ELECTRICAL ANALOG MODEL OF THE ROSWELL BASIN - ITS USE IN HYDROLOGIC ANALYSIS

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PURPOSE OF THE ANALOG MODEL

Complex ground-water systems, such as the Roswell basin, can best be studied by scaling down the system and looking at it in miniature on a reduced time scale and simulating certain stresses, such as those induced by pumping. These stresses will immediately effect the analog model in a manner that would take many years under natural conditions in the basin. This can be done because an electrical analog model of a ground-water system reacts to changes in the flow of electricity in the same way that a ground-water system reacts to changes in the flow of groundwater. An analysis of the data obtained from an electrical analog model of a ground-water system permits hydrologists to predict the effect of increasing or decreasing pumping and recharge, changes in pumping pattern, and many other factors important to the life and yield of a ground-water system.

DATA USED IN CONSTRUCTING AND PROGRAMMING THE ANALOG MODEL

The most important data used in constructing an electric analog model of a ground-water system are the geological features that limit or bound the ground-water reservoir or reservoirs and the water-transmitting and water-retarding formations in the ground-water system. Several ground-water boundaries and three hydrologic units were modeled into the electric analog of the Roswell basin. The main aquifer is the San Andres Limestone and it is called the "artesian aquifer" Figure 1.

The western boundary of the Roswell basin is where the San Andres becomes an aquifer. This boundary is marked by a rapid decrease in the ground-water gradient and this occurs where the water table in the Glorieta Sandstone and older rocks intersect the base of the San Andres Limestone, Figure 2. Groundwater moves into the permeable limestone from the underlying and less permeable formations because of regional eastward dip of the geologic formations and the slope of the water table. An eastern boundary of groundwater movement in the San Andres lies parallel to, and about 5 miles east of, the Pecos River, Figure 2. The position of this boundary can only be inferred on the basis that oil tests drilled into the San Andres

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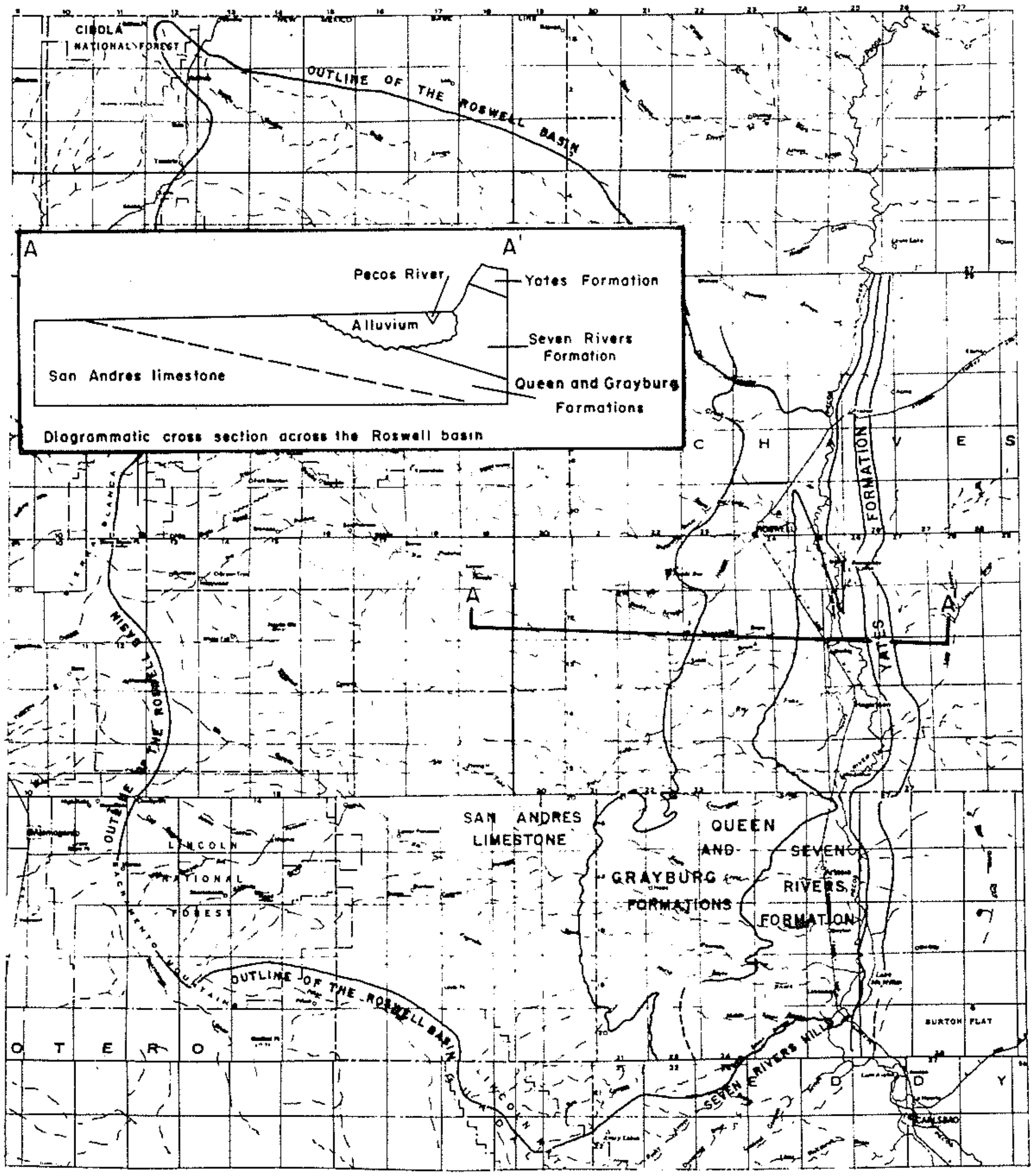

Figure 1.--Subcrops of geologic formations in the Roswell basin.

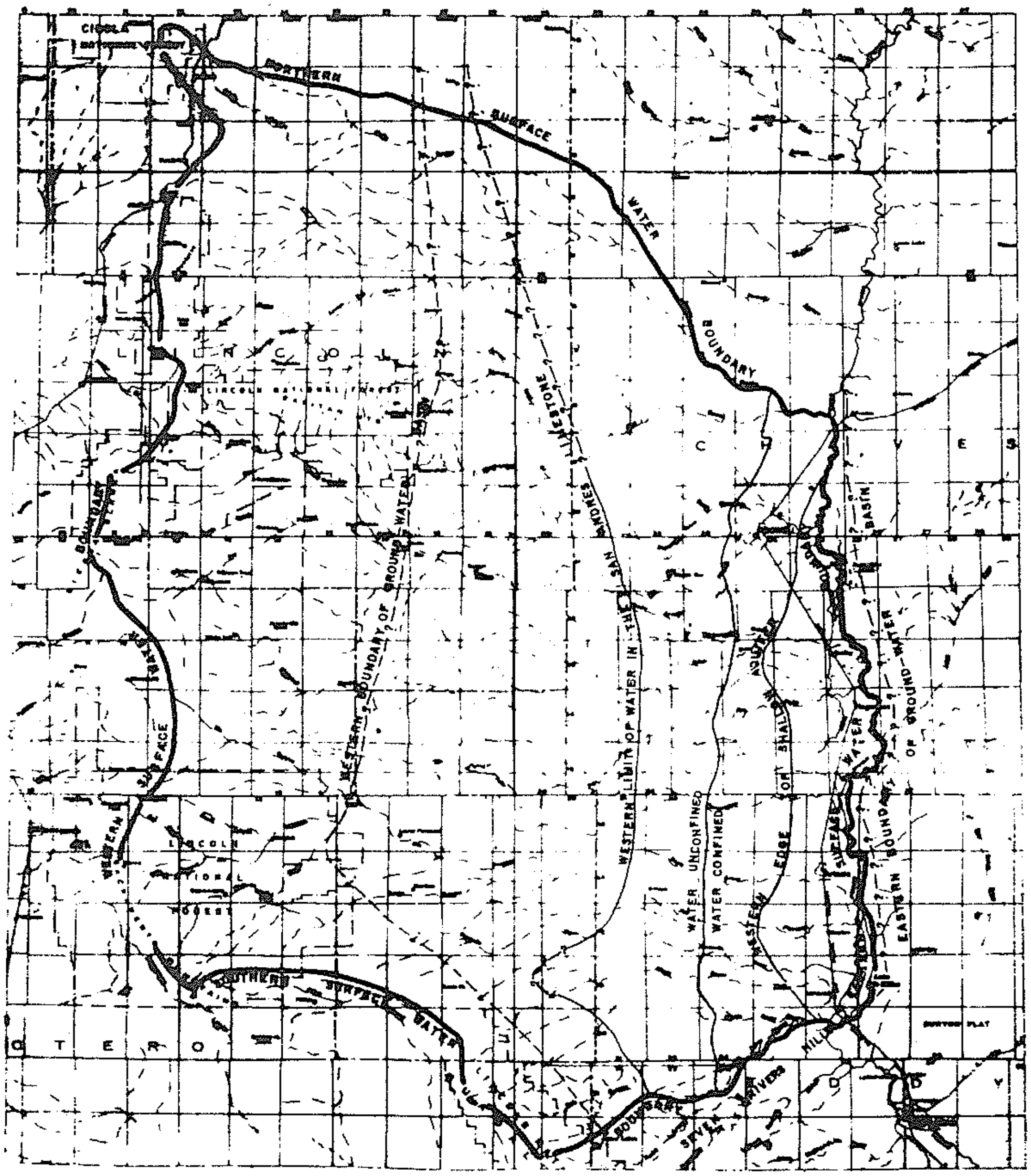

Figure 2.--Ground-water boundaries in the Roswell basin.

several miles east of the Pecos River do not encounter the large flows of groundwater as do wells drilled closer to the river. The presence of such a boundary does not mean that small amounts of water may not continue to flow eastward beyond the boundary; however, in the analog model the boundary has been designated as impermeable, that is, no water will flow eastward beyond this line.

The southern ground-water boundary of the basin is quite complex because the San Andres becomes less permeable and ceases to be an aquifer towards the southern surface-water boundary north of the Seven Rivers Hills, Figure 2. The northern ground-water boundary of the basin is very indefinite and in the analog model was considered as being at an infinite distance from the basin.

The Seven Rivers Formation and alluvium which was deposited by the Pecos River constitute the "shallow aquifer." Its western and northern boundaries are at its interception with the top of the underlying geologic formation, due to regional geologic dip and water-table gradient. Its eastern boundary is the Pecos River, and its southern boundary is the Seven Rivers Hills, Figures 1 and 2.

The Grayburg and Queen Formations lie between the shallow and artesian aquifers, Figure 1. These units are relatively impermeable compared to the San Andres Limestone and tend to confine the groundwater in the San Andres Limestone. Over a large area, however, considerable water can move between the shallow aquifer and the San Andres Limestone depending on the head difference between the two principal aquifers.

Figure 2 shows a boundary where groundwater in the San Andres becomes confined or artesian. West of the boundary, groundwater in the San Andres is unconfined or non-artesian. This boundary moves laterally with time, owing to fluctuating water levels. Its position as shown in Figure 2 is based on water levels measured in 1964 and in the boundary used in the electric analog model.

Hydrologic constants of the ground-water system must be incorporated into the analog model in order to determine the effects of stressing the system. In the Roswell basin, specific capacities of wells, or the yields of wells in gallons per minute per foot of water-level drawdown caused by pumping, were used to determine changes in the property of the artesian aquifer to transmit water, Figure 3. These specific capacities, and other data from a few pumping tests, were used to determine a value -- referred to as the coefficient of transmissibility. The various coefficients were then assigned to the aquifer at the proper geographic locations. In the analog model of the aquifer these various coefficients were simulated by various size resistors that control the flow of electricity in the same manner that transmissibility controls the flow of groundwater.

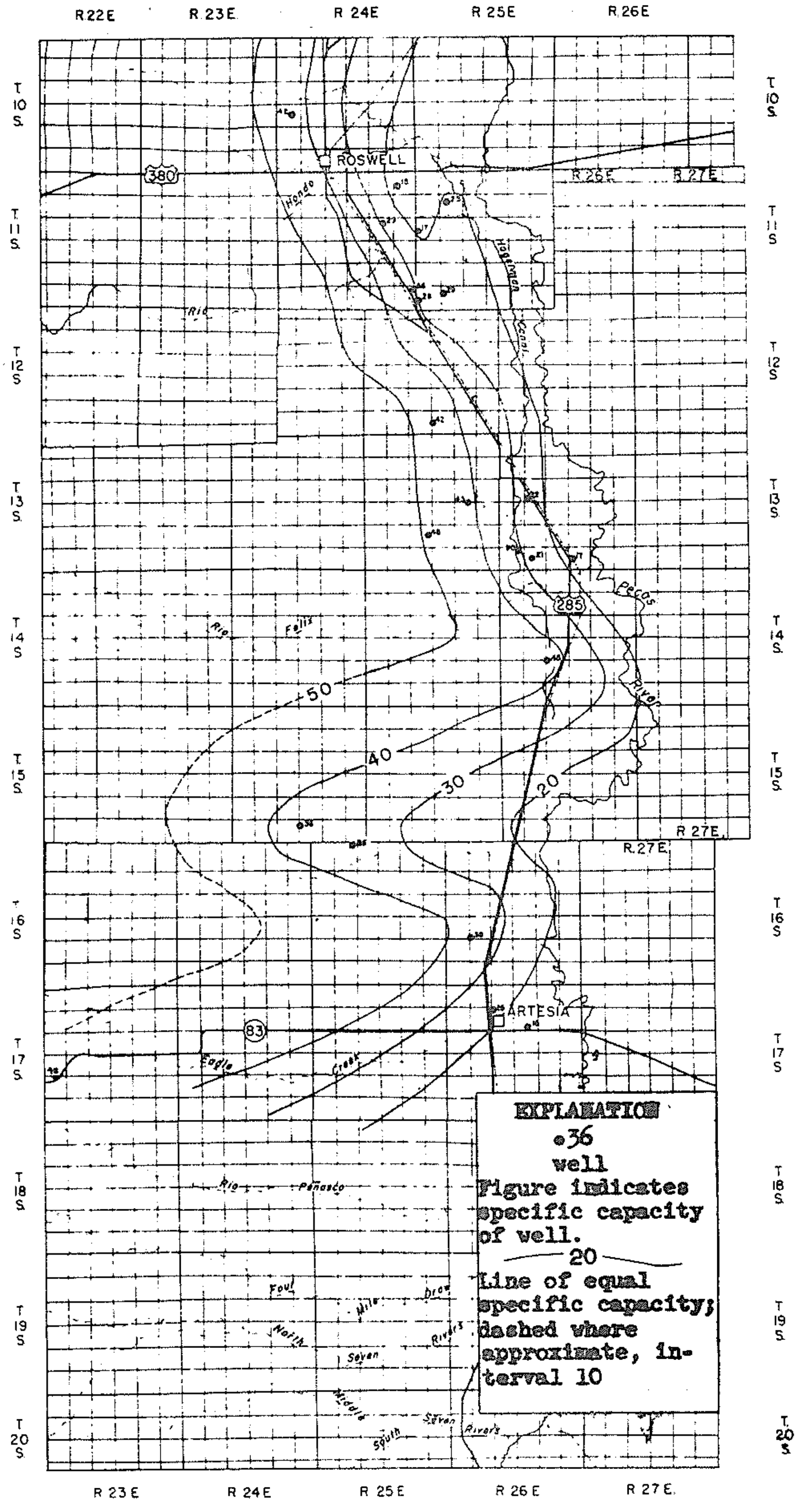

Figure 3.--Specific capacity of wells in the artesian aquifer in the Roswell basin.

The artesian aquifer was assigned a coefficient that indicated its property to take in or release groundwater -- referred to as the coefficient of storage. This feature of the aquifer, the capacity to take in or release water, was simulated in the analog model by using electrical capacitors that store electricity. Different size capacitors were used to indicate changes in the coefficient of storage.

The shallow aquifer was considered to be heterogeneous and to have no definite changes in either its property to transmit water or to store water. Consequently, only one size resistor and one size capacitor were used to represent coefficients of transmissibility and storage in the shallow aquifer. The confining units (Grayburg and Queen Formations) were considered to be heterogeneous; therefore, it too could be modeled using only a single coefficient of transmissibility, which was smaller than those used for either the shallow or artesian aquifers, and a single coefficient of storage, which was larger than those used for either the shallow or artesian aquifers.

A model must be programmed with accurate historic water-level changes in order to predict properly the future water-level fluctuations as a result of pumping or recharge. For the analog model of the Roswell basin, a hydrograph (graph showing water-level fluctuations) was used to determine changes in water levels in the artesian aquifer prior to 1964, Figure 4. Data collected by Fiedler and Nye (1933) in 1926 were used as a base point for determining later water-level changes in the artesian aquifer. It was assumed for the purpose of modeling that the artesian aquifer was in equilibrium in 1926 and that recharge equalied discharge. Water-level changes in the artesian aquifer between 1926 and 1964 were contoured, Figure 5.

Groundwater in the shallow aquifer generally was not developed before the New Mexico State Engineer closed the artesian aquifer to further development in 1933. The best and earliest data available for the shallow aquifer are given by Morgan (1938). Water-level changes in the shallow aquifer were contoured for the period 1938 to 1964, Figure 6.

Groundwater withdrawal by pumpage was computed for each year between 1926 and 1964 for the artesian aquifer and between 1938 and 1964 for the shallow aquifer, Figure 7. In addition, the base flow or the volume of water gained by the Pecos River between Acme and Artesia from 1938 through 1963 was considered to be discharge from the shallow aquifer, Figure 7. River-flow data were taken from a basic data report (Pecos River Commission, 1960) and additional data were obtained through verbal communication with Carl L. Slingerland, a member of the committee.

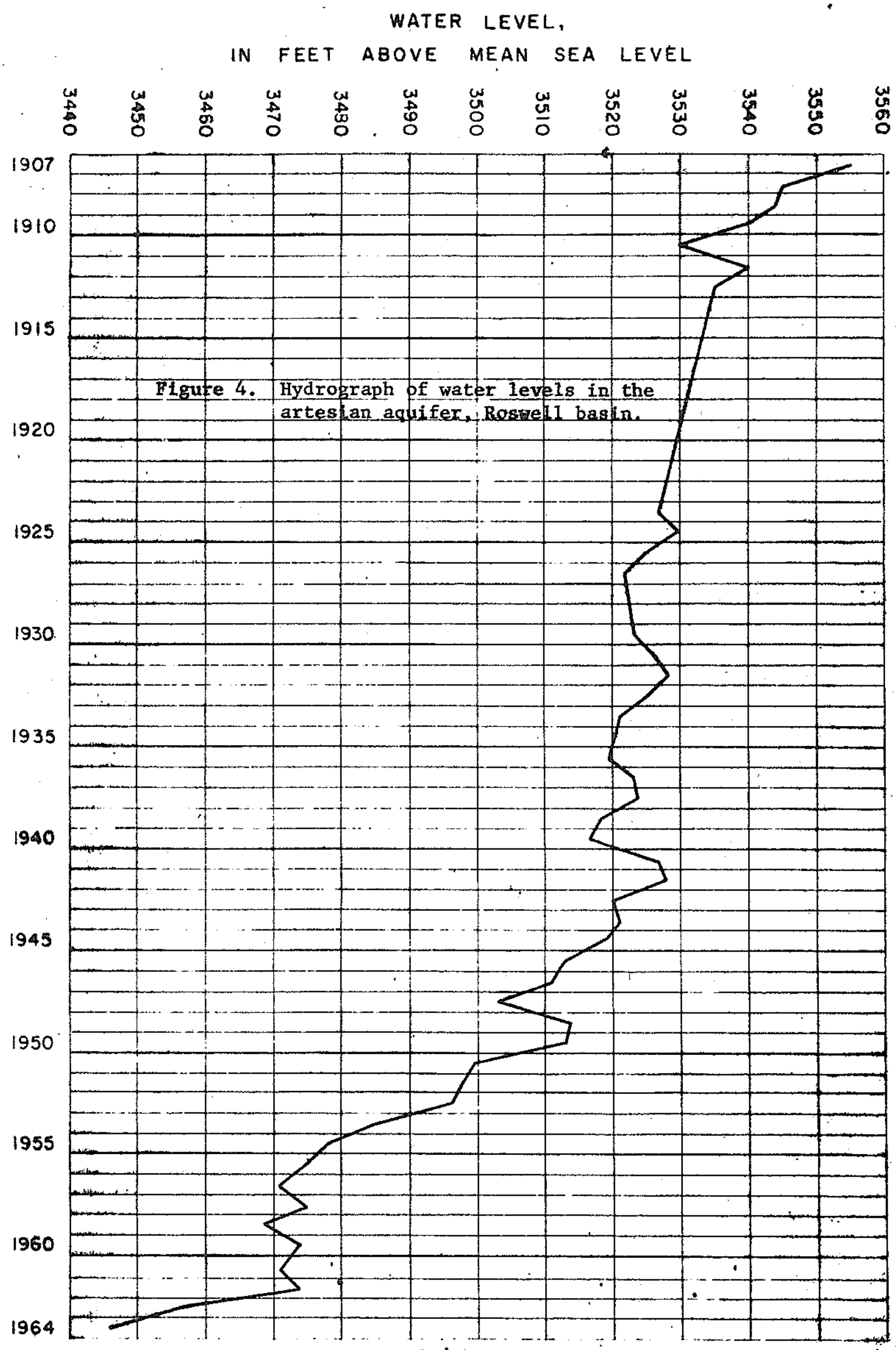

Figure 4. Hydrograph of water levels in the artesian aquifer, Roswell basin.

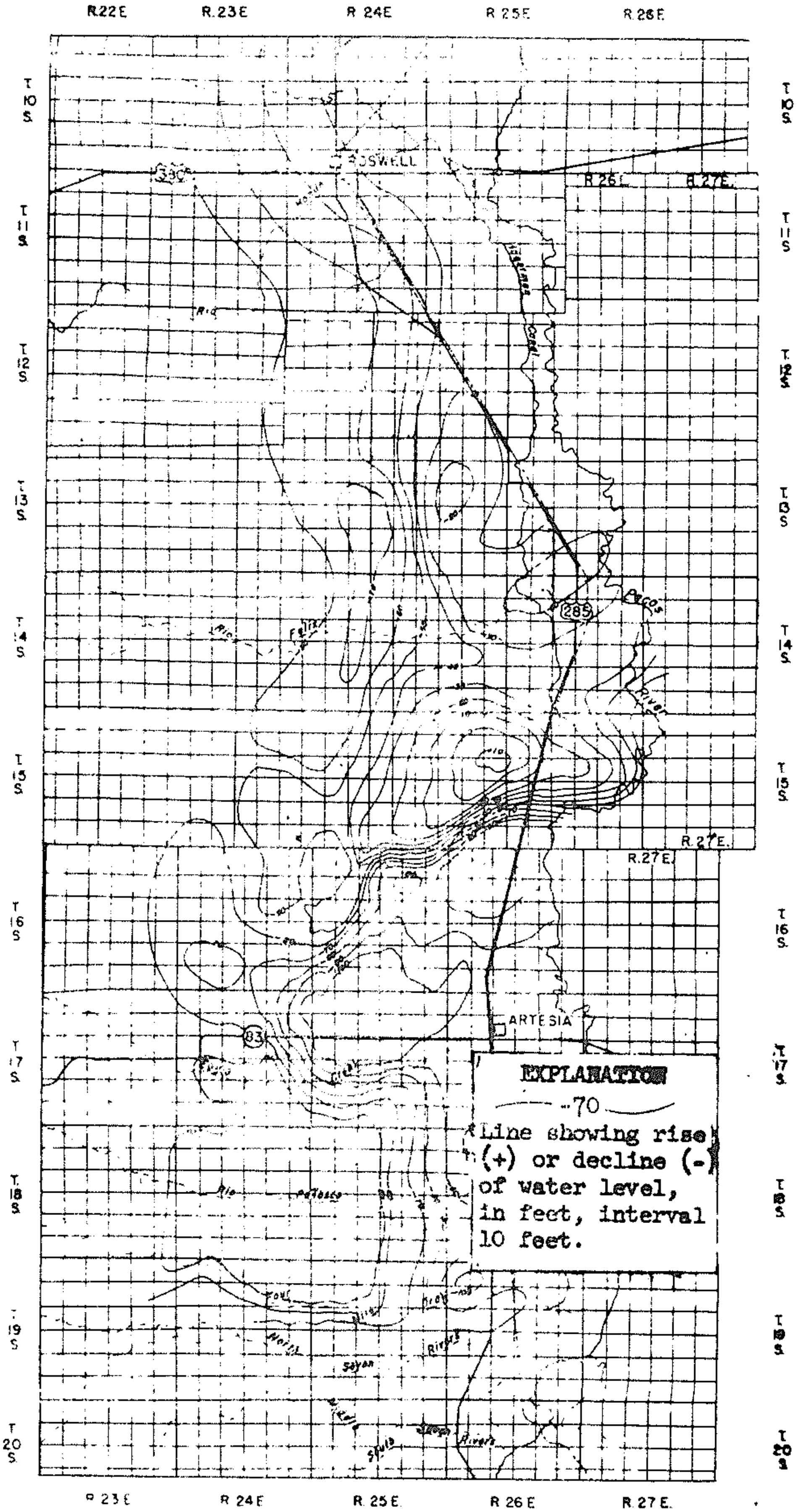

Figure 5.--Change of ground-water level in the artesian aquifer from 1926 to 1964 in the Roswell basin.

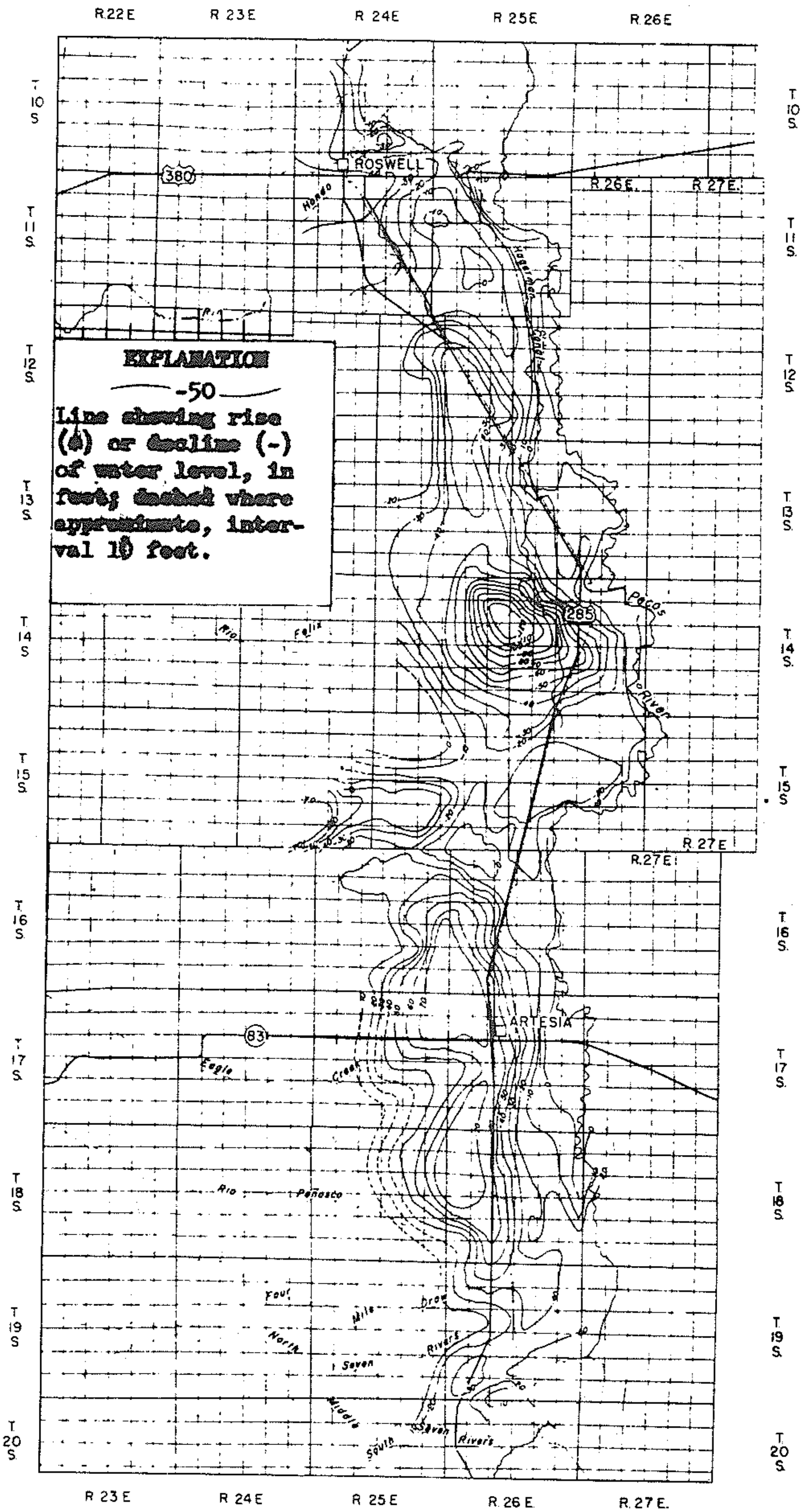

Figure 6.--Change of ground-water level in the shallow aquifer from 1958 to 1964 in the Roswell basin.

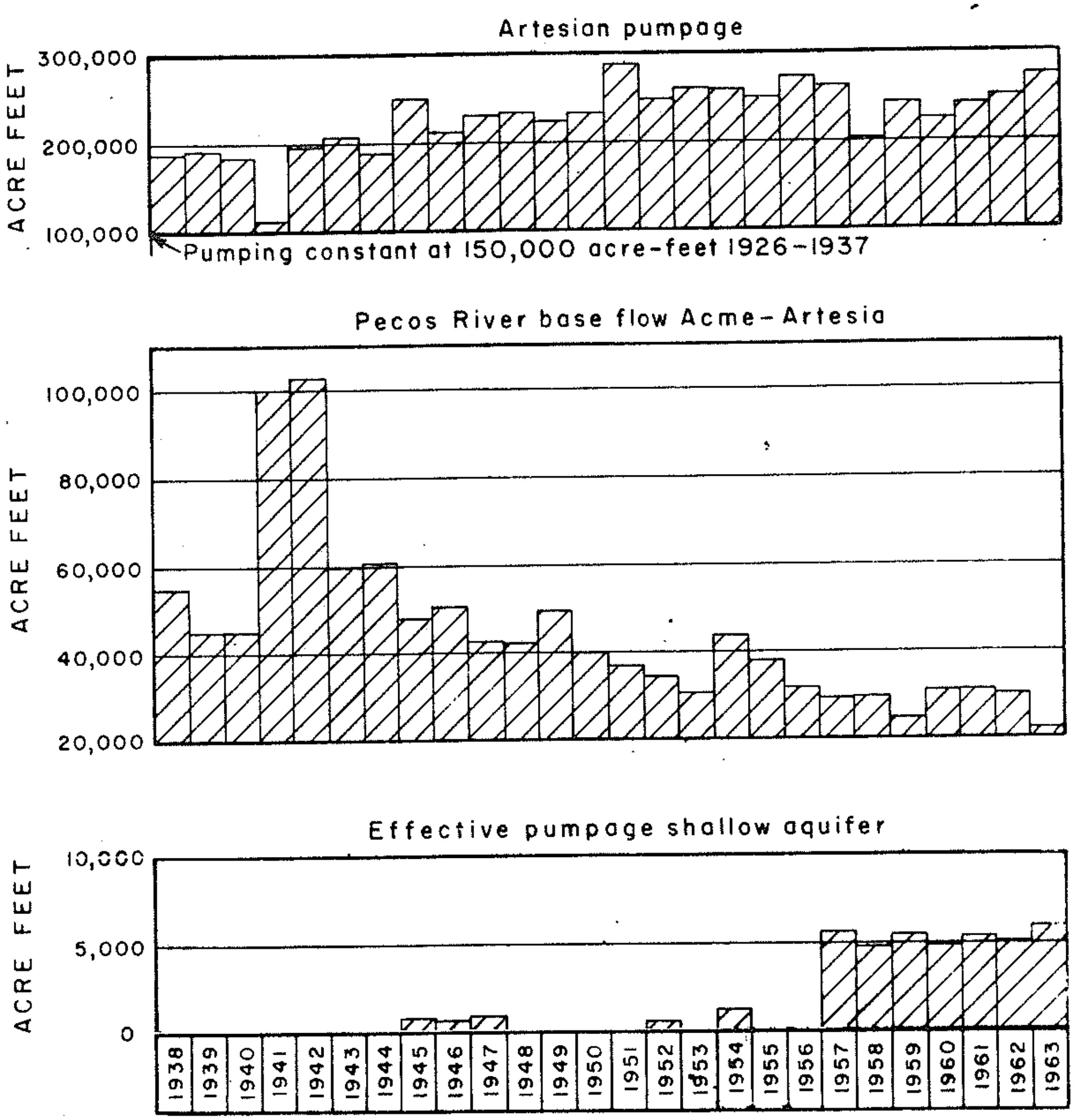

Figure 7.--Graph showing base flow of the Pecos River and ground-water pumpage from the shallow and artesian aquifers that were programmed into the analog model of the Roswell basin.

Owing to the great number of pumping wells in the basin, pumping centers representing the pumpage of surrounding wells were established for each aquifer, Figure 8. The pumping centers were located near major cones of depression in the water surfaces of the appropriate aquifers, and each center represents a percentage of the total groundwater discharged from the appropriate aquifer. The percentage of the total ground-water discharge was based on the calculated volume of groundwater pumped from each township. The volumes were calculated first by Mower (1960 and then through 1963 as part of this study. Pumpage programmed into the shallow and artesian aquifers in the model is shown in Figure 7.

Return flow from irrigation was assumed to recharge only the shallow aquifer. To account for this volume of recharge, shallow groundwater pumpage for any given year was reduced, first by a volume equal to 40 percent of the artesian pumpage for that year, and second by a volume equal to 40 percent of the gross shallow ground-water pumpage for that year.

Total annual recharge to the artesian system was assumed to be 236,500 acre-feet, the volume calculated by Fiedler and Nye (1933). This volume best represents long-term natural recharge to the artesian aquifer.

Vertical leakage from the artesian to the shallow aquifer across the Grayburg-Queen Formations was modeled as 70,000 acre-feet of water per year, the volume calculated by Fiedler and Nye (1933). Comparison of hydrographs of shallow and artesian wells for the period of record indicate vertical leakage to the shallow aquifer probably decreased until 1948, when vertical leakage stopped. Leakage from the artesian aquifer has been modeled as an increasing input to the aquifer since 1948 which reached a maximum of 70,000 acre-feet per year in 1954.

Ground-water discharge by springs discharing from the artesian aquifer around Roswell and Major Johnson Springs at the southern end of the basin was modeled at 166,500 acre-feet per year between 1926 and 1933, when it was assumed that all spring flow stopped. Consequently, as of 1933, 166,500 acre-feet of water per year became an input to the artesian aquifer to account for cessation of flow by the springs.

INTERPRETING THE ANALOG MODEL

The pumping of wells is simulated in the electric analog model by withdrawing electricity from the pumping centers. The simulated decline in the ground-water level caused by the "pumping" of electricity is read on an oscilloscope that measures changes in voltages in the model. The decline in voltage in the model is analogous to

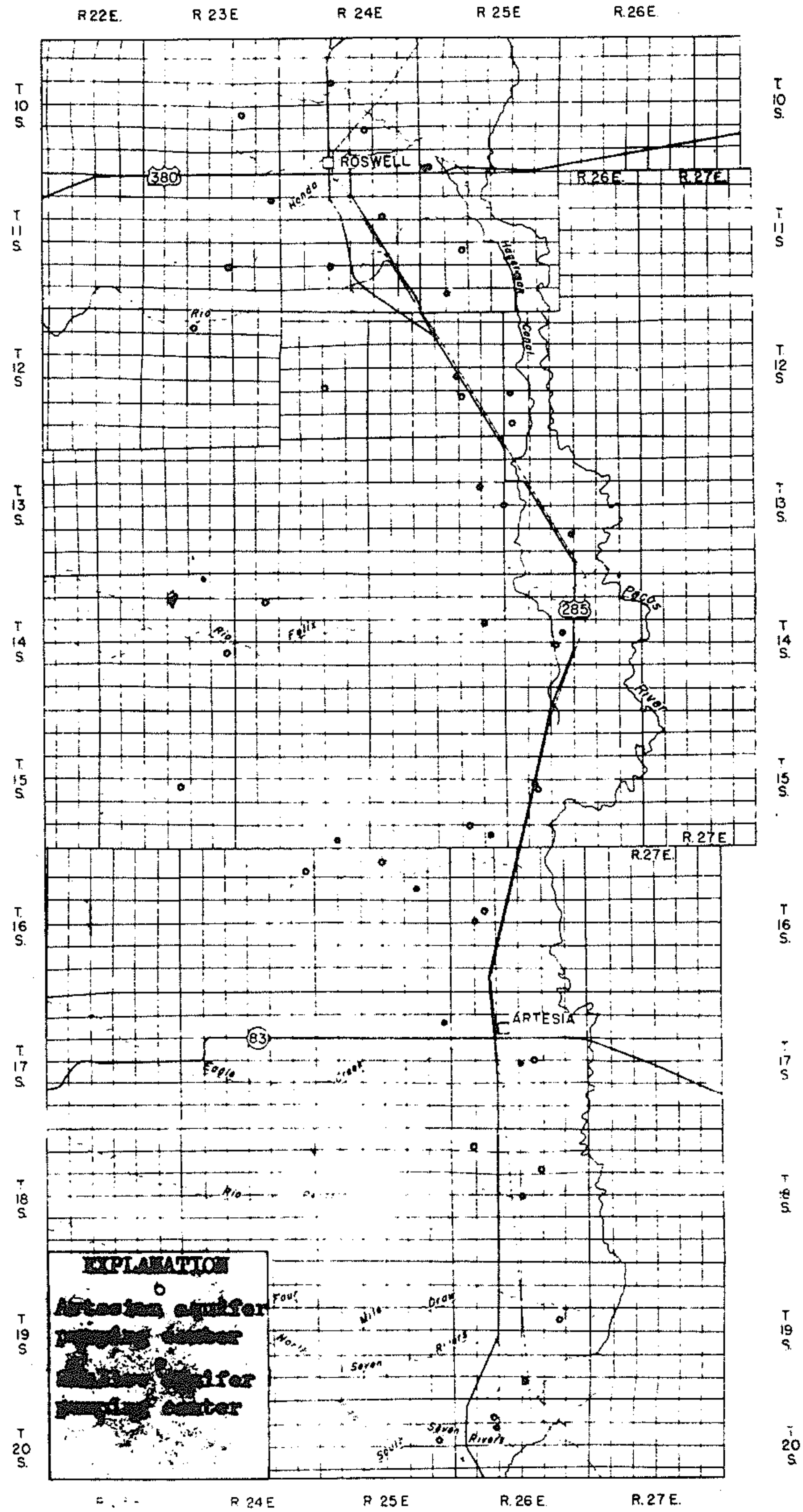

Figure 8.--Pumping centers for the shallow and artesian aquifers in the Roswell basin.

the decline in water level in the ground-water system. The oscilloscope has the scales of a graph on its screen so that feet of change of water level can be read directly for any unit of time desired.

The rates and patterns of past pumpage are programmed into the model by varying the electric current going into the model until it accurately reflects known historical data for the basin. Then various patterns and rates of pumping are also programmed into the model by varying the electric current going into and being taken out of the model. Water-level declines in the model are observed on the oscilloscope at random points and water-level decline maps are drawn. In this manner, the model can be manipulated to show quickly the long-term effects of pumping or recharging the aquifers throughout the Roswell basin.

REFERENCES

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