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GROUND WATER FLUCTUATIONS AT KEARNEY PARK, CALIFORNIA

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INTRODUCTION

Many of the problems which confront the engineer in irrigated regions would be much simplified if there were available reliable and detailed information concerning the fluctuation and movement of underground waters. Probably the two most important of these problems are the design of drainage works and the development of underground water supplies for irrigation.

The height to which the water table rises, the rate of rise and fall as it fluctuates at different seasons, the time at which maximum and minimum heights occur and the rate of yearly increase or decrease have an important bearing on the size, location, and depth of artificial drains and on the size, location, number and capacity of pumping plants, whether used for irrigation or drainage.

Unfortunately, the collection of data on ground water movements is seldom begun until its need becomes so urgent that studies can not be continued for sufficient time to make them entirely reliable. The studies carried on by the writer at Kearney Park near Fresno, California, are no exception to this rule. They are, however, of more than usual length and are in sufficient detail to be of considerable value for the purpose in mind, namely, the designing of a drainage system.

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INSTALLATION

Although these observations were confined to Kearney Vineyard and interlying property at Kearney Park, the area covered (7000 acres) is sufficiently large and the soil conditions sufficiently like that found throughout some 100,000 acres in and about Fresno to make the results here obtained applicable to the larger area.

With minor exceptions, the depth to water was recorded weekly for eight out of the eleven years, 1912 to 1922 inclusive, in twenty-one regularly spaced test wells covering the area. In all, some 8000 observations were made. Figure 1 shows the relative location of the test wells and the general nature of the topography of the area.

The test wells consisted of auger holes ten feet in depth lined with 3-inch galvanized iron pipe. The top of the pipe projected about a foot above the surface. Each well was originally protected by being placed at the center of a triangle formed by three posts about which was wrapped three strands of barbed wire. This protection did not, however, in every case, withstand the attacks to which it was subjected by cattle and heavy farming machinery.

Being regularly spaced, these wells were subject to the natural variations which are likely to occur in an area of this size, such as variations in soils, topography, nature of tillage operations, irrigation requirements of different crops, distance from main supply canals and other local characteristics.

It will be noted, for instance, that wells 11, 12, 8, 9, and 3 are all on or adjacent to a low sandy ridge extending across the property, while wells 1 and 10 were influenced materially by seepage from the adjacent Fresno Sewer Farm.

PRESENTATION OF EXPERIMENTAL DATA

Although the factors mentioned unquestionably had considerable influence on the water table conditions surrounding any particular well and tend to emphasize the unreliability of individual observations, the fact that these variations exist should make the average results for the large series of wells of considerable general application. The height of the water as observed weekly was plotted for each of the twenty-one wells. Figure 2 gives the record sheets for wells 5, 10, 14, and 17, these being chosen as typical.

Because of the difficulty of keeping the wells in repair at all times, some of the early and late season readings do not give the full depth to water, the wells having become silted up. Note, however, was made of the actual depth at which they were found dry.

The actual elevations were obtained of the top of the well casing, to which all readings unless otherwise noted are referred, and of the surrounding ground surface. This information is shown on the record sheets.

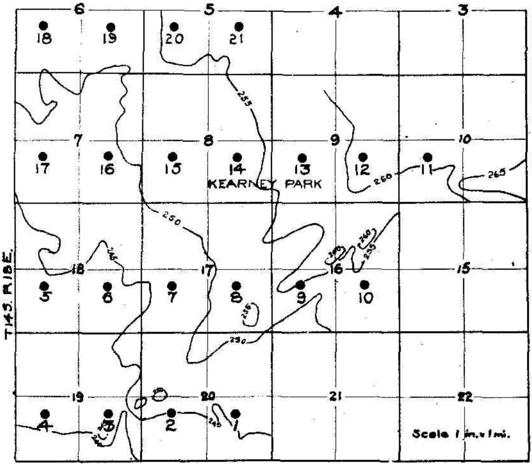

Fig. 1. Sketch showing location of test wells at Kearney Park.

In order to obtain a comprehensive view of the actual conditions *uninfluenced by local happenings at any particular well*, the curves of all the wells for any given year were superimposed and from them an average curve for the year was obtained. These average curves for each of the eight years are shown first in consecutive order in figure 3 and then superimposed in figure 4. It is from these two figures that the engineer can obtain the most data of real value.

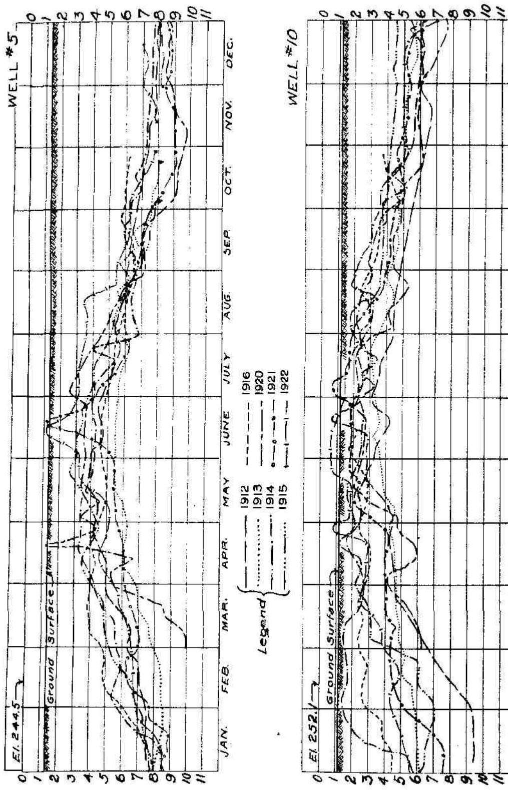

Fig. 2. Record sheets for four representative test wells, showing the position of the water table with reference to the ground surface.

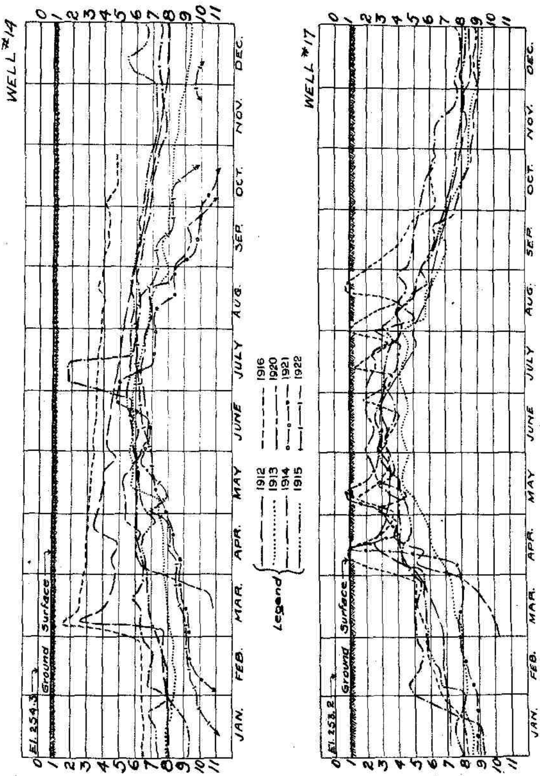

Fig. 2. (*Continued.*)

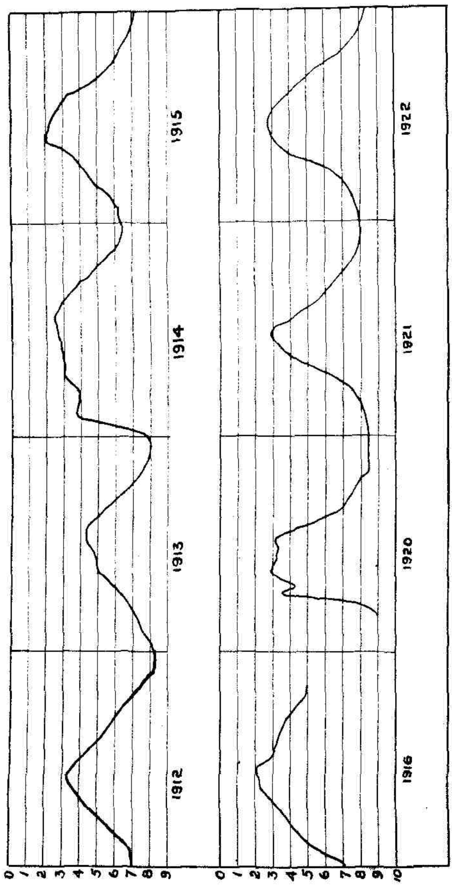

Fig. 3. Curves showing average of all well readings for each year.

Figure 5 was obtained by drawing an average curve through the eight yearly curves shown in figure 4. This curve shows more clearly the normal rate of rise over a considerable time, but is not so valuable in furnishing engineering data as those in figure 4. In the designing of drainage structures maximum rises and maximum supplies of water are controlling factors, while in the designing of irrigation structures the opposite conditions control.

In order to further bring out the fact that there is considerable variation between wells, table 1 is given, which shows for each well the approximate number of days in which the water stood at a given distance from the ground surface. This table was prepared from the data shown on the record sheets.

TABLE 1

TABLE GIVING FOR EACH WELL THE APPROXIMATE NUMBER OF DAYS WHEN THE WATER TABLE WAS WITHIN THREE AND WITHIN SIX FEET OF THE SURFACE

Depth	0′—3′								3′—6′							
Well No.	1912	1913	1914	1915	1916	1920	1921	1922	1912	1913	1914	1915	1916	1920	1921	1922
1	110	100	290	210	225	365	365	365	365	365	285	340	365	365	365	365
2	5	0	30	0	X	30	55	70	165	225	270	175	X	135	155	200
3	0	0	5	15	0	0	10	20	55	50	175	110	105	60	65	135
4	0	0	45	40	15	25	X	X	130	50	155	205	195	130	X	X
5	60	0	115	75	60	105	25	140	210	190	320	240	300	180	240	330
6	40	0	155	145	140	120	125	190	275	195	305	270	255	180	210	335
7	90	5	110	80	100	100	X	X	315	270	270	255	280	160	X	X
8	0	0	80	10	0	20	20	X	65	65	190	75	85	120	65	X
9	95	15	170	105	120	X	X	X	225	190	315	290	300	X	X	X
10	80	95	260	240	300	95	165	225	300	365	365	365	365	365	365	365
11	10	0	95	90	125	20	25	X	150	165	260	230	330	125	115	X
12	0	0	0	X	X	10	X	X	0	0	100	X	X	75	X	X
13	0	0	0	0	0	0	0	0	0	0	155	0	0	0	0	0
14	35	0	15	0	180	0	0	0	220	95	235	260	365	260	55	85
15	5	0	10	15	10	10	0	0	150	0	275	315	365	135	90	110
16	100	40	125	130	130	95	65	60	280	235	305	240	330	155	135	165
17	95	0	125	80	120	100	X	X	270	180	305	235	305	175	X	X
18	90	35	140	45	10	80	215	X	245	135	300	215	180	180	250	X
19	10	0	145	85	70	10	5	10	215	315	365	260	365	180	150	205
20	0	0	30	0	0	0	5	0	170	85	310	215	300	65	85	85
21	0	0	5	0	0	0	X	X	35	0	160	105	150	20	X	X

Note: X denotes records incomplete.

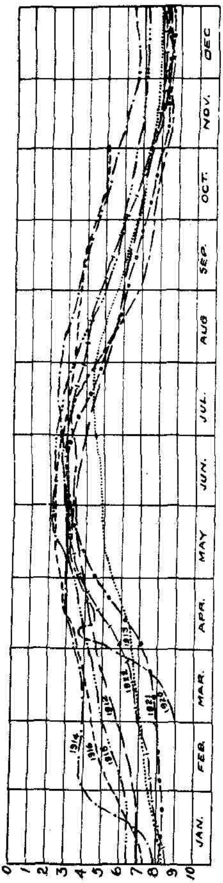

Fig. 4. Curves showing yearly fluctuations in water table, each curve being the average of weekly readings on twenty-one wells covering an area of 7,000 acres.

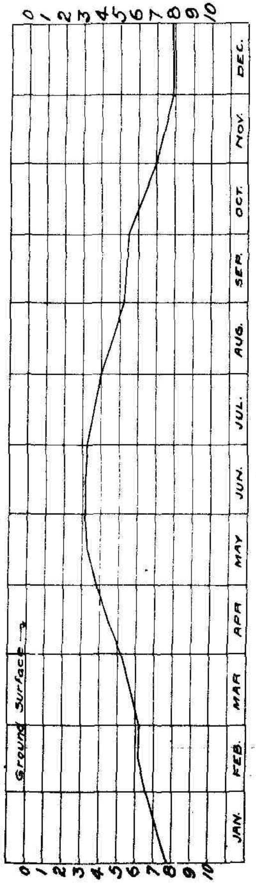

Fig. 5. Typical water table fluctuation curve showing the average of eight years' observations at Kearney Park.

OBSERVATIONS AND ANALYSIS OF DATA

From the data which have been secured, the following observations seem to stand out as most worthy of particular attention:

(1) Many of the wells show rather erratic fluctuations due to irrigation and when taken individually do not indicate actual conditions, except in the immediate vicinity of the particular well.

(2) The water table reaches a point nearest the surface during June. It is during this month that crops are growing in their most vigorous condition and abundant supplies of water are required to supplant that lost by transpiration. This water must be supplied by irrigation, which is frequently over-done, the excess going to raise the water table. During June, irrigation water is usually plentiful, but toward the end of the month and always in July, except in districts where storage water is available, there is a very rapid decrease in the supply. It is a common practice to apply excessive amounts of water in June in anticipation of a shortage in July. This fact is most strikingly illustrated by the conditions in the Turlock Irrigation District in 1923. Before 1923 no storage water was available and the usual practice of heavy irrigation in June was followed. In 1923, however, when late water was made available by storage in the Don Pedro reservoir, irrigation in June was more nearly in accordance with plant requirements, and as a consequence, the water table did not rise so high by several inches as it had done in previous years, although for the whole season about one-third more water was applied than had ever been used before.

(3) During most of the year, the water table is well within the ideal root zone of plants. During the mid-summer when root development should be the greatest and the feeding zone the most extensive, it is in reality most restricted because of the position of the water table.

(4) For the type of soil found in this region and with the shallow depth to the ground water, it is probable that water will rise to the surface by capillarity during the entire year, and during that part of the year when the temperatures are most favorable for high evaporation, the water table is nearest the surface. There must necessarily be a rapid accumulation of alkali at the surface under these conditions.

(5) During the season of high water table, the average distance of the water from the surface is not more than 2 feet, whereas during mid-winter the average is from 7 to 8 feet. The seasonal fluctuation is therefore between 5 and 6 feet.

(6) The most rapid rise in the water table occurs during March and April. This occurs within a short time after water is turned into the canals and the first irrigation of the season is applied. Seepage is probably excessive from the canals at this time because they have been dry during the winter months; evaporation and transpiration are at a minimum because the temperatures are relatively low and the plants small, and water is usually plentiful.

(7) As the season progresses, although the water table continues to rise until about the first of July, the rate of rise is much less than in the early spring. This may be accounted for by increased evaporation due to the rising temperatures, but it is more probably due to the greater use of water by the more abundant foliage of the crops.

(8) During June, there is very little fluctuation, but as soon as the water shortage begins in July the water table recedes. The recession is usually at a more uniform rate than the rise. By the first of December, the low point is reached and no particular change takes place during this month.

(9) The rate of rise in the water table after dry seasons is more rapid than in other years. The years 1913 and 1919 were both abnormally dry (this survey does not show the position of the water table in 1919), and it will be noticed on the following years, 1914 and 1920, the water table began to rise early and at a much more rapid rate than in other years. Also, that it remained at its high point for a much longer period. This is unquestionably due to the fact that water was applied in excessive amounts early in the season with the idea of overcoming the effects of the previous shortage and also in an attempt to save the crops from a possible shortage of water during the succeeding summer.

(10) There appears to be little or no tendency toward an annual increase in the height of the water table. In fact, there is an indication both from these data and from observations made elsewhere that 1914 is the year when the most undesirable conditions occurred. In order to give an exact account of the rise of the water table from depths of 60 or 80 feet, where it is said to have once stood, annual records for many years previous to 1912, when annual observations were first made, would be needed. However, in 1902, C. G. Elliott reports in U. S. Department of Agriculture Circular No. 50, drainage

conditions for this area that are almost as bad as those shown here, and before that date Dr. E. W. Hilgard in the California Experiment Station Report for 1886 sounds a warning on drainage for the country west of Fresno.

USE OF DATA

In designing drainage systems, provision must be made for removing the excess water in abnormally wet years, otherwise permanent crops such as orchards, vineyards and alfalfa may be injured. From the data at hand, it would then appear necessary to provide drainage of such capacity that rises in the water table similar to those in 1914 and 1920 could not occur, at least within the normal root zone.

The rate of rise and particularly the maximum rate is of as much importance in drainage design as the total annual rise. Since all of the fluctuations take place well above a safe drainage depth for irrigated regions, drainage to be adequate must be sufficient to preclude any rise whatever within the zone now affected.

From figure 5, it can be found that the average total effective rise for the eight years under observation was 4.35 feet, occurring within 135 days (January 1 to May 15). This is equivalent to an average rise of .032 foot per day. Assuming that for this particular soil the void spaces are 30 per cent of the volume, it would require 1.30 acre feet of water per acre to have caused this rise. This is, of course, in addition to that removed by deep percolation, evaporation and transpiration. From January 15 to January 27, 1914 (12 days), there was an average rise of 2.6 feet over the area or a rise at the rate of 0.216 foot per day. This is equal to the addition of 41.47 acre feet per square mile per day or 1 c.f.s. for each 30 acres under observation.

In 1920 from March 24 to April 7 (18 days), the rise was 4.3 feet or an average of 0.24 foot per day. This is the equivalent of 46.08 acre feet per square mile per day or 1 c.f.s. for each 27 acres. Assuming that 50 per cent of this could be removed from the soil by drainage, it would mean that drainage must be provided to remove 1 cubic foot per second for each 54 acres in order to prevent this rise.

For a large area a uniform system of drains of the capacity indicated would probably not be necessary, but the information given here, when taken in conjunction with that in table 1, will be of value in planning an adequate drainage system.

As an example of the practical use to which data of this nature may be put, the following drainage design may be mentioned. A system of drainage by pumping has been planned for the property upon which these data were collected. This system will consist of eleven pumping plants having an average capacity of 3.21 cubic feet per second which are to operate continuously from March 15 to December 1. During this period, it is estimated that a total of 17,000 acre feet of water will be discharged.

Although the 35 cubic feet per second, total capacity provided, is not sufficient to overcome a rise similar to that of April, 1920, the total discharge of 17,000 acre feet per year (2.43 acre feet per acre over 7000 acres or nearly twice the eight-year average) will lower the table so far below the surface that abnormal fluctuations should all occur at depths well below the danger point. In the case of tile or open ditch drainage, where the maximum drainage depth is usually but little below the required minimum, greater capacity would, of course, be necessary.