UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TEST-OBSERVATION WELL NEAR ODESSA, WASHINGTON: DESCRIPTION AND PRELIMINARY RESULTS

By

Kenneth L. Walters, D. R. Cline, and
J. E. Luzier

Prepared in cooperation with the
State of Washington Department of Ecology

OPEN-FILE REPORT
72-441

Tacoma, Washington
1972

CONTENTS

ILLUSTRATIONS

TEST-OBSERVATION WELL NEAR ODESSA, WASHINGTON: DESCRIPTION AND PRELIMINARY RESULTS

By Kenneth L. Walters, D. R. Cline, and J. E. Luzier

ABSTRACT

The test-observation well drilled near Odessa, Wash., provides information on the area's aquifer characteristics which is not otherwise available from existing deep irrigation wells. The information is of value to the State of Washington Department of Ecology in its management decisions in this area where heavy ground-water withdrawals have resulted in increasing annual water-level declines.

The 10-inch well is 750 feet deep and penetrates six aquifer zones (A through F) in basalt. The upper 60 feet of the well is cased, while the remainder of the hole is open in the basalt. The well was test pumped during drilling and showed specific capacities of (1) 0.65 gpm (gallon per minute) per foot of drawdown when at the 258-foot depth and open to aquifers A and B, (2) 0.62 gpm per foot of drawdown when at the 540-foot depth and open to aquifers A through D, and

(3) 22 gpm per foot of drawdown when at the full 750-foot depth and open to all six aquifers.

To supplement the driller's log of the well, borehole geophysical logging provided information on natural gamma radiation, water temperature and resistivity, downhole movement (via flowmeter) of the water, and borehole diameter (via caliper log). Upon completion of the well each aquifer zone was isolated from the others by cement seals, and piezometer pipes were installed to each zone to allow definition of the vertical hydraulic gradient and an estimate of the vertical ground-water movement in the area, along with chemical-quality sampling of the various zones and monitoring of any changes in water quality with time. The initial measurements of water levels showed that the levels generally decrease with aquifer depth, with about 200 feet of head difference existing between the uppermost and lowermost aquifer zones. Another pipe, installed for providing thermometer access, permits recording the geothermal gradient with depth in the well, and provides another basis for estimating vertical ground-water movement in the area.

Prior to isolation of the various aquifer zones, the composite water level was recovering from the cessation of pumping at the end of the 1970 irrigation season. On

April 6, 1971, this composite water level had begun declining, presumably as a result of pumping of an irrigation well 1 mile to the northwest. By May 6, after the aquifer zones had been isolated and piezometer pi s installed, water levels in aquifers E and F had declined 11 feet in 15 days, in response to pumping for irrigation in the area. Water levels in aquifers B, C, and D declined somewhat, but mostly in response to the draining of these aquifers to deeper aquifers down the many deep-well boreholes in the area.

INTRODUCTION

The test-observation well described in this report has been designed to yield key ground-water information for a highly productive agricultural area of the State in which essential water supplies are being depleted. The information already obtained from the construction and testing of this well, and data that are expected in the near future, are considered necessary to sound management of the ground-water resources of this area. Although much information previously was available for the area, partly from earlier studies by the U.S. Geological Survey in cooperation with the State of Washington Departments of Conservation and Water Resources, much of the information being derived from this test-observation well could not have been obtained in any other way. This study will amplify and extend our knowledge of this complex ground-water-flow system.

The work is part of a project for drilling, testing, and periodically collecting data from test-observation wells in selected areas of the State. These wells are being drilled where there is a critical need for ground-water data for water-management purposes and where the data cannot be obtained from existing wells or by other reasonable means. This project is part of a continuing cooperative program of water-resources investigations in Washington, and is financed jointly by the U.S. Geological Survey and the State of Washington Department of Ecology. The data from this well will facilitate another cooperative investigation--a current computer-modeling study of the ground-water-flow system in the Odessa area and of the relation between pumpage and decline of ground-water levels.

The locations of this and other test-observation wells being drilled under this project during fiscal year 1971 are shown in figure 1.

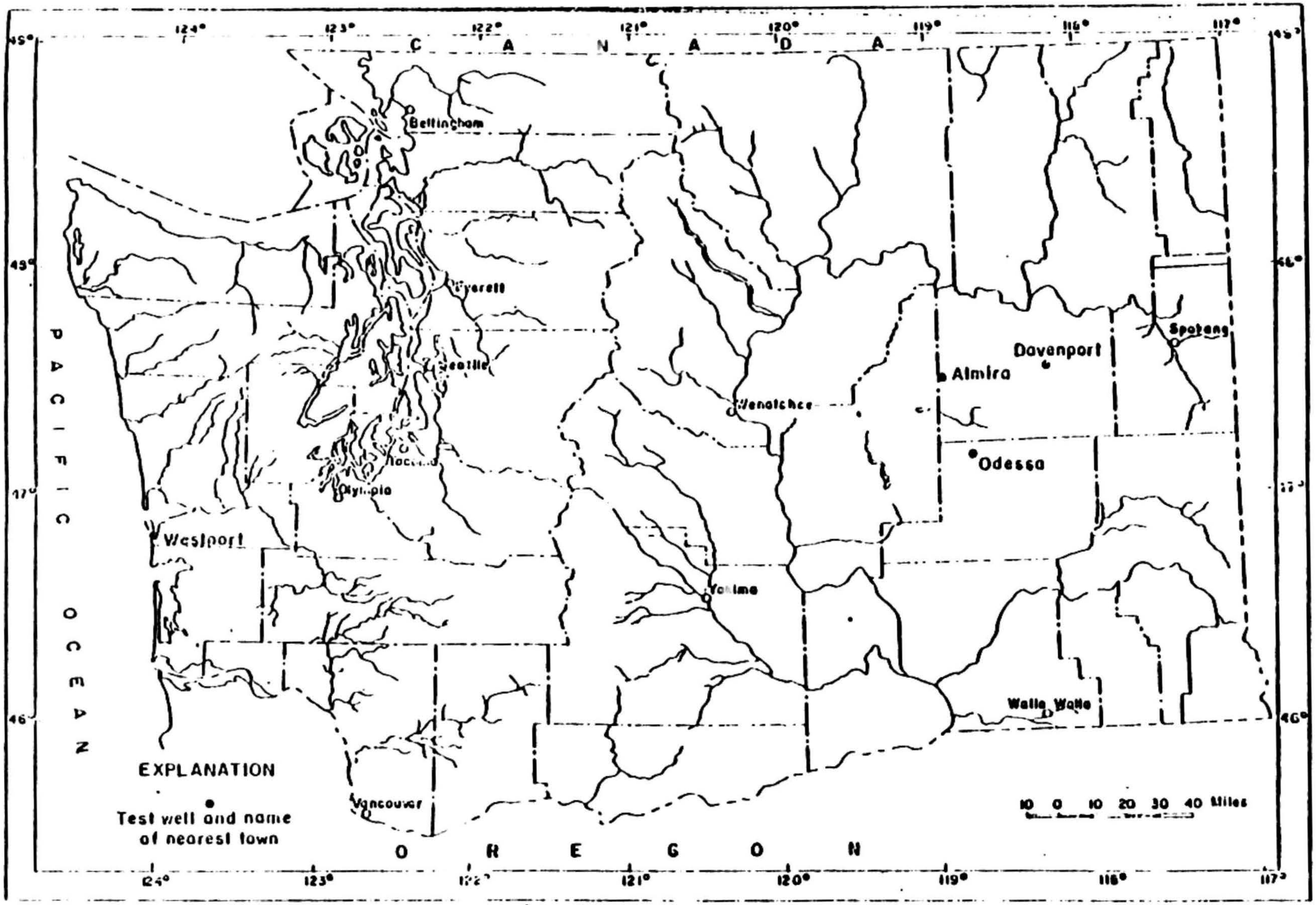


FIGURE 1.--Locations of test-observation wells in Washington.

BACKGROUND AND GROUND-WATER PROBLEMS OF THE AREA

Since about 1963, there has been a continuing increase in the use of ground water from basalt wells in the Odessa area, largely for irrigation of wheat and, in more recent years, beans, peas, potatoes, and sugar beets. Although irrigated acreage comprises only a moderate percentage of this region of predominantly dryland farming, small, localized areas of water-level decline and well interference were detected as early as 1964. The areas of water-level decline quickly enlarged and coalesced to involve about 700 square miles by March 1968, and more than 1,000 square miles (nearly all of the Odessa area as outlined in fig. 2) by March 1971. During this period, pumpage increased sharply from about 13,000 acre-feet in 1963 to more than 70,000 acre-feet in 1968; it leveled off to about 70,000 acre-feet in 1970.

Despite this leveling off in pumpage, water-level declines in the deep, heavily pumped basalt aquifers have continued to accelerate from a rate ranging from about 6 to 12 feet for the year, spring 1967 to spring 1968, to about 10 to 30 feet or more during the past year (1970-71). Nearly all irrigators in the Odessa area are paying higher power costs each year because of the continued decline in water level, and a

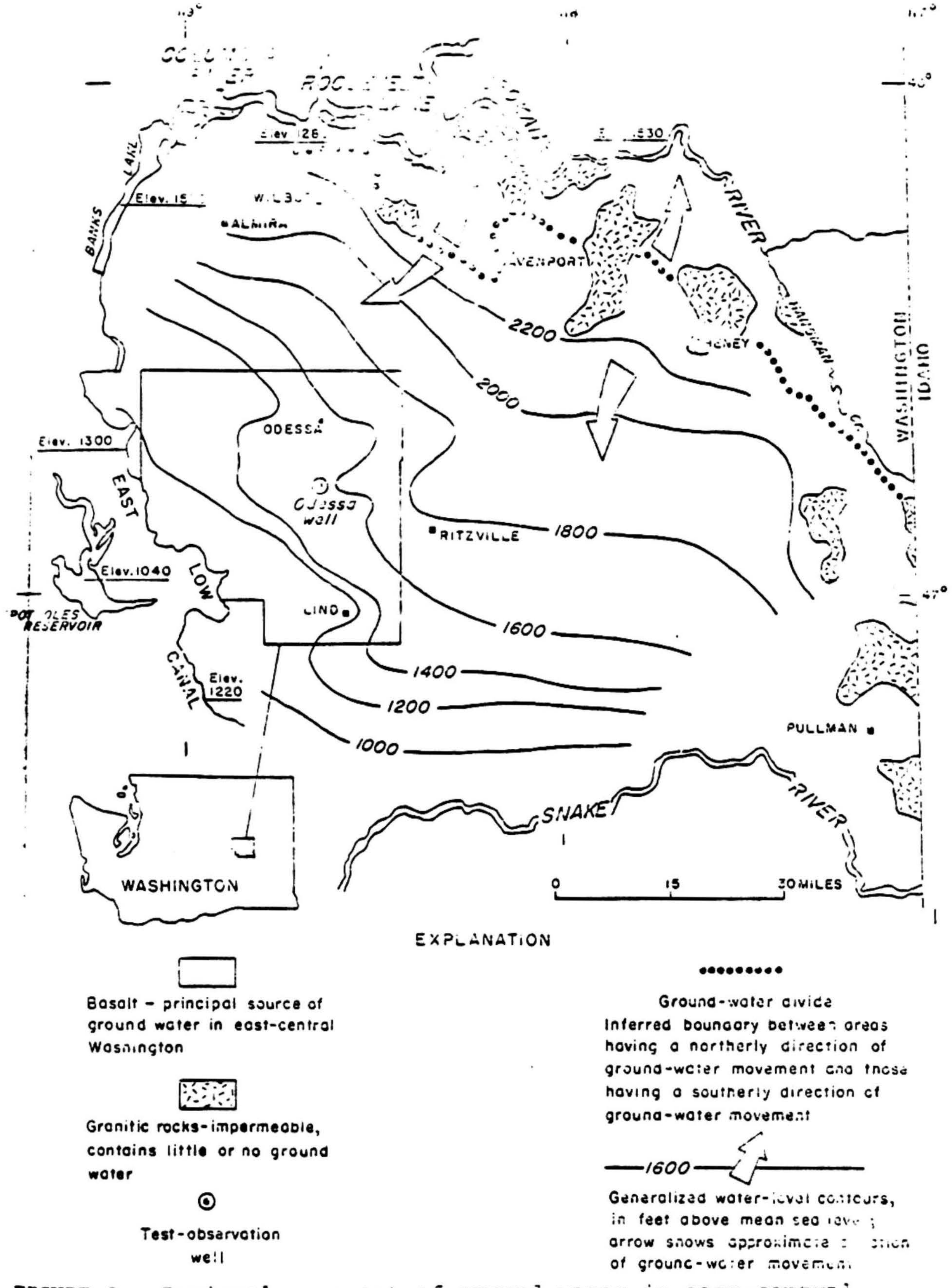


FIGURE 2.--Regional movement of ground water in east-central Washington and locations of Odessa area and test-observation well.

substantial percentage of the irrigators have been affected additionally by much higher costs for deepening and reaming wells, and lowering pump bowls.

Widespread declines of water levels also are occurring in shallower aquifers tapped by numerous domestic and stock wells, but at substantially lower annual rates of decline. Because these shallow wells normally do not have much water standing in them, an annual decline of only 1 or 2 feet may be sufficient to cause failure and much added expense to the owners. Many of these wells already have failed and numerous others are likely to fail in the future.

In basalt, most ground water occurs and moves in well-defined roughly horizontal fracture and rubble zones that mark the contacts between individual basalt flows. These water-bearing zones (aquifers) are separated from one another by the dense nearly impermeable central parts of the flows. Hydraulic heads in the individual aquifers, as reflected by water levels in wells that tap them, usually vary with depth. In much of east-central Washington the levels are highest in the shallow basalt wells and lowest in the deeper wells.

Borehole geophysical logs and other data show that the shallower aquifers are being drained almost continuously by the short-circuiting effect of many uncased deep wells. The deep wells simply act as open conduits in the basalt that interconnect an otherwise isolated series of aquifers, allowing downward flow of ground water to deeper aquifers having lower water levels. The short-circuiting effect is highly detrimental to upper aquifers, and appears to have only minor benefit as recharge to the deeper aquifers.

In general, the downward flow of ground water in deep wells, and the decreasing water levels with depth, result in an average, or composite, water level that may be very misleading in an evaluation for water-management purposes, of the relation between pumping and water-level declines in a given area. Without more detailed and sophisticated information it would be nearly impossible to make precise or quantitative evaluations so necessary for management of the area's ground-water resource. All deep wells available and used (of necessity) for observation in the Odessa and adjacent areas have such composite water levels. Clearly, in view of the very serious degree of ground-water depletion that is occurring in the Odessa area, properly constructed test-observation wells are essential to obtain the detailed information necessary for understanding of the subsurface flow system and an accurate determination and prediction of aquifer response.

INVESTIGATIONAL PROCEDURES

The Odessa well was drilled and tested during the period February 16–July 24, 1970 by the H. O. Meyer Drilling Co. of Kirkland, Wash. Because water levels in wells that are open to all aquifers penetrated are often ineffective or misleading for water-management purposes, all design decisions such as hole diameter, casing depth, and tested intervals were made to permit isolation and measurement of water levels in individual aquifers. The air-rotary drilling method was used throughout construction to provide a smooth, straight borehole for ease of installation of water-level-measuring equipment, in preference to mud-rotary drilling because of the latter's potential for plugging of aquifers by invasion by drilling mud. No casing or liner was installed, except in the upper 60 feet of the hole, although the interval from 60 to 100 feet was partly lined with cement.

The well was test pumped when it had reached depths of 258, 540, and 750 feet (final depth). After drilling had proceeded to the final depth, borehole logs of natural gamma radiation, fluid temperature, fluid resistivity, hole diameter (caliper), and fluid movement were obtained (fig. 4). These data and the driller's log were used in selection of the zones in which water levels were to be monitored.

For water-level measurements in various aquifer zones, pipes were suspended into the test hole, with short well screens opposite each aquifer to be monitored (fig. 3). The hole was then backfilled around the pipes with permeable gravel, with a cement plug being placed at the top and base of each monitored zone to isolate it. This allowed measurement of changes in water levels in six distinct aquifers with no influence through the borehole from one aquifer to another.

Natural vertical movement or leakage from one aquifer to another, through cracks and joint systems in the dense rock, may alter the pattern of natural heat flow outward through the earth, thereby causing a distortion in the observable geothermal gradient. By careful measurement of this distortion, the rate of vertical ground-water movement--and recharge of one aquifer by one higher or lower in the system--may be calculated with greater precision and at far less expense than by most other methods available. For this purpose, an access pipe (fig. 3) was installed to accommodate a temperature-sensitive measuring device.

The well was drilled on State school land that is under the jurisdiction of the Washington State Department of Natural Resources. The Washington State Department of Ecology and the U.S. Geological Survey have perpetual access to the well for the purposes of observation and testing.

RESULTS OF THE WORK

Description of the Well

The Odessa test well is 10 inches in diameter to a depth of 704 feet and 8½ inches from 704 to 750 feet. The well, cased to 60 feet, penetrates various basalt layers, in which much of the rock was dense and hard, and several aquifers which proved to have very different hydrostatic heads. The difference in water levels after the aquifers were isolated was almost 200 feet (fig. 3). Depths to water during drilling of the well were as follows:

Date	Depth cased (ft)	Well depth (ft)	Depth to water (ft)
2-23-70	0	119	72
3- 2-70	60	119	80
3-13-70	60	258	95
3-25-70	[1/]253	357	97
4- 7-70	[1/]253	582	98
4-17-70	[1/]253	600	150
4-24-70	60	704	145
7-22-70	60	750	289
11-25-70	60	750	149

[1/] Temporary casing, subsequently withdrawn.

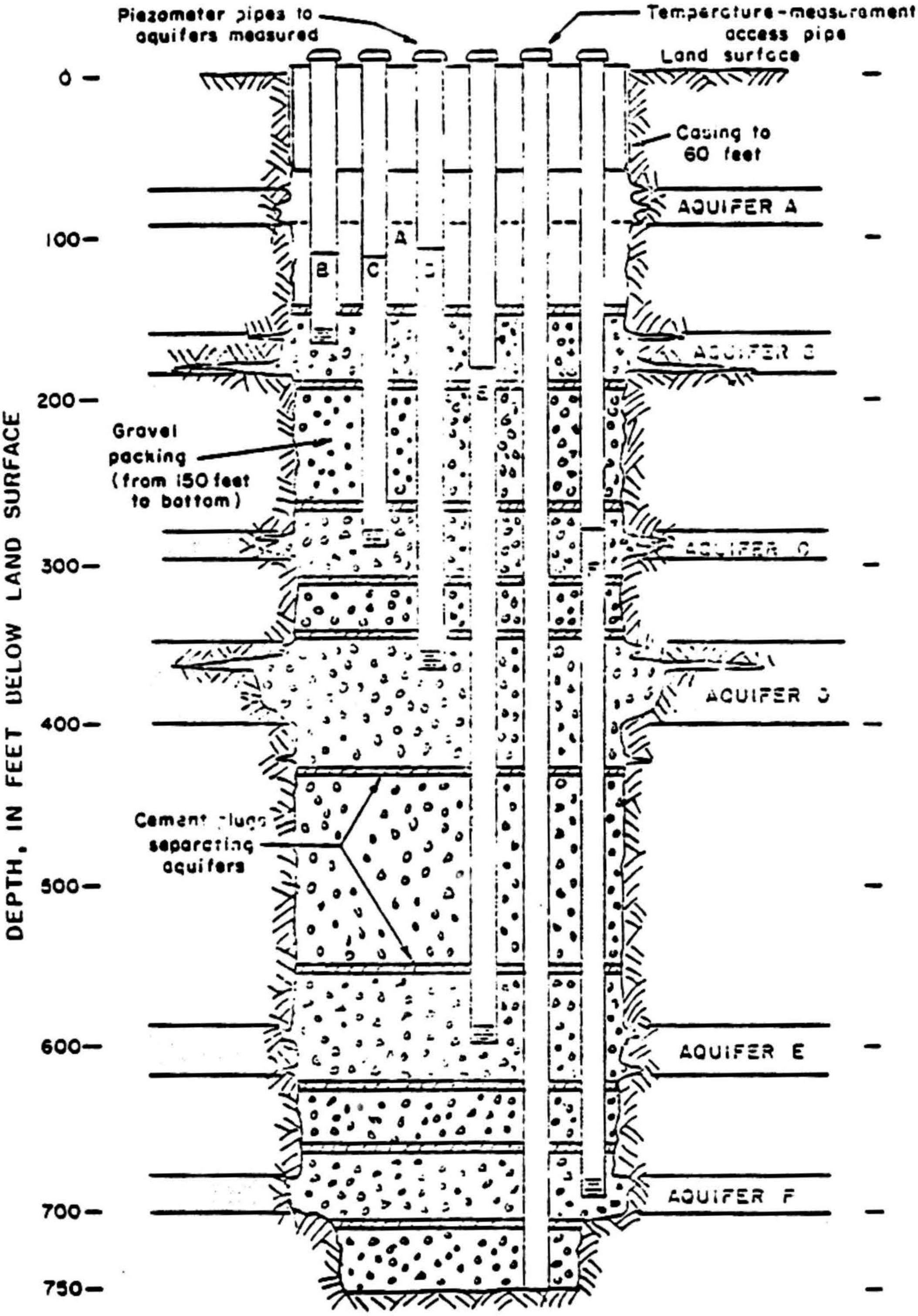


FIGURE 3.--Diagrammatic section through Odessa test well, showing temperature-measurement access pipe and five piezometer pipes, and aquifer zones measured.

The water level measured during July was much lower than the level either before or after, because of the pumping of irrigation wells in the area during the summer (fig. 6).

The individual water levels of the five deeper aquifers (B through F, fig. 3) in the test well are monitored by five piezometers--1¼-inch-diameter pipes with short well screens at their bottoms--set opposite these aquifers. The water level of the uppermost aquifer (A) is monitored directly through the open part of the well. A sixth pipe in the well extends to the bottom and is used to measure the thermal gradient in the well bore.

The six aquifers are summarized as follows:

Aquifer	Depth interval (ft)	Material
A	70-94	Basalt, creviced and broken
B	158-183	Clay, with some cindery basalt
C	282-299	Basalt, honeycombed, and clay
D	352-401	Basalt, soft and hard, honeycombed, and some clay
E	586-616	Basalt, soft and hard, and some sand
F	676-701	Basalt, soft

Results of Aquifer Test

When the well had been drilled to a depth of 258 feet, an aquifer test was conducted to determine the hydraulic character of aquifer B. At a pumping rate of about 85 gpm (gallons per minute) for about 4 hours, the water level was drawn down from 95 feet below land surface to 227 feet below land surface--a specific capacity of about 0.65 gallon per minute per foot of drawdown. While this test did not indicate the presence of large quantities of water for irrigation use, it did establish that sufficient quantities of water for domestic and stock use occur at fairly shallow depths. It also gave a measure of the amount of water that may be lost from shallow zones to deeper zones in unlined irrigation wells whose water levels are drawn down from prolonged pumping.

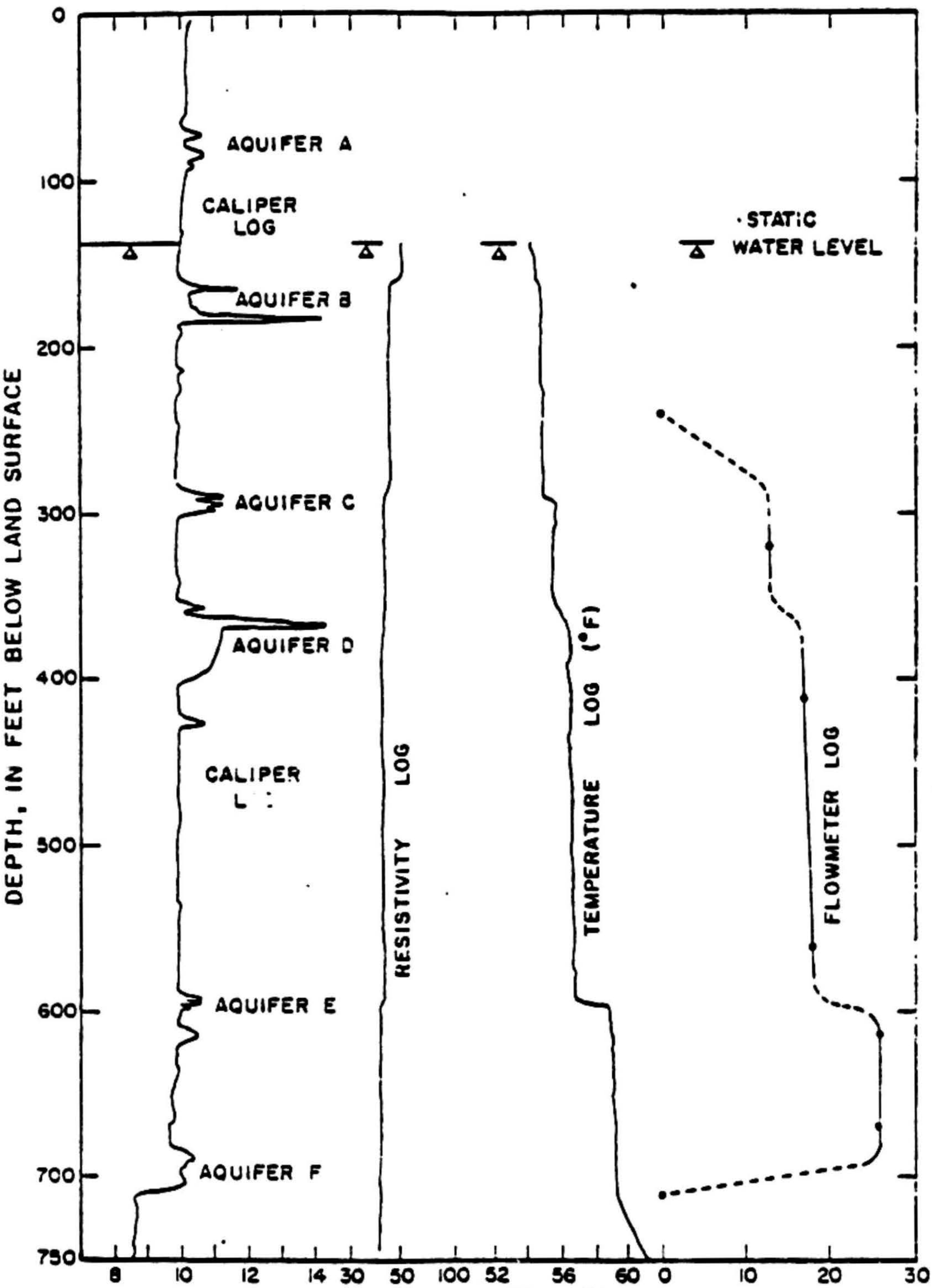
A second aquifer test was conducted when the well was at a depth of 540 feet. In this test, at a pumping rate of 200 gpm for 15 hours, the water level was drawn down from 102 to 425 feet below land surface. The specific-capacity value of about 0.62 indicates that aquifers C and D, penetrated between depths of 258 and 540 feet, contributed little additional water to the well.

In the final aquifer test, conducted with the well at the 750-foot depth and open to aquifers B through F, the water level was drawn down from 289 to 311 feet below land surface by pumping for 24 hours at a rate of about 485 gpm. The specific-capacity value of about 22 gallons per minute per foot of drawdown indicated that the main aquifers are in the lower part of the well. This conclusion was verified and refined by the borehole geophysical data.

Geophysical Logs

Borehole geophysical logs were run at various times during the period of drilling to help define the location of aquifers and select intervals for testing. The full depth of the well was first logged in February 1971, and provided data on hole diameter, water resistivity, water temperature, and vertical ground-water flow (flowmeter); these are illustrated in figure 4. (One other log made at the time and not included in the figure was natural gamma radiation.) These logs served as the primary basis for final design and selection of aquifers to be monitored.

The aquifers can be identified readily in figure 4 by (1) hole enlargements that occur in the loose and fractured basalt at the aquifer face, (2) changes in water temperature



1/ Dashed part of curve is inferred.

FIGURE 4.--Borehole geophysical logs of Odessa test-observation well, February 5, 1971.

and resistivity (degree of mineralization) near the aquifer face, and (3) increases in the amount of water flowing down the well bore near each aquifer face. Aquifers A and B did contribute to the downhole flow, but not enough to measure with the flowmeter. At the time of logging the amount of water flowing down the well bore from the upper aquifers (A, B, C, and D) was estimated to be about 80 gpm; at aquifer E, the downhole flow increased by about 40 gpm, bringing the total flow entering the bottom aquifer to about 120 gpm. Below that aquifer, the well bore penetrates only dense basalt in which the water column is stagnant and shows gradual warming with depth, in response to increasing rock temperature. The downhole flow clearly demonstrates the widespread short-circuiting effect of deep wells, as mentioned previously. Although these rates of downhole flow probably have a large variation during the year, continuous rates of flow at 80 to 120 gpm are equivalent to about 130 to 200 acre-feet per year.

Quality of Ground Water

Water samples for chemical analysis could not be collected from individual aquifers during drilling of the well. However, the quality of water from shallow basalt aquifers, and mixing of water from shallow and deep aquifers, are well known from sampling of other wells in the area. If necessary, water samples can be collected from the isolated aquifers by means of the piezometer pipes, and their analyses can be compared to determine the difference in chemical quality of ground water with depth and to note any changes in quality that may occur over a long period of time.

Short-Term Water-Level Changes

Before the piezometers were installed in the Odessa test-observation well the composite water level was recovering from the cessation of irrigation pumping during the summer of 1970 (fig. 5). On April 6, 1971, an irrigation well 1 mile to the northwest (fig. 6) was turned on and the composite water level in the Odessa test well began declining. Other irrigation wells in the area started pumping about this time also. By means of the piezometers installed opposite individual aquifers, the different water levels could be measured (fig. 5). As of May 6 the water level in the outer casing, representing the uppermost aquifer (A) apparently had not yet adjusted to changes caused by the plugging operations and isolation of the various aquifers. However, the water levels in the piezometers representing the other

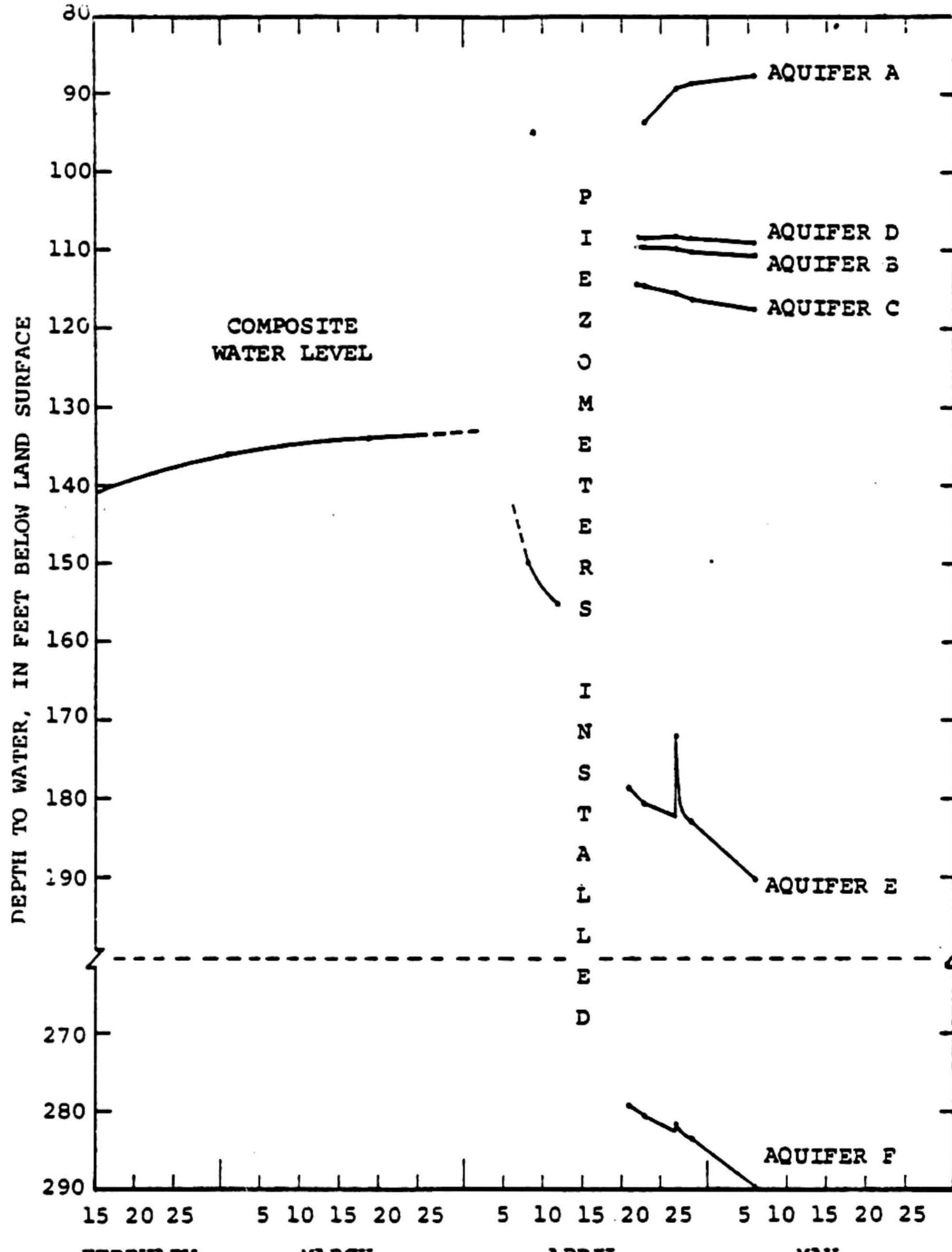


FIGURE 5.--Hydrographs of composite water levels and individual aquifer levels in Odessa test-observation well, during early 1971.

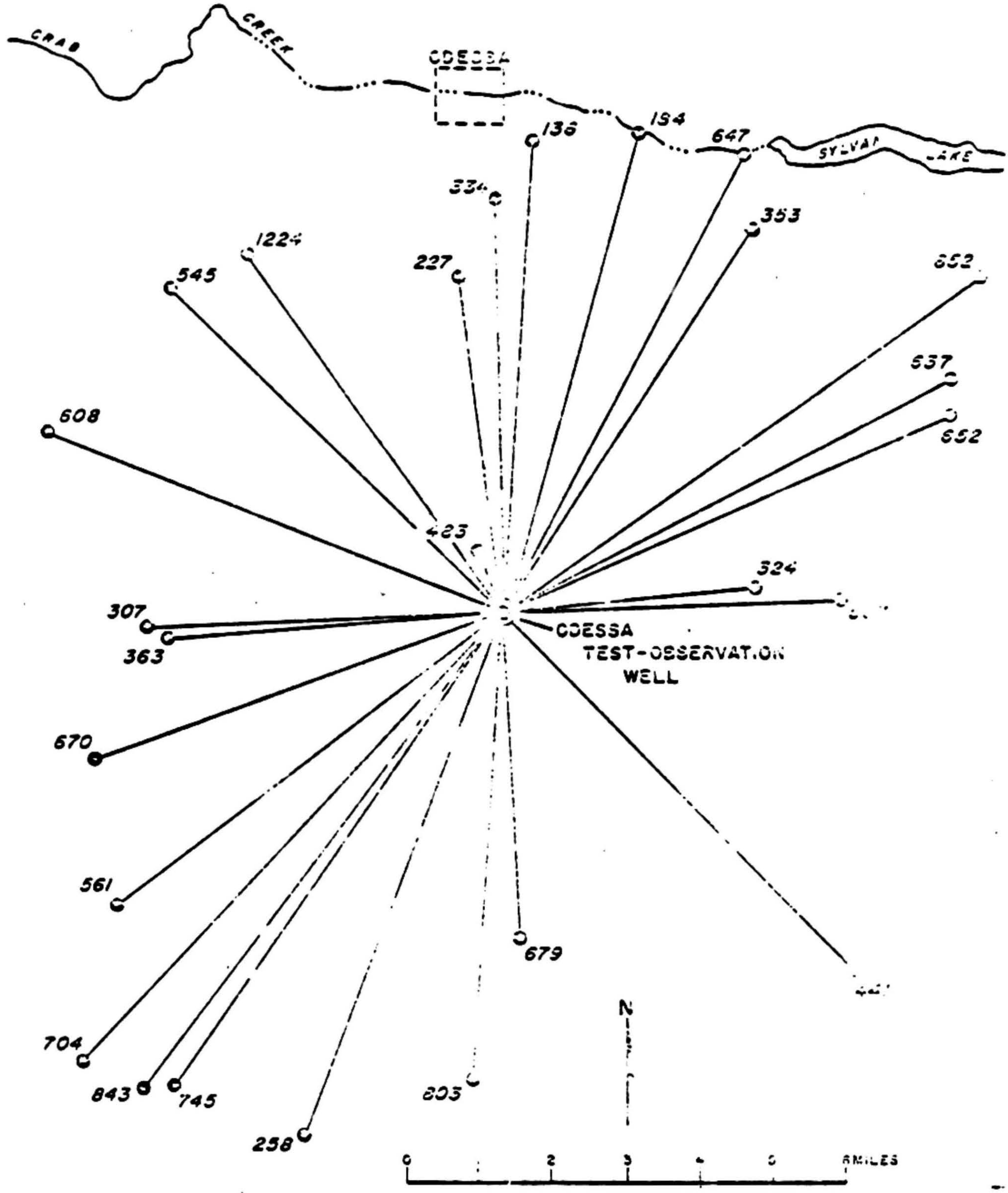


FIGURE 6.--Deep irrigation wells (solid circles) near Odessa test-observation well, and their pumpage (number), in acre-feet, during 1970.

aquifers had adjusted much earlier. The most significant observation was that the water levels in piezometers representing aquifers E and F were declining rapidly--11 feet in 15 days--in response to pumping for irrigation in the Odessa area. The sudden 10-foot rise in water level in piezometer E on April 27, 1971, was caused by a power failure at the irrigation well 1 mile to the northwest that occurred shortly before the measurement was made. The irrigation well taps aquifer E but not aquifer F; however, the head in F rose about 1 foot, apparently in response to the water-level change in the aquifer above. The response of aquifer F, therefore, may suggest some degree of hydraulic interconnection. However, this cannot be established until more water-level records have been collected and tests performed.

The heads in aquifers B, C, and D also are declining somewhat, but mostly in response to the draining of the upper aquifers into the deeper aquifers by movement down the many deep-well bores in the Odessa area.

Although water levels generally decrease with aquifer depth, it is interesting to note that the water level in piezometer D is slightly higher than the levels in the shallower B and C piezometers. Long-term records possibly may indicate, however, that this relation does not always prevail.

The hydrographs of figure 5 clearly demonstrate that, to understand the ground-water hydraulics in this multiaquifer basalt system, the water-level fluctuations of individual aquifers must be monitored.

ADDITIONAL INFORMATION EXPECTED

The test-observation well is in a key location to sense the composite effects of the pumping of many large-yield wells in the vicinity (fig. 6). Besides the information obtained on the sequence of aquifers at the test site, the relative yields of various zones, the geophysical profiles, and the general quality of the ground water, the test-observation well is expected to yield additional valuable data, as summarized below.

1. Data on differences in the hydraulic head at the various depths monitored by the piezometer pipes will define vertical hydraulic gradients. These in turn will provide the basis for estimates of the vertical movement of water through the ground-water reservoir, which are essential for a quantitative understanding of the ground-water-flow system.
2. Seasonal differences in the patterns of water-level fluctuation in the various piezometer pipes will clearly

define the intensively pumped aquifers, and should allow a better evaluation of the hydrologic impact of vertical leakage from one aquifer to another through the many unlined well bores in the region.

3. Accurate temperature measurements through the access pipe will assist in the interpretation of the general pattern of ground-water flow, and also may provide the basis for an independent method of estimating vertical ground-water movement through the basalt sequence.

4. The piezometer pipes are available to monitor any sizable future changes in ground-water quality by means of downhole-conductivity sensors.

In summary, the data already provided by the test-observation well constitute valuable guidance for critical water-management decisions that are needed for the area. These data could not have been obtained by other practical means. Additional data that are expected from the well may prove to be even more helpful for management of the ground-water resources of the area.

REFERENCES

Garrett, A. A., 1968, Ground-water withdrawal in the Odessa area, Adams, Grant, and Lincoln Counties, Washington: Washington Dept. Water Resources Water-Supply Bull. 31, 84 p.

Luzier, J. E., Bingham, J. W., Burt, R. J., and Barker, R. A., 1968, Ground-water survey, Odessa-Lind area, Washington: Washington Dept. Water Resources Water Supply Bull. 36, 31 p.