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GEOLOGICAL SURVEY

PROGRESS REPORT

January 1970 - June 1972

LAKE OKEECHOBEE SEEPAGE MONITORING NETWORK

By

Donald J. McKenzie

OPEN-FILE REPORT

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U.S. GEOLOGICAL SURVEY
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INTRODUCTION

In 1962, the Central and Southern Florida Flood Control District requested the Geological Survey to evaluate the seepage beneath the Hoover Dike along the south shore of Lake Okeechobee. The objectives were to describe the manner in which seepage was occurring, to determine the seepage rate, and to estimate the increase in seepage that would result if the stage of the lake were raised from 14 to 16.5 feet above msl (mean sea level). Because the study involved about 50 miles of dike, estimates of seepage were based upon detailed studies at five sites, shown in figure 1. Results of the study were reported by Meyer (1971). The data showed that seepage from the lake initially moves landward from a deep borrow (the Navigation Canal) that rims the lake and that seepage is retarded by a filtercake that lines the borrow. Computation of seepage rates at the five sites ranged from 0.1 to 0.9 cfs (cubic feet per second) per mile per foot of head across the dike.

The study indicated, among other things, a need for a monitoring program which would be helpful in determining the effects that build-up of a filtercake in lakeside borrows and changes in drainage works would have on future seepage rates.

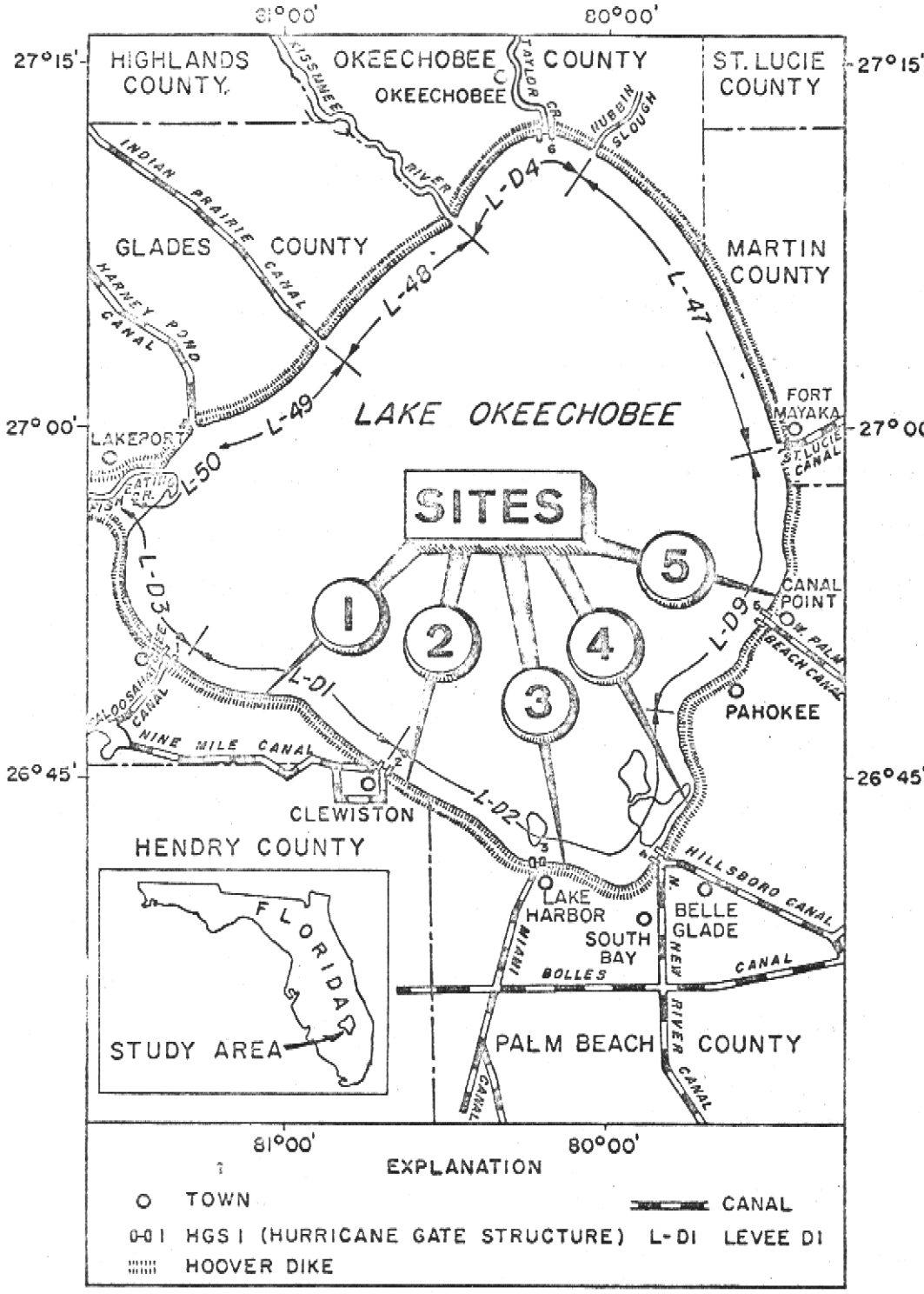

Figure 1.--Map of Lake Okeechobee showing locations of seepage study stations.

This report summarizes the data collected at the five original monitoring sites along the south shore of Lake Okeechobee from January 29, 1970 to June 28, 1972. In order to use the hydrographs in this report to full advantage, they should be studied in conjunction with Meyer's graphs and text (1971).

During steady-state conditions, water seeps from the lake through the filtercake and through the aquifers beneath the dike. At those sites where the filtercake is missing, or has about the same permeability as the aquifers, the seepage from the lake is about equivalent to the flow through the aquifers.

Present data are insufficient to determine whether or not filtercake buildup has reduced seepage. No appreciable change in drainage occurred during the observed period.

LAKE OKEECHOBEE

Lake Stage at Hurricane Gate 3 (HGS 3)

Figures 2, 3, and 4 show the daily average stages recorded at HGS 3, near Lake Harbor, from Octer 1970 to July 1972. Figure 5 presents the monthly averages for the lake stage at HGS 3 from January 1970 to June 1972. During January 1970 to June 1972, the monthly average lake level, recorded in feet above msl at HGS 3, varied from 10.5 in June 1971 to 16.1 in January 1970. The maximum daily mean stage was 16.8 on April 3, 1970 and the minimum daily mean stage was 10.2 on May 13, 1971.

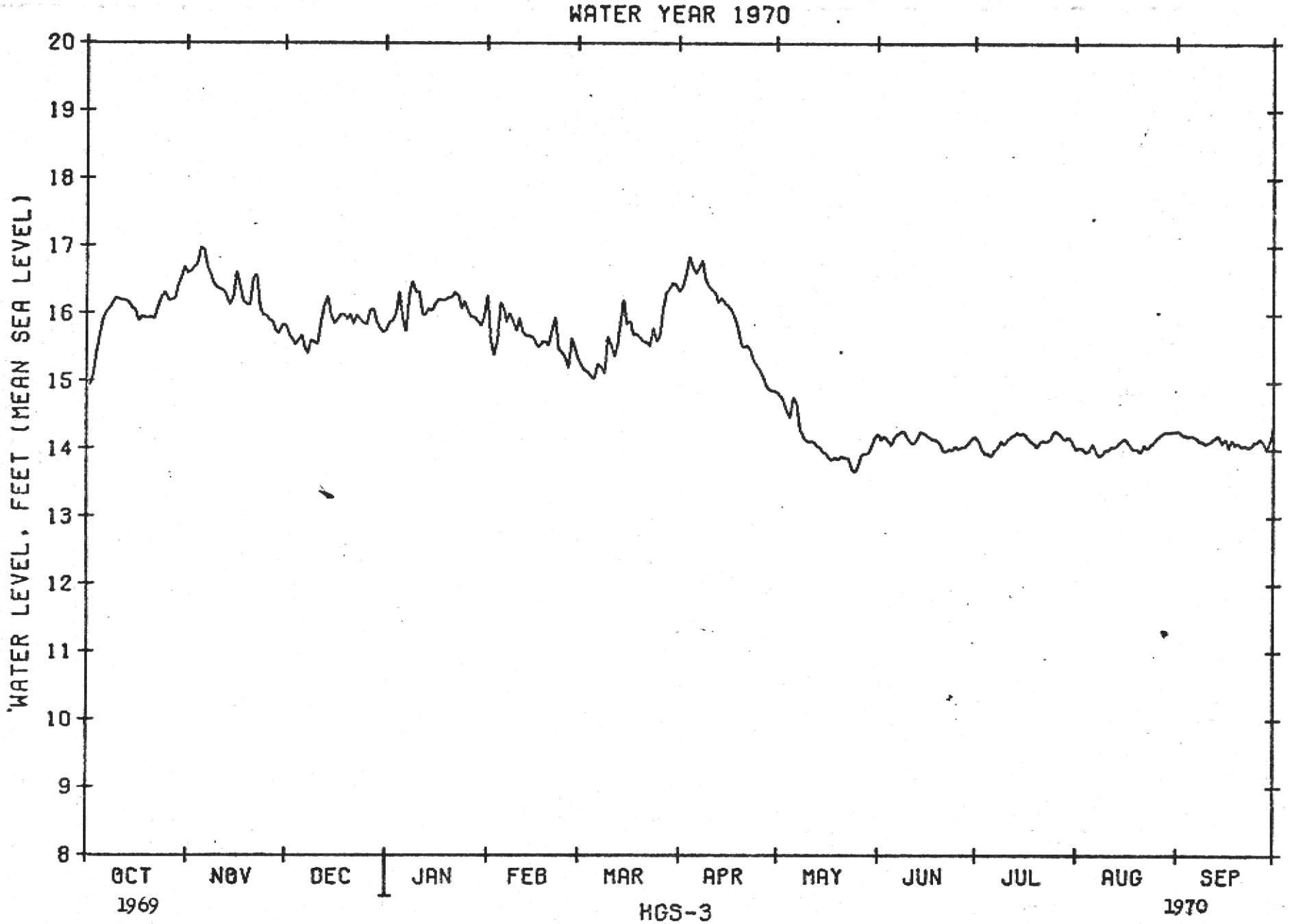

Figure 2.--Hydrograph of lake stage at HGS-3, from October, 1969 to September, 1970.

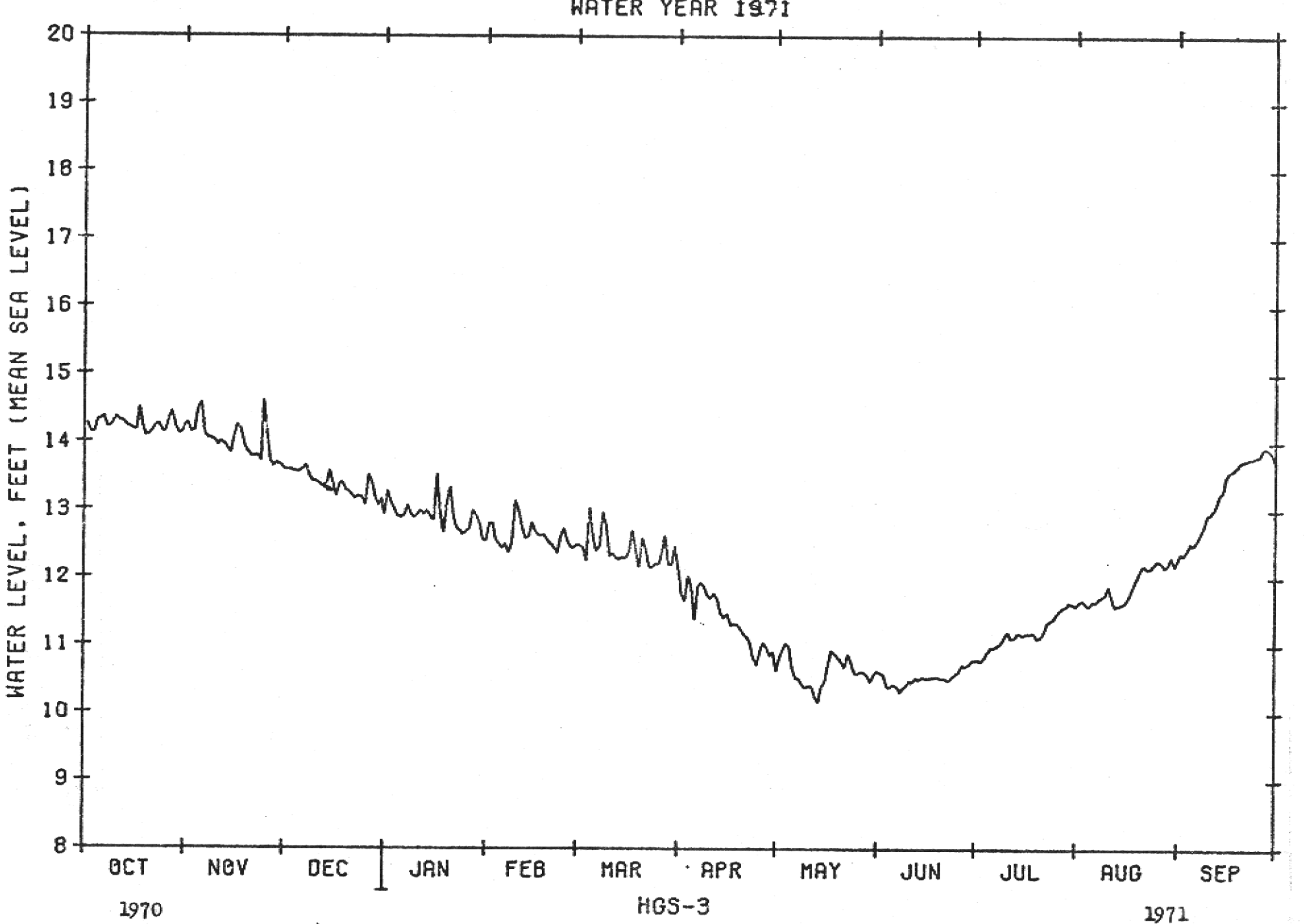

Figure 3.--Hydrograph of lake stage at HGS-3, from October, 1970 to September, 1971

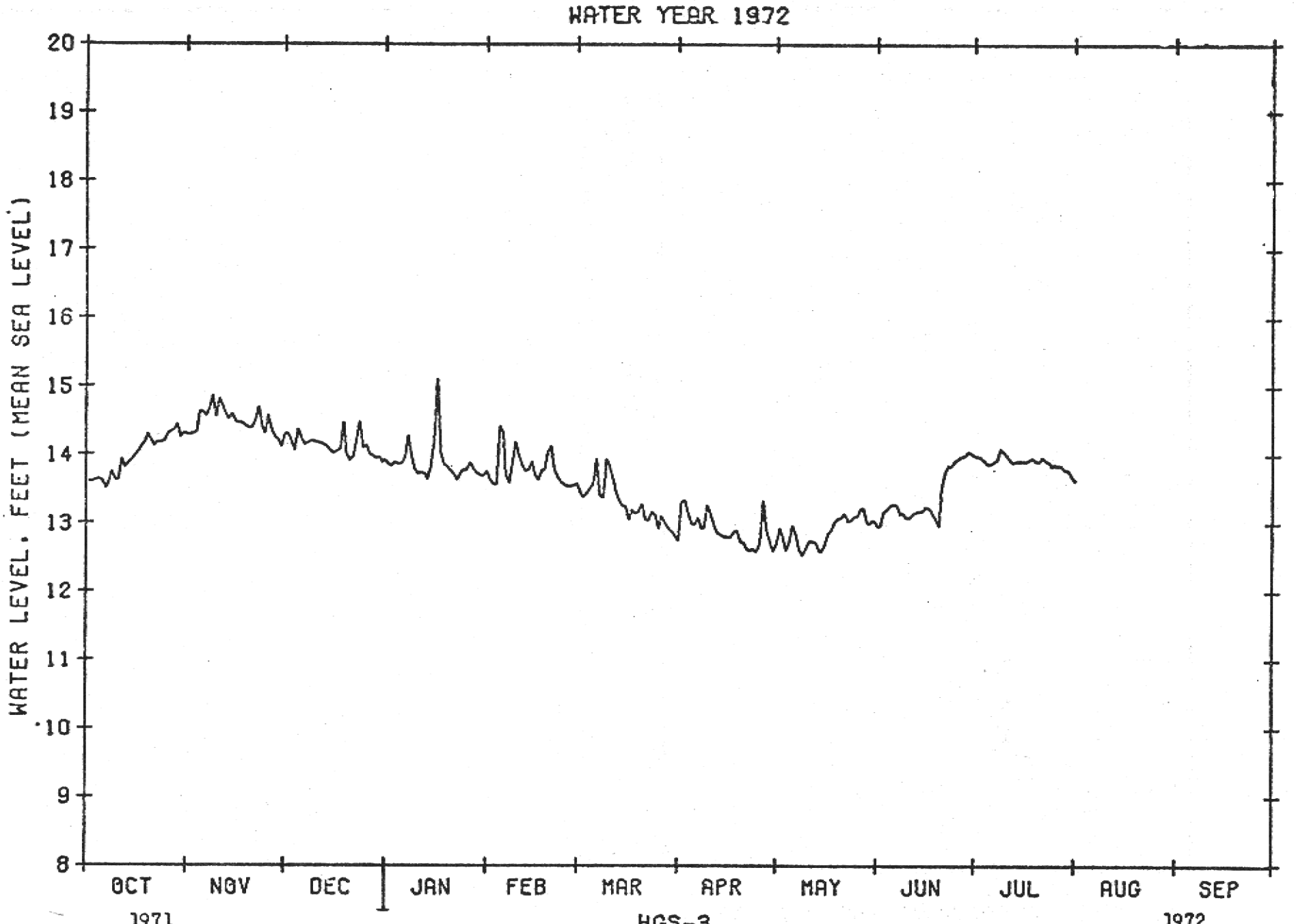

Figure 4.--Hydrograph of lake stage at HGS-3, from October, 1971 to September, 1972.

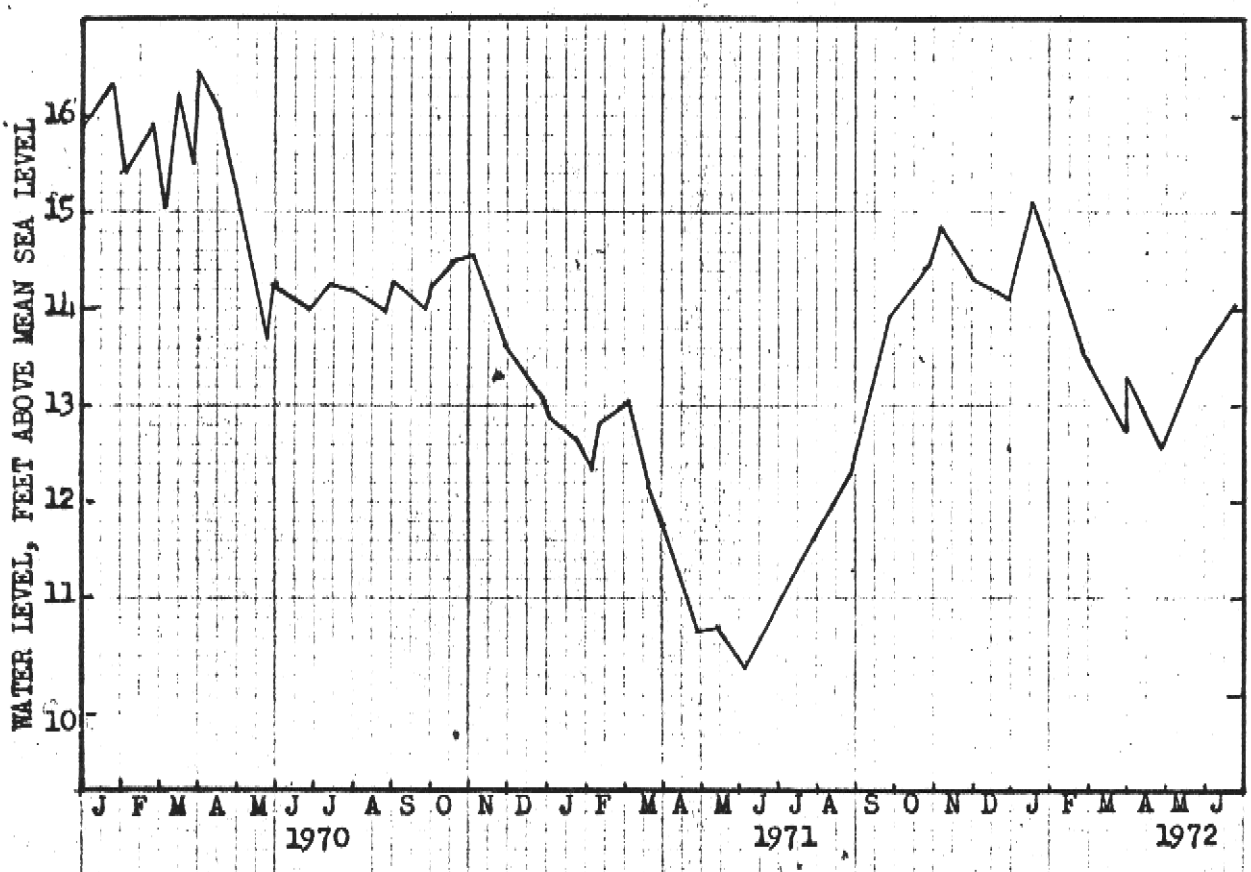

Figure 5. Graph showing monthly average stages for Lake Okeechobee at HGS-3

SITE 1

Site 1 is in Glades County on the southwest shore of Lake Okeechobee, about 5 miles east of Moore Haven (fig. 1). The site consists of five data-collection stations on a line about 820 feet long and normal to the Hoover Dike, as shown in figure 6. Four of the stations consist of three wells each, and each well penetrates one of the three aquifers (hereafter referred to as A-1, A-2 and A-3) underlying the dike. The fifth station has two wells which penetrate the upper two aquifers. Surface observation points were used to obtain water levels for the lake and the L-D1 Canal.

The three stations nearest the lake have been measured and sampled since October 1969, the beginning of regular monitoring at the site. However, the two landward stations, approximately 500 and 820 feet from the lake, have only recently been included in the regular monitoring schedule and the data will be presented in subsequent semiannual reports.

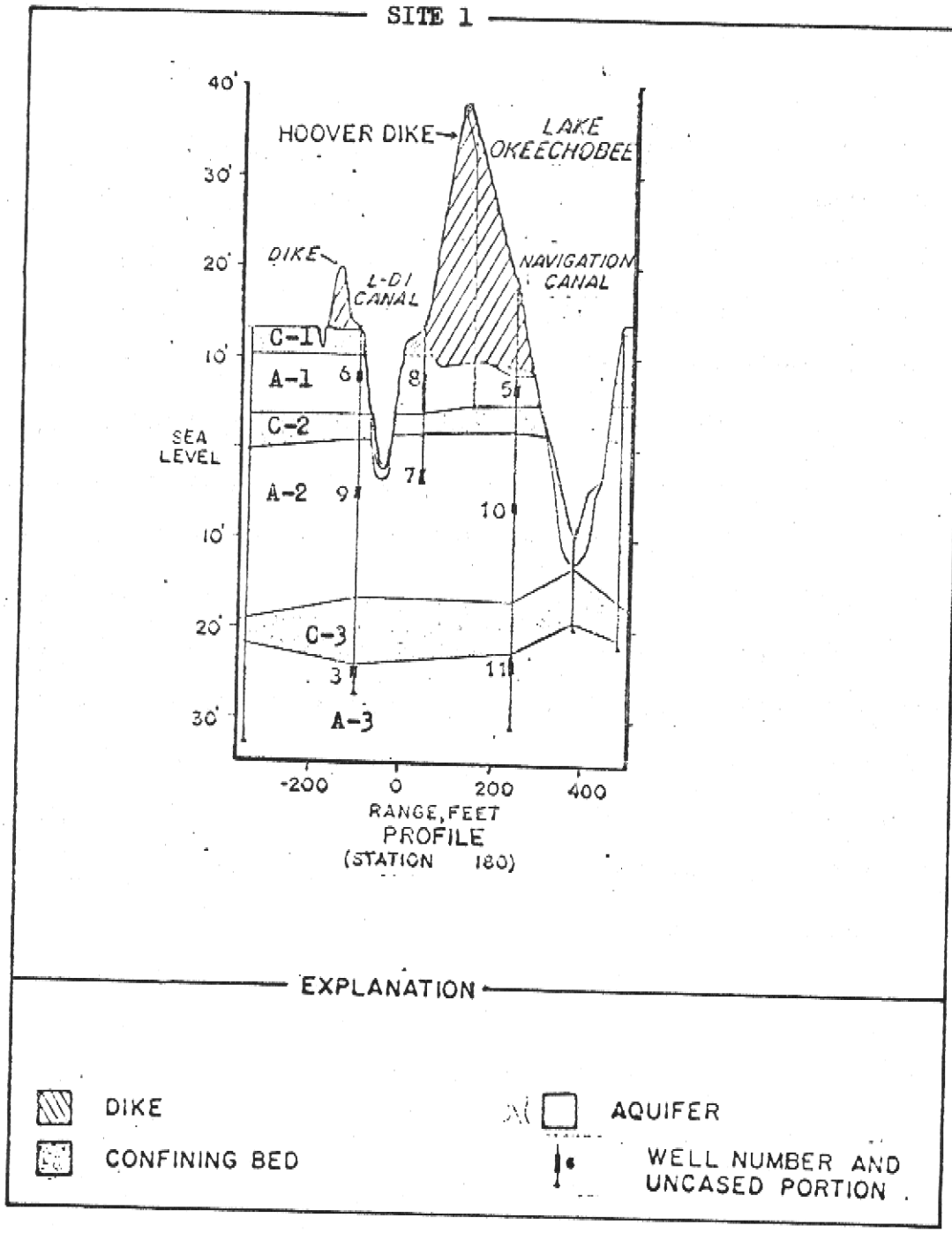

Figure 6.--Profile showing aquifers, confining beds, and depths of observation wells at site 1.

Aquifers and Confining Beds

Confining bed C-1 is composed of relatively impermeable black organic soil. The bed retards the movement of water between the surface and underlying beds, but its confining ability is locally ineffective where the bed is cut by many canals and ditches. Aquifer A-1 is chiefly a sandy-marly limestone with a relatively impermeable upper surface; locally occuring solution holes account for zones of high permeability. Confining bed C-2 is composed of shelly sand and is only slightly less permeable than the overlying aquifer. Aquifer A-2 is chiefly shell and is highly permeable. Confining bed C-3 is composed of green clay and is relatively impermeable. Aquifer A-3 is moderately permeable sand.

Water Movement and Fluctations

Seepage from Lake Okeechobee to the agricultural area is related to the lake level, to rainfall, and to drainage operations in the agricultural area. Figure 7 shows total monthly rainfall at Moore Haven, Lock Number One.

The Navigation Canal in the lake is the perennial recharge boundary. The L-D1 Canal is the chief dry season discharge boundary and the network of ditches in the fields nearby is the chief wet season discharge boundary.

In dry periods (the growing season), the L-D1 Canal is maintained at, or slightly above, the desired stage of the water table in the adjacent fields. During wet periods, the L-D1 Canal is ponded by controls.

Seepage occurs chiefly through two aquifers, A-1 and A-2, that underlie the dike between 10 feet above msl and 20 feet below msl. The aquifers, breached by deep borrow canals on the lake and land sides of the dike, function as a hydrologic unit.

Graphs in figures 8 through 10 compare water levels and chloride content in wells that tap the three aquifers with data for the lake and L-D1 Canal. The lines representing data from wells are coded by numbers of dots--the line with the least dots represents the well nearest the lake.

Most of the seepage occurred through aquifers A-1 and A-2. The close, equal spacing of the lines indicating water levels in figures 10-14 and the low chloride content in aquifers A-1 and A-2 (figs. 8 and 9) beneath the Hoover Dike suggest that, locally, the upper 25 to 30 feet of strata act as a unit. The high chloride content in water in aquifer A-3 (fig. 10) suggests that relatively little water seeps from the lake through that unit.

After heavy rains in June 1971, (fig. 7) water levels in the Diston Island Drainage District rose above lake level and reverse seepage occurred. With the freshening effect of the rain, the chloride concentration in the lake decreased. The short-range effect of this event is marked by the almost unchanged chloride content of the aquifers and the L-D1 Canal, shown in figures 8 through 10.

Figures 11 through 14 are hydraulic gradient profiles adapted from the hydrographs in figures 8, 9, and 10. They illustrate the interrelationship of the three aquifers with the lake during various water level stages.

Figure 11 shows hydraulic gradients on January 29, 1970 when the lake stage was 15.7 feet. It was the highest lake level recorded at site 1 during this study. Water in aquifers A-1 and A-2 moved principally from the Navigation Canal to the L-D1 Canal.

Water in aquifer A-3 moved principally southward toward an undetermined point of discharge in the Diston Island Drainage District, bounded by the Caloosahatchee and Nine Mile canals. According to the water levels at HGS-3 (fig. 2), a lake level of over 15 feet was maintained from October 1969 through April 1970. The similarity of gradients for aquifers A-1 and A-2, for October 1971 when the lake level was 13.9 feet (fig. 12) is immediately apparent, further indication of their action as a unti aquifer.

Figure 13 represents approximate average lake water level conditions of January 1971. The level of the lake was 12.9 feet. Seepage was from the Navigation Canal to the Diston Island Drainage District.

As the lake level approaches and drops below the 11-foot stage, a nearly level hydraulic gradient begins to develop. For example, on May 20, 1971 when the stage of both the lake and L-D1 Canal was 10.8 feet, hydraulic gradients were low (fig. 14), and the principal direction of flow in aquifers A-1, A-2 and A-3 was from the Navigation Canal toward the Diston Island Drainage District.

At present, data are insufficient to determine whether filtercake buildup reduces seepage. No appreciable changes in the amount of seepage occurred during the observed period.

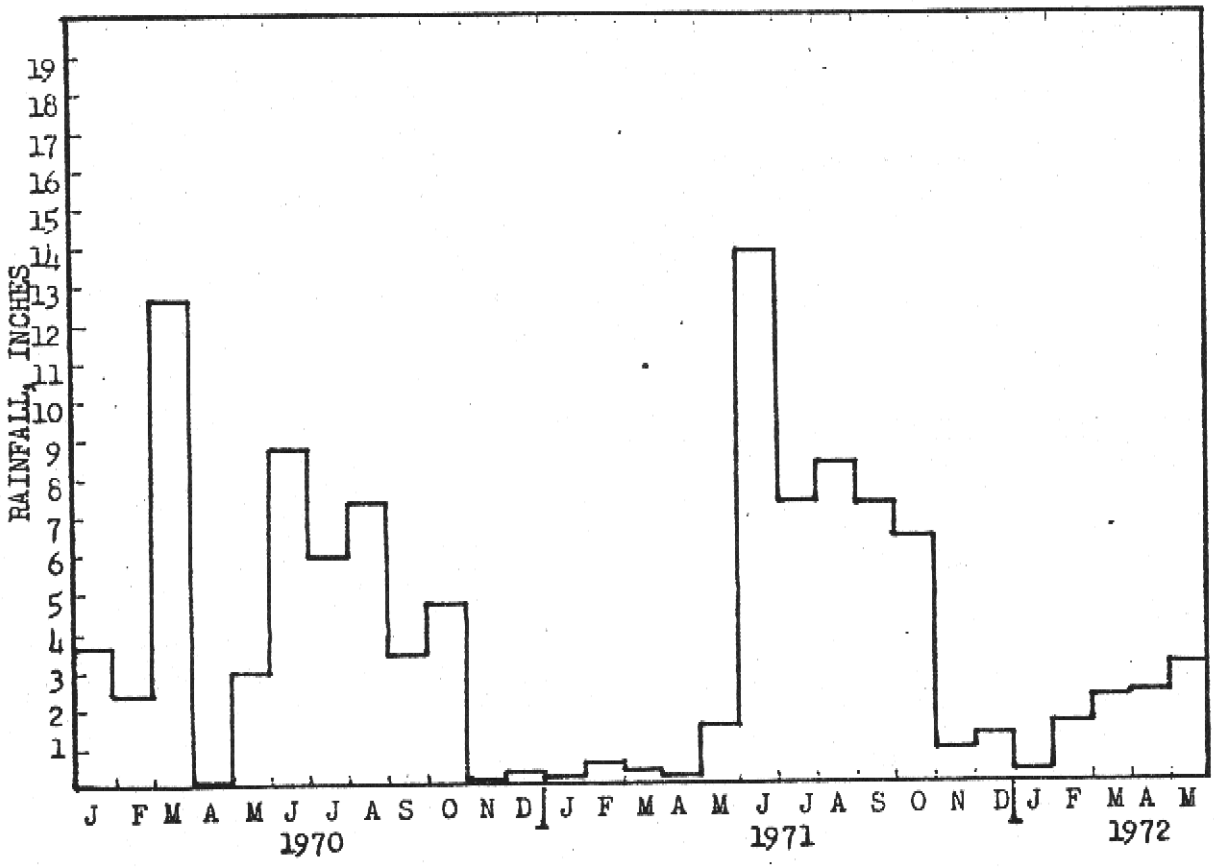

Figure 7. --Graph showing monthly rainfall at Moore Haven, Lock 1.

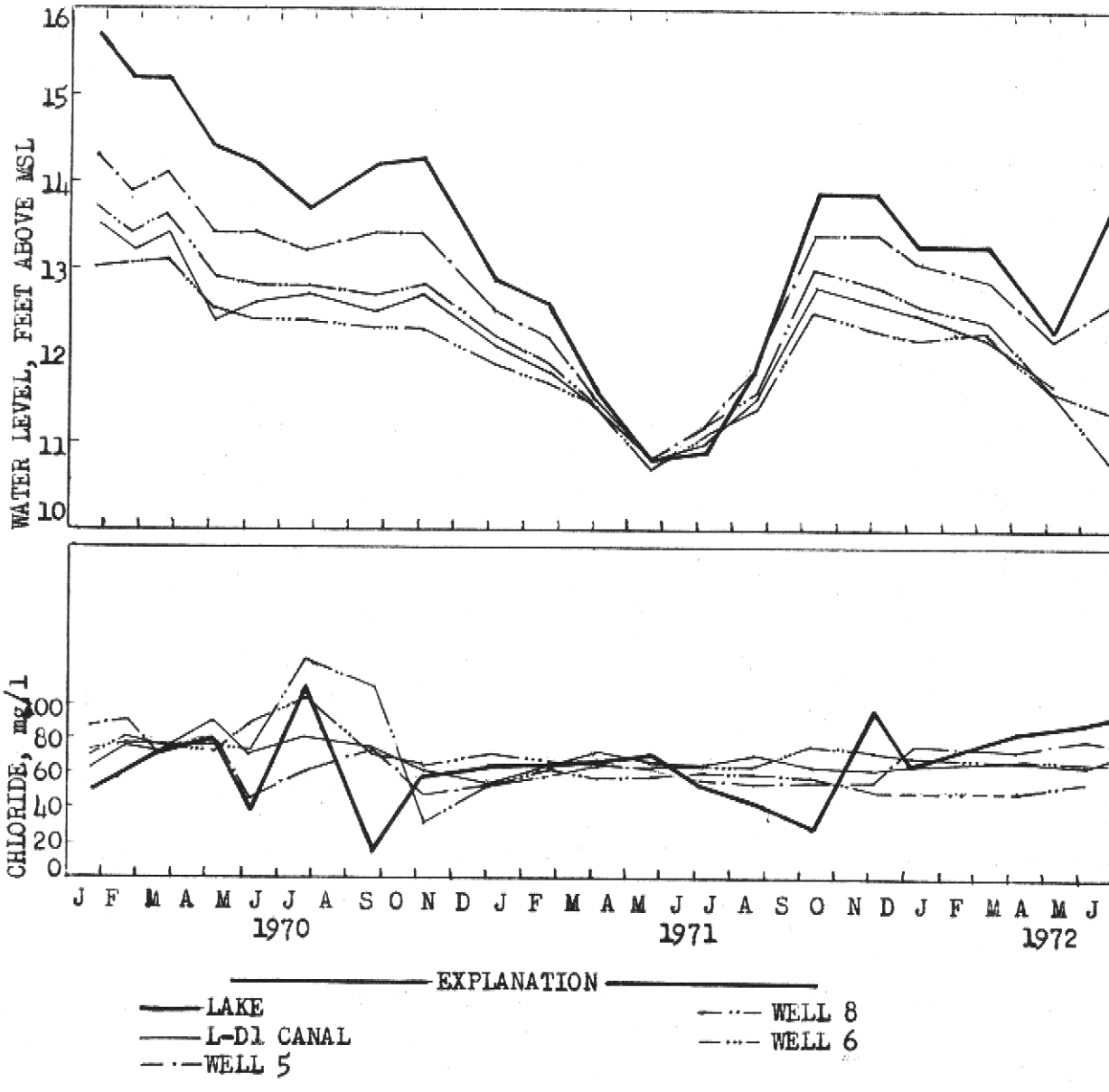

Figure 8. Graphs comparing water levels and chloride content in wells that tap aquifer A-1 at site 1 with data for the lake and the L-D1 Canal, January 1970 - June 1972.

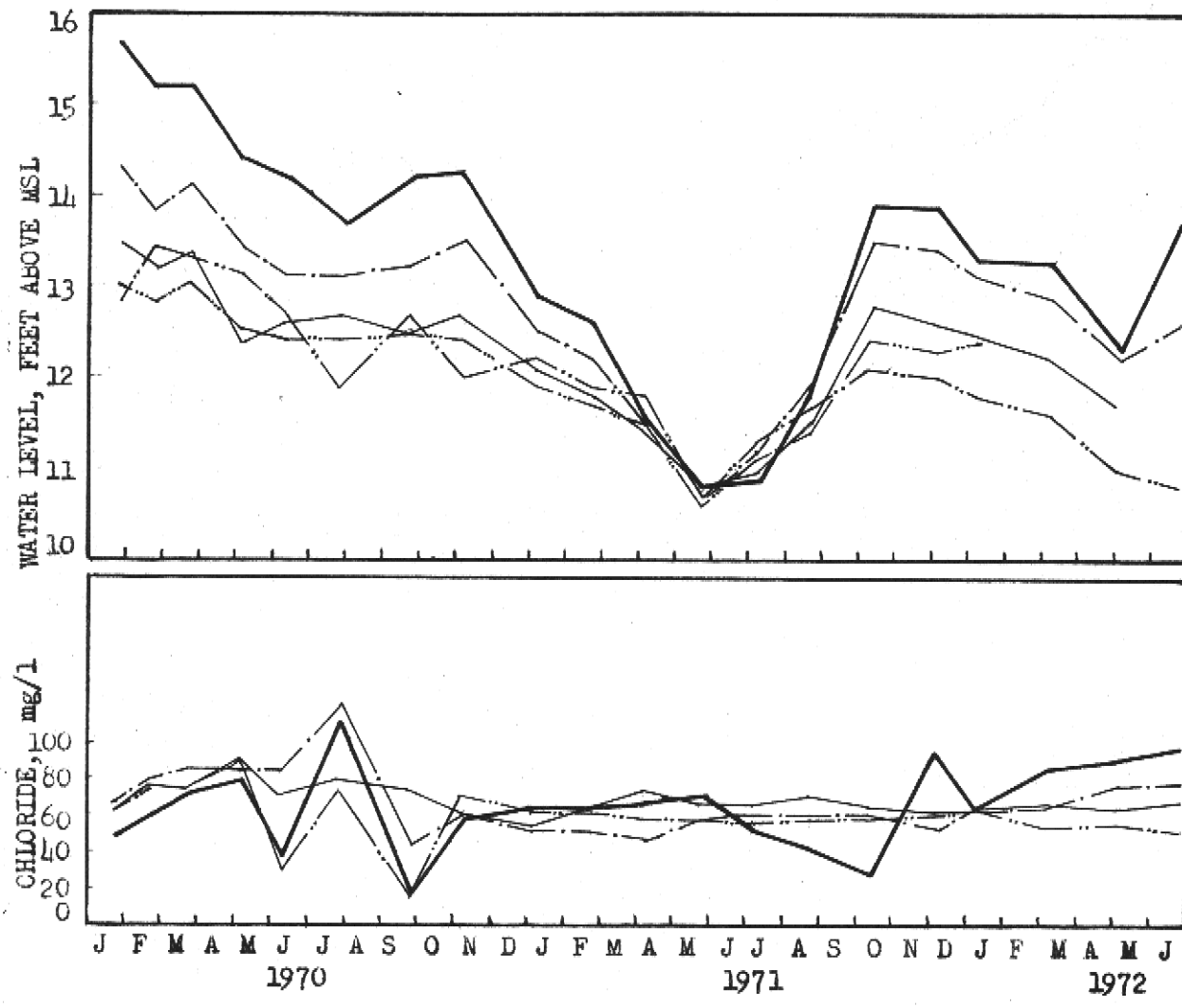

Figure 9. Graphs comparing water levels and chloride content in wells that tap aquifer A-2 at site 1 with data for the lake and the L-D1 Canal, January 1970 - June 1972.

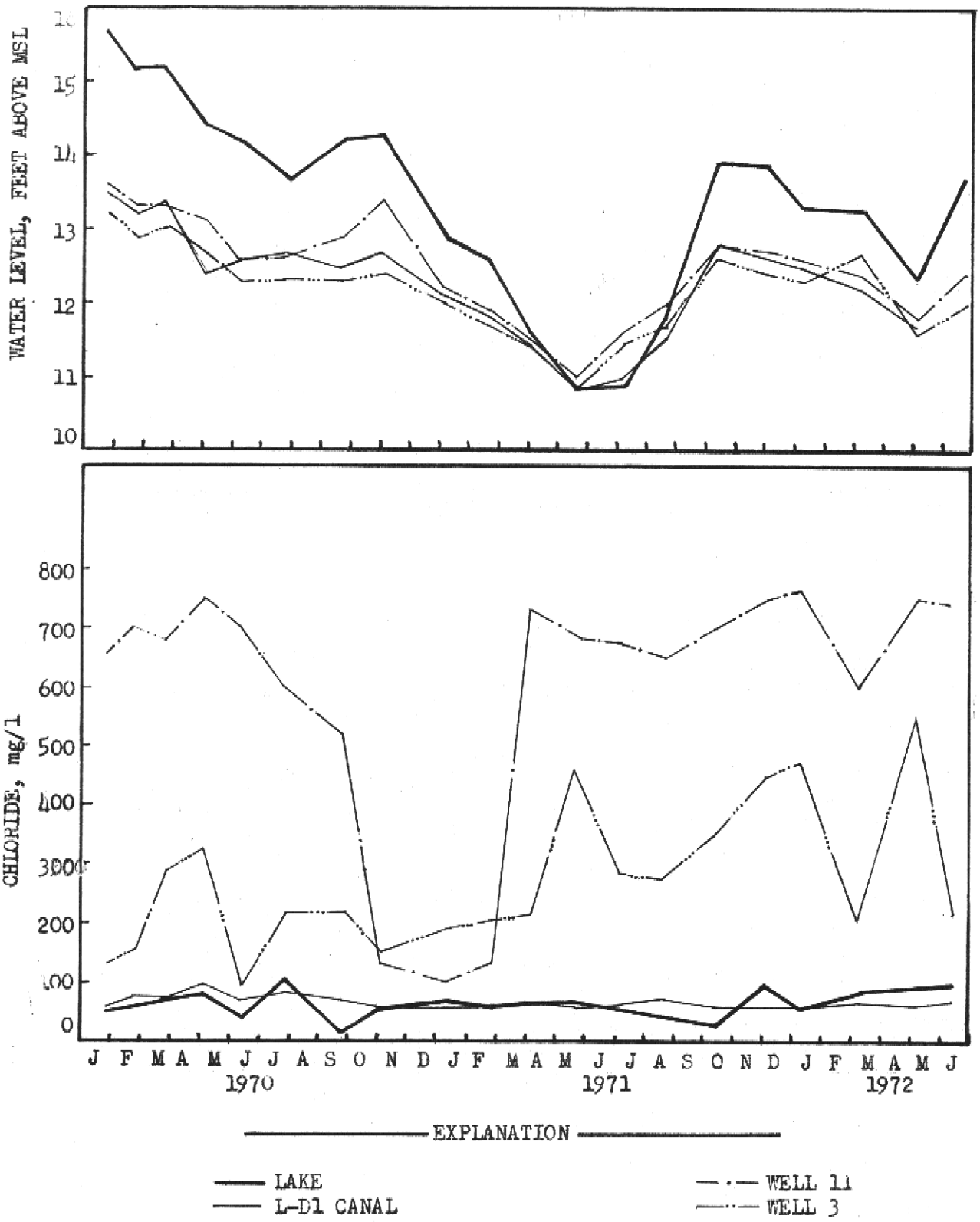

Figure 10. Graphs comparing water levels and chloride content in wells that tap aquifer A-3 at site 1 with data for the lake and L-D1 Canal; January 1970 - June 1972.

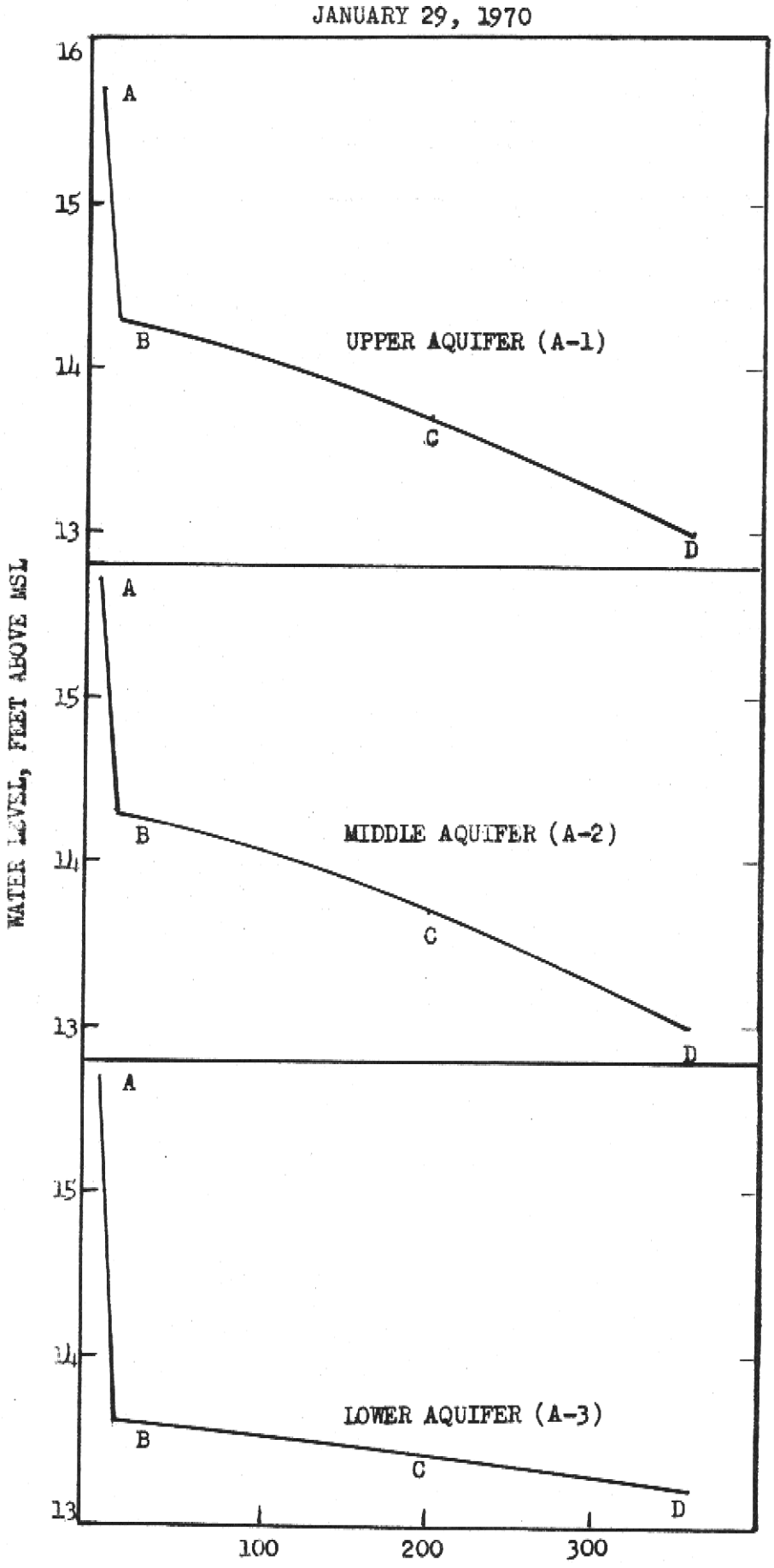

Figure 11. Hydraulic gradients of the three aquifers under the levee, during a lake stage of 15.7 feet. "A" is the lake stage. "B" - "D" represent the wells which tap the aquifers.

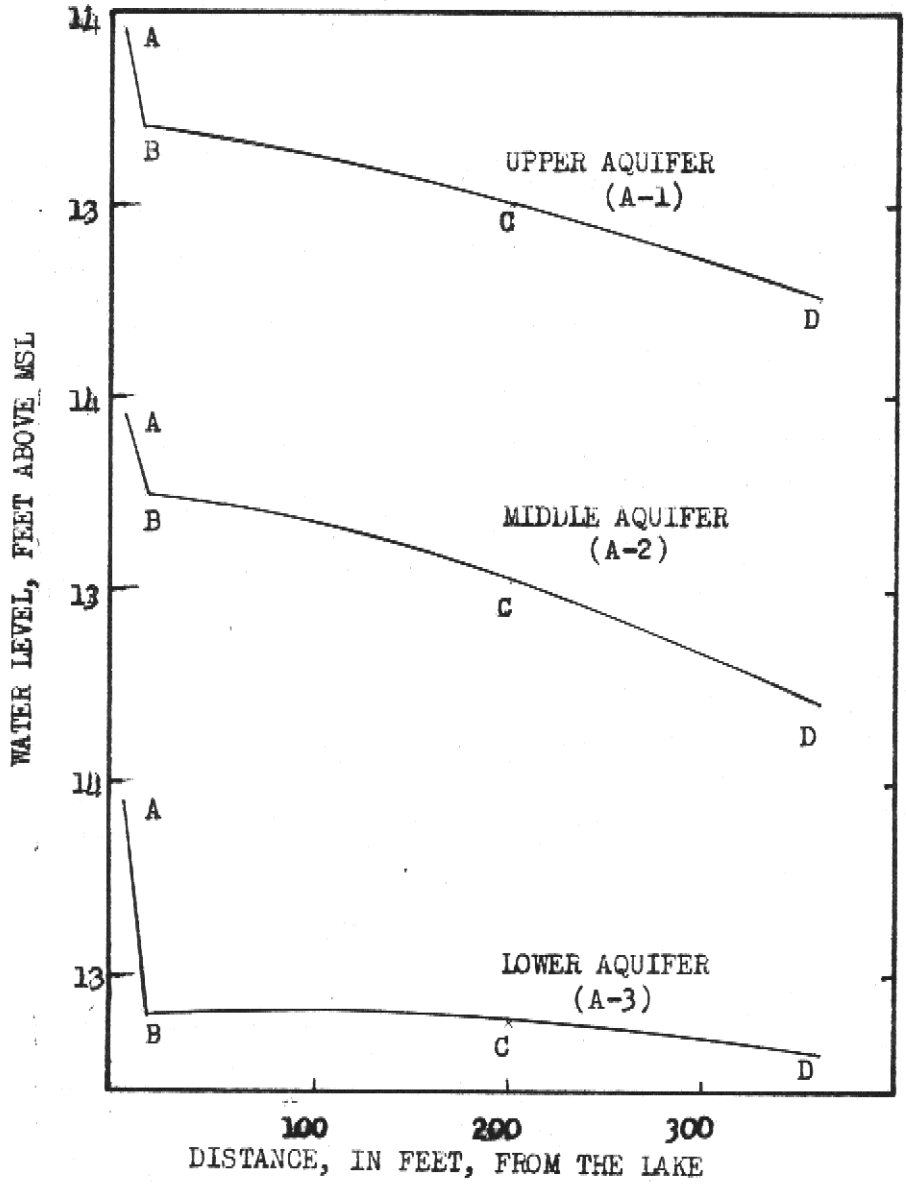

Figure 12. Hydraulic gradients of the three aquifers under the levee, during a time of high water. "A" is the lake stage. "B" -"D" represent the wells which tap the aquifers

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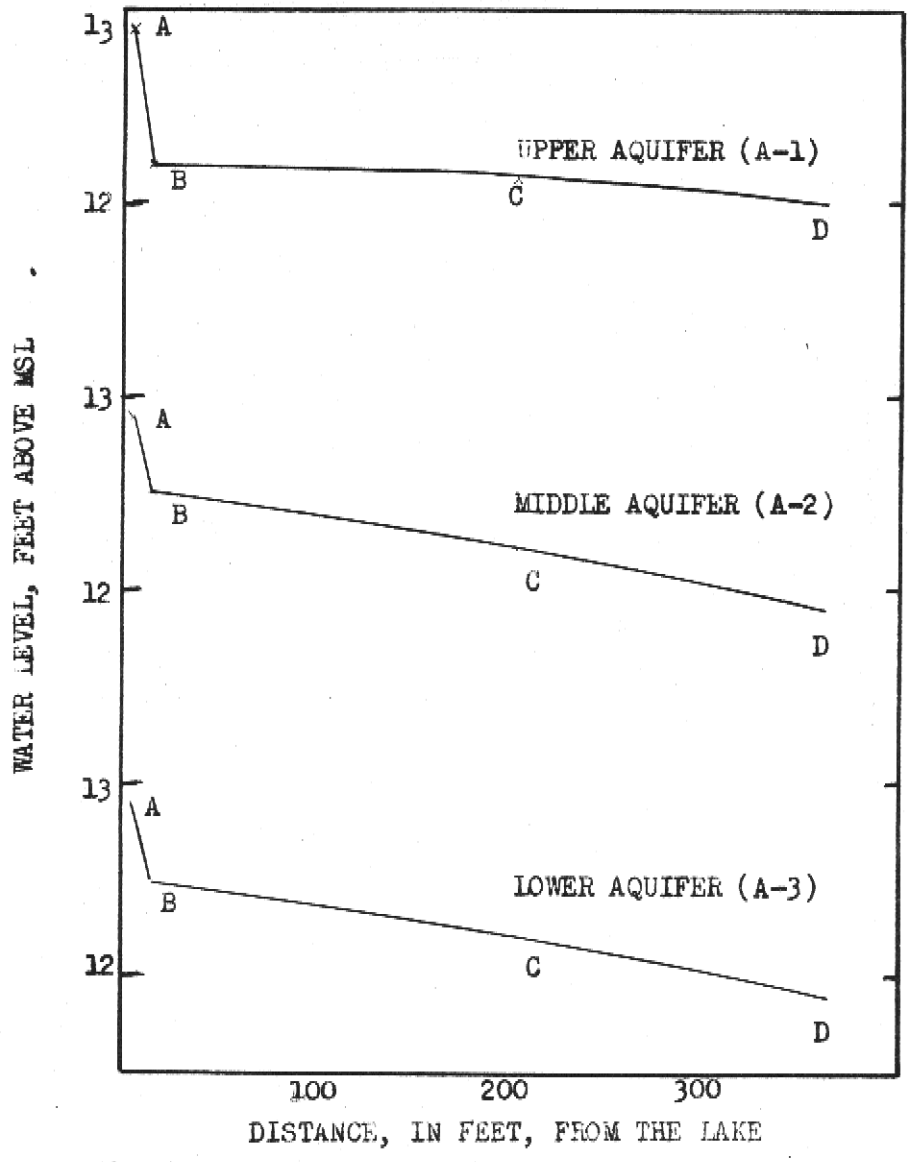

Figure 13. Hydraulic gradients of the three aquifers under the levee, during a time of intermediate water levels. "A" is the lake stage. "B" - "D" represent the wells which tap the aquifers.

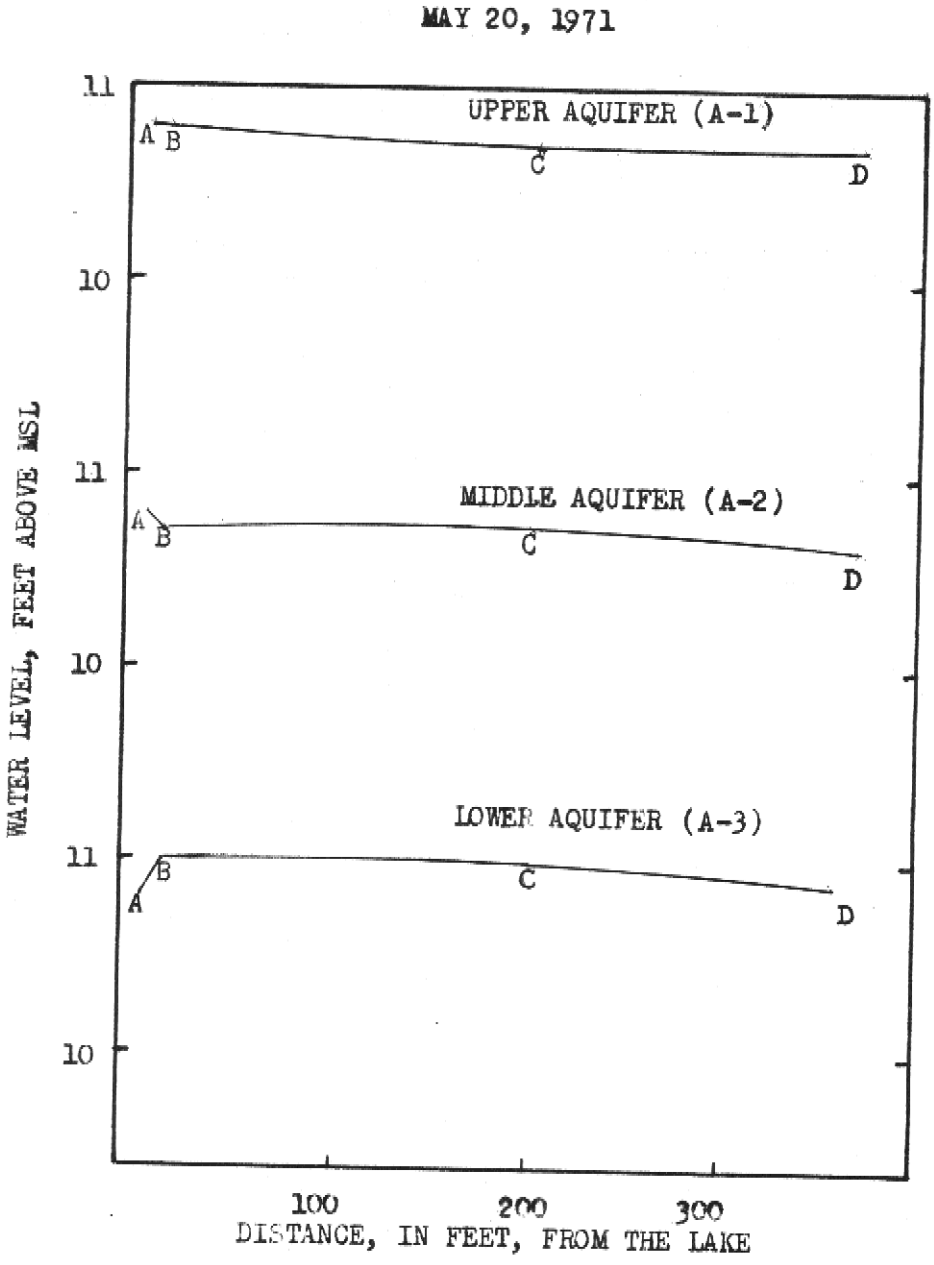

Figure 14. Hydraulic gradients of the three aquifers under the levee, during a time of low water. "A" is the lake stage. "B" - "D" represent the wells which tap the aquifers.

SITE 2

Site 2 is in Hendry County on the southwest shore of Lake Okeechobee about one mile east of Clewistown. The site comprises two data-collection stations on a line about 470 feet long, normal to the dike. A station is on each side of the dike, within 10-15 feet of water's edge. Three wells at each station tap aquifers A-1, A-2 and confining bed C-2 (fig. 15). Two observation points were used to obtain data on water levels in the lake and L-D2 Canal.

Aquifers and Confining Beds

Aquifer A-1 ranges from 2 to 7 feet thick and is a hard, sandy limestone that locally contains solution holes. Confining bed C-2 is a sandy marl, about 17 feet thick beneath the center of the dike. Aquifer A-2 is 2 feet thick and is chiefly shell. Confining bed C-3 is a 3-foot layer of sandy clay and shell. Aquifer A-2 and confining bed C-3 dip southward from the lake toward the agricultural area.

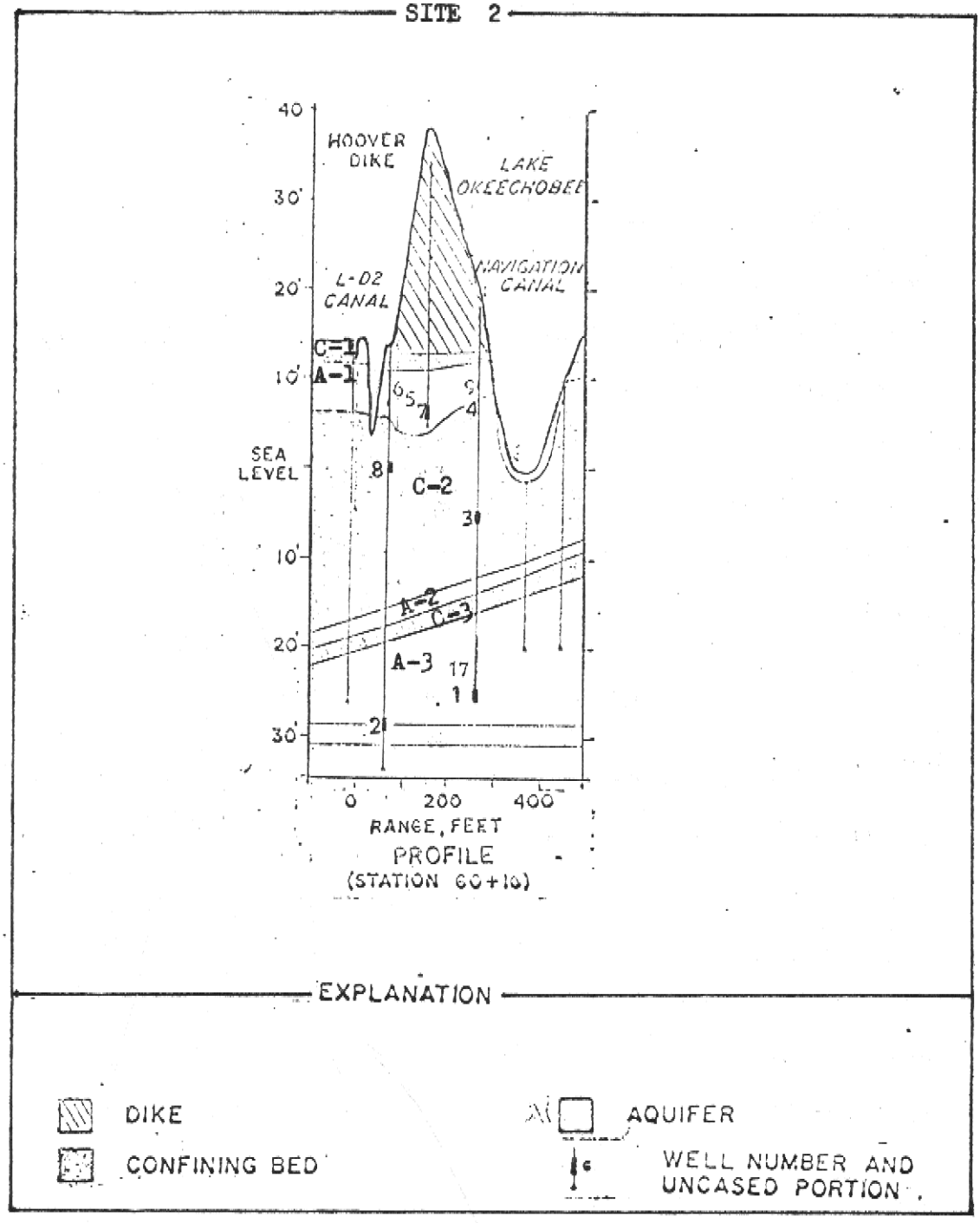

Figure 15.--Profile showing aquifers, confining beds and depths of observation wells at site 2.

Water Movement and Fluctuations

The principal direction of seepage at site 2 is southward from the dike toward the drainage works in the agricultural area. Short reversals occur seasonally, when the stage of the lake is lowered routinely before the rainy season, or when heavy rains cause water levels in the agricultural areas to abruptly rise above the lake level. Figure 16 shows the monthly rainfall at Clewiston during the report period.

The graphs in figures 17 through 20 compare water levels and chloride content in wells that tap the selected aquifers and confining beds and for the lake and the L-D2 Canal.

The sampling points for the lake and well 4 were dry in April through October, 1971, and the measuring point for the canal was destroyed in January, 1971. Well 8 was plugged during most of the monitoring period.

During the time of record, the water levels nearest the lake in aquifer A-1 are closely related to the lake level (fig. 17). This relationship indicates that the permeability of aquifer A-1 is about the same as the permeability in the filtercake of the Navigation Canal. The hydraulic gradient, which is shown by water levels in the line of wells, indicates that water moved southward from the lake through the L-D2 Canal to the agricultural area.

Water levels in confining bed C-2 near the lake are also closely related to the water level in the lake (fig. 18). The similarity between the graphs in figures 17 and 18 suggest that permeability of aquifers A-1 and confining bed C-2 are about the same. This is further illustrated by the similar hydraulic gradients during the high water-level conditions on January 29, 1970, referred to below.

The hydraulic gradient of aquifer A-2, which is inferred from the differences between the water levels in the wells, is low. The rate of water movement in aquifer A-3 (fig.19) is probably low even if the permeability of the material is relatively high. Chloride content (fig. 20) is highest in the wells which are the deepest and farthest from the lake. This suggests that seepage through A-3 is insignificant.

Figure 21 shows the hydraulic gradients of aquifers A-1, A-3 and confining bed C-2 during the high water level conditions of January 29, 1970. The stage of Lake Okeechobee was 15.9 feet and the stage of the L-D2 canal was 14.6 feet. Seepage through aquifers A-1, A-2 and confining bed C-2 was southward from the lake toward the agricultural area.

Data are presently insufficient to determine any reduction in the seepage factor due to filtercake buildup. At this time, no appreciable changes in drainage have occurred.

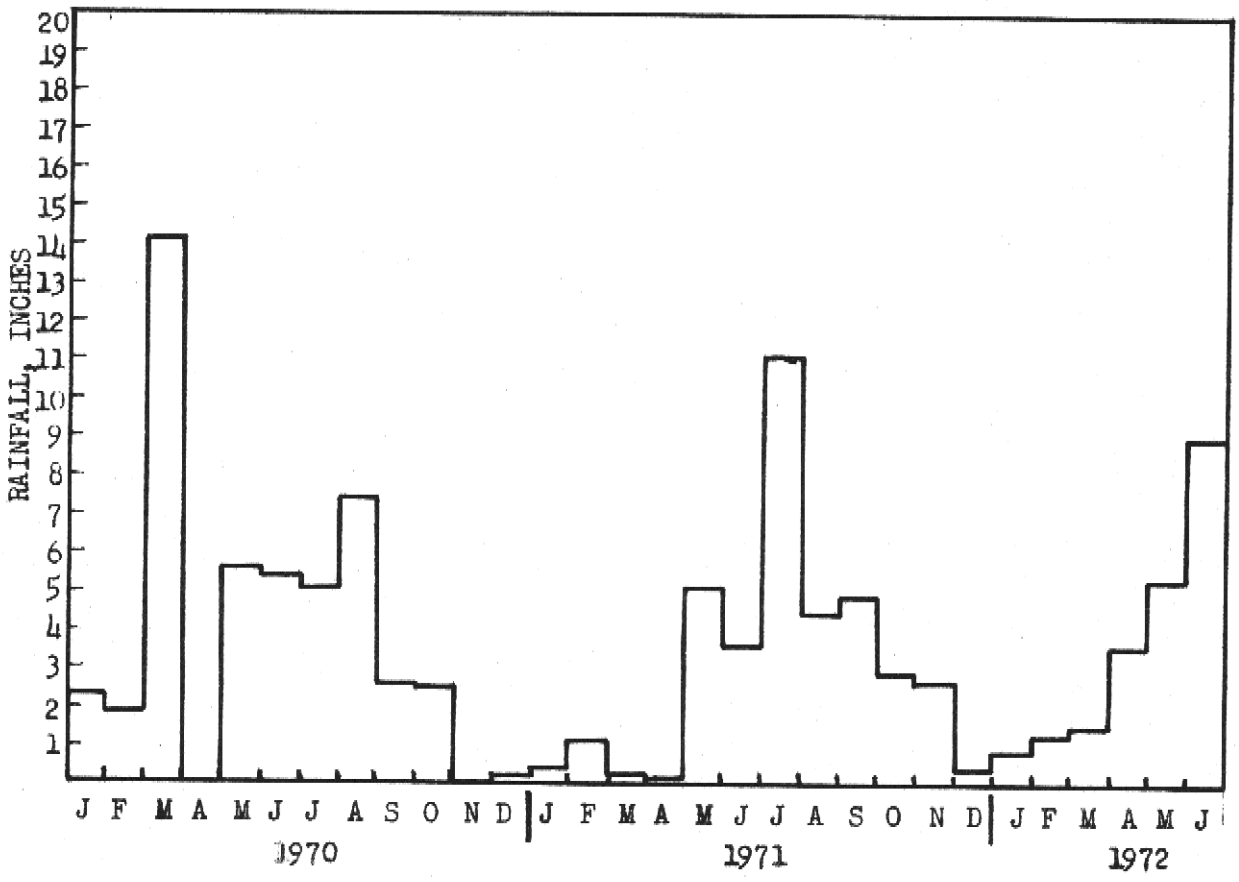

Figure 16 . Graph showing monthly rainfall at Clewiston

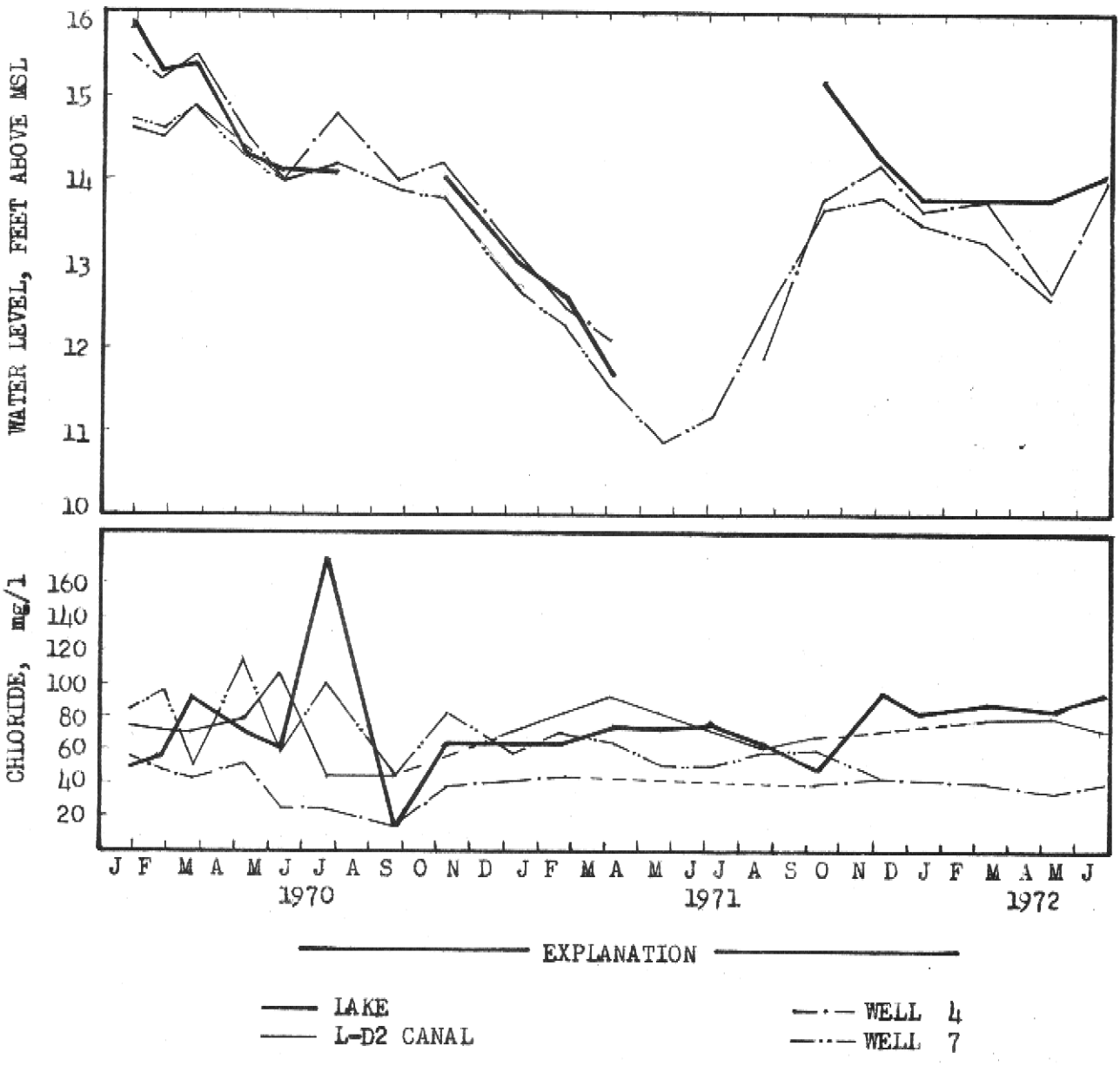

Figure 17. Graphs comparing water levels and chloride content in wells that tap aquifer A-1 at site 2 with data for the lake and the L-D2 Canal; January 1970 - June 1972.

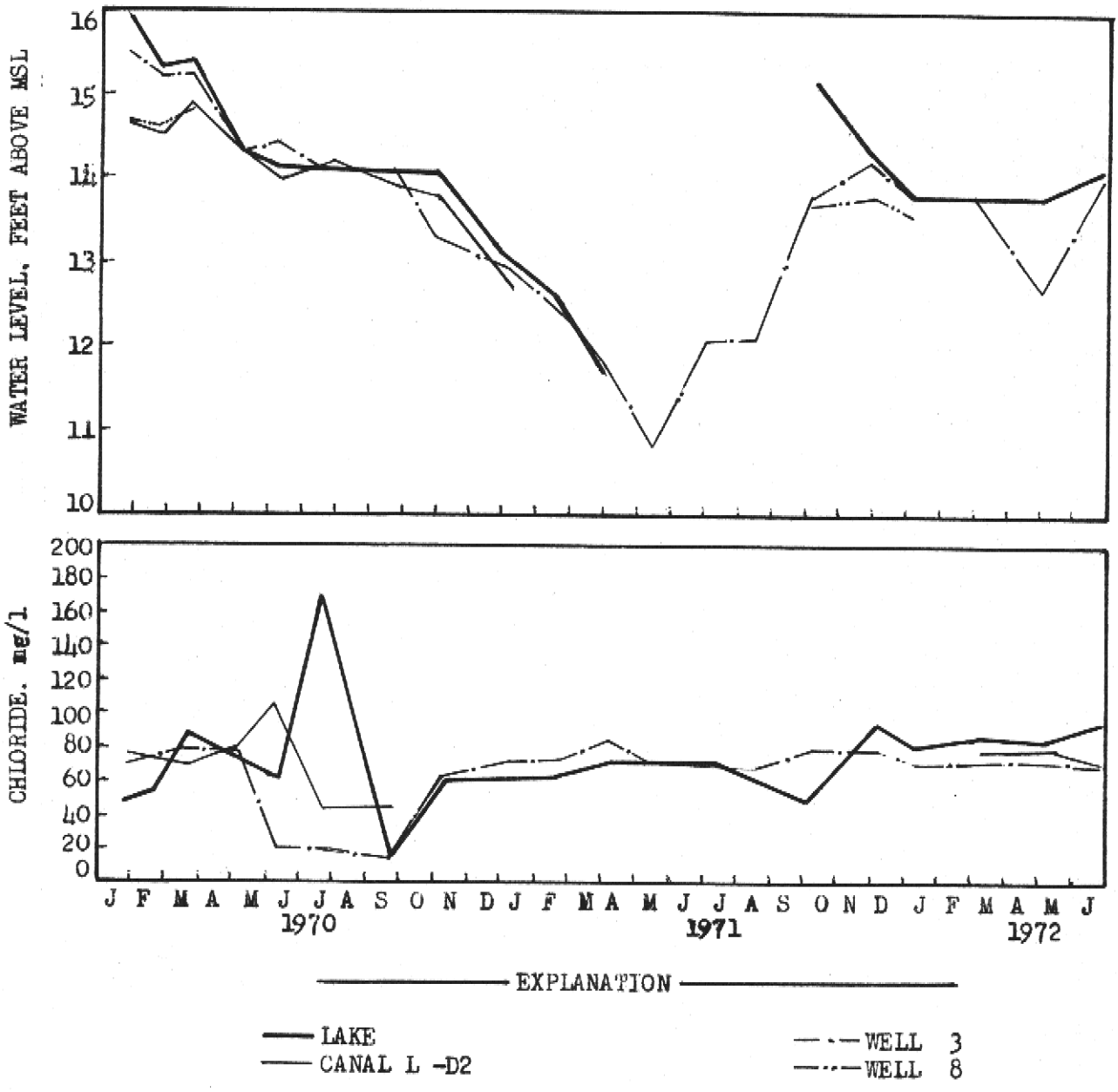

Figure 18. Graphs comparing water levels and chloride content in wells that tap confining bed C-2 at site 2 with data for the lake and the L-D2 Canal; January 1970 - June 1972.

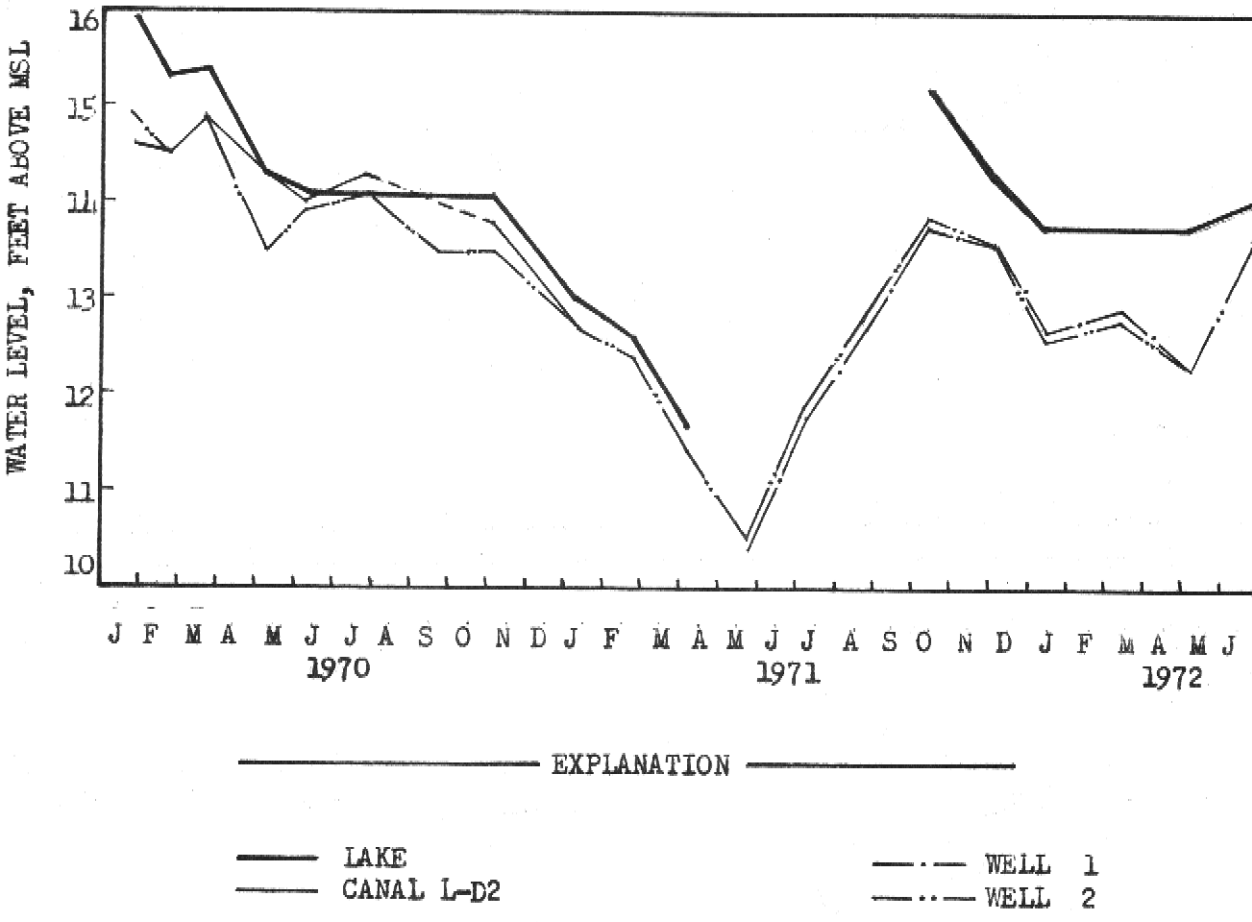

Figure 19. Graph comparing water levels in wells that tap aquifer A-3 at site 2 with data for the lake and the L-D2 Canal; January 1970 - June 1972.

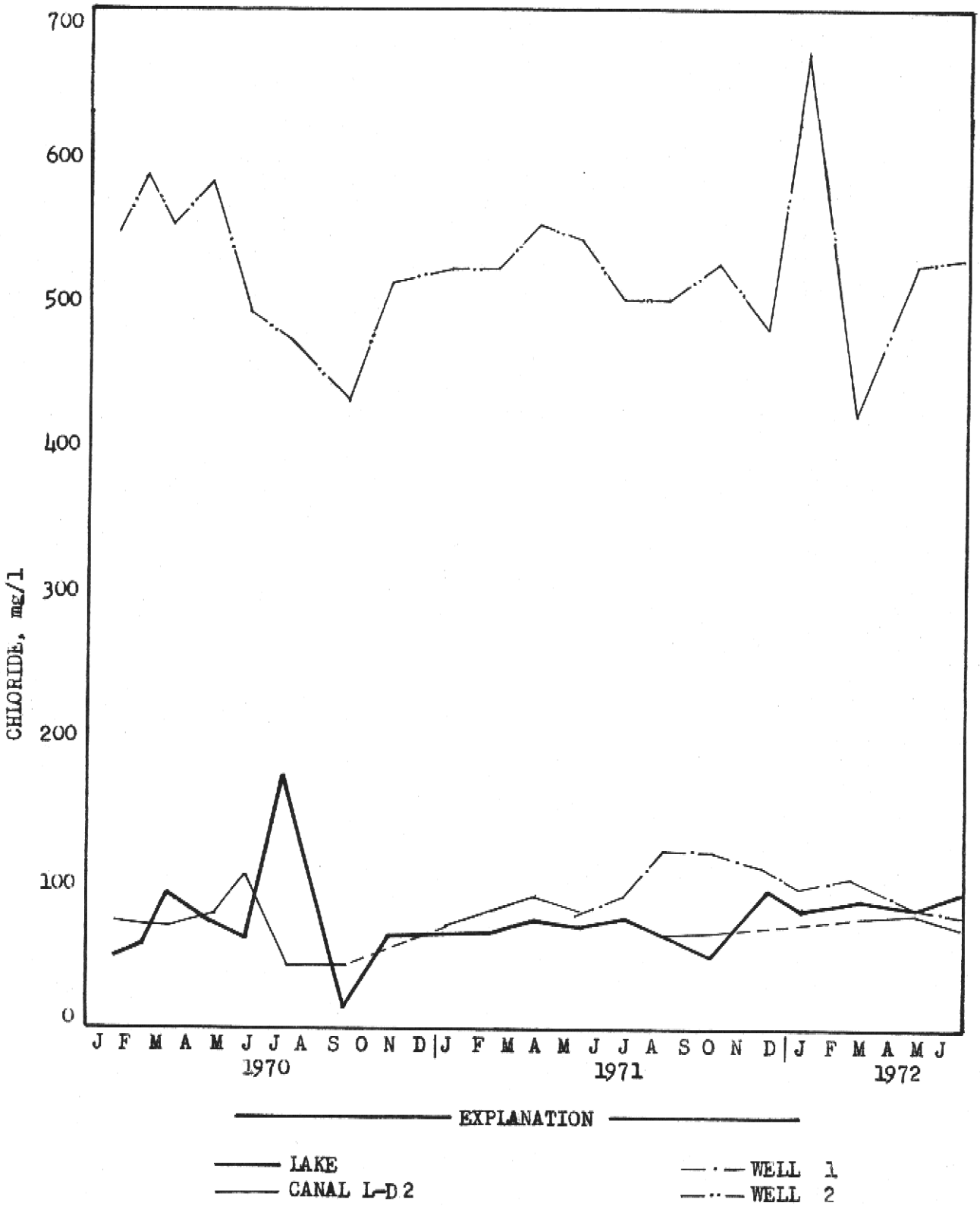

Figure 20. Graph comparing chloride content in wells that tap aquifer A-3 at site 2 with data for the lake and the L-D2 Canal; January 1970 - June 1972.

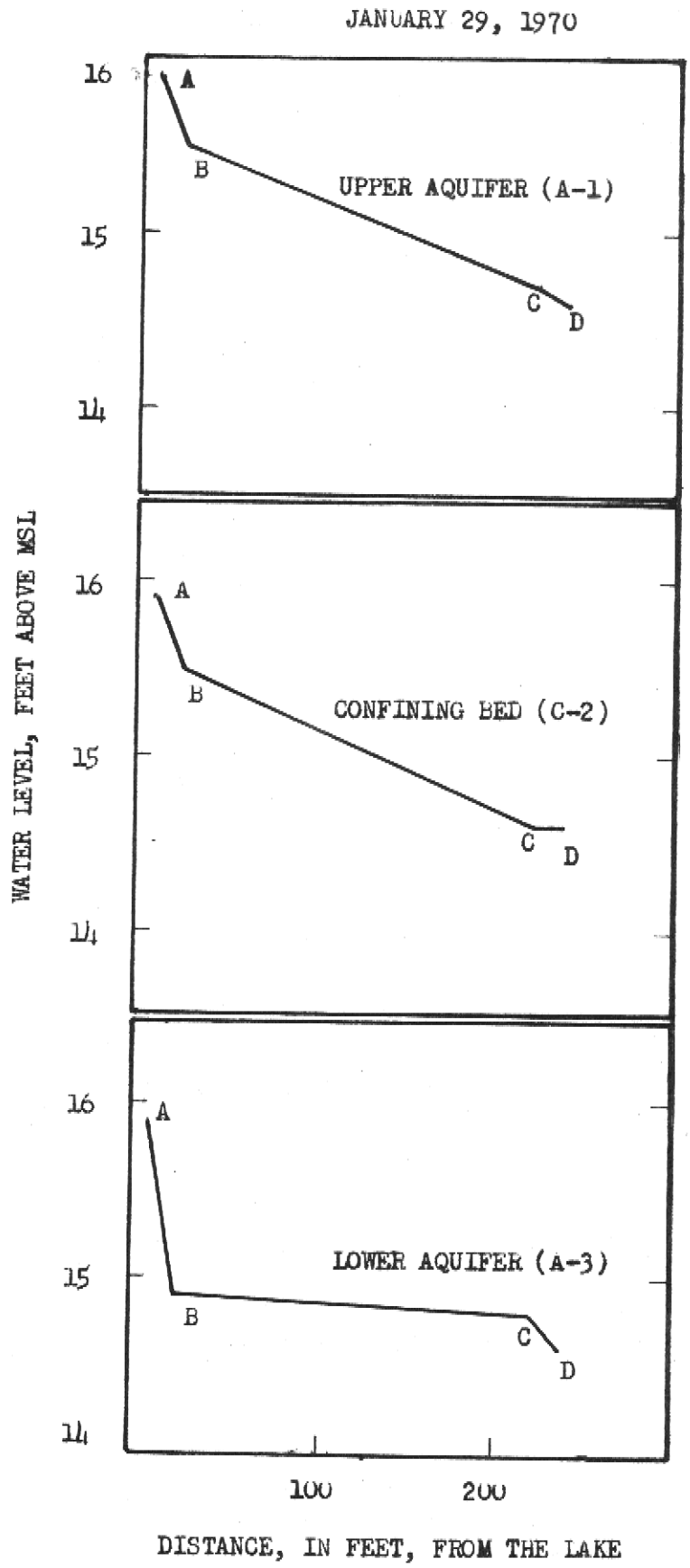

Figure 21 - Hydraulic gradients of aquifers A-1 and A-3 and confining bed C-2, at site 2, during a lake stage of 15.9 feet. "A" is the lake stage. "B" and "C" are wells which tap particular stratum. "D" is the level of the L-D1 Canal.

SITE 3

Site 3 is in Palm Beach County on the south shore of Lake Okeechobee 0.6 mile east of Lake Harbor.

The site consists of data-collection stations on a line about 325 feet long and normal to the Hoover Dike. The stations include four wells and two observation points used to obtain data on water levels and chloride content.

Aquifers and Confining Beds

The aquifers, confining beds and depths of observation wells at site 3 are shown on profile in figure 22. Confining bed C-1 is 6 to 8 feet thick and is a relatively impermeable black organic soil. Confining bed C-2 is relatively impermeable, shelly marl and limestone. Aquifer A-1 ranges from 14 to 17 feet thick and consists of permeable beds of shell and limestone containing sandy zones. Confining bed C-3 is about 10 feet thick and is fine to coarse sand, and some shell and limestone. It is of low permeability. Most of the seepage occurs through aquifer A-1.

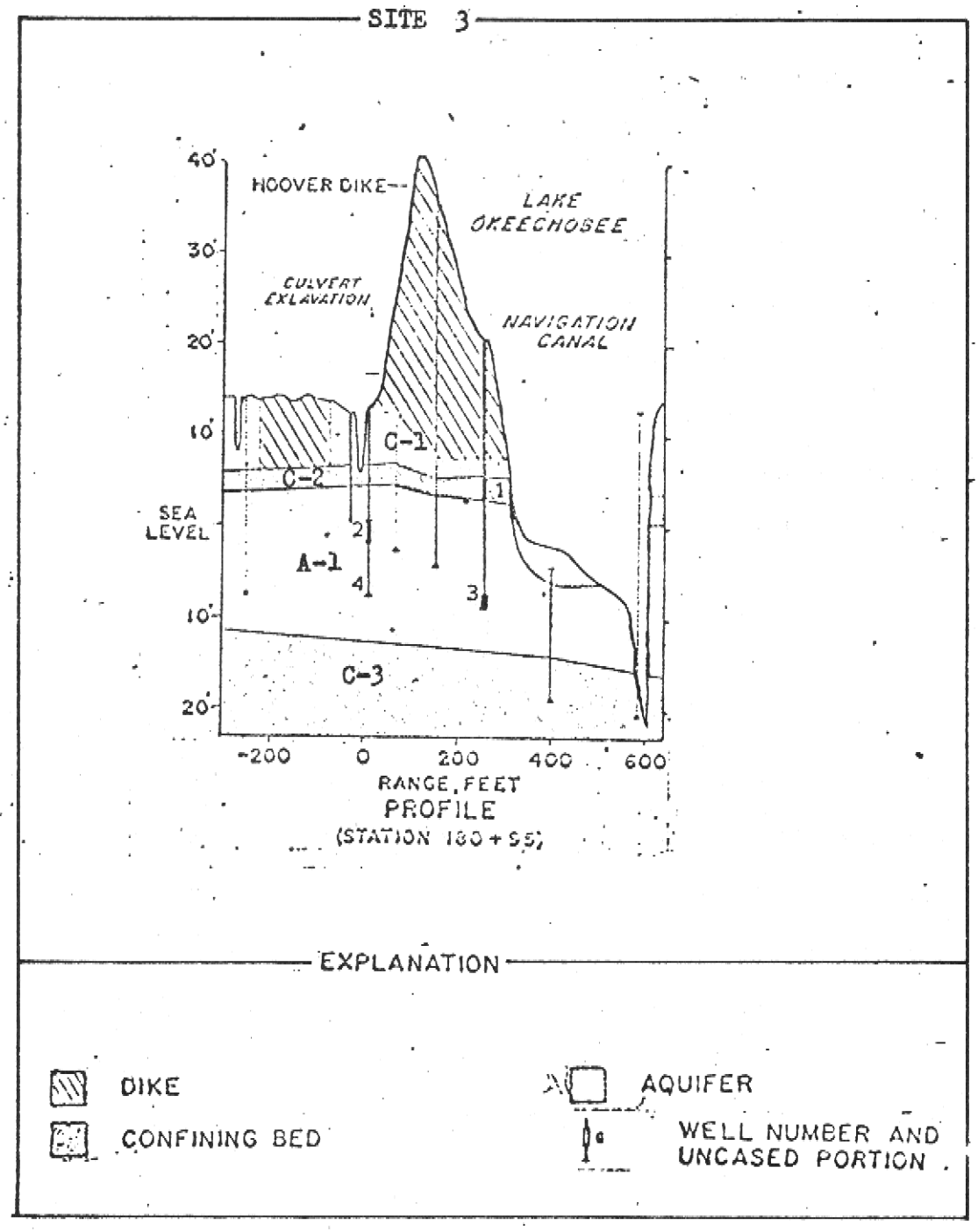

Figure 22.--Profile showing aquifers, confining beds and depths of observation wells at site 3.

Water Movement and Fluctuations

Water levels and chloride content in wells that tap aquifer A-1 and confining bed C-2 are compared with those in the Navigation Canal and the toe ditch in figures 23 through 26. Water levels were highest in the well nearest the lake and lowest in the wells nearest the agricultural area, indicating that seepage at all times was south from the lake.

On January 29, 1970, a period of high water, the stage of the Navigation Canal was 15.9 feet and the stage in the toe ditch was 7.6 feet. Seepage was southward through aquifer A-1 toward the drainage canals in the agricultural area (fig. 23 and 27).

On May 20, 1971, a time of low water levels, the stage of the Navigation Canal was 10.8 feet and the toe ditch 10.3 feet. Seepage was southward through aquifer A-1 from the lake to the agricultural area.

A comparison of chloride content in the wells in aquifer A-1 with the chloride content in the lake shows the concentration to be about equal. This suggests that aquifer A-1 is the principal conveyor of seepage from the lake.

Figures 25 and 26 graphically compare water levels and chloride content of well number one which taps confining bed C-2 with those in the toe ditch and the lake.

The hydraulic gradient in figure 27 illustrates the lake stage that occurred on January 29, 1970. The gradient for confining bed C-2 is about the same as that for aquifer A-1, shown in the illustration. Data for the "C" well water level was inferred.

No appreciable changes in drainage have occurred at site 3. Additional data are needed to determine any reduction in the seepage factor due to filtercake buildup.

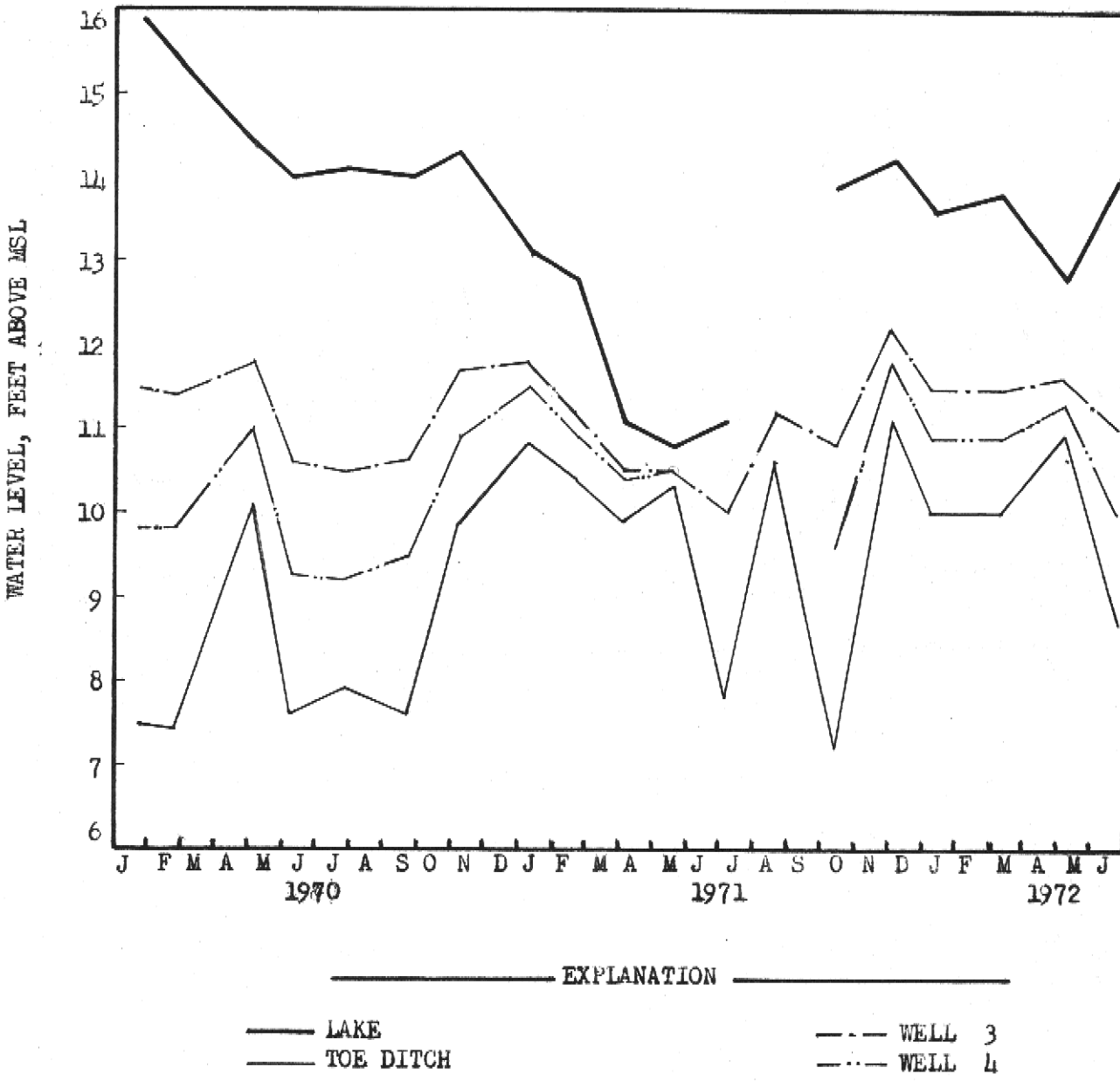

Figure 23. Graph comparing water levels in wells that tap aquifer A-1 at site 3 with data for the lake and the toe ditch; January 1970 - June 1972.

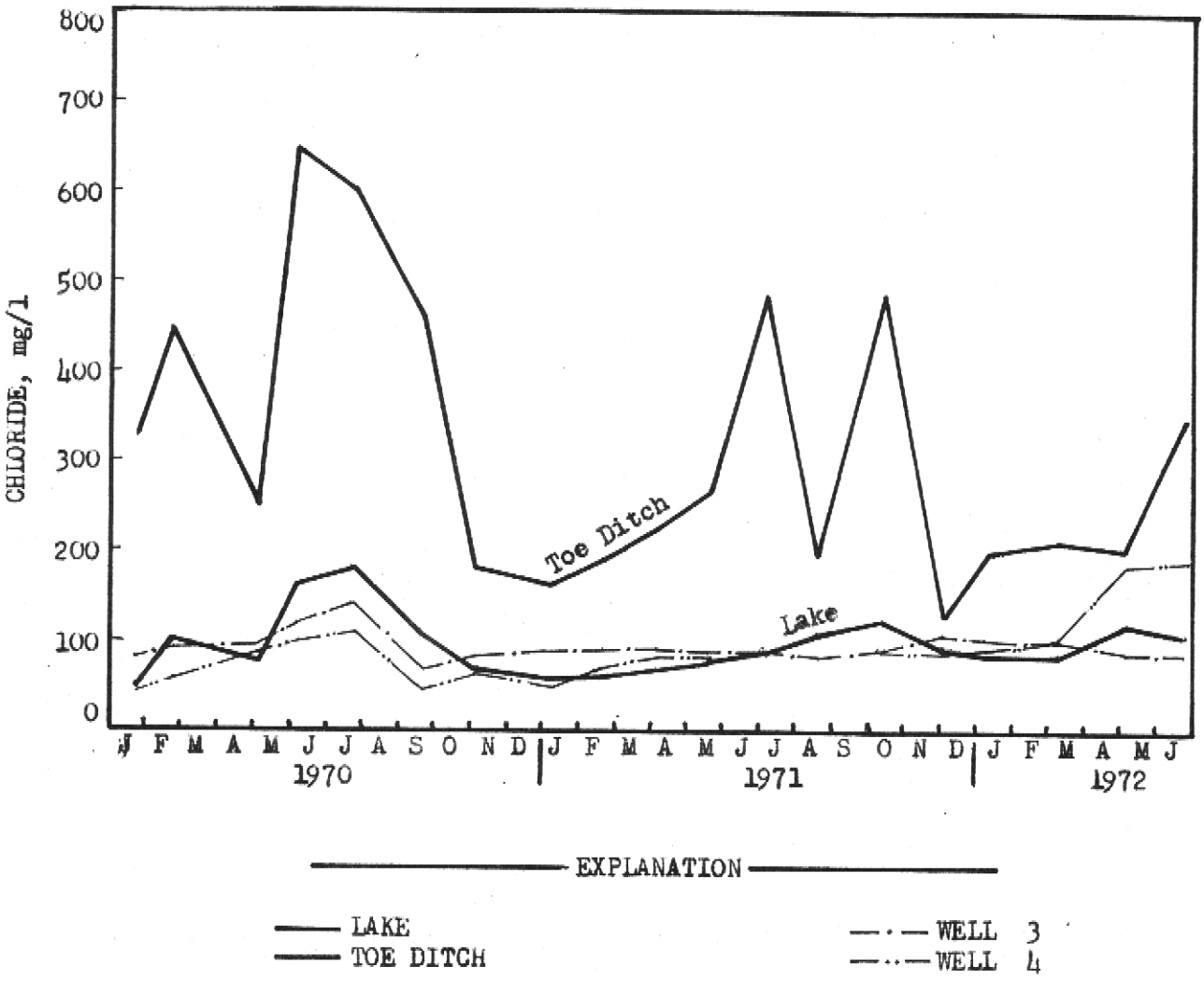

Figure 24. Graph comparing chloride content in wells that tap aquifer A-1 at site 3 with data for the lake and the toe ditch; January 1970 - June 1972.

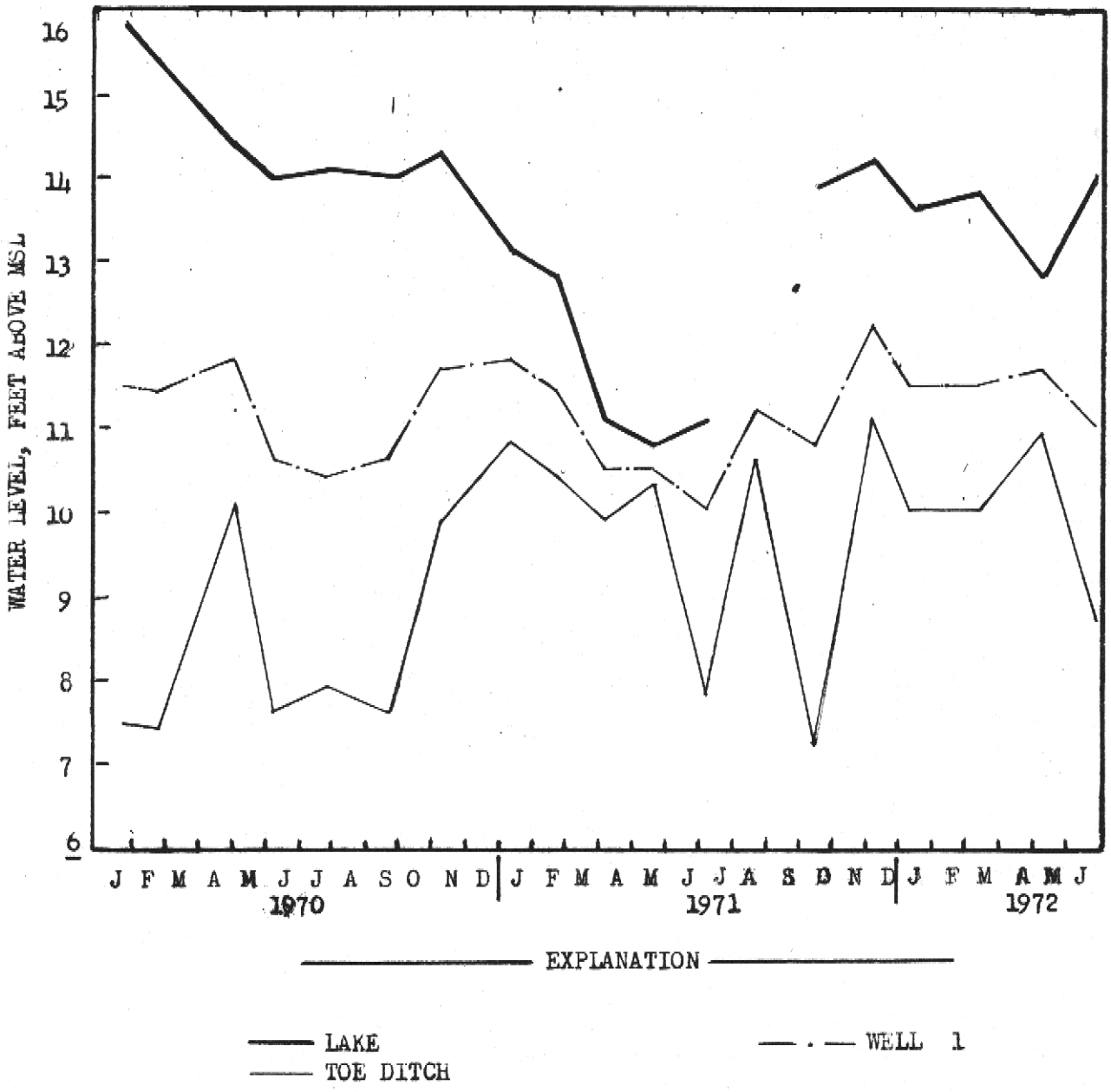

Figure 25. Graph comparing water levels in well that taps confining bed C-2 at site 3 with data for the lake and toe ditch; January 1970 - June 1972.

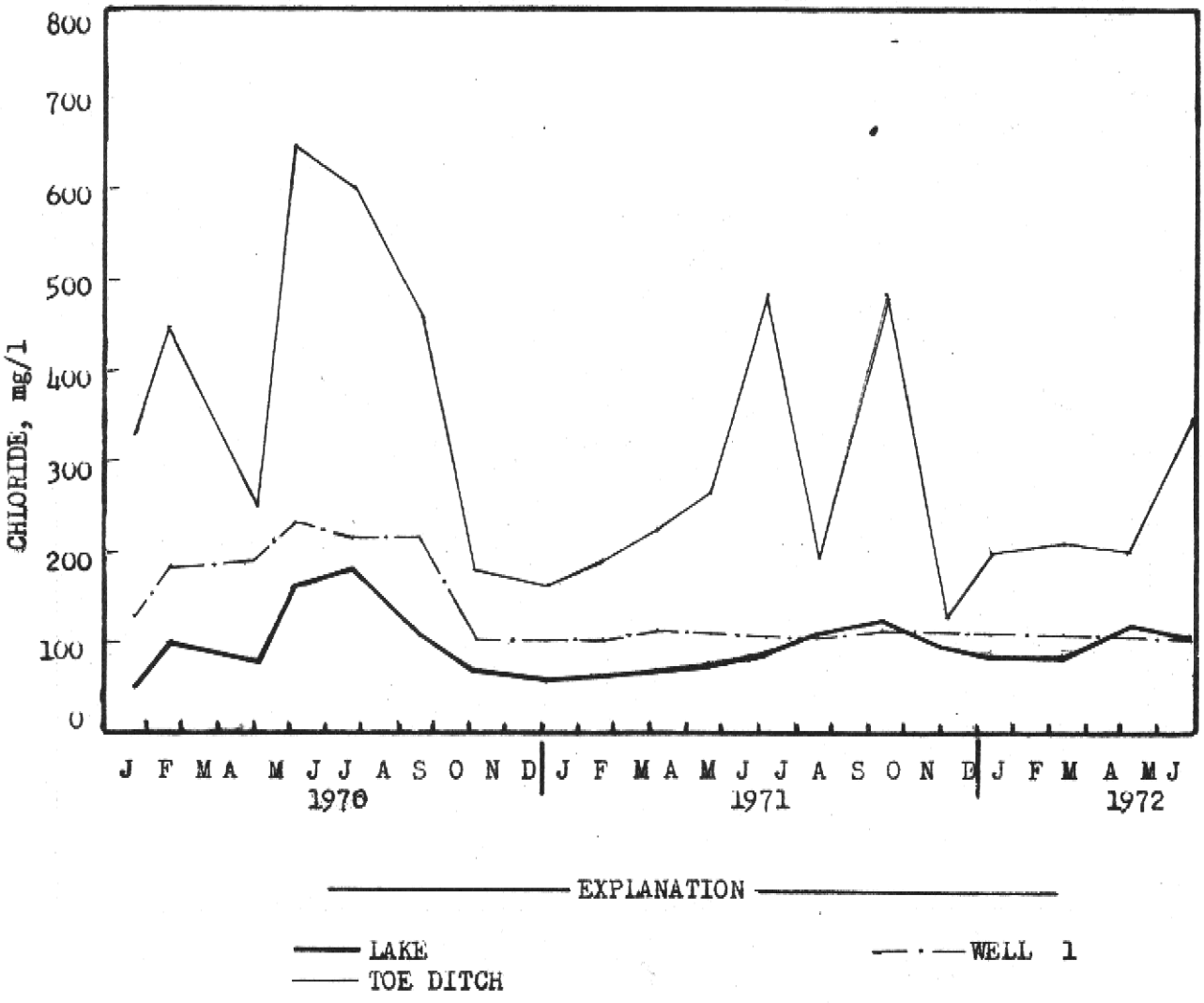

Figure 26. Graph comparing chloride content in well that taps confining bed C-2 at site 3 with data for the lake and toe ditch; January 1970 - June 1972.

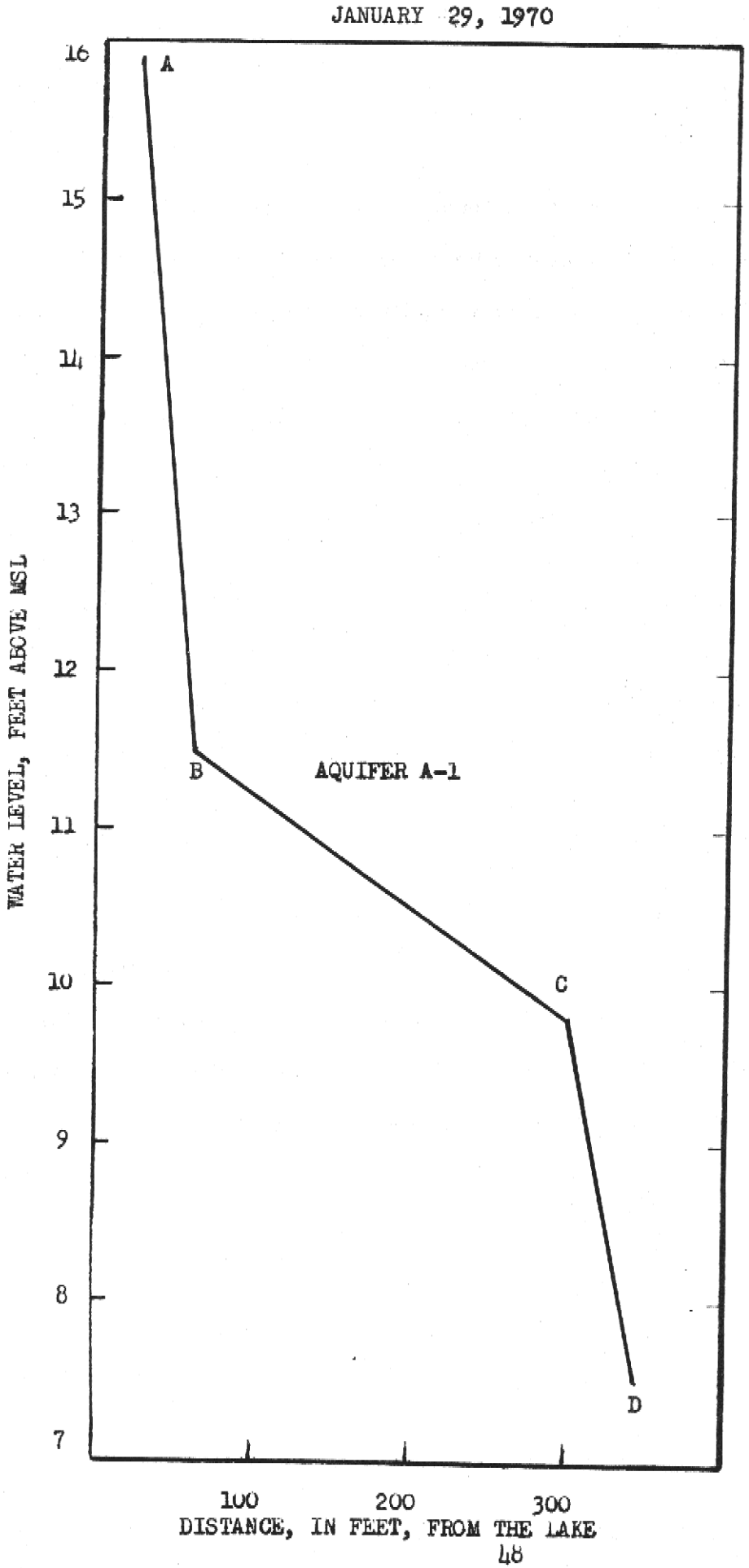

Figure 27. Hydraulic gradient of the upper aquifer, aquifer A-1, at site 3, during a lake stage of 15.9 feet. "A" is the lake stage, "B" and "C" are the wells which tap the aquifer, and "D" is the water level in the toe ditch. The hydraulic gradient for confining bed C-2 is the same.

SITE 4

Site 4 is in Palm Beach County on the southeast shore of Lake Okeechobee, about 3 miles northwest of Belle Glade. The site consists of four wells and two observation points used to obtain data on ground water levels and chloride content. The data-collection stations are on a line about 300 feet long, normal to the Hoover Dike.

Aquifers and Confining Beds

Confining bed C-1 (fig. 28), 8 to 10 feet thick, is composed of relatively impermeable, silty, organic soil. Aquifer A-1 ranges from 0 to 4 feet thick and is permeable limestone grading into marl. Confining bed C-2 is relatively impermeable, shelly marl and limestone. Aquifer A-2 is 7 to 8 feet thick, chiefly porous limestone and shell. Confining bed C-3 is more than 6 feet thick and consists of sand, shell and limestone. Permeability of C-3 is assumed to be low.

Some seepage occurs through each bed, but it is greatest through aquifer A-2, which is highly permeable and exposed to direct infiltration from the lake. Seepage through A-1 is retarded by silt deposits, or filtercake, which lines the Navigation Canal.

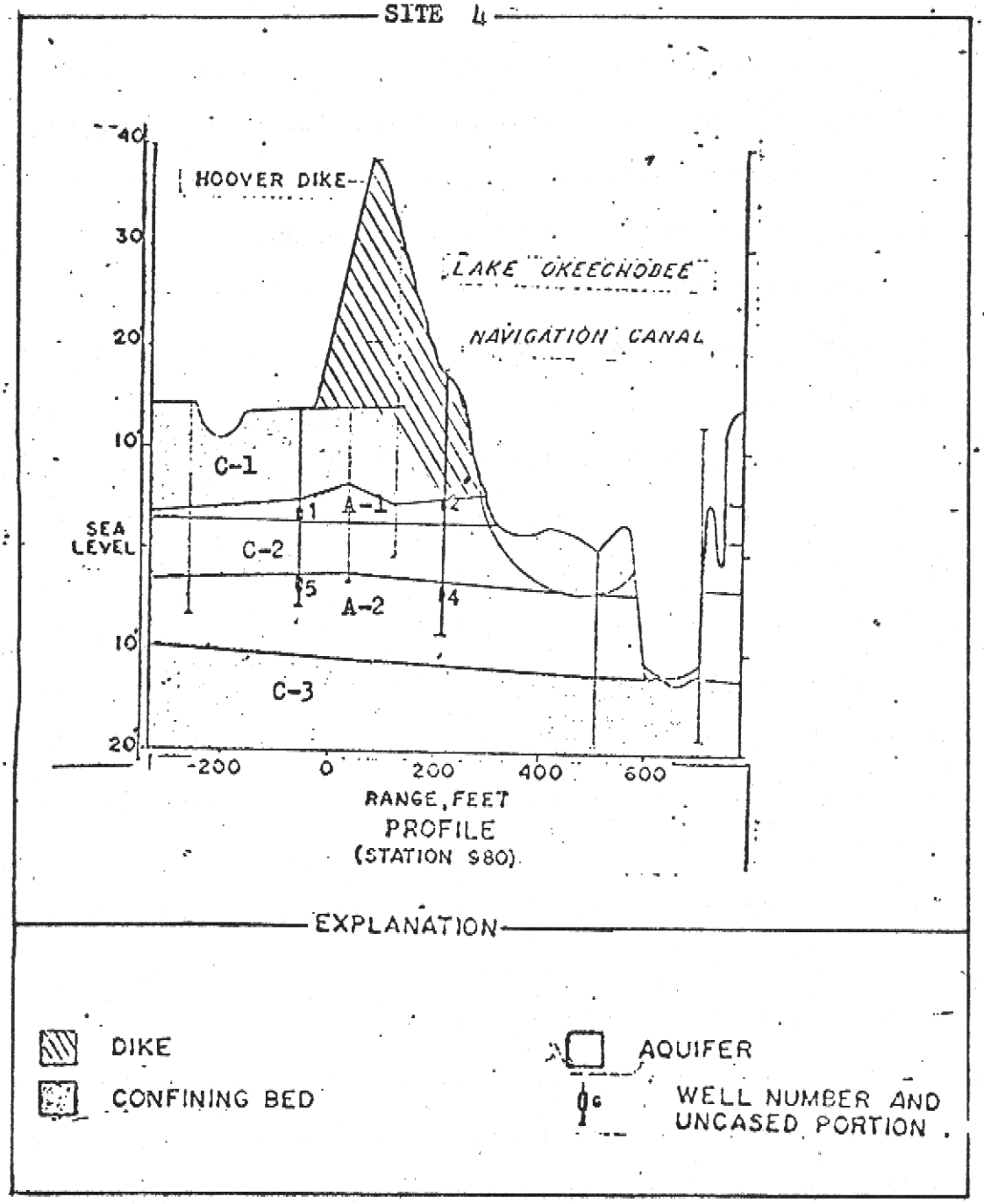

Figure 28.--Profile showing aquifers, confining beds and depths of observation wells at site 4.

Water Movement and Fluctuations

The principal direction of water movement at site 4 is eastward from the lake into the agricultural area. Water levels and chloride content in wells that tap aquifers A-1 and A-2 are compared with data for the lake and toe ditch in figures 29 and 30.

The water levels in the wells that tap A-1 fluctuate between 1 and 5 feet below the lake stage. The small spread between the water levels in the wells shows that the hydraulic gradient in A-1 was relatively low, indicating the rate of seepage to be slow. The chloride and water level data suggest that the seepage rate through aquifer A-2 is also low.

On January 29, 1970, a period of high water levels, the stage of the lake was 15.8 and the stage of the toe ditch was 8.8 feet. Water moved east from the lake through aquifers A-1 and A-2 toward the agriculture area. The hydraulic gradients are shown in figure 31.

On May 20, 1971, a period of low water level, the stage of the lake was 10.8 feet above msl and the stage of the ditch was 8.6 feet. Water moved eastward from the lake through aquifers A-1 and A-2 toward the drainage system.

More long-term water-level data for site 4 are needed to determine the seepage from the lake, which might be expected to decrease as the filtercake is built up on the exposed portions of the aquifers in the bottom of the Navigation Canal.

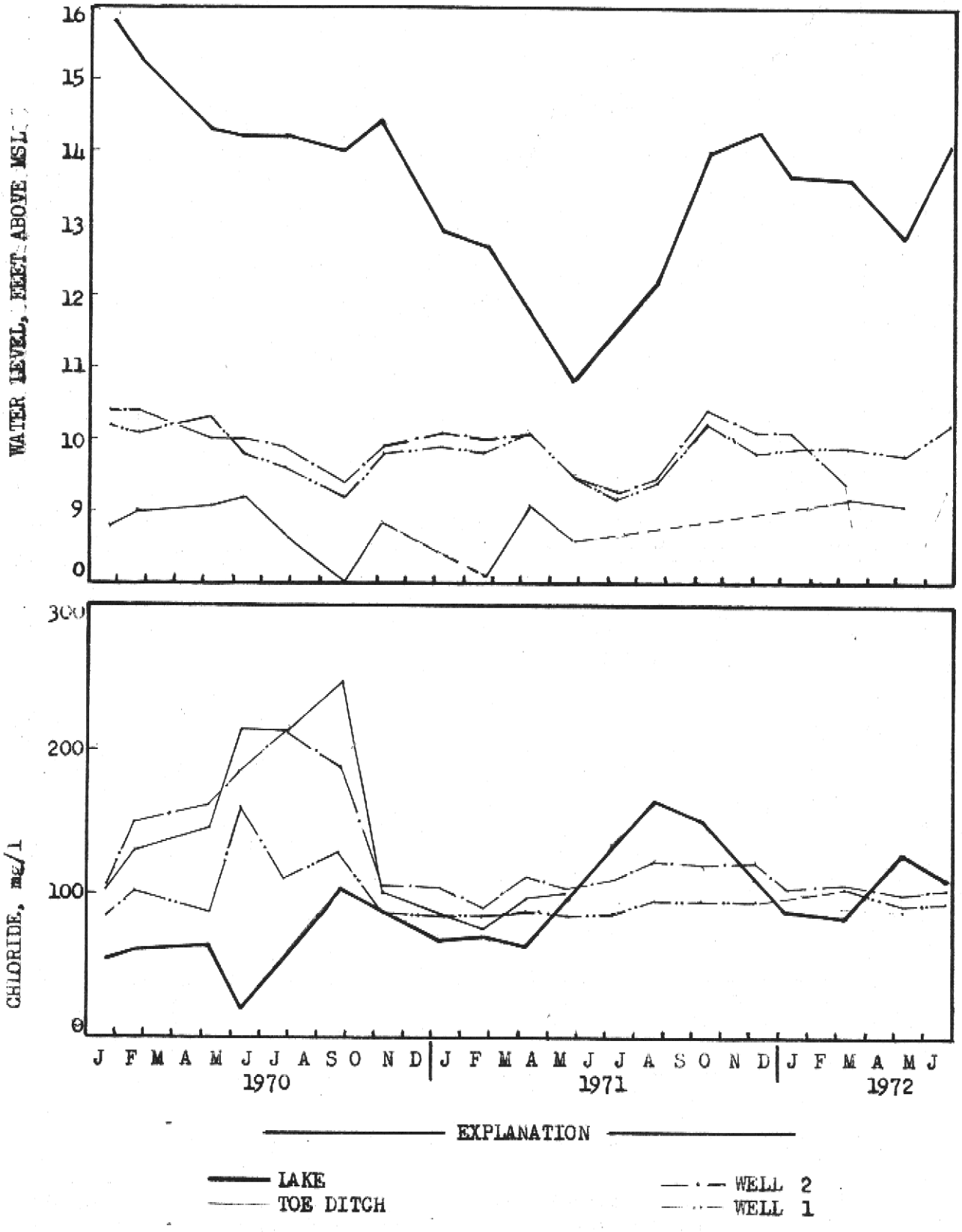

Figure 29. Graphs comparing water levels and chloride content in wells that tap aquifer A-1 at site 4 with data for the lake and toe ditch; January 1970 - June 1972.

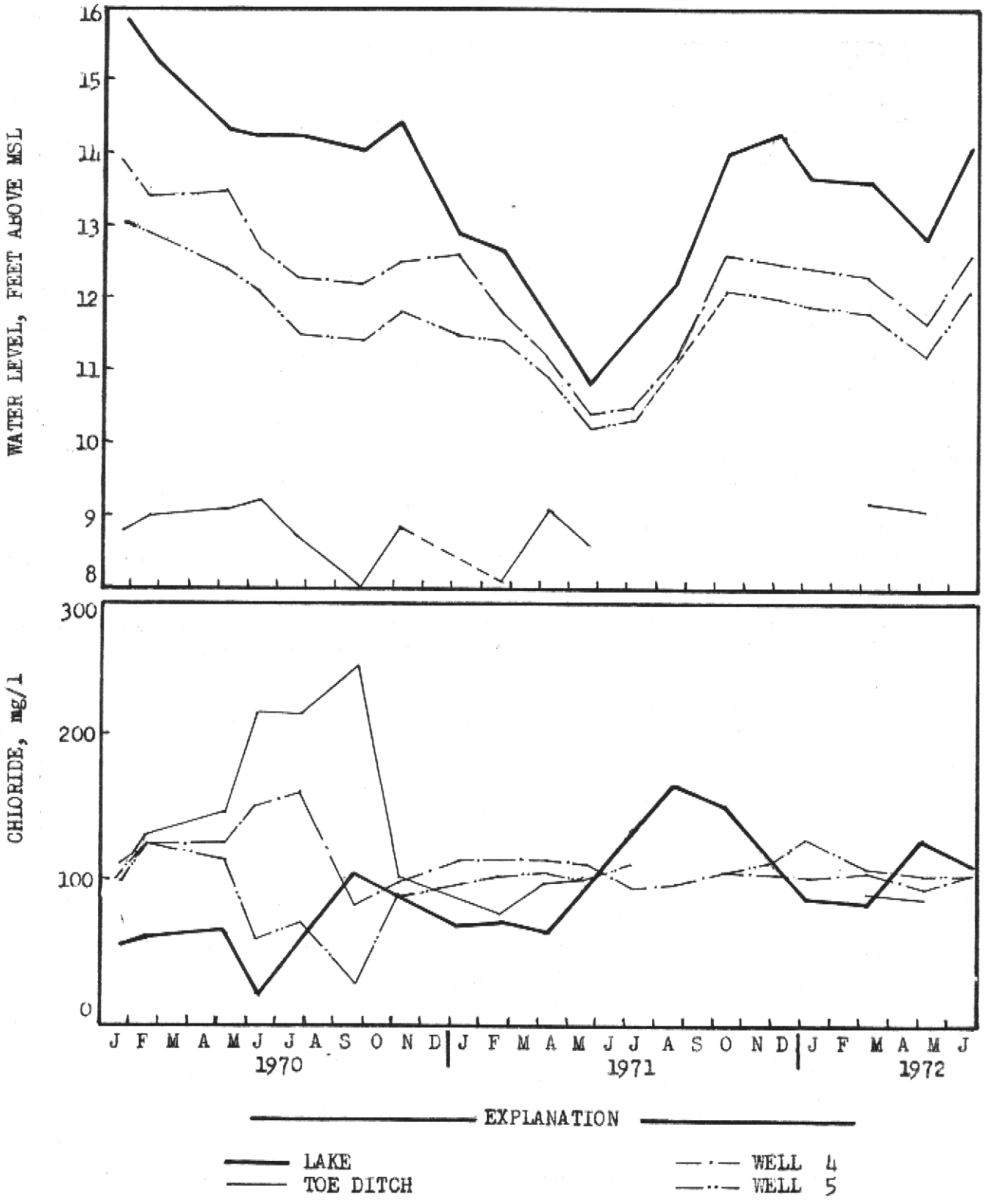

Figure 30. Graphs comparing water levels and chloride content in wells that tap aquifer A-2 at site 4 with data for the lake and toe ditch; January 1970 - June 1972.

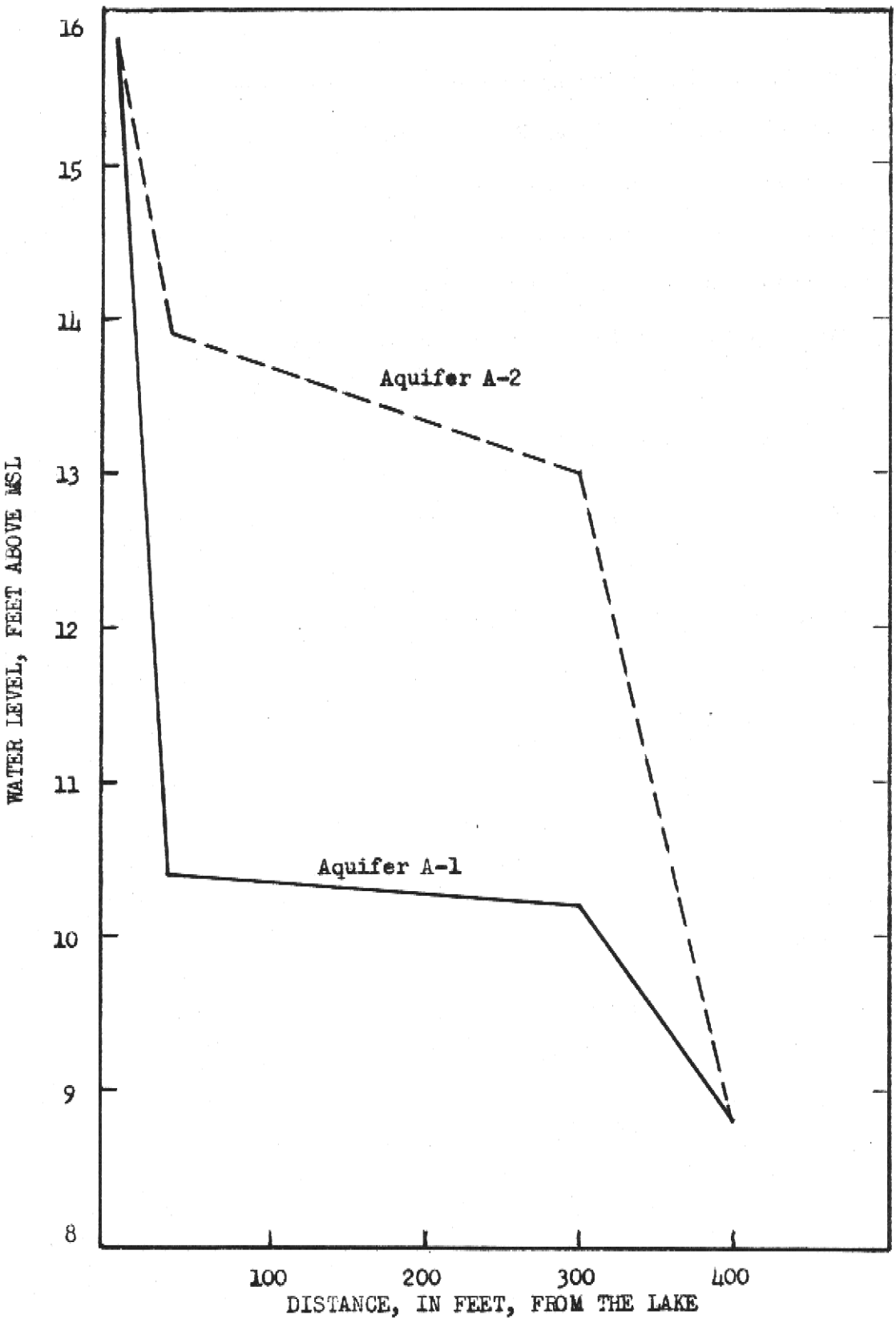

Figure 31. Hydraulic gradients of aquifers A-1 and A-2, at site 4, during a lake stage of 15.8 feet. "A" is the lake stage, "B" and "C" are wells that tap the aquifers and "D" is the water level in the toe ditch. The solid line represents aquifer A-1 and the dashed line A-2.

SITE 5

Site 5 is in Palm Beach County on the east shore of Lake Okeechobee 1.2 miles north of Canal Point. The site consists of data-collection stations along a line about 325 feet long and normal to the Hoover Dike. The station includes 6 observation wells and 2 observation points in the lake and landside toe ditch, which are used to obtain data on water levels and chloride content.

Aquifers and Confining Beds

Confining bed C-1 (fig. 32) has a maximum thickness of 12 feet. The upper 8 feet is organic soil and the lower 4 feet is clayey, shelly marl. The unit is relatively impermeable. Aquifer A-1 has a minimum thickness of 22 feet. The upper 2 feet is permeable shell and limestone, underlain by a 12 foot bed of hard crystalline limestone. The lower 8 feet is soft porous limestone. Confining bed C-2 is at least 15 feet thick and composed chiefly of fine quartz sand. Bed C-2 is relatively impermeable.

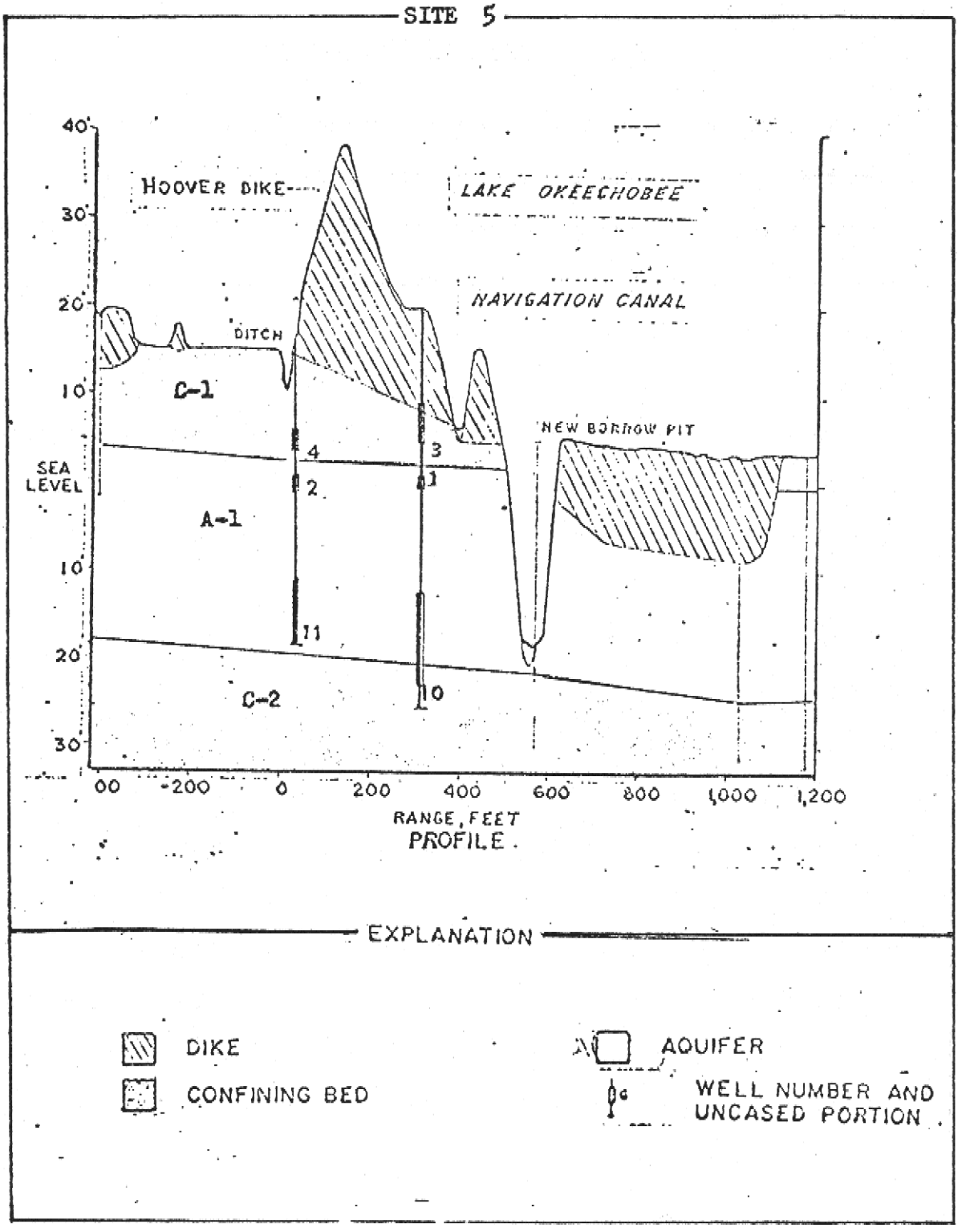

Figure 32.—Profile showing aquifers, confining beds and depths of observation wells at site 5.

Water Movement and Fluctuations

The principal direction of water movement at site 5 is eastward from the lake toward the drainage canals in the agricultural area. Short reversals occur when the water levels in Lake Okeechobee are low after a dry period, as in 1971, or routinely lowered before the rainy season. Figure 33 is a graph showing the monthly rainfall at Canal Point.

Water levels and chloride content in confining bed C-1 and aquifer A-1 are compared with data for the lake and the toe ditch in figures 34 through 37. The line with the least number of dots represents the well nearest the lake.

On January 29, 1970, when the lake stage was 16.1 feet, the direction of flow through confining bed C-1 was eastward from the lake and westward from the ground-water mound beneath the sand ridge toward the toe ditch. Flow of aquifer A-1 was eastward from the lake to the agricultural area. The hydraulic gradient is shown in figure 38.

On July 8, 1971, a period of low water levels, the stage of the lake was 10.2 feet and the toe ditch about 8.5 feet. Flow through confining bed C-1 was westward to the lake. Seepage from the toe ditch into the lake was undoubtedly caused by local drainage operations. Flow through aquifer A-1 was eastward from the lake under a relatively low hydraulic gradient.

Long term water-level data at site 5 are needed to determine the average seepage from the lake. Seepage from the lake may possibly decrease as the filtercake, which was partly removed during construction activities, is redeposited.

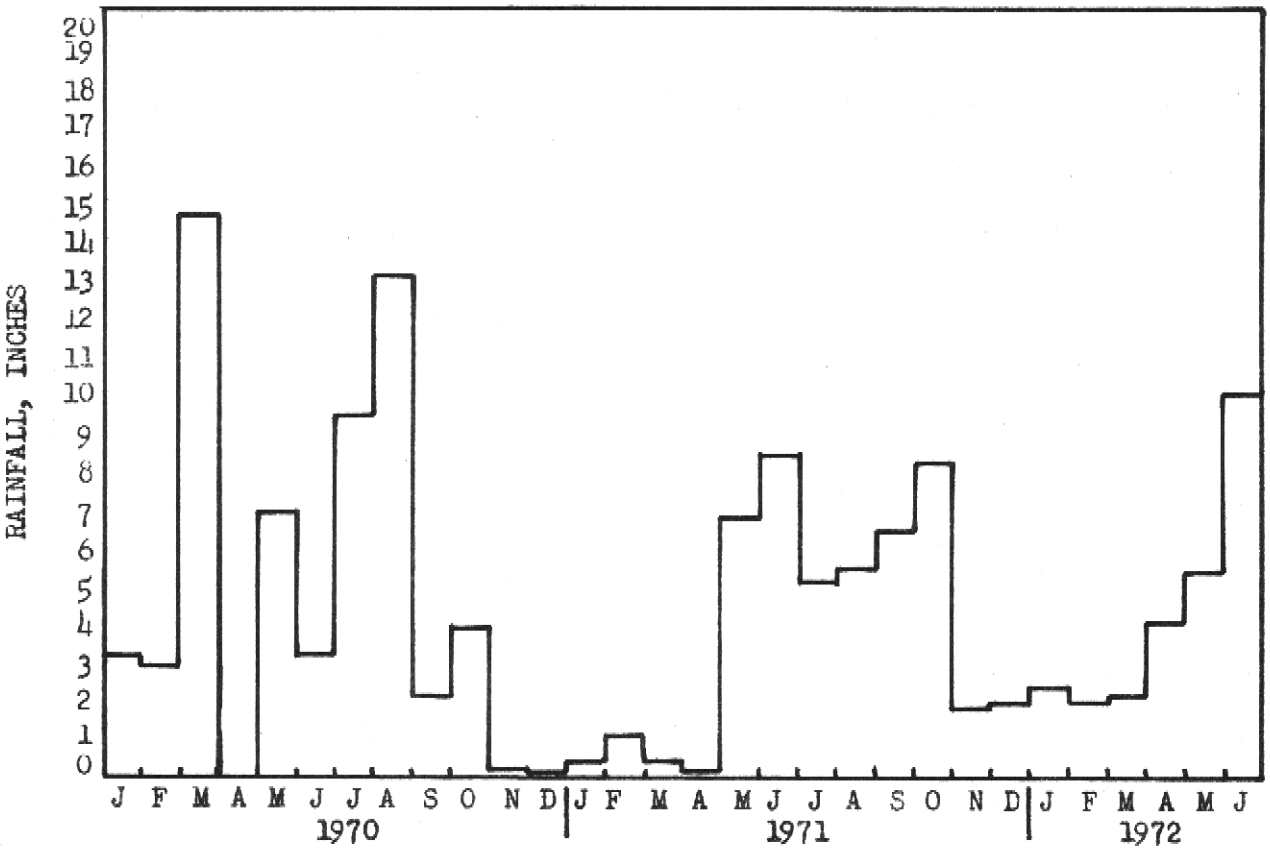

Figure 33. Graph showing monthly rainfall at Canal Point.

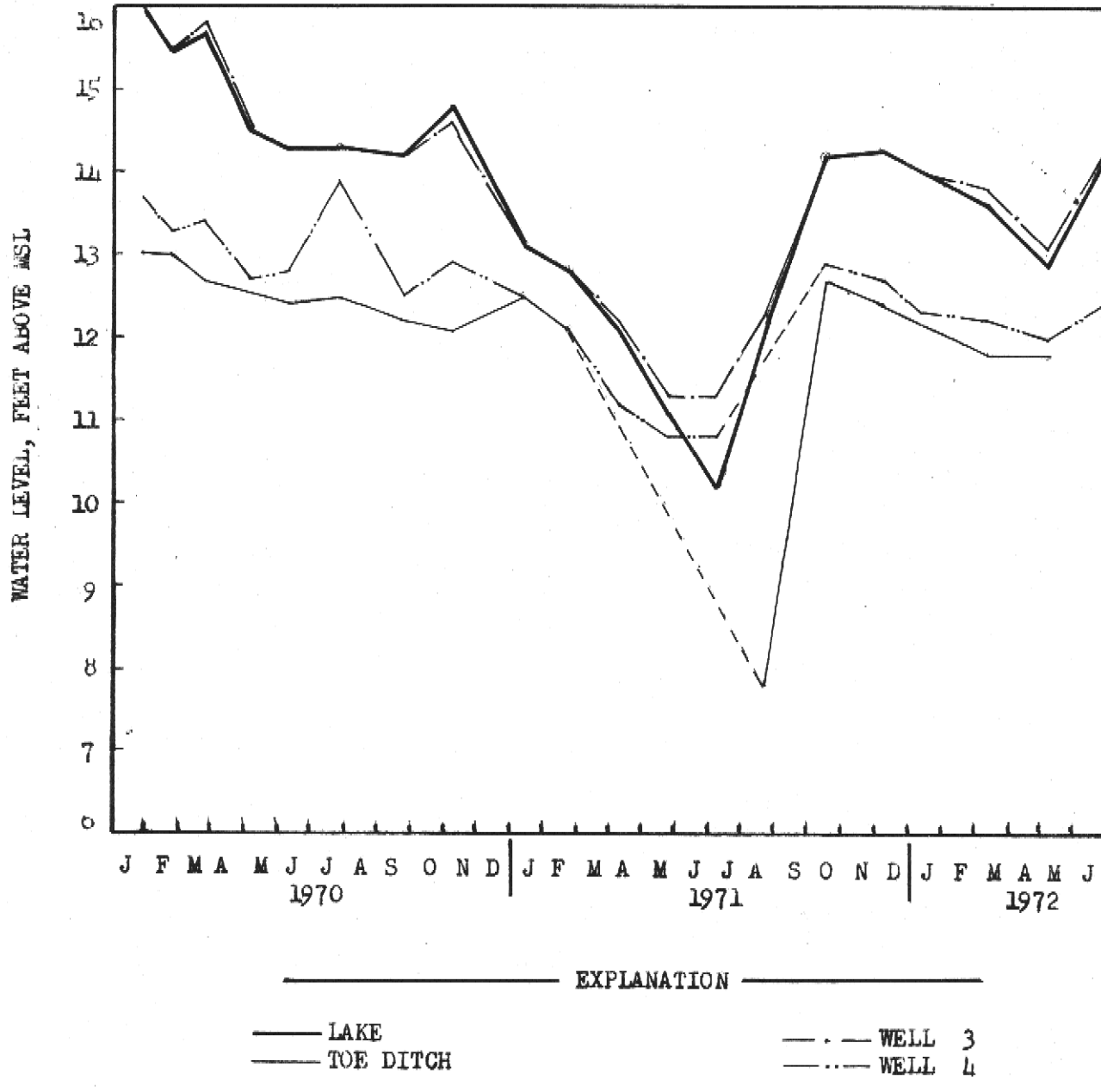

Figure 34. Graph comparing water levels in wells that tap confining bed C-1 at site 5 with the data for the lake and the toe ditch; January 1970 - June 1972.

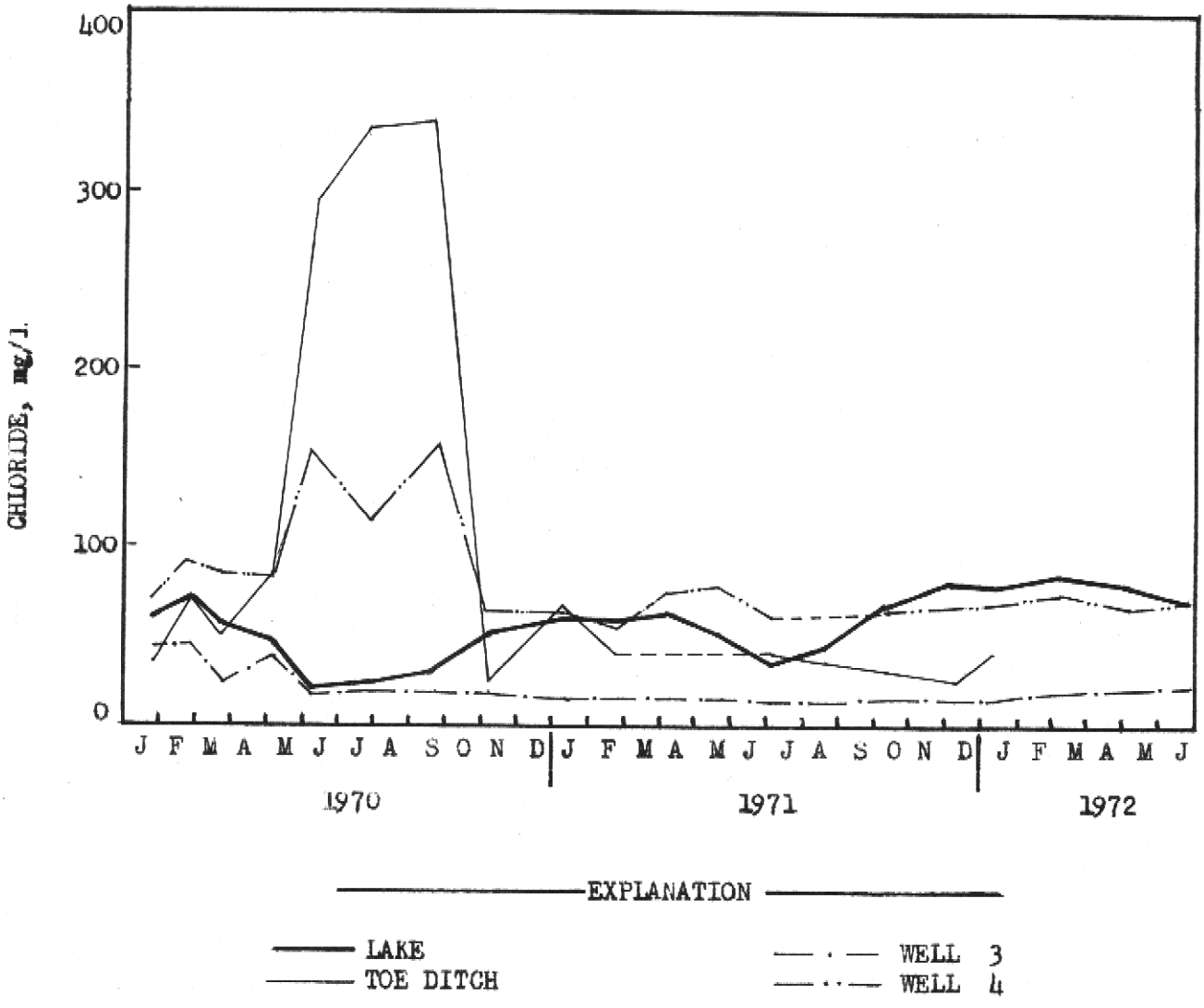

Figure 35. Graph comparing chloride content in wells that tap confining bed C-1 at site 5 with the data for the lake and the toe ditch; January 1970 - June, 1972.

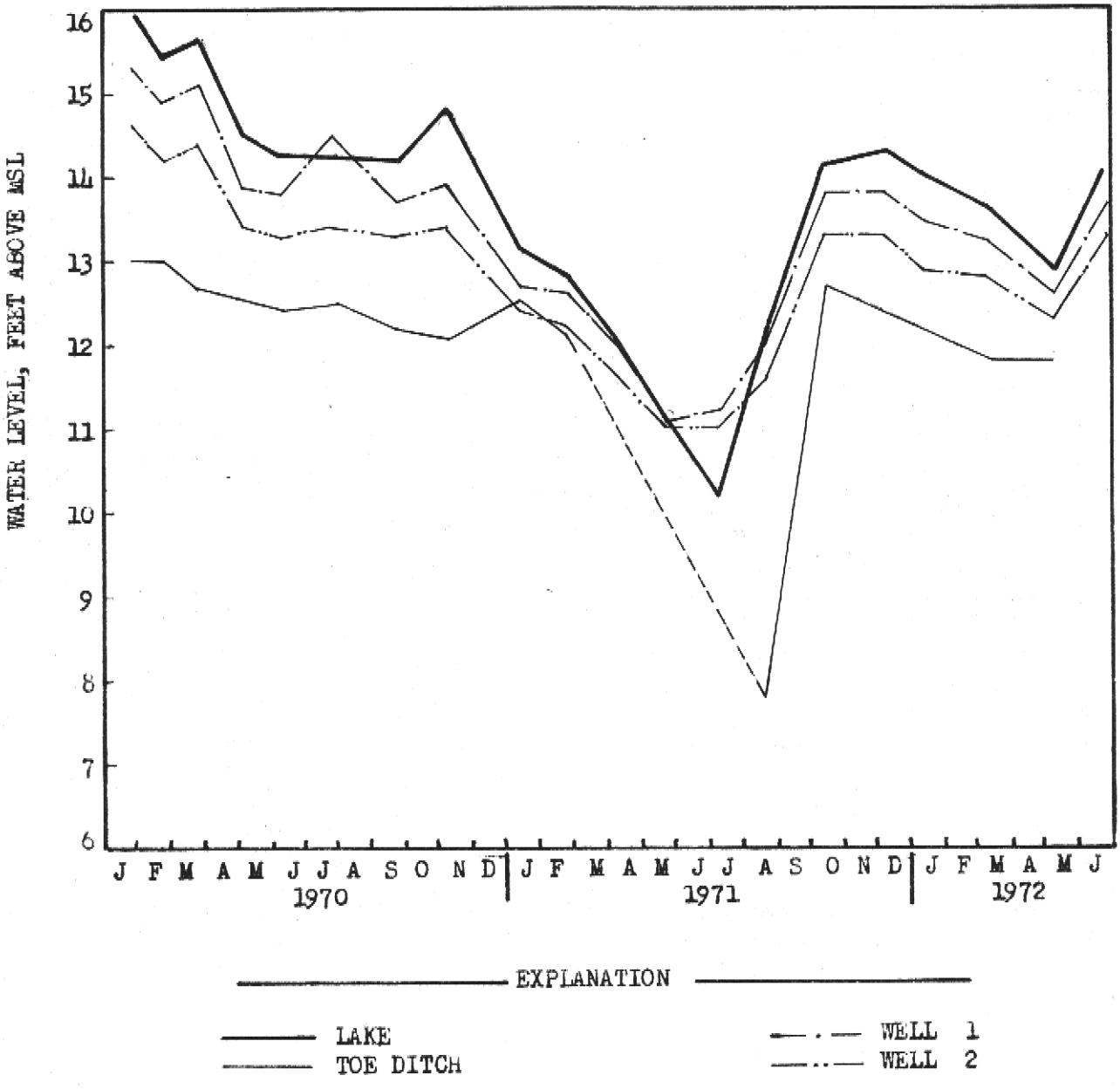

Figure 36. Graph comparing water levels in wells that tap aquifer A-1 at site 5 with data for the lake and the toe ditch; January 1970 - June 1972.

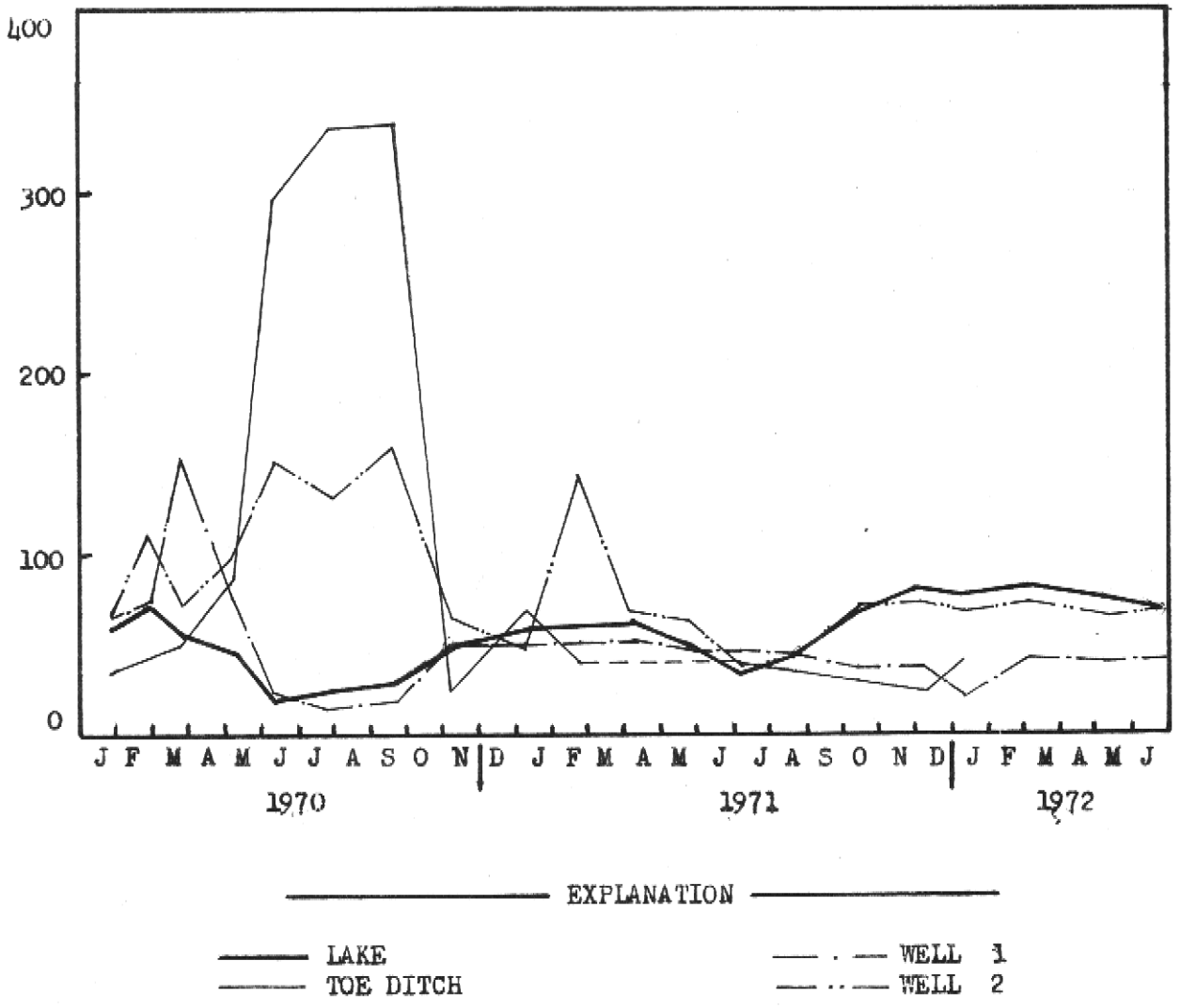

Figure 37. Graph comparing chloride content in wells that tap aquifer A-1 at site 5 with data for the lake and the toe ditch; January 1970 - June 1972.

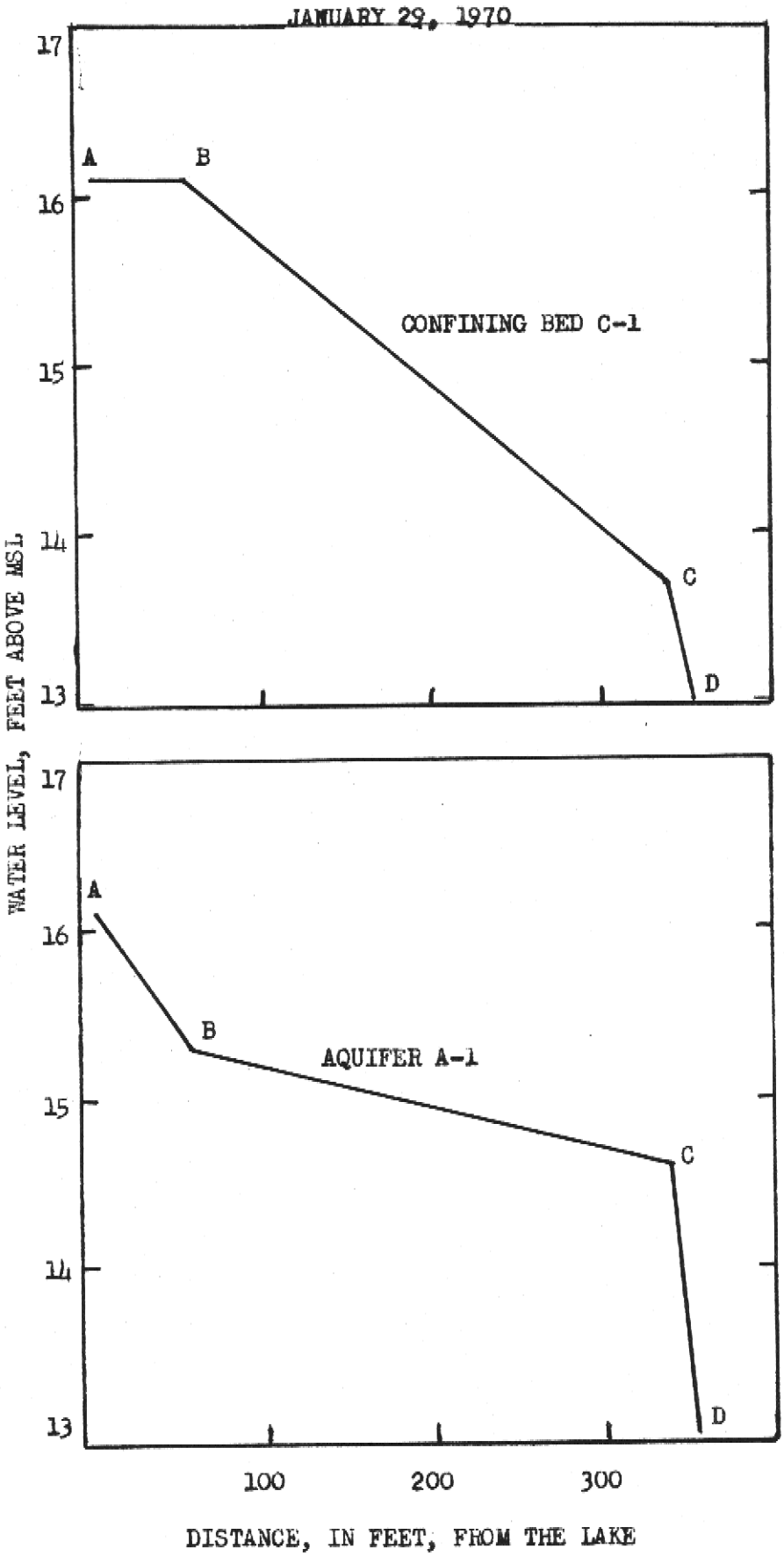

Figure 38. Hydraulic gradients of confining bed C-1 and aquifer A-1, at site 5, during a lake stage of 16.1 feet. "A" is the lake stage, "B" and "C" are wells that tap the stratum and "D" is the water level in the toe ditch.