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A HYDROLOGIC DESCRIPTION OF LAKE MINNEHAHA AT CLERMONT, FLORIDA

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Prepared by
UNITED STATES GEOLOGICAL SURVEY
in cooperation with
SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT
and the
FLORIDA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF INTERIOR RESOURCES
BUREAU OF GEOLOGY

More and more people are seeking lakeside property for its esthetic appeal and for water-oriented recreation. Inevitably, much of the land near lakes that is undeveloped or used principally for agriculture will become residential or urban. Land surrounding a lake can be developed so that the esthetic qualities of the lake are enhanced, property values are increased, and the quality of water in the lake is preserved if planning precedes the development. However, without planning, urbanized lakes deteriorate. Planning for development, including management of thè lake itself, requires a knowledge of the hydrology of the lake.

A lake's hydrology is influenced by numerous factors, such as geography, geology, climate, topography, and land use. A study of these factors and their interrelations for Lake Minnehaha and its surrounding area was made by the U. S. Geological Survey, in cooperation with the Southwest Florida Water Management District, during October 1971 to June 1972. This map report was prepared to acquaint both public officials and private interests with the hydrology of Lake Minnehaha.

GEOGRAPHIC SETTING

Lake Minnehaha is in south-central Lake County, a predominantly rural area in the heart of Florida's citrus belt. The 3.77 square-mile lake (2,410 acres) is bounded on three sides by citrus groves, with homes scattered among the trees along the shoreline. The city of Clermont borders the lake along its north shore.

Lake Minnehaha lies on the northwest edge of the Lake Wales Ridge, the most prominent topographic feature of the Florida peninsula. A highly undulating surface of broad sand ridges and hills dotted with many lakes and closed depressions characterizes the Lake Wales Ridge area. West of Lake Minnehaha is a land-form of low to moderate relief with many small lakes and marshes that interconnect during periods of high water.

The approximately 130-square-mile drainage basin (fig. 2) coincides with the head of the Oklawaha River basin. Drainage from as far south as Lake Lowery near Haines City moves northward through wide shallow swamps confined by parallel sand ridges. This area of wide shallow swamps, known as the Green Swamp Run, drains into Big Creek near the Polk-Lake County line. Big and Little Creeks drain the basin between the Green Swamp Run and Lake Louisa.

Lake Louisa is the farthest upstream and Lake Minnehaha is the next major lake in a chain of lakes that are connected by the Palatlakaha River. The Palatlakaha flows north into the Oklawaha chain of lakes. The Oklawaha flows from these lakes into the St. Johns River, which empties into the ocean.

About 31 percent of the land in the Lake Minnehaha basin is devoted to citrus groves. Only about 2 percent of the land is urban and residential. Swamps, wooded land, lakes, and pasture constitute the remaining 67 percent.

GEOMORPHOLOGY AND GEOLOGIC SETTING

The formation of Lake Minnehaha and other lakes in the area is apparently due to localized differential solution of the underlying limestone by percolating ground water, and corresponding subsidence of the surface, thus creating depressions which evolved into lakes. The evolutionary process that created Lake Minnehaha began a few million years ago and ultimately produced the surface depression that impounded the lake.

Figure 3 indicates the general lithology around Lake Minnehaha. Relatively permeable sands of the Citronelle Formation and undifferentiated surficial deposits constitute the water-table aquifer nearest land surface. The water-table aquifer becomes increasingly clayey and therefore less permeable with depth.

Beneath the Citronelle is the Hawthorn Formation; the clay content is greater and continues to increase with depth so that most of the Hawthorn acts as a confining bed. Although the transition from water-table aquifer to confining bed does not occur abruptly, it is generally coincident with the Citronelle-Hawthorn contact. Under the Lake Wales Ridge on the east side of the lake, where the water-table aquifer is thickest, the confining bed is thin or missing.

Beneath the confining bed is a sequence of highly permeable limestones about 2,000 feet thick known as the Floridan Aquifer. The Floridan Aquifer acts as a large underground reservoir, and is the principal source of water in the area. The depth to the Floridan Aquifer in the vicinity of the lake is variable and not necessarily dependent on the land-surface elevation; that is, the depth to the Floridan Aquifer does not necessarily increase as the land-surface elevation increases. The depth to the Floridan Aquifer ranges from about 60 feet to more than 200 feet below land surface.

The bottom of Lake Minnehaha is in the water-table aquifer, and the bottom is hard and sandy except in very few of the deeper holes or depressions where some muck has accumulated.

LAKE-LEVEL FLUCTUATIONS AND RELATED HYDROLOGY

Since May 1945, the stage of Lake Minnehaha (fig. 4) has fluctuated between 99.0 feet above mean sea level, on April 5, 1960, and 92.7 feet above mean sea level, on January 22, 1963. The stage of Lake Minnehaha (and also, the stages of Cherry Lake, Lake Minneola, and Lake Louisa, fig. 2) have been regulated to some degree since 1956 by a discharge control structure at the outlet from Cherry Lake, about 8.6 miles downstream of the outlet from Lake Minnehaha.

Water enters the lake as surface inflow from the Palatlakaha River, as direct runoff, as ground-water seepage, and as rainfall. Water leaves the lake as surface outflow through the Palatlakaha River, as ground-water seepage, and by evaporation. An insignificant amount is withdrawn for irrigation. The lake stage fluctuates in response to changes in the relative volumes of these sources.

Figures 5 and 6 relate the monthly rainfall, evaporation, and lake stage from 1960 through 1971. Average annual rainfall for the 12 years at the National Oceanic and Atmospheric Administration (NOAA) station 6 miles south-southwest of Clermont was 51.4 inches, nearly the same as the long-term average at that station, 51.2 inches. The influence of rainfall on the lake level is evident–the level rises during the wetter months and falls during the drier months.

For the same 12 years, discharge from Big Creek into Lake Louisa averaged 33.9 cfs (cubic feet per second), and discharge from Cherry Lake averaged 50.7 cfs. To convert cubic feet per second into millions of gallons per day, multiply the value in cubic feet per second by 0.65, thus 33.9 cfs = 22.0 million gallons per day. Big Creek drains the upper half of the Lake Minnehaha basin, an area of approximately 70 square miles. Cherry Lake receives drainage from approximately 160 square miles that includes the 130-square-mile Lake Minnehaha basin. Thus, the additional 90-square-mile area surrounding Lakes Louisa (including Little Creek drainage), Minnehaha, Minneola, and Cherry Lake contributes, on the average, only 16.8 cfs. Surface runoff east of these lakes is low because rainfall readily infiltrates the permeable sand hills in that area. The numerous small lakes and marshes west of Lakes Louisa, Minnehaha, Minneola, and Cherry Lake indicate low surface runoff in that area. Most of the rainfall that is not retained as surface storage either evaporates or soaks into the ground.

The direction and volume of ground-water flow into or out of Lake Minnehaha depends on the permeability of the subsurface strata, and the hydraulic gradient. The hydraulic gradient is the difference in head per unit of distance in a given direction. The level to which water rises above a datum (for èxample, mean sea level) in a well cased into an aquifer is the measured head at that point in the aquifer. At points along the bottom of a lake, the level of the lake is the head. Water flows from points of high head to points of low head.

Therefore, if the surface of a lake is higher than the head in surrounding aquifers, water will seep out of the lake, and vice versa, provided the lake bottom is permeable. The potentiometric surface of a confined aquifer is an imaginary surface that coincides with the head in the aquifer. Contours representing the elevation of the potentiometric surface of the Floridan Aquifer in figure 1 show that, in March 1972, the surface was lower than the lake level and sloped generally from southwest to northeast.

The confining bed of clay and sand limits the rate of downward movement of water from above, thus helping to hold both the lake level and the water table above the potentiometric surface. An indication, in addition to lithologic data from wells, that the confining bed is thin or missing east of Lake Minnehaha is the fact that the elevations of small lakes such as Jacks Lake and Wilma Lake (fig. 1) are about 10 to 15 feet lower than that of Lake Minnehaha, and nearly the same as the potentiometric surface. This also indicates that these smaller lakes are sources of local recharge to the Floridan Aquifer during wet periods and that ground-water discharges into the lakes during dry periods.

A section along line A-A' (fig. 1), parallel to the direction of ground-water flow in the Floridan Aquifer (flow is at right angles to the contours on the potentiometric surface) is shown in figure 7 to illustrate generalized ground-water flow relative to the lake. Because the vertical gradient between the lake and the Floridan Aquifer is considerably greater than the horizontal gradient due to the slope of the water table and potentiometric surface, flow through the water-table aquifer is to the Floridan Aquifer.

The vertical component of flow is relatively large also because the average permeability of the lower layer (Floridan Aquifer) is probably several hundred times greater than the average permeability of the upper layer (water-table aquifer and confining bed taken as a unit). In a layered system where an aquifer with essentially horizontal flow is recharged from above, the dominant path of flow more nearly approaches the vertical as the ratio of permeability in the lower layer to permeability in the upper layer increases.

Figure 7 also shows that ground water seeps into Lake Minnehaha from the water-table aquifer around the edges. Slight mounding of the water table is believed to occur beneath the sand hills surrounding the lake, creating a lateral gradient toward the lake. The magnitude of the gradient, and therefore the volume of ground-water inflow, is variable depending on the amount and duration of rainfall over a period of time. During relatively dry periods, the head in the water-table aquifer close to the lake, within the interval 76 to 73 feet above mean sea level (34 to 37 feet below land surface, well 832.2, figs. 1 and 8) is lower than the lake level. Mounding of the water table is probably extremely slight during such periods, especially on the east side of the lake. During wet periods, increased mounding of the water table is likely. After 5.3 inches of rain March 30-31, 1972 the head was higher at the point where well 832.2 is open to the aquifer than the lake level for several days. Thus, the gradient relative to the lake at that point was reversed, indicating a probable increase in ground-water flow toward the lake from the upper elevations of the saturated zone around the lake.

The water level in Floridan Aquifer well 832.1, at the same site as water-table aquifer well 832.2, rose nearly as much as the level in well 832.2 after the 5.3-inch rainfall of March 30-31, 1972. This does not necessarily mean that similar quantities of water were taken into storage in the two aquifers; confined aquifers generally take far less water into storage per unit change in head than water-table aquifers.

On the basis of short-term (less than 5 years duration) water-level records for wells in the general vicinity of Lake Minnehaha, the potentiometric surface may rise above the lake level on the west side of the lake during wet periods. But this condition is probably the exception rather than the rule.

The net volume of ground-water seepage to and from Lake Minnehaha has little effect on changes in the level of the lake. During 1962, no water was released from Cherry Lake through the outlet control. Inflow to Lake Louisa from Big Creek averaged only 4.2 cfs. Thus, Lakes Louisa, Minnehaha, Minneola, and Cherry Lake were, for practical purposes, a closed surface system. With virtually no surface flow passing through Lake Minnehaha, stage changes were the direct result of rainfall accretions and evaporation losses, and ground-water seepage. For each month of 1962, the change in lake level was close to the net difference between rainfall and evaporation. That is, average monthly change in level of Lake Minnehaha during 1962 was -0.09 foot, while the average monthly evaporation exceeded average monthly rainfall by 0.12 foot. Thus, the thickness and relative impermeability of the confining layer beneath Lake Minnehaha apparently limits the volume of water seeping out of the lake to small amounts relative to other sources of inflow and outflow.

The effect of discharge control at Cherry Lake from 1960 through 1971 on the stage of Lake Minnehaha (and also Lakes Louisa, Minneola, and Cherry Lake) can be seen from figures 5, 6, and 9. For example, on the average in January, rainfall exceeded evaporation by 0.43 inch; but the level of Lake Minnehaha dropped, on the average, 1.27 inches in January. Apparently, the average discharge of 44 cfs in January was greater than inflow to the four lakes. On the average in May, evaporation exceeded rainfall by 3.39 inches, but the lake level fell, on the average, 5.96 inches. Thus, the average May discharge of 40.5 cfs exceeded average inflow to the four lakes. On the average in August, the lake rose 4.77 inches, but rainfall exceeded evaporation by only 2.84 inches. Cherry Lake's average discharge in August, 51.3 cfs, was therefore less than average inflow.

The desirable range in stage for Lake Minnehaha established by Southwest Florida Water Management District is 96.00 to 97.25 feet above mean sea level, but the control structure is not operated by the Southwest Florida Water Management District. Figure 10 shows that, since the installation of the Cherry Lake discharge control structure in 1956, the stage of Lake Minnehaha has been within that range 37 percent of the time. For the years of record when no control existed, the stage was within that range 41 percent of the time. As shown in figure 10, the stage has been lower more of the time since discharge has been controlled. Yet average annual rainfall at the Clermont station for the period of record when discharge was controlled (53.3 inches) averaged 4.5 inches more than during the period when discharge was uncontrolled (48.8 inches). Rainfall at the Clermont station is believed to be as representative an estimate of rainfall on the basin as can be obtained with available data. No evidence exists to indicate that pumping from wells has lowered ground-water levels. Apparently the discharge control, together with other channel improvements downstream of the control, are less restrictive to flow than the natural channel that existed before 1956.

The extreme high stages in 1960 of nearly 99 feet and the extreme low stages in late 1962 and early 1963 of less than 93 feet probably are relatively rare occurrences. Total rainfall at the Clermont station for 1959 and 1960, 134.36 inches, was by far the highest 2-year total since the record began in 1892. Total rainfall at the station for 1961 and 1962, 72.61 inches, was the lowest 2-year total on record. The location of the 100-foot contour on the land surface around Lake Minnehaha shows that extreme high stages such as 99 feet in 1960 are not likely to cause extensive flood damage. Also the lake is deep enough close to shore so that extreme low stages do not expose much of the lake bottom. Serious problems associated with lake-level fluctuations are not anticipated.

WATER QUALITY

The quality of water in Lake Minnehaha is good, and presently appears to be stable. Comparisons of the chemical analysis of lake water sampled in March 1972 (Table 1) with previous analyses as far back as 1956 indicates no significant changes in concentration of any constituent for which analyses are available. No chemical or physical constituent determined exceeds the limits established by the U. S. Public Health Service for drinking water. However, no bacteriological analyses were made. The dissolved solids concentration in Lake Minnehaha is relatively low (48 milligrams per liter) in comparison with the 700-milligram-per-liter upper limit of dissolved solids in water considered suitable for irrigation of most crops under most conditions.

Eutrophication is the natural aging process of a lake. A eutrophic lake is characterized by high nutrient concentrations, and corresponding high biologic productivity. Nuisance growths of algae frequently occur in eutrophic lakes. A nutrient is any substance necessary for growth, repair of tissue, or reproduction. Nitrogen, phosphorus, and carbon are considered key elements among the nutrients essential for the growth of water weeds, including algae. Minimum requirements of these elements for the growth of algae vary, but concentrations of nitrogen, phosphorus, and carbon in Lake Minnehaha are relatively low. Algae has not been a problem in Lake Minnehaha.

Dissolved oxygen, specific conductance, and temperature profiles at a number of locations in the lake indicate that water in the lake is well mixed. The mixing is evidently the result of wind action more than surface-water flow through the lake.

Measurable amounts of the insecticides DDT, DDE, DDD, and dieldrin were in a sediment sample from the bottom of the lake near the center (table 2). Runoff from agricultural land may be the prime source, although dust containing the substances likely is a significant contributor. DDE, DDD, and dieldrin are insoluble in water, and DDT is practically insoluble. These substances tend to adhere to suspended sediment and settle to the bottom with the sediment; thus their concentrations are likely to be higher in the bottom sediments than in the water. The recommended limits of DDT and dieldrin in public water supplies are 42 and 17 micrograms per liter, respectively, well above the concentrations noted in Lake Minnehaha sediment. DDD and DDE are similar in composition to DDT, but both are less toxic to mammals than DDT.

Urban storm runoff to lakes and streams is a significant source of pollutants. Stormwater from Clermont discharges directly into Lake Minnehaha at a number of points. The quality and volume of stormwater from Clermont have not noticeably affected the quality of water in the lake. However, land development and urbanization usually result in an increase in the quantity and degradation of the quality of storm runoff. The quality of lake water will be adversely affected in the future if, as land around the lake is developed, its accompanying storm runoff from streets, parking lots, and rooftops is allowed to drain to the lake. Alternatives exist to discharging storm runoff into convenient lakes. One possibility is to collect storm runoff in holding ponds. If properly located, designed and maintained, the ponds will permit stormwater to be disposed of by evaporation and infiltration.

In general, the good quality of water in Lake Minnehaha can be attributed to a largely undeveloped drainage basin. A previous study of 69 lakes in southwestern Orange County and two lakes in Lake County, indicates that the variation in quality among the lakes is due primarily to land-use practices in the lake basins. Lakes in predominantly undeveloped basins are of better quality than lakes in basins where the major land use is for citrus groves or housing. The fact that surface runoff from grove land in the Lake Minnehaha basin is very low minimizes the amount of nutrients, pesticides and other agricultural chemicals reaching the lake.

The continued good quality of Lake Minnehaha will depend for the most part on the future course of planned growth and development in the drainage basin. Sedimentation and enrichment by nutrients are the principal contributors to eutrophication of lakes. Much sedimentation occurs during land development. Earth-moving, grading, road building, installation of utilities and other construction activities leave the ground bare and vulnerable to erosion during storms. Erosion control, or at least the containment of eroded material at construction sites can decrease sedimentation. Some nutrient enrichment of Lake Minnehaha is inevitable. However, the rate of enrichment as the lake's drainage basin is developed can be minimized if all reasonable care is exercised in the location, design, and installation of septic tanks and sewage treatment facilities. Septic tanks in areas where the water table is near land surface, or in areas close to lakes or streams where the direction of ground-water flow is toward the lake or stream can cause accelerated nutrient enrichment of the lake. Control of nutrient and sediment sources as the basin develops is one way to prevent the quality of water in Lake Minnehaha from deteriorating.

Table 1.--Chemical analysis[1] of water in Lake Minnehaha; integrated sample collected March 22, 1972 at center of lake; constituents in milligrams per liter except as noted; metals are total recoverable.

Silica (S_iO_2)	0.7
Calcium (Ca)	3.2
Magnesium (Mg)	1.5
Strontium (Sr)	.03
Sodium (Na)	6.4
Potassium (K)	.4
Bicarbonate (HCO_3)	3
Carbonate (CO_3)	0
Sulfate (SO_4)	7.6
Chloride (Cl)	12
Fluoride (F)	.1
Total organic nitrogen (N)	.61
Nitrate (NO_3)	.0
Nitrite (NO_2)	.04
Ammonia (NH_4)	.05
Total phosphorus (P)	.025
Ortho phosphate as P	.013
Total organic carbon (TOC)	9
Dissolved solids (residue at 180°C)	48
Alkalinity as $CaCO_3$	2
Hardness (Ca-Mg)	14
Noncarbonate hardness	12
Iron (Fe)	.13
Mercury (Hg) less than	.0005
Manganese (Mn)	.00
Zinc (Zn)	.02
Cadmium (Cd)	.000
Chromium (Cr)	.00
Lead (Pb)	.000
Copper (Cu)	.00
Specific conductance (micromhos at 25°C)	70
Biochemical oxygen demand (BOD)	.5
pH (field measurement)	6.5
Dissolved oxygen (field measurement)	8.5
Temperature, °F (field measurement)	68
Color	50
Turbidity (Jackson turbidity units)	4

[1] Analysis by U. S. Geological Survey.

Table 2.--Insecticide analysis[1] of lake-bottom sediment; sample collected March 23, 1972 at center of lake; constituents in micrograms per kilogram.

Aldrin	0.0
Chlordane	.0
DDD	1.6
DDE	2.8
DDT	.6
Dieldrin	.1
Endrin	.0
Heptachlor	.0
Heptachlor epoxide	.0
Lindane	.0
Toxaphene	.0
Diazinon	.0
Ethion	.0
Malathion	.0
Methyl parathion	.0
Methyl trithion	.0
Parathion	.0
Trithion	.0
PCB	.0

[1] Analysis by U. S. Geological Survey.

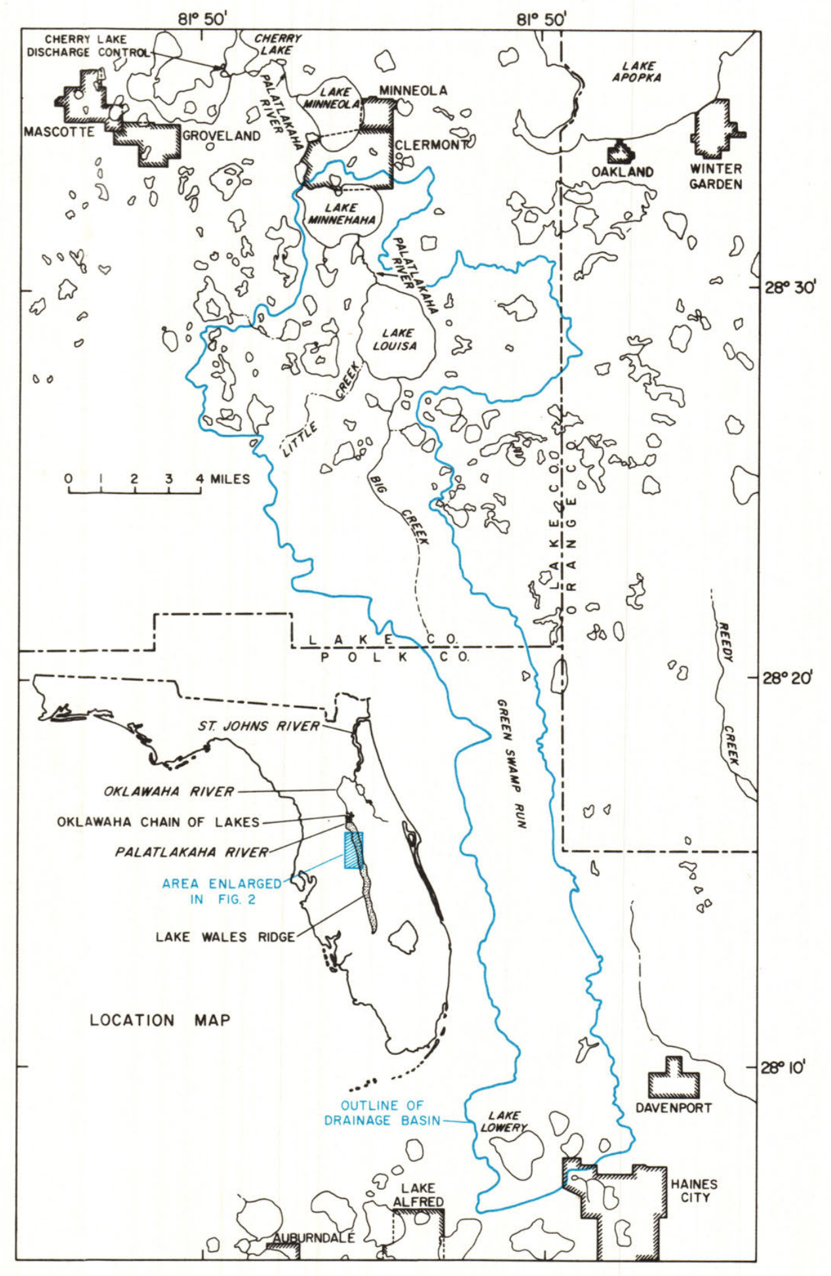

Figure 2. Lake Minnehaha drainage basin.

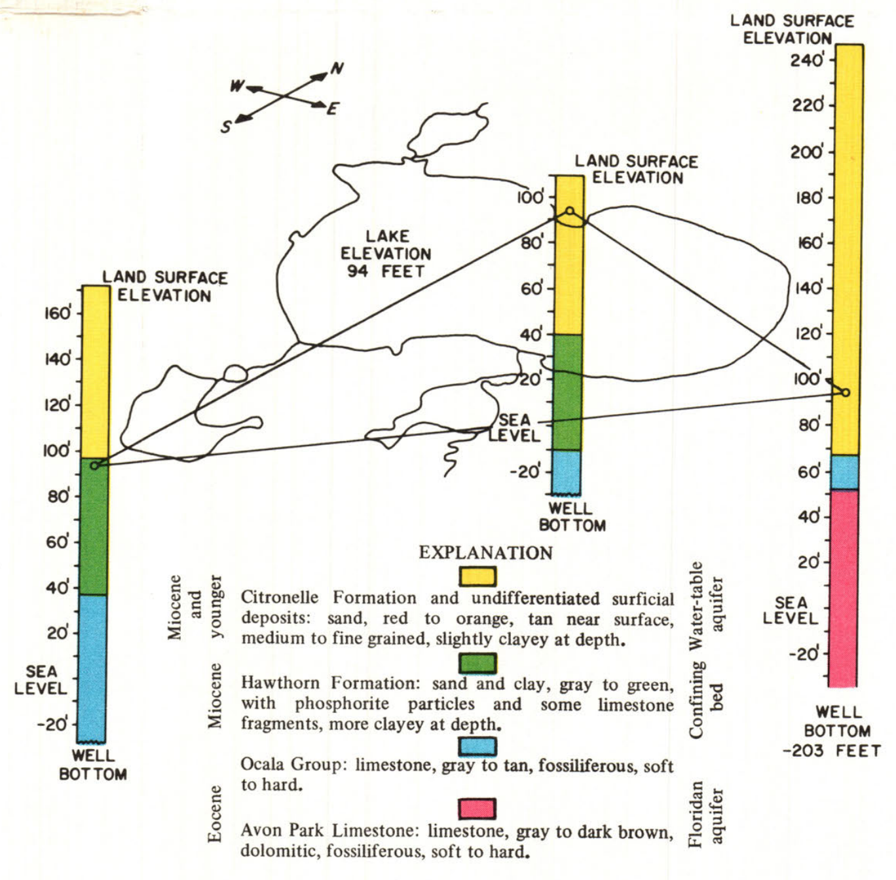

Figure 3. Lithology at 3 well sites near Lake Minnehaha.

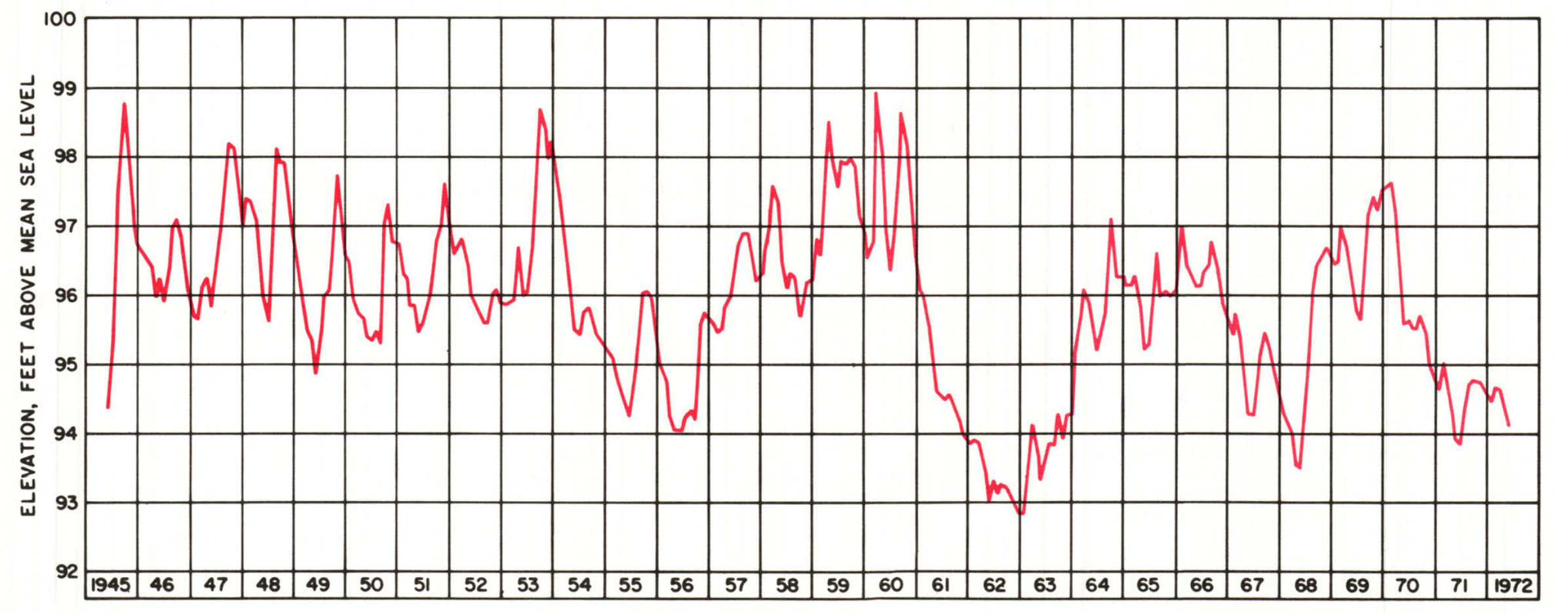

Figure 4. Month-end level of Lake Minnehaha, May 1945-May 1972.

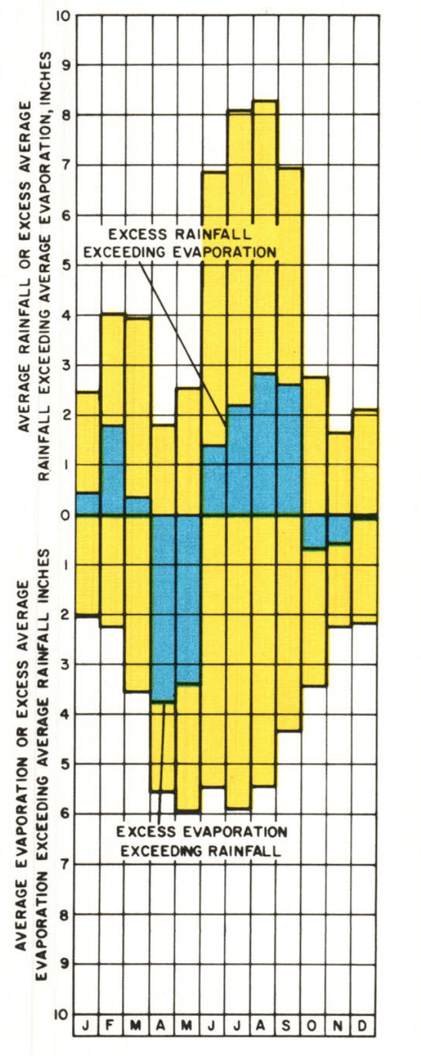

Figure 5. Average monthly rainfall at NOAA station 6 miles south-southwest of Clermont, average monthly evaporation from NOAA station at Lisbon, adjusted for lakes (Kohler, 1954), and excess of one over the other, 1960-71.

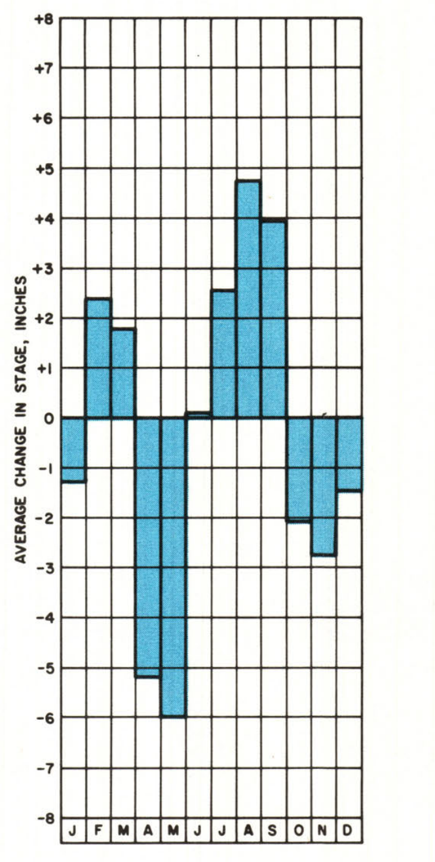

Figure 6. Average monthly change in stage of Lake Minnehaha, 1960-71.

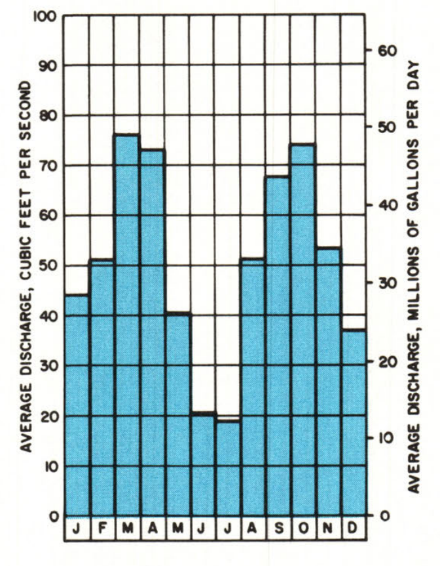

Figure 9. Average monthly discharge from Cherry Lake, 1960-71.

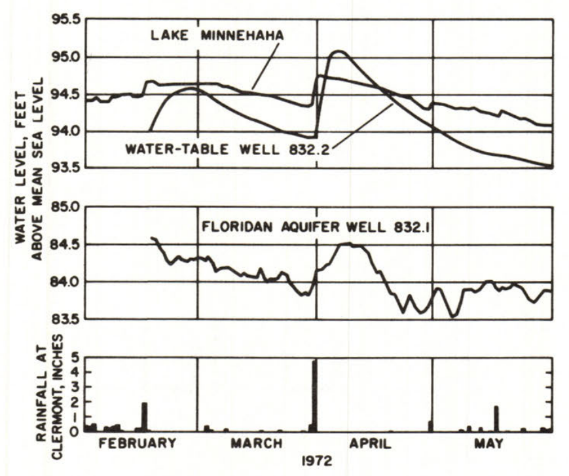

Figure 8. Comparison of water level in Lake Minnehaha and water levels in well 832.2, open 34-37 feet below land surface in the water-table aquifer, and in well 832.1, open 95-140 feet in the Floridan aquifer, and daily rainfall from U. S. Geological Survey rain gage in Clermont.

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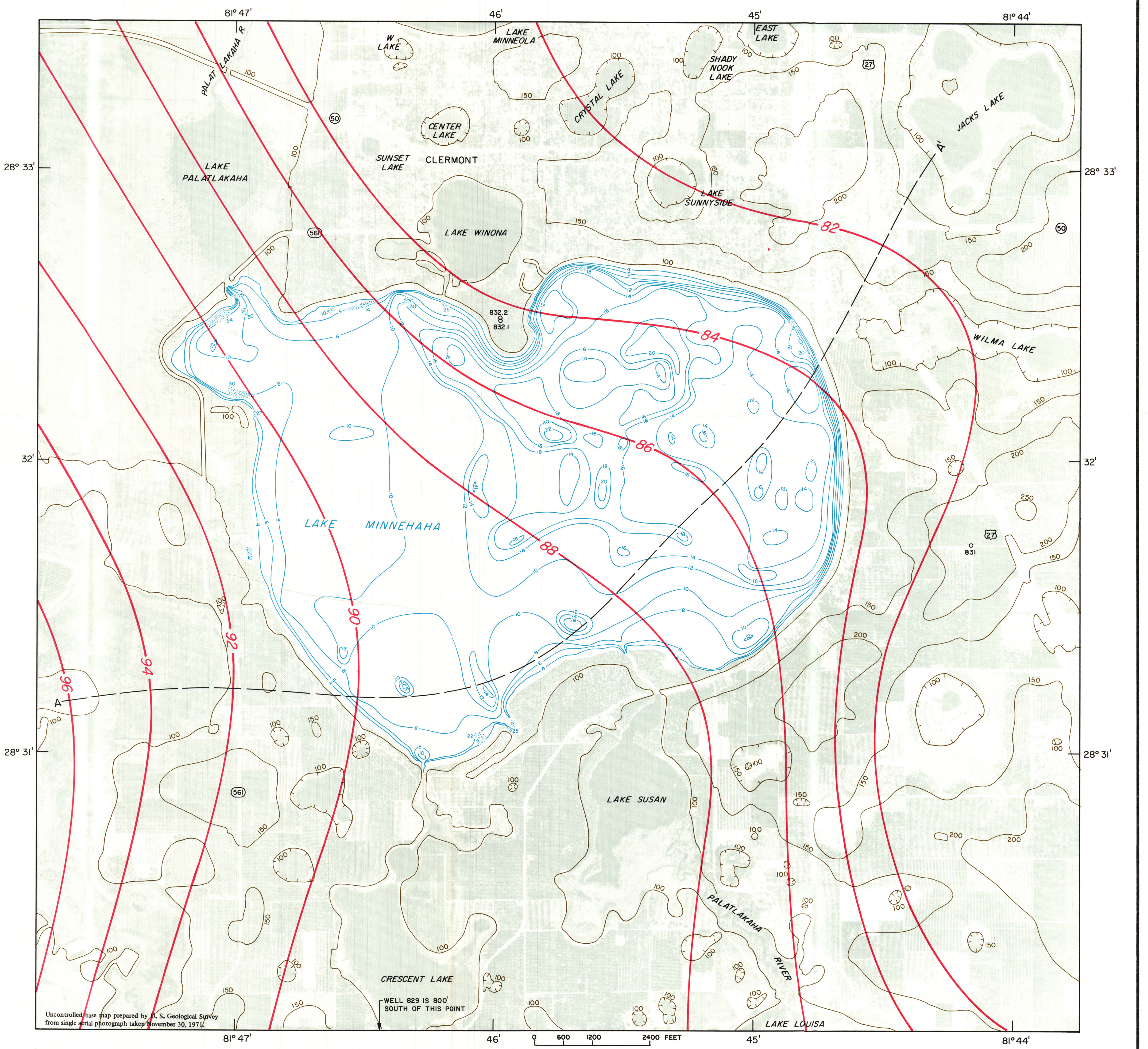

Uncontrolled base map prepared by U. S. Geological Survey from single aerial photograph taken November 30, 1971.

EXPLANATION

—10— Depth contours, April 1972. Contour interval 2 feet. Datum is lake stage of 94.7 feet above sea level.

30 Known dredged areas number is maximum observed depth, in feet.

—150— Land elevation (topographic) contours. Contour interval 50 feet. Datum is mean sea level.

—82— Potentiometric surface contours, March 1972. Contour interval 2 feet. Datum is mean sea level.

A— — —A' Line of geohydrologic section (see fig. 7).

○831 Well location and number.

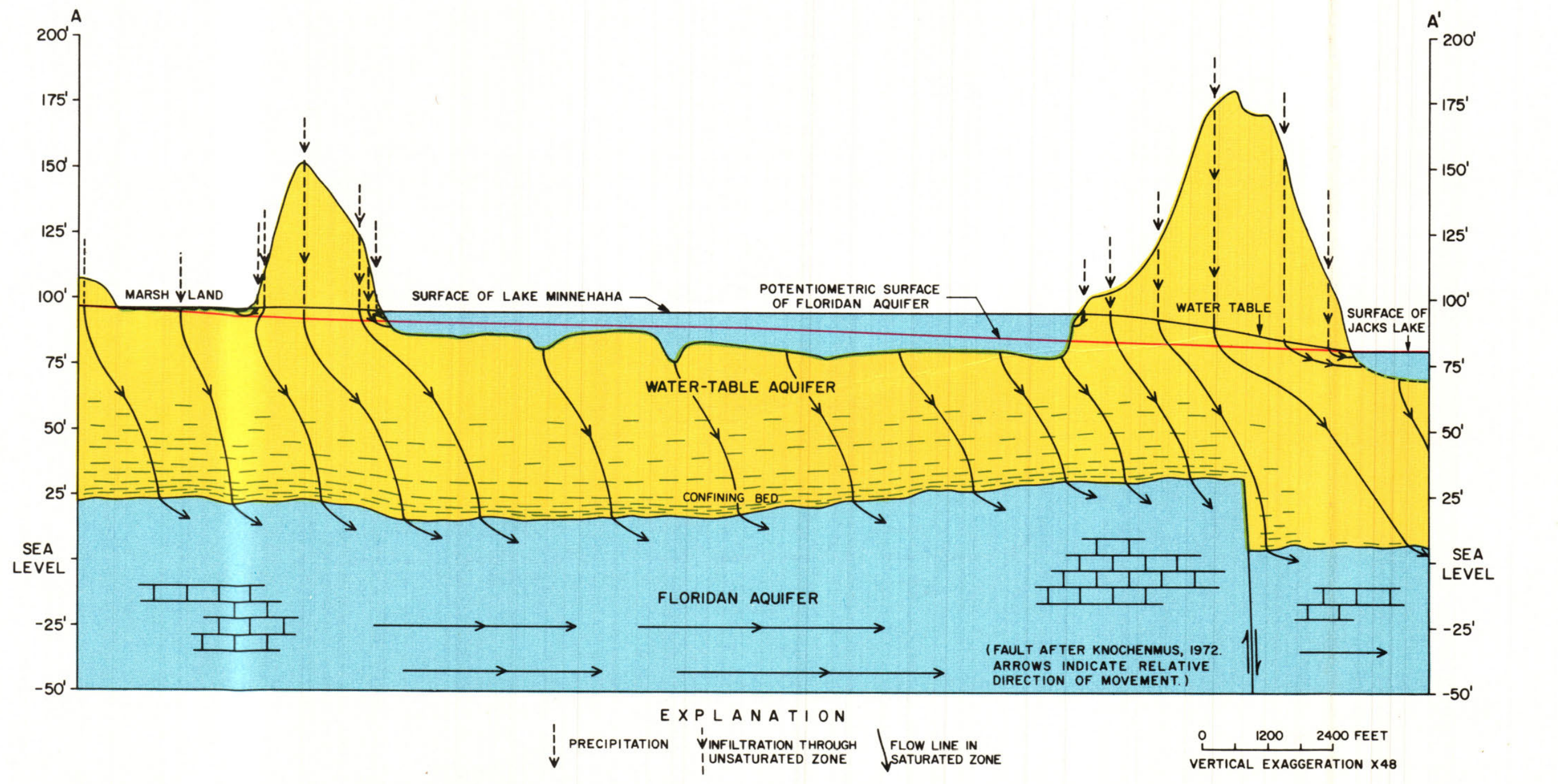

Figure 7. Generalized ground-water flow along section A-A' (fig. 1) for Lake Minnehaha.

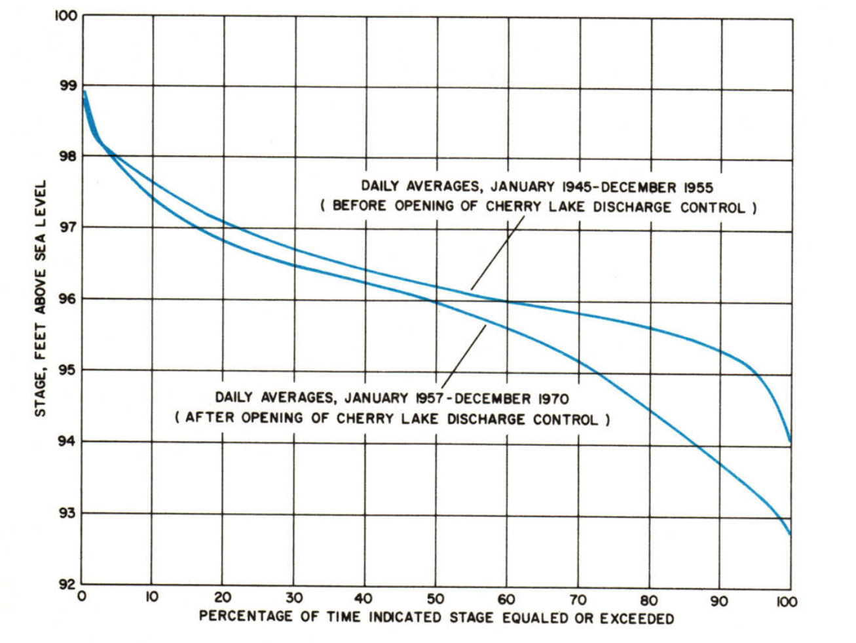

Figure 10. Stage-duration curves for Lake Minnehaha before and after opening of Cherry Lake discharge control in 1956.