State Water Survey Division

GROUND WATER SECTION

Illinois Department of
Energy and Natural Resources

SWS Contract Report 352B

PART B. THE AMERICAN BOTTOMS DIGITAL GROUND WATER FLOW MODEL

for the study

GROUND WATER LEVEL ANALYSIS BY COMPUTER MODELING: AMERICAN BOTTOMS GROUND WATER STUDY

by

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PREFACE

Groundwater Level Analysis by Computer Modeling is an in-depth investigation of groundwater flow in the American Bottoms area. There were five objectives to this study. They were 1) to compile current hydrologic data pertaining to the area, 2) to develop a computer model that could simulate the movement of groundwater, 3) to analyze existing and future groundwater levels in the area, 4) to present alternatives to lower or maintain groundwater levels at specified elevations in a designated area of interest and 5) to provide documentation of the model including a user's guide.

The five objectives of this study are addressed in five separate reports that may be used independently or conjunctively.

Part	Title
A	Groundwater Levels and Pumpage
B	American Bottoms Digital Groundwater Flow Model
C	Existing and Future Groundwater Levels
D	Evaluation of Alternative Measures
E	Digital Flow Model Description and User's Guide

A brief summary of each part of the study is given here. Each part has an introduction, an explanation of methods, results and references. Part E, the model user's guide, includes attachments for data and program listings.

Acknowledgments

A project of this size required the cooperation of many Illinois State Water Survey employees. Their efforts were important in the completion of this project. Noteworthy contributions were made by James D. Miller in gathering background information for Part A, by Mark C. Collins in modifying the ISWS aquifer model for Part B and by Anne Klock in making groundwater level probability exceedance calculations for Part C. Graphics were done by John Brother, Bud Motherway and Linda Riggin. Word processing was done by Pamela Lovett and Kathy Brown. A special appreciation was gained for the timely assistance of consultants at the University of Illinois Computer Services Office and the Boeing Computer Service Customer Service.

SUMMARY OF STUDIES

Groundwater Levels and Pumpage

The American Bottoms is a 175 square mile area of the Mississippi River valley lowlands that includes the urban industrial areas of East St. Louis, Granite City and Alton. Groundwater is a major source of water for the area and is used for industrial, public and irrigation supplies. Groundwater levels prior to industrial and urban development were near land surface. Intensive industrial development and construction of a system of drainage ditches, levees, and canals to protect developed areas have altered the water resources in the area. In recent years, water level rises due to reductions in pumpage, high river stages, and high precipitation producing favorable recharge conditions have caused damage to underground structures. The U.S. Army Corps of Engineers, St. Louis District has sponsored this study to examine groundwater flow in the area and its relationship to Mississippi River stage and precipitation.

Water levels and pumpage information collected over many years by the State Water Survey have been summarized and are presented in Part A. Pumpage is presented for major and minor pumping centers and is classified as public, industrial, domestic or irrigation. Hydrographs are presented for ten different observation wells for their period of record. Mississippi River stages, precipitation at St. Louis airport and pumpage at Granite City are included with the hydrographs to illustrate their interdependence. Piezometric surface maps are presented for five different groundwater conditions.

Groundwater Flow Model

The groundwater model used was a modified form of the Illinois State Water Survey aquifer model (Prickett and Lonnquist, 1971). Modifications were made to incorporate the dynamic effects of river stage and precipitation. The model was calibrated by historically matching two five-year periods with constant one-month time steps. Hydrographs of actual and simulated water levels at ten observation wells and the nearest model cell for the two five-year periods are presented. Two piezometric surface maps of actual and simulated water levels are also presented. The model was found to consistently calculate water levels within two feet of the actual measured water level within a specified area of interest.

Existing and Future Conditions

Groundwater conditions were evaluated by simulating historical Mississippi River stage and precipitation and constant pumpage for a thirty-year period. Pumpage was simulated as 1) constant for the thirty-year period at historical 1980 rates and locations, 2) forecast 2000 rates and locations and 3) no pumpage except for a dewatering site maintained by the Illinois Department of Transportation.

Groundwater levels were evaluated with the aid of groundwater level exceedance probability plots. Groundwater level exceedance probability plots were constructed for ten model cells by compiling the maximum yearly water level from monthly simulated values. Plots were based on simulation of the thirty-year period from 1951 to 1980. The Weibold formula was used for probability calculations.

Mississippi River stage and precipitation records were available from 1905 to the present. One simulation was conducted for a period of 75 years to compare the period of simulation with the length of the exceedance plot. The longer period of record was desirable; however, because low river stages as well as high river stages and low and high precipitation occur during the thirty-year period from 1951 to 1980, the impact on exceedance is minimal. Also, the cost of simulations dictated use of the shorter period.

Alternative Measures

Pumpage systems and gravity drainage collectors to maintain water levels were evaluated by the same methods used in evaluation of existing and future conditions. Two pumpage and one gravity collector systems were designed to meet three specified groundwater levels. Systems were designed for forecast 2000 pumpage and no pumpage conditions. In all, twenty systems were simulated. Systems were designed to meet the specified target elevation in all cells for 90 percent of the months simulated. Exceedance probability was calculated for ten cells, but is illustrated for only five cells. Piezometric surface maps are presented for June 1973 conditions for designs with year 2000 pumpage.

Digital Flow Model Description and User's Guide

The computer model is documented by sections describing model capabilities, theory and assumptions. Explanation for preparing data files and understanding output is also included, as are three' sample problems. Four attachments are provided to: 1) list and explain file names supplied on magnetic tape, 2) list data of all inputs to the model, 3) list the Fortran V source code for the model, and 4) define all variables in the computer code.

The text for Part B, American Bottoms Digital Groundwater Flow Model, follows.

PART B. THE AMERICAN BOTTOMS DIGITAL GROUNDWATER FLOW MODEL

This report on the groundwater flow model was prepared by the Illinois State Water Survey as part of the study entitled Groundwater Level Analysis by Computer Modeling, American Bottoms Groundwater Study funded by the U.S. Department of the Army, St. Louis District, Corps of Engineers. The emphasis in this section of the report is to demonstrate that the model is a valid representation of the American Bottoms groundwater flow system. By way of introduction, a review of models previously applied to the area and a brief description of the numerical model used in this study are presented. Part B is supplemented by the model user's guide (Part E) that includes a complete description of the computer code and input data.

Introduction

Illinois State Water Survey Report of Investigation 51, "Groundwater Development in East St. Louis Area, Illinois" (Schicht, 1965) described an electric analog model constructed to simulate groundwater flow in the East St. Louis area. The model used an array of 2800 resistors and 1350 capacitors on a board 2 feet by 5 feet. The model was used to aid in the determination of practical sustained yield and potential yield.

Three separate digital flow models were applied to the area as part of Illinois State Water Survey research and project activities. Illinois State Water Survey Reprint 114, "Comparison Between Analog and Digital Simulation Techniques for Aquifer Evaluation" (Prickett and Lonnquist, 1968), compares a digital model solution to the analog model solution of 1965. A second digital model was applied to the American Bottoms in 1974. The Illinois

State Water Survey, in conjunction with the Illinois State Geological Survey, modeled the American Bottoms as part of a statewide study of water resources for coal conversion. Results were presented in "Cooperative Resources Report 4" (Smith and Stall, 1975). The Illinois State Water Survey groundwater flow model was used to examine flow under water table conditions and variable aquifer thickness. Infiltration from the Mississippi River was also simulated.

A third digital model using the ISWS flow model was applied in 1975 to evaluate three dewatering schemes. Results were published under the title "Reconnaissance Report: American Bottoms Groundwater Study" (USCOE, 1979). The American Bottoms was modeled as a homogeneous water table aquifer with the Mississippi River being a recharge source of constant head. Alternatives considered to reduce water levels included: 1) a network of 28 wells, each pumping 1.3 mgd (900 gpm); 2) three gravity drainage systems withdrawing 21, 40 and 122 mgd; and 3) a reduction in infiltration.

Digital Model

Development of the digital groundwater flow model for the American Bottoms area for this study consisted of three tasks: 1) description of the conceptual model, 2) formulation of the mathematical model, and 3) construction of the numerical model. A complete explanation of each is given in the model user's guide (Part E) and a brief explanation is presented here for continuity.

A conceptual model is a compilation of assumptions that enable mathematical approximation of a real system. It identifies simplifications that can be made and restrictions that must be included in the mathematical model.

Assumptions that define the conceptual model are as follows:

1. The aquifer is homogeneous in the vertical direction.
2. Recharge to the water table occurs instantaneously.
3. Vertical flow components are negligible where compared with horizontal flow components.
4. Leakage between the aquifer and the underlying indurated sediments is negligible.
5. Groundwater flow from west of the Mississippi and Missouri Rivers has no direct impact on water levels in the valley aquifer.
6. The Cahokia Diversion Channel and Harding Ditch are hydraulically connected to the aquifer; all other canals do not significantly affect water levels.

Assumptions 1 through 3 pertain to restrictions on the equation describing groundwater flow and are described in Part E. Assumptions 4 through 6 pertain to the groundwater flow system and are described under the subheading "boundary conditions" (Part E).

In addition to simplifying assumptions, restrictions that must be incorporated in the mathematical model are included in the conceptual model. They are as follows:

1. Mississippi River stage must be reflected in groundwater levels near the river.
2. Precipitation fluctuations are reflected in groundwater levels.

These restrictions and their impacts are further described in Part E.

A mathematical model is an equation or set of equations which represents a real system. A mathematical model incorporates assumptions and restrictions into the resulting equations. The general equation which was used to describe groundwater flow in the American Bottoms buried valley aquifer is

$$\frac{\partial}{\partial x}\left(Kb\,\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(Kb\,\frac{\partial h}{\partial y}\right) = S\,\frac{\partial h}{\partial t} + Q \qquad (1)$$

where:

Kb = T = aquifer transmissivity
K = hydraulic conductivity
b = saturated thickness of aquifer
h = hydraulic head
S = aquifer storage coefficient
t = time
Q = net groundwater withdrawal rate per unit area
x,y = rectangular coordinates

This is the general equation for non-steady state groundwater flow in two dimensions in water table conditions in a heterogeneous isotropic aquifer (Bittinger et al., 1967). There is no general solution to this equation; however, numerical techniques can be used to obtain a solution.

A numerical model is a means of solving a mathematical model by approximating continuous real system parameters with an equivalent set of discrete elements. Substitution of boundary conditions into the discretized form of the general flow equation yields a set of simultaneous equations which can be solved by numerical techniques. The numerical model developed for this study used the finite difference approach and the resulting set of simultaneous equations was solved by a modified form of the alternating direction implicit method.

The digital model developed for the American Bottoms incorporates modifications to the published Illinois State Water Survey composite aquifer simulation (Prickett and Lonnquist, 1971). Modifications to the computer program are summarized in figure 1 . Modifications were required to permit the following: input of historical and future pumpage data, adjustment of

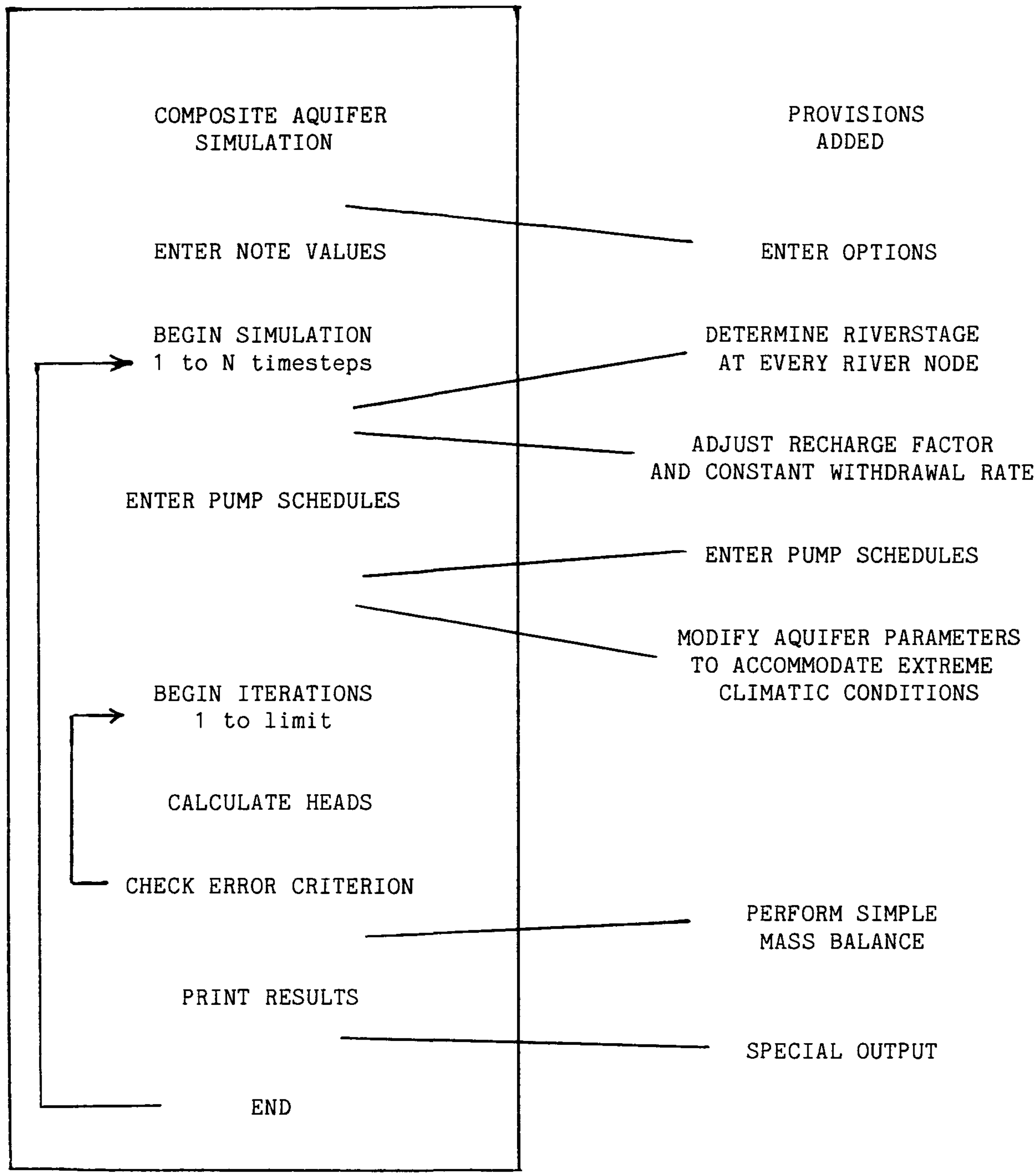

Figure 1. American Bottoms aquifer model diagram of modifications to the ISWS composite aquifer simulation

recharge and constant withdrawal rate terms to include the effects of precipitation and riverbed leakage, adjustment of river stage elevation to include the effects of stage fluctuation, adjustment of aquifer parameters and boundary conditions to include the effects of extreme climatic conditions and selection of optional printed output. The finite difference grid and boundary conditions are illustrated in figure 2.

Verification of the Digital Flow Model

Verifying that the model is a valid representation of the groundwater flow system is imperative in a study emphasizing the results of simulations. In this study, significant modifications were made to the original computer program and interpretations of geology and hydrology reflect additional information gathered since previous modeling studies. Therefore, it is essential to demonstrate that this version of the model satisfies the required degree of accuracy. This judgement is based on comparison of historical water levels in observation wells with simulated water levels at corresponding locations in the model (nodes). Water level records and piezometric surface maps that have been previously published provide adequate information for comparison.

The model was calibrated by simulating water level data from two five-year periods, from 1954 to 1958 and from 1972 to 1976. These periods were selected because the lowest groundwater levels and the highest groundwater levels on record occurred during these periods. An assumption implicit in this decision is that, if the model correctly simulates extreme groundwater levels, more moderate water levels will also be correctly predicted when appropriate. Hydrographs of historical and simulated water levels and piezometric surface maps were produced for comparison. Differences were noted and

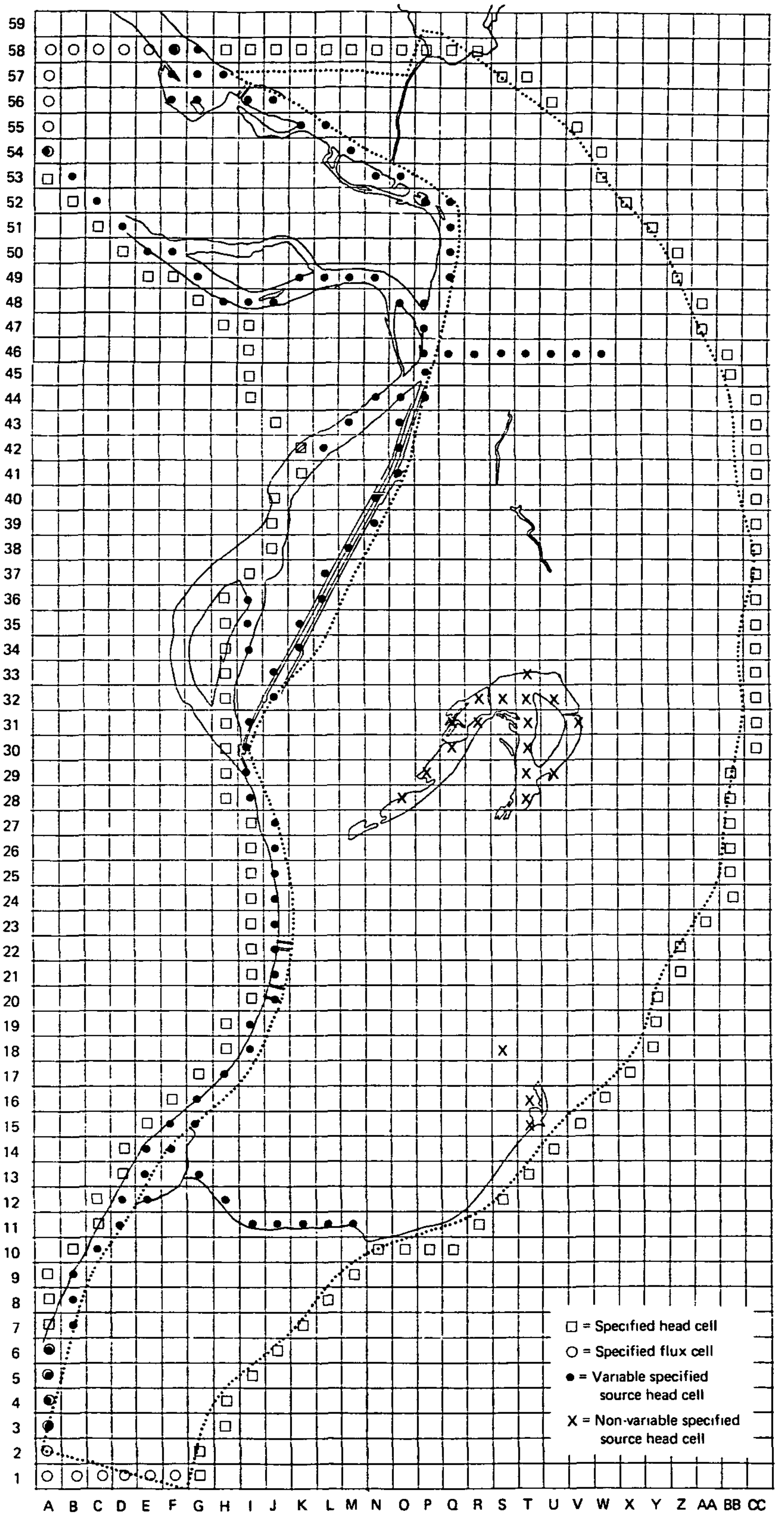

Figure 2. The finite-difference grid and boundary conditions.

analyses were made to determine the reasons for variations. Parameters known to have an impact on water levels and those in which there was a low degree of confidence were adjusted to improve the match. Hydrographs and piezometric surface maps were again simulated and compared with the historical hydrographs and piezometric surface maps. This process was repeated until either the match was within the limits of accuracy required of the model or the legitimate adjustment of parameters was exhausted.

The digital model was required to have an average difference of less than two feet between historical and simulated water levels for the area of primary interest (see figure 3). There are causes for a poor match between historical and simulated water levels which are unavoidable and legitimize exceptions to the model requirements.

The simulated water level is a composite water level for the entire nodal area (1/4 square mile), whereas an historical value is a water level at a particular location. If the gradient of the water table is small compared to the dimensions of the area assigned to the grid node, the simulated water level should be expected to represent the historical water level. This is the situation in most of the American Bottoms. There are specific areas, however, where gradients are sufficiently steep that point data are not well represented.

The water levels within the sloping area that marks the transition from the lowlands of the American Bottoms and the highlands of the bluffs change significantly over short distances. . Both lowlands and highlands may be represented at one particular node area, where water levels in wells may differ as much as 50 ft. Therefore, the location of the observation well and the node center may cause a significant difference from historical to simulated water levels.

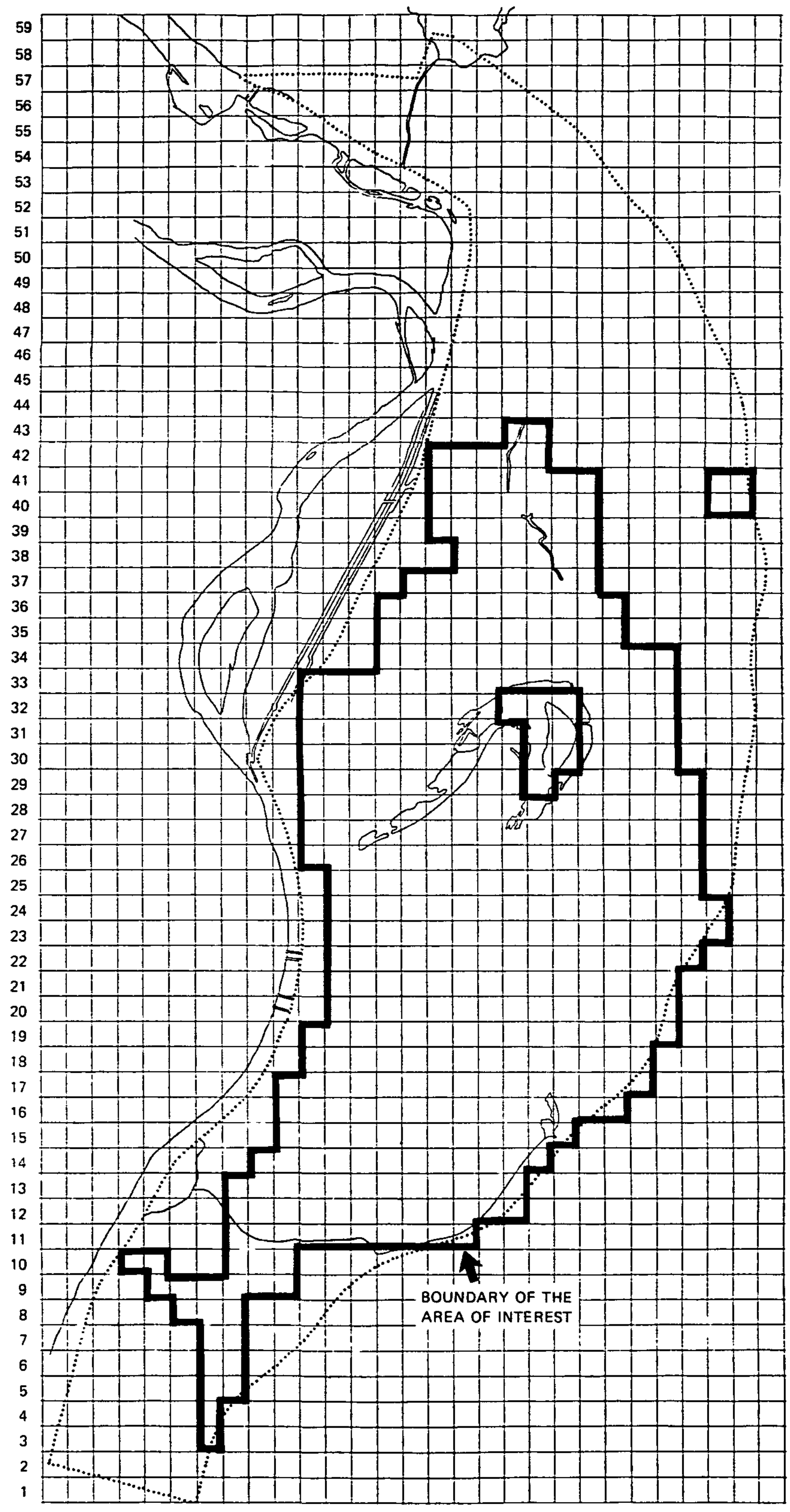

Figure 3. Location of the area of interest.

Near the Mississippi River, groundwater levels are strongly affected by changes in river stage. For simplification, river stage is modeled as a constant value (the average of mean daily river stages) for each month; actual river stages and water levels are instantaneous values for the particular day of record. Thus, simulated water levels should reflect long term trends, but should not necessarily be expected to match daily or monthly extremes.

As with observation wells, production wells do not always coincide with the location of nodes on the grid pattern. This causes some distortion in the shape and location of the cone of depression. Another difficulty is that the model simulates pumpage water removed from the whole area represented by a node. If pumpage is actually from a number of evenly spaced wells withdrawing the same amount of water, the result should be a reasonable approximation of the piezometric surface within the node area. If, however, pumpage is from wells not evenly distributed within a node area, a significant difference between the historical and simulated water levels may result.

In the model, aquifer recharge is determined using historical precipitation data. Precipitation has been shown to vary over the American Bottoms area (see Changnon et al., 1977). The greatest impact is in the summer when convective thunderstorms produce significant local differences in rainfall. The effect may be a recharge event not included in a simulation or the inverse, in which modeled precipitation affects the simulated water levels when no precipitation occurred at a particular location.

The rate and quantity of water used (pumpage) by a municipality or industry varies according to their needs. Municipal water use in general varies according to season. Industrial water use patterns can not be gener-

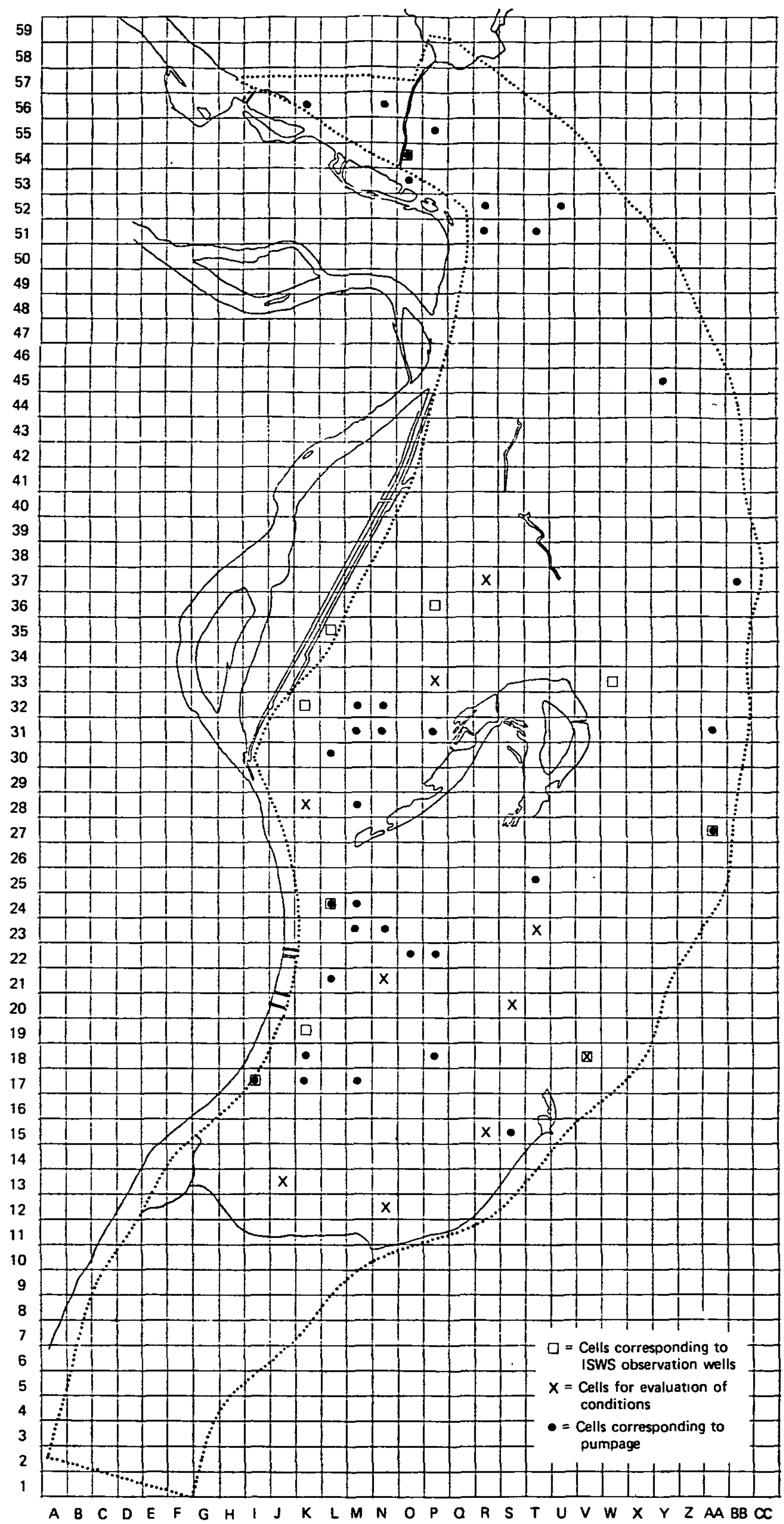

Figure 4. Locations of observation and pumpage cells.

alized. Variability in use patterns can cause some disparity between historical and simulated water levels.

Analysis of Hydrographs

Observation well 01073 (figure 5a and b) is located in the City of Collinsville well field. While this well is not a production well, water levels in it are likely affected by several nearby production wells. This could account for a portion of the difference between simulated and observed water levels. The well field is also within 1/2 mile of the bluff. Because of the proximity to the bluff, simulated water levels are affected by the boundary conditions in the bluff.

There is a good match for the period from 1954 to 1957. Water levels were lowered in the bluff to better represent conditions during the drought.

Differences between simulated and observed water levels in 1973, 1974, and 1975 are significant. Water levels in the bluff should reflect long-term fluctuations in conditions. Therefore, the magnitude of change that occurred each year is caused by factors in addition to the bluff. Factors may include a change in pumping schedules *or* a local climate anomoly.

Well 01077 (figures 6a and b) is an irrigation well that is sparingly used for truck farm crops. This well was constructed in 1955 and used as an observation well from 1955 to the present. Pumpage for irrigation may vary for the entire growing season from no pumpage to over six million gallons for an entire year depending upon climatic conditions. Six million gallons is a negligible impact on water levels and therefore was not considered in the model. A good match exists from 1956 to 1958 and from 1971 to 1975. This was done to simulate the dry lake bed during parts of 1954, 1955, and 1956. As a result, boundary conditions were altered in the Horseshoe Lake area,

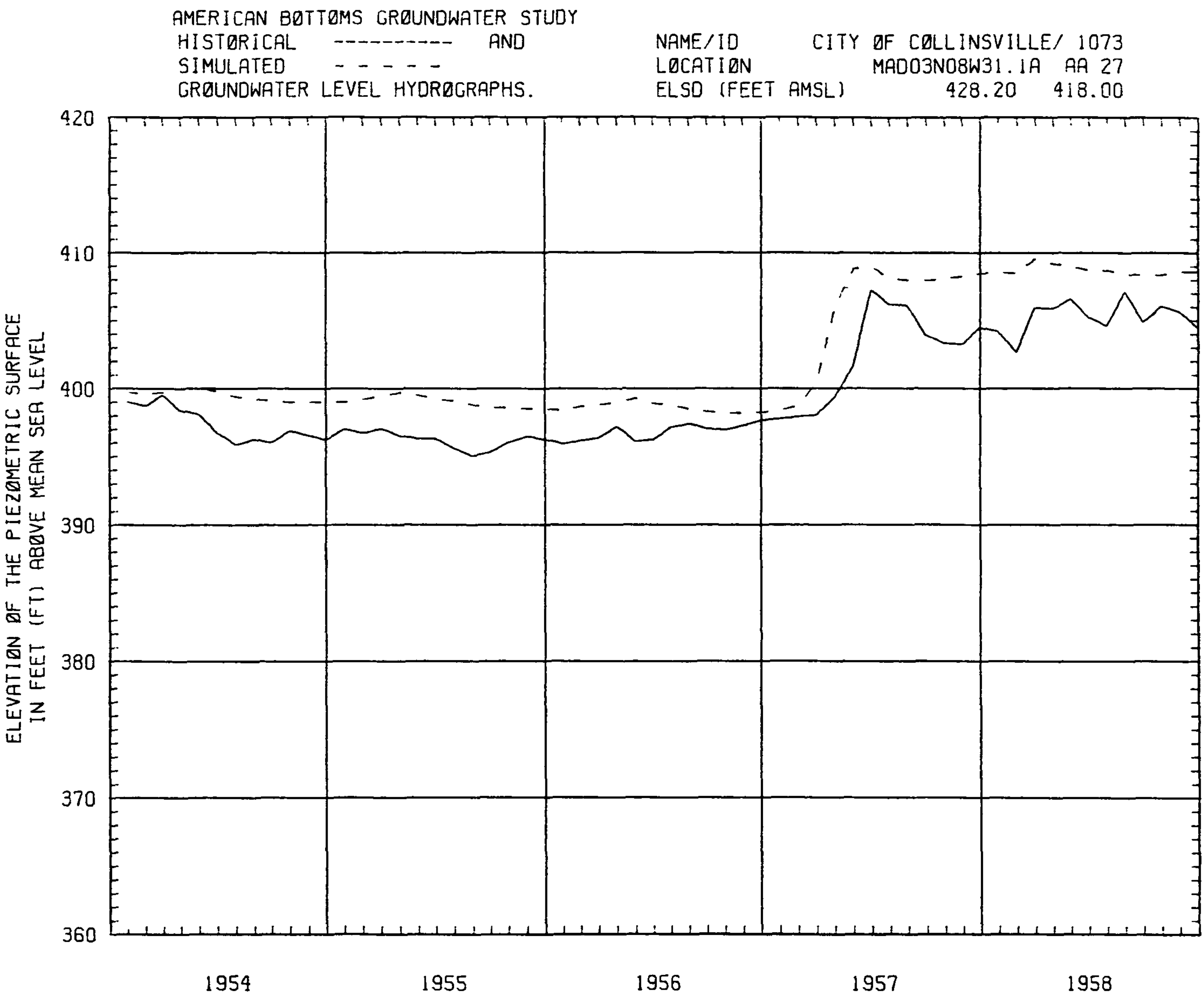

Figure 5a. Water levels in well MAD 3N8W-31.1a and at cell AA 27, 1954-1958.

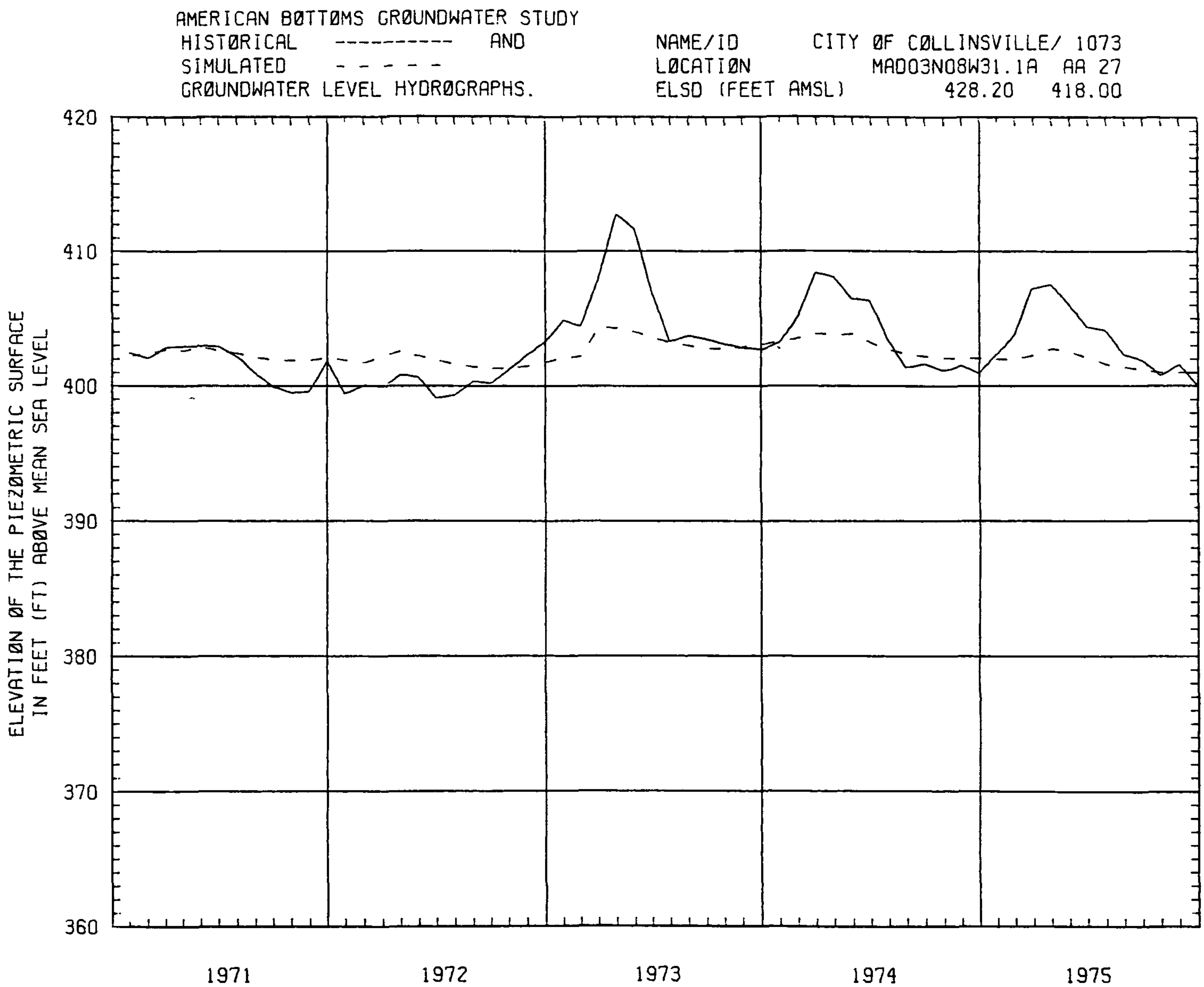

Figure 5b. Water levels in well MAD 3N8W-31.1a and at cell AA 27, 1971-1975.

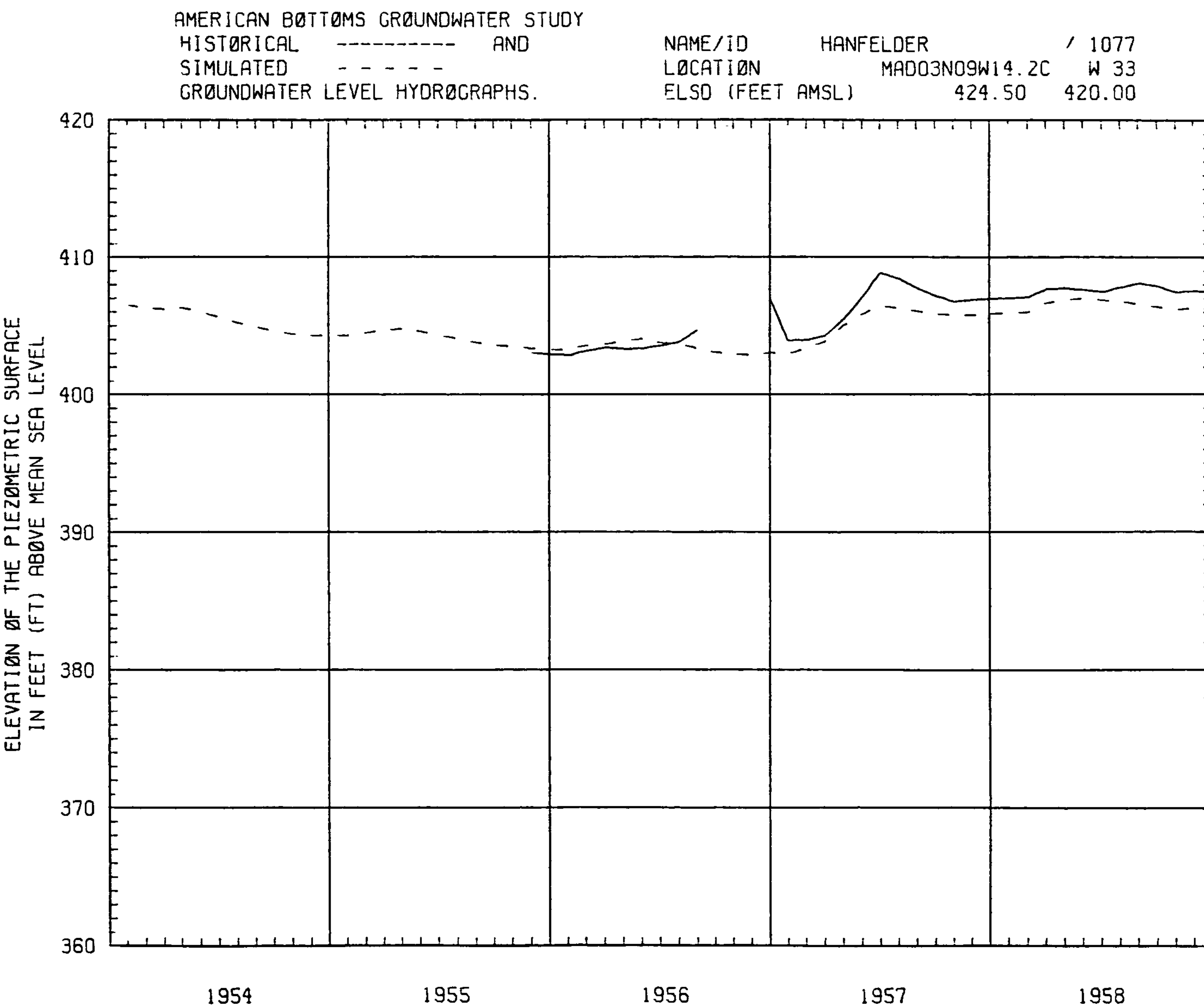

Figure 6a. Water levels in well MAD 3N9W-14.2c and at cell W 33, 1954-1958.

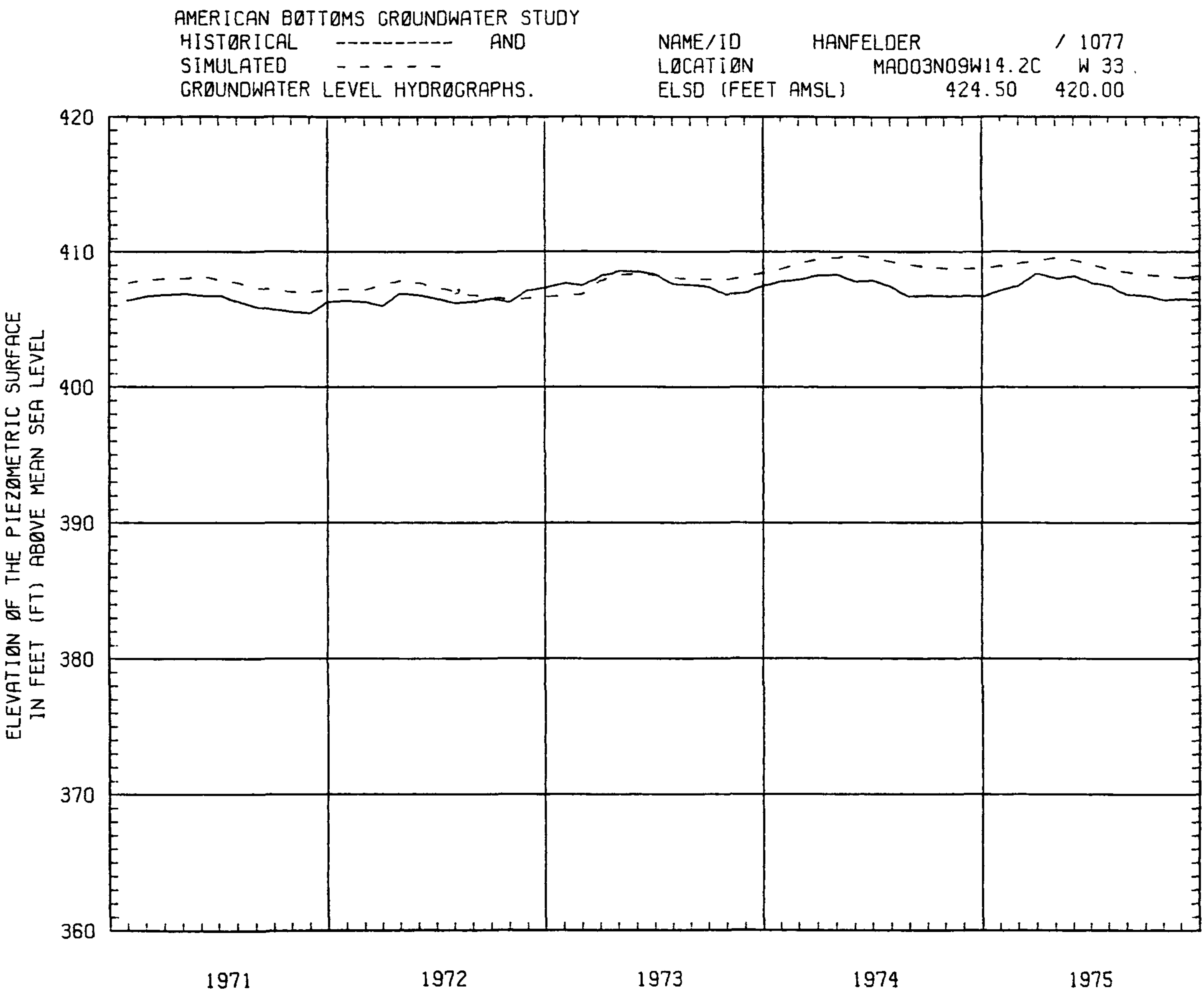

Figure 6b. Water levels in well MAD 3N9W-14.2c and at cell AA 27, 1971-1975.

which is proximate to well 01077, from 1954 to 1956. For this period conditions were changed from specified heads in a source bed (normal treatment for a lake) to no source bed (normal treatment for land).

Well 00181 (see figure 7a and b) is located next to a small business in a residential area of East St. Louis approximately 3/4 mile from the bluff. Water levels in the bluff were adjusted to simulate varying conditions of the bluff. The rapid increase in historical water levels in March of 1972 can not be attributed to a period of high recharge and other potential causes are not considered justifiable. Thus, the causes of this increase are not fully known. Nonetheless, the overall response of the model in this area is considered acceptable.

Well 01072 (a levee relief well) is located 1/4 mile east of the Mississippi River (see figure 8a and b). Proximity of the Mississippi River and a high capacity well to well 01072 makes observed water levels difficult to match through simulation. The State Water Survey also monitors well 01071 (see figure 8c) that is located near well 01072. Both of these observation wells are represented at the same node in the model. Historical water level records from these two wells differ because they are located at different distances from the Mississippi River and the collector well (see figure 8d). The large-diameter high-capacity collector well is located between well 01072 and the Mississippi River. Measured water levels at well 01072 are generally higher than those at 01071 because well 01071 is closer to the collector well than well 01072. Simulated behavior at wells 01071 and 01072 responds correctly to hydraulic stresses.

Well 01076 is a relief well located along the east flank of the Chain of Rocks Canal levee. River stages in the canal are controlled by lock and dam 27 and were modeled as equal to the Mississippi River stage at the north

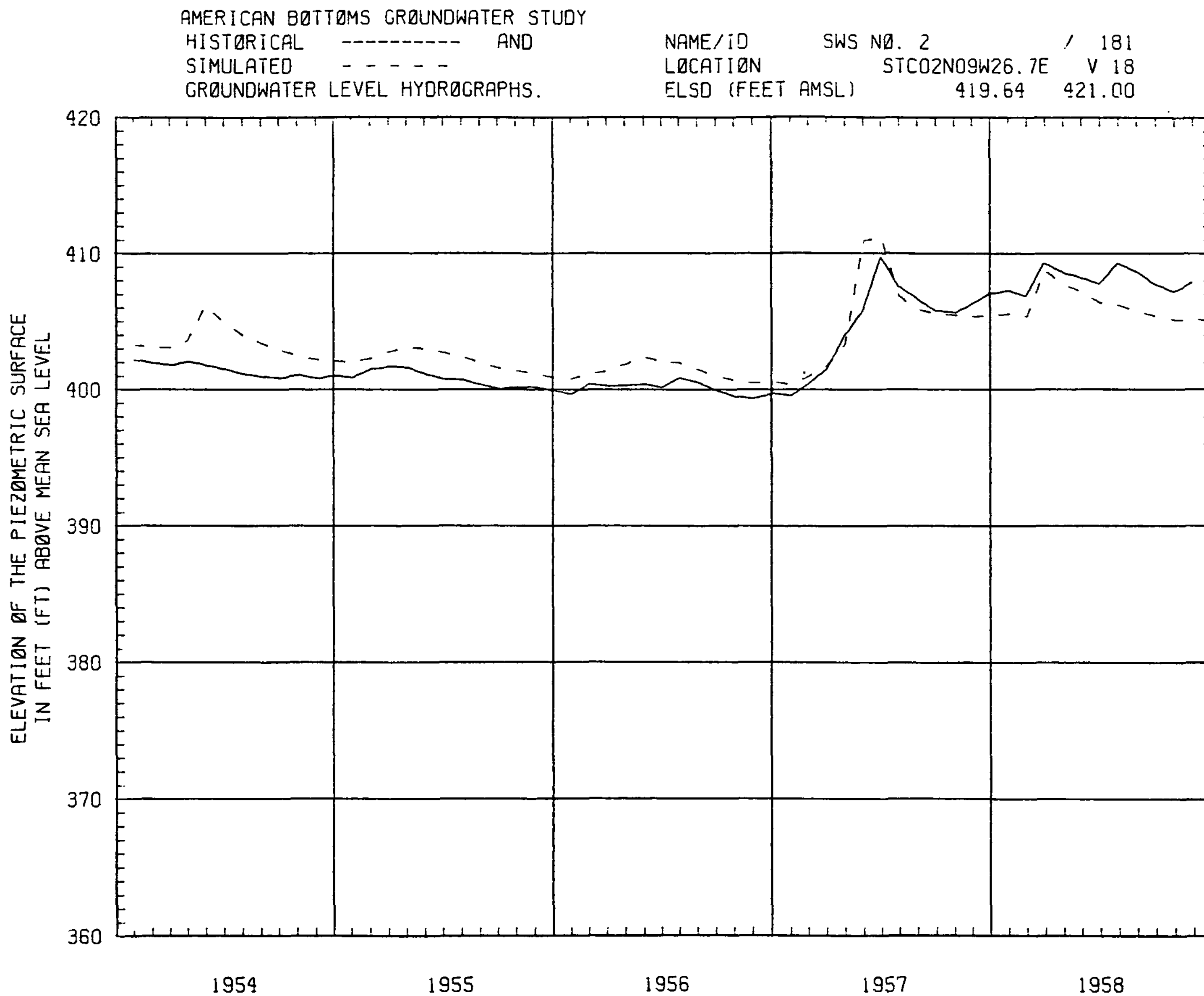

Figure 7a. Water levels in well STC 2N9W-26.7e and at cell V 18, 1954-19.58.

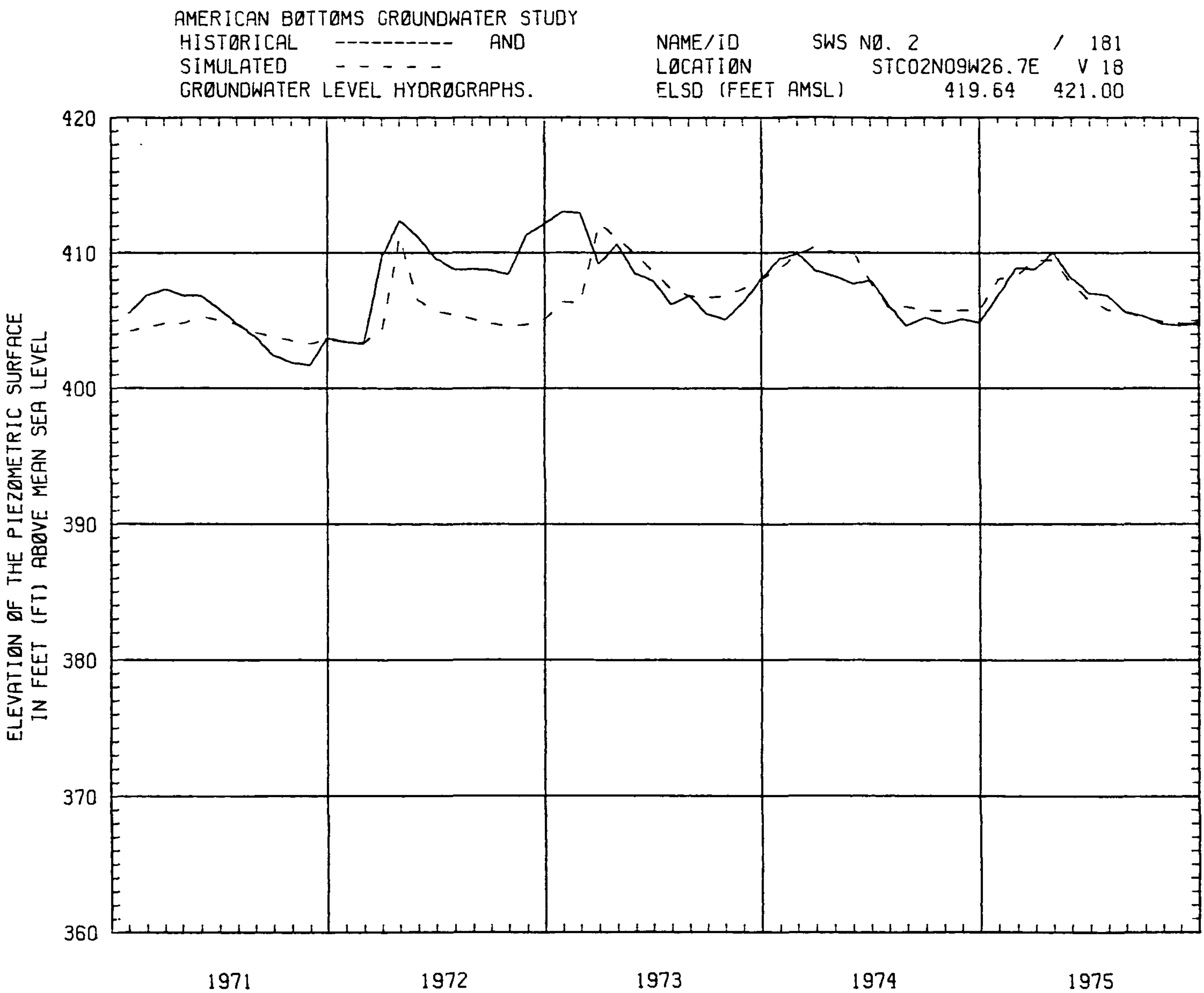

Figure 7b. Water levels in well STC 2N9W-26.7e and at cell V 27, 1971-1975.

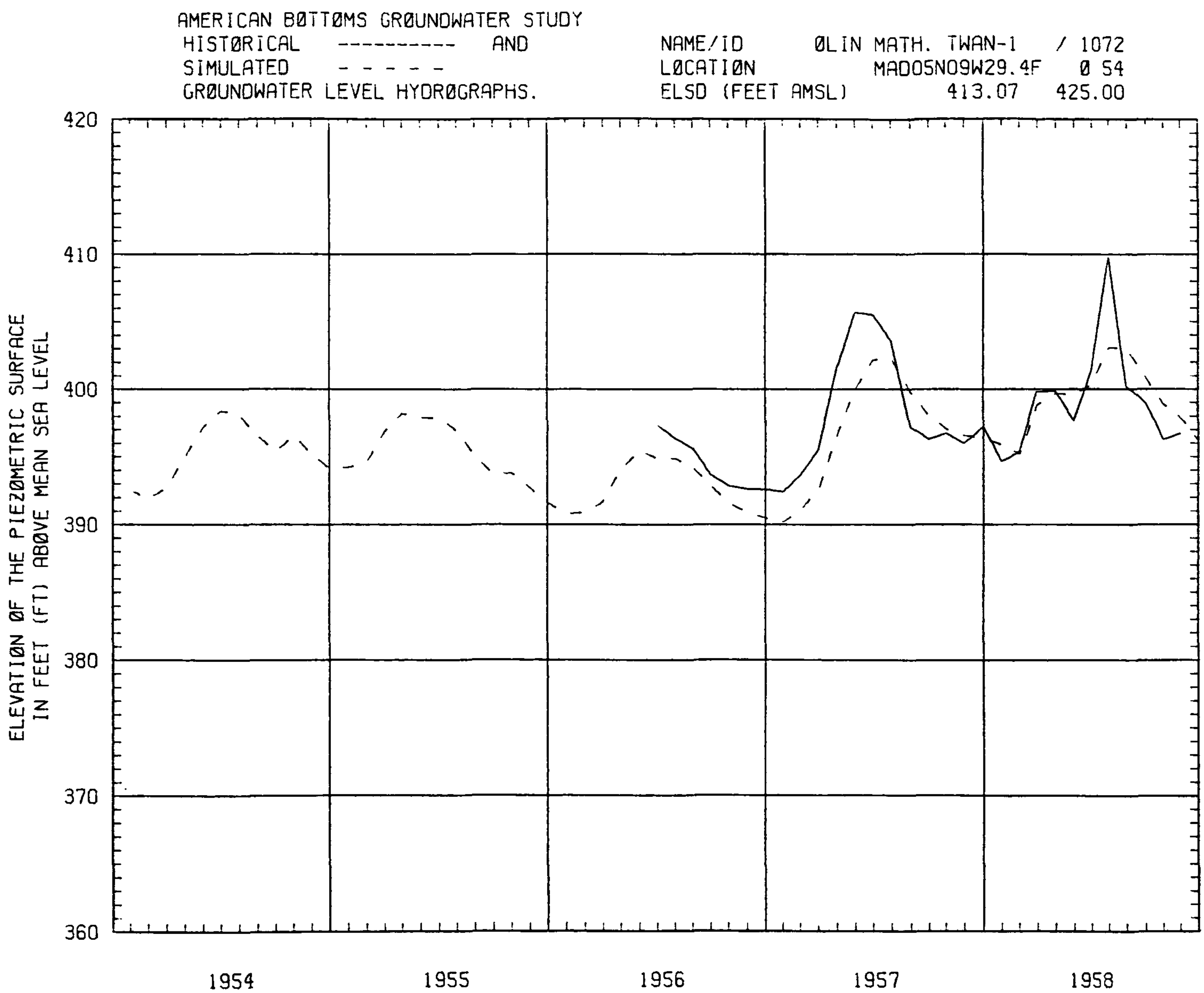

Figure 8a. Water levels in well MAD 3N9W-29.4f and at cell 0 54, 1954-1958.

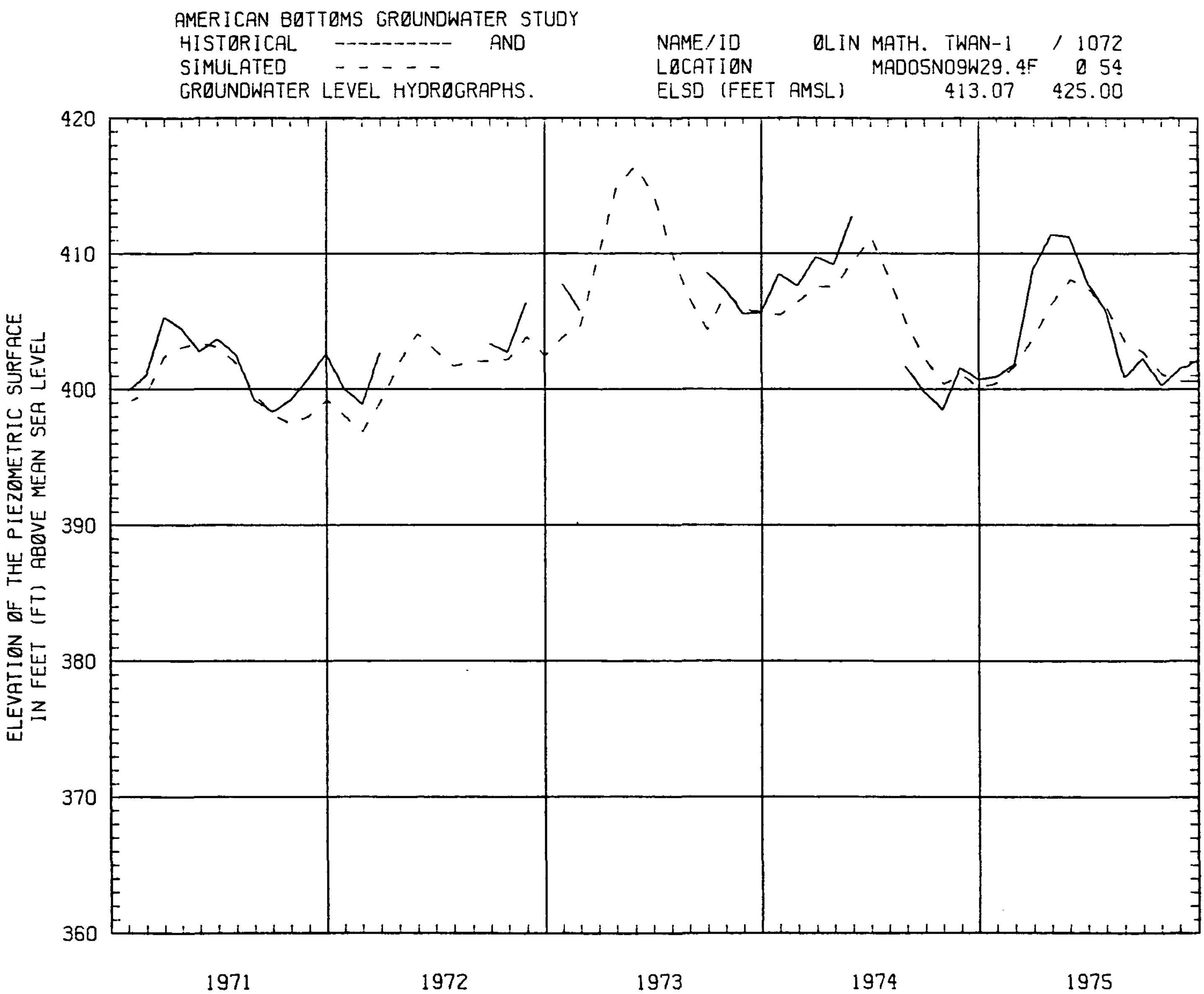

Figure 8b. Water levels in well MAD 3N9W-29.4f and at cell 0 54, 1971-1975.

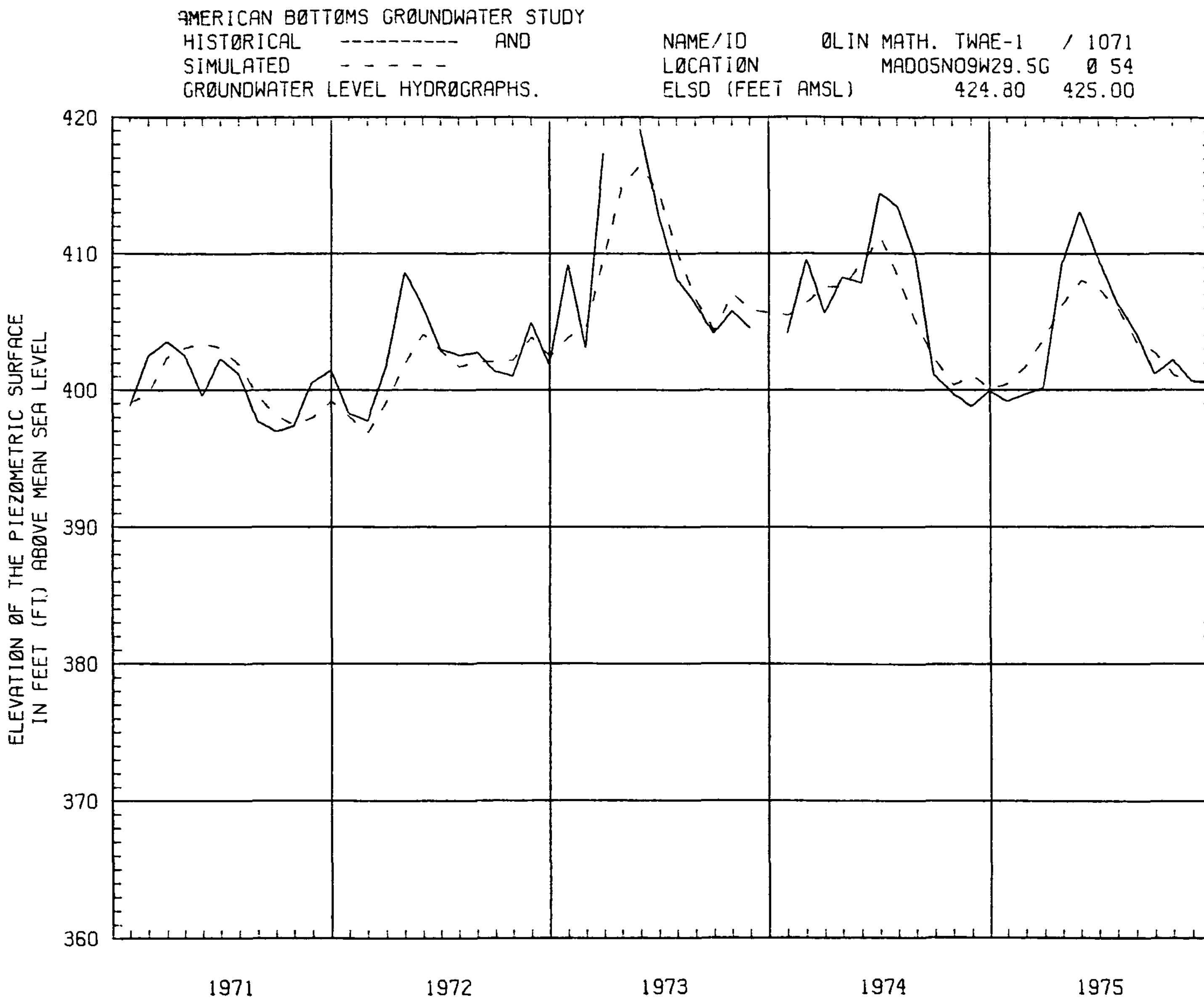

Figure 8c. Water levels in well MAD 3N9W-29.5g and at cell 0 54, 1971-1975.

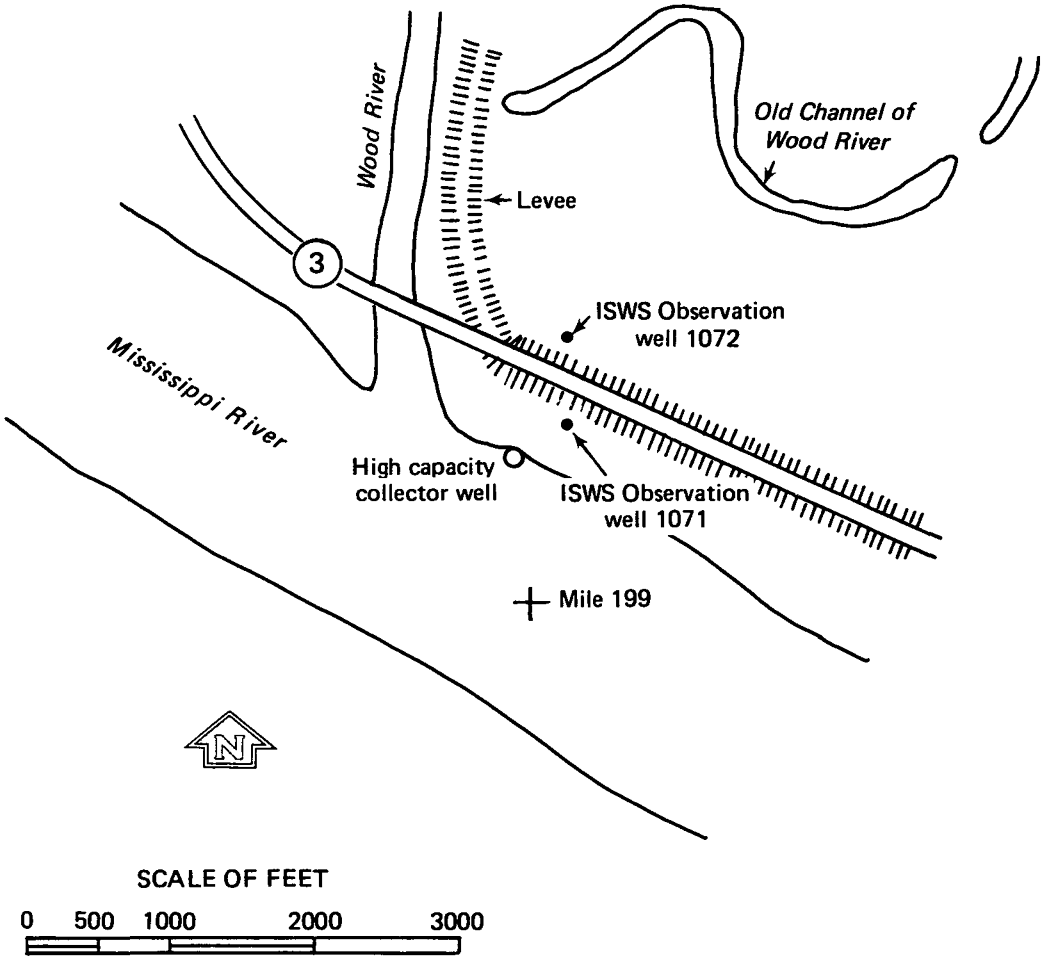

Figure 8d. Locations of observation wells and collector well in relation to the Mississippi River.

entrance to the canal. Historical and simulated water levels match extraordinarily well for the period from 1954 to 1958 (see figure 9a). The match for the period from 1971 to 1975 is satisfactory. Comparison of increases and decreases between historical and simulated water levels indicate that the model accurately represents flow conditions (see figure 9b).

Well 01225 is located approximately 100 yards from the Mississippi River and has been the site of occasional (negligible) pumpage. Computed water levels for the periods shown in figures 10a (1954 to 1958) and 10b (1971 to 1975) reflect the changes in Mississippi River stage as computed for that location.

Well 01223 is located about 2-1/2 miles east of the Mississippi River in the downtown area of Granite City. Measured water levels at well 01223 do not fluctuate as much as wells located nearer the Mississippi River or at observation wells where pumpage occurs. Computed water levels represent actual water levels satisfactorily (see figure 11a and b).

Well 01075 is located close to the Chain of Rocks Canal near lock and dam 27. It was constructed in 1953 as a relief well for the Chain of Rocks Canal levee. For the period from 1954 to 1958 and from 1971 to 1975, computed water levels were significantly lower than actual water levels (see figure 12a and b). This is considered an effect of the grid spacing of the model and the proximity to pumpage in the Granite City area. Well 01075 is located approximately 200 yards east of the Chain of Rocks Canal; however, in the model it must be simulated as the nearest node which places it at a distance of 880 yards (one half mile) from the canal. Simulated water levels for the node representing the observation well will not show the proper effect of the river stage in the canal because of the simulated distance between them. This effect is enhanced by the effect of a pumping well to the

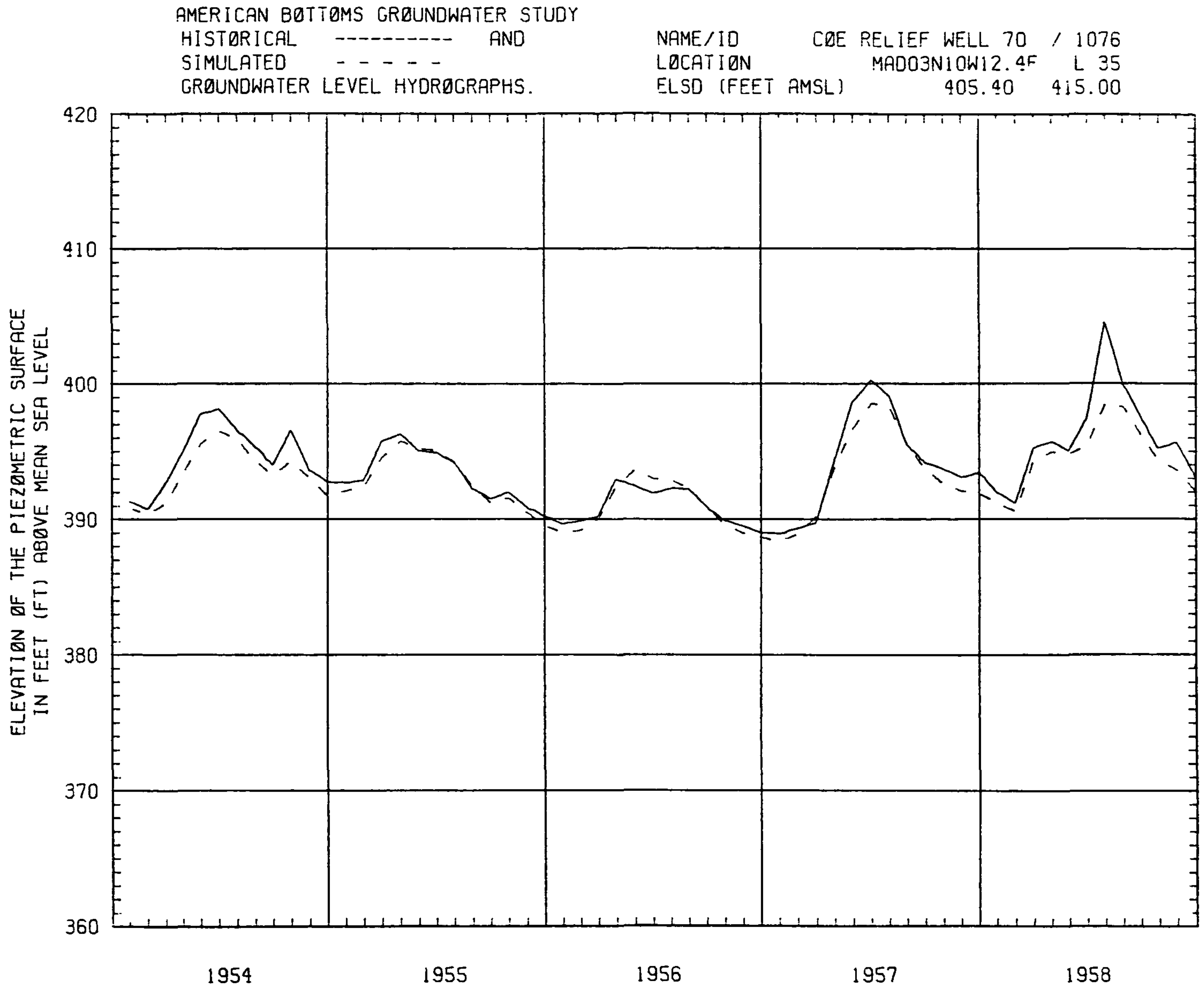

Figure 9a. Water levels in well MAD 3N10W-12.4f and at cell L 35, 1954-1958.

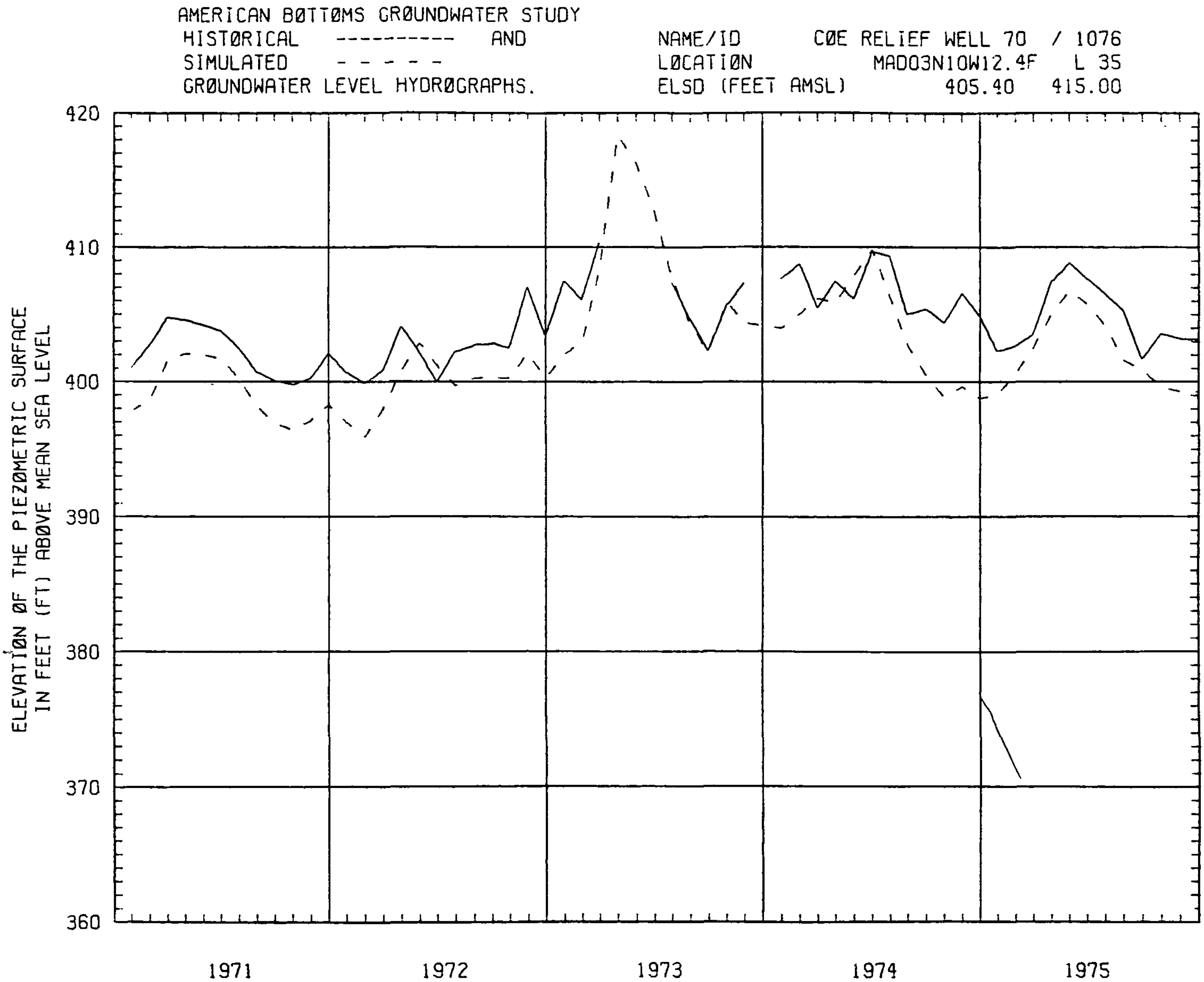

Figure 9b. Water levels in well MAD 3N10W-12.4f and at cell L 35, 1971-1975.

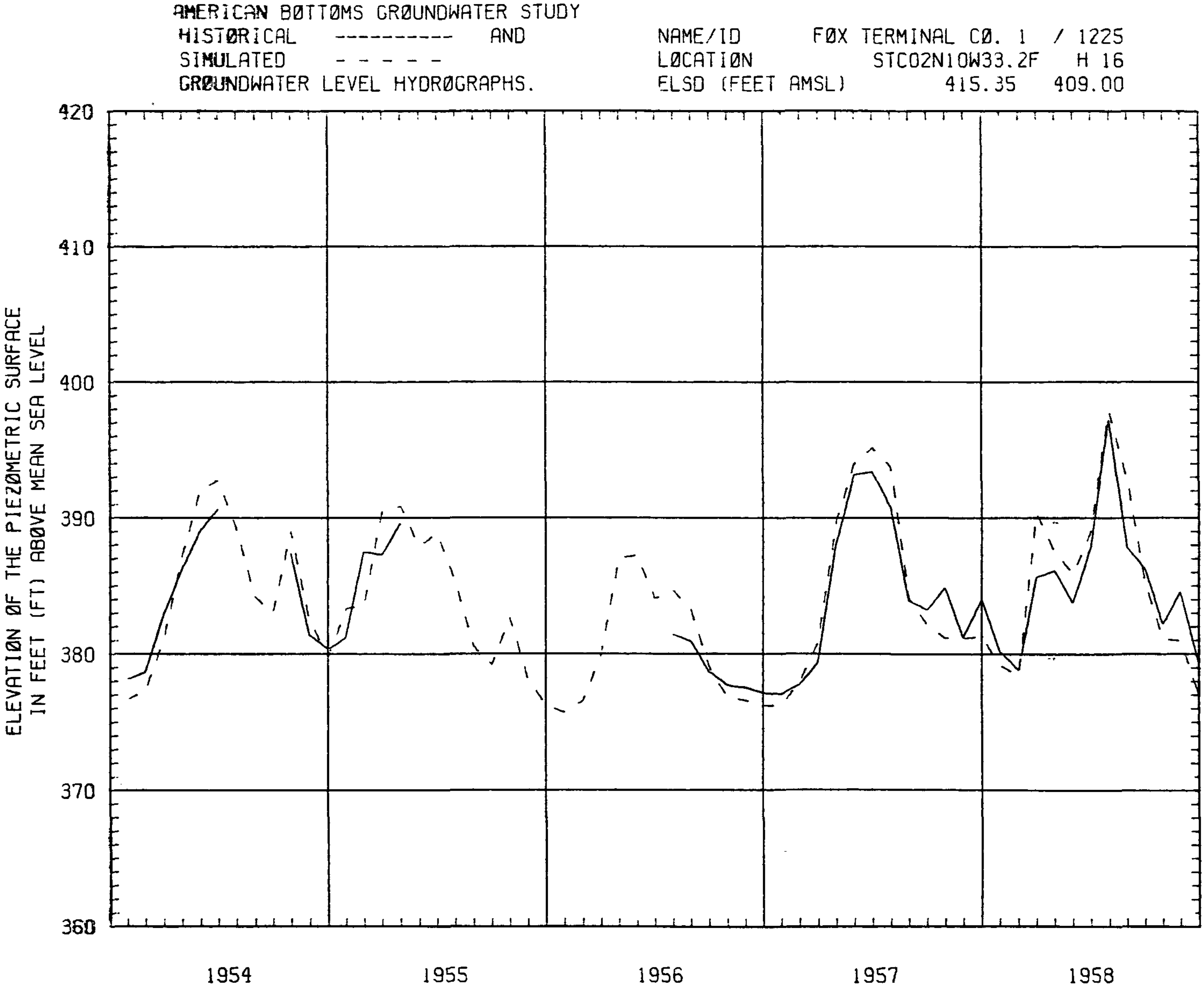

Figure 10a. Water levels in well STC 2N10W-33.2f and at cell H 16, 1954-1958.

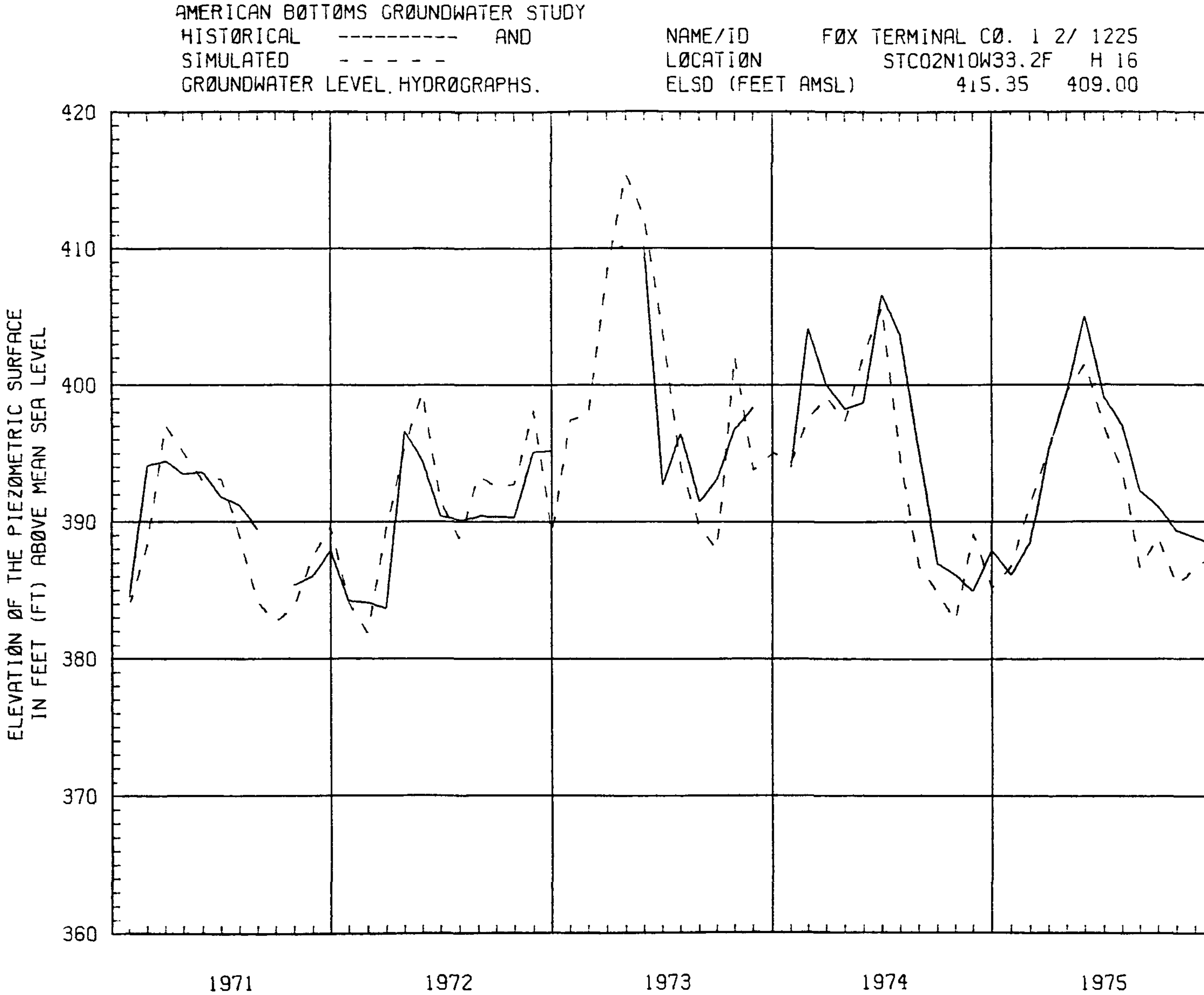

Figure 10b. Water levels in well STC 2N10W-33.2f and at cell H 16, 1971-1975.

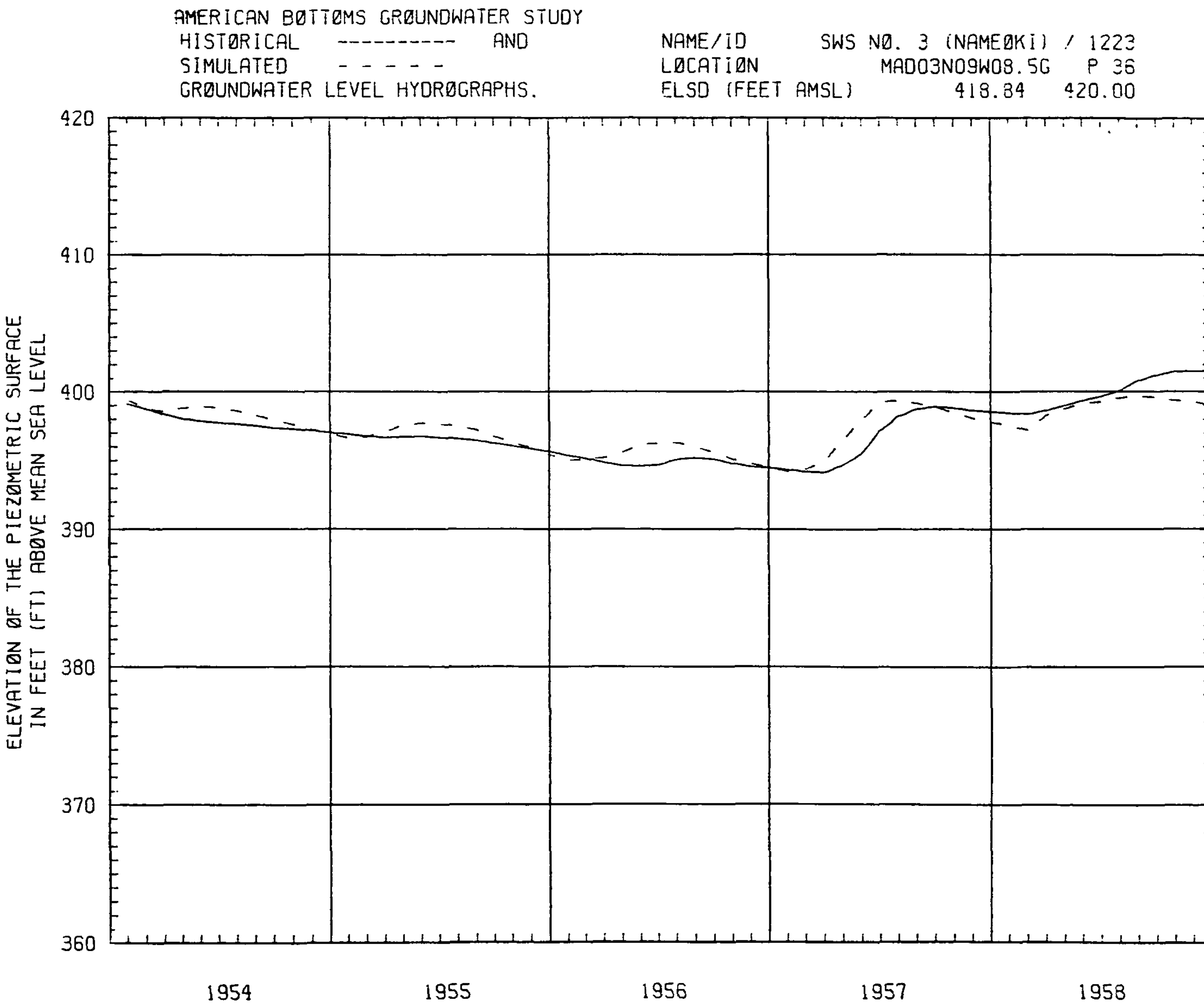

Figure 11a. Water levels in well MAD 3N9W-8.5g and at cell P 36, 1954-1958.

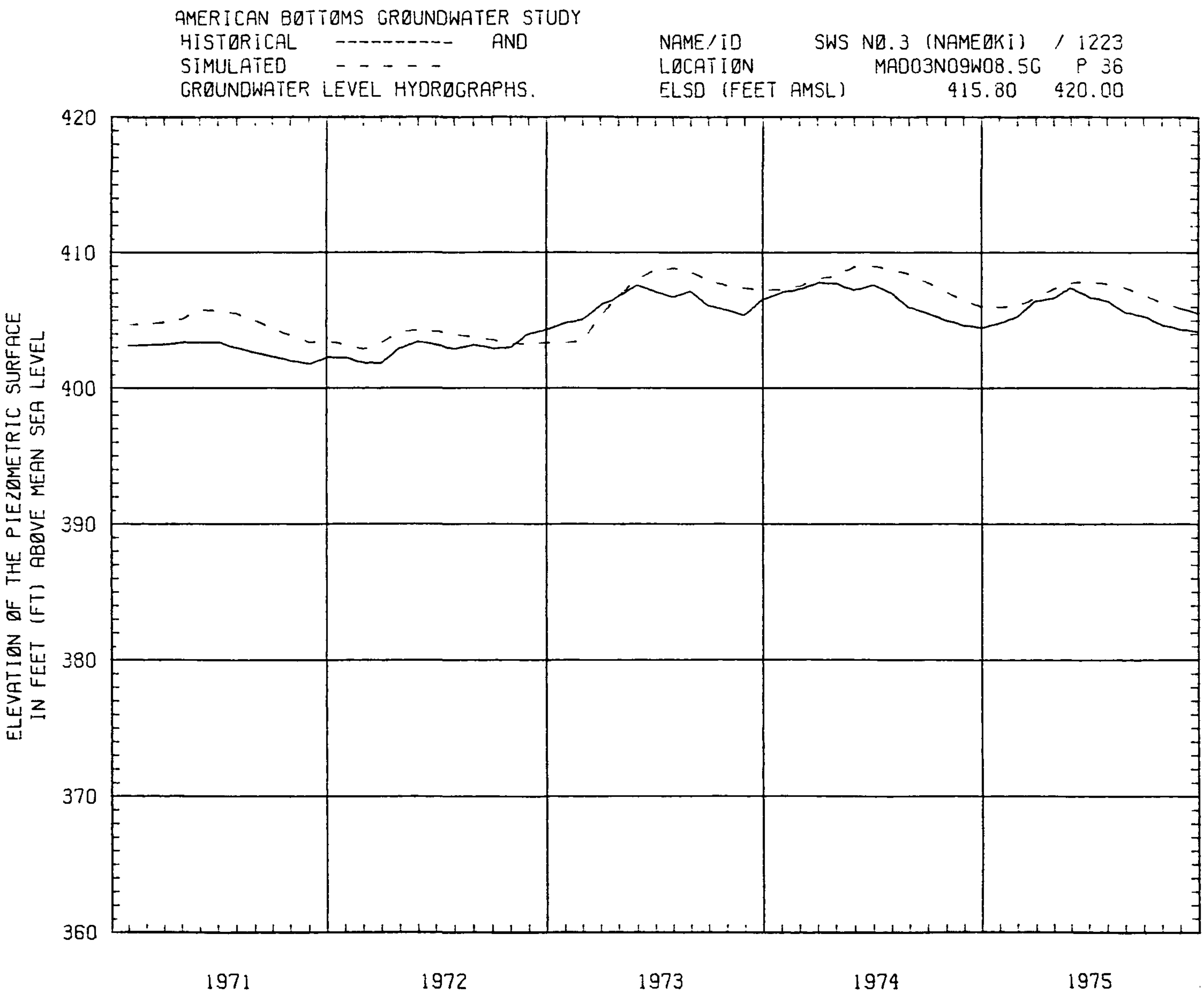

Figure 11b. Water levels in well MAD 3N9W-8.5g and at cell P 36, 1971-1975.

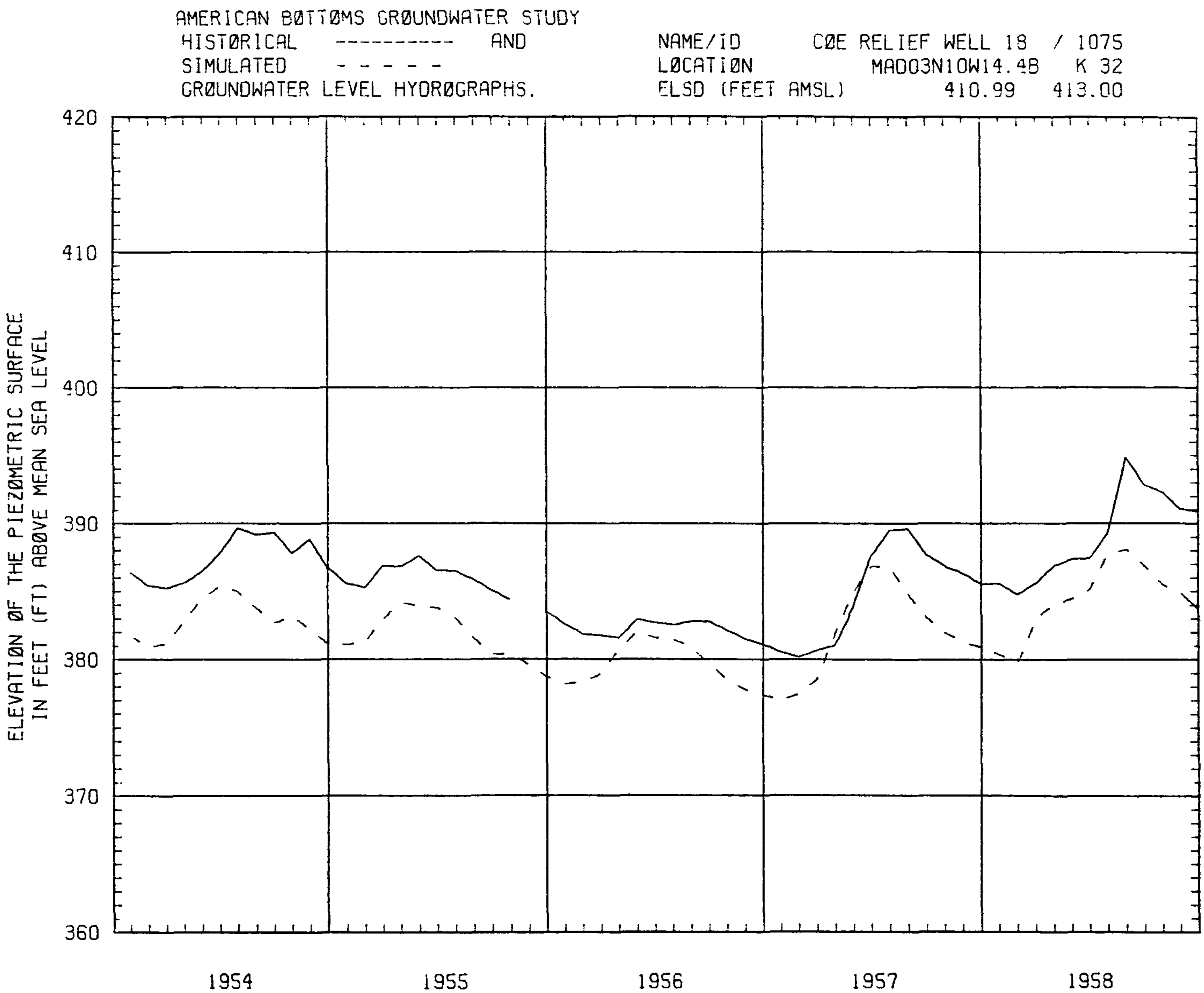

Figure 12a. Water levels in well MAD 3N10W-l4.4b and at cell K 32, 1954-1958.

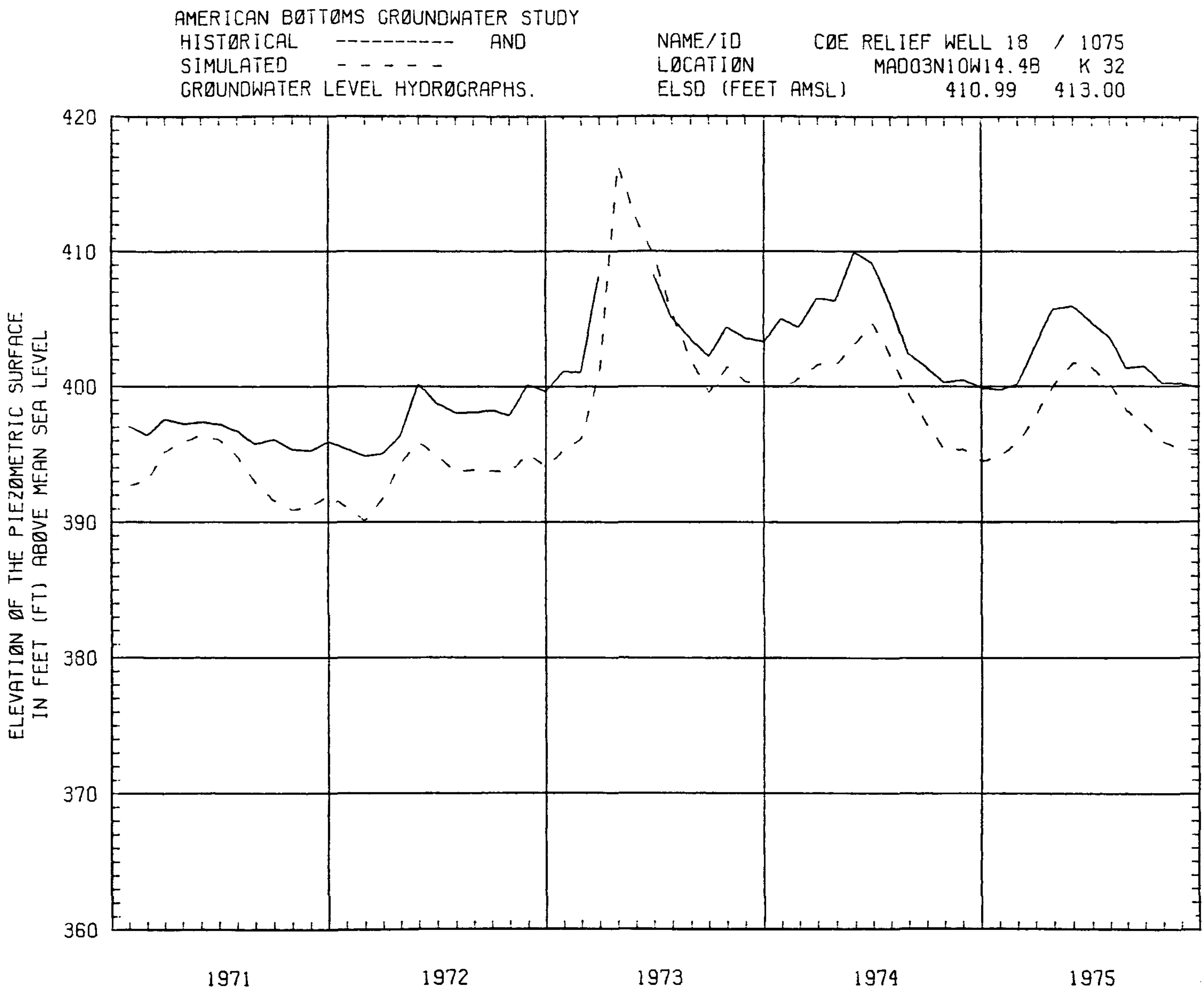

Figure 12b. Water levels in well MAD 3N10W-14.4b and at cell K 32, 1971-1975.

east whose relative distances to the canal and observation well are also distorted. Increases and decreases of historical and simulated water levels correspond well with each other. This agrees with the differences expected by pumpage at a distance.

Well 01086 was constructed in 1956 as a water supply well and was in use for that purpose from 1957 to 1971. It is located about one mile from the Mississippi River in the National City area. The supply well of another industry is located 500 feet northwest of well 01086 and is treated in the model to be at the same location. Water levels were measured beginning when the well was constructed; a good match exists between computed and actual water levels (see figure 13a). The relative locations of the observation well, supply wells, and the Mississippi River are distorted in the model. The good match indicates a spatial balance of nearby pumpage and the Mississippi River. For the period 1971 to 1975, computed water levels are consistently higher than observed water levels (see figure 13b). The poor match is a result of an imbalance of pumpage, that was reduced from the 1950's to the 1970's, and the Mississippi River.

Well 01165 (see figure 14a and b) is located 3/4 of a mile east of the Mississippi River just south of the MacArthur Bridge in East St. Louis. The well was constructed in 1940 as a water supply well for a warehouse. The well supplied approximately 5000 gallons per day until the mid 1960's when pumpage virtually ceased. The well was abandoned in 1975. Pumpage from this well was not included in the model because it would not produce a measurable effect; however, pumpage from a supply well of an industry nearby was modeled as occurring at the node. Other large groundwater users are located nearby. The disparity between calculated and actual water levels for the years 1954 to 1957 (figure 14a) is due to pumpage that occurred near the well. Pumpage

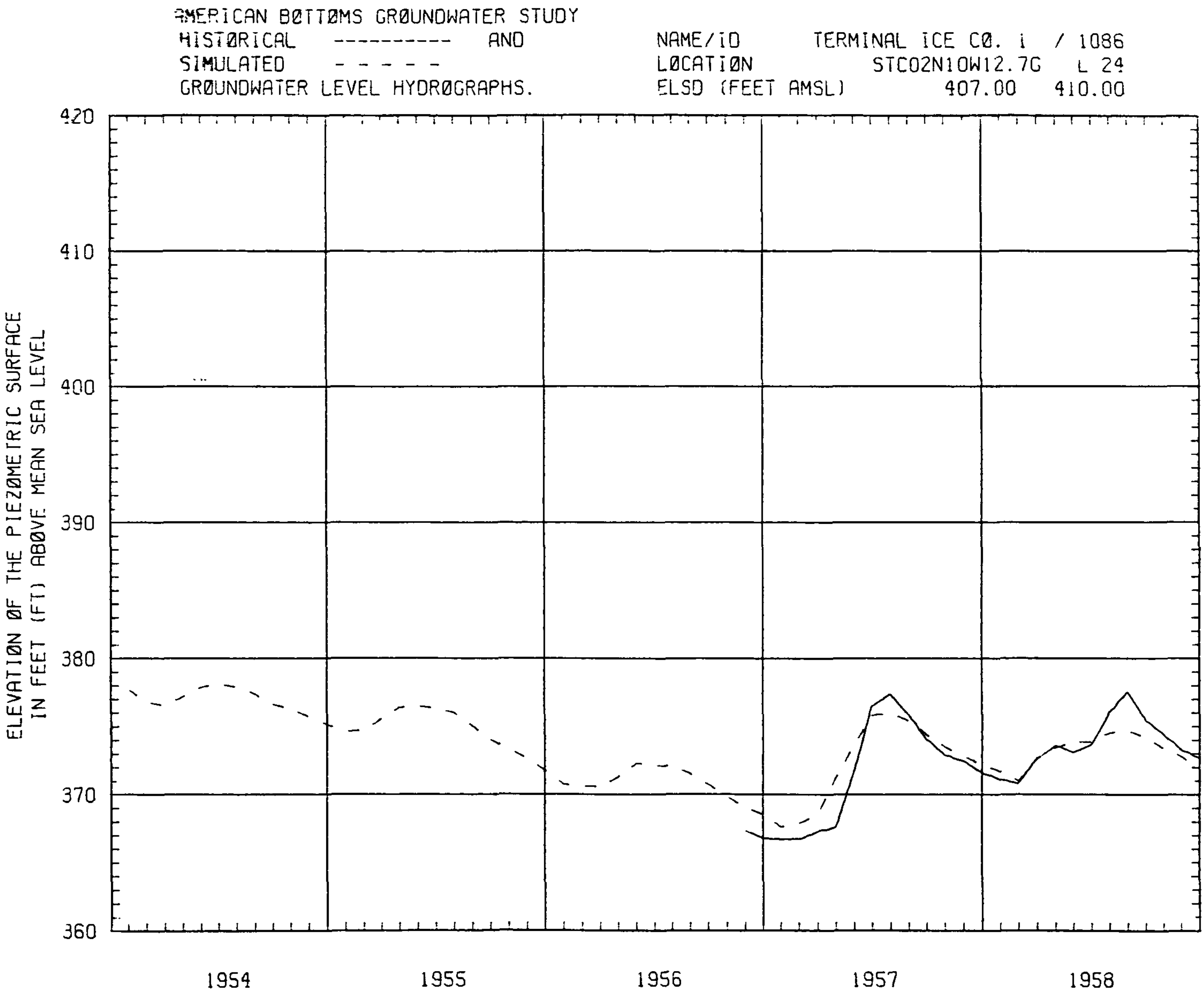

Figure 13a. Water levels in well STC 2N10W-12.7g and at cell L 24, 1954-1958.

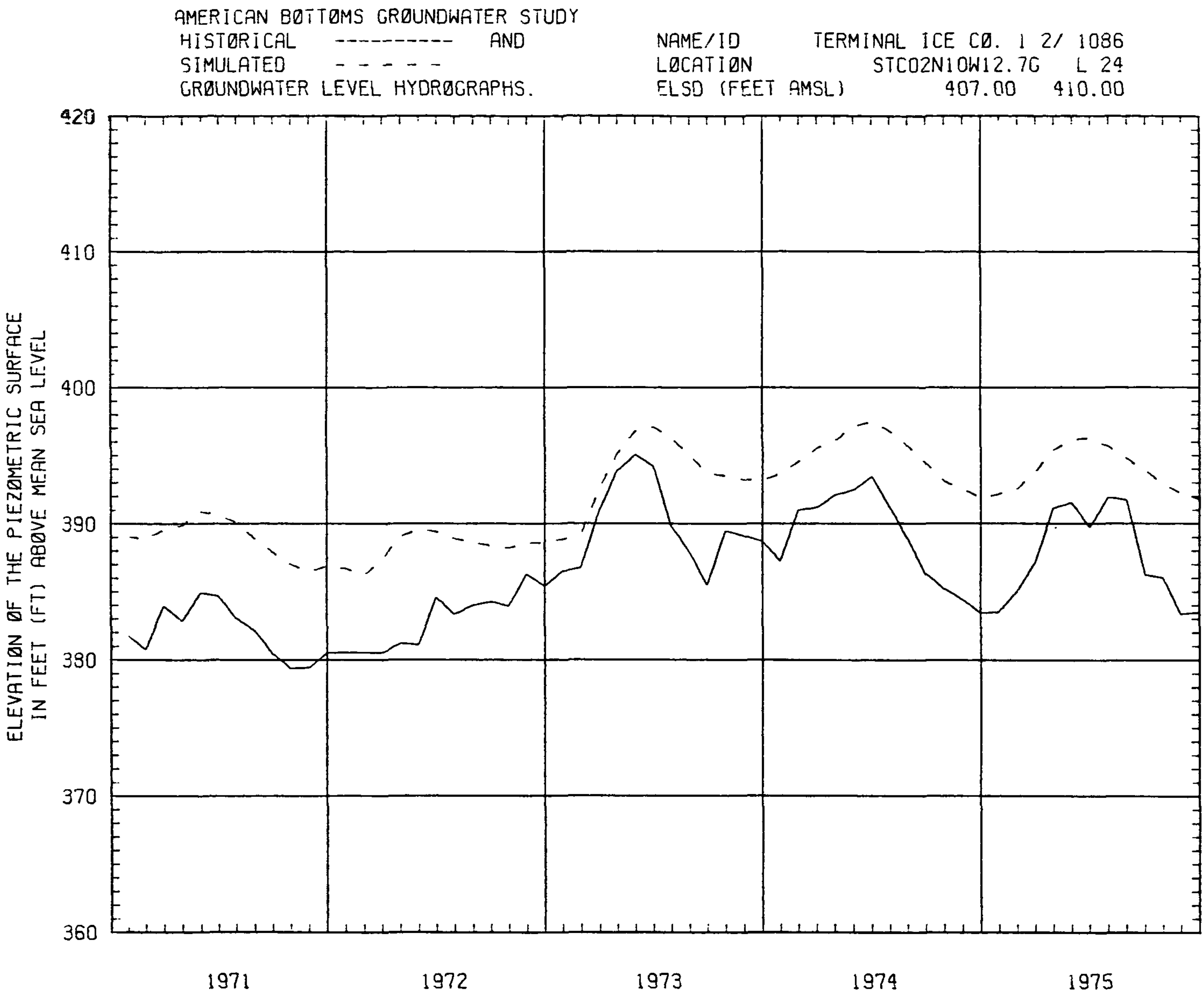

Figure 13b. Water levels in well STC 2N10W-12.7g and at cell L 24, 1971-1975.

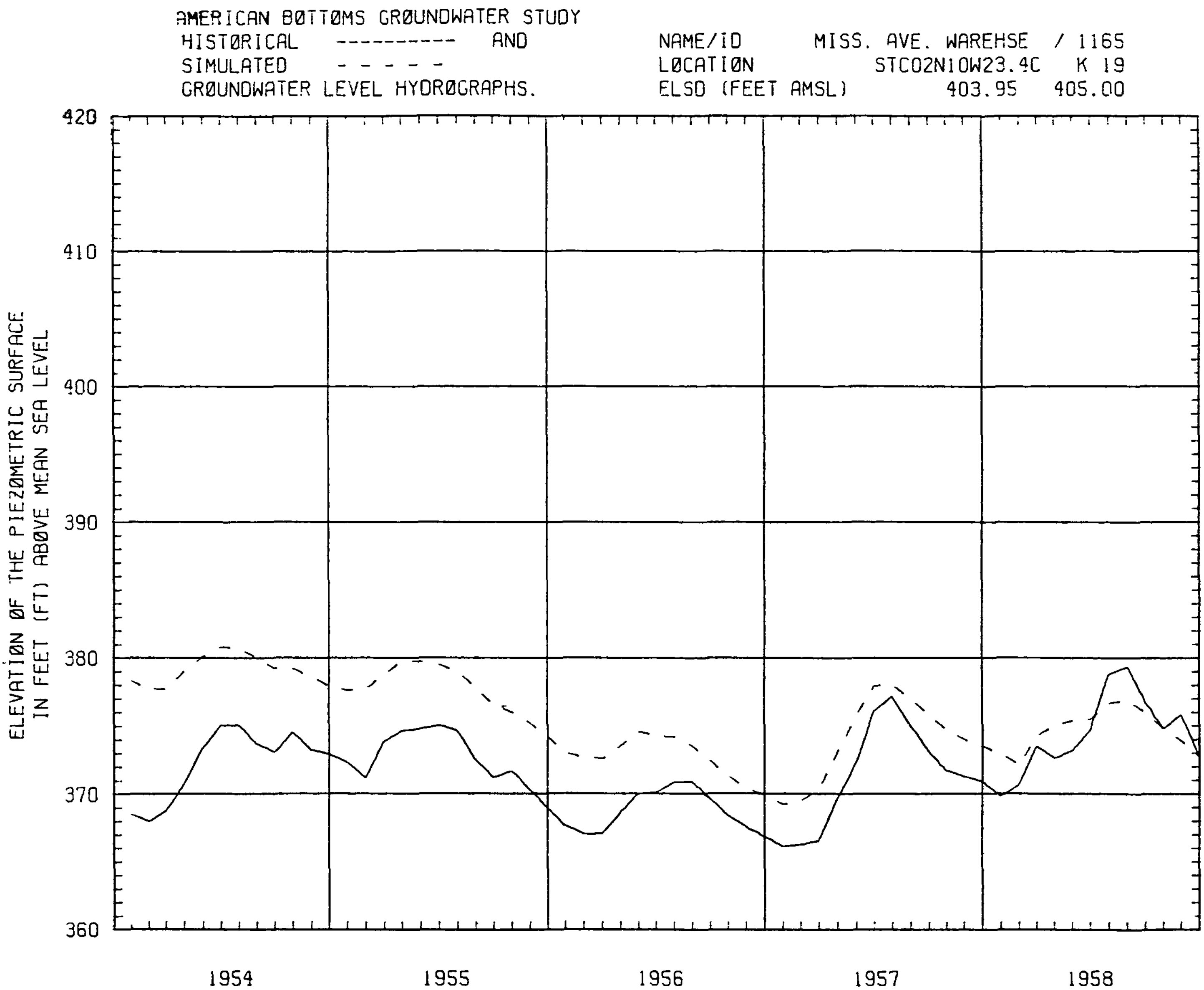

Figure 14a. Water levels in well STC 2N10W-23.4c and at cell K 19, 1954-1958.

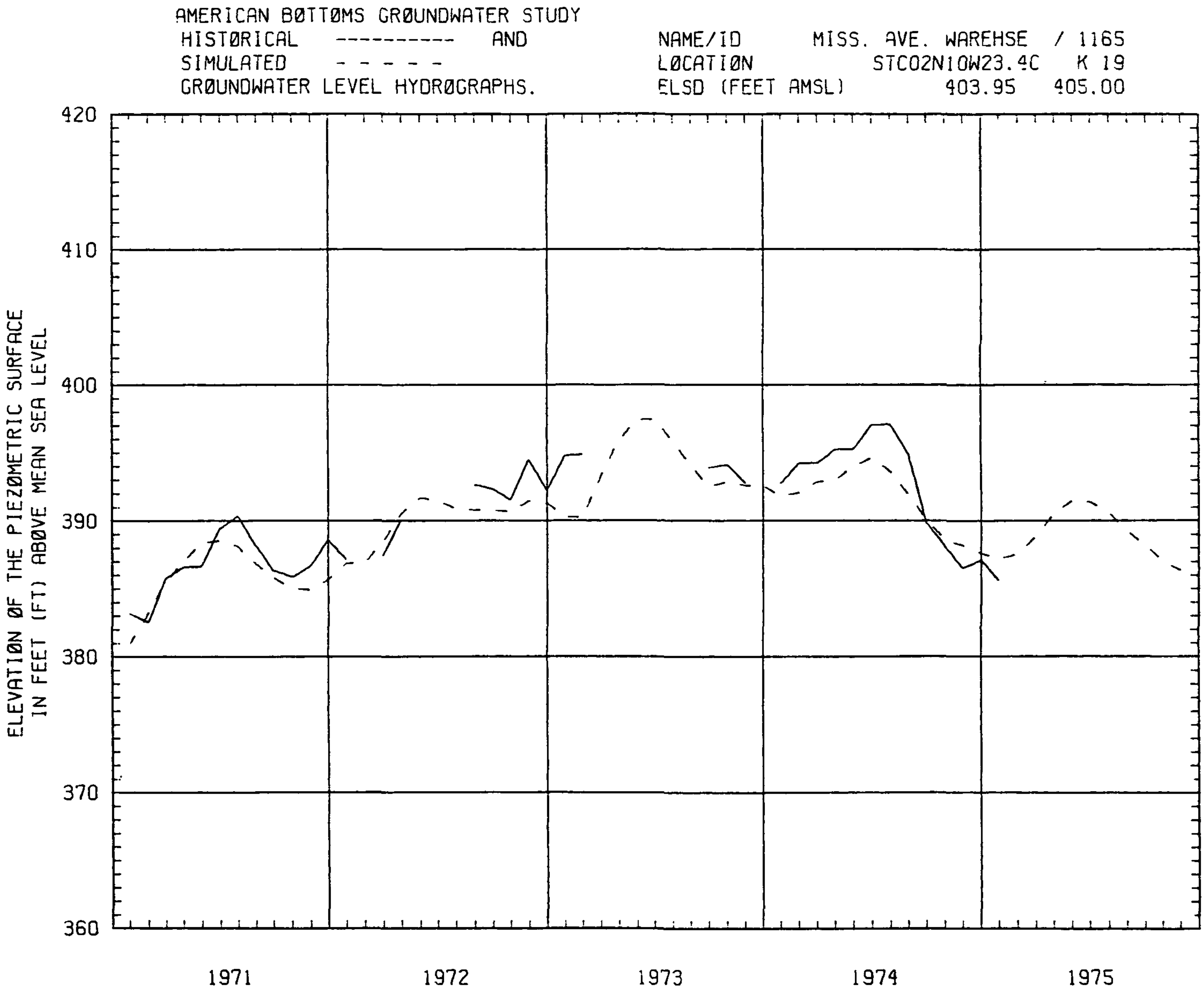

Figure 14b. Water levels in well STC 2N10W-23.4c and at cell K 19, 1971-1975.

in the vicinity of well 01165 was reduced drastically from the 1950's to the 1970's and, therefore, results in a better match.

Analysis of the Piezometric Surface

Piezometric surface maps of computed water levels are presented for two different years. The simulated water level surface corresponds to times at which comprehensive water level measurements were taken (see ~~Appendix~~ Part A, pages 43-53). Figures 15 and 16 depict the computed piezometric surfaces in December of 1956 and June of 1973, respectively. Water levels from December of 1956 are near to the lowest ever recorded and those from June of 1973 are near to the highest.

The reference piezometric surface for 1956 was drafted by hand based on information from 86 wells and 18 river and lake gages. The simulated piezometric surface was drafted by a computer program using the "CONREC" subroutine of computer graphics software developed by the National Center for Atmospheric Research.

Table 1 presents a comparison of simulated and reference piezometric surface maps for December 1956. Table 2 presents a comparison of simulated and observed estimated hydraulic gradients of surface maps for December 1956. The estimated hydraulic gradient is the change in water level over the distance of a cone of depression created by a pumping center. Tables 1 and 2 indicate that some difference occurs at most of the major pumping centers. These differences are all within a reasonable limit with respect to approximations in withdrawals and grid spacing.

The reference piezometric surface for 1973 was drafted by hand based on 211 wells and 9 river and lake gages. The simulated piezometric surface was done in the same manner as the 1956 simulated piezometric surface map.

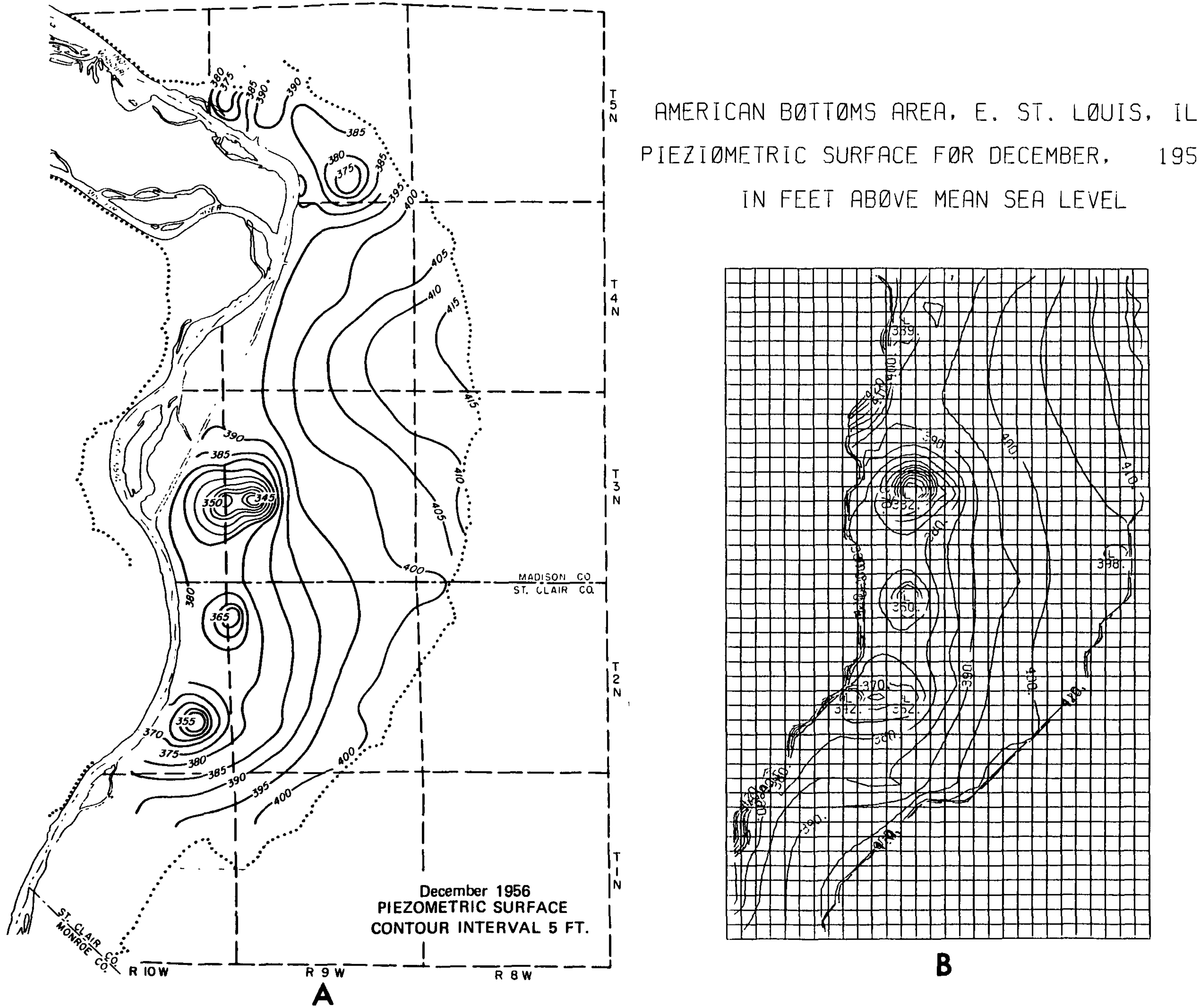

Figure 15. Elevation of the piezometric surface, December 1956,
Actual (A), Simulated (B).

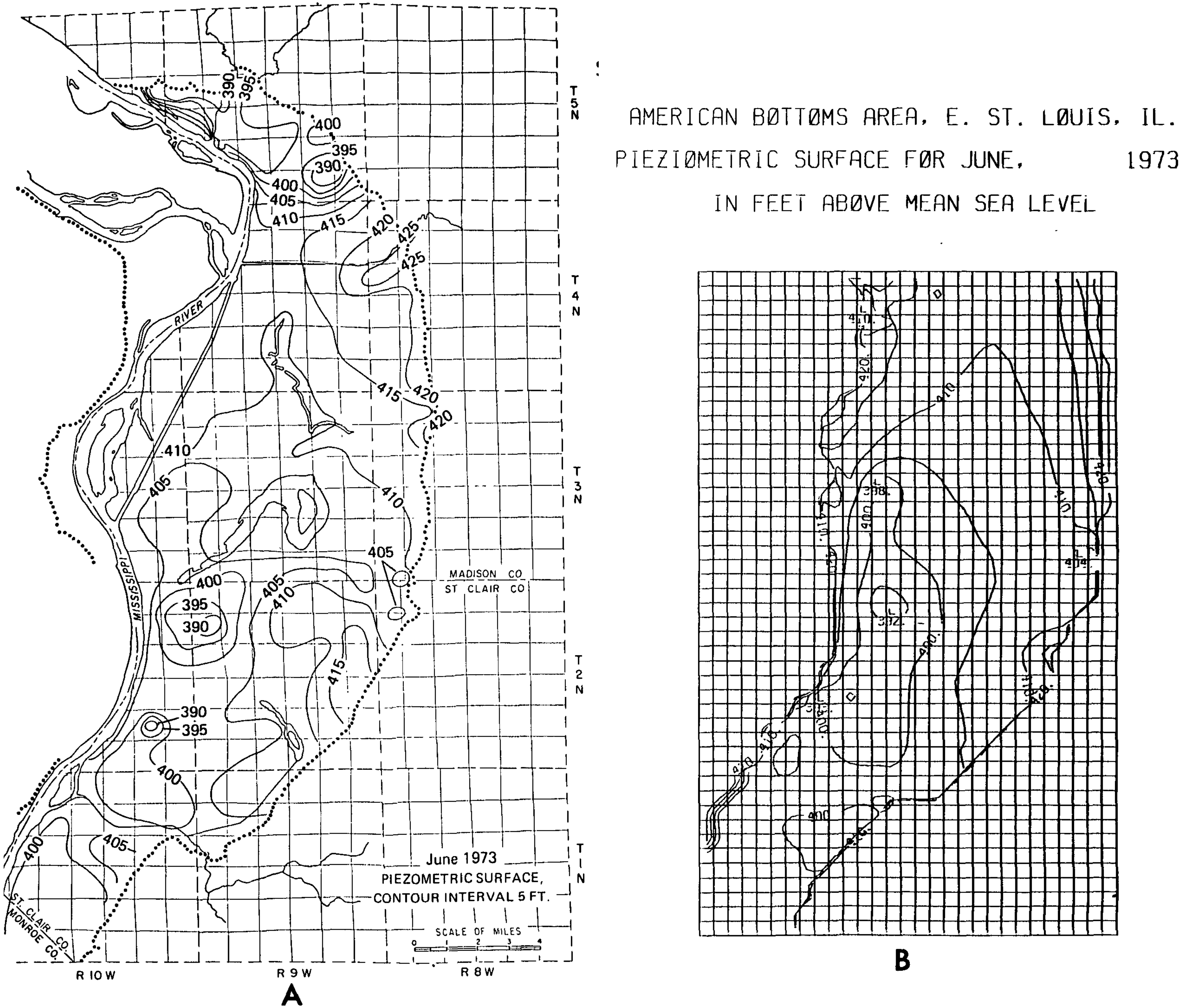

Figure 16. Elevation of the piezometric surface, June 1973,
Actual (A), Simulated (B)

Table 1. Comparison of Computed and Actual Water Levels in Pumping Centers December 1956

Pumping Center	Water-level elevation (ft above msl) Computed	Actual
Alton area	366	375
Wood River area	373	375
Granite City area	332	350
National City area	355	365
Monsanto area	342	355
Caseyville area	398	400

Table 2. Comparison of Computed and Actual Hydraulic Gradients for December 1956

Pumping Center	Average gradient (ft/mi) Computed	Actual
Alton area	10	15
Wood River area	10	15
Granite City area	30	30
National City area	15	10
Monsanto area	30	25

Table 3. Comparison of Computed and Actual Water Levels in Pumping Centers for June 1973

Pumping Center	Water-level elevation (ft above msl) Computed	Actual
Alton area	410	390
Wood River area	397	390
Granite City area	400	405
National City area	392	390
Monsanto area	393	390
Caseyville area	403	405

Table 4. Comparison of Computed and Actual Hydraulic Gradients for June 1973

Pumping Center	Average gradient (ft/mi) Computed	Actual
Alton area	10	25
Wood River area	10	20
Granite City area	5	5
National City area	5	10
Monsanto area	10	20

Tables 3 and 4 present a comparison of simulated and reference piezometric surface maps for June 1973 and a comparison of simulated and observed average hydraulic gradients for June 1973.

Summary

The hydrographs and piezometric surface maps of simulated and historical water levels provide evidence as to the validity of the digital model. The validity of a model ultimately depends on the application of the model and the conclusions which are drawn from it. When a simple and cost efficient model is desired, the validity of the model is often compromised to meet the overall requirements of the study. Furthermore, the availability and quality of data that is required affects the potential accuracy of the model.

It is purported that this model is valid as described for application to the objectives of this study. The model was not developed to accurately delineate the piezometric surface in all areas of the American Bottoms under all conceivable conditions. Therefore, differences between simulated and historical water levels in the northern part of the American Bottoms, as well as in other areas previously described, have not been considered with the detail of other areas in the American Bottoms.

The model is most consistent in accurately simulating water levels in wells 01077, 01076, 01225, and 01223. Historical water levels at two observation wells, both near the Mississippi River (see discussion on wells 01072 and 01075), are not accurately simulated because of their proximity to the Mississippi River and to pumpage.

Hydrographs of observation wells located along the Mississippi River, but not at the river (see discussion on wells 01086 and 01165), are satisfactorily simulated by the model.

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