SUMMARY OF RESULTS OF AN INVESTIGATION TO DEFINE THE GEOHYDROLOGY AND SIMULATE THE EFFECTS OF LARGE GROUND-WATER WITHDRAWALS ON THE MISSISSIPPI RIVER ALLUVIAL AQUIFER IN NORTHWESTERN MISSISSIPPI

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ABSTRACT

The 7,000 square mile Mississippi River alluvial plain in northwestern Mississippi (the Delta) is underlain by a prolific aquifer that currently (1983) yields about 1,100 Mgal/d (million gallons per day) of water to irrigation wells. Commonly about 20 feet of clay underlying the Delta land surface is underlain by about 80 to 180 feet of sand and gravel that forms the Mississippi River alluvial aquifer. This study of the alluvial aquifer was prompted by recent declines of water levels. The study was designed to better define the hydrology of the aquifer and to quantify effects of future withdrawal of water from the aquifer.

The Mississippi River is in good hydraulic connection with the alluvial aquifer and freely recharges or drains the aquifer, depending on head differences between the aquifer and the river. Generally smaller streams are less likely to recharge the aquifer. In the interstream areas vertical recharge to the alluvial aquifer from the 52 inches of precipitation is small, especially in the central part of the Delta.

A two-dimensional finite-difference computer model of the alluvial aquifer was constructed, calibrated, and verified using water levels observed for five dates within the period April 1981 to September 1983.

Results from simulation show that the aquifer had a net loss in storage of about 360 Mgal/d for the 2-year period April 1981 to April 1983. During this period, pumpage was about 1,100 Mgal/d (1,270,000 acre feet per year) and the net inflows from the sources of recharge were: Mississippi River, 390 Mgal/d; recharge along east edge of the Delta, 170 Mgal/d; streams within the Delta, 81 Mgal/d; and areal recharge from infiltration of rainfall, 180 Mgal/d.

The effects of several levels of pumpage of ground water -- 670, 1,100, and 1,900 Mgal/d -- were projected 20 years into the future. In 2003 the effects of the 1,100-Mgal/d pumping rate, about average for the early 1980's, indicated that 46 percent of the water would be coming from storage, water levels would be lowered more than 20 feet in a large area in the central part of the Delta, and ground-water levels would continue to decline.

INTRODUCTION

Most of the water pumped in the Delta is used for irrigation and catfish farming and comes from the Mississippi River alluvial aquifer. In recent years the catfish farming industry has become a major user of ground water, second only to irrigation. Use of water from the alluvial aquifer increased from about 200 Mgal/d in the early 1970's to about 1,100 Mgal/d in the early 1980's. This increasing use of water from the alluvium and decreasing water levels in the early 1980's prompted this study.

Purpose of Investigation and Cooperation

The purpose of this study was to better understand and define the hydrology of the Mississippi River alluvial aquifer in northwestern Mississippi and to quantify the effects of future withdrawals of water for irrigation, catfish farming, and other uses. This report describes the geohydrology of the Mississippi River alluvial aquifer as determined by field investigations and a digital model of the aquifer. The report was prepared by the U.S. Geological Survey in principal cooperation with the Mississippi Department of Natural Resources, Bureau of Land and Water Resources. The Mississippi Research and Development Center also provided financial support.

Reports Resulting from this Investigation

Nine reports have resulted from this investigation of the Mississippi River alluvial aquifer in the Delta. The principal report (in preparation) fully describes the geohydrology of the alluvial aquifer as determined by field investigations, data analysis, and by development and testing of a digital model of the alluvial aquifer. This report is condensed from the principal report and presents the results of the model, without a description of the analytical techniques used. The principal report will be published as a U.S. Geological Survey Water-Supply Paper and as U.S. Geological Survey Open-File Report 84-822 (Sumner and Wasson, 1985). Also resulting from the study were seven potentiometric surface map reports: Wasson, 1980; Darden 1981, 1982a, 1982b, and 1983; Sumner, 1984a and 1984b.

GEOGRAPHY OF AREA

The Mississippi River Alluvial Plain, a part of the Gulf Coastal Plain, includes part of the Yazoo River basin in northwestern Mississippi. Locally known as the Delta, the basin surface slopes about one-half foot per mile from about 220 feet above sea level at the upper end near Memphis, Tenn., to about 80 feet near Vicksburg, Miss., a distance of about 200 miles (fig. 1). The Delta has an area of about 7,000 square miles. The Mississippi River forms the western edge of the Delta, or study area. An escarpment, the Bluff Hills, about 100 to 200 feet higher than the alluvial plain, forms the eastern edge of the Delta. The Yazoo-Tallahatchie-Coldwater River system drains the eastern edge of the Delta and collects water from many streams that enter the Delta from the hills to the east. Along the western edge of the Delta, a continuous levee along the Mississippi River prevents any surface runoff from the Delta from entering the Mississippi River except through the Yazoo River at Vicksburg. The Sunflower River drains the central part of the Delta. Generally, along east-west lines, there is a land-surface slope of about one-half foot per mile toward the Sunflower River from both the Mississippi and the Yazoo Rivers.

Precipitation in the Delta averages about 52 inches annually. Seasonal distribution of precipitation is approximately: winter, 17 inches; spring, 15 inches; summer, 11 inches; and fall, 9 inches. Average annual temperature ranges from 62°F near Memphis to 66°F near Vicksburg. The normal frost-free growing season extends from early April to early November.

Before 1800, all of the Delta was covered with hardwood forest. By 1930, about half of the Delta had been cleared and was in row crops--mostly cotton. In 1984, only small areas of the hardwood forest remain, except for the Delta National Forest in Sharkey County and the floodway areas between the levees of the Mississippi River.

GEOHYDROLOGY OF AREA

The 7,000 square mile Mississippi River alluvial plain in northwestern Mississippi (the Delta) is underlain by a prolific aquifer that currently (1983) yields about 1,100 Mgal/d of water to irrigation wells. Commonly about 20 feet of clay underlying the Delta land surface is underlain by about 80 to 180 feet of sand and gravel. Water-level profiles developed during the study proved that the Mississippi River is in good hydraulic contact with the alluvial aquifer. These profiles generally show that the smaller and less deeply incised the stream, the less likely it is to have a good hydraulic connection with the aquifer. Water-level profiles, potentiometric surface maps, and well hydrographs generally show that direct vertical recharge to the alluvial aquifer from precipitation is small, especially in the central part of the Delta.

COMPUTER MODEL CONSTRUCTION

A finite-difference digital model (McDonald and Harbaugh, 1984) was selected to simulate ground-water flow in the alluvial aquifer in northwestern Mississippi. The steps in the evolution and application of the model are outlined below:

- Development of conceptual model of aquifer system.
- Finite-difference discretization of conceptual model of aquifer system.
- Calibration of digital model.
- Sensitivity analysis.
- Model verification.
- Application of model for predictive purposes using pumpage scenarios proposed by the Delta Council in December 1983.

The model was calibrated and verified based on water levels observed for five dates within the period April 1981 to September 1983. A satisfactory correlation between model-generated heads and observed heads was achieved.

The model showed that the aquifer had a net loss in storage of about 400,000 acre feet per year (360 Mgal/d) for the 2-year period April 1981 to April 1983. During this period, pumpage was about 1,270,000 acre feet per year (1,100 Mgal/d) and the net inflows from the sources of recharge were:

	Acre-ft/year	Mgal/d
Mississippi River	440,000	390
Areal recharge	200,000	180
Recharge area along east edge of the Delta	190,000	170
Yazoo-Tallahatchie-Coldwater River system	51,000	45
Oxbow lakes	27,000	24
Sunflower River	12,000	11
Bogue Phalia	1,100	1

A comprehensive description of the model development, calibration, and verification is presented in the principal report (Sumner and Wasson, 1985).

SIMULATED EFFECTS OF GROUND-WATER WITHDRAWALS

The calibrated and verified model of the alluvial aquifer was used to estimate aquifer responses in the future. The following pumping stresses were simulated for the 20-year period beginning September 1983.

- o Pumpage of 670 Mgal/d -- minimum average pumpage during next 20 years as estimated by Delta Council (oral commun., 1983).
- o Pumpage of 1,100 Mgal/d -- 1983 pumpage as estimated by Delta Council.
- o Pumpage of 1,900 Mgal/d -- maximum average pumpage as estimated by Delta Council.

These three scenarios of pumpage input to the 20-year projection model cover a wide range of possibilities. The Delta Council's estimated pumpage for 1983 of 1,100 Mgal/d is about equal to the average pumpage from 1978 to 1984.

Pumpage for rice and catfish was distributed to model nodes in the proportions as existed in 1982. Pumpage for soybeans and cotton was distributed uniformly among the active nodes of the model. The pumpage projection scenarios are assumed to be supplied from the alluvial aquifer and not fom surface sources. In recent years streams and lakes have supplied about 15 percent of the irrigation water if water for catfish ponds is excluded, and about 10 percent if ground-water pumpage for catfish ponds is included. Pumpage at three power plants was assigned as appropriate. Another change from the basic calibration model was the use of long-term average stage values for river nodes and specific-head nodes, rather than monthly fluctuations.

The predictive model runs have constant-stress stream stages and pumping rates. With the three rates of ground-water pumpage, increases occur in withdrawals of water from aquifer storage, percentage of pumpage derived from storage, boundary flow, and stream-to-aquifer leakage. At 670 Mgal/d the percentage of pumpage coming from storage is 32 percent; at 1,100 Mgal/d, 46 percent; and at 1,900 Mgal/d, 56 percent.

A series of three maps (fig. 2-4) show the simulated potentiometric surface for the year 2003 for the three pumping scenarios. With each increased rate of pumpage, the simulated potentiometric surface maps show a lower water surface and enlargement of the depressed potentiometric surface in the central part of the Delta compared to the September 1983 potentiometric surface map.

Another series of maps (figs. 5-7) show the drawdown that occurs during the 20-year projections. With increasing pumping rates the drawdown depths and areas increase.

A third series of maps (figs. 8-10) show the remaining saturated thickness of the alluvial aquifer after 20 years of continuous pumpage at specified rates. As water levels decline and the saturated thickness of the aquifer becomes less, it will become more difficult to obtain large yields from wells. Presently large-capacity irrigation wells in the Delta are constructed with 20 to 60 feet of screen and have 20 to 50 feet of drawdown space above the top of the screen. As saturated thickness diminishes, the average yields of wells will be smaller and water-supply problems are likely to occur.

The saturated thickness map (fig. 8) resulting from the 670 Mgal/d pumping rate simulation shows several small areas in the Delta where no more than 75 feet of the alluvial aquifer is saturated. The largest area having less than 75 feet of saturated aquifer is in that part of Washington County where the total thickness of the alluvial aquifer is less than in most of the Delta. The 1,100 Mgal/d simulation (fig. 9) shows that several large areas will have less than 75 feet of saturated aquifer and some small areas will have less than 50 feet of saturated aquifer. The 1,900 Mgal/d simulation (fig. 10) shows that a large part of the central Delta would have less than 75 feet of saturated aquifer and two small areas in Bolivar and Sunflower Counties would have less than 25 feet at the end of 20 years.

It is not possible to simulate steady-state water levels for the aquifer for a 1,100 Mgal/d pumping rate because parts of the aquifer become unsaturated at some time exceeding 20 years, but before equilibrium of flow in the aquifer is reached.

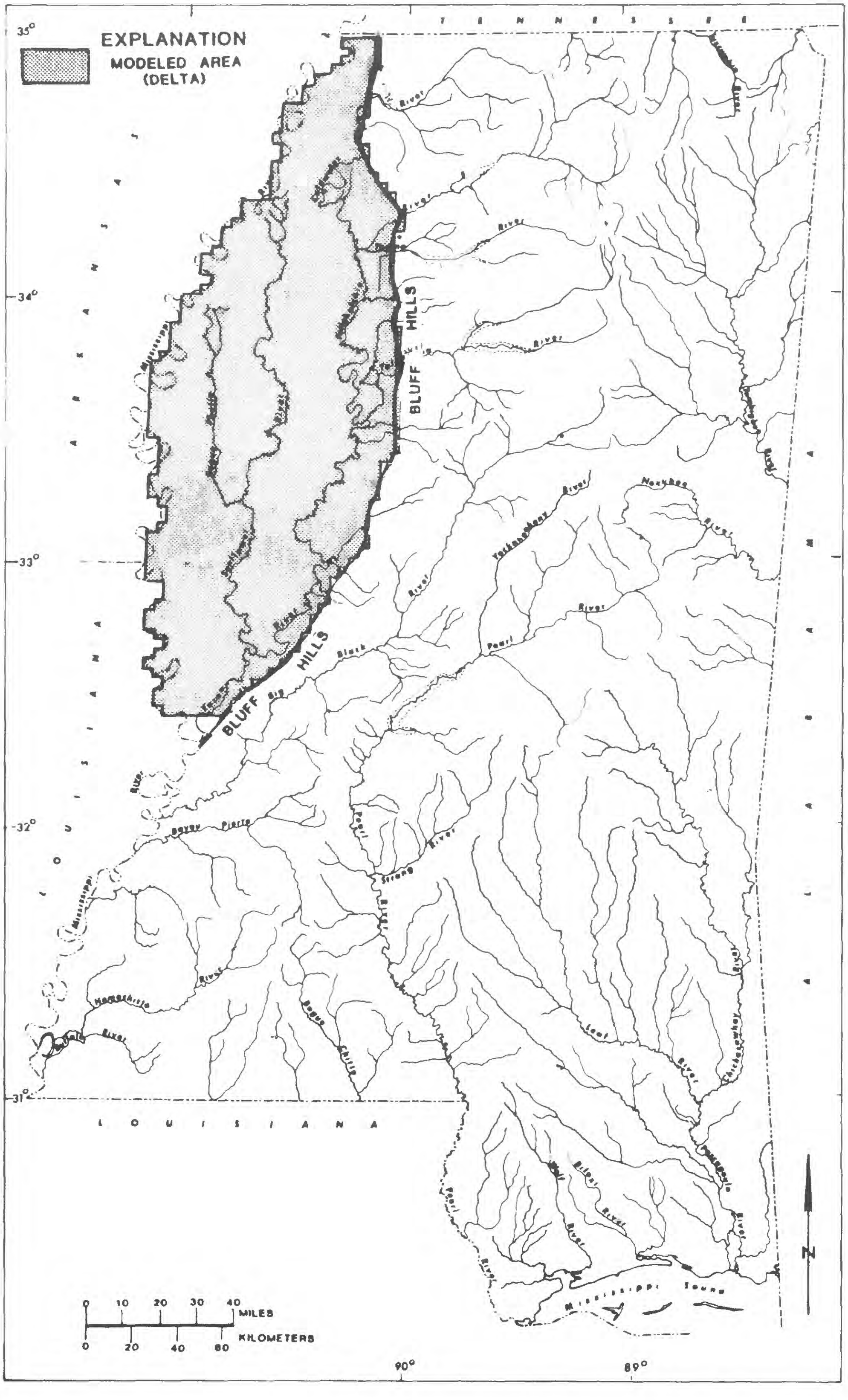

Figure 1.--Location of the study area (Delta) in north-western Mississippi.

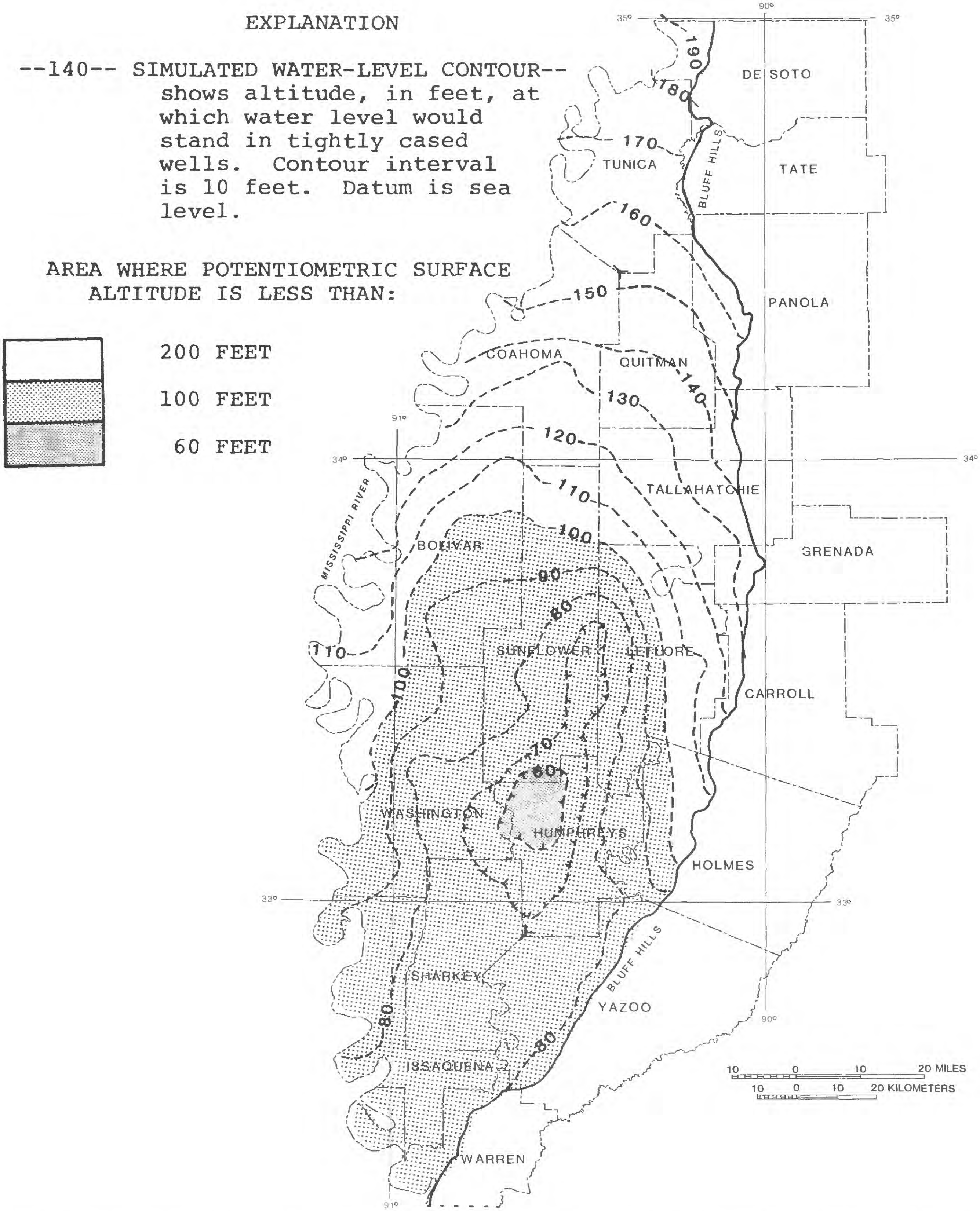

Figure 2.--Simulated potentiometric surface of the alluvial aquifer in the Delta for the year 2003 assuming pumpage is 670 million gallons per day.

EXPLANATION

--140-- SIMULATED WATER-LEVEL CONTOUR--
shows altitude, in feet, at which water level would stand in tightly cased wells. Contour interval is 10 feet. Datum is sea level.

AREA WHERE POTENTIOMETRIC SURFACE ALTITUDE IS LESS THAN:

200 FEET

100 FEET

60 FEET

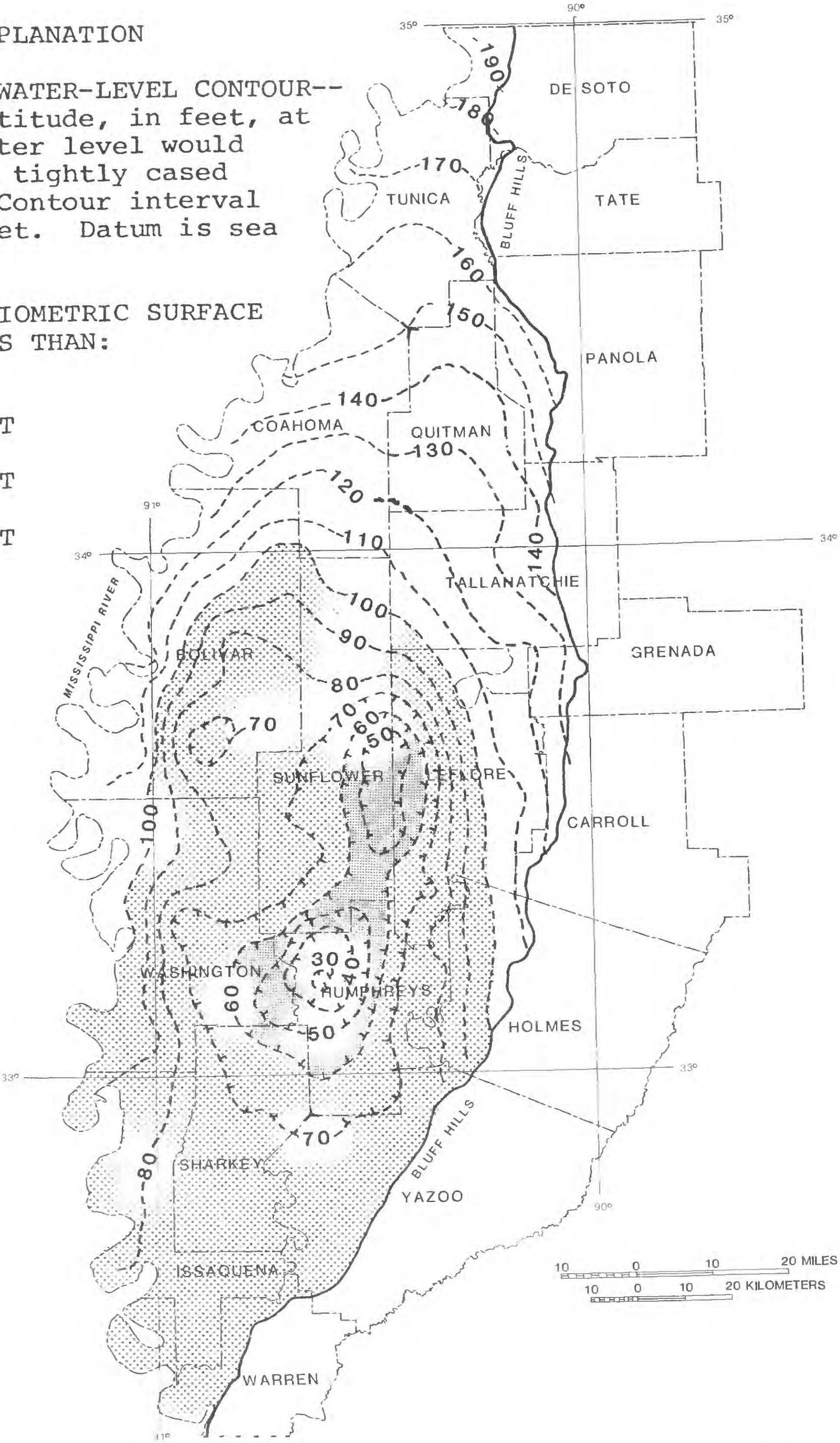

Figure 3.--Simulated potentiometric surface of the alluvial aquifer in the Delta for the year 2003 assuming pumpage is 1,100 million gallons per day.

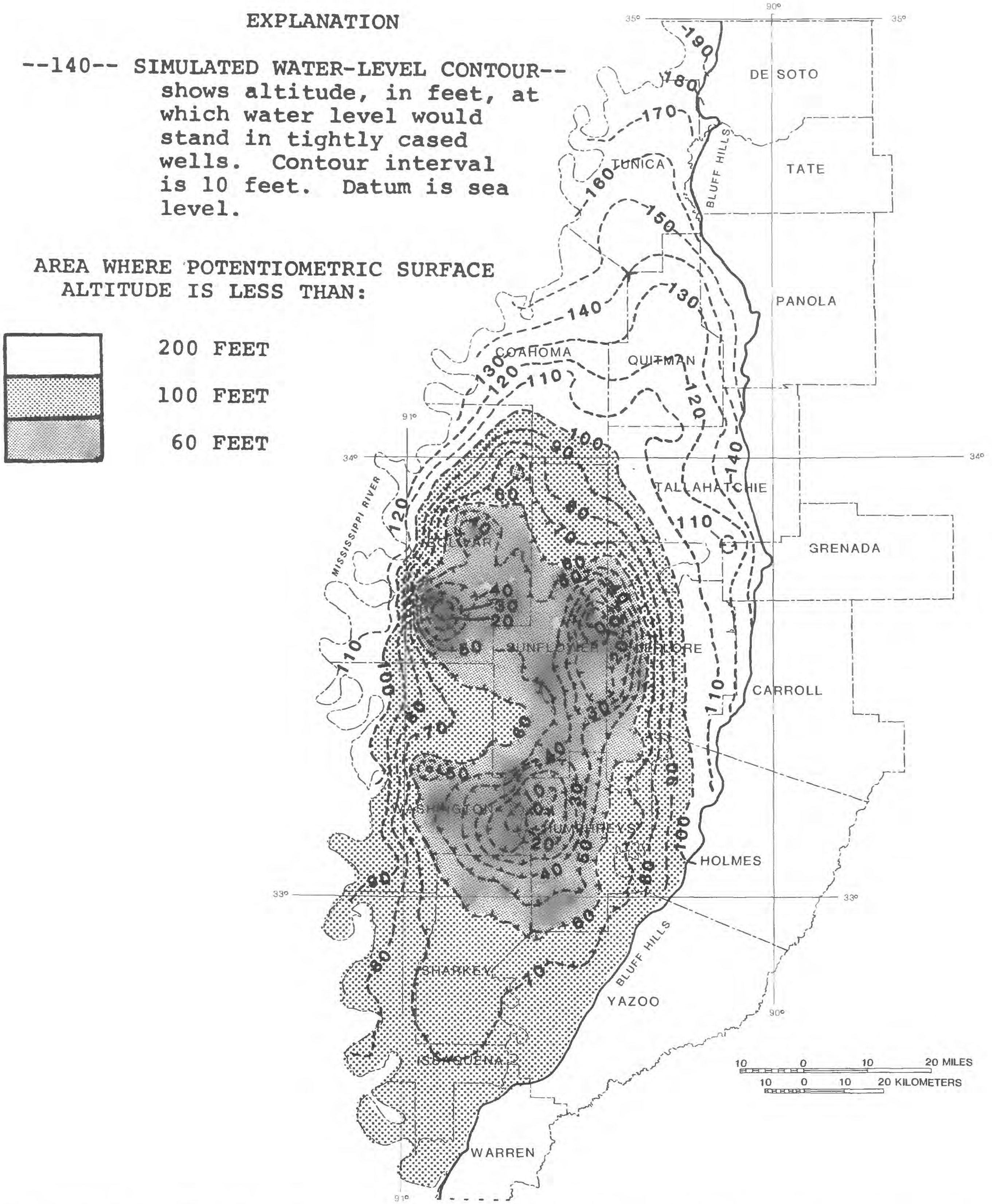

Figure 4.-- Simulated potentiometric surface of the alluvial aquifer in the Delta for the year 2003 assuming pumpage is 1,900 million gallons per day.

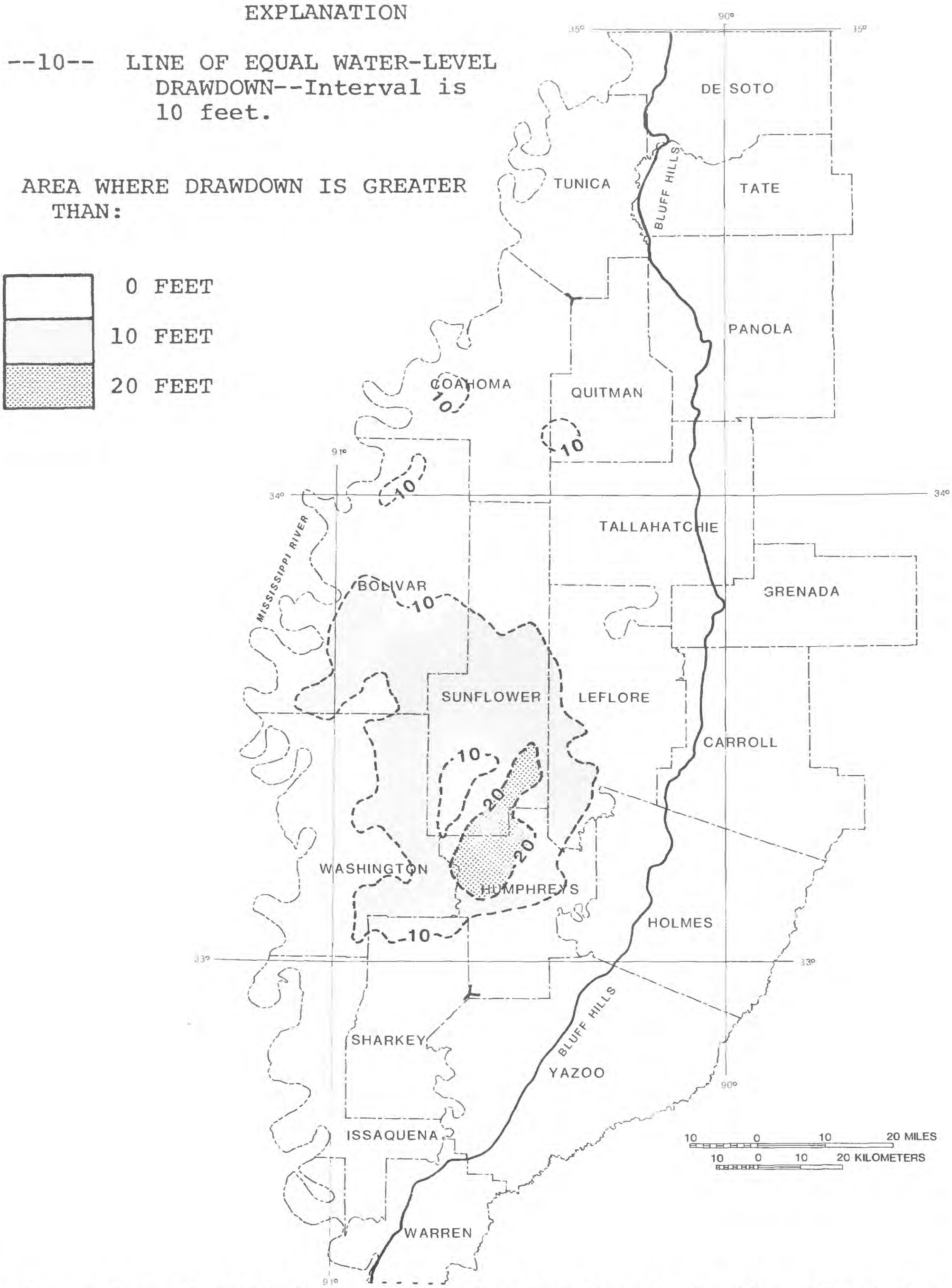

Figure 5.--Simulated drawdown of water levels in the alluvial aquifer in the Delta for the period September 1983 to September 2003 assuming pumpage is 670 million gallons per day.

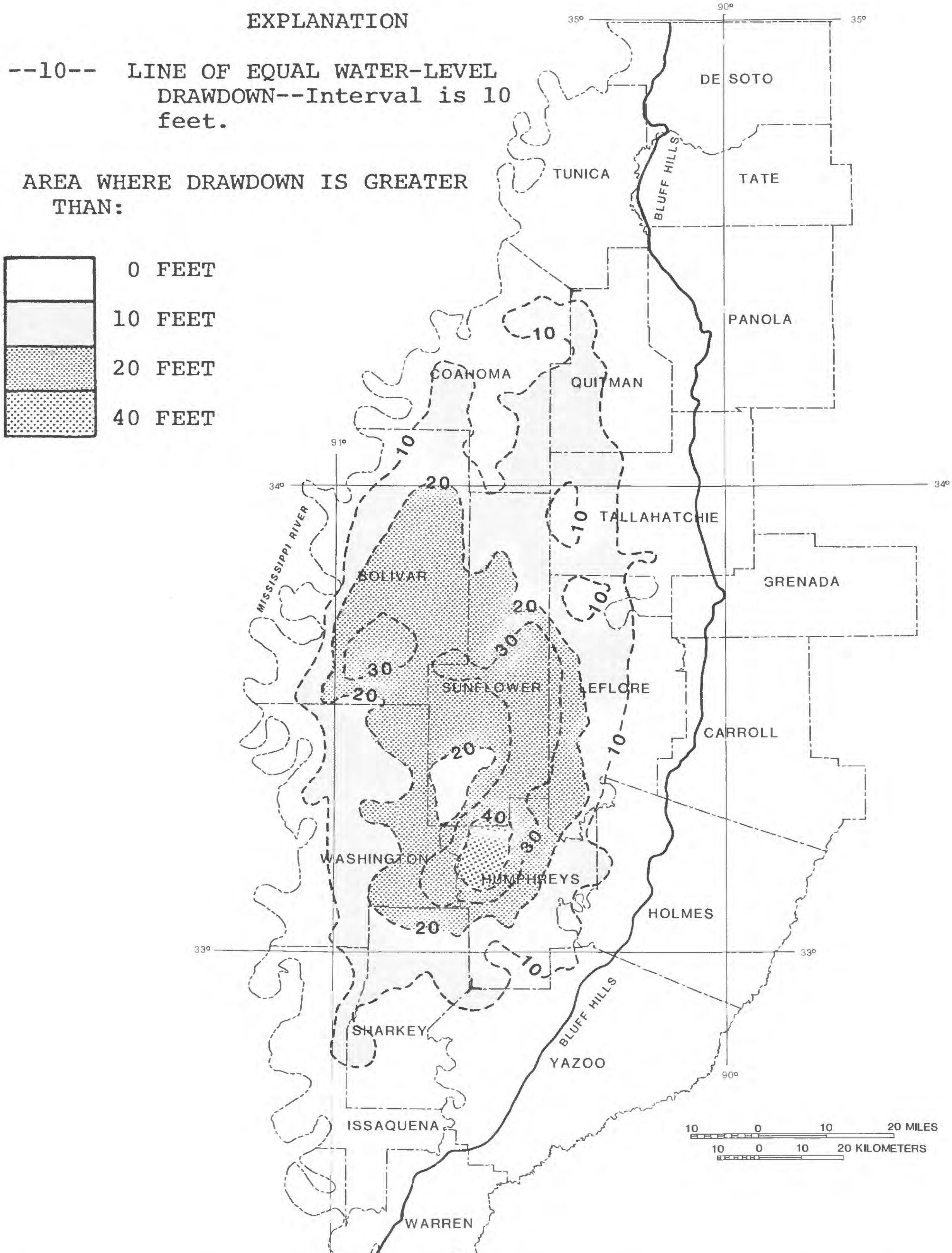

Figure 6.--Simulated drawdown of water levels in the alluvial aquifer in the Delta for the period September 1983 to September 2003 assuming pumpage is 1,100 million gallons per day.

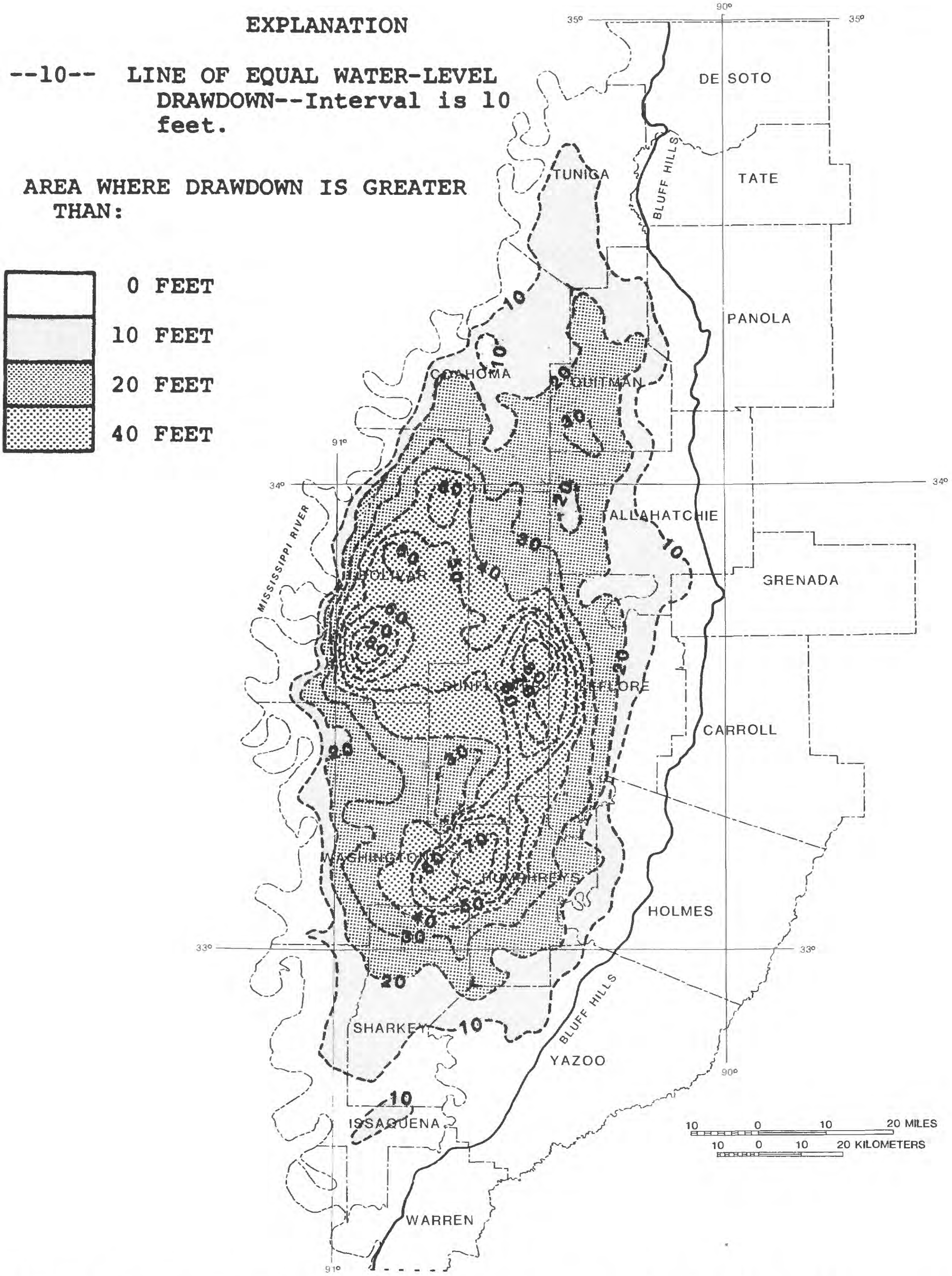

Figure 7.--Simulated drawdown of water levels in the alluvial aquifer in the Delta for the period September 1983 to September 2003 assuming pumpage is 1,900 million gallons per day.

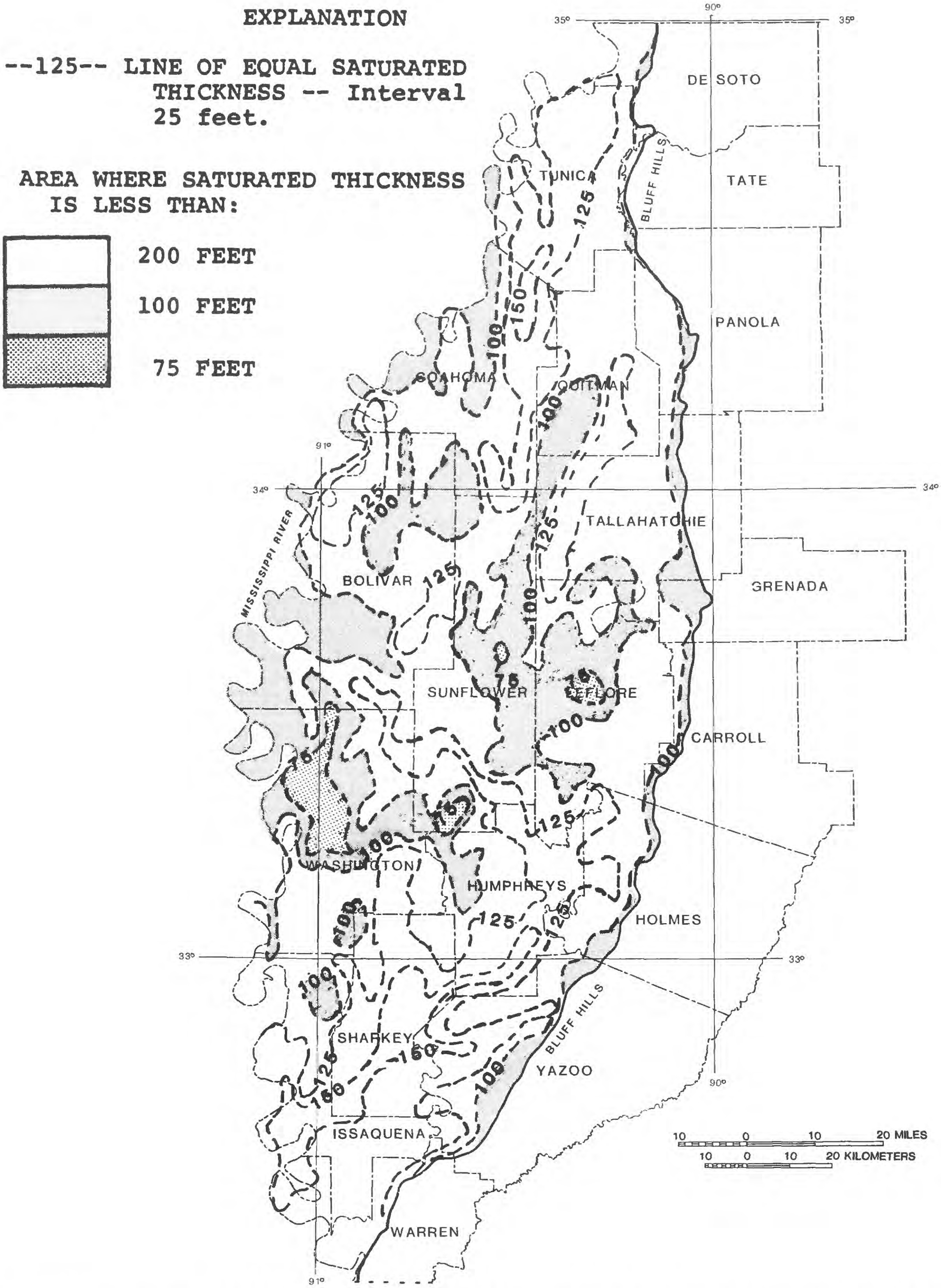

Figure 8.--Simulated saturated thickness of the alluvial aquifer in the Delta for the year 2003 assuming pumpage is 670 million gallons per day.

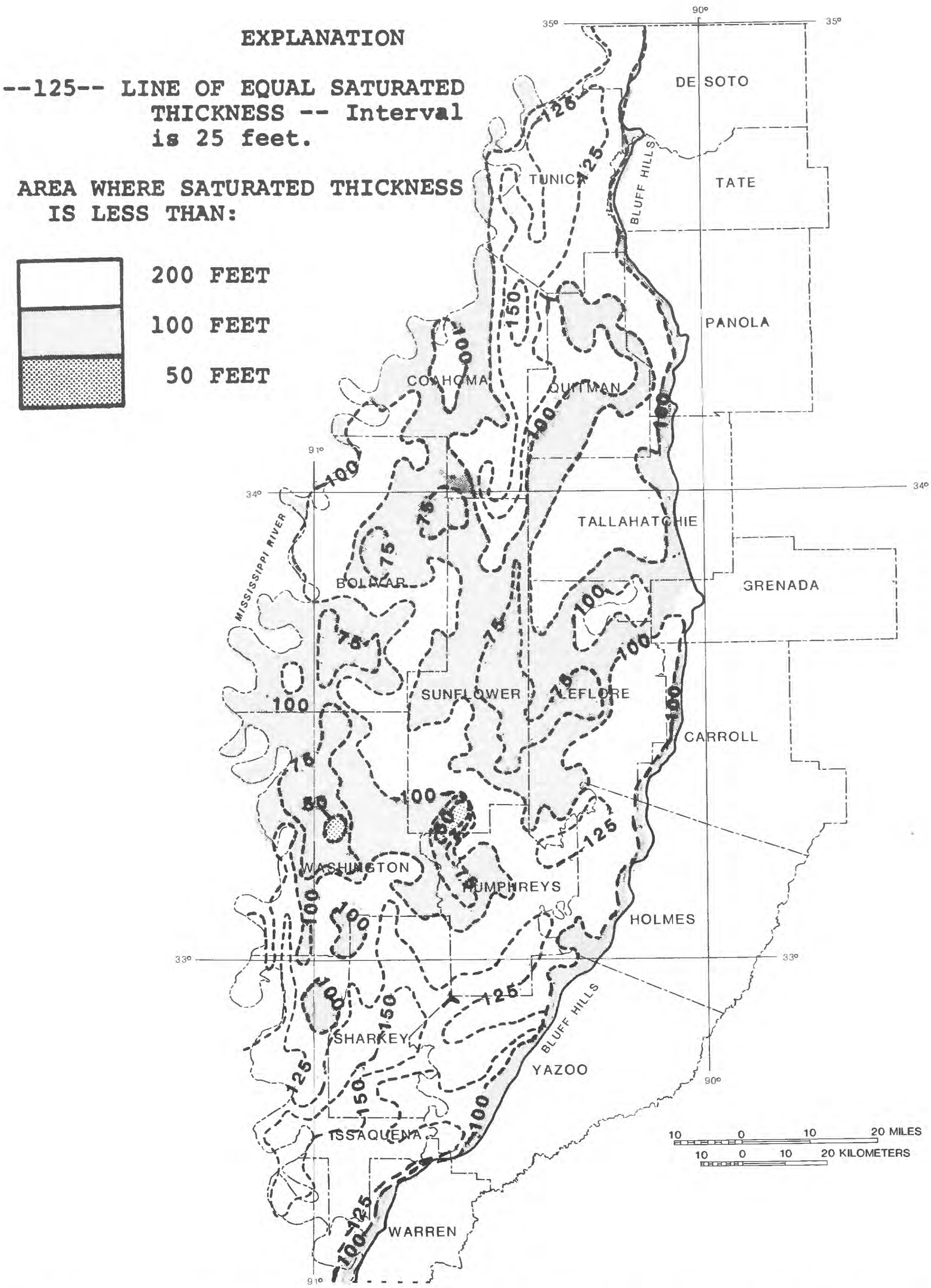

Figure 9.--Simulated saturated thickness of the alluvial aquifer in the Delta for the year 2003 assuming pumpage is 1,100 million gallons per day.

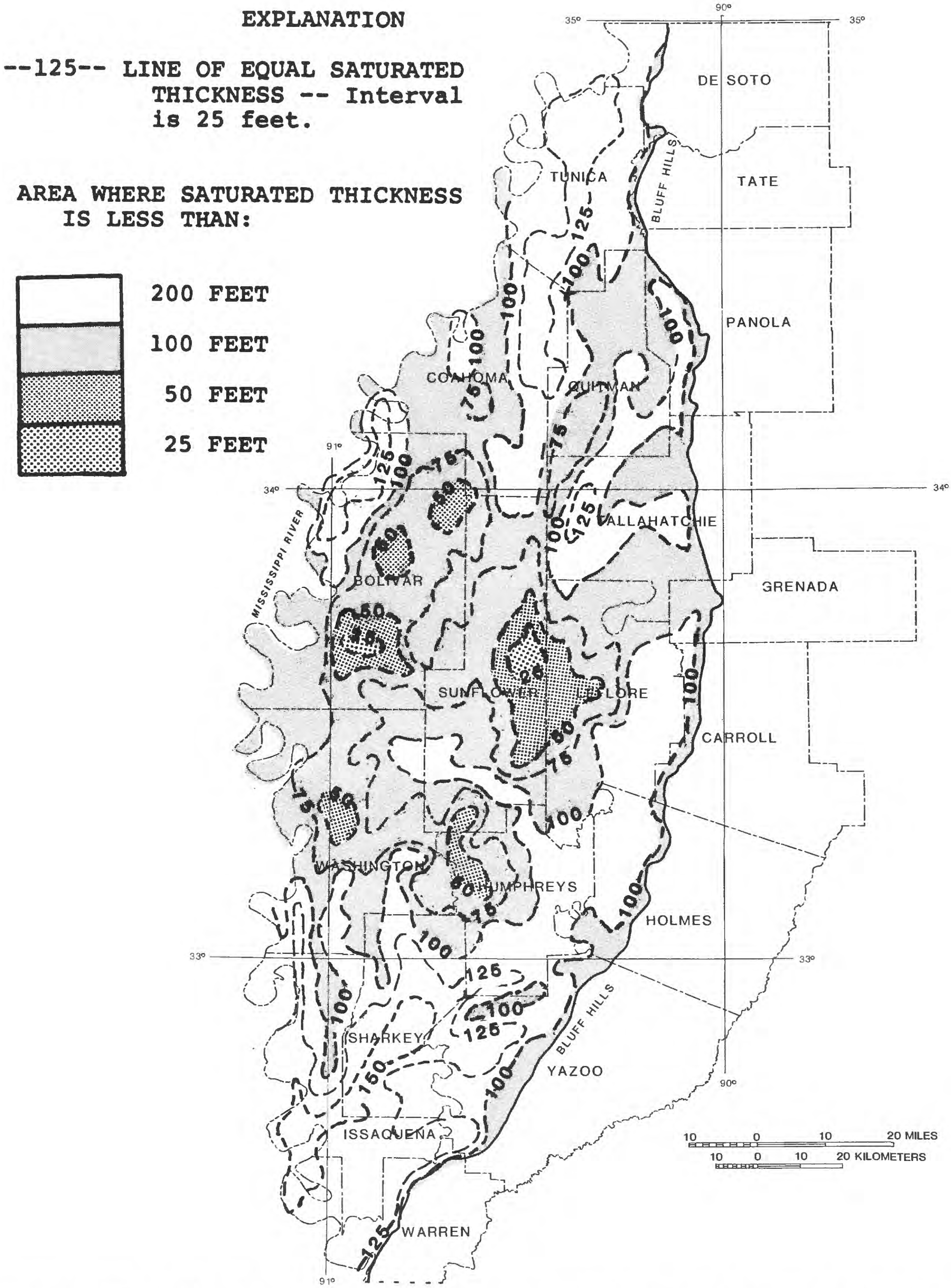

Figure 10.--Simulated saturated thickness of the alluvial aquifer in the Delta for the year 2003 assuming pumpage is 1,900 million gallons per day.

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