR BORREGO AND CLARK LAKE VALLEYS, CALIFORNIA, FOR 1980

EXPLANATION

Privately owned land inside of boundary.
State-owned land located outside of boundary.

CROPS

1 Alfalfa
2 Grass (pasture, golf course, and school playground)
3 Tree farm
4 Citrus trees
5 Grape vines (not irrigated since 1966)
6 Date palms (not irrigated)
7 Park campgrounds
8 Tomatoes (hot house)
9 Native mesquite or tamarisk trees

● SEWAGE TREATMENT PLANT AND OXIDATION PONDS

○ SEWAGE DISPOSAL SITE

Sewage spread on land surface

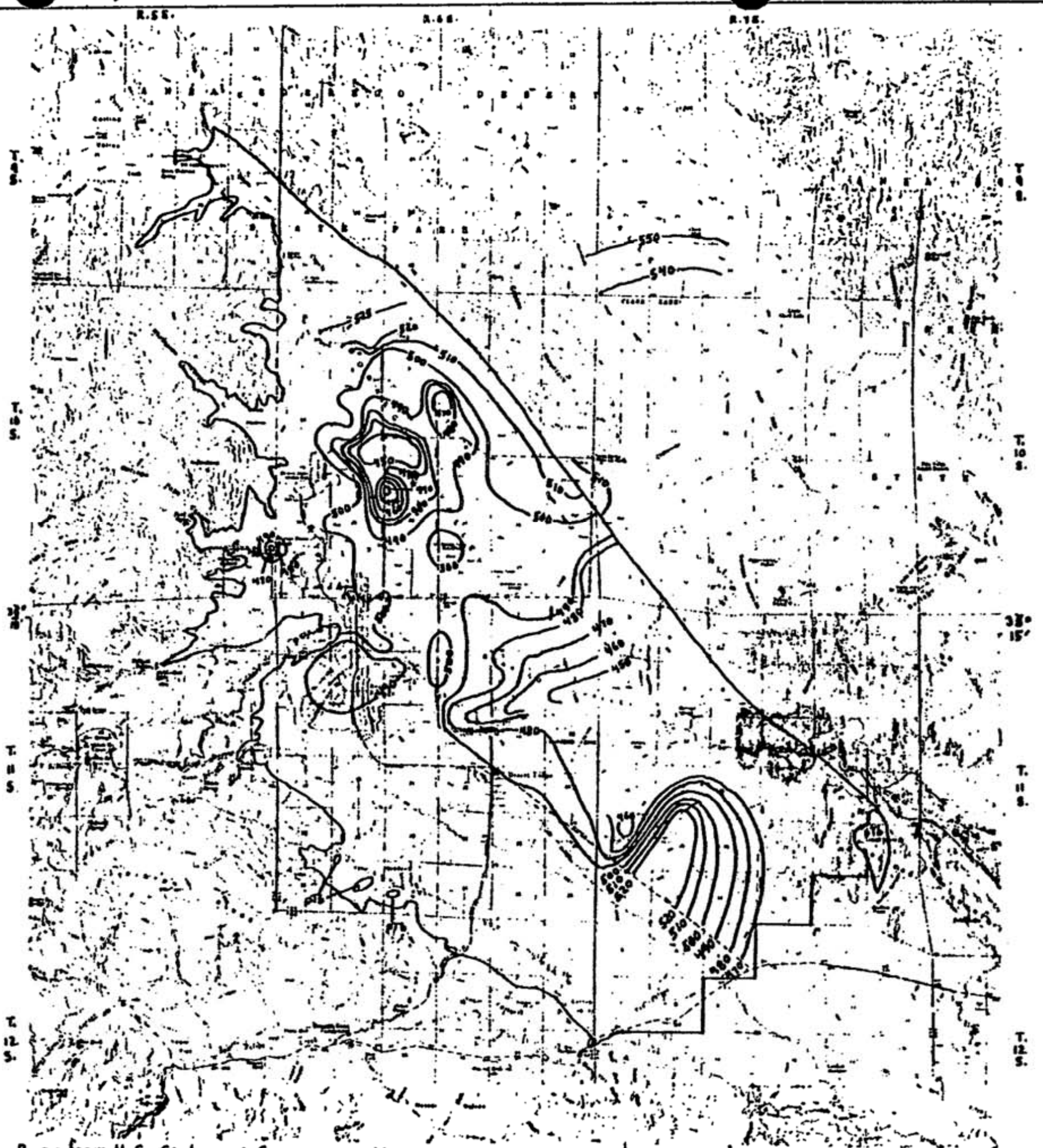
□ TRASH DUMP

RADIO TELESCOPE AND OBSERVATORY

Operated by the Universities of Iowa and Maryland. Radio telescope is 2 miles long with observatory buildings in center.

Prepared in cooperation with the
C[illegible] of San Diego

Open File Report 82-855
Plate 9B



Base from U.S. Geological Survey
Topographic maps, 1:62,500

1½ 0 1 2 3 4 MILES
10,000 5,000 0 10,000 20,000 FEET
1½ 0 1 2 3 4 5 6 KILOMETERS

Contour interval 40 and 80 feet
National geodetic vertical datum of 1929

EXPLANATION

(pTb)

BASEMENT COMPLEX

Forms hills above alluvial fill in valley

——500——

WATER-LEVEL CONTOUR

Shows altitude of water surface. Contour interval, in feet, is variable. National Geodetic Vertical Datum of 1929. Data for Water-level contours from Burnham, (1954).

————

BASIN BOUNDARY

WATER-LEVEL CONTOUR MAP OF BORREGO AND CLARK LAKE VALLEYS, CALIFORNIA, FOR 1952-53

United [...]es Department of the Interior
Geolog[...] Survey

Prepar[...] cooperation with the
Co[...] of San Diego

Open F[...]port 82-855
Plate 9D

EXPLANATION

(pTb)

BASEMENT COMPLEX

Forms hills above alluvial fill in valley

——— 470 ———

WATER-LEVEL CONTOUR

Shows altitude of water surface. Contour interval, in feet, is variable. National Geodetic Vertical Datum of 1929. Data for Water-level contours from Supplemental Data A in this report.

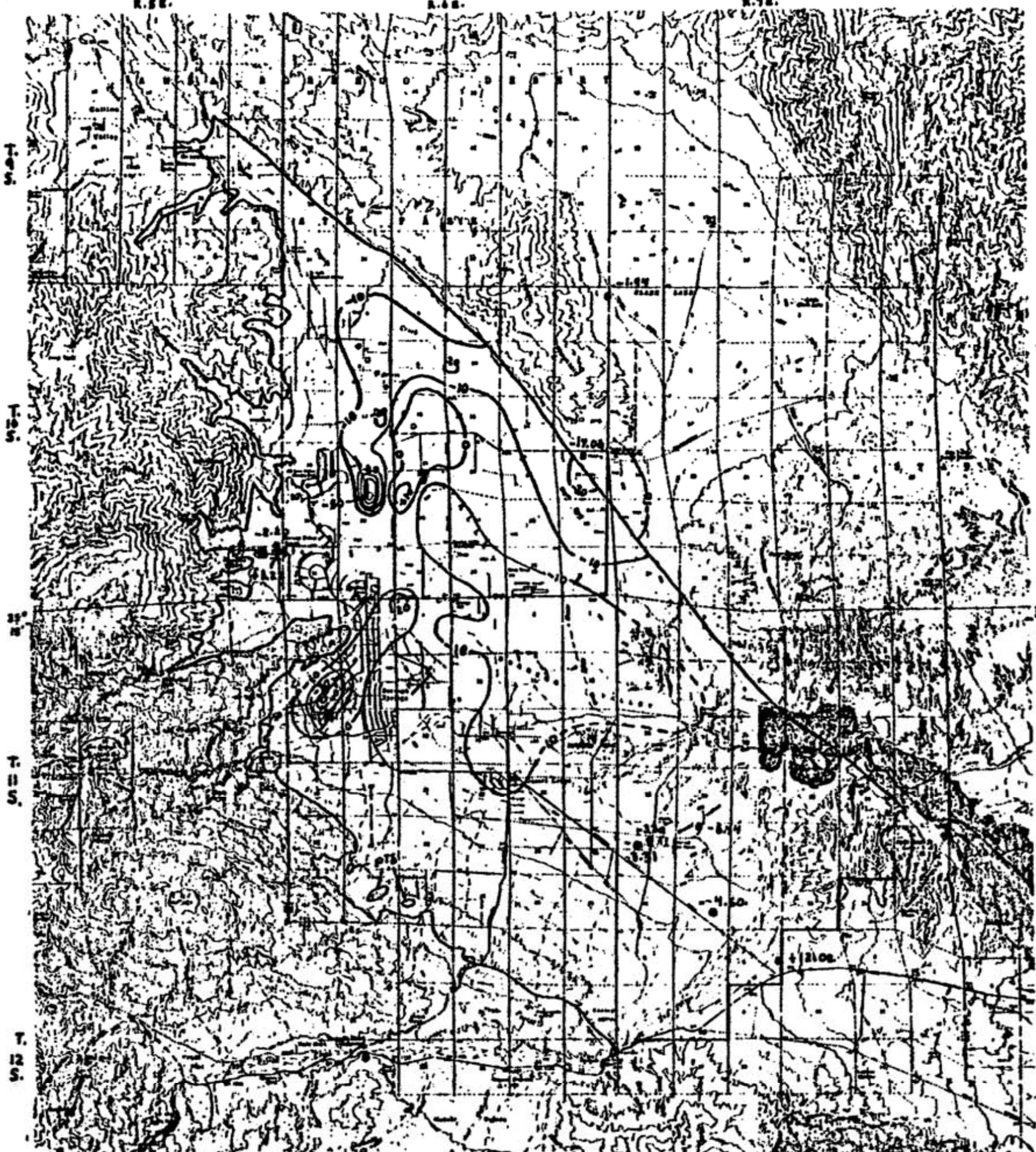
BASIN BOUNDARY

Base from U. S. Geological Survey
Topographic maps, 1:62,500

1 ½ 0 1 2 3 4 MILES
10,000 5,000 0 10,000 20,000 FEET
1 ½ 0 1 2 3 4 5 6 KILOMETERS

Contour interval 40 and 80 feet
National geodetic vertical datum of 1929

WATER-LEVEL CONTOUR MAP OF BORREGO AND CLARK LAKE VALLEYS, CALIFORNIA,



Base from U.S. Geological Survey
Topographic maps, 1:62,500

1/2 0 1 2 3 4 MILES
10,000 5,000 0 10,000 20,000 FEET
1/2 0 1 2 3 4 5 6 KILOMETERS

Contour interval 40 and 80 feet
National Geodetic Vertical Datum of 1929

EXPLANATION

(pTb)

BASEMENT COMPLEX

Forms hills above alluvial fill in valley

——20——

LINE OF EQUAL WATER-LEVEL CHANGE

Minus (-) indicates water-level decline, in feet, between 1965 and 1980. Plus (+) indicates rise in water level for the same time period. Interval, 10 feet. Dashed where approximately located.

• -1.94

WELL

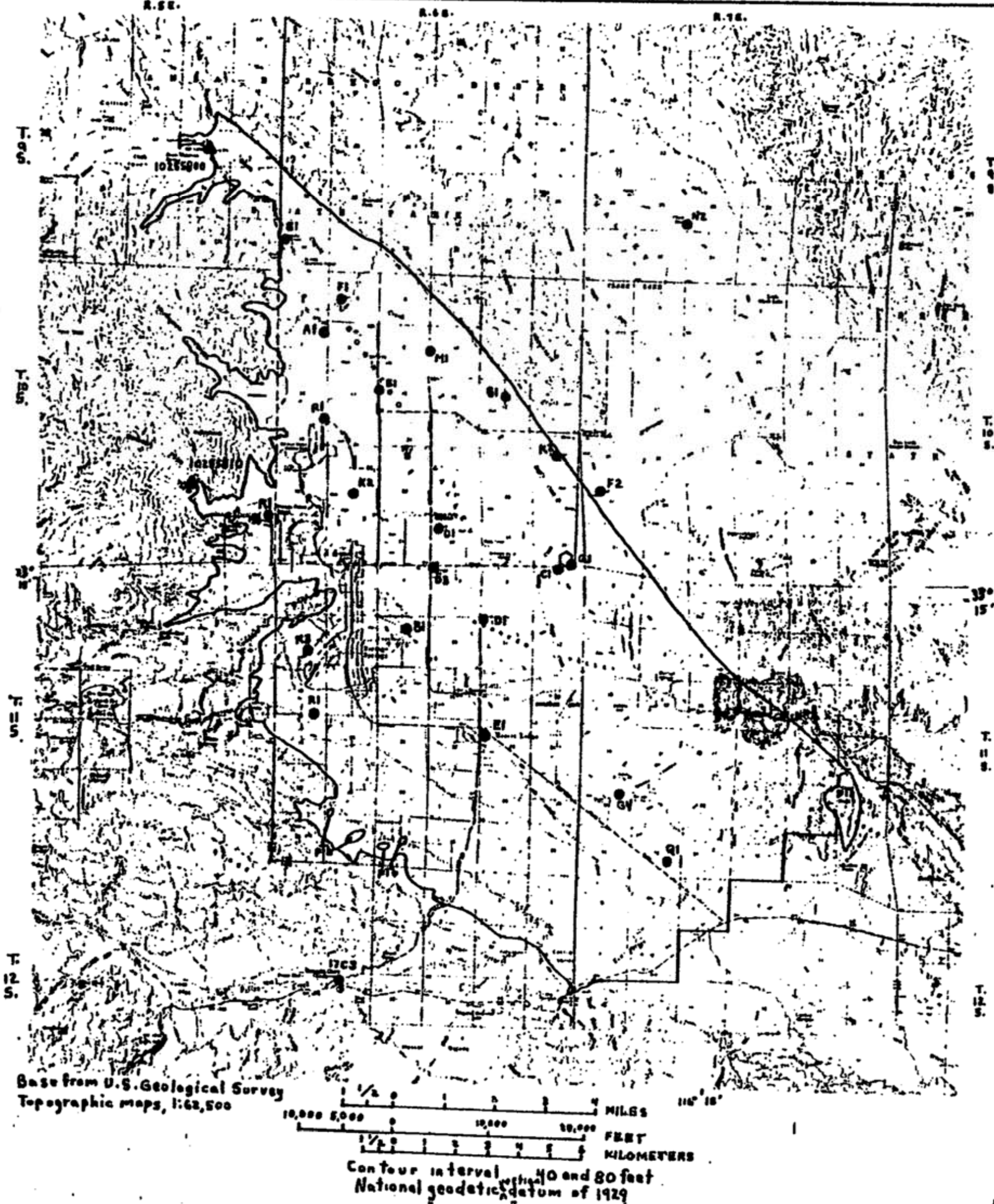
Number indicates net water-level change, in feet, between 1965 and 1980. Minus (-) indicates a decline and a plus (+) indicates a rise in water level. Used in areas where data are sparse and lines of net change could not be drawn.

BASIN BOUNDARY

PLATE 11B.--WATER-LEVEL CHANGE MAP OF BORREGO AND CLARK LAKE VALLEYS, CALIFORNIA, FOR 1965-80

Prepared in cooperation with the
County of San Diego

Open File Report 82-85
Plate 12



EXPLANATION

(pTb)

BASEMENT COMPLEX

Forms hills above alluvial fill in valley

● D1

WELL

Location where ground-water sample was collected. Letter and number indicate U.S. Geological Survey well number. See text for well numbering system.

▲ 10255800

SURFACE-WATER GAGING STATION

Location where surface-water sample was collected. Number is U.S. Geological Survey surface-water station number.

O

SEWAGE WATER

Location where sewage-water sample was collected.

———

BASIN BOUNDARY

MAP SHOWING LOCATION OF SITES WHERE WATER-QUALITY SAMPLES WERE COLLECTED IN THE BORREGO VALLEY AREA, CALIFORNIA, 1980