RESULTS OF AN INFILTRATION STUDY ON THE CARRIZO SAND OUTCROP IN ATASCOSA COUNTY, TEXAS

by

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Texas Department of Water Resources

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RESULTS OF AN INFILTRATION STUDY ON THE CARRIZO SAND OUTCROP IN ATASCOSA COUNTY, TEXAS

RESULTS

Neutron moisture logs, supplemented by precipitation data, were used to determine the quantity of rainfall resulting in recharge to the Carrizo aquifer. The rainfall which percolates downward beneath the zone of evapotranspiration is recharge to the aquifer. During the period from April 5, 1976 to April 4, 1977, the study site received approximately 35.35 inches (89.8 centimeters) rainfall, of which, about 16.5 percent or 5.8 inches (14.7 cm) went to deep percolation. Therefore, within the 470 acre drainage basin of the study area it is estimated that about 229 acre-feet (0.28 cubic hectometers) of rainfall went to recharge the Carrizo aquifer.

INTRODUCTION

Purpose and Scope

The purpose of this infiltration study was to determine the amount of deep percolation that recharges the Carrizo aquifer. Various methods of increasing the efficiency of rainfall infiltration into the Carrizo outcrop have been described (Getzendaner, 1953). A quantitative study of actual deep percolation to the Carrizo Sand outcrop, however, has not been available heretofore. It is hoped that this report will satisfy those needs for rainfall infiltration and deep percolation data in the Carrizo Sand outcrop.

Acknowledgements

The authors appreciate the cooperation extended by Mr. George Thompson of Devine, Texas in permitting the use of his property to conduct this study.

Acknowledgement is also extended to the Atascosa County Agricultural Extension Service Office and to the Soil Conservation Service for providing valu-

able information on the soils and vegetation within the study boundaries.

DESCRIPTION OF STUDY SITE

Site Location

The recharge investigation site is located nine miles east of Devine, Texas in Atascosa County as shown in Figure 1. The study area consists of a 470 acre watershed drained by an intermittent stream as shown on the topographic map in Figure 2. This intermittent stream flows for 0.9 miles (1.4 kilometers) southeastward where it discharges into Siestedera Branch Creek.

The land in the study area is characterized by low rolling sand hills. Most of the rolling sand hills in the area are stabilized by annual and perennial grasses. Movement of unstabilized sand hills occurs with every windstorm and cultivated fields also lose sandy topsoil to strong winds. While there is sand movement due to wind, soil erosion due to water is not active in the study area which indicates the lack of surface runoff and the high degree of internal soil drainage.

On Site Equipment

The study area is equipped with a special 20 foot (6.1 meters) moisture test borehole for moisture logging. The borehole is cased with 2-inch (5.1 centimeter) diameter aluminum tubing which is sealed at the bottom to exclude moisture. To insure accuracy of the soil moisture measurements, the aluminum casing must fit tightly into the borehole with no voids existing between the casing and the borehole. Other equipment used in the study area included a recording raingauge, ground-water level observation well, and a recording weir to record flow of the intermittent stream draining the study area. The location of the equipment used in the study area is noted on Figure 2.

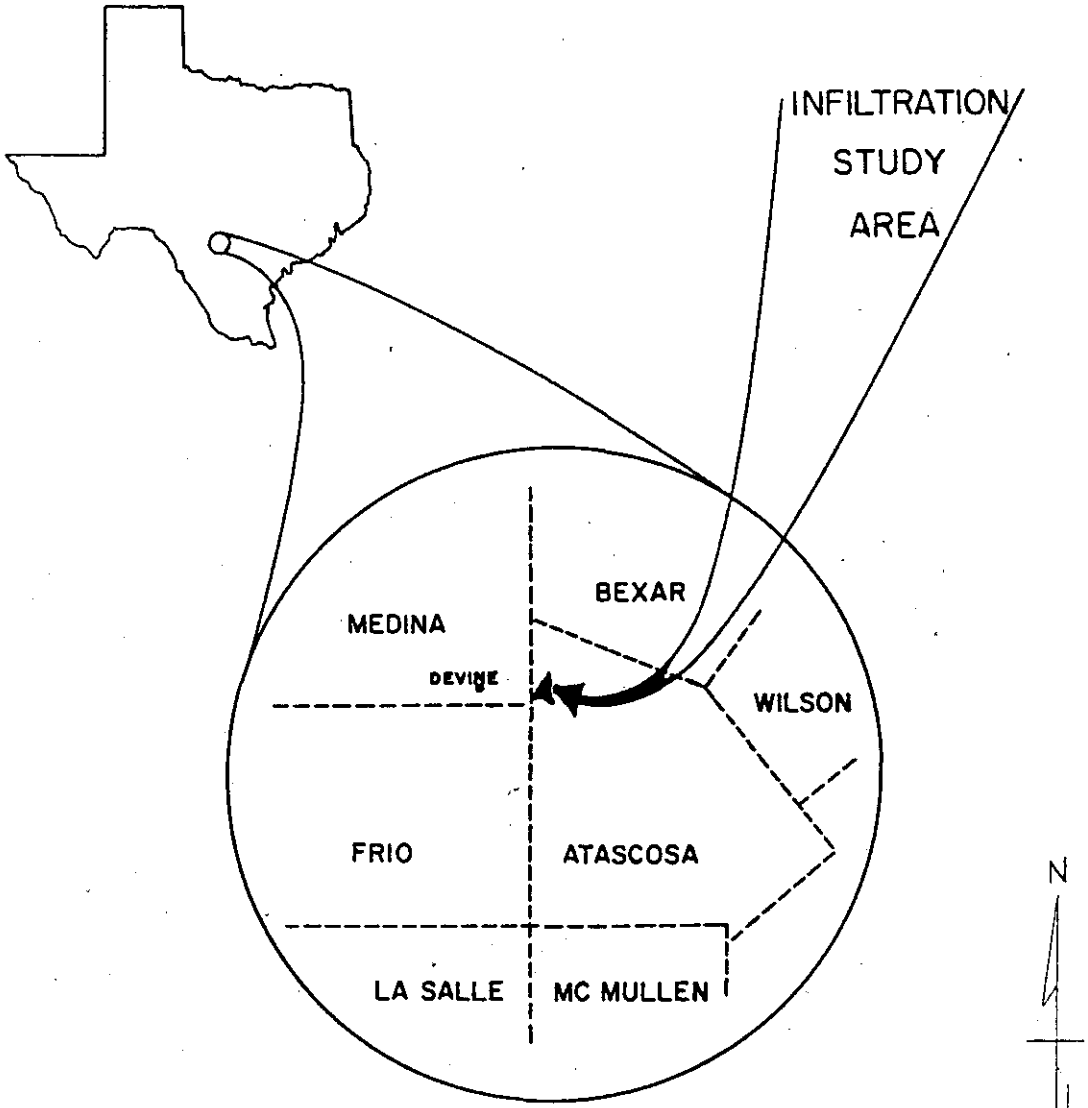


Figure 1

Location Map

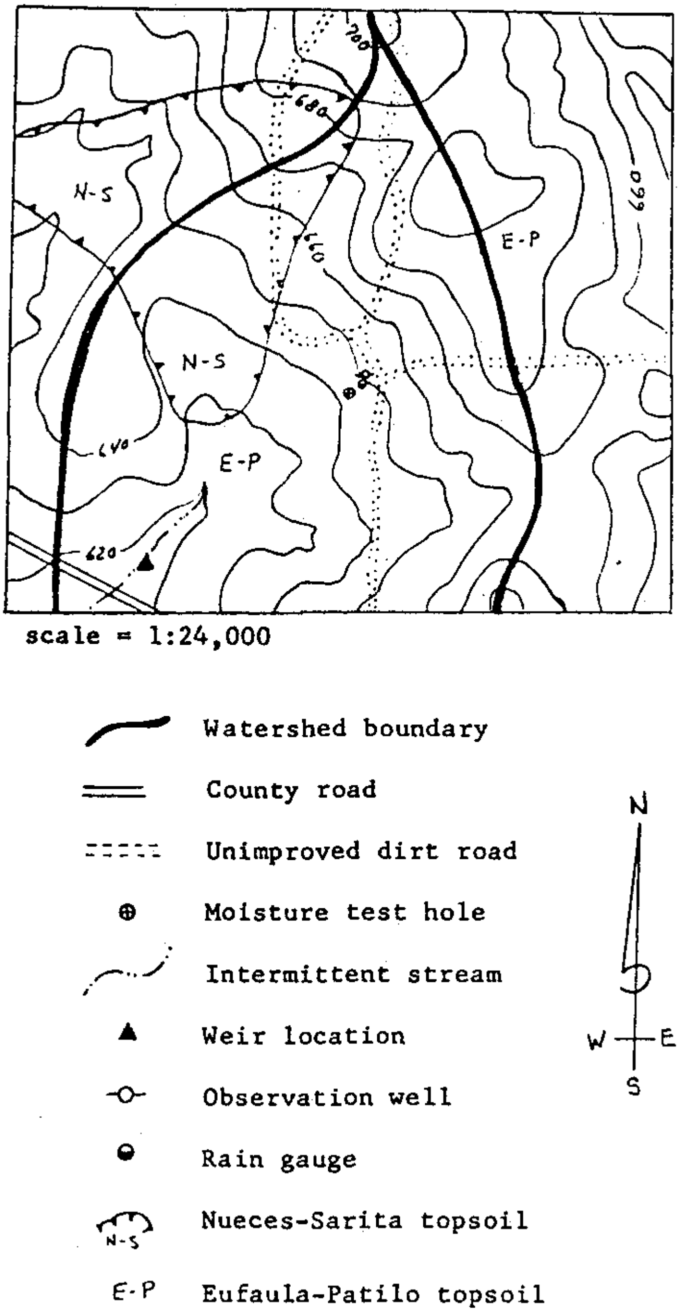


Figure 2
Topographic Map

Geohydrology

The following discussion on geohydrology refers to the Carrizo aquifer in the study area and not to the entire extent of the aquifer. The Carrizo aquifer consists mainly of fine to medium-grained sand interbedded with layers of sandy clay. Saturated thickness of the Carrizo aquifer in January, 1977 was about 300 feet (91.4 meters) and the water levels were about 150 feet (45.7 m) below land surface. The estimated total porosity and specific yield of the aquifer are about 34 and 28 percent respectively (Duffin, 1977). The aquifer's transmissibility is estimated to be about 120,000 gallons per day per foot (1,490,160 liters per day per meter) and the permeability is estimated to be about 400 gallons per day per square foot (16,296 liters per day per square meter) (Klemt, 1976).

Soils

Soils in the study area are typical of the Carrizo outcrop with topsoils ranging in composition from 80 to 90 percent pure silica and subsoils ranging from 40 to 60 percent clay (Lonsdale, 1935). The thickness of the topsoil varies from 0.8 feet (24.4 cm) up to 4 feet (1.2 meters) and averaging about 2 feet (0.61 m). Subsoil depth is arbitrarily chosen to the total depth of the 20 foot (6.10 m) moisture test hole. Sandy clay layers in the subsoil, alternating with sand and sandy clay, range from predominately red to yellow, orange, white, and green. Figure 3 shows the soil profile of the test hole which is located near the center of the watershed. Zones of evapotranspiration and deep percolation are shown on the soil profile.

There are two soil types in the watershed, the Nueces-Sarita and the Eufaula-Patilo soils. The grey-brown colored Nueces-Sarita is a fine, sandy loam 36 to 40 inches (91.4 - 101.6 cm) thick. The white-tan colored Eufaula-Patilo also is a fine, sandy loam, 20 to 40 inches (50.8 - 101.6 cm) thick. These two soil types differ most significantly in that the Eufaula-Patilo sandy loam has

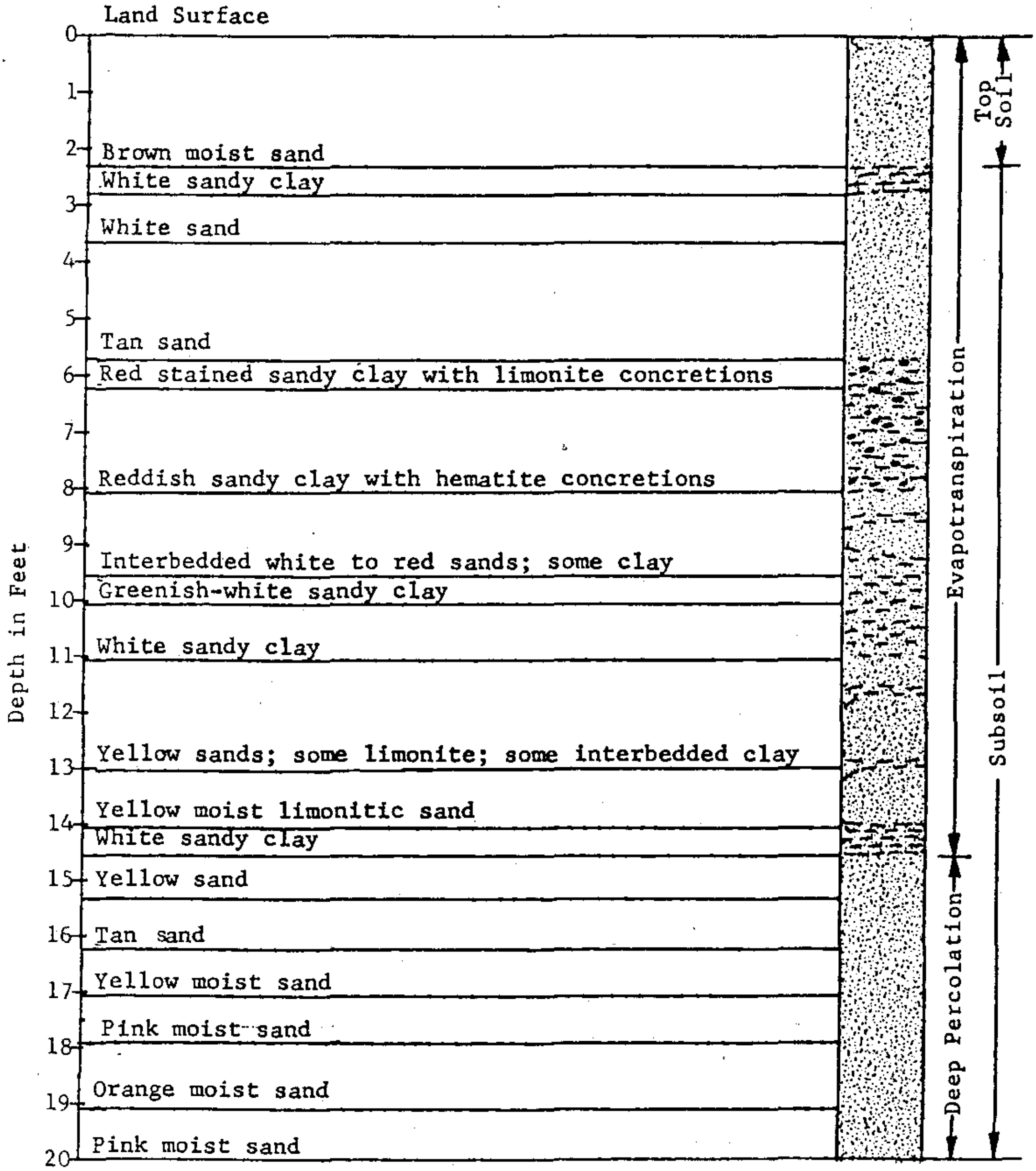


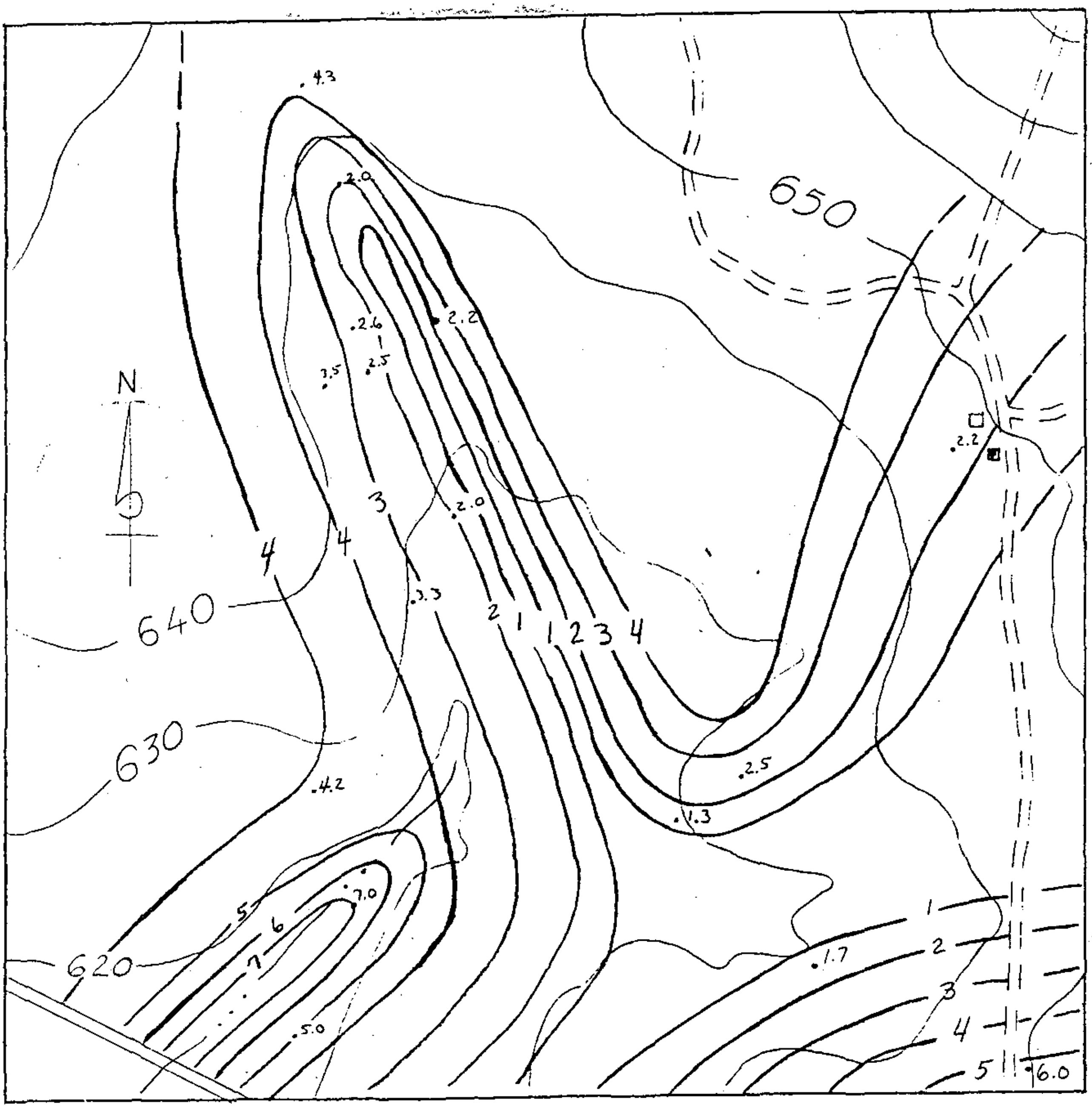
Figure 3
Soil Profile at Test Hole

less clay in its profile and generally contains less moisture than the Nueces-Sarita sandy loam. Both soils, as shown in Figure 2, were weathered from sandy clay loam subsoils and are listed by the Soil Conservation Service as being very slowly permeable. The Texas Department of Water Resources' Materials Testing Laboratory found the Eufaula-Patilo subsoil's permeability to be 3.93 x 10^{-8} cubic inches per hour (1.79 x 10^{-10} milliliters per second). The very low permeability of this subsoil is offset by the subsoil's tendency for cracking when dry. These drying and cracking tendencies allow for the subsoil to be much more permeable when dry.

The sandy clay subsoils throughout the area are important as reservoirs of soil water because of their ability to store more water than can the sandy topsoils. Average moisture holding capacity of clay soil ranges from 300 to 400 percent higher than the moisture holding capacity of sandy soil (Carter, L-244).

Stream drainage in the study area is not well developed because of the sandy soils ability to absorb water rapidly in large amounts. As evidence of the sandy topsoil's ability to absorb rainfall, runoff during the study period amounted to only about 0.2 acre-feet (2.47 x 10^{-4} cubic hectometers).

Surface drainage in the study area does not greatly affect infiltration and deep percolation. However, subsurface drainage or horizontal flow does occur due to clay beds which results in perched soil-water in several locations. The depth to the top of the subsoil is shown by contours on Figure 4. The differential permeabilities of the topsoil and sandy clays within the subsoil in the study area, 6.3 - 20 cubic inches per hour (103.3 - 328 milliliters per hour) (SCS, 1976) and 3.93 x 10^{-8} in ^{3}/hr (6.4 x 10^{-7} ml/hr) respectively, permit initial rapid uptake of water by the topsoil but the water is unable to pass freely through the subsoil. The water then flows down gradient on top of the subsoil until it reaches the surface and forms a seep, or until it reaches a basin which will perch the soil-water. Both of the above examples still allow



3 — Contours showing depth in feet of topsoil

640 — Contours on ground surface

Unimproved road

Improved road

•2.0 Depth in feet to subsoil

Figure 4

Depth to Top of Subsoil

for percolation through the subsoil but the amounts of soil-water available for percolation are seriously reduced by being either perched high in the soil profile subject to evapotranspiration or exposed at the ground surface. The amount of horizontally flowing soil-water is significant in that it represents a major limitation to increasing rates of both rainfall infiltration and deep percolation into the Carrizo aquifer.

Vegetation

Vegetation in the watershed consists of Blackjack Oak, Live Oak, Wild Walnut, brush, and annual and perennial native grasses. While much of the study area is in unimproved pasture, peanuts, watermelons, and maize are crops which are grown on cultivated fields.

Climate

The climate of the study area is semiarid with rainfall averaging 25 inches (63.5 cm) annually (Carr, 1976). Tucker and Griffiths (1965) place the probability of receiving between 30 inches (76.2 cm) and 40 inches (1.02 m) of rainfall annually in the study area as ranging between 6 and 35 percent. According to the above statistics, the 35.35 inch (89.8 cm) rainfall from April 5, 1976 to April 4, 1977 represented a very wet year for the study area.

METHOD OF INVESTIGATION

A neutron moisture logging tool was used to determine the amount of soil moisture going to deep percolation. The neutron moisture tool indirectly measures the moisture content by measuring the concentration of hydrogen in the soil. Hydrogen in the soil generally is in the form of water and the amount of hydrogen is therefore proportional to the amount of water in the soil. This technique for measuring soil moisture content has the advantage that it is a nondestructive method which allows repeated measurements on an undisturbed, in-place sample. An example of a neutron moisture log showing a soil moisture buildup is shown in Figure 5.

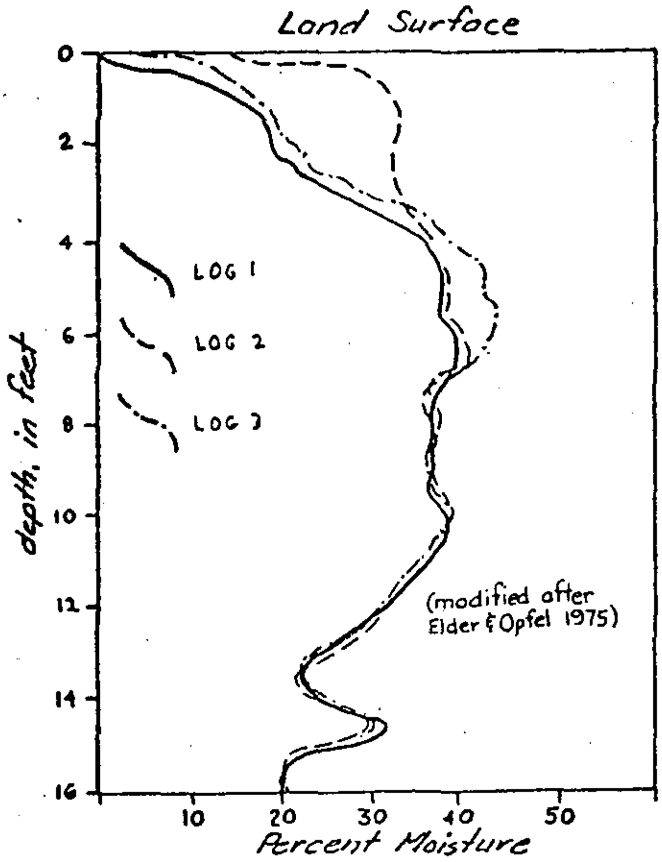


Figure 5
Indication by Neutron Logs of a Moisture Buildu

The logs in Figure 5 illustrate the successive buildup and the downward movement of accumulated moisture. Moisture Log 1 was arbitrarily selected as the base log to which successive logs would be compared. An increase in moisture in the upper four feet (1.22 m) of the soil profile is indicated by Moisture Log 2 as a deflection to the right of the base log. This is typical of what would be expected shortly after a rain. Moisture Log 3 is recorded after a period of two weeks and reflects the rate of movement of the moisture accumulation. The moisture front has percolated downward between four feet (1.22 m) and seven feet (2.13 m). The upper four feet (1.22 m) has since returned to almost the same position as occupied two weeks previously. This same principle also applies to the logs shown in Appendix A, however, in this study the primary concern was with the amount of water moving through a zone, rather than the rate of movement of a moisture front.

The neutron moisture logs (Appendix A) were taken from April 5, 1976 to April 4, 1977 as near to a weekly basis as possible. The logs were used to determine the amount of soil moisture which moved through a particular interval and eventually entered the zone of saturation. The interval under consideration was the 14.5 - 19 foot (4.42 - 5.79 m) interval. It consists mostly of clean sands "capped" by a layer of sandy clay as shown on the soil profile in Figure 3 and is considered to be the recharge threshold. The depth to the recharge threshold was based on the depth of feeder roots of trees growing in this watershed. Soil moisture gains and losses were established for this interval by comparing the area of the first log in April, 1976 to the area of the second log in April, 1976. The area of the second log was compared to the area of the third log. This routine was continued with all the logs. The difference in area between each log was then converted to percent moisture by using the graph in Figure 6.

The graph was derived by plotting different percentages of moisture versus the area of a 4.5 foot (1.37 m) interval using an unused portion of the recording strip chart. The area values on the graph have no units as they are planimeter readings. They could be converted to square inches or other units by multiplying them by the appropriate factor. This, however, would be an additional time-consuming step and is unnecessary. Close inspection of the strip chart paper reveals that the percent lines are not equidistant. The lines in the center of the strip chart are closer spaced than those on each side. This is to compensate for the recording needle which pivots at the center of the strip chart. The one percent lines from zero to five percent and from 45 to

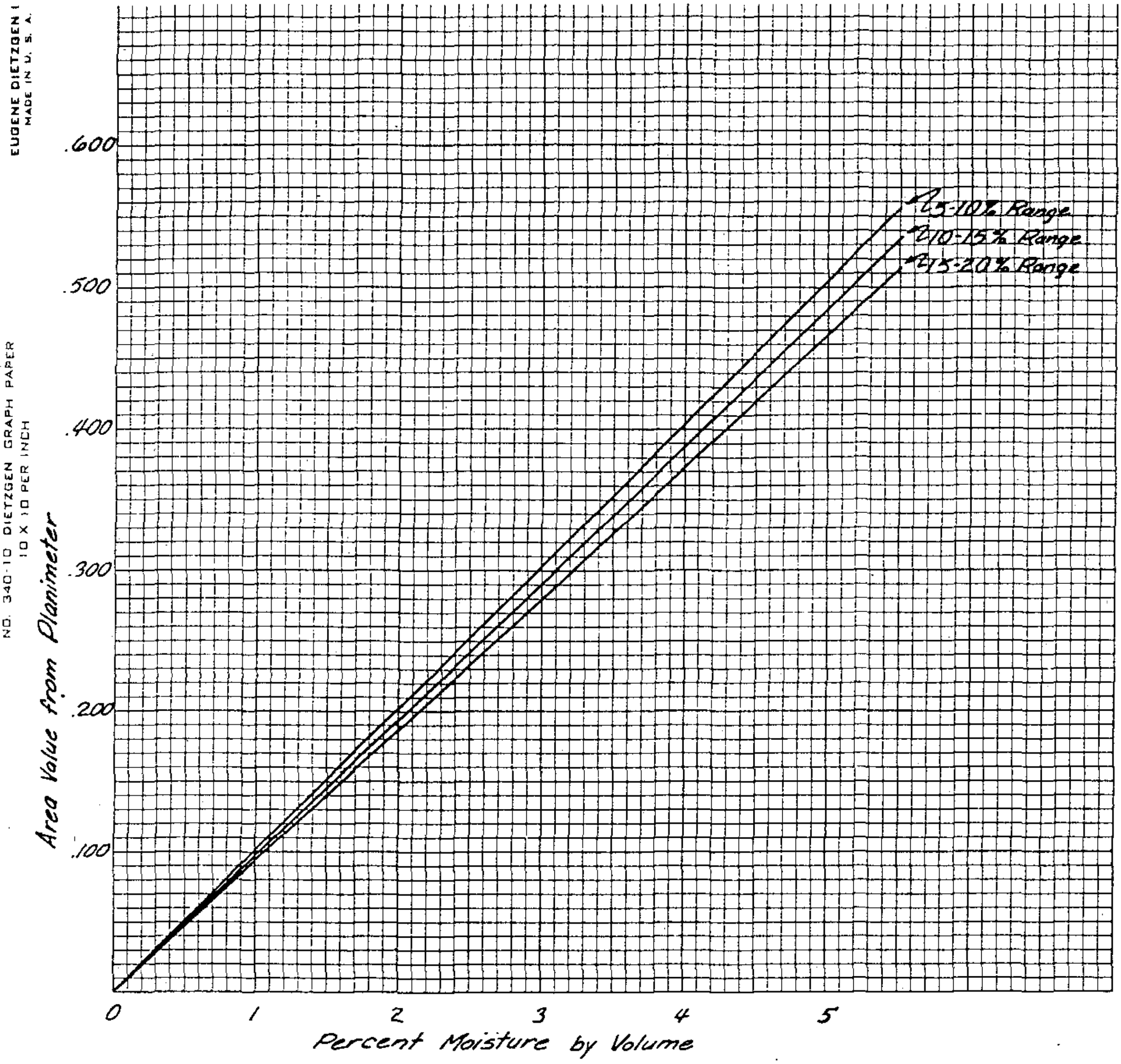


Figure 6

Relation Between Percent Moisture and Planimetered Areas of Moisture

50 percent are equidistance as are the 5 to 10 and 40 to 45 percent groups. Therefore it was necessary to graph the area of each 5 percent group from zero to 25 percent. It became necessary then when determining the moisture loss or gain to select the appropriate graphed line in Figure 6 according to the percent moisture range in which the change between the two compared logs occurred. Change in only one five-percent range rarely occurs, therefore, the range in which most of the change in moisture between any two logs took place was selected to determine the percent moisture lost or gained. During this study some drift was experienced in the recording needle. To compensate for this drift it was decided to planimeter the area of each log and convert area to percent moisture. Another reason for planimetering a 4.5 foot (1.37 m) interval was to include any downward moving moisture fronts. This method also avoided the necessity of taking an infinite number of moisture readings from the logs to arrive at an average percent moisture.

Annual deep percolation was calculated by adding the moisture losses in the 14.5 - 19 foot (4.42 - 5.79 m) interval as derived from the year's accumulation of neutron moisture logs by the above described methods. The moisture losses are considered as percent moisture passing through a horizontal plane. The horizontal plane in this instance is the 14.5 - 19 foot (4.42 - 5.79 m) interval. The monthly moisture losses are tabulated in Table 1 along with runoff and rainfall and show that a total of 207 acre-feet (0.26 cubic hectometers) of the total rainfall was recorded as going to deep percolation.

However, during this one year period five weeks were unrecorded. To compensate for the unrecorded period an average weekly moisture loss was calculated to arrive at an estimated annual moisture loss of 229 acre-feet (0.28 cubic hectometers). This quantity of moisture loss amounts to about 16.5 percent of the total annual rainfall.

Table 1 -- Tabulation of Rainfall, Runoff, and Deep Percolation

	Rainfall (inches)	Rainfall (ac-ft)	Runoff (ac-ft)	Deep Percolation (ac-ft)
From April 5, 1976	4.00	156.7	0	9.42
May	5.80	227.2	0	12.30
June	0.45	17.6	0	23.89
July	4.40	172.3	0	20.73
Aug.	2.00	78.3	0	10.23
Sept.	3.55	139.0	0	15.31
Oct.	7.25	284.0	0	23.47
Nov.	2.80	109.7	0	10.51
Dec.	1.85	72.5	0.08	13.52
Jan. 1977	2.05	80.3	0.12	12.34
Feb.	0.40	15.7	0.02	28.32
Mar.	0.35	13.7	0	26.95
To April 4, 1977	0.45	17.6	0	0.00
	35.35	1,385	0.22	207

207 acre-feet for 47 weeks = 4.404 acre-feet per week

4.404 acre-feet x 52 weeks = 229 acre-feet per year

$$\frac{229 \text{ acre-feet} \times 100}{1{,}385 \text{ acre-feet}} = 16.5 \text{ percent}$$

CONCLUSIONS

When comparing ground-water levels in the observation well, deep percolation and precipitation (Figure 7), there appears to be fairly good correlation between deep percolation and water levels. The sharp water level declines in June, July, and August are attributed primarily to heavy pumpage from two nearby irrigation wells.

It is evident that the amount of recharge is influenced by factors other than just quantity of rainfall. One factor is the duration of the rainfall. In most instances the rainfall duration was relatively short, ranging from about fifteen minutes to about two hours. The time interval between many of the rains was of sufficient length to allow most of the precipitation to be lost to evapotranspiration.

The occurrence of surface runoff and sub-surface lateral drainage were observed as an increase in baseflow at the weir site only from November, 1976 through March, 1977. Measurable quantities of runoff occurred only during December, 1976 through February, 1977 and amounted to approximately 0.2 acre-feet (2.47×10^{-4} cubic hectometers).

Deep percolation has remained at a relatively stable position throughout the year. The estimated average annual deep percolation was calculated to be 229 acre-feet (0.28 cubic hectometers) for the study area. This amounts to about 16.5 percent of the total annual rainfall which will ultimately recharge the Carrizo aquifer.

RECOMMENDATIONS

The authors recommend the development of techniques for faster installation of access tubes and that access tubes be not less than 30 feet (9.14 m) in depth. Installation of tubing 30 feet (9.14 m) or greater in depth will allow for longer lapse of time between logging periods without missing a moisture front. Access tubes should also be installed in several different types of

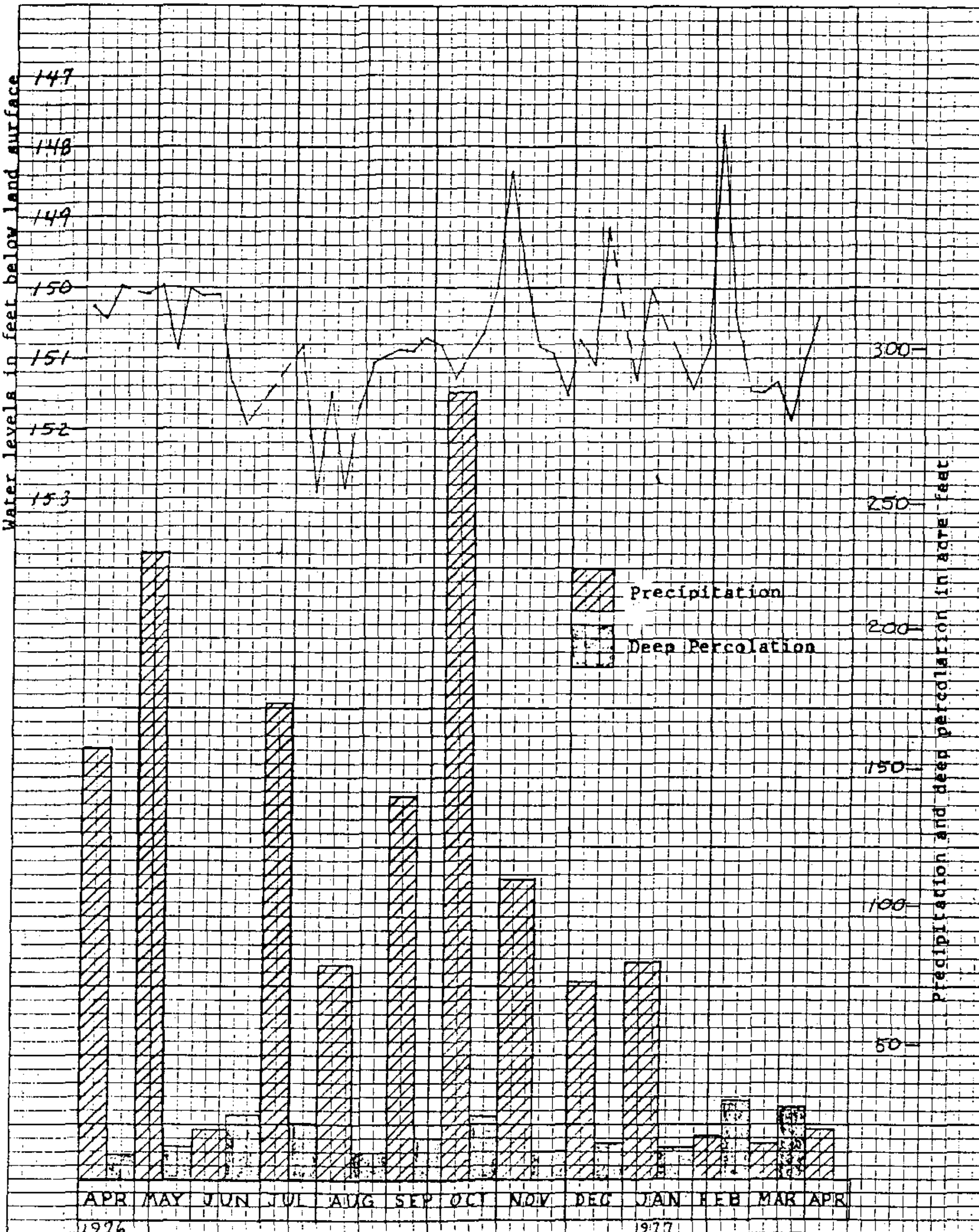


Figure 7

Bar Graph of Precipitation and Deep Percolation with Hydrograph of Observation Well (AL68-58-204) vegetation at each test site to discern differences in rate of moisture movement. Logging of test holes should be accomplished each day until the rate of movement is established.

The authors also recommend that additional soil moisture test sites be established in the Carrizo outcrop near previously studied seismic profile sites.

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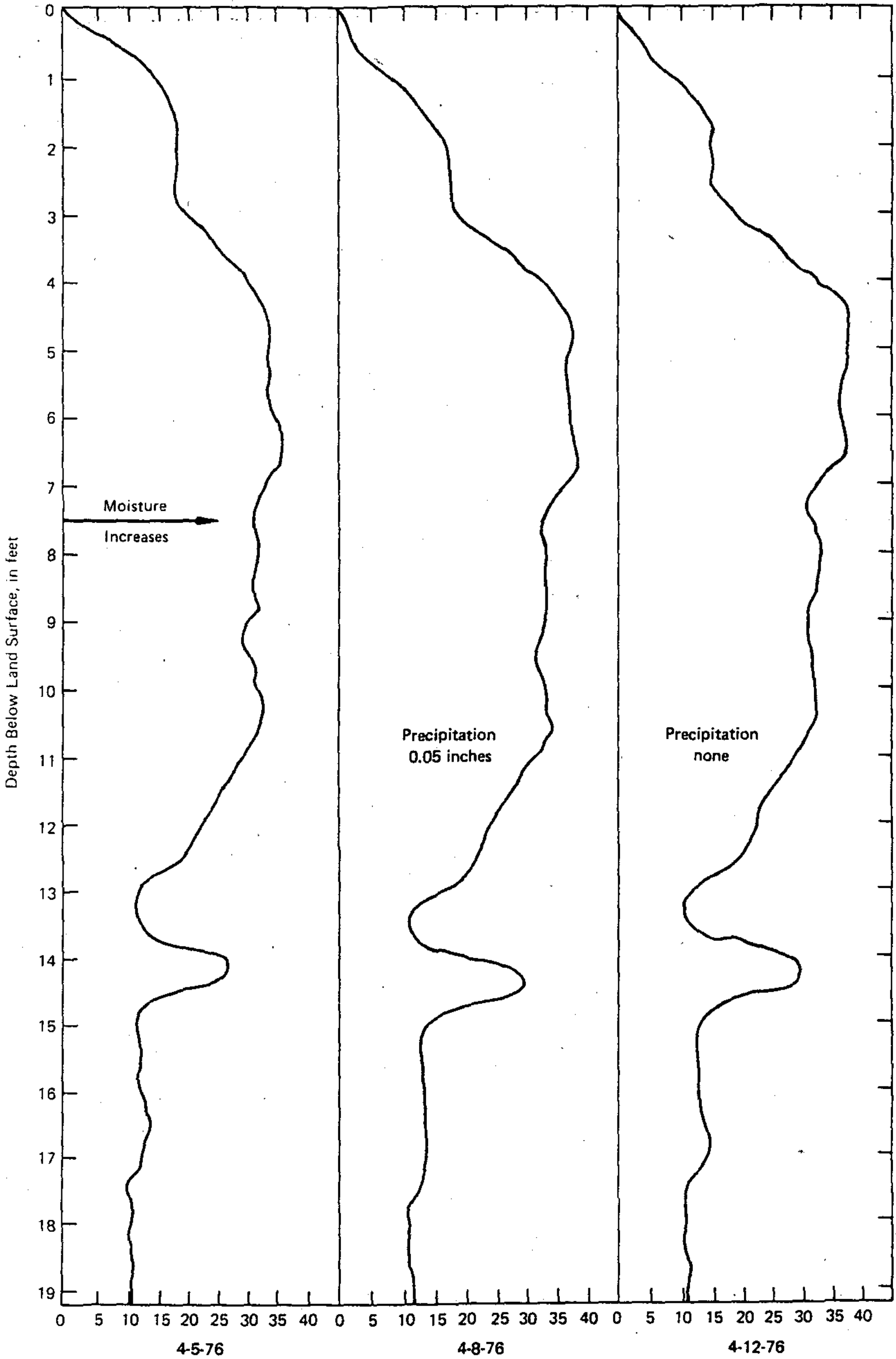
Depth Below Land Surface, in feet
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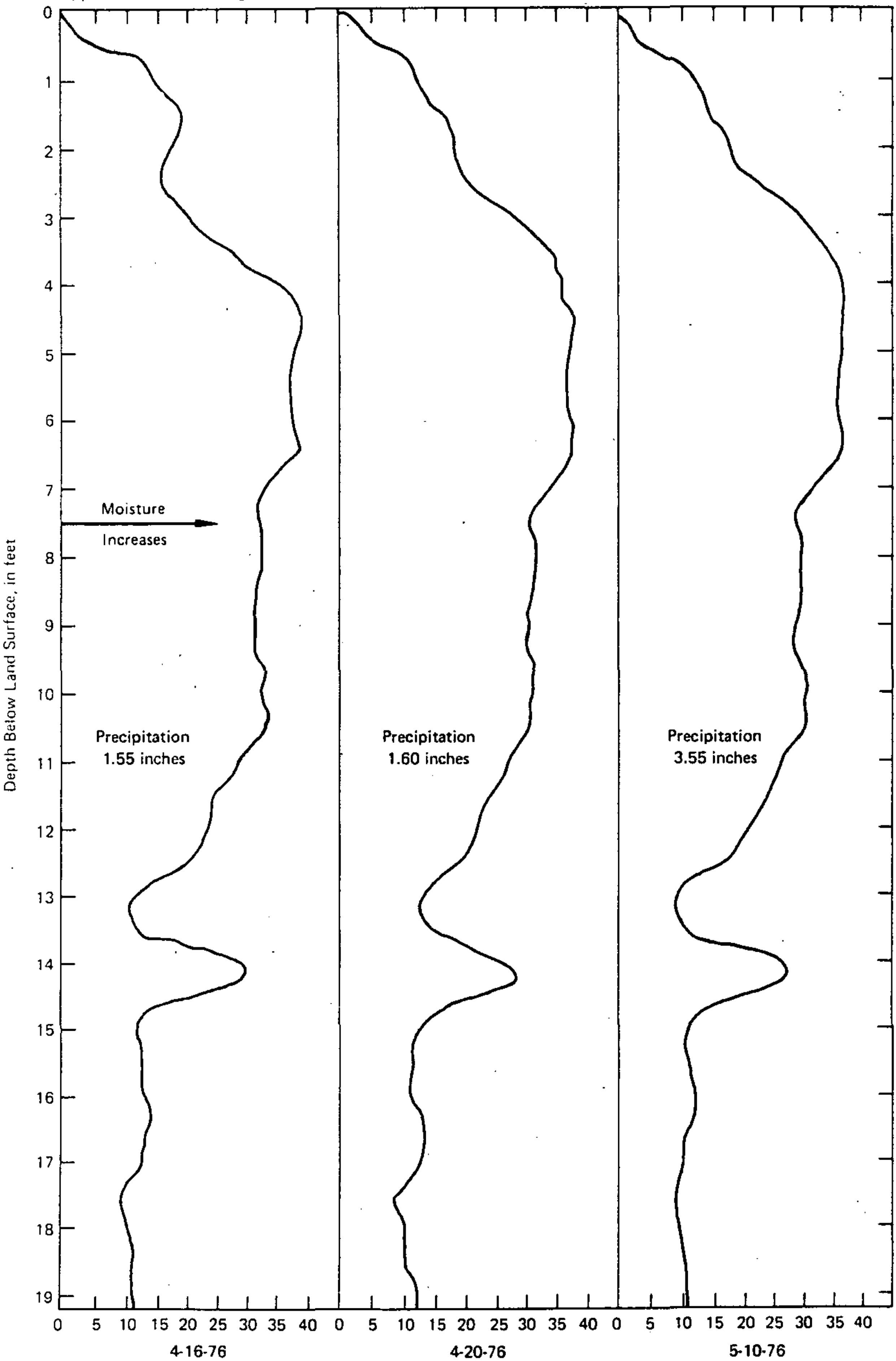
Moisture
Increases
0 5 10 15 20 25 30 35 40
4-5-76
Precipitation
0.05 inches
0 5 10 15 20 25 30 35 40
4-8-76
Precipitation
none
0 5 10 15 20 25 30 35 40
4-12-76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Moisture
Increases
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1.55 inches
Precipitation
1.60 inches
Precipitation
3.55 inches
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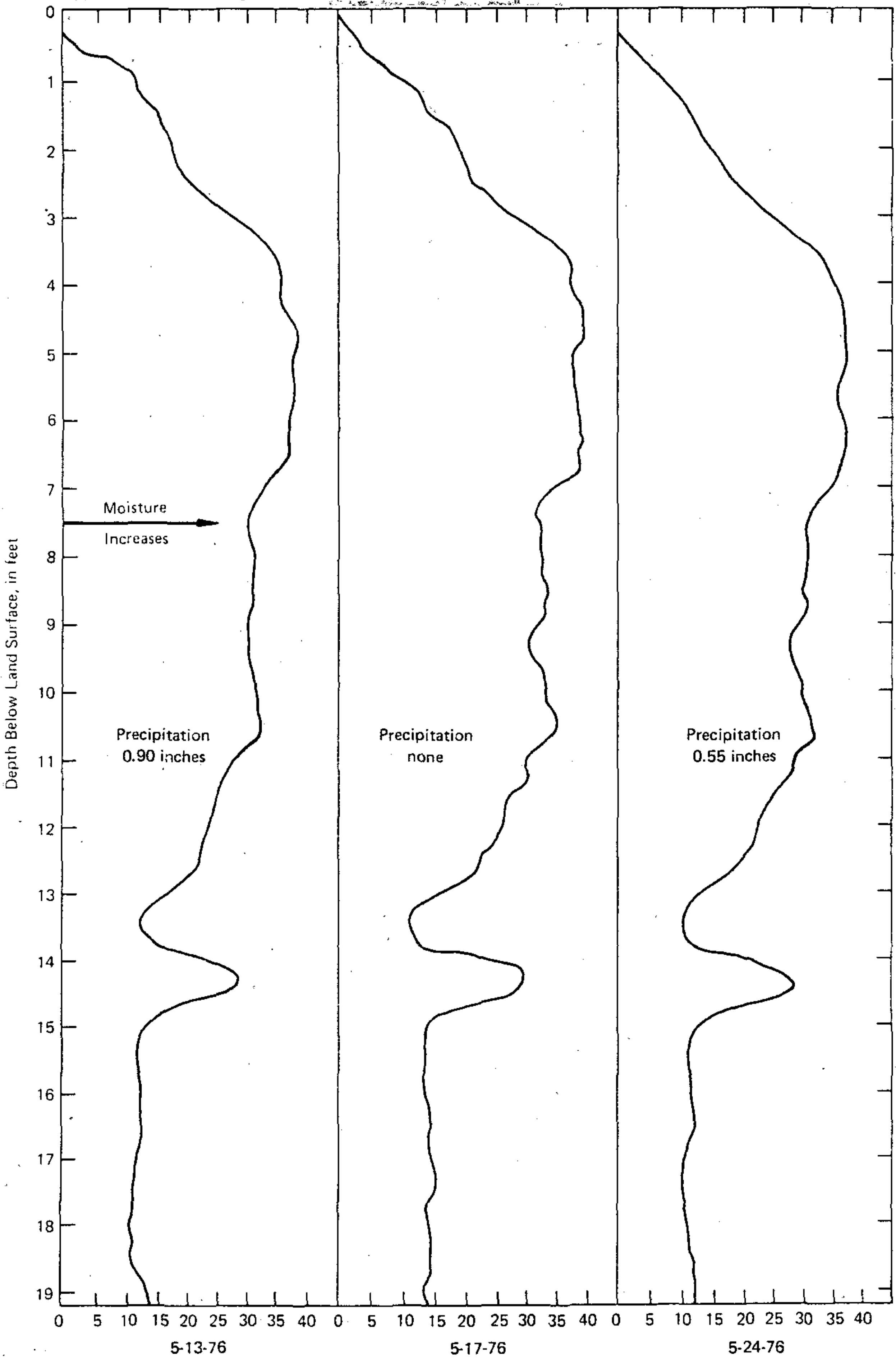
0 5 10 15 20 25 30 35 40
4-20-76
0 5 10 15 20 25 30 35 40
5-10-76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Moisture
Increases
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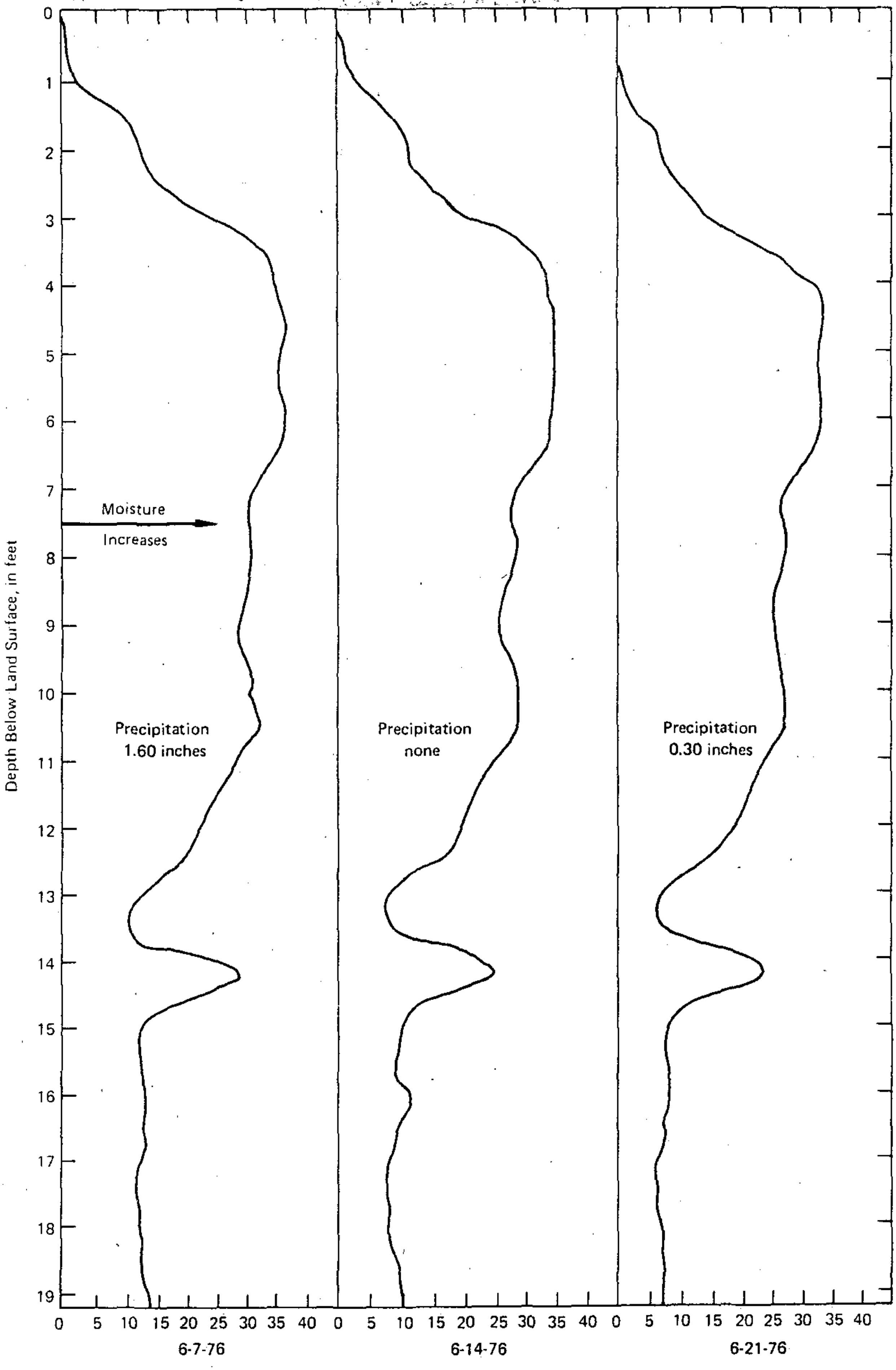
5-24-76



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Moisture
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0.30 inches
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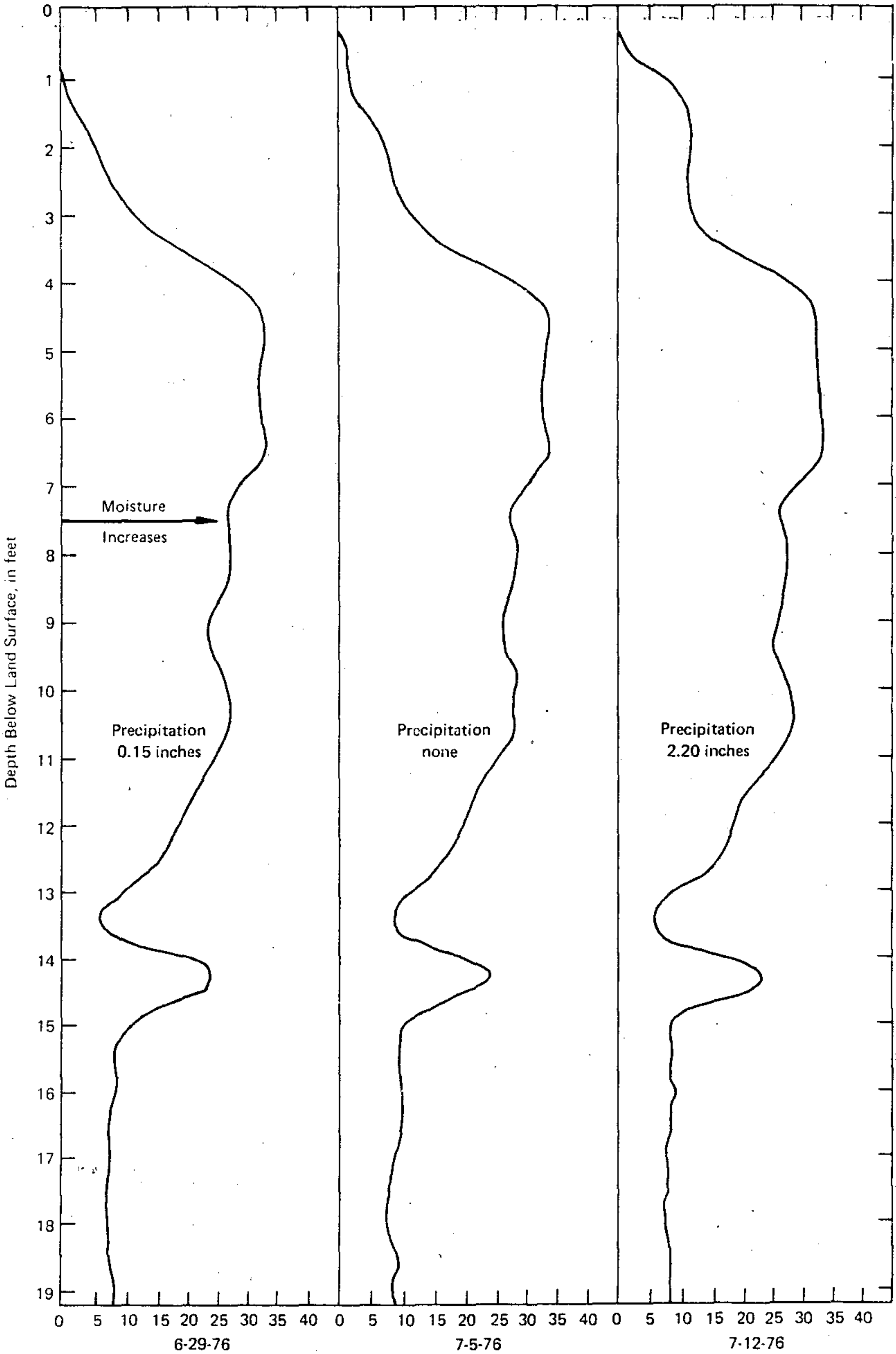
6-21-76



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Moisture
Increases
Precipitation
0.15 inches
Precipitation
none
Precipitation
2.20 inches
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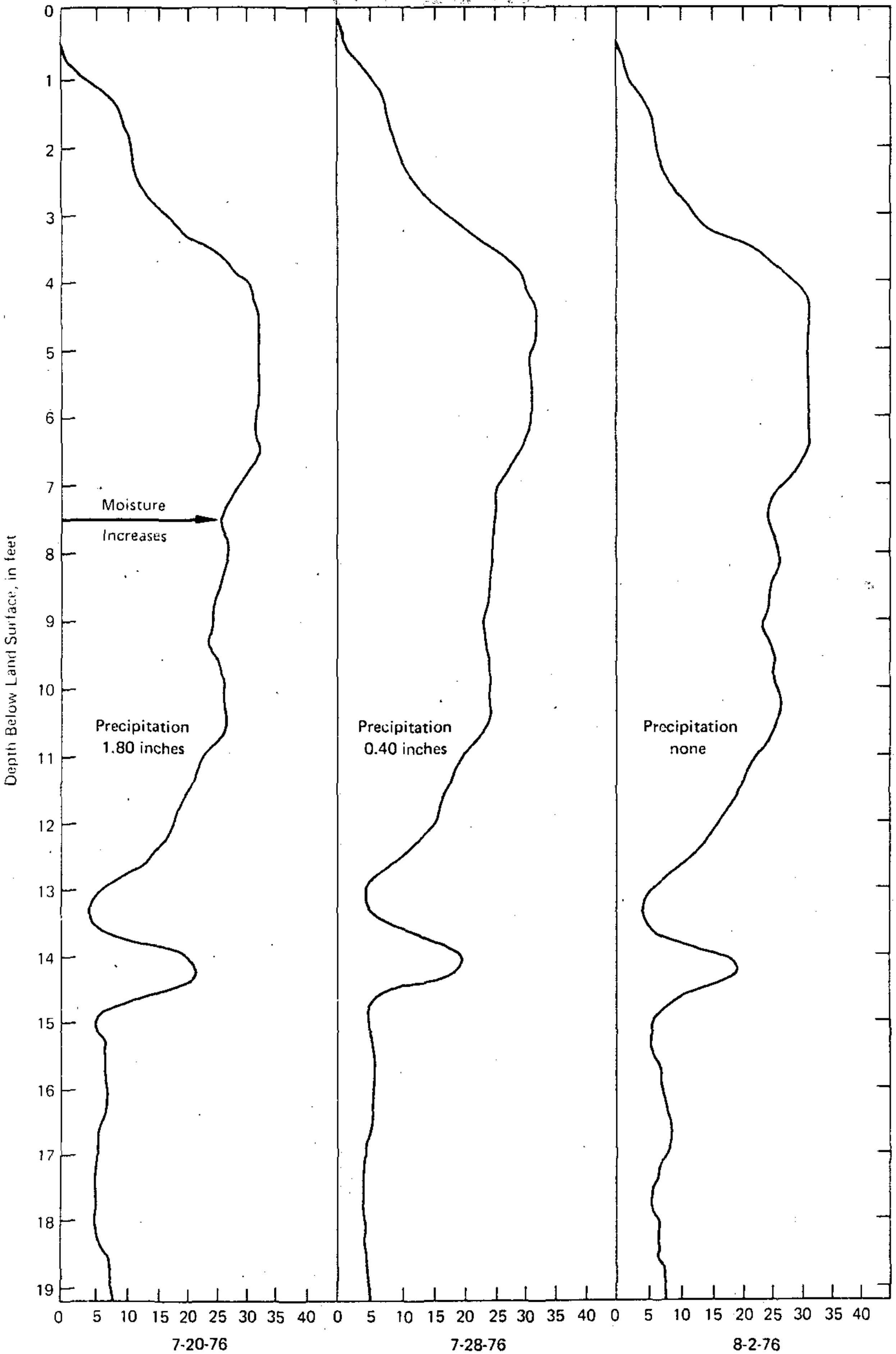
7-5-76
0 5 10 15 20 25 30 35 40
7-12-76


Depth Below Land Surface, in feet
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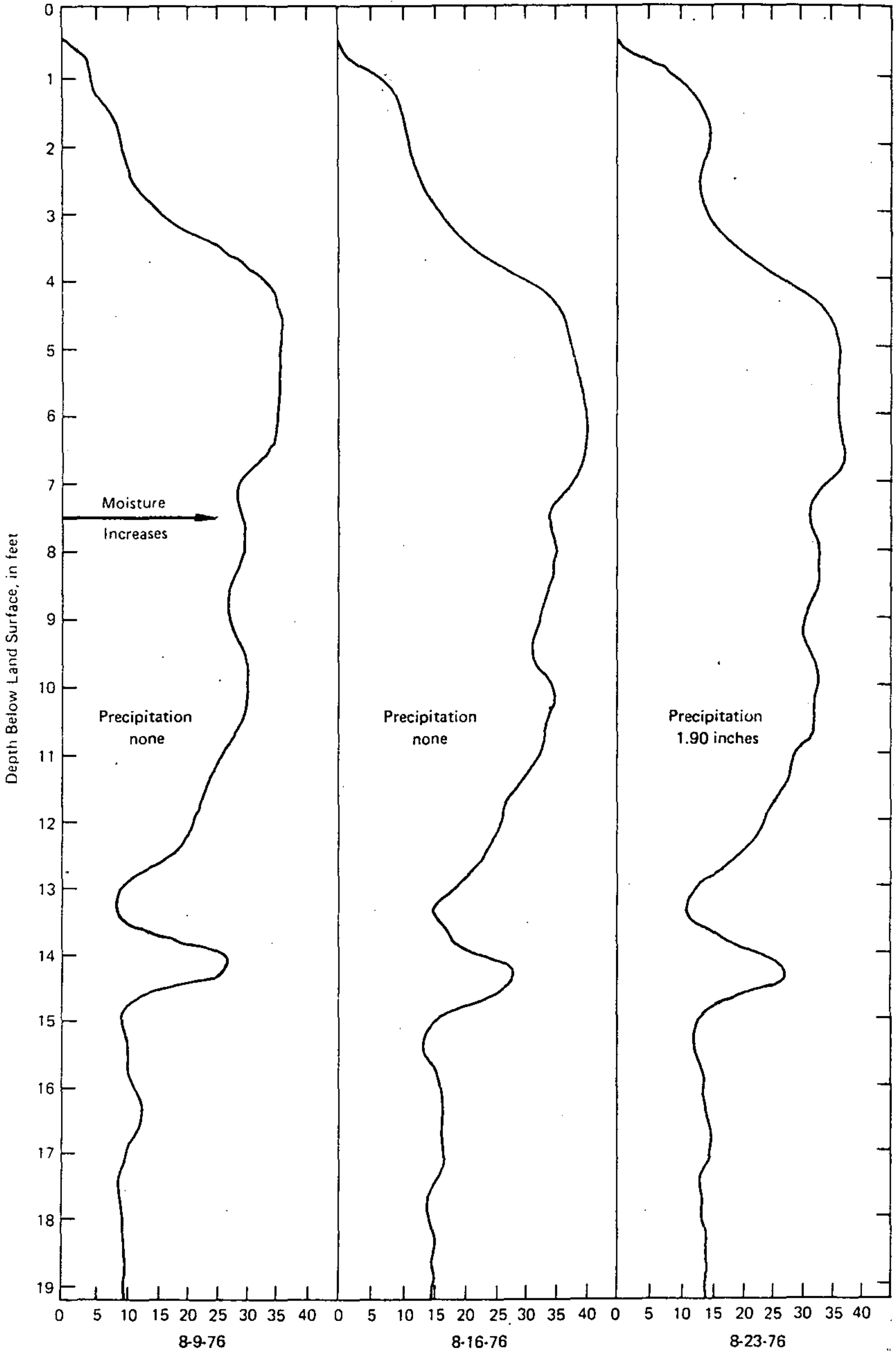
8-2-76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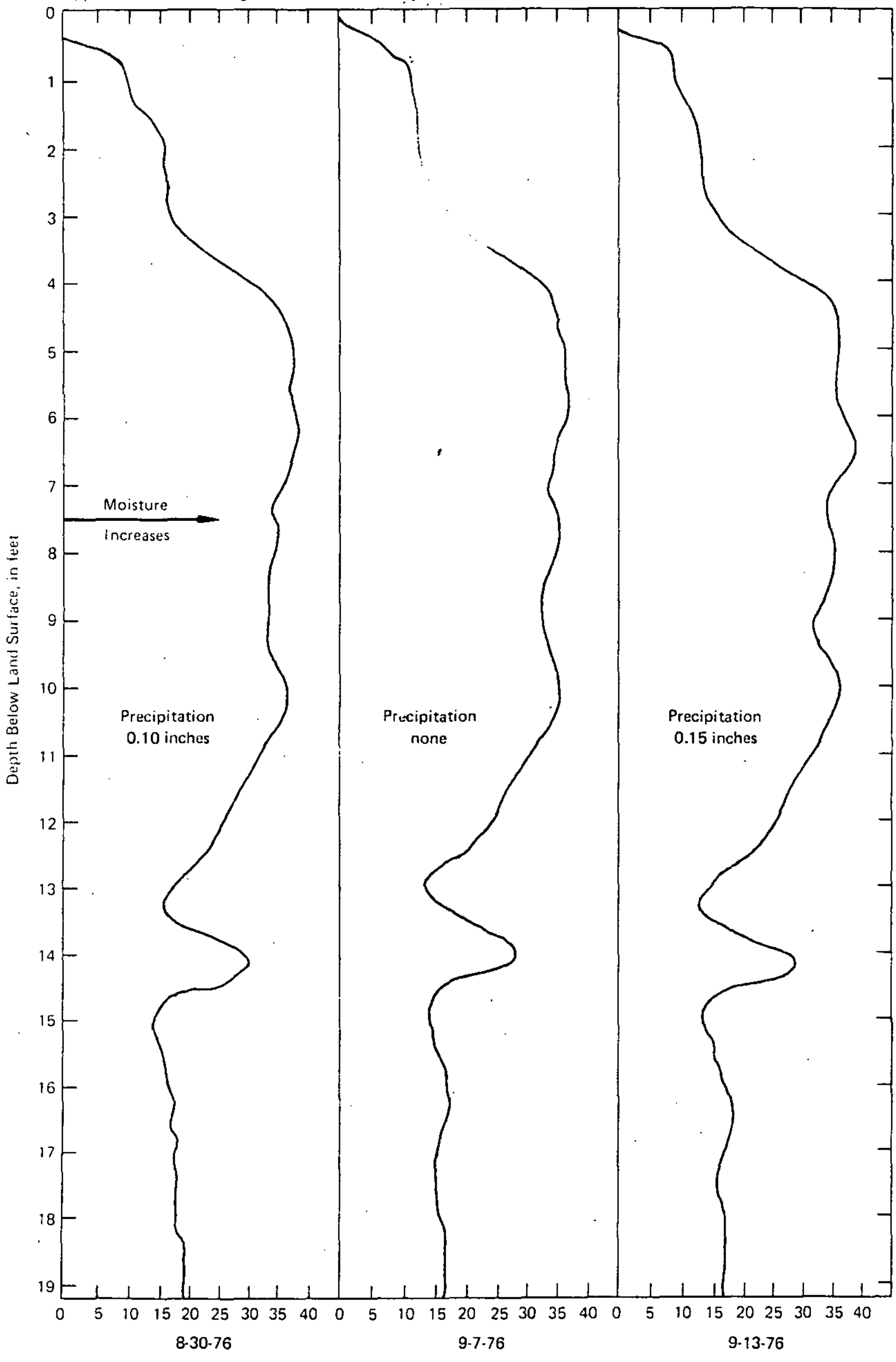
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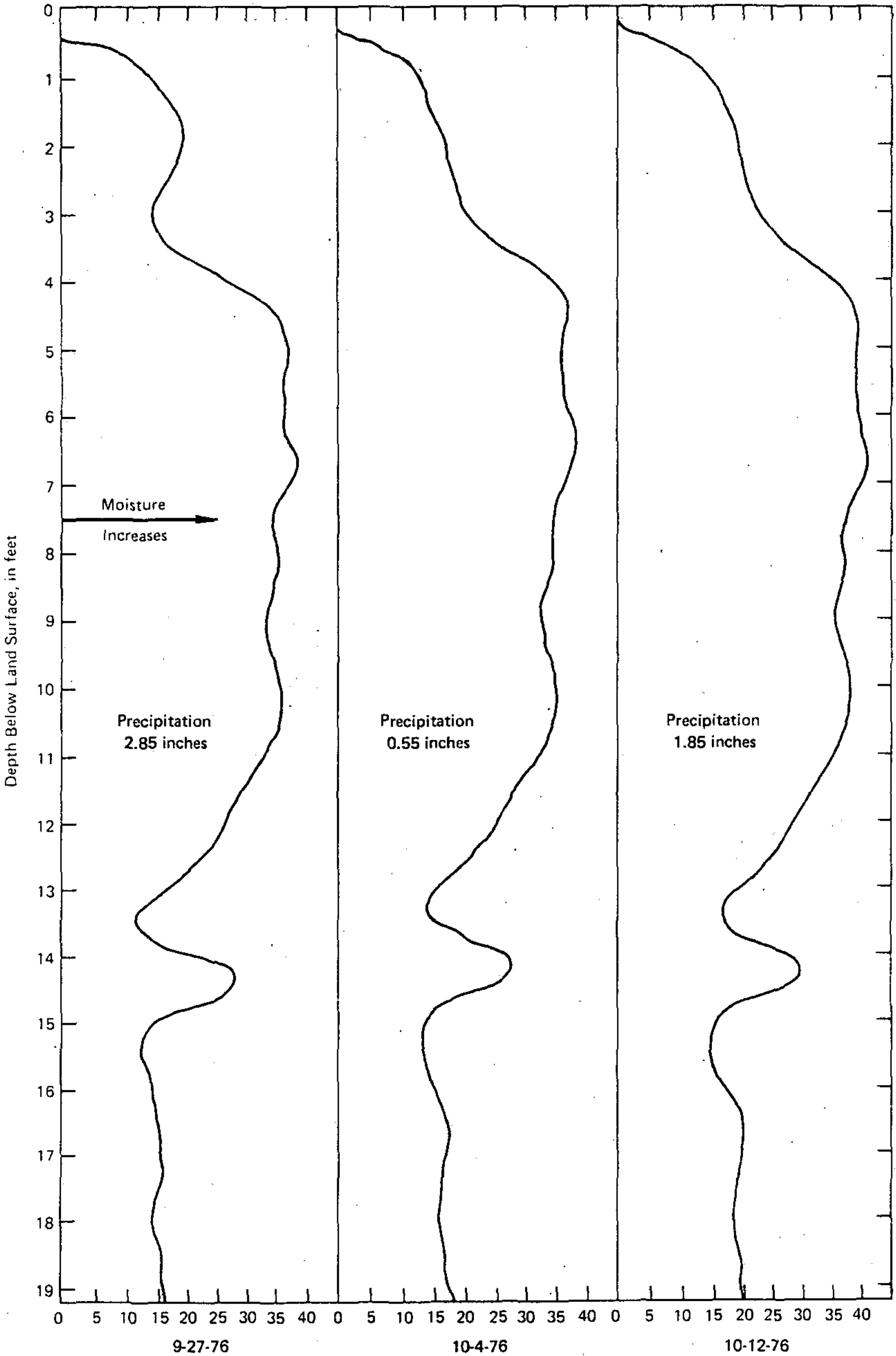

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Moisture
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Precipitation
2.85 inches
Precipitation
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Precipitation
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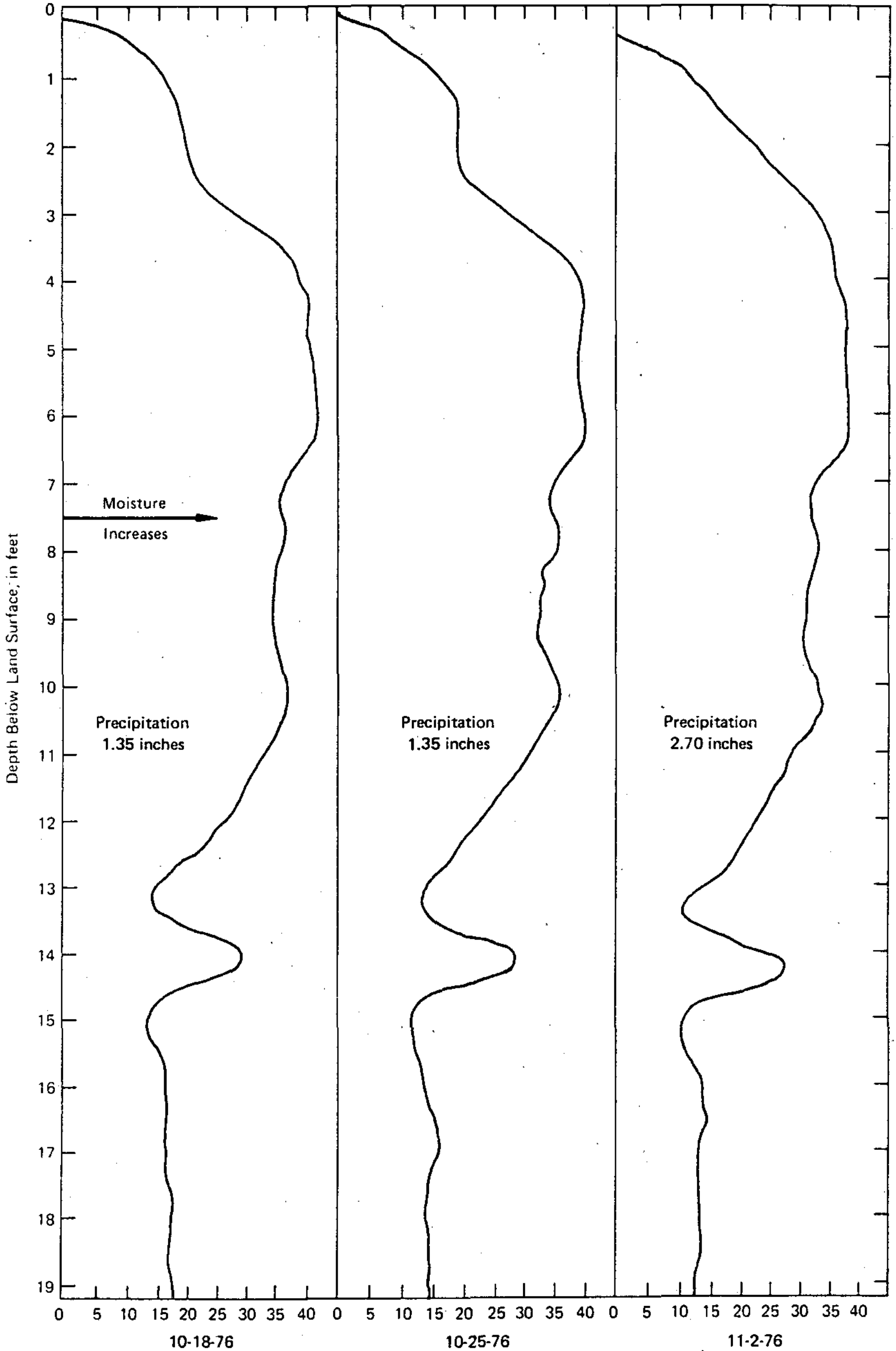
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Moisture
Increases
Precipitation
1.35 inches
Precipitation
1.35 inches
Precipitation
2.70 inches
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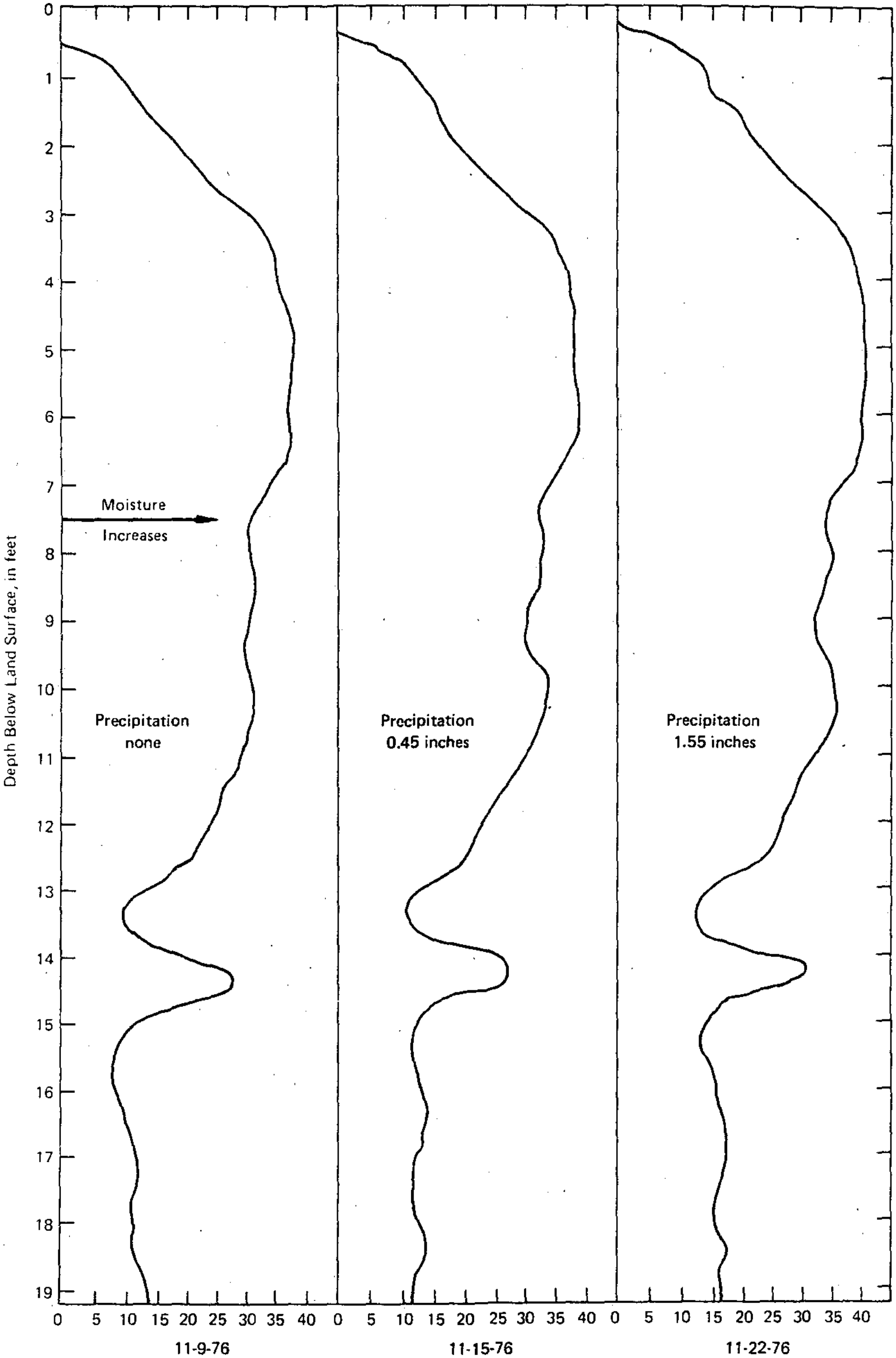
11-2-76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Moisture
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Precipitation
0.45 inches
Precipitation
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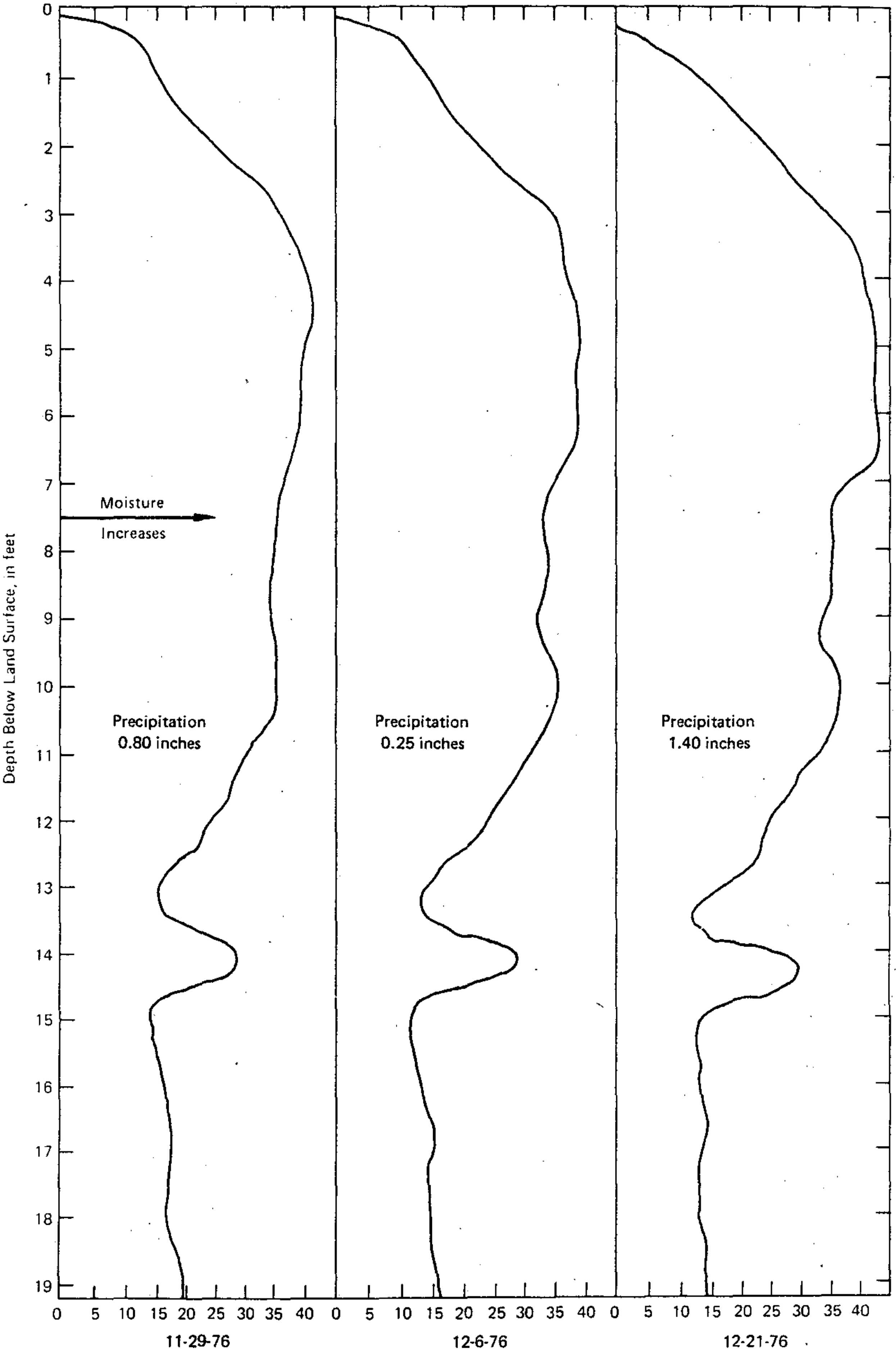
11-15-76
11-22-76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12
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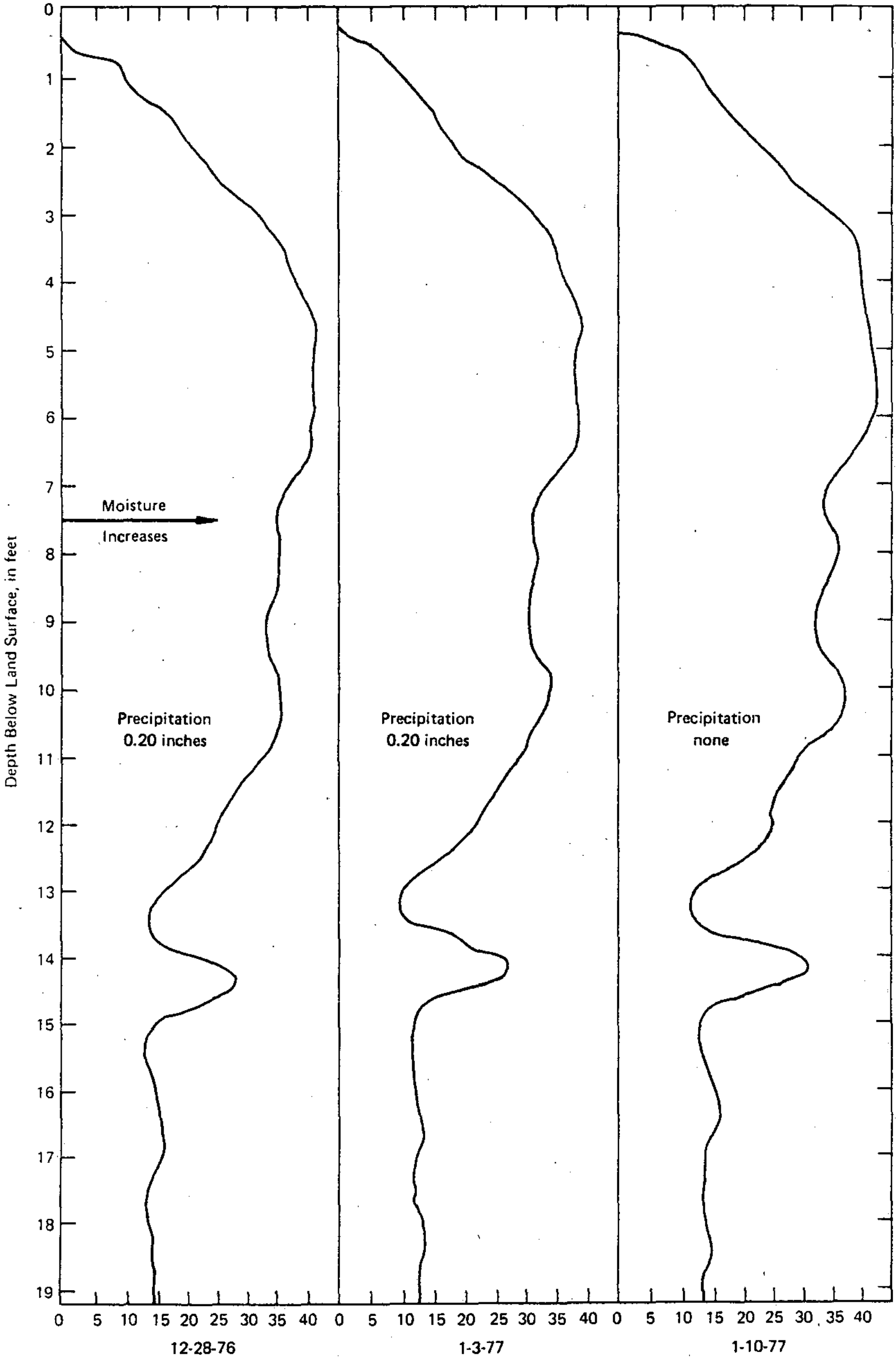
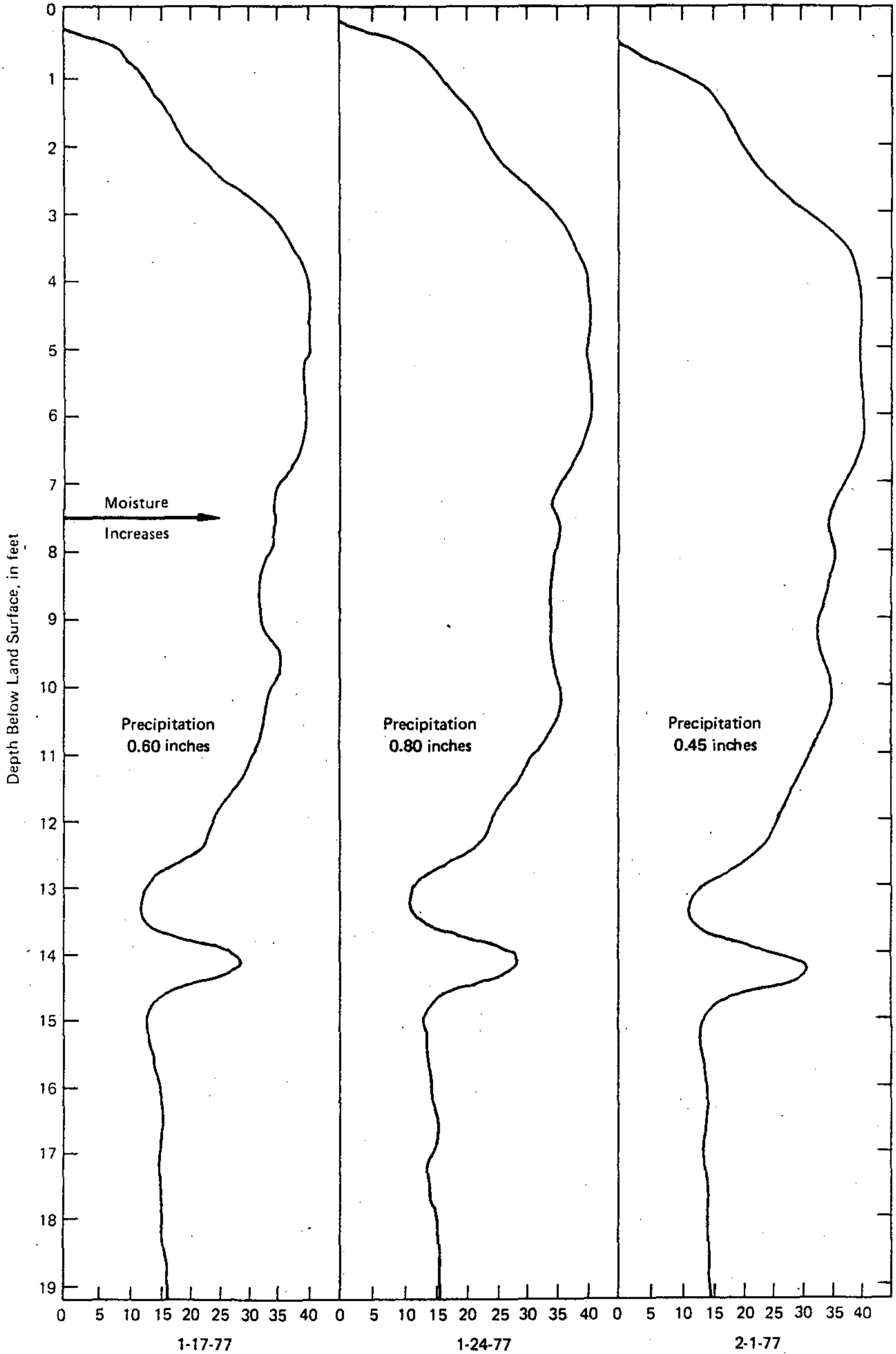
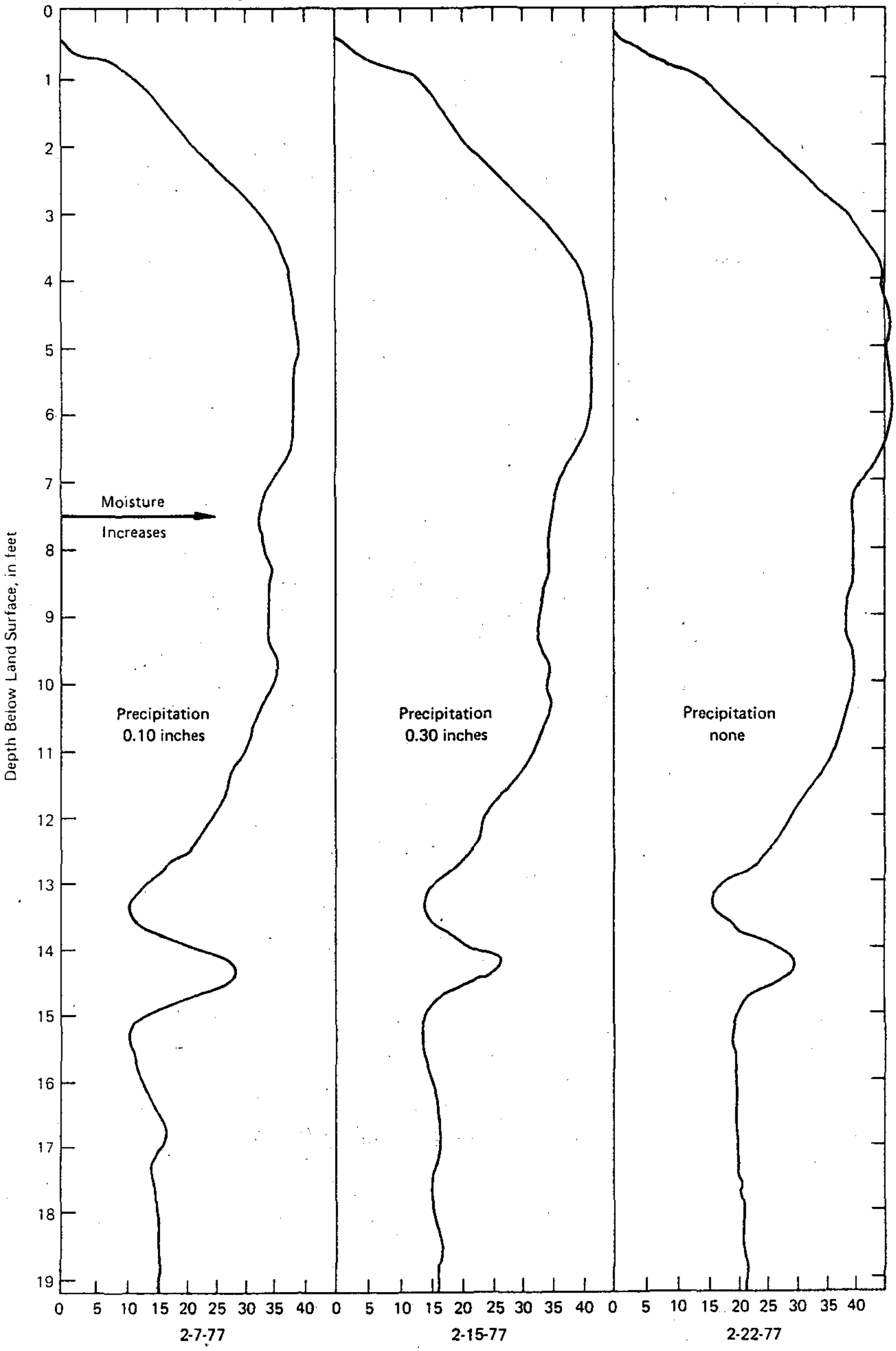
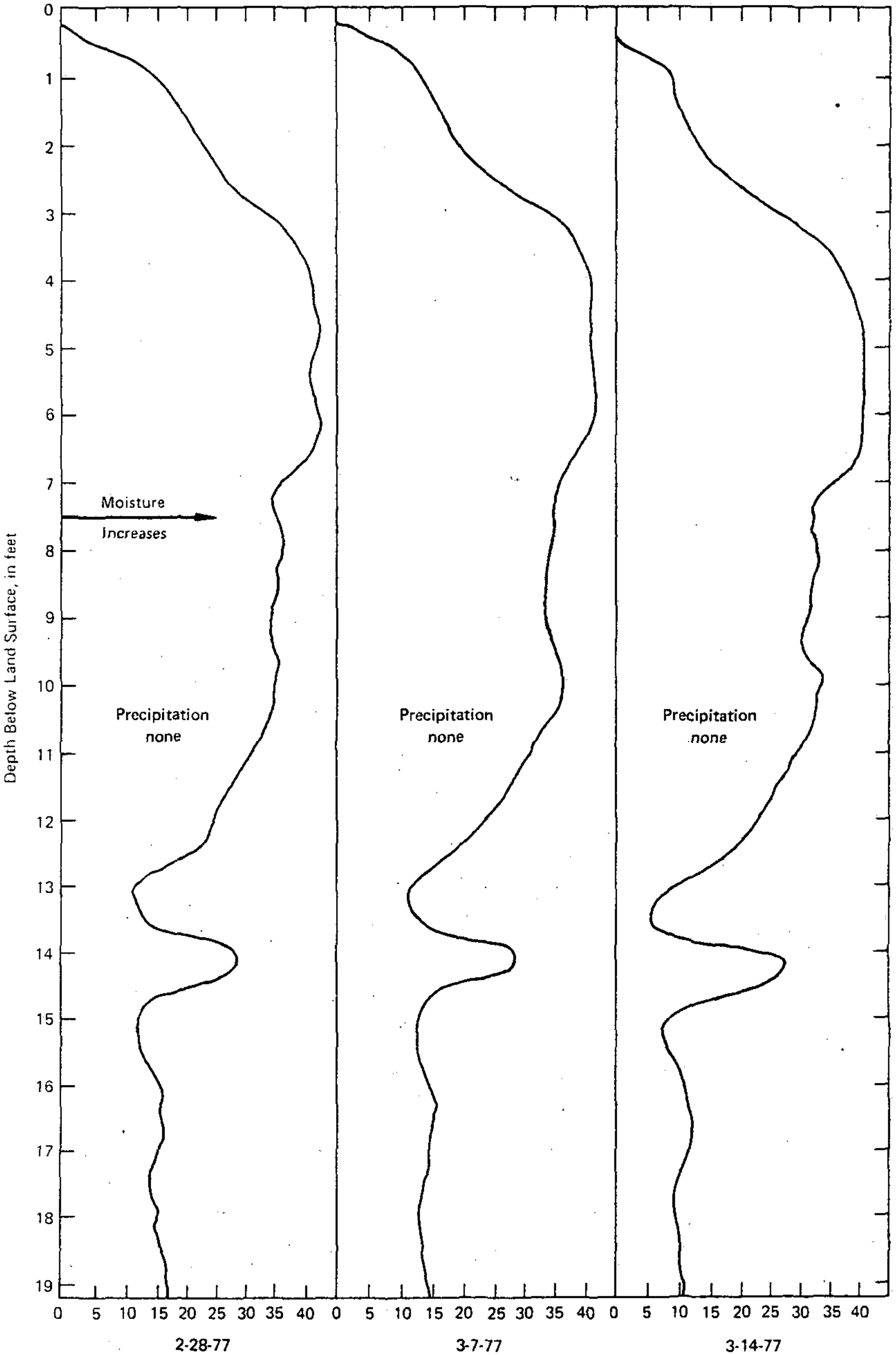
14
15
16
17
18
19
Moisture
Increases
Precipitation
0.80 inches
Precipitation
0.25 inches
Precipitation
1.40 inches
0 5 10 15 20 25 30 35 40
11-29-76
0 5 10 15 20 25 30 35 40
12-6-76
0 5 10 15 20 25 30 35 40
12-21-76



0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Depth Below Land Surface, in feet
Moisture
Increases
Precipitation
0.20 inches
Precipitation
0.20 inches
Precipitation
none
0 5 10 15 20 25 30 35 40
0 5 10 15 20 25 30 35 40
0 5 10 15 20 25 30 35 40
12-28-76
1-3-77
1-10-77


Depth Below Land Surface, in feet
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Moisture
Increases
Precipitation
0.60 inches
Precipitation
0.80 inches
Precipitation
0.45 inches
0 5 10 15 20 25 30 35 40
0 5 10 15 20 25 30 35 40
0 5 10 15 20 25 30 35 40
1-17-77
1-24-77
2-1-77


Depth Below Land Surface, in feet
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Moisture
Increases
Precipitation
0.10 inches
Precipitation
0.30 inches
Precipitation
none
0 5 10 15 20 25 30 35 40
2-7-77
0 5 10 15 20 25 30 35 40
2-15-77
0 5 10 15 20 25 30 35 40
2-22-77


Depth Below Land Surface, in feet
Moisture
Increases
Precipitation
none
Precipitation
none
Precipitation
none
0
1
2
3
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5
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11
12
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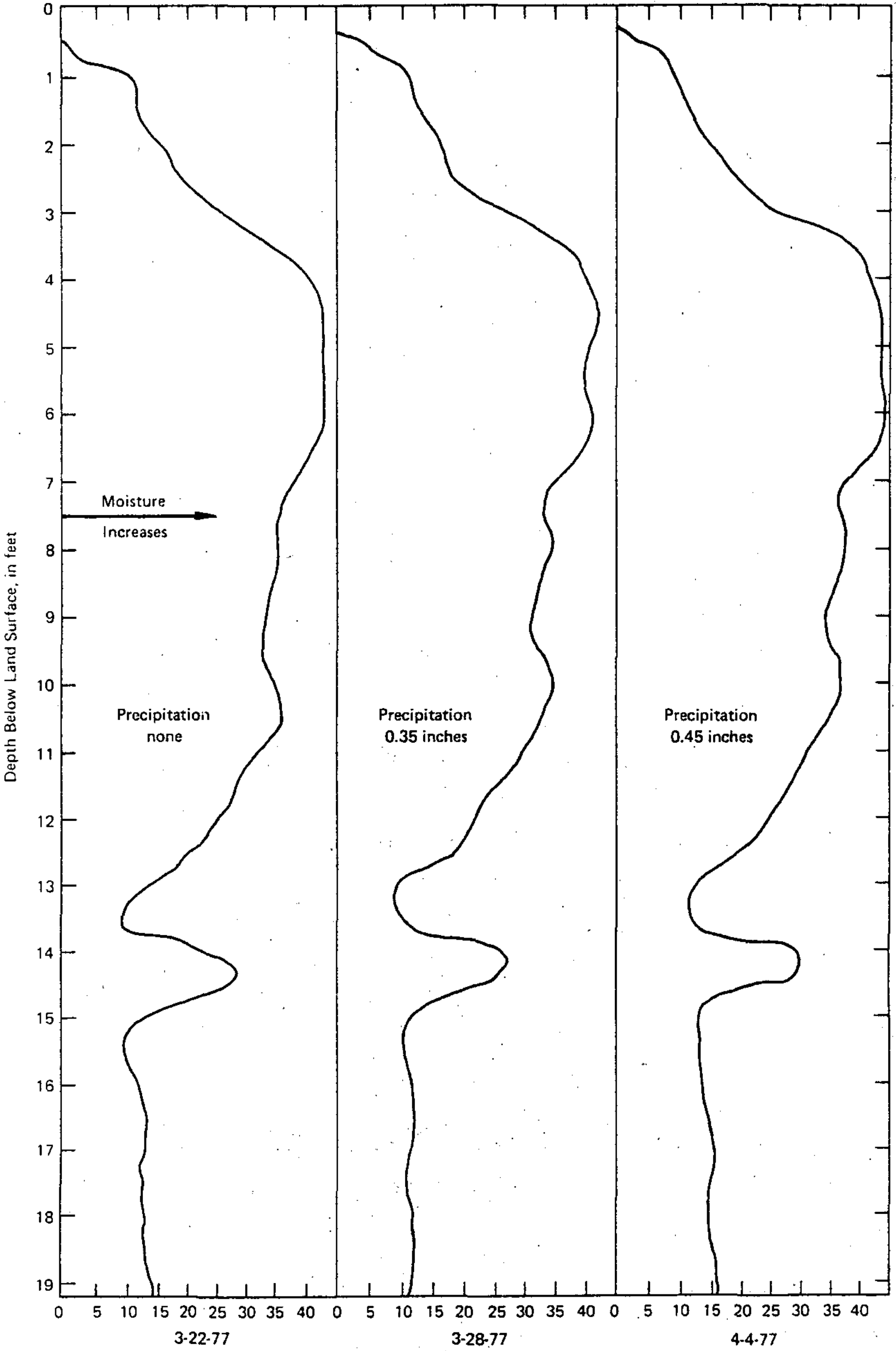
14
15
16
17
18
19
0 5 10 15 20 25 30 35 40
0 5 10 15 20 25 30 35 40
0 5 10 15 20 25 30 35 40
2-28-77
3-7-77
3-14-77


0
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18
19
Depth Below Land Surface, in feet
Moisture
Increases
Precipitation
none
Precipitation
0.35 inches
Precipitation
0.45 inches
0 5 10 15 20 25 30 35 40
3-22-77
0 5 10 15 20 25 30 35 40
3-28-77
0 5 10 15 20 25 30 35 40
4-4-77