DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

HYDROLOGIC INVESTIGATION
ATLAS HA-434

ANALOG SIMULATION OF WATER-LEVEL DECLINES IN THE SPARTA SAND, MISSISSIPPI EMBAYMENT

INTRODUCTION

Large local ground-water withdrawals from several of the aquifers in the Mississippi embayment have caused lowering of water levels that are of regional and interstate significance. The purpose of this study was to determine and evaluate the effects of increasing water withdrawals from the Sparta Sand, with the use of an electrical analog model. The Sparta Sand was chosen from the many aquifers in the Mississippi embayment because the problems associated with ground-water development are more imminent in the Sparta than in other aquifers. The study area is shown in figure 1. The Sparta Sand extends for an indeterminate distance downdip, but the location of the boundary was arbitrarily picked where the transmissivity becomes less than approximately 3,000 sq ft per day (square feet per day). North of the 35th parallel, the Sparta Sand is part of a thick sand section in the middle and lower parts of the Claiborne Group. This sand section, known as the Memphis aquifer, includes in descending order the Sparta Sand, sandy facies equivalents of the Cane River Formation, and the Carrizo Sand (Hosman and others, 1968, p. 20).

POTENTIOMETRIC SURFACE PRIOR TO DEVELOPMENT

The "original" potentiometric surface of the Sparta Sand and the Memphis aquifer (fig. 2) is based on measurements made prior to extensive development. The first significant use of water from the Sparta Sand was at Memphis, Tenn., beginning in 1886.

MEASURED WATER-LEVEL DECLINES

By 1965 approximately 3½ trillion gallons of water had been pumped from the Sparta Sand and the Memphis aquifer in Arkansas, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee. In response to this pumpage, water levels have declined throughout the Sparta Sand and the Memphis aquifer in this six-State area. Cones of depression caused by large withdrawals are of interstate significance in such places as Memphis, Tenn., north-central Louisiana, and south-central Arkansas; the maximum amount of decline reached 300 feet in 1965 in south-central Arkansas (fig. 3).

SIMULATION OF DECLINES BY ANALOG MODEL

The analog model was constructed to analyze water-level changes in the Sparta Sand and in the Memphis aquifer. For readers not familiar with the construction and use of analog models, a general discussion of principles is given by Robinove (1962). The model was constructed with a grid spacing of 4 miles.

Transmissivity of the Sparta Sand south of the 34th parallel is from Payne (1968, pl. 7). North of the 34th parallel, the transmissivity of the analog model, determined by E.M. Cushing from data in files of the U.S. Geological Survey (written commun., 1968), ranged from 7,000 tc 70,000 sq ft per day. The storage coefficient used in the analog model was assumed to be proportional to the thickness of the aquifer and ranged from 0.0001 to 0.001.

Preliminary analysis of water-level declines was made using the analog by assuming that all of the water pumped came from storage in the aquifer. The analog drawdown greatly exceeded that calculated from records of water levels, especially in the Memphis area. Recharge sources were added at the boundaries of the model to represent induced recharge or captured discharge at the outcrop. These sources were located where perennial streams crossed the outcrop, or where the outcrop was covered by alluvial aquifers of Quaternary age. Recharge sources representing vertical leakage were also added within the model. The model was then modified by adjusting the recharge to the aquifer until a similarity between the analog and observed drawdowns was achieved (fig. 4). This analysis assumed that the distributions of transmissivity and storage coefficient are correct as modeled.

The combined pumping rate from the Sparta Sand and the Memphis aquifer in the project area was about 350 million gallons per day in 1965. Analog analysis of the water balance for the Sparta Sand and the Memphis aquifer shows that in 1965 only about 20 percent of the water pumped was depleting storage in the aquifer, and that the other 80 percent was balanced by induced recharge or captured discharge (table 1). Water derived from changes in the rate of vertical leakage was the largest item in the 1965 water balance, amounting to 60 percent of the pumpage. Although large in total amount, when considered as an average throughout the area where the Sparta Sand or the Memphis aquifer occurs, the change in vertical leakage is small, averaging less than 0.1 inch per year. There has also been a change in flow where the outcrop of the Sparta Sand is overlain by Quaternary alluvial deposits. Induced recharge, or captured discharge, at this subcrop was about 20 percent of the pumping rate in 1965.

Table 1.—*Water balance as indicated by analog analyses*

[Rates of water flow in million gallons per day]

	1965	1990
Storage depletion	60	80
Total induced recharge and captured discharge	290	550
Change in vertical leakage	210	350
Change in flow at boundaries	80	200
Pumping rate	350	630

PROJECTED WATER-LEVEL DECLINES

The locations and rates of pumping of present (1970) and proposed new withdrawals were projected to the year 1990. Although the change in pumping rate differs from place to place, the average change in rate was about 80 percent from the period 1961–65 to the period 1966–90. The analog response to this projected pumping rate is shown in figure 5. The analog model indicates that in 1990 about 10 percent of the projected pumpage will be from storage in the aquifer and the rest will be induced recharge or captured discharge (table 1). Changes in vertical flow will account for about 60 percent of the 1990 pumpage, and changes in flow across the horizontal boundaries, about 30 percent. The analog analysis also indicates that in some places the water level will decline below the top of the aquifer (fig. 5), which in turn will cause a reduction in transmissivity and an increase in storage coefficient.

SUMMARY

Because local ground-water withdrawals from several aquifers in the Mississippi embayment have caused water-level declines that are of regional and interstate significance, an analog model of the Sparta Sand was used to predict and evaluate the regional effects of increasing future water withdrawals. The Sparta Sand and the Memphis aquifer were chosen because the problems associated with ground-water development were more imminent in these aquifers than in others.

Although the model was constructed with a coarse grid spacing and although data in some areas were scarce, it nevertheless seems to give reasonable regional values for water levels that may be expected as a result of projected pumping rates and proposed future withdrawals (fig. 5). This model can be useful not only as a starting point in the construction of more detailed models of local problem areas within the Mississippi embayment, but also as a tool in the planned management and wise use of the water resources of the entire region.

REFERENCES

Hosman, R.L., Long, A.T., Lambert, T.W., and others, 1968, Tertiary aquifers in the Mississippi embayment: U.S. Geol. Survey Prof. Paper 488-D, 29 p.

Payne, J.N., 1968, Hydrologic significance of the lithofacies of the Sparta Sand in Arkansas, Louisiana, Mississippi, and Texas: U.S. Geol. Survey Prof. Paper 569-A, 17 p.

Robinove, C.J., 1962, Ground-water studies and analog models: U.S. Geol. Survey Circ. 468, 12 p.

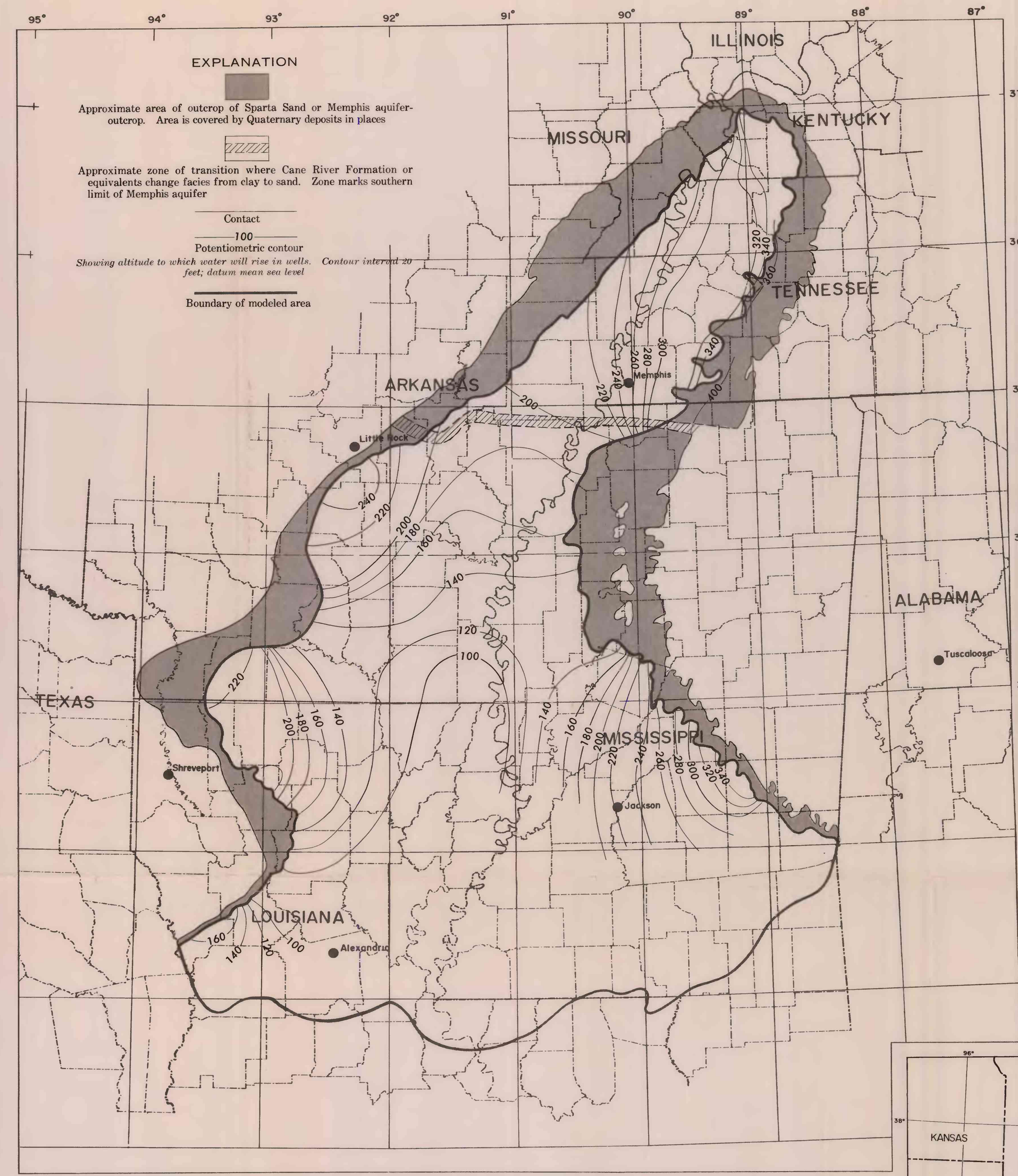


FIGURE 2.—Potentiometric surface of the Sparta Sand and Memphis aquifer in 1886.

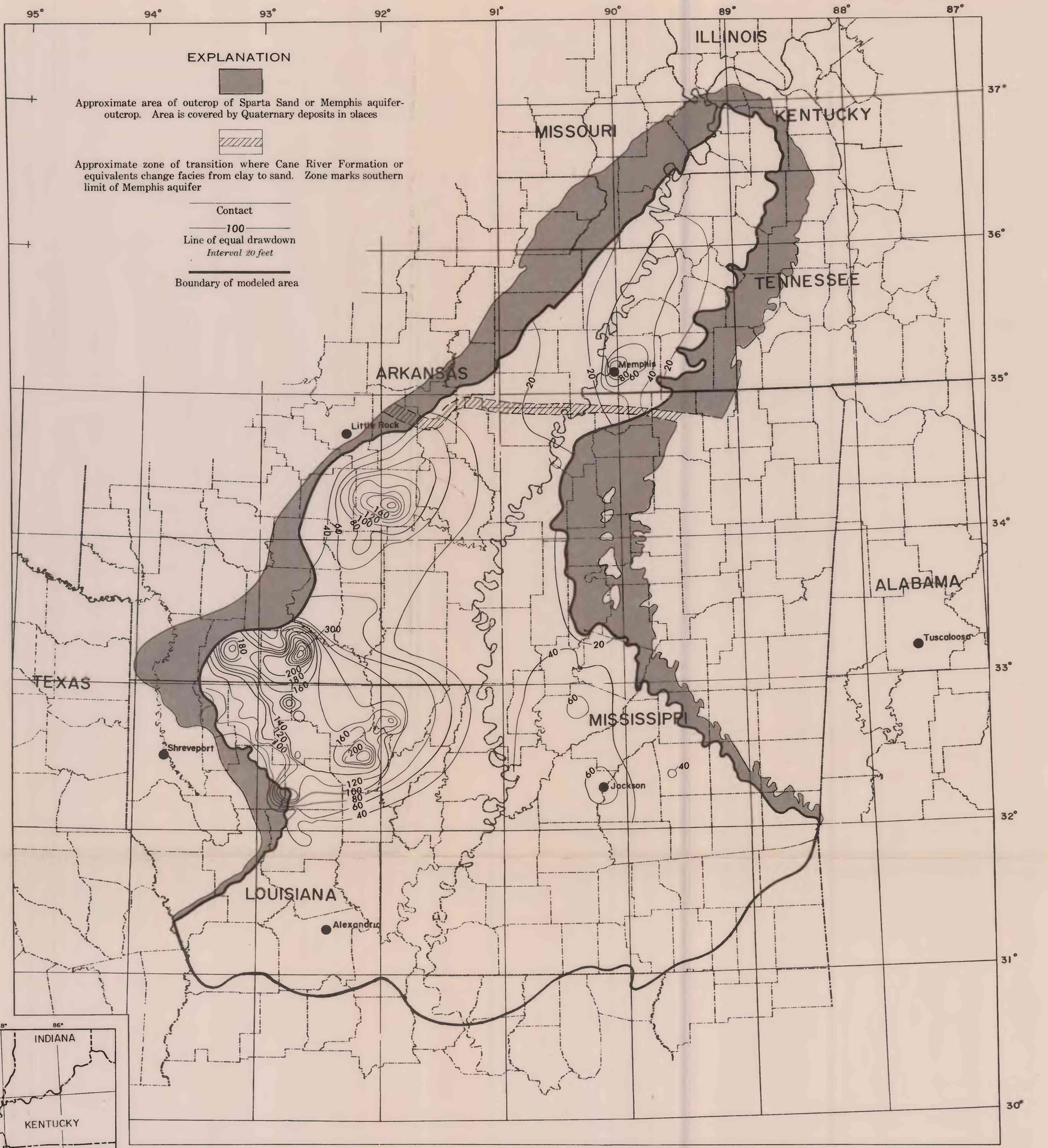


FIGURE 3.—Lowering of water level in the Sparta Sand and Memphis aquifer in the period 1886-1965.

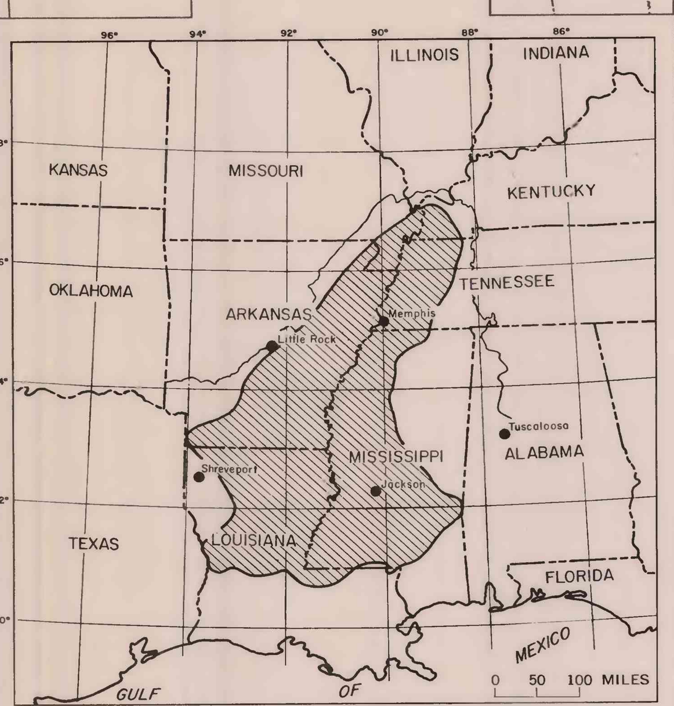
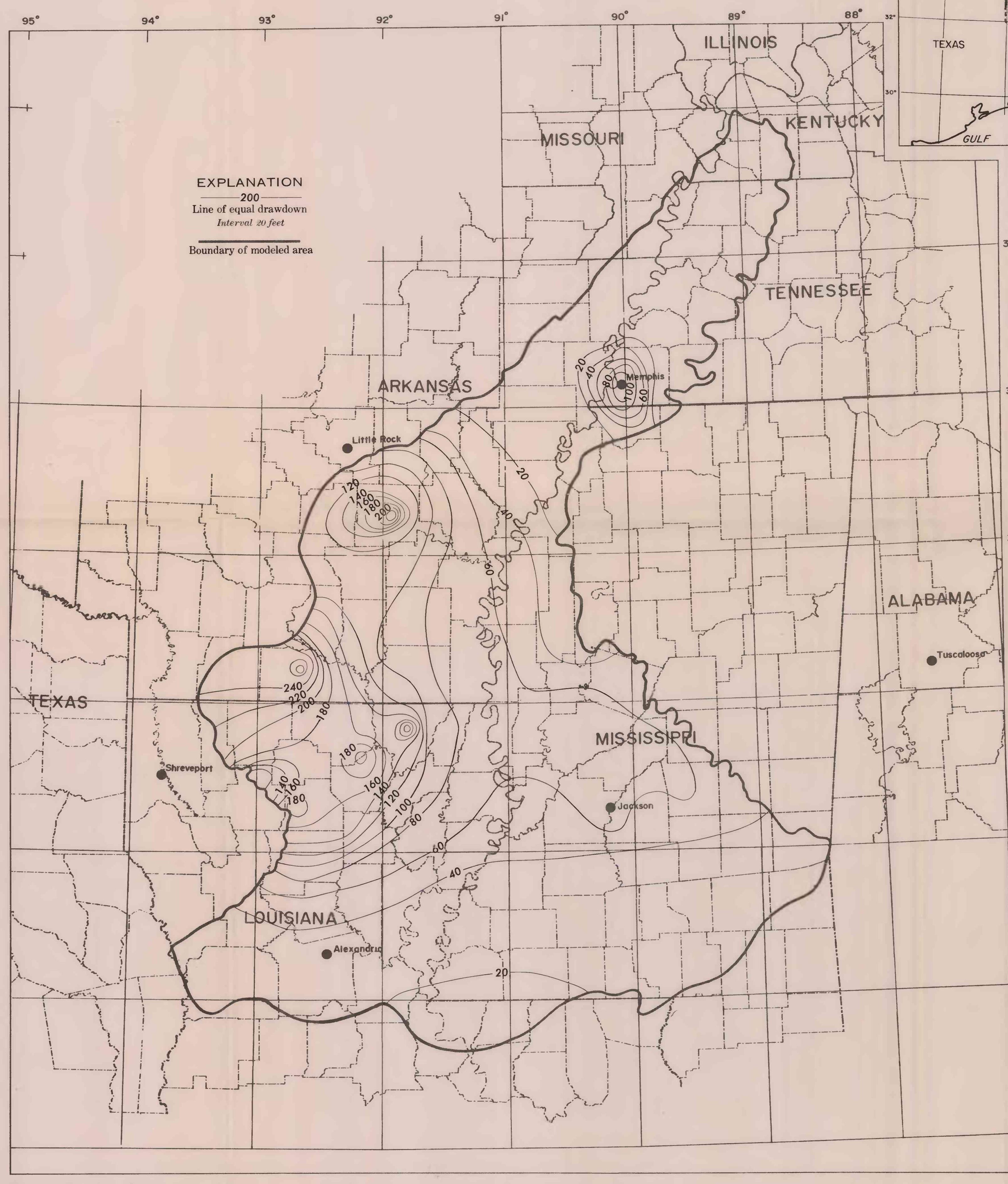


FIGURE 1.—Location of study area



Base from U.S. Geological Survey

FIGURE 4.—Lowering of water level as indicated by the analog model for the period 1886-1965.

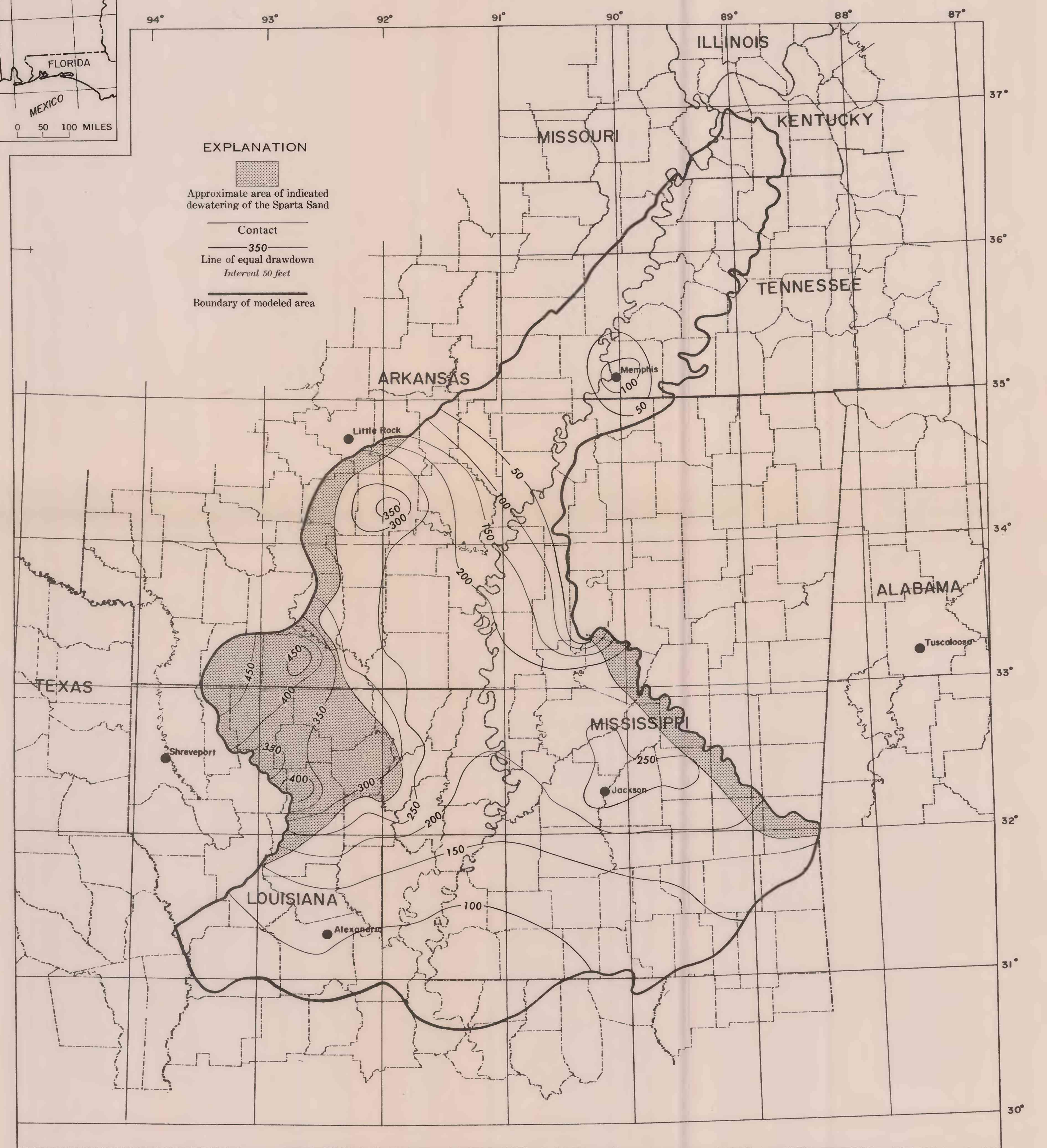


FIGURE 5.—Lowering of water level as indicated by the analog model for the period 1886-1990.

SCALE 1:2 500 000

50 0 50 100 150 200 250 MILES

50 0 50 100 150 200 250 KILOMETERS

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By
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1972

For sale by U.S. Geological Survey, price 75 cents