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SHAPE OF THE WATER TABLE IN TILE DRAINED LAND

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In 1915, while investigating drainage conditions at Kearney Park, California, the author was attracted by what appeared to be a discrepancy between the shape of the water table profile between lines of tile as found in the field and those usually shown in textbooks and other published papers on drainage. At the time, the shape of this profile was attributed to the heavy flooding which was being done on the drained tract.

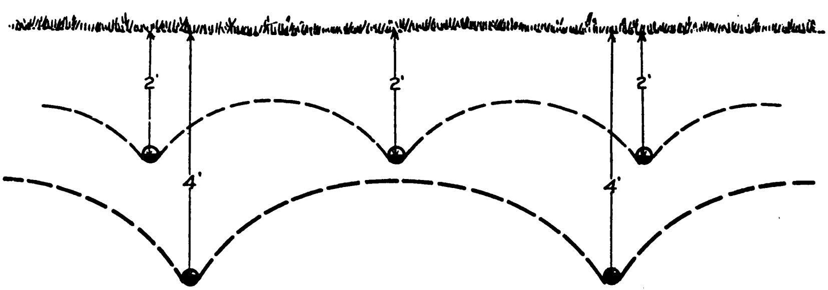

Fig. 1. A diagram similar to those commonly used to illustrate the shape of the water table between tile lines but which shape is not in accordance with the findings herein described.

A year or two later similar characteristics were observed on tile drained tidal marsh lands in Marin County, and this was attributed to the very heavy-textured soil of this area. It is now believed, however, that these observed shapes were not due to unusual or particular conditions, but that they represent the normal conditions of the .water table on drained land.

[1] Assistant Drainage Engineer in the Experiment Station.

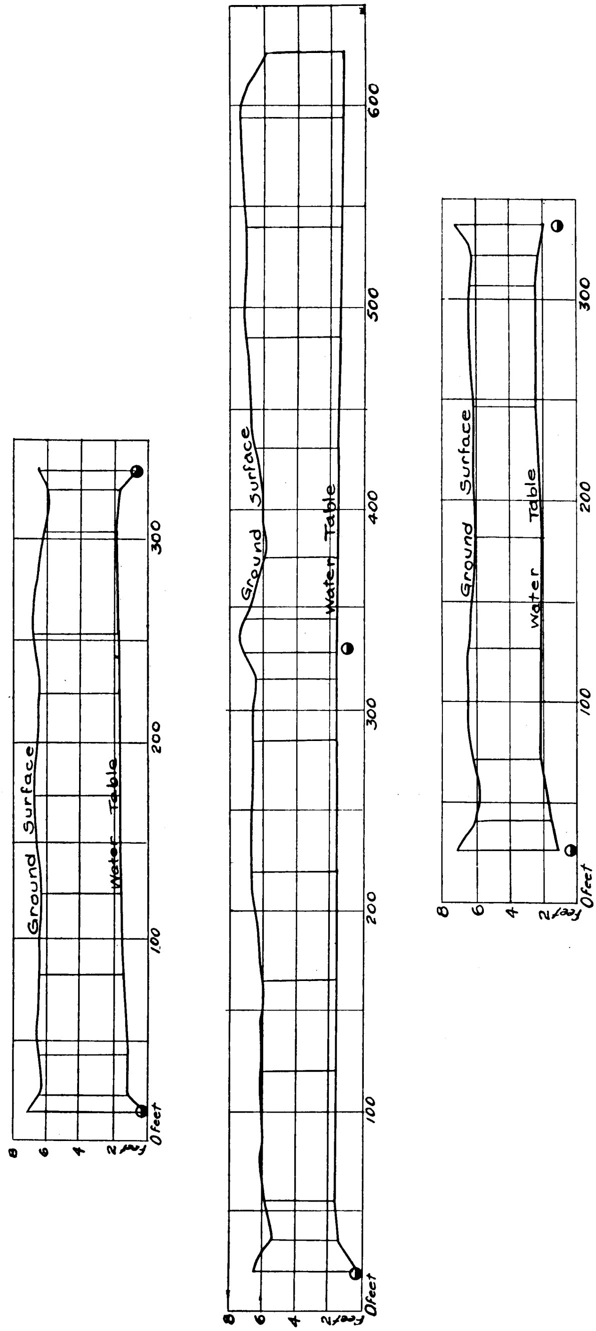

Fig. 2. Water table profiles in sandy loan soil at Kearney Park, California. Points at which measurements were taken are indicated by vertical lines from the surface to the water table.

Figure 1, which is taken from one of the author's own papers, is illustrative of the general type of information on the shape of the water table to be found in many publications. Although in this, as in most of the publications, the illustration was used for another purpose than to show the shape of the curve, it leaves what the writer now believes to be an erroneous impression in the mind of the reader.

SOURCES OF DATA

The data obtained at Kearney Park, California, in 1915, has been used to construct the profile shown in figure 2. In this drainage system the tile are in parallel lines 315 feet apart and about 6 feet deep. All of the lateral drains are 6 inches in diameter. The soil on the Kearney Park Tract is a fine sandy loam containing non-continuous layers of hardpan, which, however, does not appear to interfere with the downward movement of water.

In Marin County, the area from which data were obtained is a heavy-textured tidal marsh from which tidal overflow is prevented by dikes. The tile lines, consisting of 4-inch tile, were 190 feet apart and between 3 and 4 feet in depth. Figure 3 shows the water table profiles from this tract.

In order to obtain more detailed and complete information regarding the shape of the water table than was available from the work at Kearney Park and in Marin County the investigations described more in detail were conducted in the Newhope Drainage District of Orange County during the summer of 1926.

This District contains about 4,000 acres of tile drained irrigated land and is situated on the west side of the Santa Ana River, directly west of the city of Santa Ana.

The soil of this area is Hanford sand and fine sandy loam. This is a recent alluvial deposit which is deep and readily permeable to roots and water.

The drainage system consists of lines of tile located in roughly parallel, north and south lines, about one-quarter mile apart. The tile used in this system vary in size from 30 inches in diameter at the lower end of the main line to 8 inches in diameter at the upper ends of laterals. The average depth of drain is between 8 and 9 feet. The water table has been quite generally lowered over the district, as indicated by measurements taken both before and after the drainage system was installed. In many places this has amounted to 3 feet

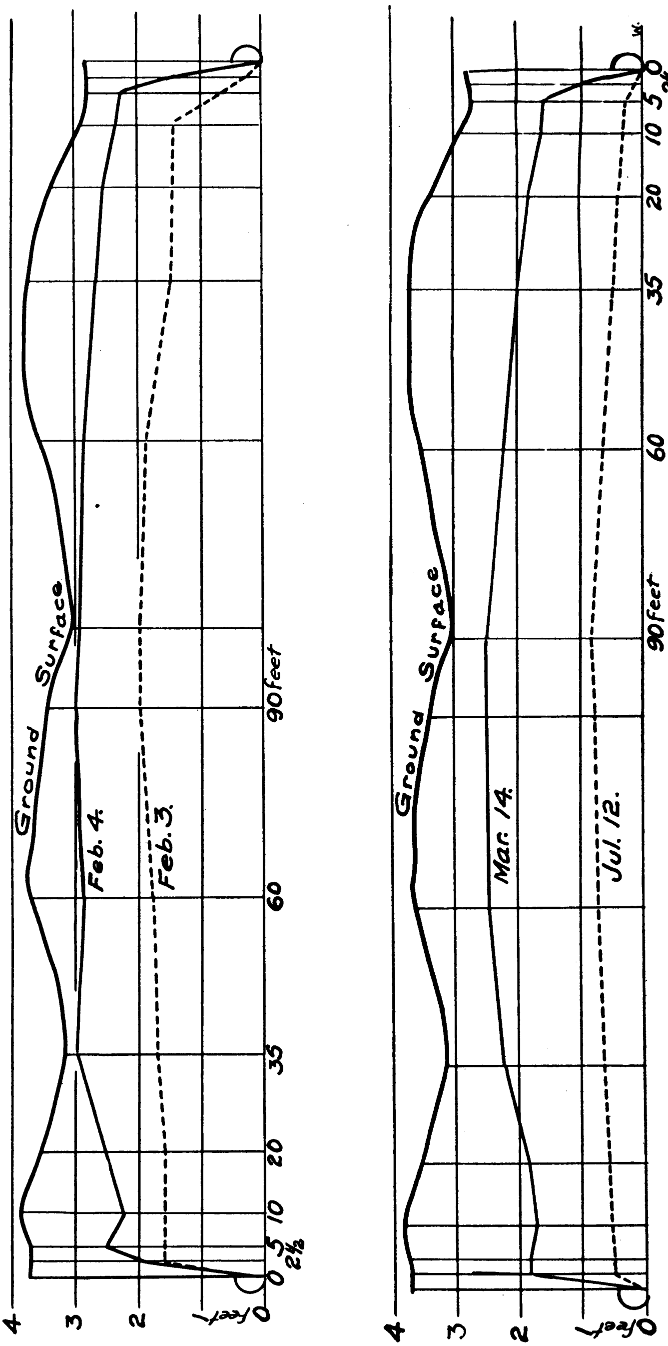

Fig. 3. Water tables profiles on a reclaimed tidal marsh in Marin County, California. Vertical lines indicate points at which measurements were taken. Profiles are from the same points but on different dates.

or more. Figure 4 is a map of the district showing the location of the drains with respect to the boundaries of the district.

This district appeared to have almost ideal conditions for the study of water table profile shapes because the soil is fairly uniform in texture, depth and general characteristics. The drains run principally all in one direction and far enough apart to provide for full

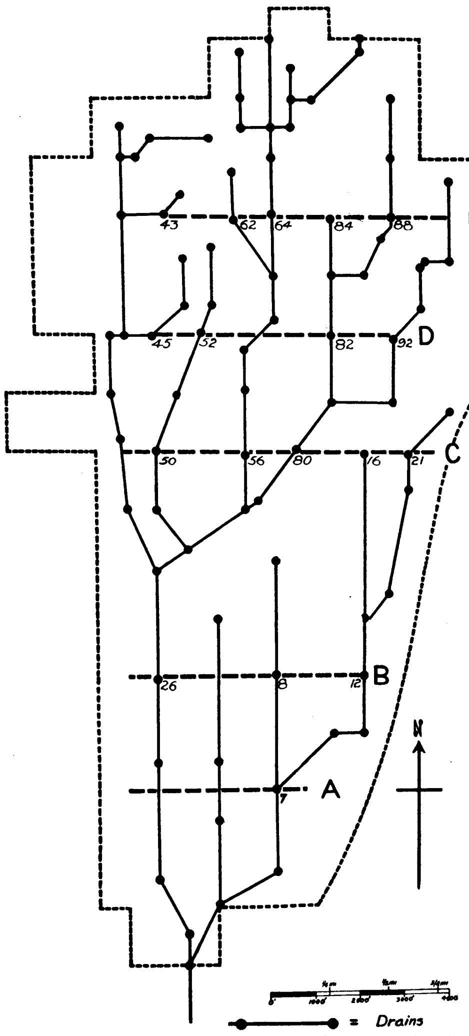

Fig. 4. Map of New Hope Drainage District showing location of drains and profiles. Only those manholes at which measurements were taken are shown numbered in the map.

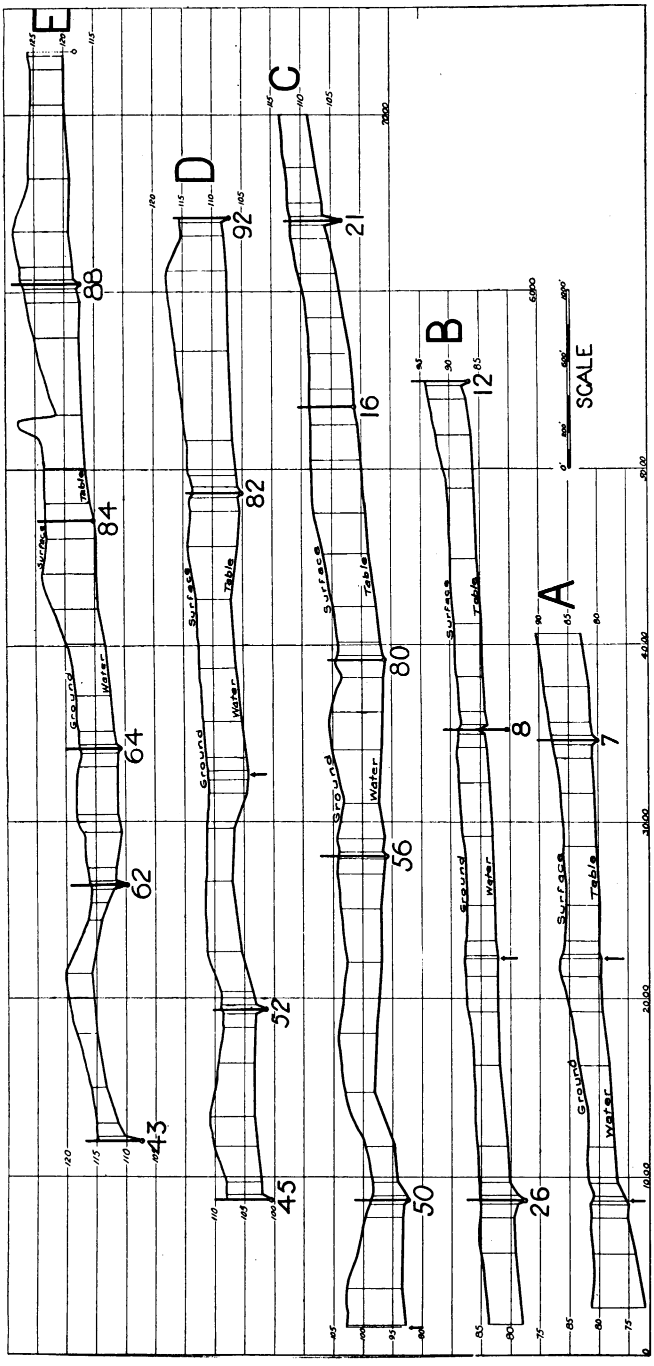

Fig. 5. Profiles of water table in Newhope Drainage District. The profile designations and manhole numbers correspond with those taken in figure 4. Light vertical lines indicate points where measurements were taken.

development of water table profiles. The drains are also deeper than usual and the tract is satisfactorily drained.

The field work consisted of locating five profile lines across the district as shown in figure 4, and of boring down and determining the depth to water at frequent intervals along these lines. The elevation of the ground and the water table at each point and the relation between one point and another was determined by a line of levels. The elevations used, however, are from an assumed datum. These profile lines were located along the roads in order to make use of the greatest number of manholes, which are more or less regularly located along the tile lines, as points where the elevation of the water as it stood in the tile could be measured. There are only three instances in which there was no manhole at the point where the profile line crossed the tile line.

Profile A, the most southerly, is through the center of section 21, T 5 S., R 10 W., S.B.B.& M. It is 3,790 feet long, crosses three tile lines and contains 25 points of observation.

Profile B, one-half mile north of A, is along Smeltzer Avenue. It is 5,310 feet long, crosses four tile lines and contains 31 points of observation.

Profile C, one mile north of B, is along First Street. It is 6,840 feet long, crosses six tile lines and contains 42 points of observation.

Profile D, one-half mile north of C, is along Hazzard Avenue. It is 5,540 feet long, crosses five tile lines and contains 34 points of observation.

Profile E, the most northerly, and one-half mile north of D, is along Seventeenth Street. It is 6,160 feet long, crosses six tile lines and contains 40 points of observation.

There is some variation in the spacing of the test points on the profile lines due principally to a variation in distance between tile lines, but in the main an observation was made directly over a tile line, usually through a manhole and at 25 feet, 100 feet, 300 feet and 600 feet on either side of the tile lines. These points, as well as the distance from the ground surface to the water, are shown in figure 5.

ANALYSIS OF DATA

The significant feature of the profiles shown in figure 2 is that, except within 10 or 15 feet of the tile line, the water table is practically horizontal. There is a slight rise in the water table at mid points between tile lines, but in no case is this rise more than one foot and in most instances only a few inches. The fact that the general water table stands a foot or more above the tile has no particular significance so far as the shape of the water table curve is concerned.

In figure 3 it will be noted that beyond about five feet from the tile line, the water table is practically horizontal. The shape of the water table surface is not materially changed by the depth to water as the four profiles are, for all practical purposes, parallel.

The data secured from the Newhope Drainage District is presented in figure 5. Here, as in the work previously referred to, the water table assumes a nearly horizontal position between tile lines with a very sharp and marked depression immediately over the drain. As has been mentioned, many writers have implied by drawings and otherwise that the surface of the water table takes a much more rounded curve between tile lines than has been found to be the case in these studies.

It can be seen from the profile that with only about three exceptions the water table at any point more than 100 feet from the tile line is very nearly at the same elevation that it is 600 feet or midway between lines. It should be remembered in considering this point that the water table has been lowered about three feet over the entire district as the result of the drainage system.

Unless there was a manhole within 50 feet of the point where the profile line crossed the tile line, the elevation of the water table in the tile was not obtained, but in three such cases borings were made directly over the line.

On profile A (fig. 5) the only place where the water in the tile was measured, was at manhole 7. On profile B the water stood very high in manhole 8 due to a stoppage in the tile below this point; in fact, the water stood considerably higher in the manhole than it did in the immediately surrounding soil. For a considerable distance along the north side of profile B, the land was planted to peppers which receive heavy weekly irrigations. This fact, together with that of the obstructed tile, undoubtedly accounts for the water table being so near the surface along this line. On profile C the west slope and top of the sandy ridge between manholes 50 and 56 was irrigated the afternoon and evening before these measurements were taken. This probably accounts for the high water table at the 4th and 5th observation east of manhole 50. Manhole 16 is at the upper end of a drain. This is also true of manhole 84 on profile E. The high water table between manholes 52 and the next tile line to the east on profile D may have been caused by a recent irrigation about midway between these two lines of tile, and the extremely high water table between manhole 43 and 62 on profile E is unquestionably due to the very heavy irrigation of a pepper field on the high ridge just north of this profile line. It can be seen that this has affected the water table even beyond the tile line on which manhole 62 is located.

It does not appear that the shape of the water table midway between tile lines is materially affected by the fact that the table is considerably above the tile line as on profile B or it is on the same level as at manholes 16 and 84. It is not definitely known that the elevation of the water in a flowing tile line actually represents the elevation of the water table in the soil even immediately adjacent to the tile. Evidence tending to show that this is not the case can be found at four points where borings were made directly over the tile, as at manhole 62 and one point on profile B and at two points on profile A. At these points the water table appears to be standing higher than the flow line in the tile. However, where the water table, as shown in figure 3, was measured at 2½ and at 5 feet from the tile, it is much lower at the points nearer the tile.

The scale to which it is necessary to reduce the profiles for reproduction in this paper does not permit of the detailed study that the author enjoyed while working with the larger scale original drawings.

It is believed by some,[2] if not by most writers on drainage that water enters a tile line from the bottom as the result of the tile having intercepted a vertical pressure upward. If this view is accepted, a flattened water table curve between tile lines should be the natural consequence. The height above the flow line in the drain, at which the water table stands between drains would be a measure of the magnitude of the upward pressure. If, on the other hand, the theory of a lateral flow into a drain is accepted, a much more rounded curve to the water surface between drains would be expected in order to create sufficient head to cause the lateral movement. In this case, the height of this curve above the flow line in the drain would be a measure of the rate of lateral movement.

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[2] Murphy, D. W. Drainage engineering, p. 1–172, McGraw-Hill Book Company. 1920.

SUMMARY AND CONCLUSIONS

From the data which were obtained under these widely different soil conditions and widely different spacing and depth of tile, it appears reasonable to conclude that:

1. The water table between lines of tile is practically a straight line, except within a very short distance of the tile.

2. The depth of tile or the spacing between lines of tile does not materially alter the *shape* of the water table.

3. The water table under certain conditions may stand above a tile line at points directly over it and yet the drainage be efficient and the tile lines only partially filled with flowing water.

4. Because of the flatness of the water table, it would appear probable that the major part of the lateral adjustment in the water table, due to the removal of water by a drain, takes place below the flow line; and in that portion of the water table above the flow line the movement is largely vertical. It seems logical that the lateral gradient in the surface of the water table must be greater than has been shown in these profiles before there is a significant lateral movement toward a drain in that portion of the water table which is above the flow line.

5. The depth of tile rather than the spacing between tile lines is the more important feature affecting the efficiency of a drainage system.

6. To obtain the same efficiency (that is the same lowering of the water table) in areas where the vertical pressures differ, the tile must be either deeper or closer together in the case of the greater pressure.

The titles of the Technical Papers of the California Agricultural Experiment Station, Nos. 1 to 20, which HILGARDIA replaces, and copies of which may be had on application to the Publication Secretary, Agricultural Experiment Station, Berkeley, are as follows:

1. The Removal of Sodium Carbonate from Soils, by Walter P. Kelley and Edward E. Thomas. January, 1923.
3. The Formation of Sodium Carbonate in Soils, by Arthur B. Cummins and Walter P. Kelley. March, 1923.
4. Effect of Sodium Chlorid and Calcium Chlorid upon the Growth and Composition of Young Orange Trees, by H. S. Reed and A. R. C. Haas. April, 1923.
5. Citrus Blast and Black Pit, by H. S. Fawcett, W. T. Horne, and A. F. Camp. May, 1923.
6. A Study of Deciduous Fruit Tree Rootstocks with Special Reference to Their Identification, by Myer J. Heppner. June, 1923.
7. A Study of the Darkening of Apple Tissue, by E. L. Overholser and W. V. Cruess. June, 1923.
8. Effect of Salts on the Intake of Inorganic Elements and on the Buffer System of the Plant, by D. R. Hoagland and J. C. Martin. July, 1923.
9. Experiments on the Reclamation of Alkali Soils by Leaching with Water and Gypsum, by P. L. Hibbard. August, 1923.
10. The Seasonal Variation of the Soil Moisture in a Walnut Grove in Relation to Hygroscopic Coefficient, by L. D. Batchelor and H. S. Reed. September, 1923.
11. Studies on the Effects of Sodium, Potassium, and Calcium on Young Orange Trees, by H. S. Reed and A. R. C. Haas. October, 1923.
12. The Effect of the Plant on the Reaction of the Culture Solution, by D. R. Hoagland. November, 1923.
13. Some Mutual Effects on Soil and Plant Induced by Added Solutes, by John S. Burd and J. C. Martin. December, 1923.
14. The Respiration of Potato Tubers in Relation to the Occurrence of Blackheart, by J. P. Bennett and E. T. Bartholomew. January, 1924.
15. Replaceable Bases in Soils, by Walter P. Kelley and S. Melvin Brown. February, 1924.
16. The Moisture Equivalent as Influenced by the Amount of Soil Used in its Determination, by F. J. Veihmeyer, O. W. Israelsen and J. P. Conrad. September, 1924.
17. Nutrient and Toxic Effects of Certain Ions on Citrus and Walnut Trees with Especial Reference to the Concentration and Ph of the Medium, by H. S. Reed and A. R. C. Haas. October, 1924.
18. Factors Influencing the Rate of Germination of Seed of Asparagus officinalis, by H. A. Borthwick. March, 1925.
19. The Relation of the Subcutaneous Administration of Living Bacterium abortum to the Immunity and Carrier Problem of Bovine Infectious Abortion, by George H. Hart and Jacob Traum. April, 1925.
20. A Study of the Conductive Tissues in Shoots of the Bartlett Pear and the Relationship of Food Movement to Dominance of the Apical Buds, by Frank E. Gardner. April, 1925.