PRELIMINARY GROUND-WATER MODEL OF THE MESILLA VALLEY

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Introduction

The Mesilla Valley is located along the Rio Grande in southern New Mexico and west Texas. Figure 1 shows the location of the area which was modeled. The study area extends along the Rio Grande Valley from the El Paso Narrows on the south to Radium Springs on the north.

Agriculture is the principal user of ground-water in the Mesilla Valley. Since the drought of the mid- 1950's the ground-water resources of the valley have been developed extensively as a supplemental supply of irrigation water.

A mathematical ground-water model would be beneficial in helping to guide the future development of the Mesilla Valley ground-water basin. The central objective of this study of the Mesilla Valley ground-water conditions was to develop and verify a mathematical model of the Mesilla Valley ground-water basin. The modeling was accomplished by incorporating all available geologic and hydrologic data into a computer program that was developed by Dr. Willem Brutsaert of New Mexico Institute of Mining and Technology. The model was calibrated by adjusting the storativity of the aquifer until the computer generated data closely duplicated existing computer generated data on water table fluctuations.

Development of Model

The Mesilla Valley ground-water system was modeled by using a digital computer (IBM 360-50) to solve the mathematical equations which describe ground-water flow. Equation 1,

$$\frac{\partial}{\partial x}\left(K_x h \;\Delta y \;\frac{\partial H}{\partial x}\right) \Delta x + \frac{\partial}{\partial y}\left(K_y h \;\Delta x \;\frac{\partial H}{\partial y}\right) \Delta y = S \;\Delta x \;\Delta y \;\frac{\partial H}{\partial t} + q \;, \qquad [1]$$

is the differential equation which describes incompressible, two-dimensional, saturated, unconfined ground-water flow. Equation 1 can be derived from Darcy's law and the mass-continuity equation using the differential element of Figure 2.

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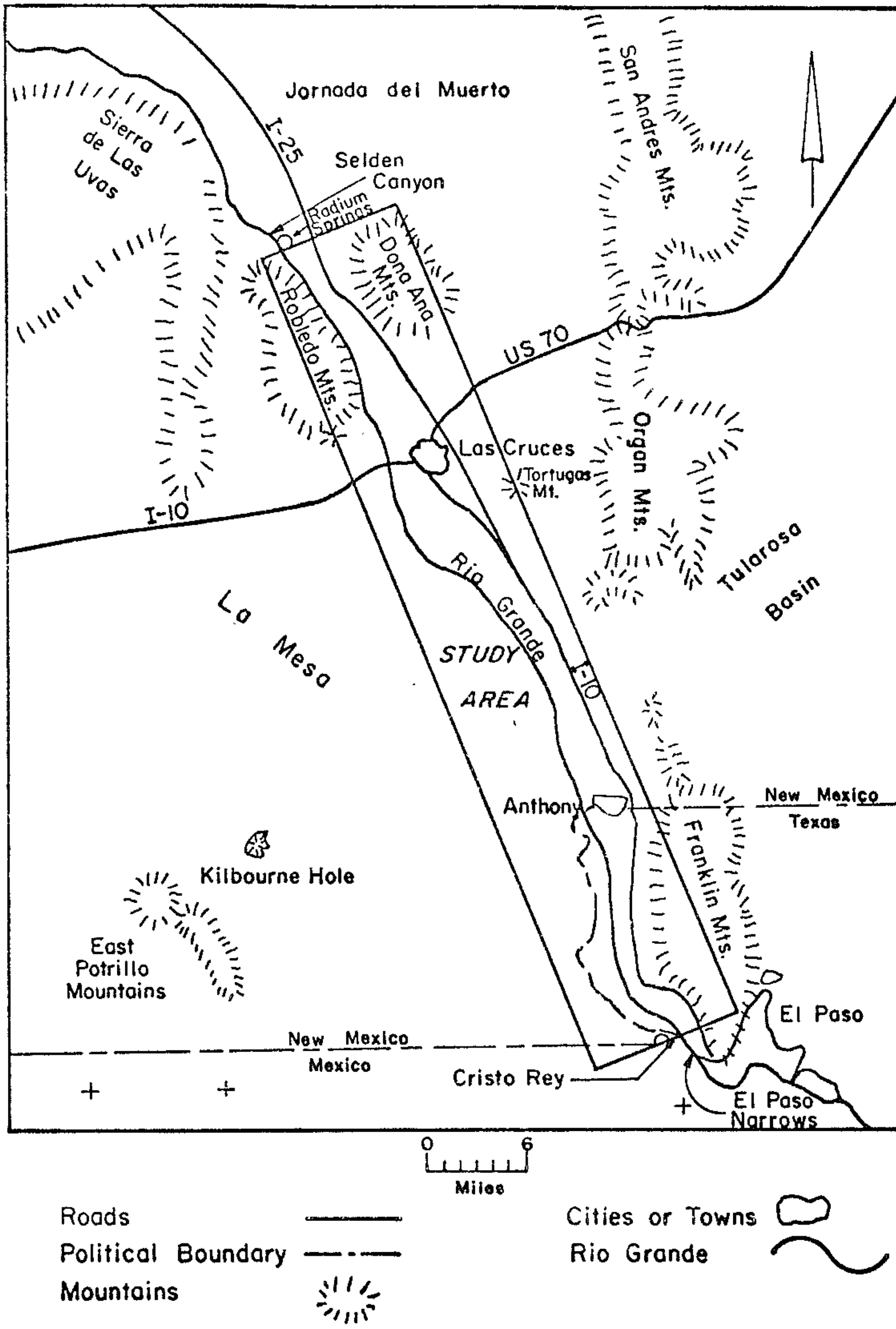


Figure I. Index Map

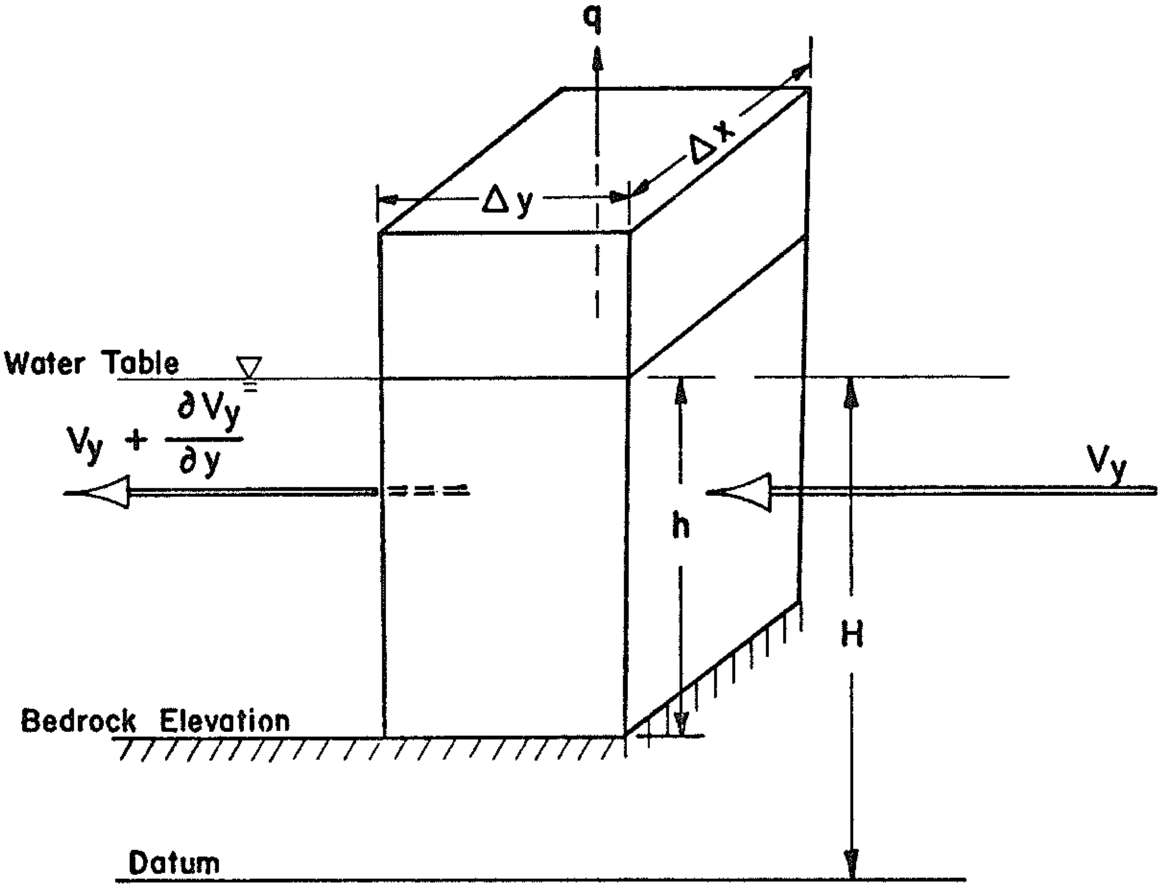


Figure 2. Differential Element of an Unconfined Aquifer

Since equation 1 does not have an exact solution a finite difference approximation is used to determine an approximate solution. The application of the finite difference technique requires that the study area be divided into a system of rectangular grid blocks. Figure 3 shows the 12 x 47 grid system that was superimposed on the study area. It is a uniform system with each grid block being 4000 feet in the Y-direction and 6000 feet in the X-direction. Using an implicit, central finite difference form, a nodal point equation was developed which describes the ground-water flow between adjacent grid blocks.

The digital computer program, which was developed by Dr. Brutsaert, writes a nodal point equation for each grid block in the study area. The entire set of equations is then solved simultaneously, by the computer, to determine the predicted water table elevations for each grid block in the study area at a succeeding time level. The new water table elevations are then used as the initial values for the next time step, and the entire process is repeated.

Input Data

The technique of modeling ground-water basins by the use of a digital computer is becoming increasingly popular in geohydrologic studies. The ability to simulate time dependent water table fluctuations is proving to be very valuable in ground-water basin management. The development of the Mesilla Valley ground-water model took place in four major steps. These steps were as follows:

1. determination of the extent of the ground-water basin,
2. determination of the aquifer constants,
3. quantification of the components of the water budget, and
4. determination of initial water table elevations.

All available geologic information was used in establishing the boundaries of the study area. The study area boundaries were placed such that underflow into and out of the study area would be as small as possible. To aid in locating geologic boundaries within the Mesilla Valley study area, a set of geologic cross-sections of the valley were constructed. These cross-sections (Figures 4, 5, 6, and 7) were constructed with the aid of gravity data, well logs and the personal knowledge of Dr. John W. Hawley of the U.S.D.A. Soil Conservation Service, and who was formerly assigned to the Agronomy Department at New Mexico State University. As can be seen by the geologic cross-sections the northern and southern boundaries were located in positions where the valley is narrowed by bedrock outcrops. The eastern boundary passes through the Franklin Mountains on the south, through Tortugas Mountain and through the Dona Ana Mountains on the north. Boundary flow is not excluded along the southern portion of the western boundary by any geologic formations, however. There is only a small amount of boundary flow in this area because the gradient of the water table is parallel to the boundary.

The total saturated thickness of the shallow ground-water aquifer in the Mesilla Valley is not known. Therefore, an effective base of the aquifer was assumed. North of Anthony the aquifer was assumed to be

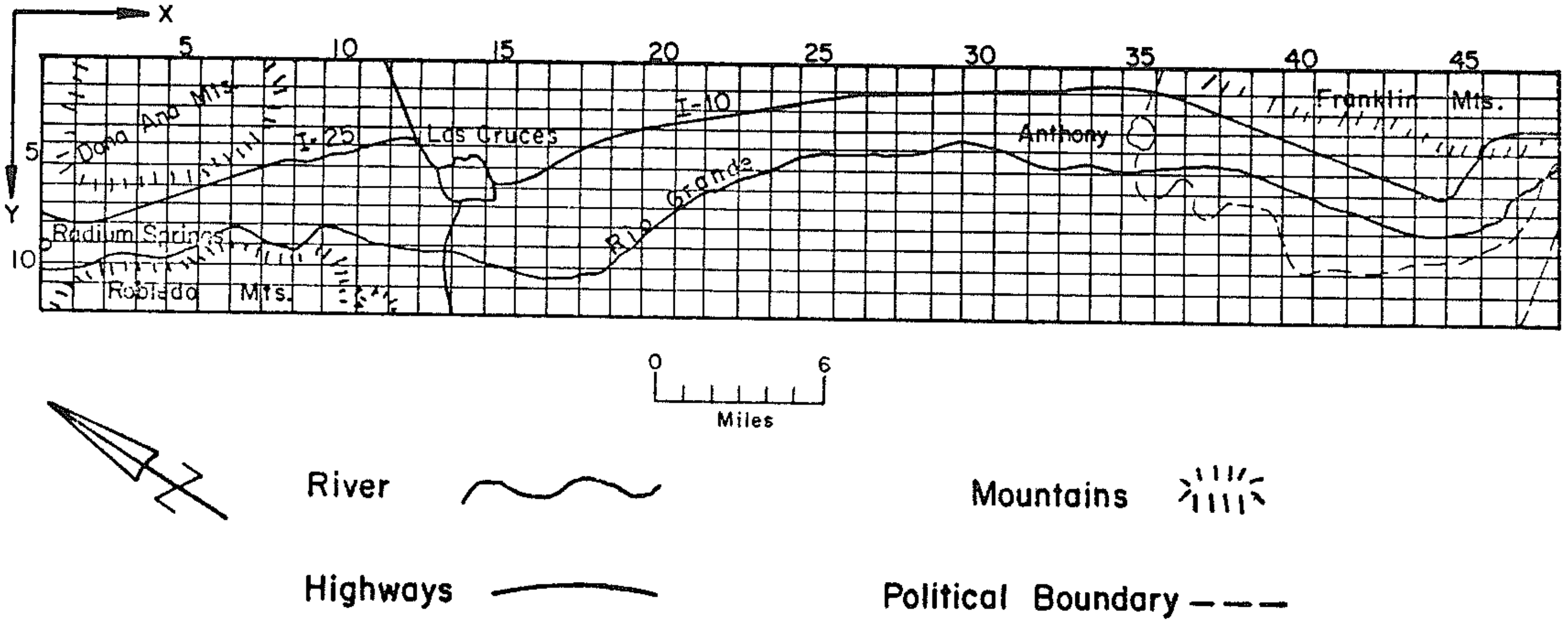
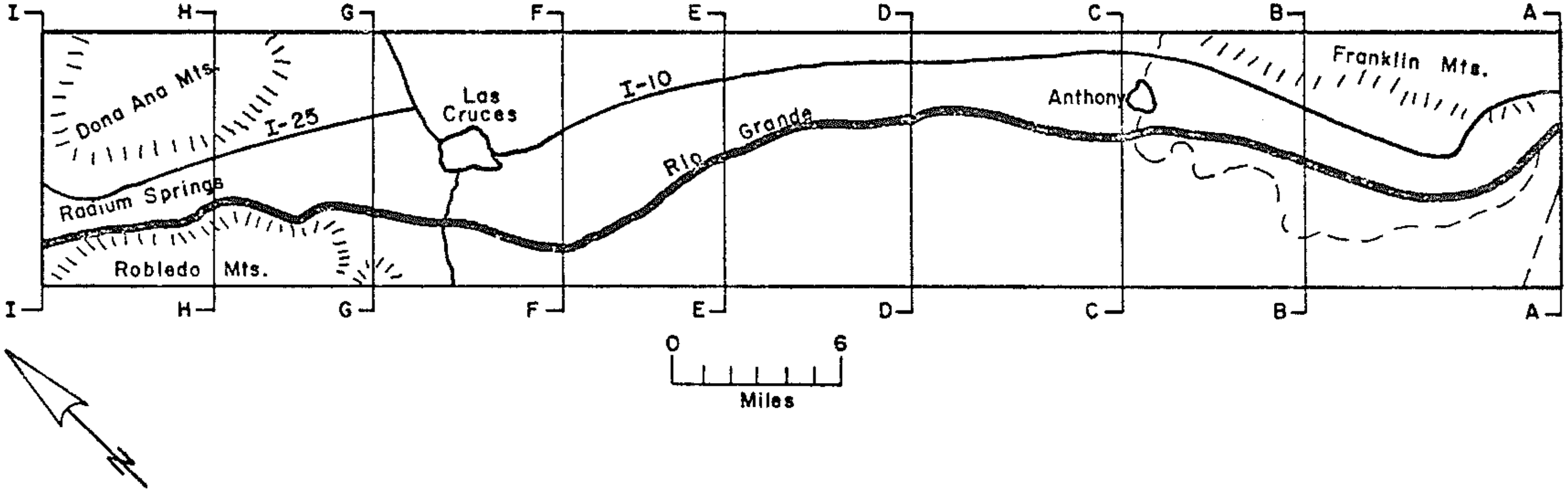


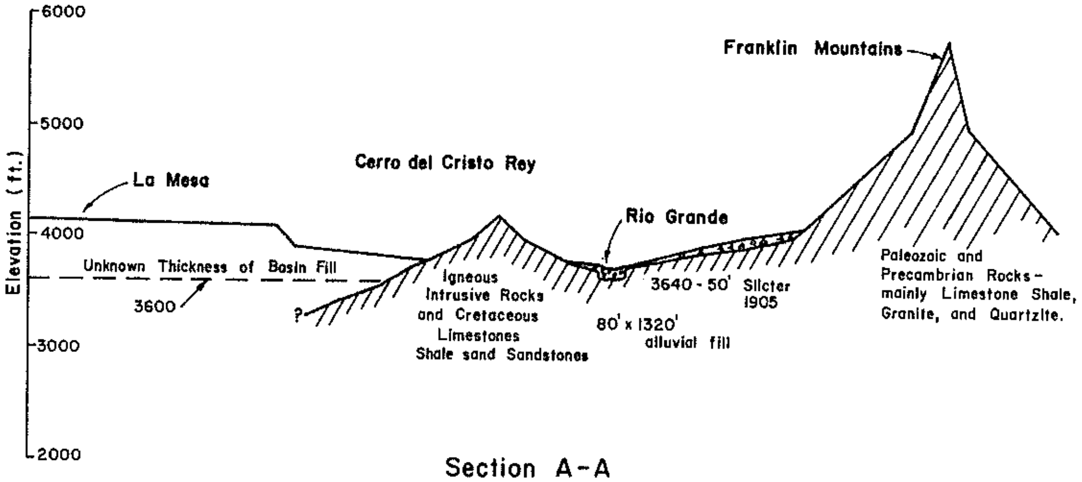
Figure 3. Grid System of Study Area

Figure 4.

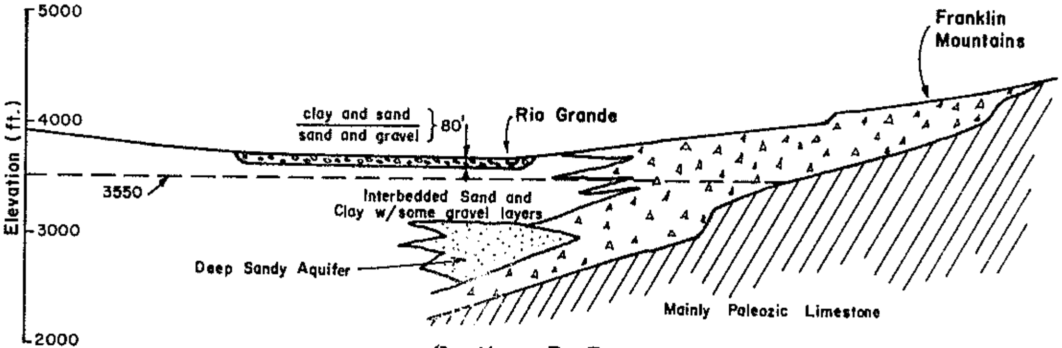
LOCATION OF GEOLOGIC CROSS SECTIONS



— — —	Assumed Effective Bedrock Elevation	─	Land Surface Elevation
▨	Bedrock	☰	Sand, Gravel, and Clay of Santa Fe Age
○	Recent Valley Fill	⁘	Sand
△	Fan Alluvium	‖	Lava



Section A-A



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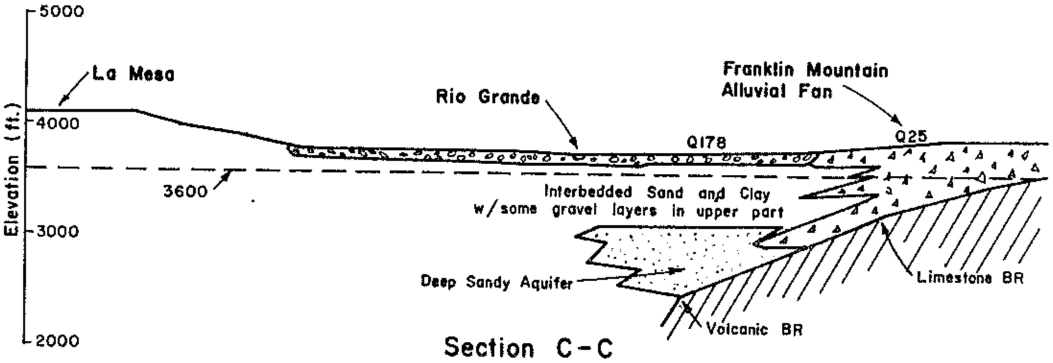
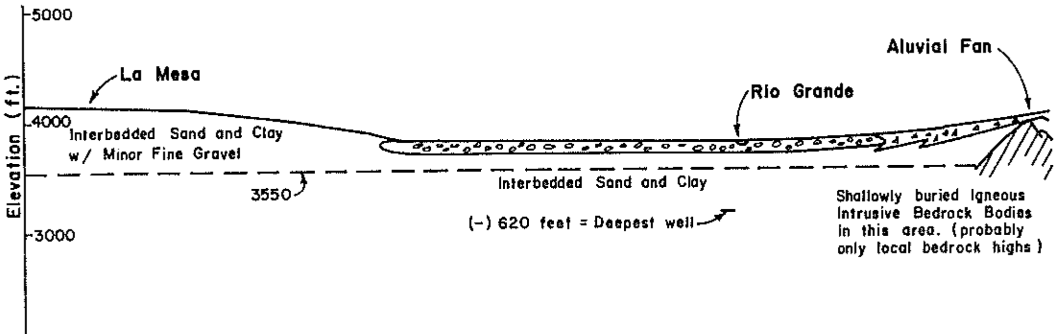


Section C-C

Figure 5.



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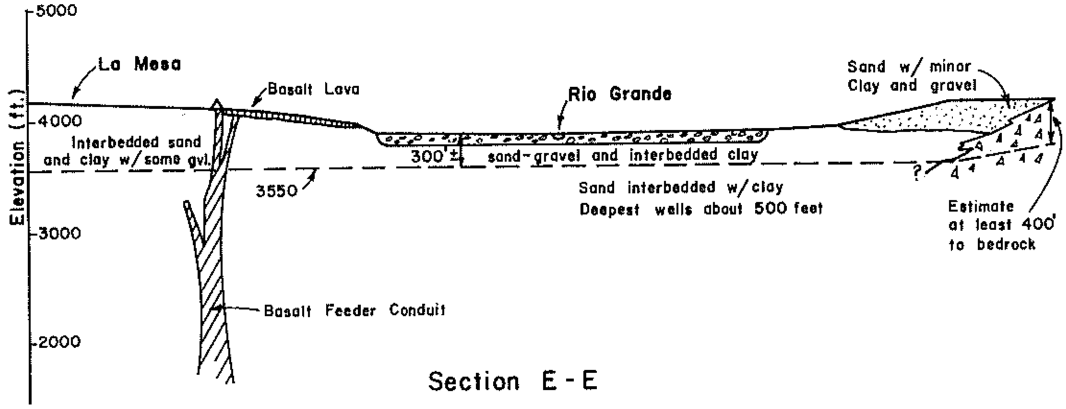

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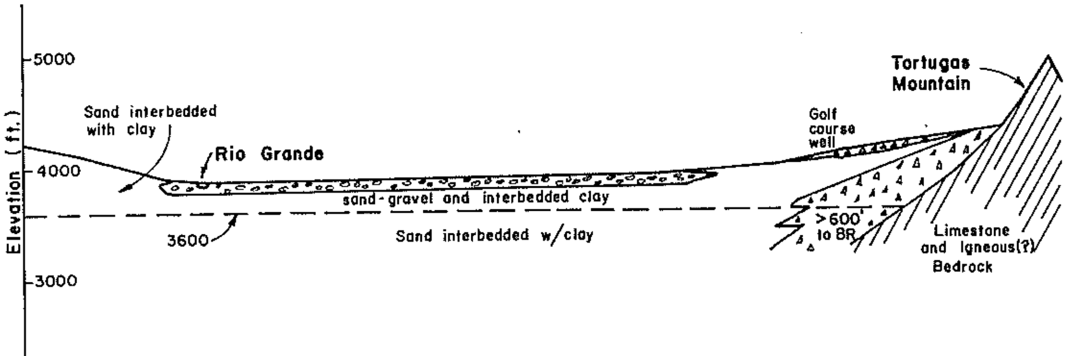
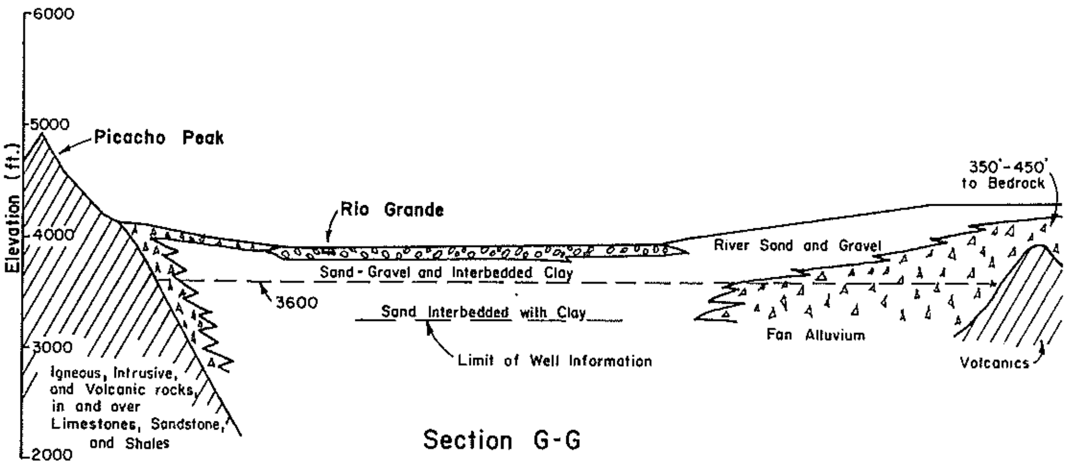


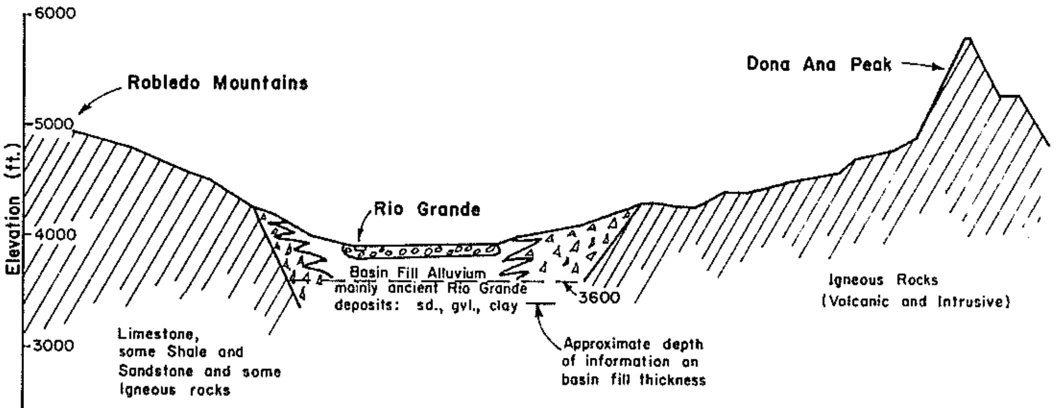
Section F - F

Figure 6.



Section G-G

1 mile



Section H-H

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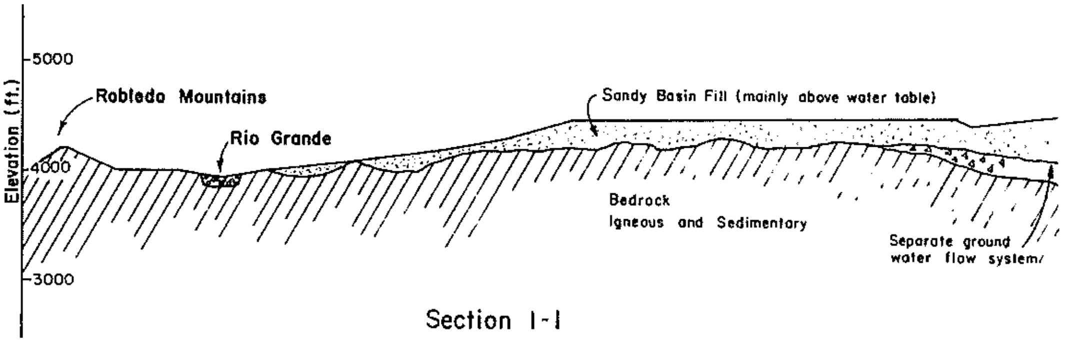

Section I-I

1 mile

Figure 7.

about 300 feet thick, and south of Anthony it was assumed to be about 200 feet thick. South of Anthony clay lenses become predominant enough, at a depth of about 200 feet, to effectively segregate the shallow aquifer from the medium and deep aquifers.

The two aquifer constants, transmissivity and storativity, are the parameters which define the behavior of ground-water in an aquifer. The transmissivity is a measure of the rate at which water flows through an aquifer, and the storativity relates the drawdown of the water table with the quantity of water removed from the aquifer. Considering all of the available pumping tests, which are shown in Table 1 , and some work done by Conover (1954) correlating water table slopes near drain ditches and flows in the ditches, an average transmissivity of 75,000 gpd per foot was programmed into the model. Values for the storativity of the shallow aquifer in the Mesilla Valley are not available. However, Conover (1954) estimated that the storativity of the shallow aquifer probably averaged about 25 percent. A uniform storativity of 25 percent was used as an initial estimate for the model. The major means of calibrating the model was varying the storativity because of the lack of confidence in this value and because of its influence between volumes removed and drawdown.

In effect, computer ground-water modeling is obtaining a hydrologic balance for each grid block in the study area for each time step. The computer accounts for the flow between grid blocks, while any inflows to or outflows from each block must be included as input data to the computer. Figure 8 illustrates the components of the water budget which were accounted for in the Mesilla Valley ground-water model. The agricultural water budget, which is illustrated in Figure 9, is the major source of inflow to and outflow from the Mesilla Valley ground-water basin. As can be seen from Figure 9, there are four major components affecting the ground-water basin which are connected with agricultural water usage. Estimates of all four components of the agricultural water budget are combined and read into the model as the net irrigation pumpage. The determination of the net irrigation pumpage for 1964 is illustrated in Table 2.

The basic time step used in the modeling was one month. As a result the components of the water budget were read into the model in acre-feet per year with a corresponding monthly distribution factor. The last column in Table 2 and Table 3 illustrate examples of monthly distribution factors used in the model. The other components of the water budget that were accounted for in the model are municipal pumpage, industrial pumpage, exchange between the Rio Grande and the ground-water basin, flow into the drain ditches, phreatophyte consumptive usage, infiltration of rainfall and boundary flow.

In order to model a ground-water basin, an initial water table elevation must be determined for each grid block. All available water level records for January 1967 were gathered and a water table contour map was plotted for that date. Figure 10 shows the water table map. The 12 x 47 grid system was then overlain on the water map, and the

Table 1.

AVAILABLE PUMPING TEST RESULTS FOR THE MESILLA VALLEY

Well Location	Transmissivity (gpd/ft.)	Pumping Rate (gpm)	Specific Capacity (gpm/ft.)	Depth to SWL (ft.)	Depth of Well (ft.)	Source of Data	Approximate Date of Test	Remarks
23.1E.13.244	91,000	64	16	15	83	Con.	1946	A.T. & S.F. Ry.
23.2E.08.434	73,000	250	21	186	300	Con.	1946	L.C. #5
23.2E.29.143	116,000	1270	98	13	50	Con.	1946	N.M.S.U.
27.3E.14.433	---	600	6.6	17.3	200	E.P.	1964	E.P. Well No. 115
27.3E.14.433	---	700	5.25	17.3	200	E.P.	1964	E.P. Well No. 115
27.3E.23.114	---	1200	13.0	12.6	218	E.P.	1964	E.P. Well No. 117
27.3E.23.213	---	825	6.3	16.8	220	E.P.	1964	E.P. Well No. 116
27.3E.23.433	158,000	---	---	5.5	152	LL&H	1956	Q-82
27.3E.26.112	121,000	---	---	4.9	170	LL&H	1956	Q-165
27.3E.26.132	104,000	---	---	6.0	194	LL&H	1956	Q-166
27.3E.26.231	145,000	---	---	5.0	160	LL&H	1956	Q-83
27.3E.26.414	110,000	---	---	4.3	122	LL&H	1952	Q-84
27.3E.26.432	155,000	---	---	---	---	LL&H	1956	Q-86
27.3E.27.222	140,000	---	---	5.2	160	LL&H	1956	Q-90
27.3E.27.242	150,000	---	---	6.2	202	LL&H	1956	Q-91
27.3E.35.212	---	1065	10.7	17.7	209	E.P.	1964	E.P. Well No. 118

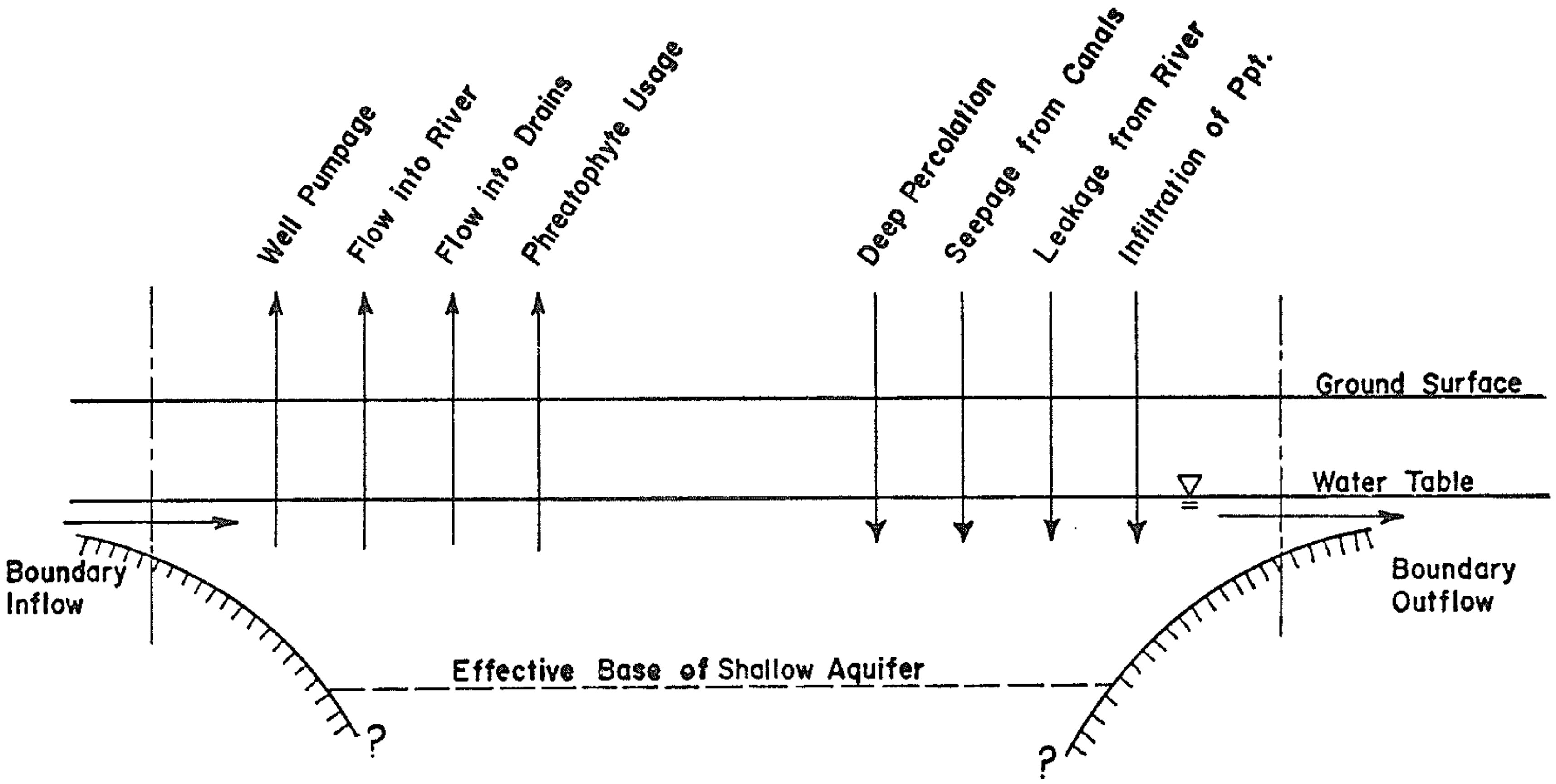

Figure 8. Water Budget for the Mesilla Valley Ground-Water Basin

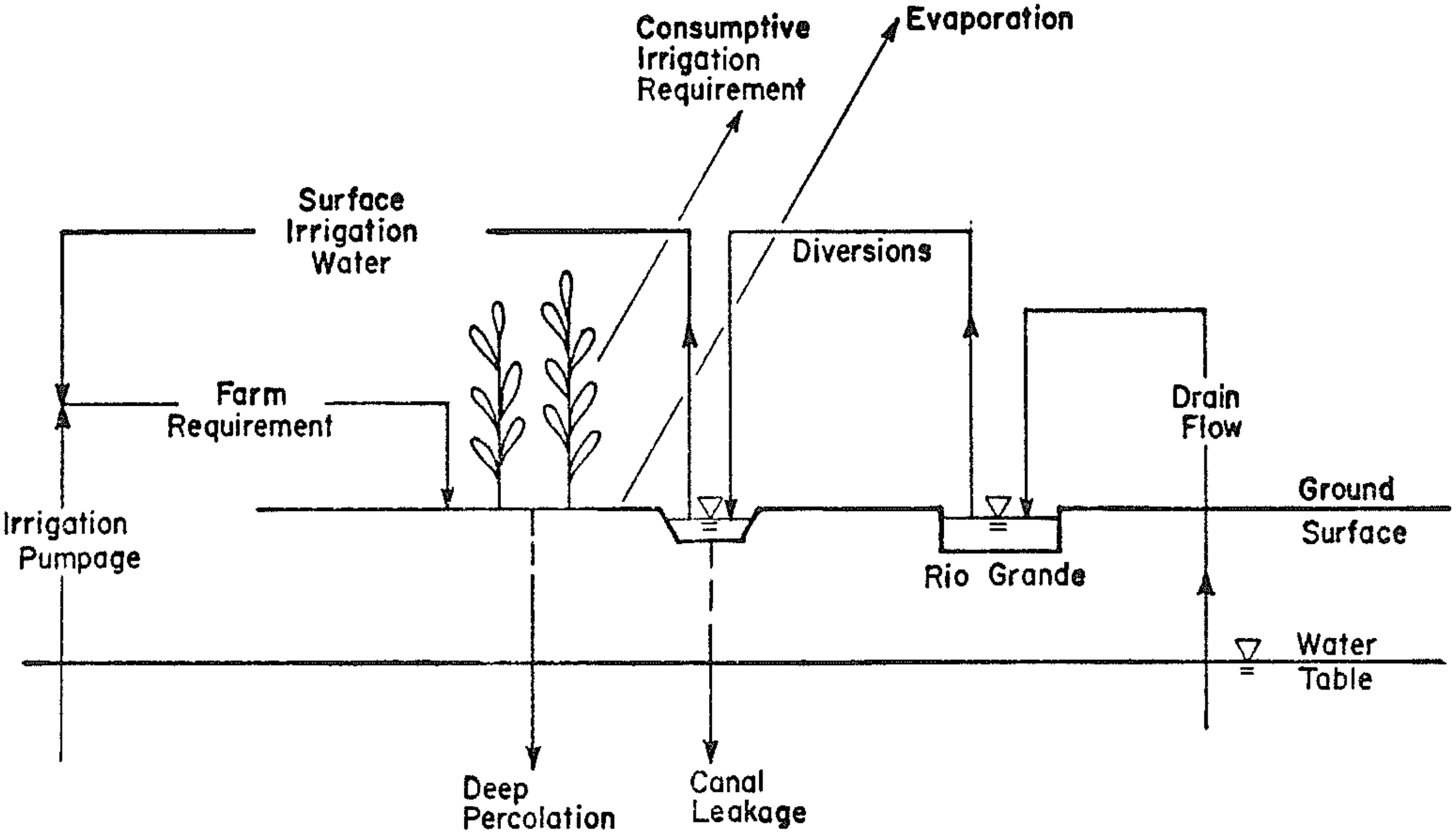

Figure 9. Agricultural Water Budget for the Mesilla Valley

Table 2

Monthly Distribution of Net Irrigation Pumpage for 1964

Month	Gross Irrigation Pumpage (Ac-ft/Ac) +	Drain Flows (Ac-ft/AC) +	Deep Percolation (Ac-ft/Ac) –	Canal Leakage (Ac-ft/Ac) –	Net Irrigation Pumpage (Ac-ft/Ac)	Monthly Distribution of Net Pumpage (%)
Jan	–	0.058	–	–	0.058	3.9
Feb	–	0.041	–	–	0.041	2.8
Mar	0.37	0.039	0.140	0.034	0.235	15.9
Apr	0.36	0.044	0.159	0.102	0.143	9.7
May	0.22	0.027	0.077	–	0.170	11.5
Jun	0.39	0.019	0.148	0.034	0.227	15.3
Jul	0.50	0.021	0.196	0.068	0.257	17.3
Aug	0.57	0.017	0.229	0.090	0.268	18.1
Sep	0.26	0.019	0.126	0.112	0.041	2.8
Oct	0.02	0.011	0.005	–	0.026	1.7
Nov	–	0.007	–	–	0.007	0.5
Dec	–	0.007	–	–	0.007	0.5
Total	+2.69	+0.31	-1.08	-0.44	+1.48	-100.0

Note: – indicates recharge
+ indicates discharge

TABLE 3

MONTHLY DISTRIBUTION OF MUNICIPAL PUMPAGE FROM LAS CRUCES CITY WELLS

MONTH	% OF TOTAL 1960-1969 AVERAGE	1964
January	4.7	4.9
February	4.7	4.5
March	6.5	5.9
April	8.7	7.5
May	11.4	11.3
June	12.1	12.7
July	12.3	12.8
August	11.4	12.4
September	8.8	9.5
October	7.2	7.9
November	7.5	5.9
December	4.7	4.7
TOTAL	100.0%	100.0%

NOTE: From production data provided by the City of Las Cruces.

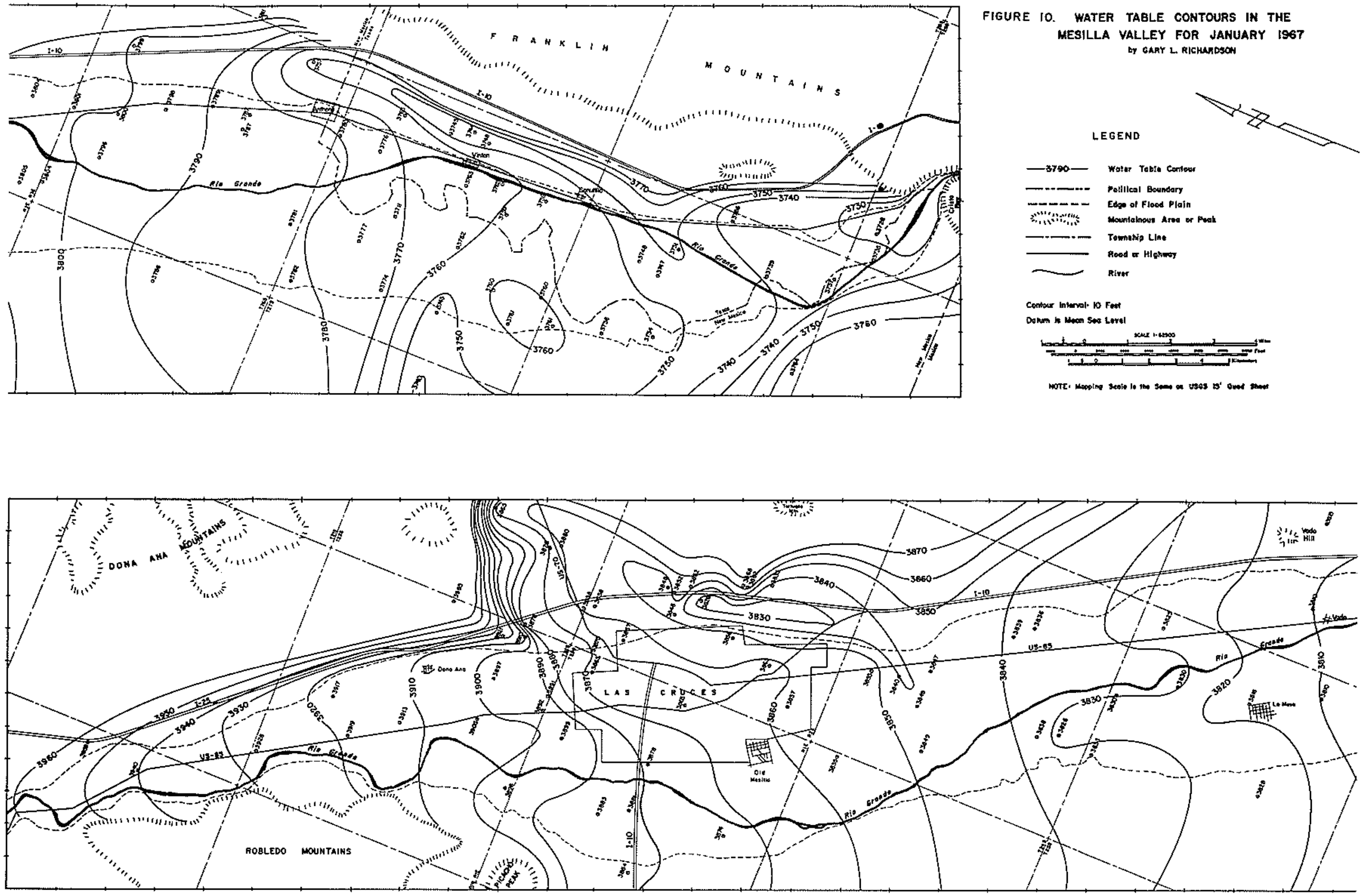

FIGURE 10. WATER TABLE CONTOURS IN THE MESILLA VALLEY FOR JANUARY 1967

by GARY L. RICHARDSON

water table elevation was determined for the center of each grid block. These elevations were then read into the computer to provide the initial water table conditions for the model.

Calibration

Calibration of the Mesilla Valley ground-water model consisted of adjusting the storativity until the best simulation of historic fluctuations for 1962 and 1964 was accomplished. The years 1962 and 1964 were chosen for calibrating because they are good and bad surface water years respectively. Figures 11 , 12 , and 13 illustrate the calibration process. A storativity of 20% was determined to be a good average value for the Mesilla Valley. Although it is known that the storativity is not constant throughout the valley, data is not presently available to warrant making judgments as to more accurate values.

Following the calibration the sensitivity of the model to changes in several of the input parameters was studied. As an example Figure 14 illustrates the sensitivity of the model to changes in the exchange between the Rio Grande and the shallow aquifer.

Conclusions

The good correlation between the computer generated water table fluctuations and the historic fluctuations strongly indicates that most of the presently available geologic and hydrologic information concerning ground-water conditions in the Mesilla Valley is basically correct. It was concluded from this investigation that no unknown variables exist within the Mesilla Valley which affect the response of the water table. It is felt that for short term predictions of a few years in duration the ground-water model developed as part of this study would be sufficiently accurate. As more new and comprehensive data becomes available, the data can be verified in the model and can be used to refine the model to the point to which reliable long range predictions can be made with it.

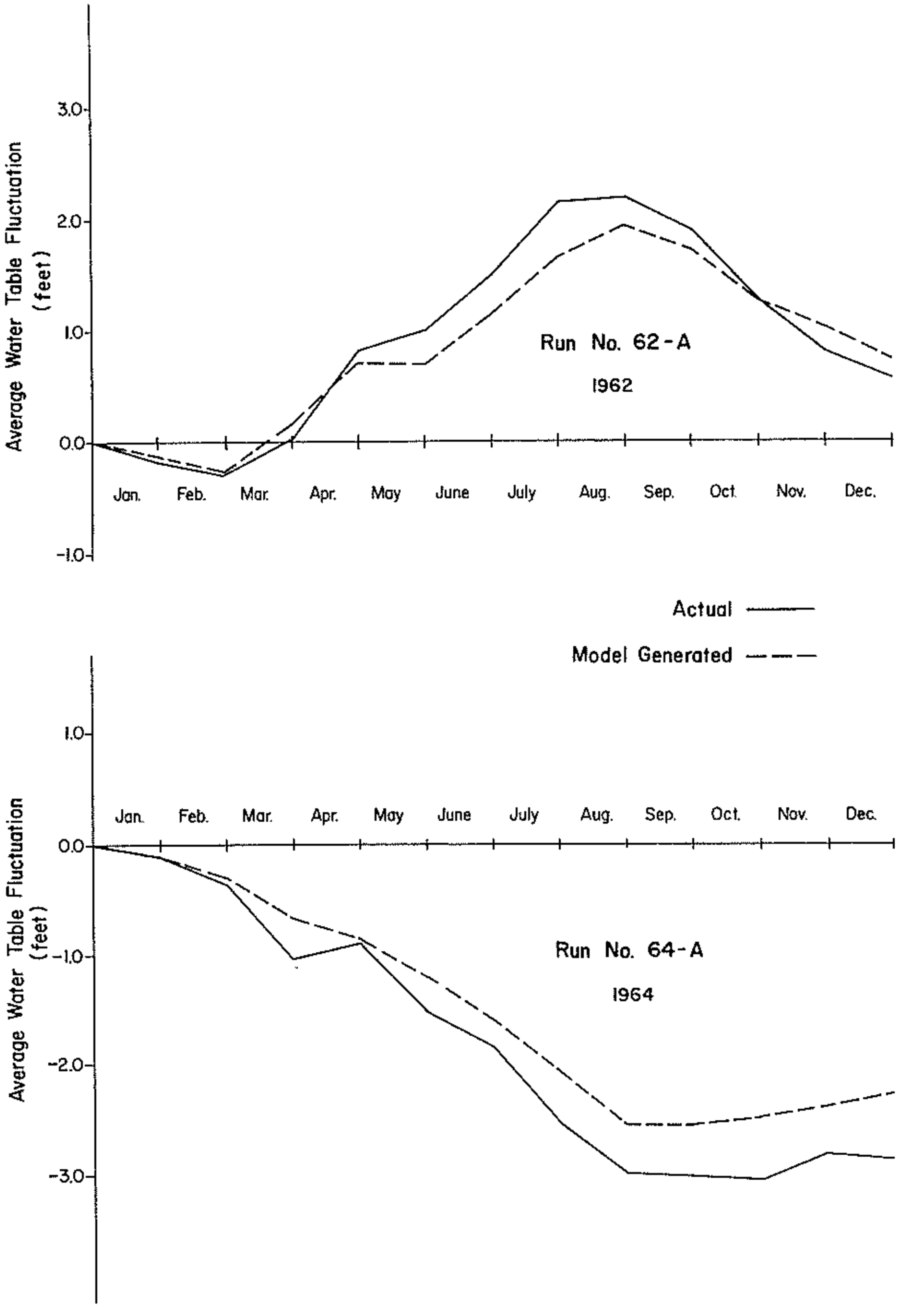

Figure 11. Storativity = 0.25

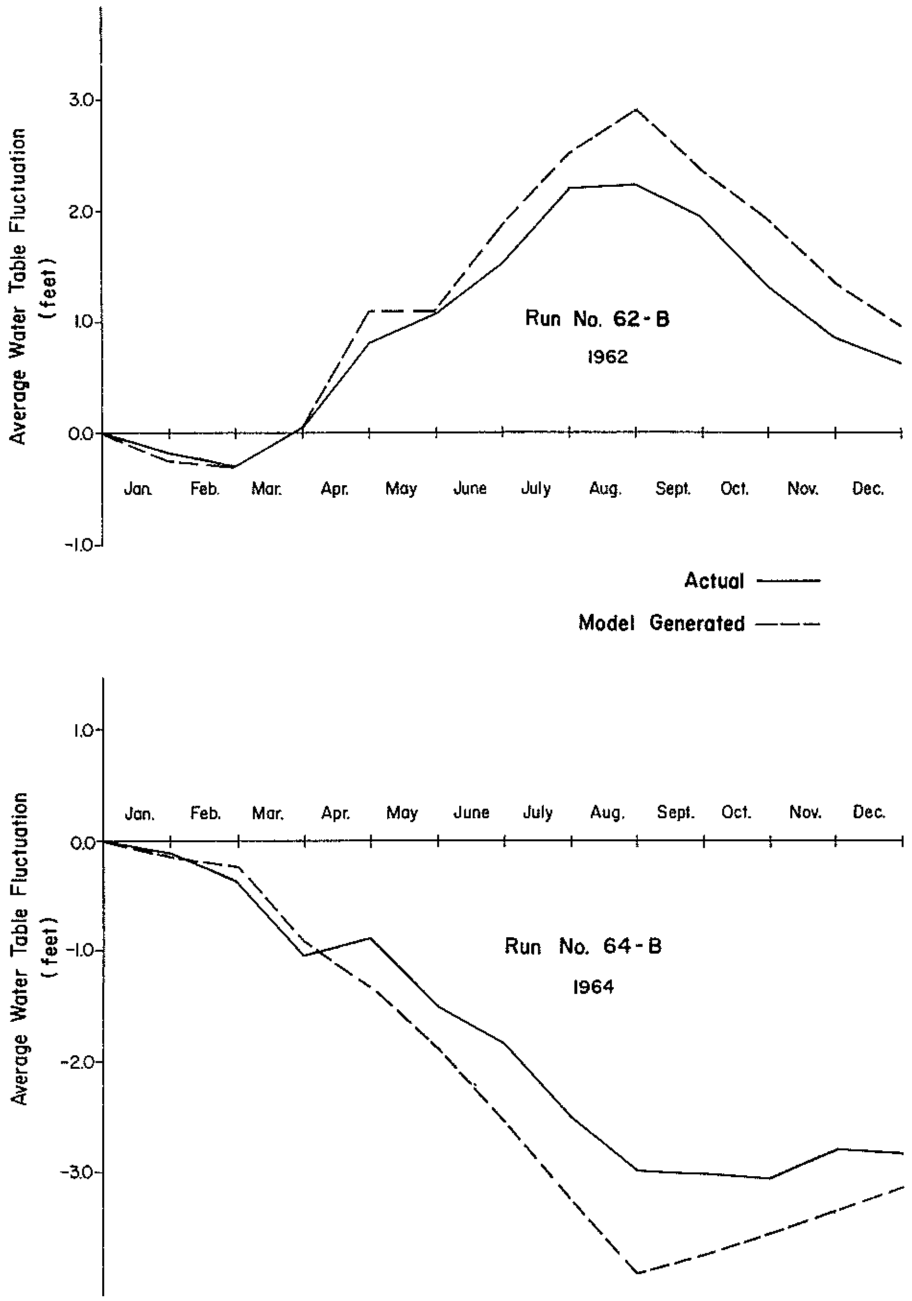

Figure **12.** Storativity = 0.15

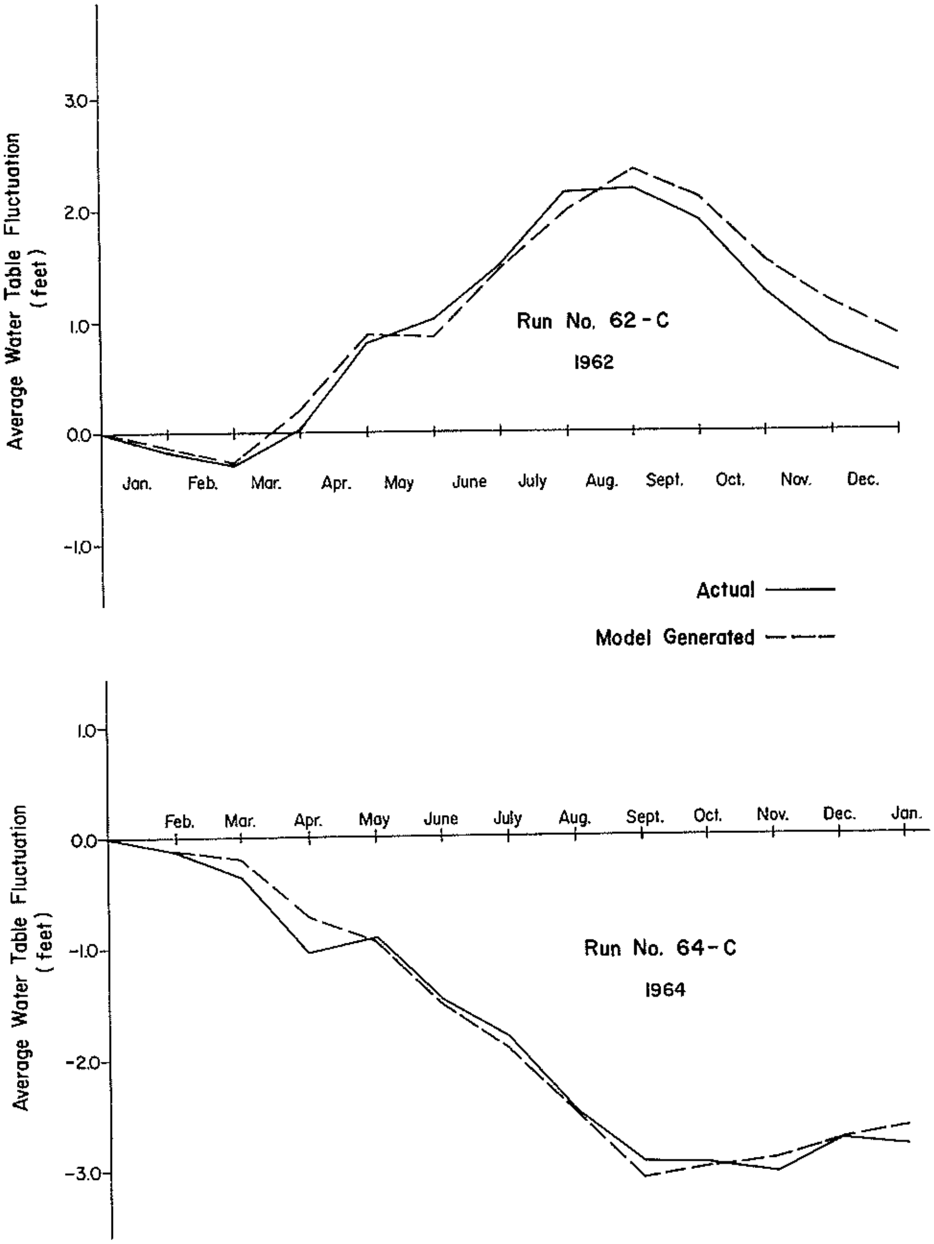

Figure 13. Storativity = 0.20

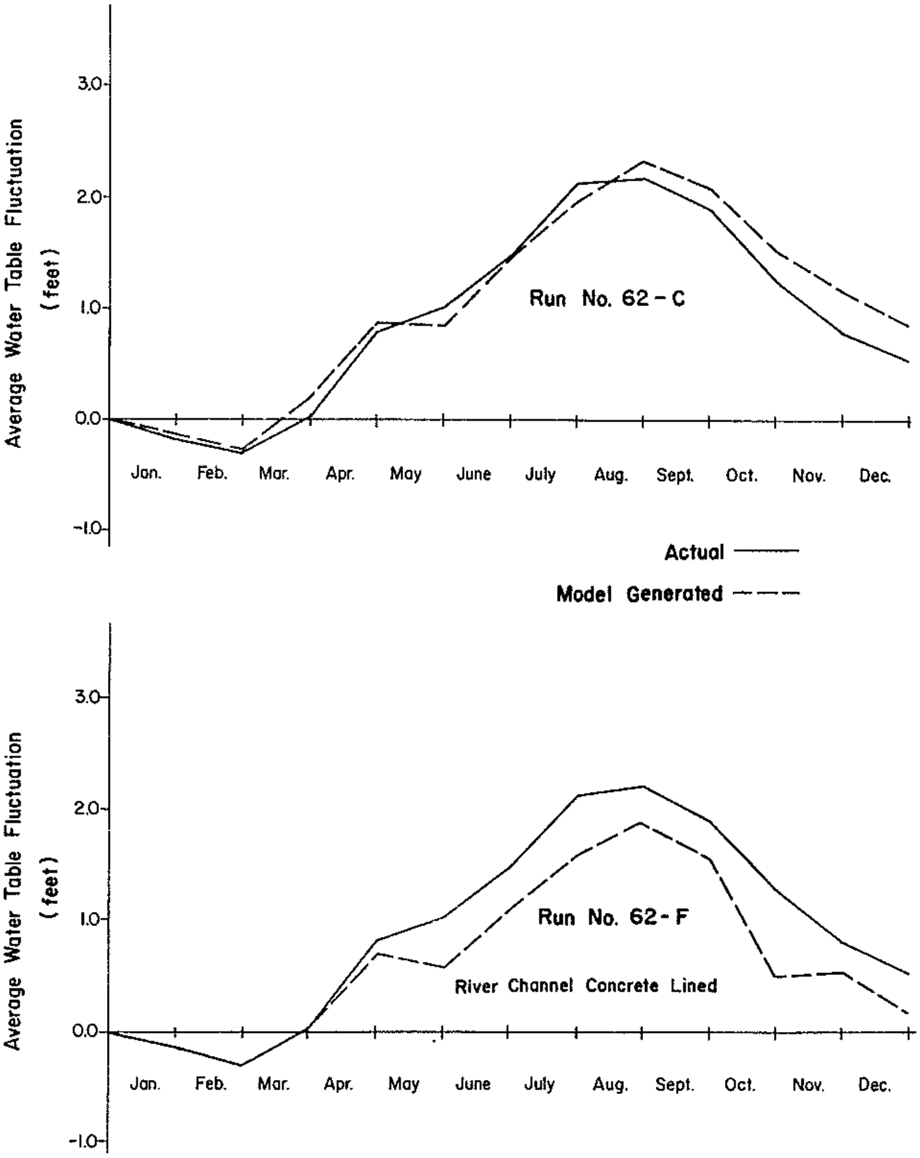

Figure 14. Sensitivity of Model to Changes in the Exchange Between the Rio Grande and the Shallow Aquifer

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