A HYDROGEOLOGIC STUDY

THE EFFECTS OF GROUND-WATER WITHDRAWALS IN THE ORLANDO AREA

For
Orlando Utilities Commission
Orange County, Florida

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SUMMARY

The Orlando Utilities Commission provides potable, treated water to approximately 225,000 people in the Orlando area. The source of this water supply is the Floridan aquifer, with 95 percent being withdrawn from the lower zone. General Waterworks Corporation, serving a smaller population, also receives its supply from the Floridan aquifer upper and lower zones.

The aquifer transmissivity in the Orlando area, particularly in the lower zone, is extremely high, reflecting the well-developed secondary permeability of the carbonate aquifer. Although further study may result in more accurate values for aquifer characteristics, a transmissivity of approximately 668,000 ft^2/day (5,000,000 gpd/ft) is probably a close estimate.

Study of the historical water level data back to 1931, prior to any large municipal use of ground-water, suggests that pumpage has had little effect on the potentiometric surface. In fact, natural phenomena such as drought and rainfall have had more effect on long-term water level trends than have ground-water withdrawals.

Aquifer modeling using assumed hydraulic characteristics has confirmed the hypothesis that future OUC withdrawals at the planned rate will have little effect on the potentiometric surface nor on adjacent water users.

Chapter 1
INTRODUCTION

On 25 November 1975 the Orlando Utilities Commission (OUC) Water Operations Department submitted a consumptive use permit application to the South Florida Water Management District (then Central and Southern Florida Flood Control District). This application was submitted in compliance with rules and regulations adopted by the management district to govern the withdrawal and use of water resources. On 10 August 1978 the South Florida Water Management District, together with the St. Johns River Water Management District, issued a consumptive water use permit to OUC for the amount of 25.8 billion gallons per year or 70.68 mgd (million gallons per day). The permit (No. 48-00064-W) has a duration of 10 years and is subject to 12 special conditions. This study was conducted to satisfy special condition No. 9, which states:

> "Within 18 months after the date of issuance of this permit, the permittee shall submit to the District a hydrogeologic study which will consist of the following:
>
> a. An assessment of the possible decrease in the potentiometric head of the Floridan aquifer with time within the OUC service area as a direct result of future increased withdrawals.
>
> b. An assessment of the impact on any existing users of the Floridan aquifer within the OUC cones of depression.
>
> c. Mapping of all cones of depression for all OUC wells using projected withdrawals."

The hydrogeologic regime in the Orlando area has been described by several investigators, including Sellards, 1908; Stringfield, 1953; Unklesbay, 1944; Lichter, Anderson, Joyner, 1968; and others. Two transmissive zones have been recognized: one extending from 150 to 600 below land surface and the other from 1,100 to 1,500 feet below land surface. The upper zone is the strata within which some 400-plus drainage wells are completed. It is also a source of water for those areas, outside and up-gradient of the immediate Orlando area. The lower zone is the source of water for OUC and Winter Park, with the exception of two wells at the Martin Plant and two wells at GWC Plant No. 1. For the most part, this report focuses on the lower zone.

Chapter 2
SERVICE AREA AND EXISTING FACILITIES

Two service areas within the study limits are provided with water from the lower producing zone. The OUC service area, as described in the consumptive use permit application, consists of approximately 150 square miles located in Orange County, Florida. The Winter Park service area, located north of Orlando, is approximately one-quarter as large as the OUC service area. Figure 2-1 illustrates the boundaries of these two service areas.

The OUC system consists of eight water treatment plants and 23 wells with an installed capacity of approximately 110 mgd (millions gallons per day). The plants are located throughout the OUC service area.

The details of the wells, treatment plants, and system are provided in the consumptive use permit application.

The Winter Park system, operated by General Waterworks Corporation (GWC), consists of five water treatment plants and six wells with an installed rated capacity of approximately 26 mgd. Figure 2-1 illustrates the location of treatment plants for both the OUC and the GWC systems.

The projected average annual water demand for OUC service area, based on a best fit curve of the data from 1963 through 1974, was provided in the consumptive use permit application. These data, together with 1975 through 1979 data, were used to update and slightly revise this projection. Figure 3-1 illustrates a computer-generated best fit curve of the historical data and the projected future demand. The results of this effort reflect only a slight change in the original projected demand. For example, the previous projected 1984 average annual demand was 20,394,000,000 gallons (55.87 mgd) and the revised 1984 demand is 20,038,500,000 gallons (54.90 mgd).

The OUC peak daily demand, as stated in the permit application, is approximately 180% of the average daily demand. The per capita consumption within the OUC service area is approximately 189 gallons/day. The peak rate is 280 percent of the average demand.

Based on Figure 3-1 and the above information, the 1978 and 1988 water requirements are as follows:

	Year		
	1978	1988	Average
Average daily flow (mgd)	48.5	61.2	54.9
Peak daily flow (mgd)	87.3	110.2	98.8
Peak rate flow (mgd)	135.8	171.4	153.6

This period (1978 to 1988) represents the duration of the permit.

The historical data from the General Waterworks System was also input to the computer and a best fit curve was generated, as illustrated on Figure 3-2. As can be seen from the historical data, the average annual demand for this system has not followed as smooth a trend as has that for OUC. Therefore, this best fit curve, projected for future requirements, is not as reliable as that projected for OUC. Comparing this forecast with that projected for GWC in 1969 (BC&E report for GWC), the 1980 demand is as follows:

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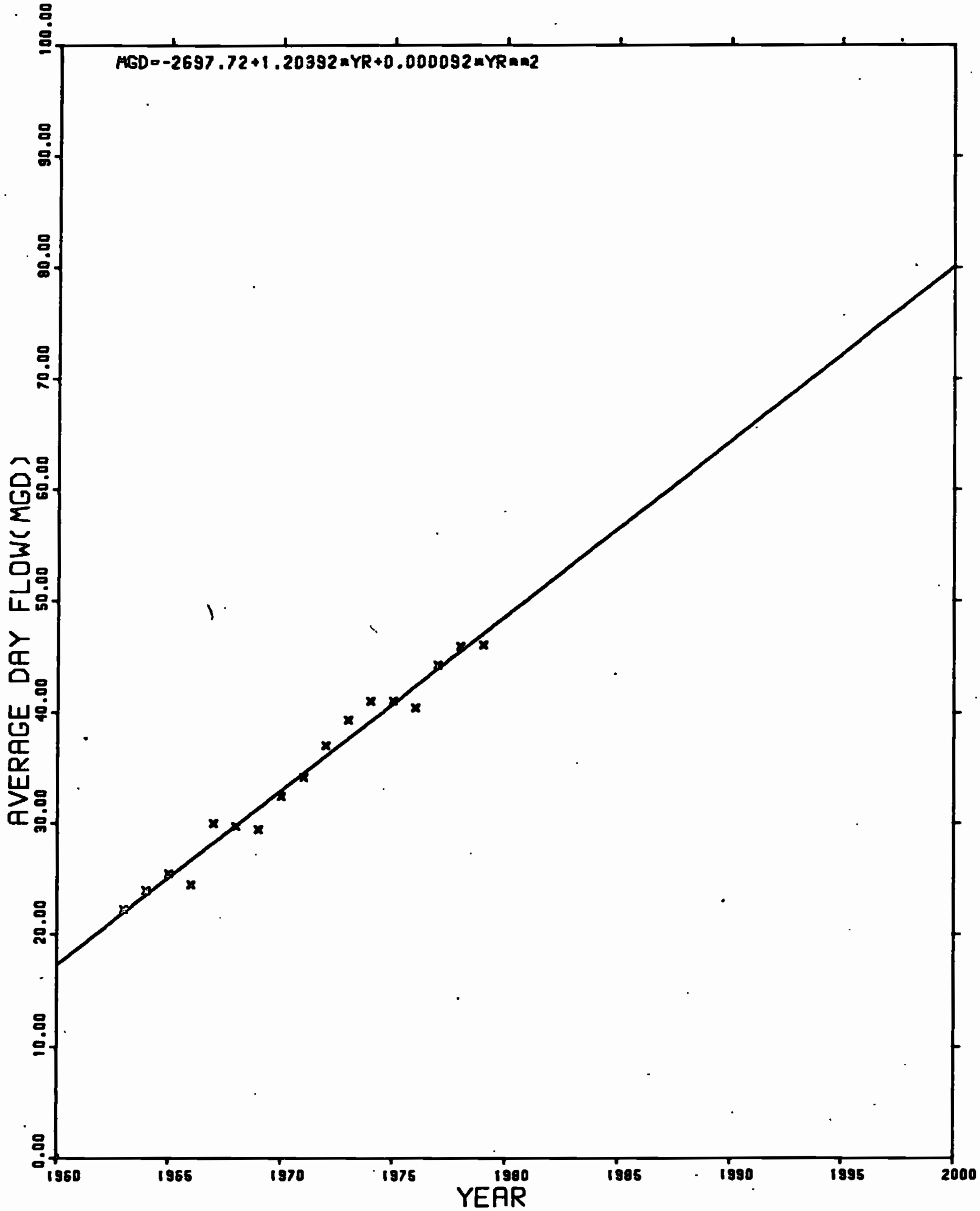

FIGURE 3-1. Historical and projected water demand—Orlando Utilities Commission.

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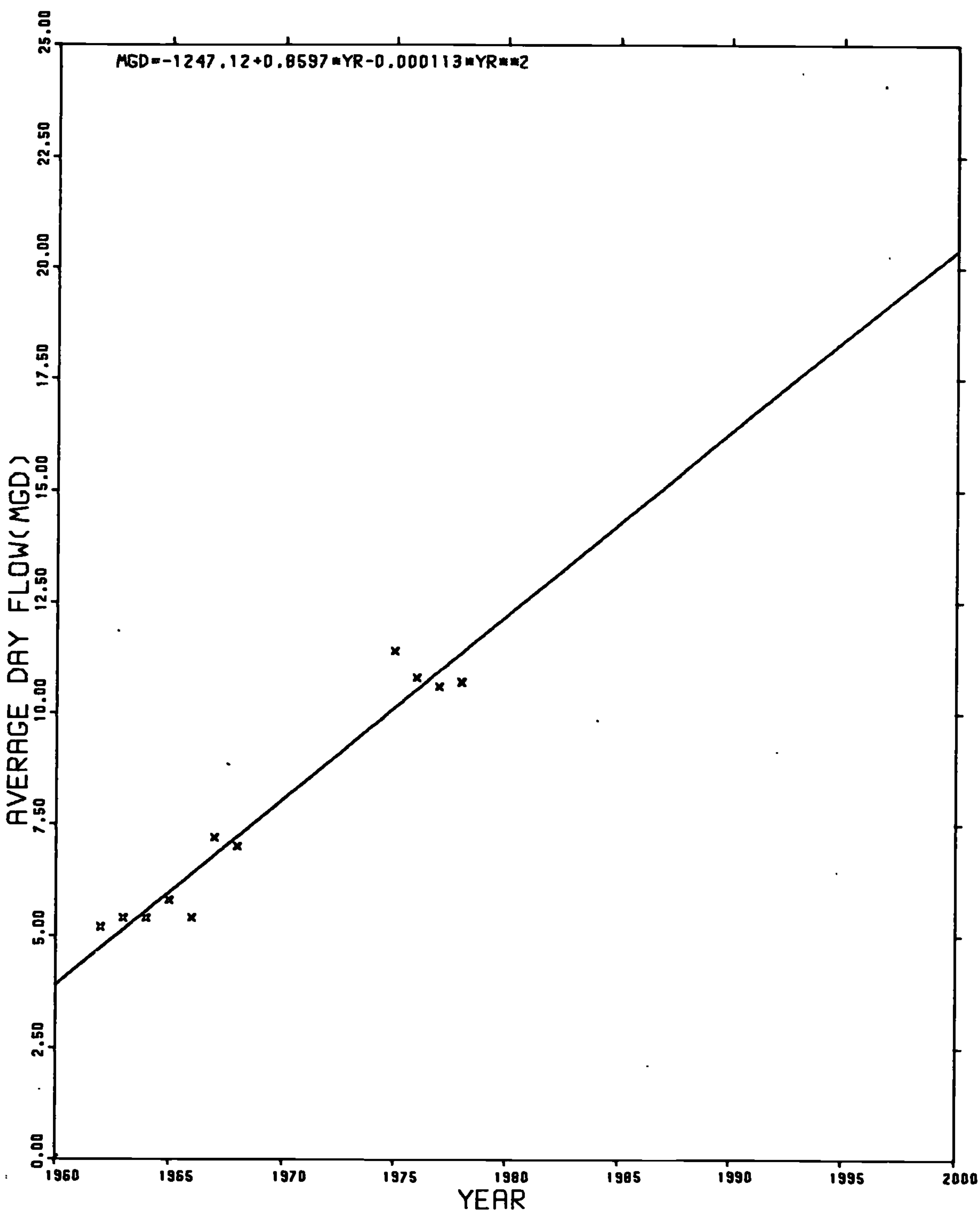

FIGURE 3-2. Historical and projected water demand—General Waterworks Corporation.

1969 Projections for 1980

Average daily flow (mgd)	10.8 range 9 to 12
Peak daily flow (mgd)	28.7 range 24 to 33
Peak rate flow (mgd)	33.5 range 29 to 39

Current Projections for 1980

Average daily flow (mgd)	11.8
Peak daily flow (mgd)	31.5
Peak rate flow (mgd)	36.6

From this analysis, the 1966 GWC projections were fairly accurate and the curve used for the current projections can be used with some confidence.

Based on Figure 3-2 and historical data the 1978 and 1988 water requirements are as follows:

	1978	1988	Average
Average daily flow (mgd)	10.8	16.0	13.4
Peak daily flow (mgd)	20.2	32.0[a]	26.1
Peak rate flow (mgd)	33.5	49.6	41.6

[a]Peak daily to average day ratio assumed to be 2.0.

The 1978-1988 average daily flow values will be used in a computer model to assess the effects of present and future ground-water withdrawals on the lower zone of the Floridan aquifer in the Orlando-Winter Park area.

Chapter 4
HYDROGEOLOGY

The hydrogeologic setting of the Orlando area has been described by previous investigations dating back to 1908 (E. H. Sellards, Florida Geological Survey, Bulletin No. 1). In the early years emphasis was placed on the upper zone (150 to 600 feet), with data being obtained primarily from drainage wells constructed randomly throughout the area. Until the early 1950's, Orlando received its water supply from surface lakes, including Lakes Ivanhoe, Concord, and Underhill. Later this supply was augmented by ground water provided from two wells completed in the upper zone. In the late 1940's, the lower producing zone was identified as a water supply source due to pollution of the upper zone from drainage wells and, in the early 1950's, Orlando began to install a series of wells in the lower producing zone. The Orlando Utilities Commission now has 23 supply waters, all but two of which are completed in this lower producing zone.

As discussed in previous studies (BC&E, 1973), the Floridan aquifer in the Orlando area is composed of limestone and dolomite strata extending to several thousand feet in depth. Freshwater is present in the aquifer to a depth of at least 1,600 feet.

Geologically the strata comprising the part of the aquifer penetrated by water supply wells are, in descending order, the Ocala Limestone, the Avon Park Limestone, and the Lake City Limestone. The aquifer is overlain in the Orlando area by approximately 200 feet of sand, clay, and silt, which are of relatively low permeability. Figure 4-1 illustrates a generalized cross section of the Floridan aquifer in the Orlando area.

The Floridan aquifer is recharged by percolation of water through the beds overlying the aquifer, by percolation through the bottoms of sand-filled sinkholes, and by flow into drainage wells. Most of the waters recharging the aquifer in the Orlando area come from rain, which falls on western Orange County and adjacent parts of Lake County. Discharge of water from the aquifer is by pumping from wells, spring discharge, and underground flow to discharge areas to the east of Orange County.

Although it is referred to as a single unit, the Floridan aquifer in the Orlando area actually consists of at least two distinct hydrologic units. As shown on Figure 4-1, the upper zone is composed of strata generally less than

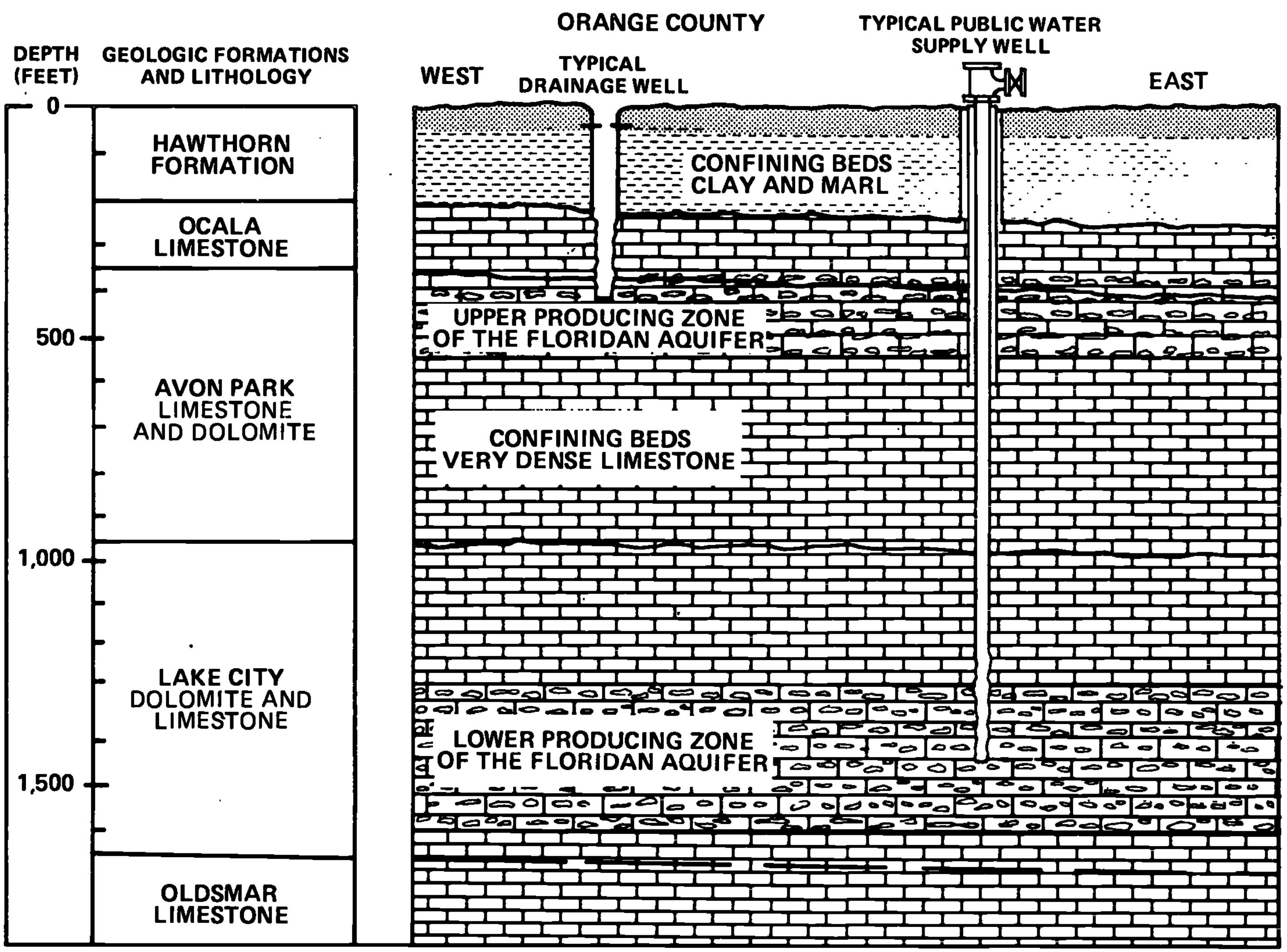

FIGURE 4-1. Generalized hydrogeologic section, Orlando, Florida.

600 feet in depth. The lower zone lies generally below 1,000 feet in depth. Both zones contain freshwater of similar chemical quality. Water from the lower zone is slightly more mineralized than that in the upper zone, but the difference is normally insignificant.

The lower zone is the source of most of the supply for OUC and Winter Park. Some supplies, including those for our Martin Plant, are obtained from the upper zone in those areas where drainage wells have not polluted the upper zone.

To date information regarding the hydraulic interconnection of the upper and the lower zones is inconclusive. The results of a pumping test conducted in 1964 by USGS at the Primrose Plant (Lichtler, et al., 1968) suggested a very low leakance, (0.00009 gpd/ft^2). However due to physical conditions (primarily the fact that the radius between pumped and observation well was too large), the accuracy of this value is questionable. The low value obtained for leakance is probably in the right order of magnitude. Other data indicates a lack of or very low degree of interconnection between the upper and the lower zone within the study area.

During the course of this investigation, a aquifer pumping test was conducted to obtain preliminary values for aquifer hydrologic characteristics in the Orlando area. The purpose of this test was to obtain values for transmissivity, storage coefficient, and leakance (if possible) to be used in a computer model of the lower zone of the Floridan aquifer. Wells No. 1, 2, and 3 at the Highlands Plant were selected for this test. In addition, a drainage well, completed in the upper zone, was also part of the testing program. Well No. 2 was used as the pumping well and Wells No. 1 and 3 were used as observation wells during the pumping test. Well No. 1 is located 825 feet south of well No. 2, and well No. 3 is located 1,365 feet east of well No. 2. The drainage well is located approximately 2,200 feet south of well No. 2. Figure 4-2 shows the location of wells within the Highlands plant area.

Two Stevens Type F continuous water level recorders were intalled at Wells No. 1 and 3 by using a series of pulleys to allow a 1-1/4-inch PVC float to operate between the pump column and the casing. The float line was brought through a 2-inch angled drawdown tube in each well. The recorders were installed 24 hours prior to the start of the pumping test. In addition, a Stevens recorder was installed at the drainage well 6 hours prior to the start of the test. The water level record obtained from the drainage well during the test showed no discernible response to pumping.

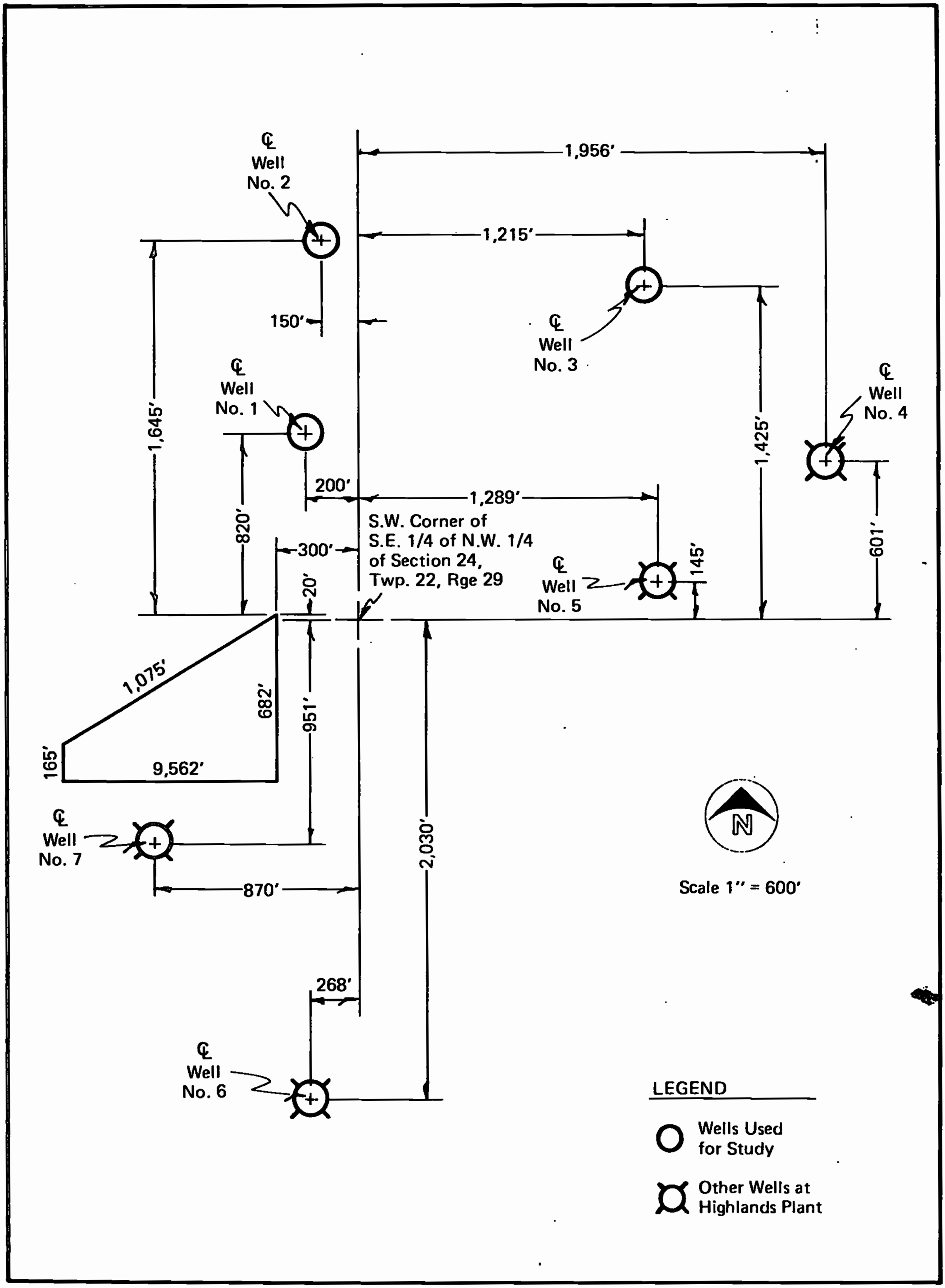

FIGURE 4-2. Highlands Plant well location map.

At the pumped well an electronic, pressure-sensitive transducer, coupled to a power supply and continuous strip chart recorder was installed 24 hours prior to the beginning of the test. The transducer was lowered to 80 feet below the top of the casing through the 2-inch angled drawdown tube and the transducer/recorder were calibered to the static water level.

Flow measurement during the test were made at the inline venturi tube located at the Highlands Plant, by installing a sensitive manometer. This flow, obtained by reading the pressure differential at the venturi, was checked by obtaining discharge pressure at Well No. 2 and calculating the flow rate from the pump curve. The flow rate, calculated versus measured, checked within 146 gpm (3,740 gpm calculated and 3,886 gpm measured).

The test was conducted by pumping only one of the seven wells at the Highlands Plant. However due to operational constraints at the treatment plant, one well, No. 7, was pumped up to the start of the pump test and shut-off as withdrawal began at Well No. 2. Well No. 7 is located 2,596 feet south of Well No. 2.

Data obtained from the pumping test were used to calculate aquifer characteristics using several different methods. Time versus drawdown and time versus recovery data were plotted on semi-log and log-log graph paper for the observation wells. Time versus drawdown and time versus recovery data were plotted on semi-log graph paper for the pumping well only.

Figures 4-3 through 4-5 illustrate three of the semilog data plots. From these graphs, transmissivity and storage coefficient were calculated by equations derived by C. V. Thies and modified by C. E. Jacobs. The equations are:

$$T = \frac{264\,Q}{\Delta s} \qquad (1)$$

where:

T = transmissivity (gpd/ft)
Q = pumping rate (gpm)
s = difference in drawdown per 1-log cycle (ft)

Note: 264 is a portional constant which includes multipliers for units.

And:

$$S = \frac{0.3T\ to}{r^2} \qquad (2)$$

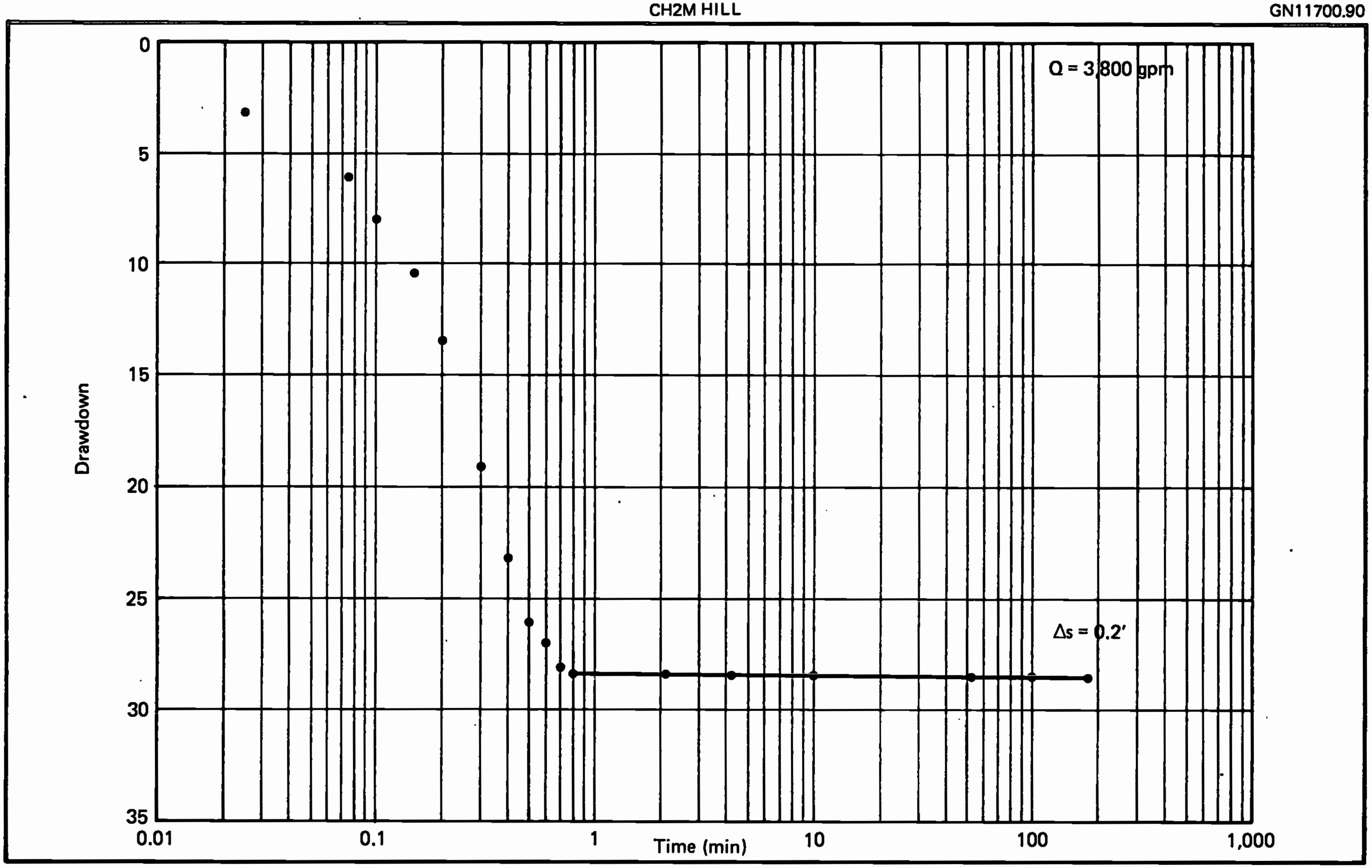

FIGURE 4-3. Drawdown at pumped well, Highlands No. 2.

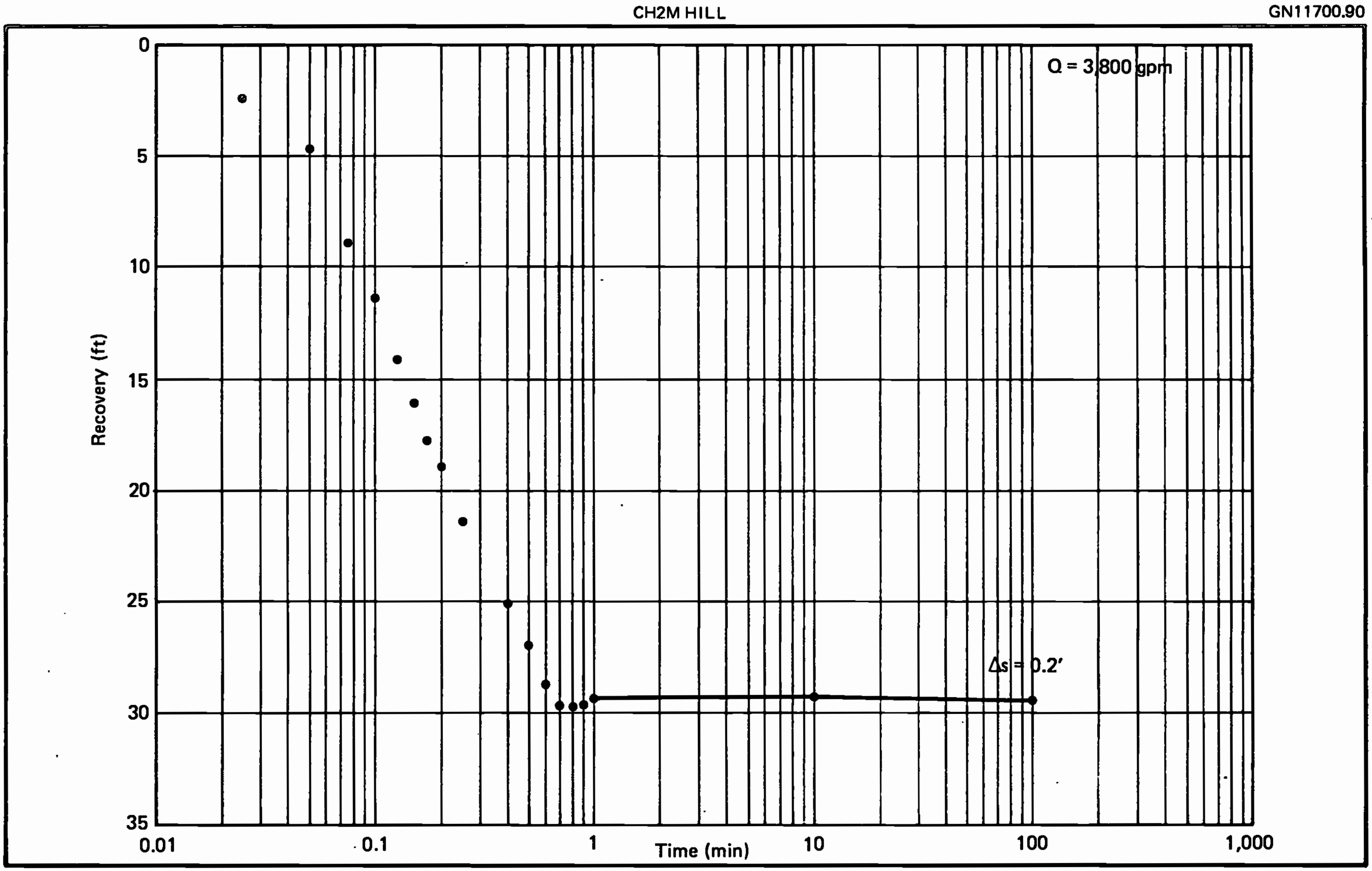

FIGURE 4-4. Recovery at pumped well, Highlands No. 2.

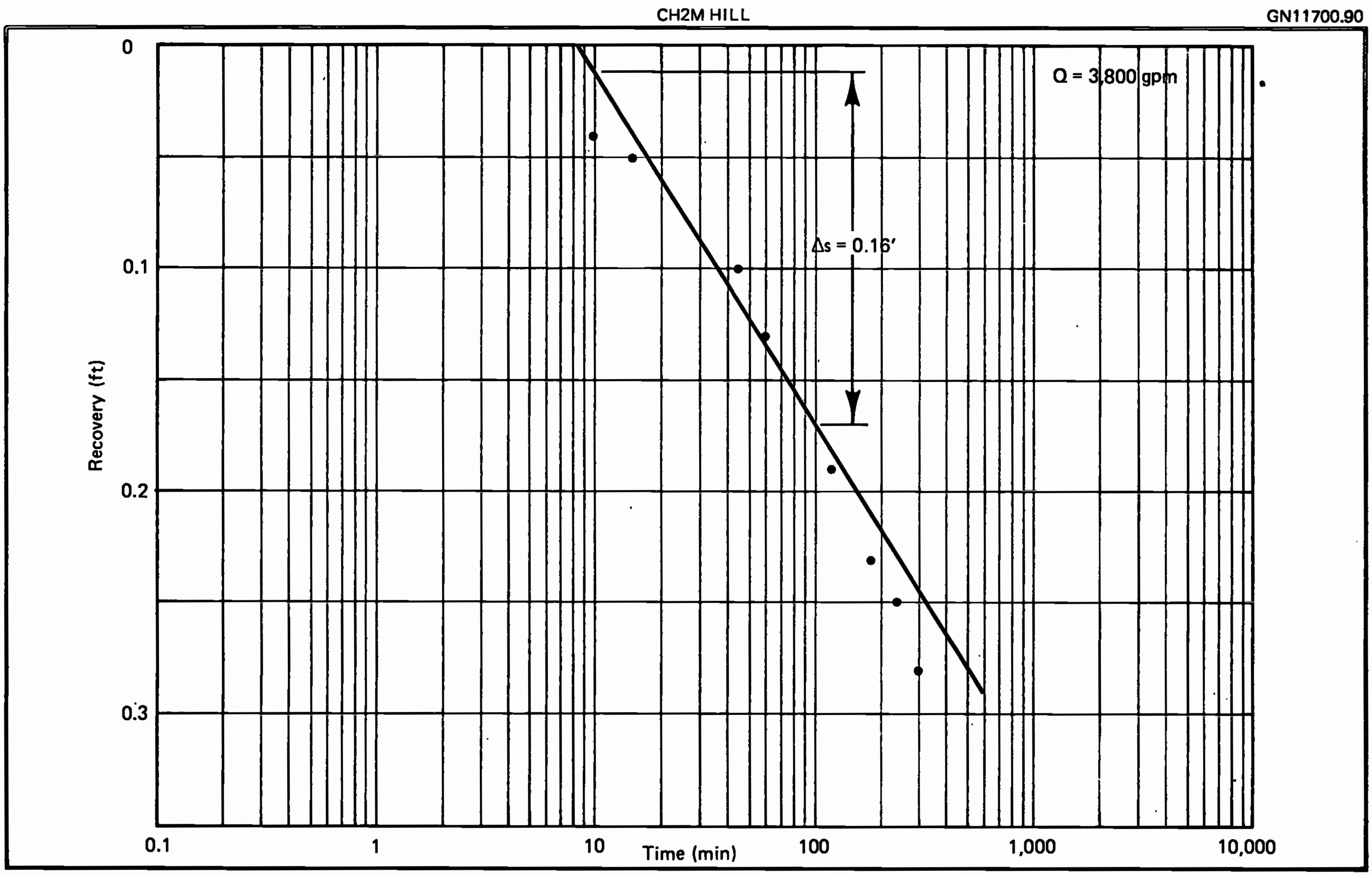

FIGURE 4-5. Recovery at observation well, Highlands No. 1.

Where:

S = storage coefficient
T = transmissivity (gpd/ft)
to = extrapolated time at zero drawdown (days)
r = distance to observation point (ft)

The time versus drawdown/recovery data plotted on log-log graph paper were used to solve equations for aquifer characteristics described by Lohman, Theis, Walton, and others. Figure 4-6 illustrates one of these data plots. The equations used to calculate transmissivity, storage, and leakance by this method are as follows:

$$T = \frac{Q}{4\sqrt{s}} \qquad L(u,v) \tag{3}$$

where:

T = transmissivity (ft^2/day)
Q = pumping rate (ft^3/day)
S = drawdown at the match point (ft)
L(u,v) = match point (conveniently selected as 1)

and:

$$S = 4T\,\frac{t/r^2}{1/u}$$

where:

S = storage coefficient
T = transmissivity (ft^2/day)
t = time at match point (day)
r = distance to observation point (ft)
u = match point, conveniently selected, 1/u = 1)

and:

$$k'/b' = 4T\,\frac{V^2}{r^2}$$

where:

k'/b' = leakance (day^{-1})
T = transmissivity (ft^2/day)
v = matched curve value
r = distance to observation point (ft)

Based on the analysis of pumping test data, preliminary values for aquifer characteristics were selected for use in the computer model. Those values are:

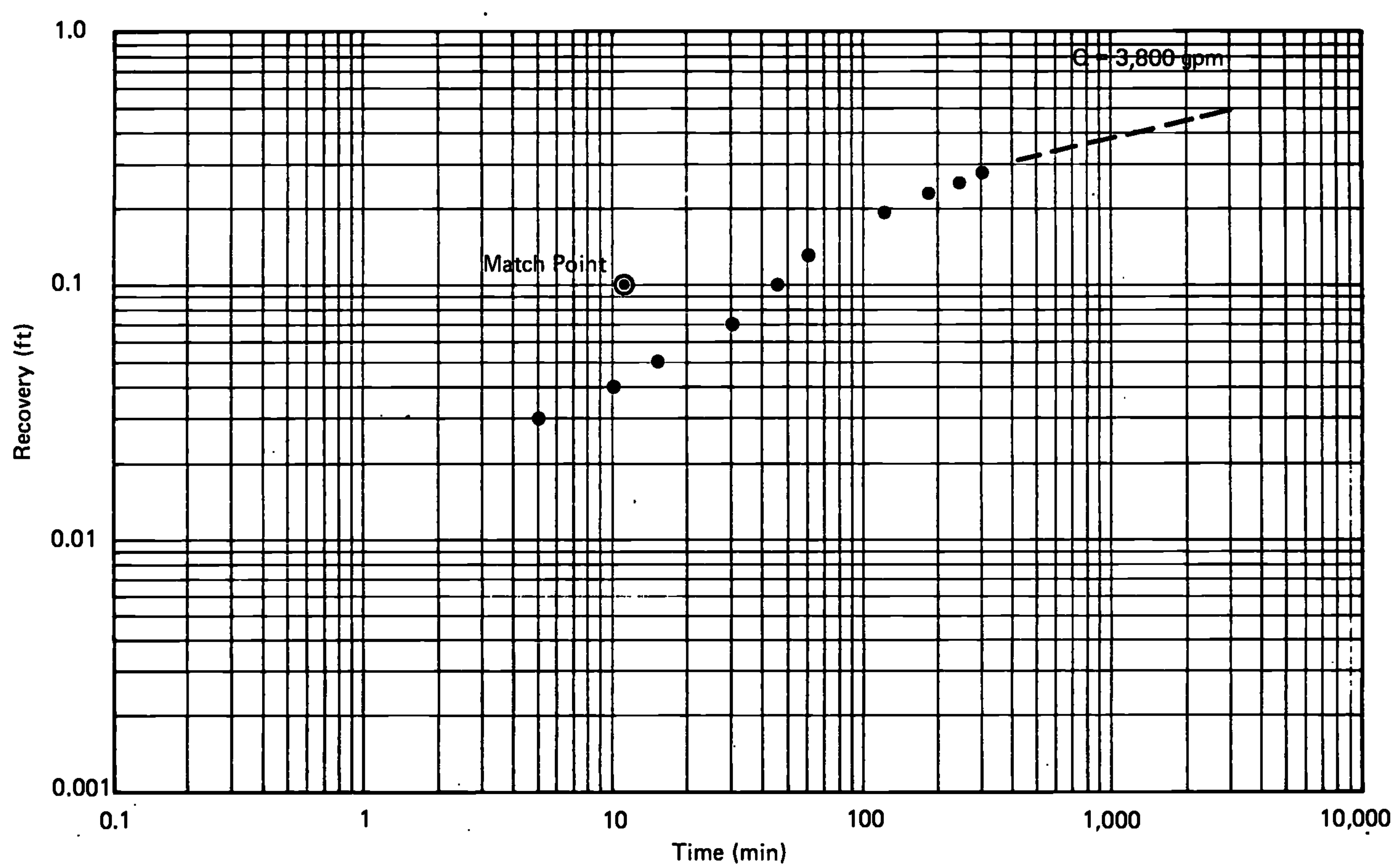

FIGURE 4-6. Recovery at observation well, Highlands No. 1.

Transmissivity = 668,000 ft^2/day (5.0 mgd/ft)

Storage = 2.0×10^{-3}

Due to the constraints of this pumping test with regard to duration, interference, and radial distance to the observation wells, no reliable data were obtained to calculate a leakance number. Since the leakance is assumed to be very low, the physical model assumed for purposes of this analysis is a confined, artesian aquifer. This is probably not the case, and there is most likely a finite leakance number applicable to the aquitard separating the upper and lower zone. By assuming no leakance, drawdowns predicted by theoretical calculations would be greater than would actually occur.

Conversely this test, again due to physical constraints, has resulted in a calculated value for the storage coefficient, which intuitively appears high for a rigid, limestone aquifer. A lower storage coefficient, which the aquifer most likely does have, would result in more drawdown than that predicted by theoretical calculations. The assumption of no leakance has the tendency to mitigate the effects of assuming a high storage coefficient.

Based on the assumed aquifer characteristics, Figure 4-7 illustrates theoretical distance-drawdown curves for one well, pumped at a rate of 3,500 gpm. This theoretical calculation is based on various assumptions, including no recharge. Theory states that a true artesian aquifer never reaches equilibrium, since by definition there is no source of recharge. However the rate of decline of head continuely decreases as the cone of depression expands. For practical purposes there is a time within which decline in head is minimal. To illustrate this point, compare the two theoretical distance-drawdown curves on Figure 4-7. The lower curve assumes a time equal to 120 whereas the upper curve assumes a time of 30 days. More than 85 percent of the 120-day predicted drawdown is obtained in 30 days.

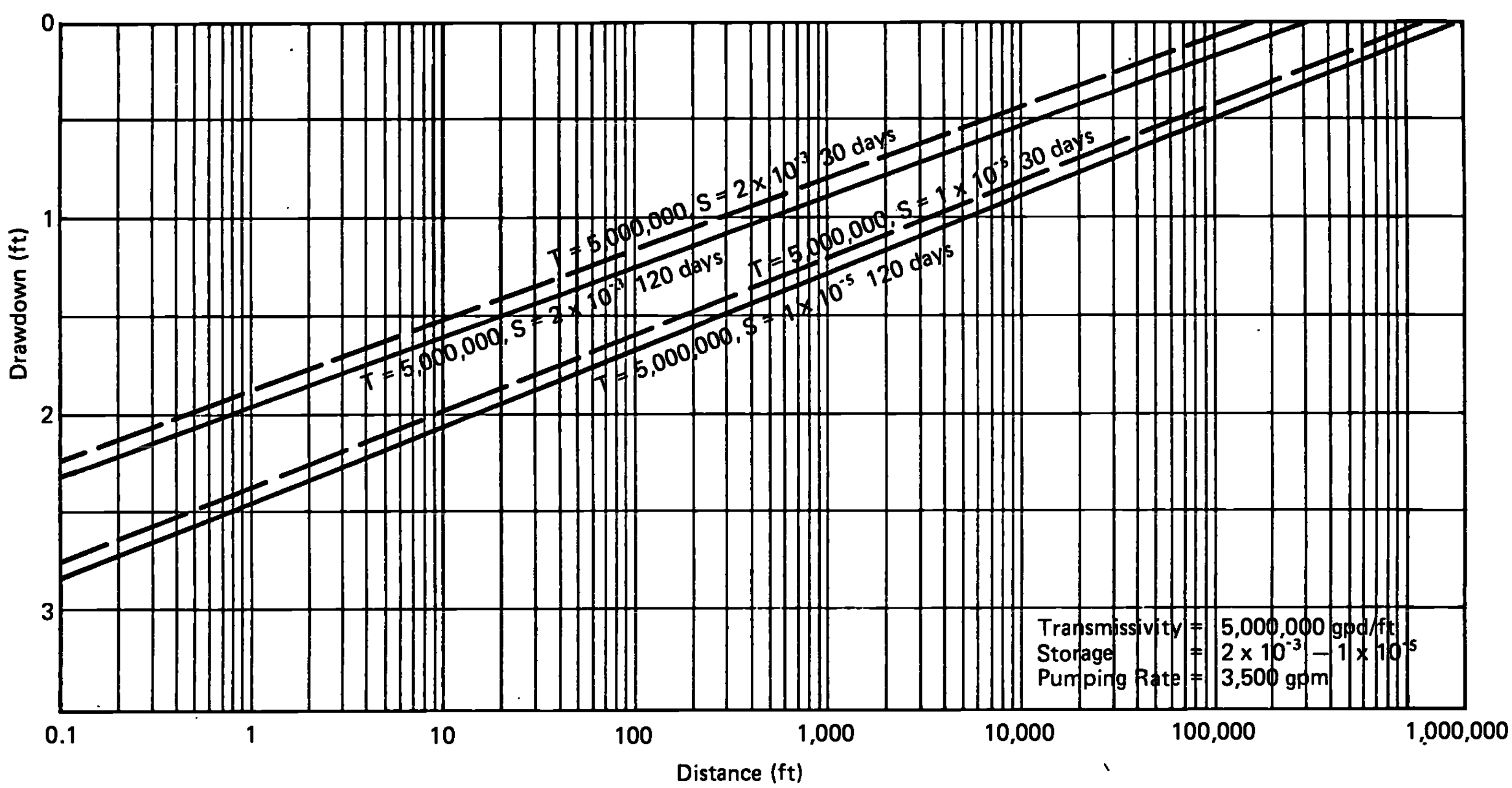

FIGURE 4-7. Theoretical distance-drawdown curves.

Chapter 5
EFFECTS OF GROUND-WATER WITHDRAWALS

Currently Orlando Utilities Commission withdrawals average approximately 50 mgd, and General Waterworks Corporation withdrawals average approximately 11 mgd, both from the Floridan aquifer. OUC receives 95 percent of its supply from the lower zone and the remainder from the upper zone (Martin Plant). GWC receives approximately 75 percent of its supply from the lower zone and 25 percent from the upper zone.

As discussed above, this study focuses primarily on the lower zone, from which ~90 percent of the water supply of these two utilities are obtained. The 1988 predicted withdrawal rates for OUC and GWC are approximately 61 mgd and 17 mgd, respectively.

At the start of this investigation, historical data pertaining to the potentiometric surface in the Orlando area were gathered. Figure 5-1 illustrates a review of past potentiometric surveys dating back to August 1931. The surveys define the potentiometric surface, which shows the altitude to which the artesian pressure will cause water to rise in cased wells which penetrate an aquifer. The surveys are for the most part made from wells completed in the upper zone. However it is generally recognized that the static, unpumped water levels in the lower zone are about the same, perhaps slightly lower, than the static water levels in the upper zone when unaffected by water contributions from drainage wells. To the extent that this is true, comparisons can be made among potentiometric surveys made from wells penetrating the Floridan aquifer. The upper zone potentiometric survey prepared in August 1931 (see Figure 5-1) after a very dry summer is probably representative of water levels in the lower zone at the same time. From this survey water levels in the Orlando area are approximately 60 to 65 feet above mean sea level. A similar survey after another dry summer was made in August 1943 when water levels in the Orlando area were approximately 55 to 60 feet above mean sea level. Even though made during a period of low water, both of these surveys still indicate by their shape the occurrence of local recharge, presumably by lakes, sinkholes, and drainage wells. Comparing these surveys to surveys conducted in September 1960 at high water conditions, May 1962 at extreme low water conditions, and December 1963 at normal conditions illustrates a range of water level fluctuation of between 45 to 55 feet and 70 to 75 feet in the upper zone. The most recent surveys, conducted in May and September 1978, both illustrate a range

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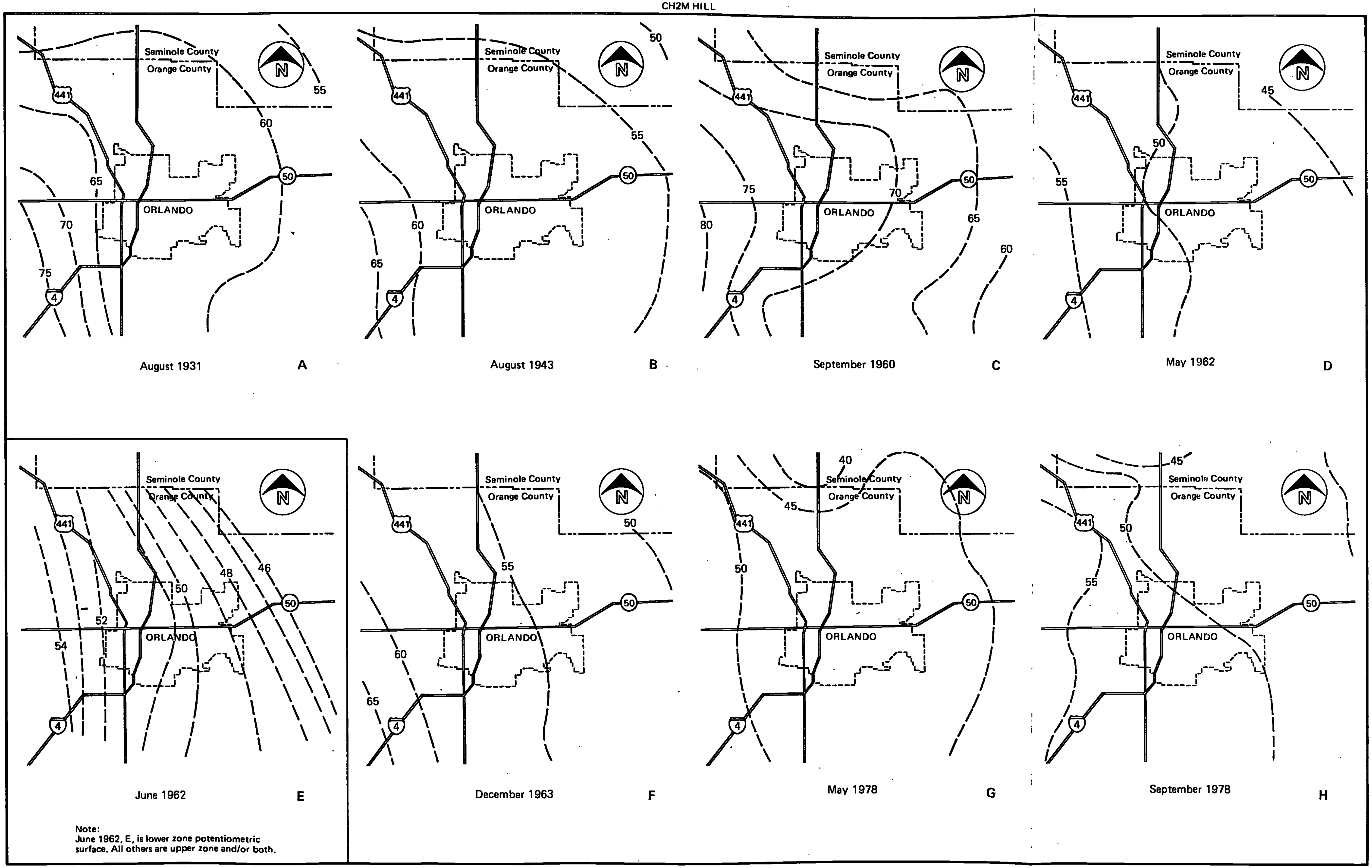


Historical view of potentiometric surface, Orlando area.

FIGURE 5-1.

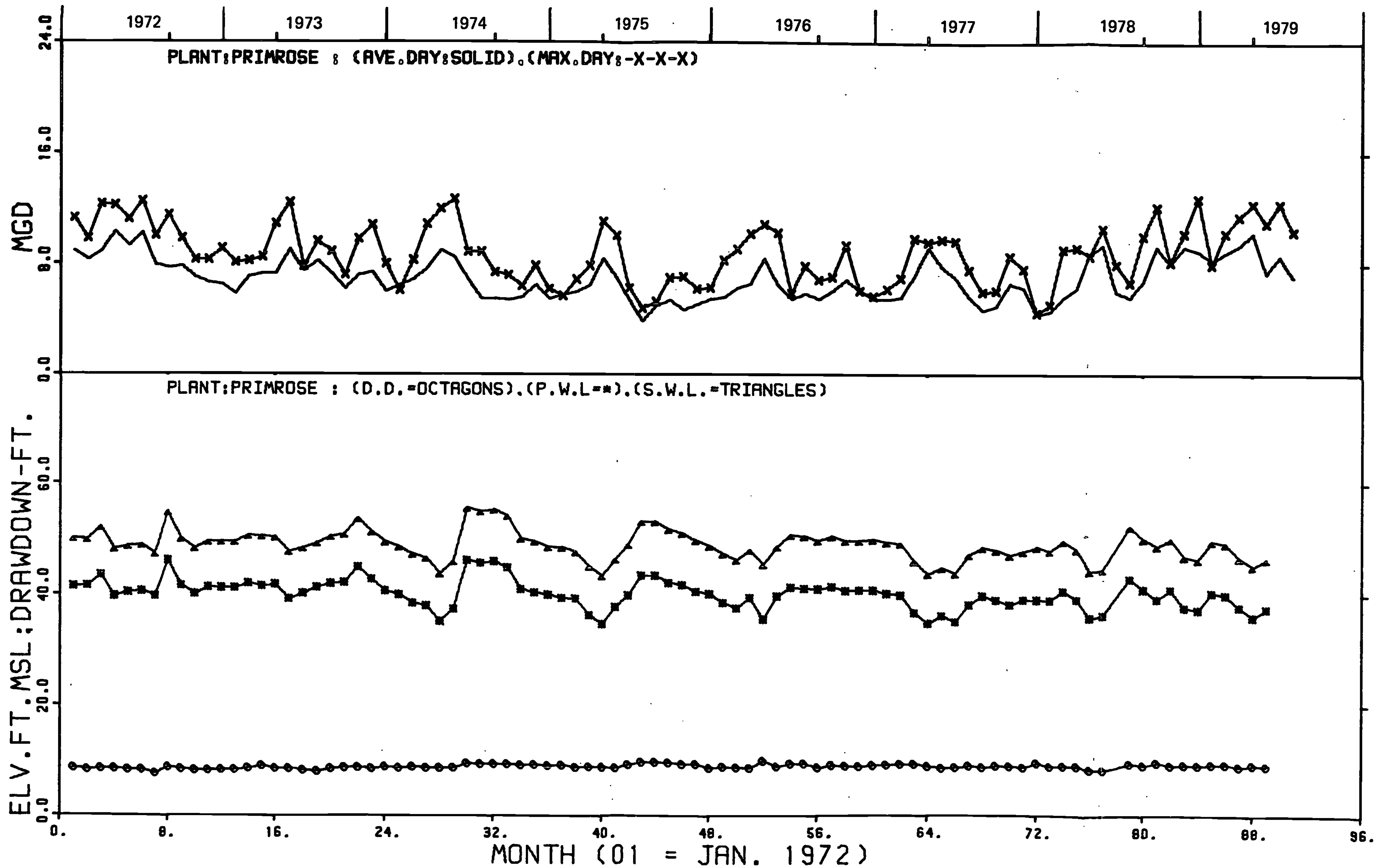
of water levels in the Orlando area of 45 to 50 feet, corresponding to an extreme low water condition. The above discussion, although applicable to the upper zone, illustrates trends in water level fluctuations which are probably reflected in the lower zone.

The surveys conducted in August 1931 and August 1943 prior to any ground-water withdrawals from the lower zone are probably a good approximation of the static water surface of that zone. When compared to a lower zone survey made in June 1962, the 1943 survey illustrates that the lower zone at that time had slightly lower water levels (~5 feet) than did the upper zone. Comparing these surveys to that conducted in March 1973 (solid lines on Figure 5-2) on the lower zone only illustrates that water levels have declined from 1931 (60 to 65 feet) to 1943 (45 to 55 feet) but have increased slightly from 1962 to 1973 (50 to 55 feet). Further, comparison of the 1973 survey, conducted in the dry season, to the most recent survey of October 1979 (dashed lines on Figure 5-2), made during a dry month following a normal wet season, illustrates that water levels during that month are slightly higher than during 1973.

During the period from 1931 to 1979, the ground-water withdrawals from the lower zone went from zero in 1931 and 1943 to 25 mgd in 1962 to 47 mgd in 1973 to 57 mgd in 1979. During this period of increasing ground-water withdrawals, the water levels appear to fluctuate more in response to natural phenomenons, i.e., drought and rainfall, than to pumpage.

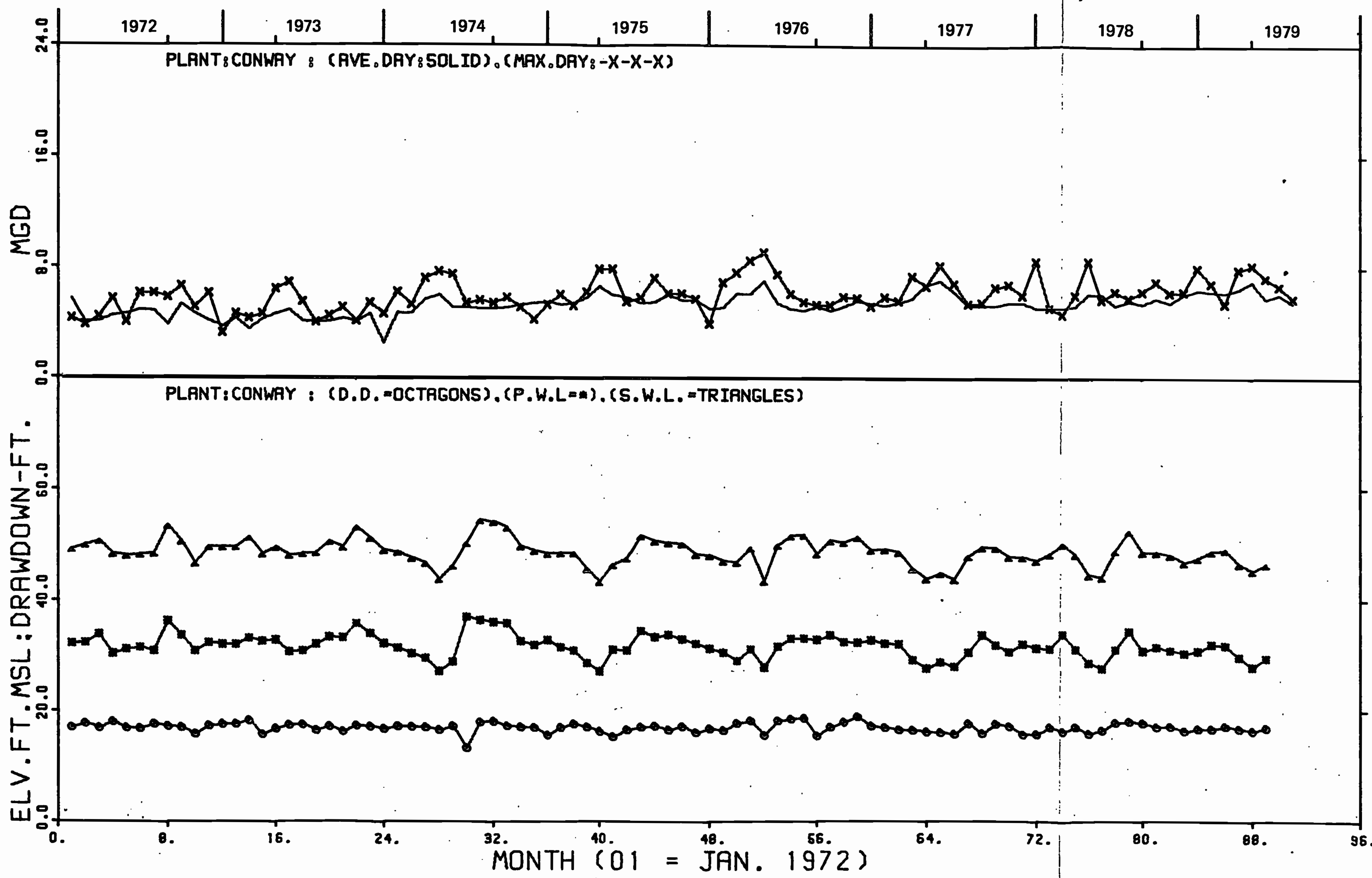
In order to further assess this trend, the historical records from the eight OUC water treatment plants were analyzed. Figures 5-3 through 5-10 illustrate the pumping record, average day and maximum day, at each plant. On the same graph, a plot of the static and pumped water levels and corresponding drawdown was made at one of the wells at each plant. The period of record is January 1972 to July 1979. During this period the average daily withdrawals for OUC went from 37 mgd in 1972 to 46 mgd in 1979 (projected total). Also, during this period, the pumping records at each plant show a slight increase however water levels have remained approximately the same, with some areas showing a slight increase (Kirkman, Primrose, and Highlands Plants), some a slight decrease (Kulh, Conway, and Martin Plants), and some remaining relatively stable (Pine Hills and Navy Plants). From the historical records, it is clear that increased ground-water withdrawals from the lower zone has not appreciably affected the potentiometric surface.

To predict the possible future effects of increased ground-water withdrawals, a computer model was used. The model, a finite difference simulation described by T. A. Prickett and C. G. Lonnquist, utilized an 80 x 80-node



Pumping record and water level response at water treatment plant and selected wells.

FIGURE 5-7.



Pumping record and water level response at water treatment plant and selected wells.

FIGURE 5-8.

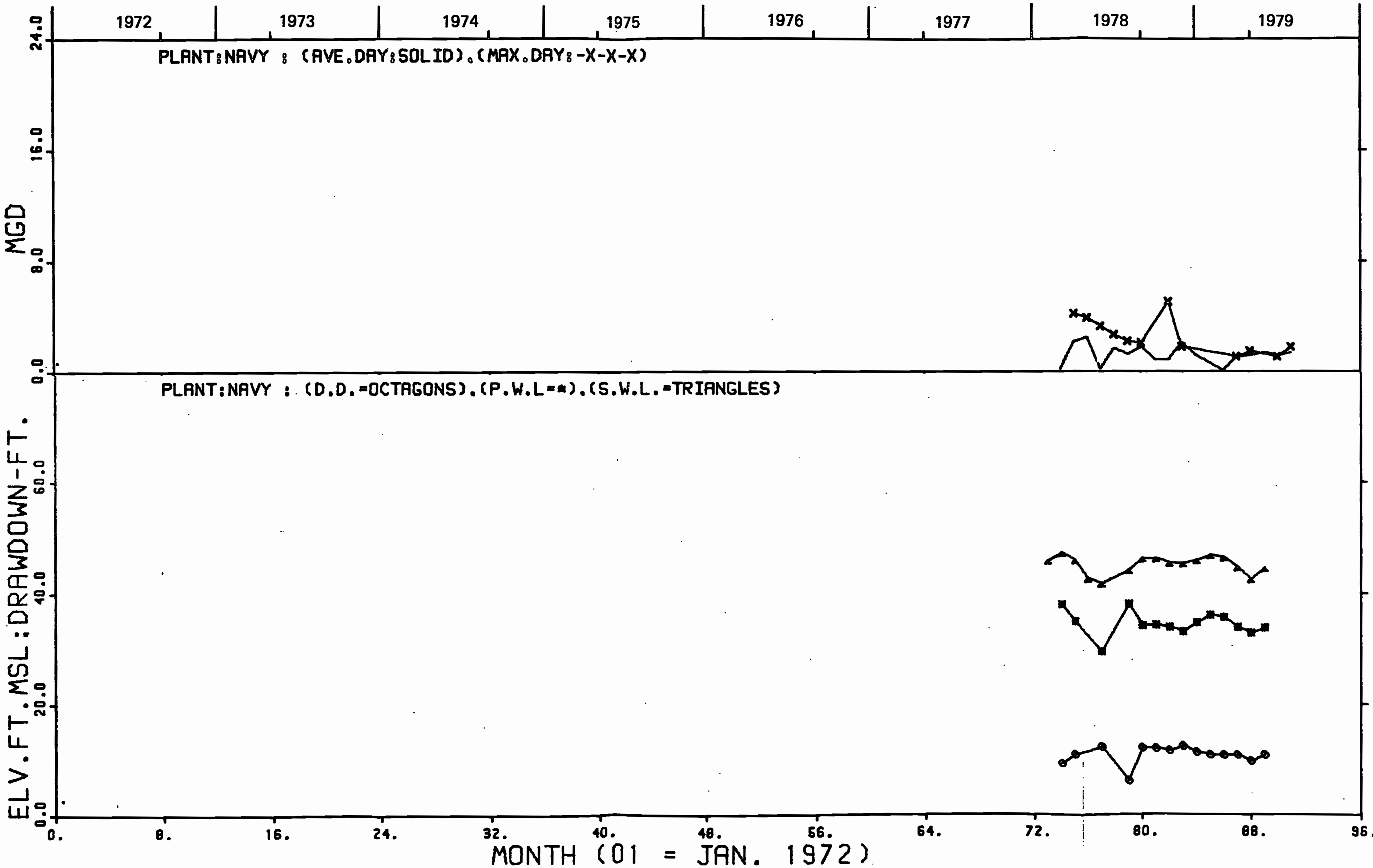
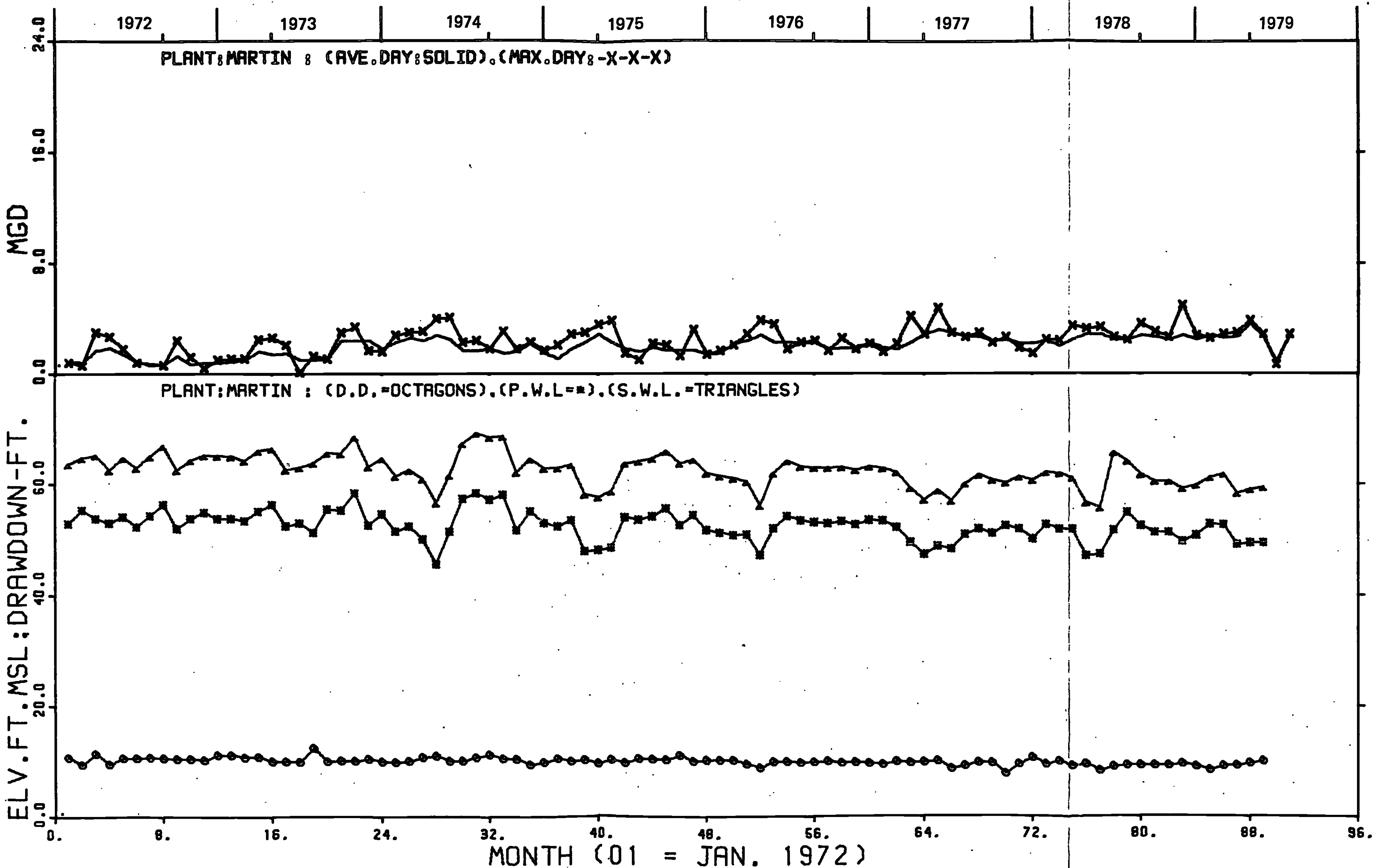


FIGURE 5-9. Pumping record and water level response at water treatment plant and selected wells.

FIGURE 5-9.



Pumping record and water level response at water treatment plant and selected wells.

FIGURE 5-10.

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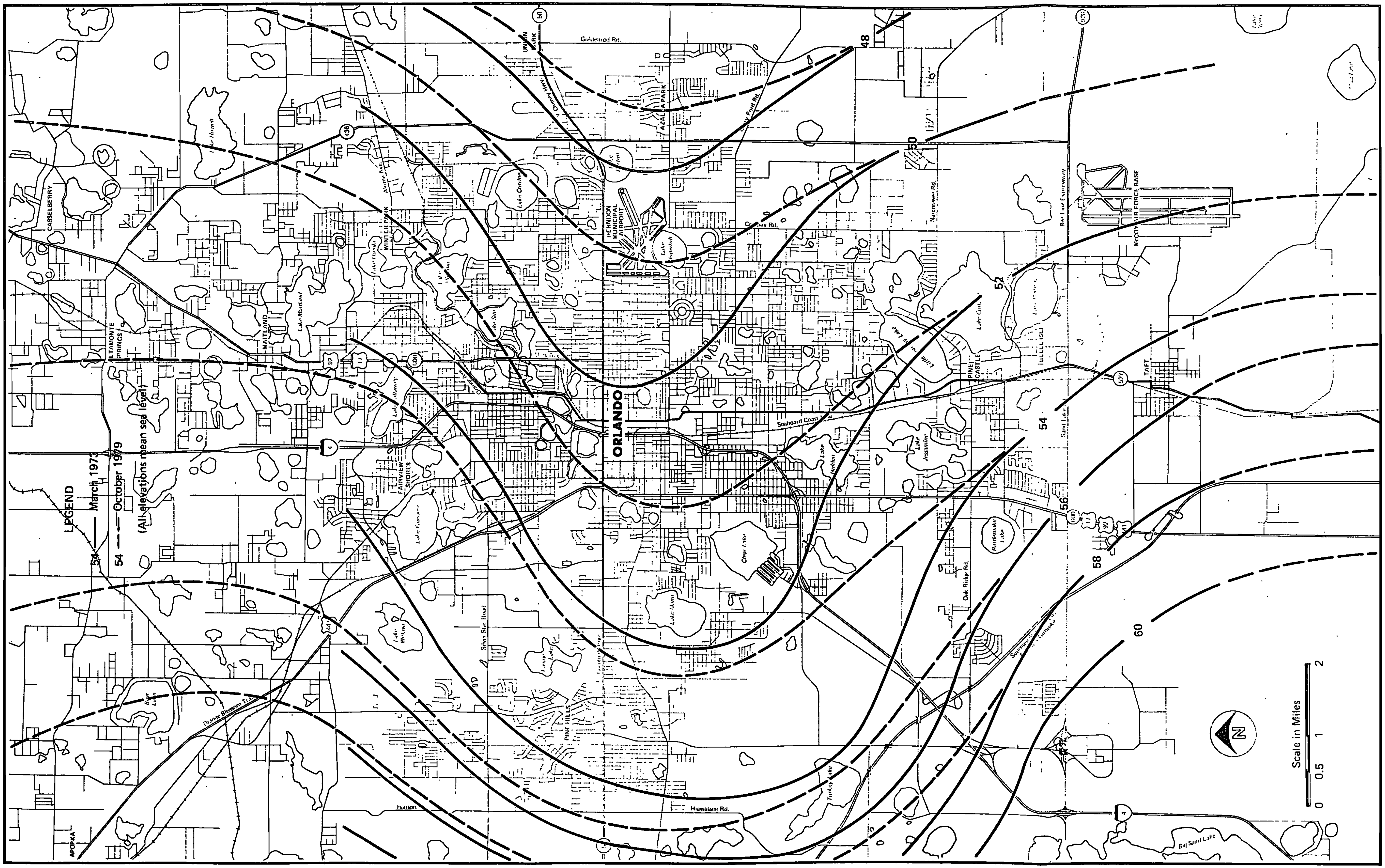
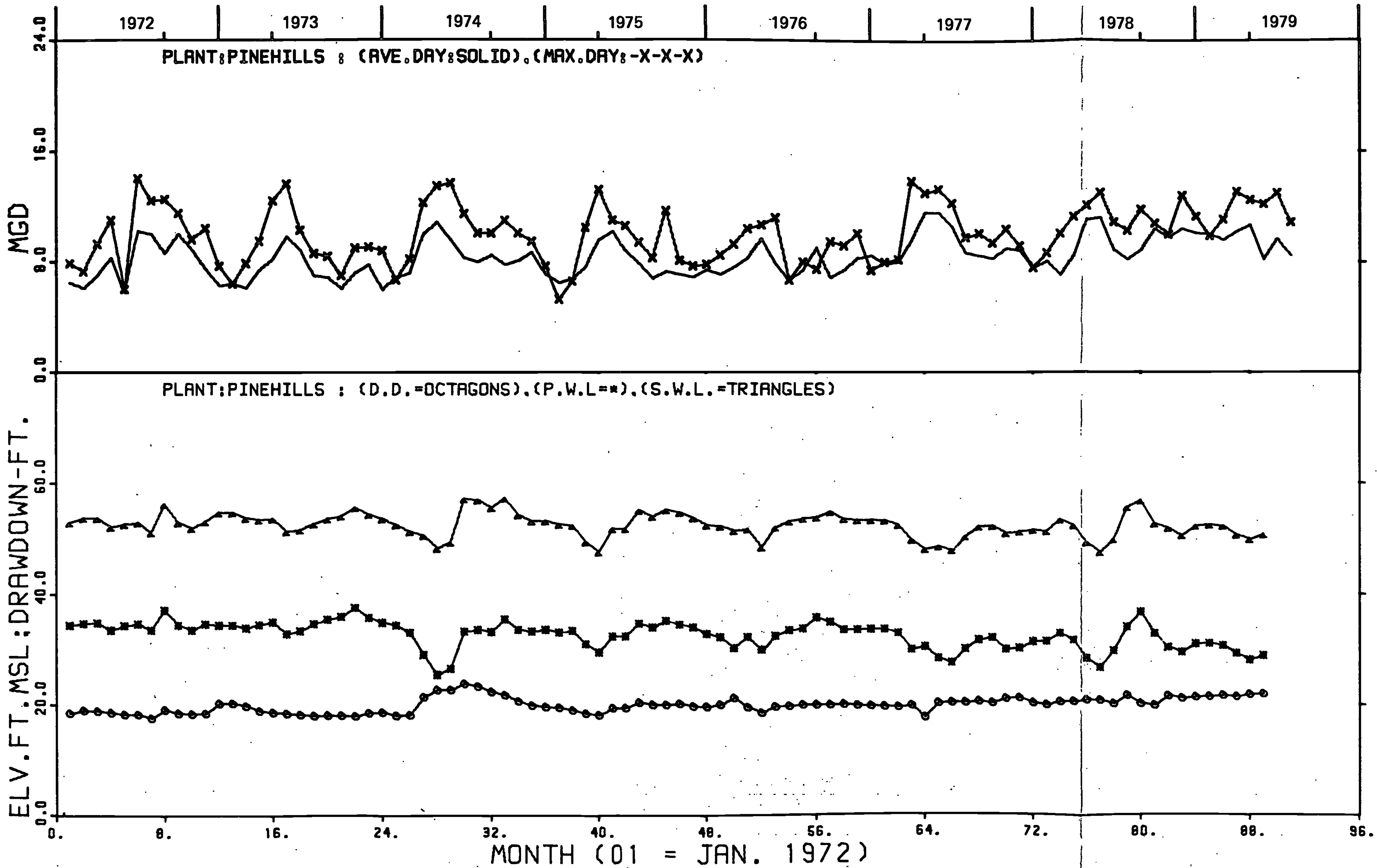


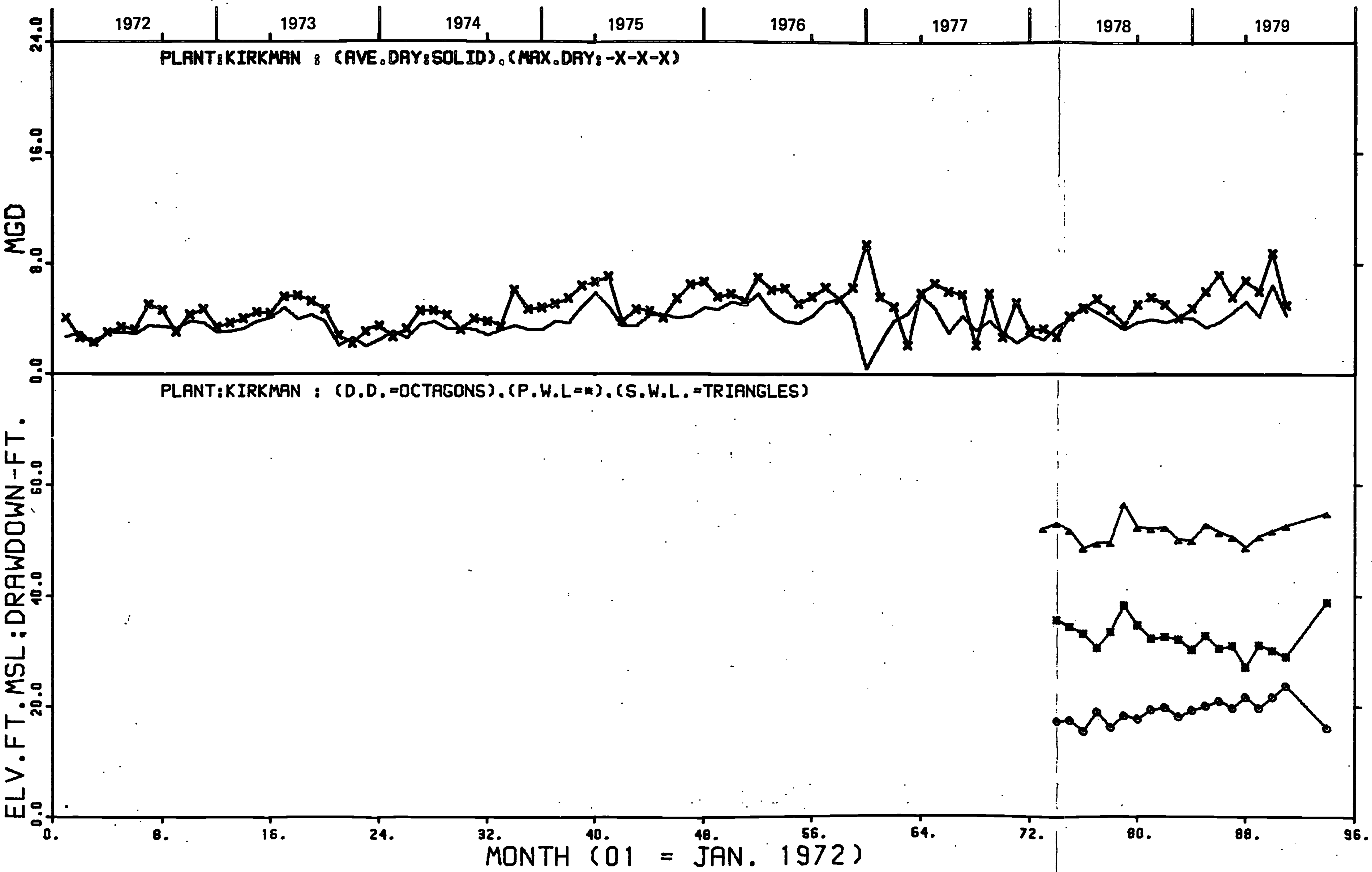
Potentiometric surface of the lower zone of the Floridan aquifer—March 1978; October 1979.

FIGURE 5-2.



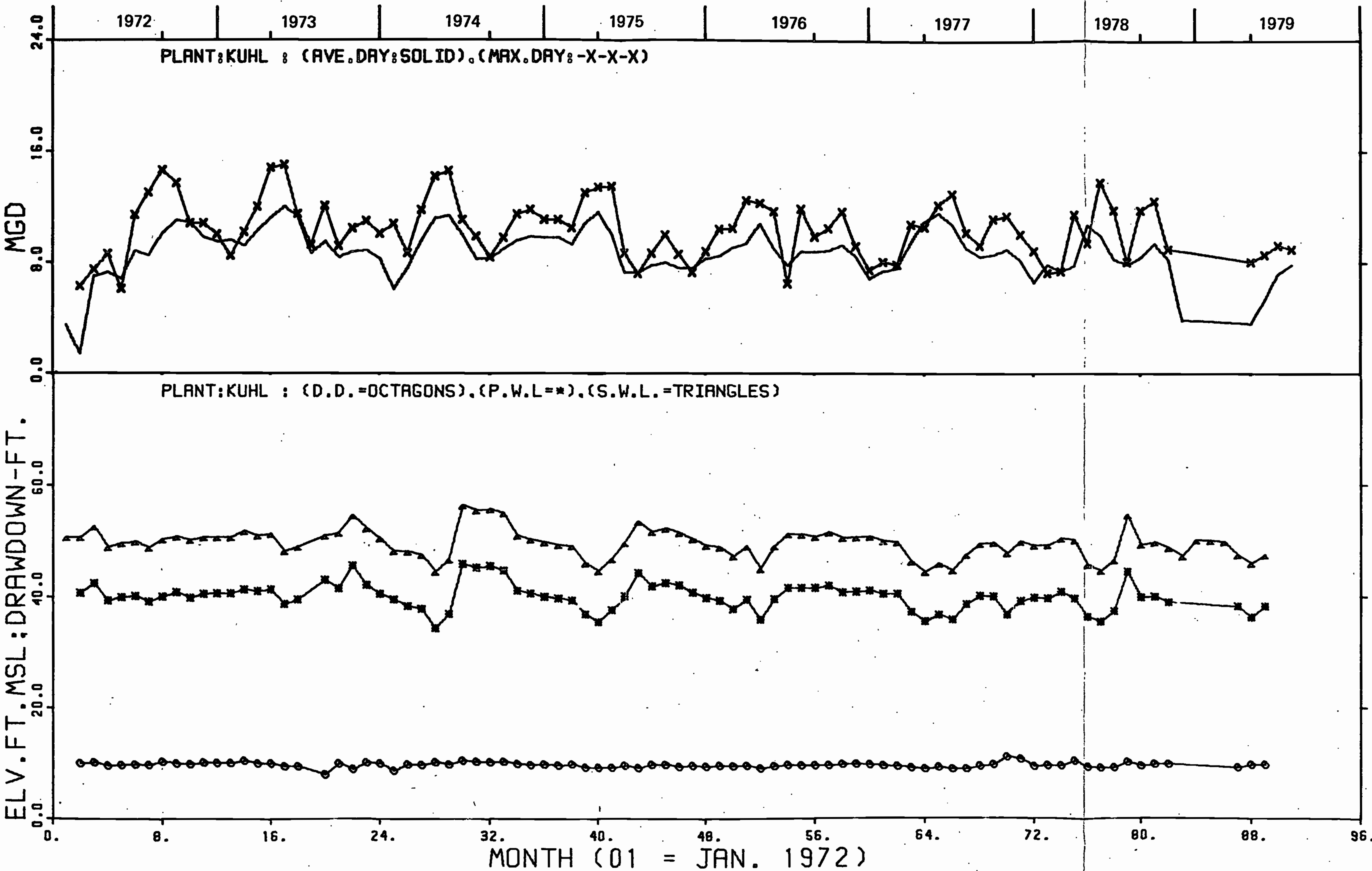
Pumping record and water level response at water treatment plant and selected wells.

FIGURE 5-3.



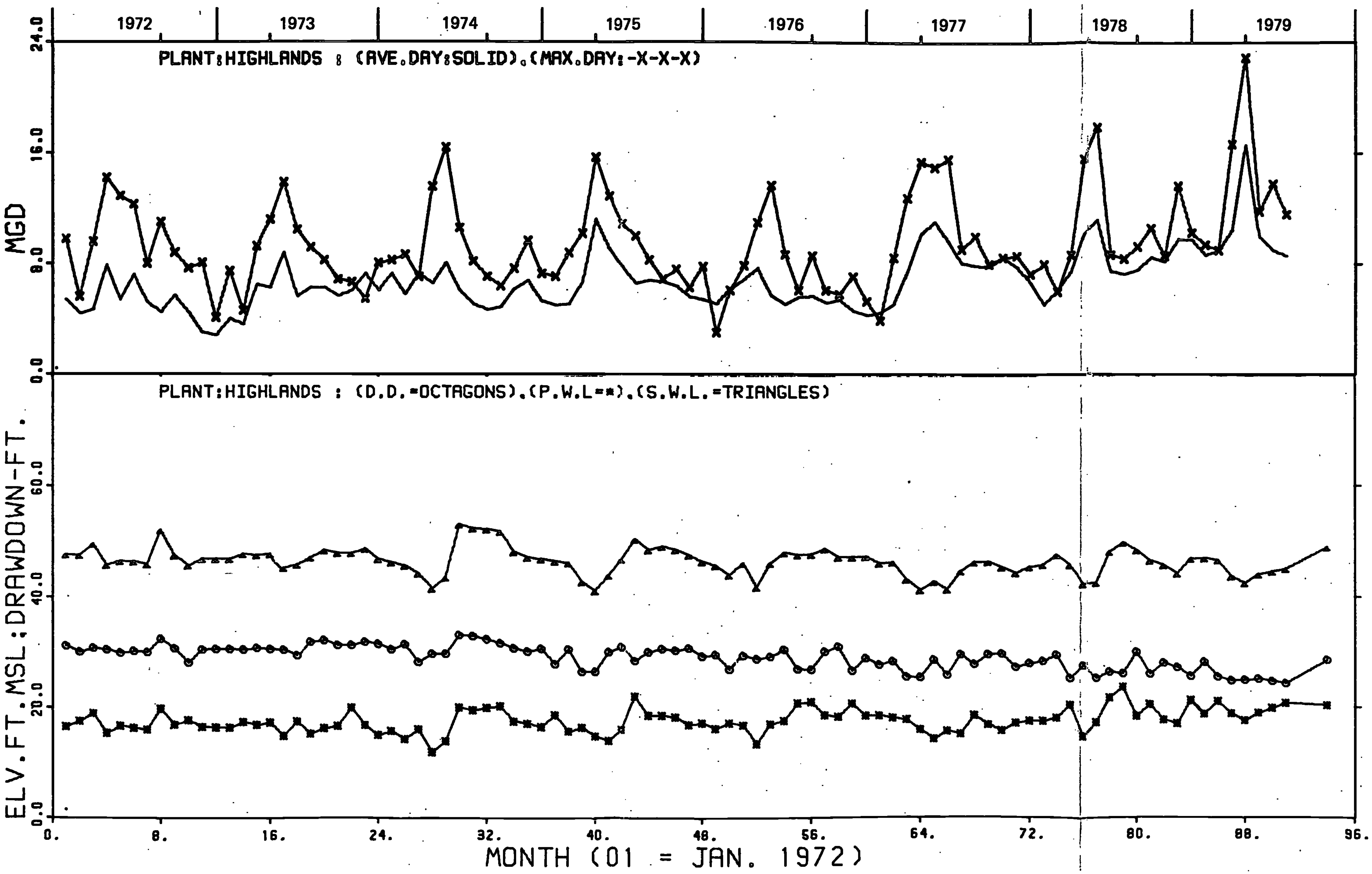
Pumping record and water level response at water treatment plant and selected wells.

FIGURE 5-4.



Pumping record and water level response at water treatment plant and selected wells.

FIGURE 5-5.



Pumping record and water level response at water treatment plant and selected wells.

FIGURE 5-6.

square grid. The node spacing was 4,000 feet, giving a coverage of 60 miles square, centering approximately on the Highlands Plant. The large spacing was necessary to accommodate a large areal coverage necessitated by a very high transmissivity. At the 4,000-foot spacing, it was necessary to combine the pumpage from several wells at each plant and to place the center of pumping at a node. The lower zone only was modelled and the model included plants operated by General Waterworks Corporation in Winter Park. Table 5-1 lists the pumping notes assigned to each plant (node) to simulate ground-water withdrawals.

The model was simiplified by assuming a uniform aquifer and using those values for transmissivity and storage obtained from a pumping test, described above, at the Highlands Plant. Those values are:

Transmissivity = 668,000 ft^2/day (5 mgd/ft)

Storage = 2.0×10^{-3}

The aquifer was considered to be nonleaky artesian and a time frame of 30 days of continuous pumping at the average daily flow (ADF) rate was used.

The first run, made after numerous trial "debugging" runs of the Orlando aquifer model, was based on 1978 ADF (average day flow) at each plant in both OUC and GWC systems.

If the model in fact simulated actual conditions in the field, then this run should check fairly close with the current potentiometric surveys. To check this, the curvilinear October 1979 potentiometric contours were "straightened out" in a north-northwest direction. This was considered to be the static potentiometric surface of the lower zone if no pumping from that zone had every occurred. The drawdowns predicted by the 1978 aquifer simulation were superimposed on the static surface, and a computer-predicted potentiometric surface was calculated. The resulting map was then compared to the actual survey completed in October 1979. The computer-generated map checked within 2 feet of the actual measured surface. Given the simplifying assumptions made initially for the model, this proved to be a close check with actual field conditions.

This exercise indicated that the computer model was "calibrated" fairly close to reality and could be used to predict effects of ground-water withdrawals.

With the model calibrated, Run No. 2 was made by removing the GWC wells, simulating drawdown conditions if OUC were the only lower zone user. Again 1978 ADF rates at each plant were used. Table 5-2 lists the predicted 1978 drawdowns at each plant with OUC only and with OUC and GWC

Table 5-1
Composite Pumping Rates Assigned to OUC and GWC Water Plants

Plant Name	1978 Average Daily Flow (mgd)	Percent of Total	1988 Average Daily Flow (mgd)
Kirkman	3.9	8	4.5
Pine Hills	9.4	20	9.4
Highlands	8.2	18	8.2
Kuhl	8.2	18	8.2
Navy	1.3	3	1.6
Conway	5.6	12	6.6
Martin[a]	2.6	6	3.2
John Young	0.0	0	3.7
McCoy	0.0	0	1.8
GWC-1[a]	2.9	27	3.8
GWC-2	--out of service--		
GWC-3	2.5	23	3.2
GWC-4	1.9	18	2.5
GWC-5	3.7	34	4.8

[a]Upper zone wells.

Table 5-2
Predicted Drawdown at Water Treatment Plants--1978 Average Daily Flow (feet)

Plant	OUC and GWC	OUC Only	GWC Only
Orlando Utilities Commission			
Kirkman	3.20	3.14	0.06
Pine Hills	4.01	3.87	0.14
Highlands	4.63	4.33	0.30
Kuhl	4.45	4.30	0.15
Primrose	4.48	4.23	0.25
Conway	3.72	3.57	0.15
Navy	3.52	3.15	0.37
General Waterworks			
GWC-3	3.50	2.88	0.62
GWC-4	2.88	2.17	0.71
GWC-5	3.16	2.36	0.80

together. The difference between the two runs represents drawdowns expected if GWC were the only user. This table illustrates that 1978 GWC withdrawals cause less than 0.5 feet of drawdown at any OUC plant and that OUC wells cause less than 3 feet of drawdown at any GWC well.

The third computer run made simulated the 1988 predicted drawdowns. The flow rates for GWC were obtained by using the 1988 total ADF predicted from historical data (Figure 3-2) and assigning the same percentage of the total pumped from each plant in 1978. The OUC 1988 rates were obtained in a slightly different manner. Table 6-1 of the OUC consumptive use application indicated that three existing plants would be expanded (additional wells) in future and that two additional plants would be constructed. Based on these data, it was assumed that those plants not earmarked for additional wells would supply water at current ADF rate in 1988. Those plants which will be expanded will supply water at higher rates but at the same percentage of the total that they supplied in 1978. The additional water required would be provided by the two additional plants (John Young, and McCoy) in the amounts of 3 mgd and 7 mgd ADF respectively.

This run was used to calculate the expected additional drawdown associated with 1988 ground-water withdrawals. Table 5-3 lists 1978 and 1988 predicted drawdowns at each plant utilizing lower zone wells. From this table it can be seen that with the exception of the new plants, the 1988 predicted drawdowns will increase approximately 1/2 foot.

The last computer run made, simulated 1988 conditions as if OUC were the only lower zone ground-water user. Table 5-4 lists the predicted 1988 drawdowns at each plant with OUC only and with OUC and GWC together. The difference represents GWC only. From this table it is shown that the GWC wells produce less than 0.5 feet of drawdown at OUC wells and OUC wells produce slightly greater the 3 feet of drawdown at GWC wells. Figure 5-11 illustrates graphically this relationship. This is similar to 1978 results listed in Table 5-2.

The large grid spacing necessitated by aquifer conditons in the Orlando area precluded modeling the system on a well-by-well basis. At this time accurate values for aquifer characteristics and the distribution of these values are rather scarce. The values used for this anlysis result in theoretical distance-drawdown curves (Figure 4-6). This graph can be used together with the known withdrawal rate to map the cone of depression for each lower-zone OUC well. Since it is based on an assumed uniform aquifer, this mapping would result in similar cones of depression for each well, differing only in the withdrawal rate. Since OUC wells all pump at about the same rate, (3,500 to 4,200 gpm), a generalized

Table 5-3
Drawdown at Water Treatment Plants
Predicted by Computer Model

Plant	Drawdown (ft) 1978	1988	Difference
Orlando Utilities Commission			
Kirkman	3.26	3.75	0.5
Pine Hills	4.10	4.59	0.5
John Young (Proposed)	3.79	4.92	1.1
Highlands	4.80	5.30	0.5
Kuhl	4.55	5.06	0.5
Primrose	4.62	5.11	0.5
McCoy (Proposed)	2.07	2.89	0.8
Conway	3.81	4.49	0.7
Navy	3.69	4.18	0.5
General Waterworks			
GWC-3	3.70	4.25	0.6
GWC-4	3.08	3.56	0.5
GWC-5	3.35	3.92	0.6

Table 5-4
Drawdown at Water Treatment
Plants Predicted by Computer
Model--1988 Average Daily Flow (feet)

Plant	OUC and GWC	OUC Only	GWC Only
Orlando Utilities Commission			
Kirkman	3.75	3.64	0.11
Pine Hills	4.59	4.37	0.22
John Young (proposed)	4.92	4.55	0.37
Highlands	5.30	4.81	0.49
Kuhl	5.06	4.79	0.27
Primrose	5.11	4.69	0.42
McCoy (proposed)	2.89	2.77	0.12
Conway	4.49	4.22	0.27
Navy	4.18	3.57	0.61
General Waterworks			
GWC-3	4.25	3.30	0.95
GWC-4	3.56	2.46	1.10
GWC-5	3.92	2.67	1.25

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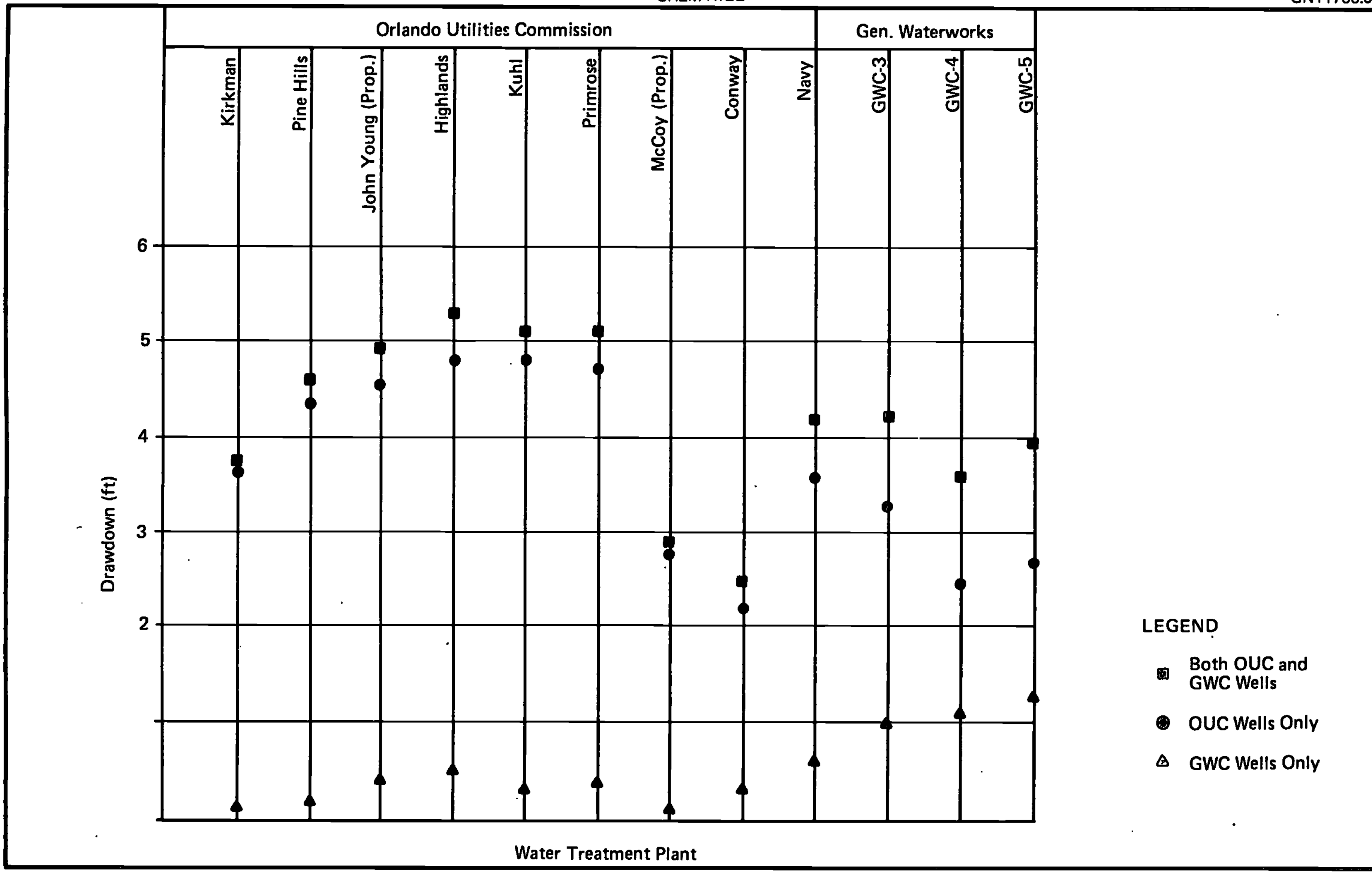

FIGURE 5-11. Predicted drawdown at water treatment plants in Orlando and Winter Park, 1988 average daily flow.

cross sectional profile was prepared to illustrate the approximate conditions associated with a typical OUC supply well. Figure 5-12 illustrates the relationship between drawdown and distance for one well pumping at 3,500 gpm.

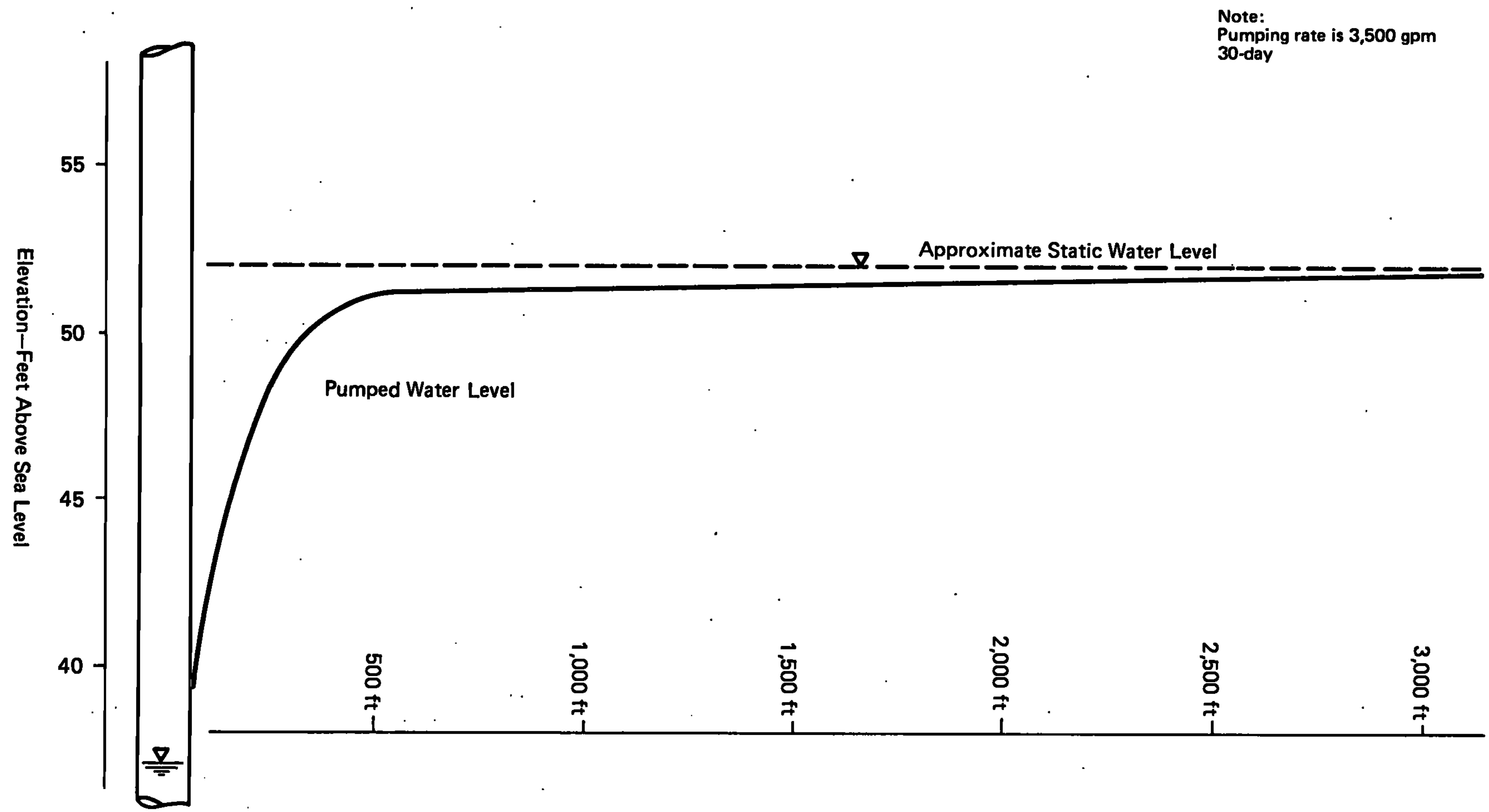

FIGURE 5-12. Generalized distance-drawdown relationship at OUC wells.

CHAPTER 6
CONCLUSIONS

Based on the results of this study, the following conclusions have been reached:

1. Ground-water withdrawals from the Floridan aquifer seem to have had little effect on water levels in the Orlando area.

2. Natural phenomenons seem to have more effect on long-term water level trends than do ground-water withdrawals.

3. The spreading out of pumping over a large area has helped mitigate adverse effects on water levels in the Orlando area.

4. Aquifer characteristics could be more accurately determined and the aquifer model improved with additional data. Specifically, observation well or wells need to be placed close to a pumping well (less than 50 feet), and capable of monitoring independently water level response in both the upper and lower zones. At this time no such wells exist in the Orlando area.

5. General Waterworks Corporation 1978-1988 ground-water withdrawals have little effect on Orlando Utilities Commission supply wells.

6. Orlando Utilities Commission 1978-1988 ground-water withdrawals result in 3.5 feet or less of interference with General Waterworks Corporation supply wells.

7. The decline in potentiometric head predicted for 1988 by computer model is approximately 0.5 feet.

8. The theoretical distance-drawdown curve using a 3,500-gpm pumping rate and 120 days is less than 1 foot at a distance of 500 feet from a pumping well.

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Current (June 1988) Disposition of Waste Water Treatment

Plant	Plant Effluent Amount MGD	Present Disposal
Sand Lake Road (Orange County)	11.24**	Citrus Irrigation* West Orange/East Lake County. West Effluent disposal area (percolation ponds of South extension of International Drive)
Eastern Subregional (Orange County)	3.5**	Stanton Energy Center for cooling tower makeup
	3.5	Wetlands
	3.5	Rapid Infiltration Basins on site
Cypress Walk (Orange County)	0.4**	Cypress Walk golf course irrigation
Meadow Woods (Orange County)	0.44**	Golf course irrigation (75 acres)
	0.73	percolation
South Central (Orange County)	0.5**	Hunters Creek golf course irrigation
Conserv I (City of Orlando)	3.0	Percolation ponds
Conserv II (City of Orlando)	11.0**	Citrus Irrigation* West Orange/East Lake County
Ironbridge (City of Orlando)	8.0	Wetlands augmentation

*West Orange/East Lake County disposal area is a joint project of the City of Orlando and Orange County. Primary disposal is irrigation of 6,000 acres of citrus and 10 acres of ferns. Secondary disposal is rapid infiltration basins. (530 acres of which 138 acres is wetted) Recharge capacity is 15.75 mgd.

**Reuse applications. (Total = 27.08 mgd)

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BREAKDOWN OF PROJECTED WATER USES FOR: Orlando Utilities Commission DATE: 07/11/88 CUP Application No. 2-095-0002AUMGR
(MILLION GALLONS PER DAY - MGD)

YEAR	PROJECTED POPULATION	HOUSEHOLD TYPE (RESIDENTIAL)		COMMERCIAL/INDUSTRIAL		IRRIGATION:			METERED UTILITY (OUC Use)	FOR SALE OUT	WATER UTILITY (loss,UAW)	TOTAL PUMPED:		INSTALLED WELLFIELD CAPACITY
							WATER AMOUNT:							
Fiscal Year Ending	OUC Service Area (persons)	AVG. DAY (MGD)	MAX. DAY (MGD)	AVG. DAY (MGD)	MAX. DAY (MGD)	AREA (acres)	AVG. DAY (MGD)	MAX. DAY (MGD)	AVG. DAY (MGD)	AVG. DAY (MGD)	AVG. DAY (MGD)	AVG. DAY (MGD)	MAX. DAY (MGD)	(MGD)
1980	277,630	26.343	(1)	16.696	(1)	(2)	2.459	(1)	0.100	0.000	3.504	49.102	81.329	111
1981	283,480	27.664	(1)	17.341	(1)	(2)	3.230	(1)	0.087	0.000	5.858	54.180	84.346	111
1982	286,514	25.216	(1)	16.613	(1)	(2)	3.066	(1)	0.072	0.083	6.703	51.753	72.690	109
1983	297,980	26.342	(1)	17.237	(1)	(2)	2.646	(1)	0.066	0.661	5.212	52.164	86.070	135
1984	314,712	28.321	(1)	18.044	(1)	(2)	3.142	(1)	0.080	0.700	6.189	56.475	92.630	135
1985	329,866	30.818	(1)	19.620	(1)	(2)	4.656	(1)	0.078	0.840	7.413	63.425	102.060	135
1986	341,870	30.707	(1)	20.390	(1)	(2)	5.225	(1)	0.087	1.029	10.015	67.452	112.230	135
1987	351,483	32.961	(1)	22.215	(1)	(2)	6.601	(1)	0.081	1.077	9.433	72.368	116.020	142
1988	365,855	35.854	(1)	23.736	(1)	(2)	9.050	(1)	0.100	0.391	9.816	78.947	120.470	157
1989	377,902	37.034	(1)	24.524	(1)	(2)	9.931	(1)	0.100	0.000	10.390	81.979	124.580	(3)
1990	389,781	38.199	(1)	25.120	(1)	(2)	10.800	(1)	0.100	0.000	10.539	84.758	129.020	(3)
1991	401,477	39.345	(1)	25.852	(1)	(2)	11.657	(1)	0.100	0.000	10.927	87.881	133.660	(3)
1992	412,949	40.469	(1)	26.582	(1)	(2)	12.496	(1)	0.100	0.000	11.310	90.957	138.230	(3)
1993	424,268	41.578	(1)	27.286	(1)	(2)	13.325	(1)	0.100	0.000	11.685	93.975	142.710	(3)
1994	435,314	42.661	(1)	28.016	(1)	(2)	14.135	(1)	0.100	0.000	12.058	96.969	147.170	(3)
1995	446,155	43.723	(1)	28.834	(1)	(2)	14.927	(1)	0.100	0.000	12.437	100.021	151.720	(3)
1996	456,800	44.766	(1)	29.612	(1)	(2)	15.706	(1)	0.100	0.000	12.806	102.991	156.150	(3)
1997	467,262	45.792	(1)	30.290	(1)	(2)	16.473	(1)	0.100	0.000	13.157	105.812	160.340	(3)
1998	477,557	46.801	(1)	31.000	(1)	(2)	17.224	(1)	0.100	0.000	13.507	108.632	164.540	(3)

(1) Maximum day is not available by type of use. Water consumption by type of use is compiled from monthly billing data. Maximum daily use (by type of use) cannot be observed directly from the monthly billing data.

(2) No data is available for the number of acres irrigated by water from irrigation meters.

(3) Wellfield capacity will be increased as required to meet current demand.

Orlando Utilities Commission CUP Application No. 2-095-0002AUMGR

Forecast Yearly Withdrawals by Wellfield, millions of gallons

Year	Primrose	Conway	Navy	Kuhl	Martin	Dr Phillips	Kirkman	Pine Hills	Highland	Skylake	Total System	Total Upper Zone	Total Lower Zone
1988	2,716,103	4,103,050	1,358,052	4,825,418	3,900,787	1,589,209	2,947,261	3,871,892	3,582,947	0	28,894,719	5,489,996	23,404,723
1989	2,812,684	4,248,948	1,406,342	4,997,002	4,039,265	1,645,626	3,051,889	4,009,344	3,711,066	0	29,922,166	5,684,891	24,237,275
1990	2,846,186	3,403,048	1,454,030	4,207,405	3,093,680	1,701,524	3,093,680	4,021,784	3,712,416	3,403,046	30,936,799	4,795,204	26,141,595
1991	2,951,495	3,528,961	1,507,829	4,363,079	3,208,146	1,764,480	3,208,146	4,170,590	3,849,775	3,524,214	32,076,715	4,972,626	27,104,089
1992	3,063,652	3,663,062	1,556,164	4,528,876	3,330,056	1,831,530	3,330,056	4,329,072	3,996,066	3,661,604	33,290,138	5,161,586	28,128,552
1993	3,155,562	3,772,954	1,602,849	4,664,742	3,429,958	1,886,476	3,429,958	4,458,944	4,115,948	3,783,488	34,300,879	5,316,434	28,984,445
1994	3,256,540	3,893,688	1,654,140	4,814,014	3,539,717	1,946,843	3,539,717	4,601,630	4,247,658	3,899,580	35,393,527	5,486,560	29,906,967
1995	3,357,493	4,014,393	1,705,419	4,963,248	3,649,448	2,007,195	3,649,448	4,744,281	4,379,336	4,037,354	36,507,615	5,656,643	30,850,972
1996	3,468,290	4,146,868	1,761,697	5,127,035	3,769,880	2,073,433	3,769,880	4,900,842	4,523,854	4,152,992	37,694,771	5,843,313	31,851,458
1997	3,554,997	4,250,540	1,805,740	5,255,211	3,864,127	2,125,269	3,864,127	5,123,363	4,636,950	4,140,893	38,621,217	5,989,396	32,631,821
1998	3,650,982	4,365,304	1,854,495	5,397,102	3,968,458	2,182,651	3,968,458	5,158,994	4,762,148	4,342,213	39,650,805	6,151,109	33,499,696

Orlando Utilities Commission CUP Application No. 2-095-0002AUMGR

Forecast Average Daily Withdrawals by Wellfield, millions of gallons

Year	Primrose	Conway	Navy	Kuhl	Martin	Dr Phillips	Kirkman	Pine Hills	Highland	Skylake	Total System	Total Upper Zone	Total Lower Zone
1988	7,421	11,211	3,711	13,184	10,658	4,342	8,053	10,579	9,789	0	78,947	15,000	63,947
1989	7,706	11,641	3,853	13,690	11,066	4,509	8,361	10,985	10,167	0	81,979	15,575	66,403
1990	7,798	9,323	3,984	11,527	8,476	4,662	8,476	11,019	10,171	9,323	84,758	13,138	71,621
1991	8,086	9,668	4,131	11,954	8,789	4,834	8,789	11,426	10,547	9,655	87,881	13,624	74,258
1992	8,371	10,008	4,252	12,374	9,099	5,004	9,099	11,828	10,918	10,004	90,957	14,103	76,854
1993	8,645	10,337	4,391	12,780	9,397	5,168	9,397	12,216	11,277	10,366	93,975	14,566	79,409
1994	8,922	10,668	4,532	13,189	9,698	5,334	9,698	12,607	11,637	10,684	96,969	15,032	81,937
1995	9,199	10,998	4,672	13,598	9,998	5,499	9,998	12,998	11,998	11,061	100,021	15,498	84,523
1996	9,476	11,330	4,813	14,008	10,300	5,665	10,300	13,390	12,360	11,347	102,991	15,965	87,026
1997	9,740	11,645	4,947	14,398	10,587	5,823	10,587	14,037	12,704	11,345	105,812	16,409	89,402
1998	10,003	11,960	5,081	14,787	10,872	5,980	10,872	14,134	13,047	11,896	108,632	16,852	91,780

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Orlando Utilities Commission CUP Application No. 2-095-0002AUMGR

Forecast Maximum Daily Withdrawals by Wellfield, millions of gallons

Year	Primrose	Conway	Navy	Kuhl	Martin	Dr Phillips	Kirkman	Pine Hills	Highland	Skylake	Total System	Total Upper Zone	Total Lower Zone
1988	11,325	17,107	5,662	20,119	16,264	6,626	12,288	16,143	14,935	0	120,470	22,890	97,580
1989	11,711	17,691	5,855	20,805	16,818	6,852	12,707	16,693	15,448	0	124,580	23,669	100,911
1990	11,868	14,190	6,063	17,544	12,900	7,095	12,900	16,770	15,498	14,190	129,020	19,995	109,025
1991	12,298	14,705	6,283	18,180	13,368	7,352	13,368	17,378	16,043	14,685	133,660	20,720	112,940
1992	12,721	15,210	6,461	18,805	13,827	7,605	13,827	17,975	16,596	15,204	138,230	21,432	116,798
1993	13,129	15,698	6,669	19,408	14,271	7,849	14,271	18,552	17,124	15,741	142,710	22,119	120,591
1994	13,541	16,190	6,878	20,017	14,718	8,095	14,718	19,134	17,663	16,215	147,170	22,814	124,356
1995	13,953	16,683	7,088	20,627	15,167	8,342	15,167	19,717	18,198	16,779	151,720	23,508	128,212
1996	14,368	17,179	7,298	21,239	15,617	8,589	15,617	20,302	18,735	17,204	156,150	24,207	131,943
1997	14,759	17,646	7,497	21,817	16,042	8,823	16,042	21,270	19,254	17,191	160,340	24,865	135,475
1998	15,151	18,115	7,696	22,397	16,469	9,058	16,469	21,409	19,757	18,020	164,540	25,526	139,014