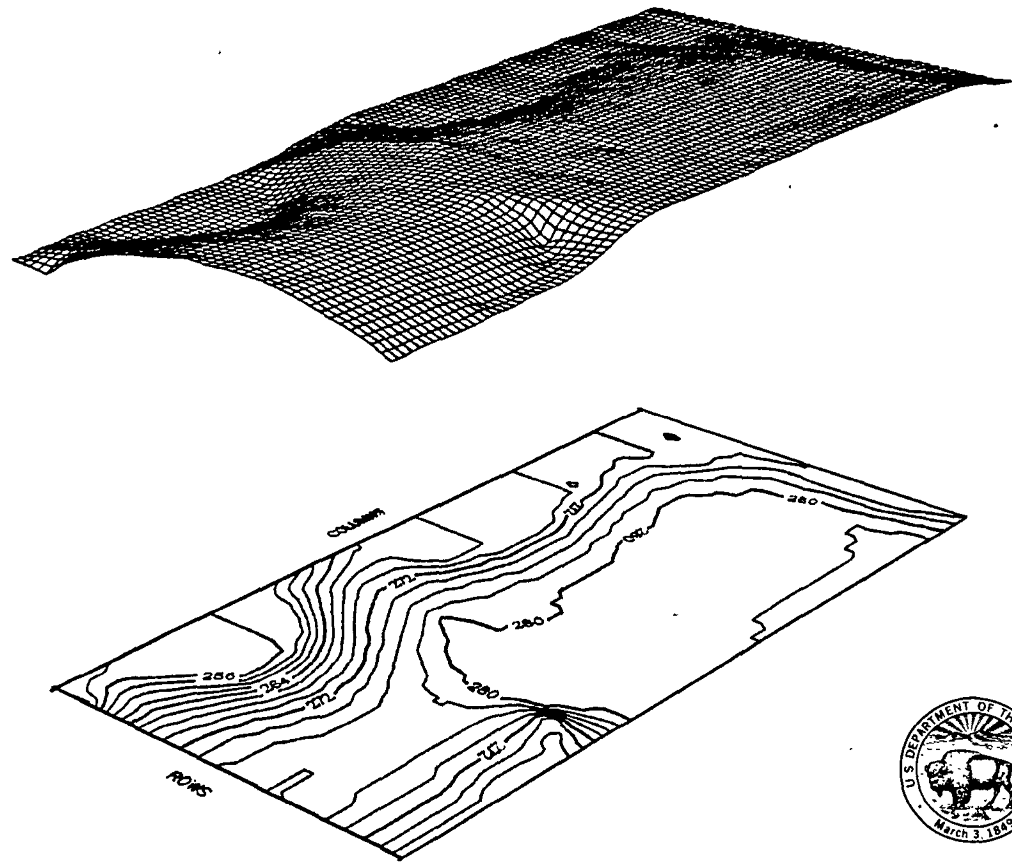
HYDROLOGY OF THE REELFOOT LAKE BASIN, OBION AND LAKE COUNTIES, NORTHWESTERN TENNESSEE

U.S. GEOLOGICAL SURVEY

Water Resources Investigations Report 85-4097



PREPARED IN COOPERATION WITH THE
TENNESSEE WILDLIFE RESOURCES AGENCY

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Cover--Model-simulated water-level contour map and 3-D projection of potentiometric surface for Reelfoot Lake study area for September 1984 water levels. Water levels in feet above sea level.

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By Clarence H. Robbins

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Nashville, Tennessee
1985

UNITED STATES DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
A-413 Federal Building
U.S. Courthouse
Nashville, Tennessee 37203

Copies of this report can be
purchased from:

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CONTENTS

ILLUSTRATIONS

Plates
(In pocket)

ILLUSTRATIONS

TABLES

CONVERSION FACTORS

For readers who may prefer to use the International System of Units (SI) rather than the inch-pound units used herein, the conversion factors are listed below:

Multiply	By	To obtain
acre	0.4047	hectare (ha)
acre-foot (acre-ft)	1233	cubic meter (m^3)
foot (ft)	0.3048	meter (m)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot squared per day (ft^2/d)	0.0929	meter squared per day (m^2/d)
inch (in.)	25.40	millimeter (mm)
inch per year (in/yr)	25.40	millimeter per year (mm/yr)
square mile (mi^2)	2.590	square kilometer (km^2)
mile (mi)	1.609	kilometer (km)

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Clarence H. Robbins

ABSTRACT

Hydrologic data and analyses and ground-water modeling results are provided to aid in the evaluation of proposed lake management strategies for Reelfoot Lake in northwestern Tennessee. Surface-water and ground-water data collected from May 1 to December 31, 1984, were used to evaluate the Reelfoot Lake hydrologic system. Long-term streamflow, rainfall, evaporation, and lake-level data were used to describe the normal hydrologic conditions at Reelfoot Lake.

Estimated monthly water budgets, assuming normal climatic and hydrologic conditions, were derived for Reelfoot Lake in order to determine the time required to refill the lake beginning on November 1, following a proposed mid-summer drawdown of 5.8 feet below normal pool. Additionally, estimates of the time required to fill the lake to 1.0 foot above normal pool were made. Results of these determinations indicate that a normal pool elevation of 282.20 feet above sea level would probably be achieved by mid-January, and a pool elevation of 283.24 feet above sea level by the end of January.

A calibrated two-dimensional ground-water flow model was used to simulate ground-water levels following the proposed lake drawdown and refill. Simulation results are presented as ground-water level difference maps which indicate the potential difference in ground-water elevations for the two proposed lake-level extremes. Low lake-level simulation results indicate ground-water levels may decline approximately 5.7 feet below normal in the areas immediately adjacent to the lake. The high lake-level simulation results indicate ground-water levels may increase approximately 1.0 foot above normal in the areas immediately adjacent to the lake.

INTRODUCTION

Reelfoot Lake is located in northwestern Tennessee in Lake and Obion Counties (plate 1). It is the largest natural lake in Tennessee, with approximately 15,500 acres at a normal pool elevation of 282.2 feet above sea level. The Reelfoot Lake drainage basin covers 240 mi^2, including a small part in Kentucky. The lake lies within the Mississippi embayment section of the Gulf Coastal Plain. Topographically, the area is characterized by several prominent physiographic features: Reelfoot Lake, Mississippi River and flood plain, Tiptonville Dome, a bluff line which bisects the basin along a northeast-southwest axis, and the uplands east of the bluffs (plate 1).

Sedimentation from the bluffs, uplands, and flood plain is contributing to an accelerated deterioration of the lake and its wetland areas. The potential loss of Reelfoot Lake with its economic and wildlife resources has prompted the State to consider several management strategies designed to help restore the lake and its environs.

The Tennessee Wildlife Resources Agency (TWRA) has been designated by the State legislature as the lead agency for management of Reelfoot Lake. TWRA has proposed a lake management strategy composed of a mid-summer drawdown of 5.8 feet below normal pool (276.4 feet above sea level), followed by a temporary late fall refill to 1.0 foot above normal pool (283.2 feet above sea level). According to TWRA, the purpose of the drawdown would be to expose large areas of unconsolidated colloidal sediments and to allow these areas to compact and dry for a period of 120 days. The purpose of the temporary above normal pool refill would be to create a larger fish habitat area to aid in repopulation of the lake.

Before this management strategy can be implemented, the State has determined that several potential environmental and social impacts must be evaluated. WRA was requested by a State legislative task force to prepare an environmental assessment of the impacts of this proposed management strategy on Reelfoot Lake and the surrounding area. The U.S. Geological Survey was requested by TWRA to make the necessary study pertaining to basin hydrology. Results of this study will be integrated by TWRA into an environmental assessment for Reelfoot Lake.

PURPOSE

The purpose of this report is to provide hydrologic data and analyses and ground-water modeling results that can be used in the evaluation of the lake management proposal. The purpose of the study is to describe: (1) hydrologic conditions during the study period, (2) normal hydrologic conditions at Reelfoot Lake, and (3) the potential effects of implementing the proposed lake management strategy on the surface-water and ground-water regimes when compared to normal hydrologic conditions.

SCOPE

This report describes the surface- and ground-water hydrology in the Reelfoot Lake basin based on available data and under the hydrologic conditions that existed during the period of data collection (May-December 1984). The report is intended to furnish the following information related to proposed lake-management strategy:

1. The expected rate of refill to normal pool beginning November 1 under normal hydrologic and climatic conditions.
2. The ground-water flow patterns in the Reelfoot Lake area.
3. The expected effects of the Mississippi River on ground-water levels and surface runoff at high and low lake levels.
4. The expected effects of above-normal lake levels on water levels in the alluvial water-table aquifer.

5. The expected effects of below-normal lake levels on water levels in the alluvial water-table aquifer.
6. The outflow discharge rates necessary for maintaining lake levels at the drawdown level during the period June 1 to October 31, under normal climatic and hydrologic conditions.

The data used in this study were collected as part of a separate cooperative program between the U.S. Geological Survey, the Tennessee Department of Health and Environment (Division of Water Management) and the Tennessee Wildlife Resources Agency. In addition to the data collected by the Geological Survey, rainfall and evaporation data were furnished by the National Weather Service in Memphis, Tenn. All surface-water and ground-water elevations in this report are referred to in feet above sea level.

SURFACE-WATER HYDROLOGY

LAKE STORAGE AND DEPTH CHARACTERISTICS

Bathymetric contour maps of Reelfoot Lake (U.S. Army Corps of Engineers, 1956) were updated using data from depth sounding surveys made in 1983 by the Water Quality and Watershed Research Laboratory of the Agricultural Research Service, Durant, Oklahoma, and in 1984 by the Tennessee Wildlife Resources Agency. The updated bathymetric contour maps were digitized to obtain surface area, capacity, mean depth, and depth characteristics as shown in table 1.

Interpolating between the 282- and 283-foot water-surface elevations in table 1, Reelfoot Lake has a surface area of approximately 15,500 acres, a volume of approximately 80,300 acre-ft, and a mean depth of approximately 5.2 feet at the normal pool elevation of 282.2 feet. Approximately 43 percent of the total lake area has a depth of 3.0 feet or less at this stage. At the proposed mid-summer drawdown elevation of 276.4 feet, Reelfoot Lake would have a surface area of approximately 5,340 acres, a volume of approximately 19,700 acre-ft, and a mean depth of approximately 3.7 feet. Approximately 68 percent of the total lake area would have a depth of 3.0 feet or less at this stage. The temporary late fall pool elevation of 283.2 feet would give Reelfoot Lake a surface area of approximately 19,500 acres, a volume of approximately 99,700 acre-ft, and a mean depth of approximately 5.2 feet. Approximately 44 percent of the total lake area would have a depth of 3.0 feet or less at this stage.

A water-surface elevation staff gage was maintained by the Geological Survey at the Reelfoot Lake spillway from July 23, 1940, to December 31, 1970. Continuous water-surface elevation data have been collected since December 2, 1970, at a gaging station about 0.75 mile west of the spillway. The maximum water-surface elevation of record at Reelfoot Lake, 287.22 feet based on surveyed high-water marks, occurred in January 1937. The minimum water-surface elevation of record, 279.59 feet, occurred on November 20-21, 1953.

Results of a stage-duration analysis based on the period of continuous record from December 1970 through September 1983 are shown in figure 1. The data base used for this analysis consisted of instantaneous lake stage readings

Table 1.--Surface area, contents, mean depth, and depth characteristics of Reelfoot Lake

Elevation of water surface, in feet above sea level	Surface area, in acres	Contents, in acre-ft	Mean depth, in feet	Percent area with depth of 1 foot or less	Percent area with depth of 2 feet or less	Percent area with depth of 3 feet or less
263	7.9	9.5	1.2	--	--	--
4	47.3	56.8	1.2	83	--	--
265	144	201	1.4	67	95	--
6	327	528	1.6	56	86	98
7	460	988	2.1	29	69	90
8	616	1,600	2.6	25	47	77
9	748	2,350	3.1	18	39	56
270	925	3,280	3.5	19	33	50
1	1,100	4,380	4.0	16	32	44
2	1,290	5,670	4.4	15	28	42
3	1,510	7,180	4.7	15	27	39
4	2,010	9,190	4.6	25	36	45
275	3,250	12,440	3.8	38	53	60
6	4,660	17,100	3.7	30	57	68
7	6,360	23,460	3.7	27	49	68
8	7,430	30,890	4.2	14	37	56
9	8,460	39,350	4.6	12	25	45
280	10,200	49,550	4.9	17	27	38
1	12,100	61,650	5.1	16	30	39
2	14,800	76,450	5.2	18	31	43
3	18,400	94,850	5.2	19	34	44
4	24,000	119,000	5.0	24	38	49
285	33,500	152,000	4.5	28	45	56

Note.--Computation of percent area with depths of 1, 2, or 3 feet or less assumes a smooth lake bottom with depths gradually decreasing toward the shore line.

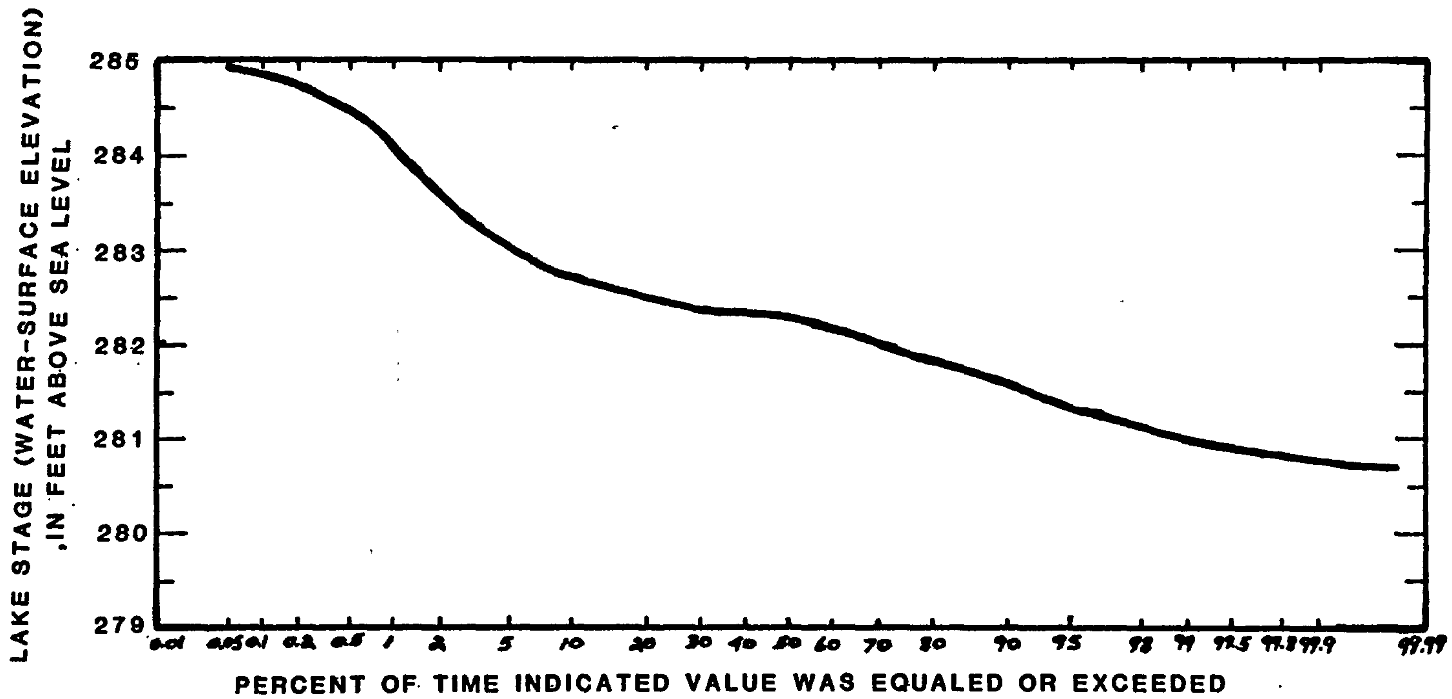

Figure 1.-- Stage-duration curve for Reelfoot Lake November 1970 to September 1983.

at midnight for the period of record. The analysis indicates that a water-surface elevation of 282.3 feet has been equaled or exceeded 50 percent of the time during the period of record. A water-surface elevation of 283.0 feet has been equaled or exceeded 5 percent of the time, and a water-surface elevation of 280.7 feet has been equaled or exceeded 99.98 percent of the time since December 1970.

RAINFALL

Total monthly rainfall over Reelfoot Lake from May 1 to December 31, 1984, was computed using the Thiessen method (Linsley and others, 1975, p. 78-83). Rainfall data needed for these computations were obtained from two Geological Survey stations at Reelfoot Lake and from the National Weather Service station at Samburg (plate 1). The total monthly rainfall was then compared to the 30-year standard normal (1951-80) monthly rainfall at the National Weather Service station at Samburg to determine the departure of the total monthly rainfall during the study period from rainfall for the 30-year standard normal period (table 2).

On an average annual basis, the minimum monthly rainfall normally occurs in October (2.55 inches) and the maximum monthly rainfall normally occurs in March (5.05 inches). During the 8-month study period, a minimum monthly rainfall of 1.16 inches occurred in July, 1984, and a maximum monthly rainfall of 9.89 inches occurred in October 1984. The July rainfall was 2.79 inches below normal and the October rainfall was 7.34 inches above normal (table 2).

EVAPORATION

Monthly pan evaporation data were obtained from the National Weather Service stations at Martin, Tenn. (approximately 28 miles east southeast of Reelfoot Lake), and Jackson, Tenn. (approximately 62 miles south southeast of Reelfoot Lake) for the period 1977-84. The Martin station is not operational during the months of November through March each year. Therefore, it was necessary to estimate pan evaporation at Martin for these months using the Jackson station assuming the interstation correlation is constant year round. The coefficient of determination (r^2) which is the ratio of the sum of squares for this analysis was 0.97, and the equation describing the relation is as follows:

$$M = 1.01J - 0.56 \qquad (1)$$

where M is mean monthly pan evaporation at Martin, Tenn., and
J is mean monthly pan evaporation at Jackson, Tenn.

Monthly free water-surface evaporation for the May 1 to December 31, 1984 period was estimated using the Martin monthly pan evaporation data and mean monthly estimates, and a pan coefficient of 0.76 (U.S. Department of Commerce, 1982). Although evaporation from a lake surface may differ significantly from free water-surface evaporation during a given month because of changes in heat storage in the lake, it was assumed for the purposes of this study that free water-surface evaporation and lake-surface evaporation were equivalent. The

Table 2.--Comparison of the total monthly rainfall over Reelfoot Lake for the period May-December 1984 to the 30-year standard normal (1951-80) monthly rainfall at the National Weather Service station at Samburg, Tennessee

[NR = no record]

	Monthly rainfall, in inches											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
30-year standard normal for Samburg station.	4.04	3.91	5.05	4.74	4.89	3.75	3.95	3.22	3.08	2.55	4.36	4.36
Total monthly rainfall over Reelfoot Lake	NR	NR	NR	NR	7.45	1.90	1.16	1.63	4.29	9.89	4.15	7.29
Departure from normal.	NR	NR	NR	NR	+2.56	-1.85	-2.79	-1.59	+1.21	+7.34	-0.21	+2.93

estimates of monthly lake-surface evaporation, and mean monthly pan evaporation for the National Weather Service stations at Martin and Jackson are listed in table 3. It should be noted the estimates of lake-surface evaporation (based on estimates of free water-surface evaporation) are probably biased by the hysteresis effect of heat storage in the lake.

On an average annual basis, pan evaporation at Martin and lake-surface evaporation at Reelfoot Lake are lowest in January (0.69 inch and 0.52 inch, respectively) and highest in June (7.51 inches and 5.71 inches, respectively). During the study period, a minimum monthly mean pan evaporation at Martin (1.15 inches) and a minimum monthly lake-surface evaporation at Reelfoot Lake (0.87 inches) occurred in December. A maximum monthly pan evaporation at Martin (7.66 inches) and a maximum lake-surface evaporation at Reelfoot Lake (5.82 inches) occurred in June during the study period.

SURFACE-WATER INFLOW AND OUTFLOW

Reelfoot Lake has three major tributaries, Reelfoot Creek, Indian Creek, and Running Slough, and one major outflow, Running Reelfoot Bayou (plate 1). Surface flow into and out of Reelfoot Lake was continuously monitored at gaging stations on each of these streams, except Indian Creek (07026795), during the study period, May 1 to December 31, 1984, as part of a separate cooperatively funded project. Indian Creek was monitored September 1 to December 31, 1984. The monthly flows for these stations were computed in terms of volume per unit time and then divided by the drainage area of each gaging station to obtain monthly surface runoff in inches. Monthly surface runoff into Reelfoot Lake at these gaging stations ranged from 9.14 inches for Running Slough at Ledford, Ky. (07026640), in May, to 0.0 inch for Running Slough and North Reelfoot Creek (07026370) in August and September (table 4). Surface outflow from Reelfoot Lake is regulated by a low-head spillway with gates, and the discharge is usually a function of surface inflow. Outflow ranged from 5.22 inches in May to 0.01 inch in September at the gaging station 1.5 river miles downstream from the spillway.

Of the 240 mi^2 drainage area, approximately 24.2 mi^2 (10 percent) are covered by the lake at normal pool. Approximately 111 mi^2 (46 percent) of the total drainage area had flows which were not measured from May to September 1984, and from September through December 1984, approximately 103 mi^2 (43 percent) had flows which were not measured. Approximately 38.1 mi^2 (37 percent) of the ungaged area are in the Mississippi River flood plain and are affected by water seeping from the Mississippi River during the months of December through May. During this period, the water-surface elevation of the Mississippi River is normally 10 to 20 feet higher, on the average, than the water-surface elevation of Reelfoot Lake and its tributaries draining the Mississippi River flood plain.

The seepage water sustains flow in the flood plain tributary streams at a higher volume than that normally attributed to rainfall during the December through May period. For example, total surface runoff for Running Slough at Ledford, Ky., for May 1984 was 9.14 inches, while the total rainfall for the month was only 7.45 inches Streamflow data from the other surface inflow

Table 3.--Pan evaporation for National Weather Service stations at Martin and Jackson, Tennessee, and lake-surface evaporation for Reelfoot Lake

[NR = no record or estimate]

	Jackson mean monthly 1977-84, in inches	Martin mean monthly 1977-84, in inches	Martin monthly 1984, in inches	Reelfoot Lake monthly 1984, in inches	Reelfoot Lake mean monthly 1977-84, in inches[c]
January	1.23	0.69[a]	NR	NR	0.52
February	1.40	0.86[a]	NR	NR	0.65
March	3.51	3.00[a]	NR	NR	2.28
April	5.89	5.02	4.34	3.30[b]	3.82
May	6.68	5.89	6.41	4.87[b]	4.48
June	7.75	7.51	7.66	5.82[b]	5.71
July	7.84	7.44	7.30	5.55[b]	5.65
August	6.98	6.62	5.45	4.14[b]	5.03
September	5.27	5.02	4.65	3.53[b]	3.82
October	4.08	3.69	2.76	2.10[b]	2.80
November	3.38	2.87[a]	NR	2.18[c]	2.18
December	1.69	1.15[a]	NR	0.87[c]	0.87

a Estimated from mean monthly pan evaporation at Jackson, Tenn.
b Estimated from monthly pan evaporation at Martin, Tenn., and a pan coefficient of 0.76.
c Estimated from mean monthly pan evaporation estimate at Martin, Tenn., and a pan coefficient of 0.76.

Table 4.--Monthly runoff for surface-water inflow and outflow stations, estimates for ungaged area, and mean monthly runoff from a long-term continuous-record station
[1 = inflow, 2 = outflow, NR = no record or estimate]

Gaging station or area	Drainage area (mi^2)	Runoff during study period, in inches											
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
North Reelfoot Cr. at Hwy 22 near Clayton, Tenn.1/ (07026370).	56.3	NR	NR	NR	NR	4.66	0.27	0.12	0.0	0.0	2.26	1.10	3.85
South Reelfoot Cr. near Clayton,Tenn.1/ (07026400).	38.6	NR	NR	NR	NR	4.20	0.14	0.04	0.0	0.03	1.66	2.53	4.14
Indian Cr. near Samburg, Tenn.1/ (07026795).	8.01	NR	NR	NR	NR	NR	NR	NR	NR	0.10	2.22	1.19	3.18
Running Slough near Ledford, Ky.1/ (07026640).	10.8	NR	NR	NR	NR	9.14	0.34	0.06	0.0	0.0	0.27	0.18	3.11
Ungaged Area1/	111 (May-Sept.) 103 (Sept.-Dec.)	NR	NR	NR	NR	6.21	0.26	0.12	0.0	0.03	1.49	1.16	3.77
Running Reelfoot Bayou near Owl City, Tenn.2/ (07027010).	247	NR	NR	NR	NR	5.22	0.37	0.33	0.27	0.01	0.27	1.31	2.95
Long-term continuous-record station (1951-73)													
Reelfoot Cr. near Samburg, Tenn.1/ (07026500).	110	1.99	2.03	2.43	1.92	1.77	0.69	0.80	0.40	0.39	0.21	0.89	1.44

stations indicate that approximately 60 percent of the total rainfall in May became surface runoff. Assuming that the same percentage of total rainfall applies to the gage on Running Slough, approximately 4.5 inches of the 9.14 inches of runoff in May was produced by rainfall. The remaining 4.6 inches of runoff is assumed to be seepage from the Mississippi River.

Surface inflow from the remaining 64.9 mi^2 (63 percent) of the ungaged area is similar to that at the three gaging stations in the Mississippi bluff and upland areas (plate 1). Based upon the areal extent of the two runoff-area types (the Mississippi River flood plain and the Mississippi bluff and uplands), monthly runoff was estimated for the ungaged area using a weighted average unit runoff coefficient. Results of these determinations, along with the measured total monthly runoff for the study period from the gaged areas are listed in table 4.

In addition to streamflow data collected during the study period, the Geological Survey maintained a continuous-record streamflow station on Reelfoot Creek near Samburg, Tenn. (07026500), from January 1, 1951, to September 30, 1973. Monthly mean runoff was computed for this station for the period of record (table 4). The minimum monthly mean runoff of 0.21 inch occurred in October, and the maximum monthly mean runoff of 2.43 inches occurred in March. Months in which these extremes occurred are the same months in which the rainfall extremes occurred during the 30-year standard normal period at the Samburg, Tenn., rainfall station (table 2).

ESTIMATED MONTHLY WATER BUDGET FOR REELFOOT LAKE

A monthly water budget for Reelfoot Lake was estimated for the study period May 1 to December 31, 1984. Hydrologic components included in the water budget were: (1) net change in lake storage, (2) surface-water inflow, (3) surface-water outflow, (4) rainfall, (5) lake-surface evaporation, and (6) ground-water inflow and outflow.

Evapotranspiration losses were not evaluated, and the amount of ground-water inflow or outflow at Reelfoot Lake was estimated as the residual of the monthly water budget. The ground-water inflow or outflow was estimated by substituting the monthly values of the hydrologic budget components indicated in the previous sections of this report into the following equation:

$$S = SI + P - SO - E \pm GW \tag{2}$$

where S is net change in lake storage, in acre-feet,
SI is total surface flow into the lake, in acre-feet,
P is total rainfall into the lake, in acre-feet,
SO is total surface flow out of the lake, in acre-feet,
E is total lake-surface evaporation, in acre-feet, and
$\pm$ GW is net ground-water flow into (+) or out of (-) the lake, in acre-feet.

Results of the computations using equation 2 and the values used for each hydrologic budget component are listed in table 5. Uncertainties associated with the monthly water-budget computations are discussed in a later section of this report.

Table 5.--Estimated monthly water budget for Reelfoot Lake for the period May 1 to December 31, 1984

Hydrologic budget component	Volume of water, in acre-feet							
	May	June	July	August	September	October	November	December
Net change in lake storage	-100	-10,600	-12,600	-7,700	-700	+27,000	+1,700	+24,700
Total rainfall into lake.	11,260	2,440	1,340	1,600	4,040	11,350	5,560	10,640
Total surface flow into lake.	64,700	2,820	1,170	0	250	19,500	15,200	43,900
Total surface flow out of lake.	68,800	4,870	4,350	3,560	130	3,560	17,300	38,900
Total lake-surface evaporation.	7,360	7,490	6,390	4,060	3,330	2,410	2,920	1,270
Net ground-water flow into (+) or out of (-) the lake.	+100	-3,500	-4,370	-1,680	-1,530	+2,120	+1,160	+10,330

Calculations were made to determine the length of time required to refill the lake during a normal climatic year to normal pool (282.2 feet) from a water-surface elevation of 276.4 feet beginning on November 1. The following assumptions were made for these calculations:

(1) Normal monthly rainfall (table 2).
(2) Normal monthly lake-surface evaporation (table 3).
(3) Normal monthly surface-water inflow (runoff) into the lake.
(4) Negligible evapotranspiration losses.
(5) No surface-water outflow.
(6) The amount of water needed to refill the lake is the volumetric difference in storage between the starting and ending water-surface elevations from table 1 (60,600 acre-ft).
(7) A net ground-water inflow of 5,000 acre-ft (based on average of October, November, and December ground-water inflow in table 5).

Mean monthly runoff from the long-term continuous-record station (table 4) was used to compute normal monthly surface-water inflow to the lake from the bluff and upland areas for the refill period. In order to account for the effects of seepage from the Mississippi River on runoff volumes in the flood plain tributaries, an adjusted normal monthly surface-water inflow was computed for the flood plain area.

A ratio of the 30-year standard normal monthly rainfall to the study period monthly rainfall (table 2) was multiplied by the study period monthly runoff at Running Slough at Ledford, Ky. (table 4), to obtain a normal monthly runoff for Running Slough. Normal monthly runoff for Running Slough was used to compute the normal monthly surface-water inflow to the lake from the flood plain area. Normal monthly inflow volumes for the bluff, upland, and flood plain areas were summed to give a total normal monthly inflow to the lake, item 3 above, for the refill period.

This procedure required compilation of additional discharge and rainfall data for Running Slough for January 1985. The volume of runoff for Running Slough for January 1985 is 2.37 inches and the Thiessen corrected total rainfall is 1.69 inches. Results of the lake refill computations and the values used in equation 2 for each hydrologic budget component are listed in table 6.

Table 6.--Estimated monthly water budget for Reelfoot Lake for refill period beginning November 1 in a normal climatic year

Hydrologic budget component	Volume of water, in acre-feet		
	November 1-30	December 1-31	January 1-31
Total rainfall into lake.	1,940	2,870	4,040
Total surface flow into lake.	9,240	18,500	32,100
Net ground-water inflow.	5,000	5,000	5,000
Total lake-surface evaporation.	970	574	520
Net change in lake storage.	15,210	25,800	40,620
Cumulative net change in lake storage.	15,210	41,010	81,630
Water-surface elevation, in feet above sea level by end of month.	278.45	280.85	283.24

According to the calculations as shown in table 6, if no water is released through the spillway starting on November 1, Reelfoot Lake will fill to approximately 1 foot above normal pool by January 31 in a normal climatic year.

Depending upon climatic conditions, more or less time may be required to refill Reelfoot Lake to a desired pool elevation in any given year. The controlling hydrologic factor in the monthly water budget is total rainfall. Rainfall determines: (1) the volume of water added directly to the lake surface; (2) the antecedent soil moisture conditions which control, to a large extent, the proportional volume of rainfall that becomes surface runoff; and (3) the volume of water available to ground-water recharge. Rainfall also influences river stage which affects the volume of seepage from the Mississippi River.

UNCERTAINTIES IN ESTIMATING THE MONTHLY WATER BUDGET FOR REELFOOT LAKE

Errors or uncertainties in measuring and estimating the hydrologic components interacting with a lake can have a significant impact on the calculation of the water budget of the lake. The errors can be large if one or more components are calculated as the residual term, and the errors in the measured components are not considered in the interpretation of that residual term (Winter, 1981).

The errors associated with the hydrologic components in a water budget can be broadly classified into those of measurement and regionalization (interpretation) (Winter, 1981). Measurement errors result from measuring a quantity at a point using imperfect instruments and inadequate sampling design and data collection procedures. Regionalization errors result from estimating quantities in a time space continuum through extrapolation from point data. Both types of errors, in turn, are influenced by one's understanding of the controlling physical principles; that is, the instrumentation, equations, and techniques used to regionally extend the point data (Winter, 1981).

Water budgets, without estimates of errors, can be misleading and can give a false impression about how well the budgets are known. No water budget is without error when compared to the exact natural phonomena and interdependency of the controlling hydrologic components. Therefore, an error analysis of the hydrologic components in the monthly water budget for Reelfoot Lake was performed in order to put the monthly water budget in perspective. This error analysis allows the use and limitations of the information contained in the water budget to be assessed by the reader and allows the budget to be used realistically.

Ground-water flow into or out of Reelfoot Lake was calculated as the residual of the water-budget equation; therefore, monthly ground-water flow estimates contain errors (uncertainties) resulting from each of the hydrologic components used in the water-budget equation along with the error associated with neglecting evapotranspiration losses. The magnitude of the error associated with measurement or interpretation of each hydrologic component was determined by methods described by Winter (1981) and is shown in table 7.

Table 7.--Hydrologic components used in the monthly water-budget calculations and percent error associated with the measurement or interpretation of each component

	Hydrologic factor					
	Net change in lake storage	Total surface-water inflow	Total surface-water outflow	Total rainfall	Total lake-surface evaporation	Net ground-water flow (residual)
Estimate of potential error, in percent.	20	15	5	15	50	40*
Average monthly quantity of water represented by the error, in acre-feet.	2,130	2,770	878	905	2,200	1,310

* Varies monthly depending upon the magnitude of each hydrologic component's contribution to the total water budget, and decreases as longer time periods are considered. The error represents an average of the maximum potential positive and negative accumulated errors using the percentage figures given for each component in the table.

In order to relate these estimates of error to the calculation of ground-water flow at Reelfoot Lake, numerous possible combinations of the magnitude and sign of the errors are possible. In computing the ground-water flow for this study, it was assumed that the errors shown in table 7 are independent and that there is some compensation of measurement and interpretation errors that are too high with those that are too low. Additionally, it was assumed that the monthly values of the hydrologic budget components in tables 5 and 6 reflect this compensation and represent the best possible values using accepted hydrologic methodology and the given data base.

A ground-water flow simulation model was developed to check independently the residual term of equation 2 (net ground-water flow into or out of Reelfoot Lake) and to estimate the effects of the proposed lake-management strategies on ground-water levels surrounding the lake. The model and the results of the analysis are discussed in the following sections of this report.

GROUND-WATER HYDROLOGY

The following generalized discussion is from Strausberg and Schreurs (1958) except where noted.

The three uppermost geohydrologic units in the vicinity of Reelfoot Lake, in descending order, consist of approximately 100 to 200 feet of Mississippi River alluvium (water-table aquifer), approximately 250 feet of clay and fine sand (confining unit), and approximately 600 feet of highly permeable sand (Memphis Sand). Proposed lake-level manipulations are assumed to effect only the ground-water levels in the alluvial water-table aquifer.

The alluvium consists of a sequence of sedimentary deposits which grade irregularly upward from gravel and coarse sand into progressively finer grained deposits of sand, silt, and clay. Average thickness of the alluvium is about 140 feet. The alluvium may be divided into a lower permeable sand and gravel unit and an upper, less permeable unit, because of the general upward decrease in grain size. The ground-water system generally is under water-table conditions; however, localized artesian conditions may exist where the upper unit contains significant amounts of clay.

Results of aquifer tests in the Mississippi River alluvium (Boswell and others, 1968) indicate that the transmissivity of the alluvium in the vicinity of Reelfoot Lake is approximately 45,500 ft^2/d. Although transmissivity probably varies areally, no additional data are available, and the transmissivity is assumed to be constant throughout the study area.

The principal source of recharge to the alluvial water-table aquifer is precipitation. According to a study by Zurawski (1978), between 17 and 20 percent of the average annual precipitation becomes recharge to the alluvial aquifer. This percentage range yields approximately 8.1 to 9.6 in/yr of recharge on an average annual basis for the Reelfoot Lake basin and is assumed to be uniformly distributed over the basin. Seepage from the Mississippi River and its tributaries, surface runoff onto the alluvial plain from adjacent uplands, seepage from Reelfoot Lake, and underflow from the bluff area also contribute recharge to the alluvial aquifer.

On a regional scale, ground water moves west toward the Mississippi River; however, when the water-surface elevation of the Mississippi River is higher than the adjacent water-table (generally during December-May), the river contributes to ground-water recharge. The rate of ground-water flow to or from the river is dependent on the head gradient between the water table and the river assuming a uniform distribution of transmissivity. Ground water is also discharged to Reelfoot Lake, tributary streams, and as evapotranspiration by phreatophytes.

A network of 31 observation wells was measured periodically throughout the study period. Potentiometric surface maps of the study area (plates 2 and 3) were prepared for the low (September 1984) and high (December 1984) ground-water elevation periods based on data from the observation wells occurring at the end of each period. At the end of September 1984, ground-water flow was generally from the bluffs toward Reelfoot Lake and then south and west from the lake toward the Mississippi River (plate 2). Additionally, water levels at the north end of the lake indicate a slight gradient (approximately 0.1 foot per mile) from the lake toward the Mississippi River. At the end of December 1984, ground-water flow was generally from the bluffs and Mississippi River toward Reelfoot Lake (plate 3). Ground water flowed from the southern end of the lake toward the Mississippi River during this period also. At the north end of the lake in December, the flow direction was reversed from that in September because of head gradient changes. Both periods indicate a ground-water divide exists between the lake and the Mississippi River (plates 2 and 3). Additionally, a ground-water mound is indicated between the southern end of the lake and the model boundary.

GROUND-WATER MODEL OF THE REELFOOT LAKE STUDY AREA

A computer program developed to simulate ground-water flow (McDonald and Harbaugh, 1984) was used to model the Reelfoot Lake study area. The program uses finite-difference techniques to solve the ground-water flow equation for two- or three-dimensional, steady or nonsteady flow in an isotropic or anisotropic, heterogeneous medium. The model was used in order to simulate and evaluate two-dimensional flow between Reelfoot Lake and the Mississippi River. Vertical-flow components, which may be present locally where silt and clay confine the aquifer, are not simulated in the two-dimensional analysis. Neglecting vertical-flow components is assumed to have a negligible effect on the overall model analysis. The aquifer was assumed to be homogeneous and isotropic.

The calibration scheme for modeling was to match the general hydrologic conditions and observed ground-water levels occurring at the end of two periods: August to September 1984 and November to December 1984. The physical properties of the aquifer, such as geometry and transmissivity, were held constant for each period. Seasonal variations between modeling periods were simulated by changing the water levels and the areal extent of the lake, its tributaries and outflow, and the Mississippi River. Steady-state conditions were assumed for modeling purposes, although hydrographs from the observation wells, Mississippi River, and Reelfoot Lake, indicate that water levels changed very slowly during the two time periods. On the average, water levels in the observation wells, the Mississippi River, and in Reelfoot Lake declined 0.7 feet, 5.0 feet, and 1.0 feet, respectively, during the August-September period and increased 0.5 feet, 2.5 feet, and 1.0 feet, respectively, during the November-December period. Values for transmissivity and recharge were initially chosen based on the previous literature cited.

Model Construction

Finite-difference techniques used in the model require that the ground-water system be divided into rectangular blocks. Average values for the aquifer characteristics are assigned to each grid block, and water-level values are assigned and calculated at the center, or node, of each block. A grid having equal-sized grid blocks was used for the study area. Each grid block represents an area of 0.21 mi^2, 2,400 feet on a side. The finite-difference grid used to simulate ground-water flow in the alluvial aquifer for November-December is shown in plate 4 and for August-September, in plate 5.

The aquifer was simulated as a one layer system having an assumed uniform transmissivity of 45,500 ft^2/d for each grid block. The clay and fine sand (confining unit) underlying the alluvium was assumed to be the impermeable base of the model. The south boundary of the model was assumed to be a no-flow boundary because ground-water flow is generally parallel to the boundary (plates 2 and 3).

Grid blocks that represent the Mississippi River (north and west boundaries, plates 4 and 5) were simulated as constant head nodes, and ground-water flow across this boundary was calculated by the model for both simulation periods. Each grid block that represents the river was assigned a water level based on the measured or calculated stage at that river mile occurring at the end of each simulation period. The large river meander along the west boundary (plates 4 and 5) was projected onto the grid as a straight line. The water levels for these grid blocks were adjusted to compensate for the change in water-surface elevation with distance.

Grid blocks corresponding to Reelfoot Lake, its tributaries, and Running Reelfoot Bayou, which is the lake outflow (plates 4 and 5) were also modeled as constant head nodes in direct contact with the aquifer. Ground-water flow across these boundaries was calculated by the model for both simulation periods. Measured surface-water levels which occurred at the end of each simulation period were used as input for the constant head nodes. Comparisons of the lake hydrograph with hydrographs of wells located near the lake indicate a good hydraulic connection between the lake and the aquifer. Changes in lake level and water levels in the aquifer appear to be simultaneous.

Grid blocks representing inflow from the bluff area along the east boundary (plates 4 and 5) were modeled as constant-flux nodes. The rate of flow for each simulation period was estimated from flow net analyses along the bluff line in plates 2 and 3. An average flow rate of 0.24 ft^3/s was used for each constant-flux node during the August-September period, and 0.98 ft^3/s for the November-December period.

Model Simulation for November-December, 1984

Steady-state ground-water conditions were assumed for the November-December period. Hydrographs from the observation wells indicate water levels changed very slowly during this time period and the system was assumed to be in equilibrium. A net areal recharge to the aquifer of 2.93 inches was assigned to each active model node. This recharge rate is approximately equal to 25 percent of the total rainfall during the 2-month simulation period.

Model results were compared to measured water levels and potentiometric contour lines from plate 3 and to estimates of the ground-water inflow to Reelfoot Lake (table 5). The average head difference between model-calculated and measured ground-water level values is 0.8 foot, and head differences range from 8.6 feet to -4.4 feet. The calculated root mean square error and standard deviation of the differences between model-calculated and measured ground-water levels is 2.5 feet and 2.3 feet, respectively.

Overall, the model-calculated water-levels are similar to the observed water levels. Model-calculated water levels generally were higher than measured levels except between the south boundary and the lake (plate 6). The lower model-calculated levels in this area may indicate that assumed aquifer transmissivity in this area was too large, or that ground-water seepage to tributary streams was overestimated, or that recharge rates to this area were underestimated. The higher model-calculated water levels along the east boundary of the model (plate 6) may have resulted from using an over-estimated average constant-flux rate for each node along the full length of the boundary, rather than a constant-flux rate for each node that varied with the computed flux rates from the flow net analyses. Higher model-calculated water levels may also be due to inaccuracies in simulating this boundary with respect to its actual location in the study area.

The model-calculated ground-water inflow to Reelfoot Lake for the 2-month simulation period is 71.6 ft^3/s (8,660 acre-ft), and the estimated water-budget ground-water inflow (table 5) is 95.0 ft^3/s (11,490 acre-ft). In this report, the ground-water flow in acre-feet is a conversion of an instantaneous flow rate to a 2-month flow rate. The 23.4 ft^3/s (2,830 acre-ft) discrepancy may result from underestimation of the areal recharge rate during the simulation period, overestimation of the transmissivity distribution, or underestimation of the flux from the east boundary (bluffs). The estimated water-budget ground-water inflow could also be overestimated because of uncertainties associated with calculating ground-water flow as the residual of the water-budget equation. The potential error associated with this calculation is approximately 40 percent. Therefore, the model-calculated value is within the accuracy range of the water-budget method.

Model Simulation for August-September 1984

Steady-state ground-water conditions were also assumed for the August-September period. Hydrographs from the observation wells indicate water levels changed very slowly during this time period and the system was assumed to be in equilibrium. This model simulation included the same transmissivity value used in the simulation of November-December conditions. Values for constant head nodes were changed to simulate water levels in the river, lake, and streams occurring at the end of September. Location of some constant head nodes were changed to reflect the lesser areal extent of the river, lake and tributaries (plate 5).

The recharge rate was varied areally in order to simulate evapotranspiration by phreatophytes in the approximately 31.5 mi^2 wetland area (estimated from topographic maps) along the west and north shores of the lake. Grid blocks representing the wetland area were simulated with no recharge, because evapotranspiration is assumed to equal recharge in the wetland area. The remaining model nodes were assigned an areal recharge of 2.93 inches for this simulation period. Although this recharge volume is equal to approximately 49 percent of the total rainfall during the 2-month simulation period, it was required in order to obtain an acceptable model simulation of observed ground-water levels. This recharge volume may be realistic because a lowered water table and other possible hydrologic factors may have resulted in less rejected recharge, resulting in a larger percentage of rainfall contributing to recharge.

Model results for this simulation were compared to the measured water levels and potentiometric contour lines from plate 2 and to estimates of the ground-water outflow from Reelfoot Lake (table 5). The average head difference between model-calculated and measured ground-water level values is -1.9 feet, and head differences ranged from 4.8 feet to -11.5 feet. The calculated root mean square error and standard deviation of the differences between model-calculated and measured ground-water levels is 3.8 feet and 3.4 feet, respectively.

Overall, the model-calculated water levels are similar to the observed water levels. Model-calculated ground-water levels generally were lower than measured levels except between the north boundary and the lake (plate 7). The higher model-calculated water levels in this area may be due to underestimation of the evapotranspiration rate, overestimation of recharge to this area, or underestimation of the transmissivity distribution. The lower model-calculated water levels between the west boundary and the lake (plate 7) may result from projecting the large river meander onto the model grid as a straight line, placing the meander closer to the lake than its true location, or from overestimation of the transmissivity distribution, or from underestimation of recharge to this area.

The model-calculated ground-water outflow from Reelfoot Lake for the 2-month simulation period is 11.7 ft^3/s (1,410 acre-ft). The estimated water-budget ground-water outflow is 26.5 ft^3/s (3,210 acre-ft) (table 5). The 14.8 ft^3/s (1,800 acre-ft) discrepancy may be due to an overestimation of evapotranspiration for the entire wetland area in the model simulation, an overestimation of transmissivity, an underestimation of the constant flux from the east boundary (bluffs), or an underestimation of recharge to the flood plain. The estimated water-budget ground-water outflow could also be overestimated because of uncertainties associated with calculating ground-water flow as the residual of the water-budget equation. The potential error associated with this calculation is approximately 40 percent. Therefore, the model-calculated value is only slightly outside the accuracy range of the water-budget method.

Model Sensitivity

Tests of model sensitivity to variations in input values were made as an integral part of the model-calibration process. The procedure was to hold all input values constant for the November-December simulation period except the one being analyzed and to vary that value through a range that included the uncertainty in the value. Variations in the root mean square error for water levels and model-calculated ground-water inflow to Reelfoot Lake from acceptable calibrated values were used to analyze model sensitivity.

Input values that were varied included transmissivity, recharge, and the constant-flux rate (figs. 2, 3, and 4). Model-calculated ground-water levels were most sensitive to variations in the recharge rate and transmissivity, and least sensitive to variations in the constant-flux rate (figs. 2, 3, and 4). Doubling the recharge rate increased the root mean square error by approximately 3.5 feet, and decreasing the recharge rate by half increased the root mean square error by 1 foot (fig. 2). Decreases in transmissivity increased the root mean square error by as much as 5.0 feet, and increases in transmissivity increased the root mean square error by as much as 1.5 feet (fig. 3). Variations in the constant-flux rate (fig. 4) had a negligible effect on the root mean square error because the constant-flux rate affects only a small part of the overall model area.

Model-calculated ground-water inflow to Reelfoot Lake was most sensitive to variations in the recharge rate and about equally sensitive to variations in transmissivity and the constant-flux rate. Doubling the recharge rate increased the ground-water inflow by 99 percent (70.9 ft^3/s), and decreasing the recharge rate by half decreased the ground-water inflow by 48 percent (34.4 ft^3/s) (fig. 3). Doubling the transmissivity decreased ground-water inflow from the Mississippi River by 25 percent (17.9 ft^3/s), and decreasing the transmissivity by half increased the ground-water inflow from the Mississippi River by 13 percent (9.3 ft^3/s) (fig. 2). Ground-water inflow to Reelfoot Lake is controlled by the head gradient between the aquifer and the lake. As transmissivity is increased, the heads are lowered and the gradient flattens and less flow is delivered to the lake. As transmissivity is decreased, the heads are raised and the gradient steepens and more flow is delivered to the lake. Doubling the constant-flux rate increased ground-water inflow to the lake by 30 percent (21.5 ft^3/s), and decreasing the constant-flux rate by half decreased ground-water inflow by 15 percent (10.7 ft^3/s)(fig. 4). Tests of model sensitivity for the August-September period show approximately the same relations except ground-water outflow from Reelfoot Lake is affected by variations in transmissivity.

Reliability of Model Calibration

The model-calculated water levels for the two simulation periods generally are within $\pm$ 5 feet of the observed water levels for these periods. Reliability of the model results cannot be evaluated solely on the basis of the similarity in water levels because the water levels are, to a large extent, controlled by river and tributary stream elevations and constant head values input to the model. Similarity of model-calculated water levels to measured levels does suggest, however, that the flow quantities and aquifer characteristics used in the model are within reason. The model-calculated ground-water inflow and outflow at Reelfoot Lake generally approximate the estimated ground-water inflow and outflow (table 5). Model results are thought to be as reliable as the estimates reported in table 5 (within approximately 40 percent). Calibration standards were set by the sensitivity analysis. A calibration was considered acceptable when the values used for transmissivity, recharge, and constant flux kept the root mean square error for water levels less than 4.0 feet. A limiting value of 4.0 feet was chosen for the root mean square error because of the generalized nature of the model, use of uniform average transmissivity values, and uncertainty in some of the model parameters.

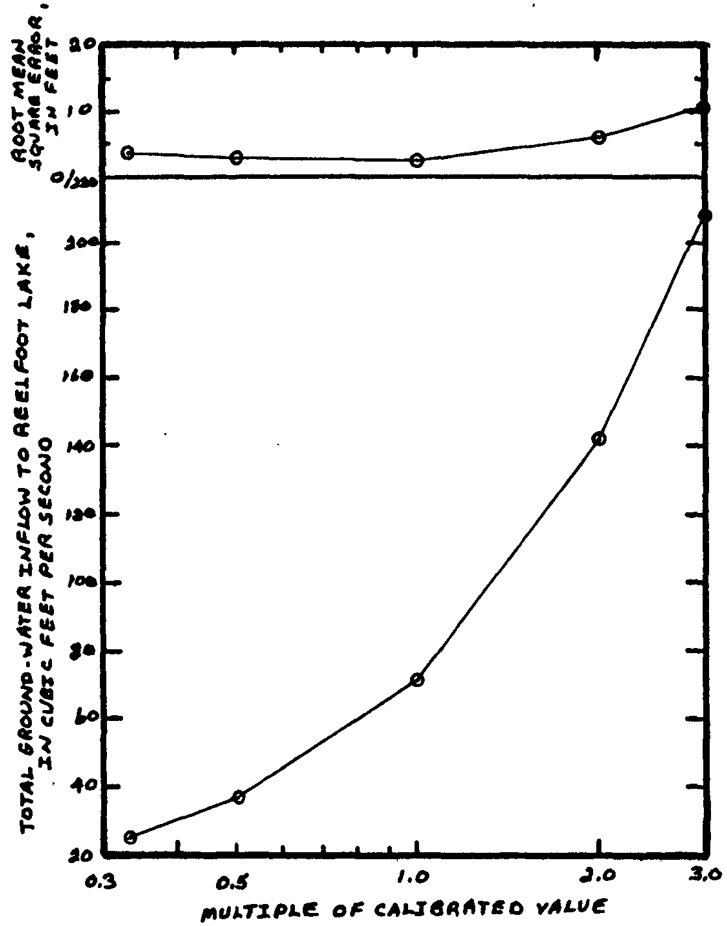

Figure 2.-- Variation of the model-calculated ground-water inflow to Reelfoot Lake and root mean square error as affected by changes in recharge rate.

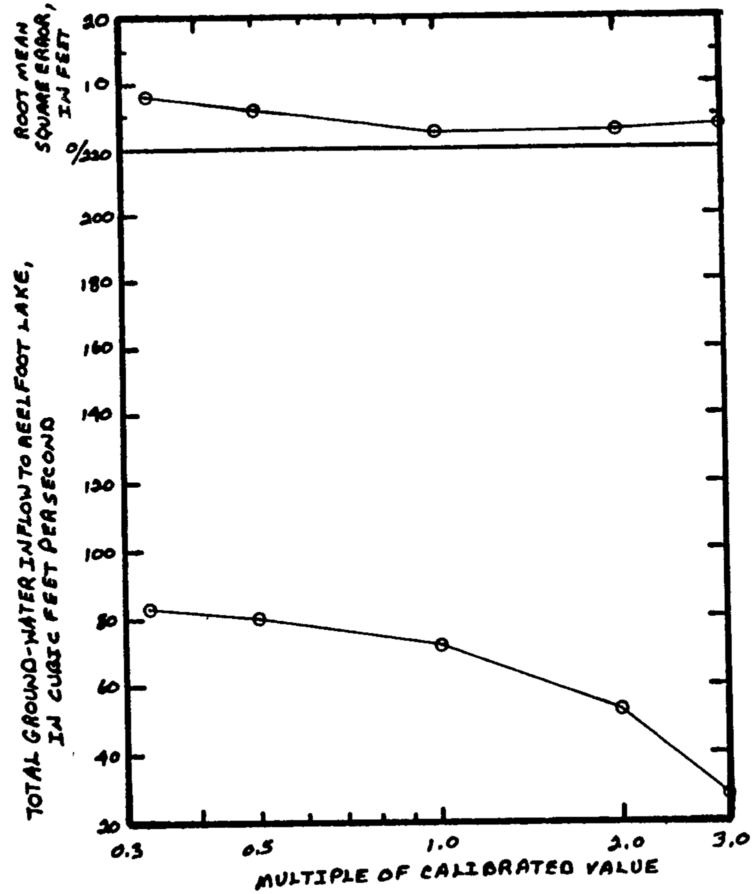

Figure 3 .-- Variation of the model-calculated ground-water inflow to Reelfoot Lake and root mean square error as affected by changes in the aquifer transmissivity.

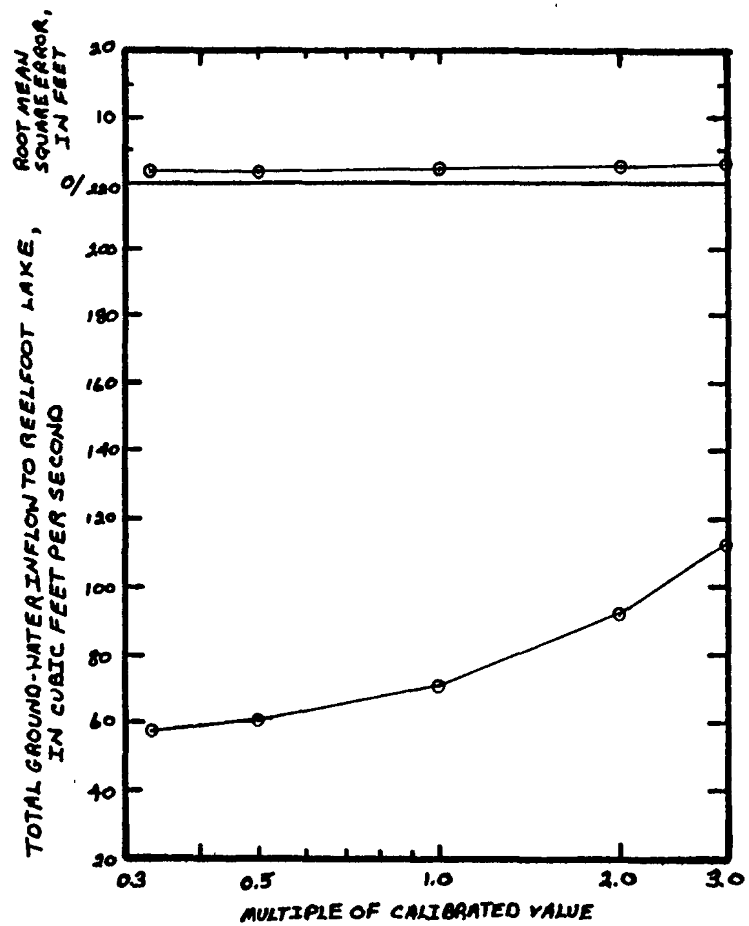

Figure 41.-- Variation of the model-calculated ground-water inflow to Reelfoot Lake and root mean square error as affected by changes in the constant-flux rate.

The relation between evapotranspiration and ground-water inflow and outflow at Reelfoot Lake is the least known factor in this study and, therefore, the most open to question. Evapotranspiration was assumed to affect the August-September simulation period only and was assumed to be equal to the recharge rate. The actual evapotranspiration rate probably is greater than the recharge rate for this season of the year, and the areal distribution of this rate is dependent on phreatophyte type and density. Use of average uniformly distributed recharge and evapotranspiration rates may be considered rough approximations at best.

The value used in the model for aquifer transmissivity is the value reported by Boswell and others (1968) and is considered reliable. Aquifer transmissivity may vary areally around Reelfoot Lake; however, the use of a uniform transmissivity value did result in an acceptably calibrated model for the study area without varying other parameters areally.

Model-calculated ground-water inflow to Reelfoot Lake indicates that the major source of ground-water inflow to the lake is from the bluff area during the winter months. The major mechanisms of discharge from Reelfoot Lake in the winter months are controlled surface outflow and ground-water outflow.

Analysis of the model results suggests that the bluff area is also the major source of ground-water inflow to the lake during the summer months. The major mechanisms of discharge from Reelfoot Lake during the summer months are evaporation, transpiration, ground-water outflow to the Mississippi River, and controlled surface-water outflow.

Overall comparisons of the model-calculated water levels to observed water levels are acceptable. The model reasonably simulated ground-water conditions at Reelfoot Lake for two different ground-water and surface-water conditions, and the model may be considered as a reasonable representation of the ground-water system under equilibrium conditions. A transient simulation might more closely represent the actual conditions in the aquifer because a longer time-period may be required for the flow system to reach steady-state than assumed, and a large quantity of water is potentially available from storage.

MODEL SYNTHESIS OF GROUND-WATER LEVELS AS AFFECTED BY PROPOSED LAKE-LEVEL MANIPULATIONS

The calibrated model for August-September 1984 and November-December 1984 was used to simulate ground-water levels resulting from the proposed lake-level manipulations under the same hydrologic conditions as those in the two calibration periods. The simulation was accomplished by changing only the water-surface elevations in the grid blocks representing Reelfoot Lake and its tributaries in the wetlands. Previously simulated hydrologic properties were not changed. The water level in the lake was changed from 280.5 feet to 276.4 feet (4.1 feet lower) for the August-September period, and from 282.8 feet to 283.2 feet (0.4 foot higher) for the November-December period. Results of the synthesis are shown as ground-water level difference maps in plates 8 and 9.

Ground-water level decreases of approximately 4.0 feet in the area bordering the lake are indicated in plate 8. It is also noted that ground-water levels decreased less with increased distance from the lake. Ground-water level decreases shown in plate 8 may represent the maximum potential drawdown because as ground-water levels drop below the phreatophyte root zones, evapotranspiration losses may decrease. This would result in less drawdown than that indicated by plate 8 in the wetland areas. It should be noted that the Mississippi River ultimately controls the amount of ground-water level decrease at great distances from the lake. Actual ground-water level decreases near the river will, therefore, be more dependent on river stage than lake stage.

The lake level during the August-September simulation period was 280.5 feet which is 1.7 feet lower than the normal pool elevation of 282.2 feet. In order to assess the potential impact of a lake drawdown of 5.8 feet from a normal pool elevation of 282.2 feet to a pool elevation of 276.4 feet, a constant of 1.7 feet must be added to each of the lines of equal value in plate 8.

Model results for the 2-month simulated drawdown period indicate a net ground-water inflow of approximately 1.4 ft^3/s (167 acre-ft) to Reelfoot Lake. Therefore, although initial surface-water outflow may be much greater, a sustained outflow of approximately 1.4 ft^3/s would be needed in order to maintain the lower pool level.

Ground-water level increases of approximately 0.4 foot in the area bordering the lake are indicated in plate 9 for the simulation of above-normal lake level. It is also noted that ground-water levels increased less with increased distance from the lake. Effects of evapotranspiration for this seasonal period would probably be negligible because the phreatophytes are normally dormant during the winter.

During the November-December simulation period, the water surface of Reelfoot Lake was at elevation 282.8 feet which is 0.6 foot higher than the normal pool elevation of 282.2 feet. In order to assess the potential impact of a lake level 1.0 foot above a normal pool elevation of 282.2 feet to a pool elevation of 283.2 feet, a constant of 0.6 foot must be added to each of the lines of equal value in plate 9. Changes in ground-water levels near the river will be controlled by river stages more than by lake stages.

SUMMARY

Surface-water and ground-water data collected from May 1 to December 31, 1984, under an ongoing separate cooperatively funded project were used to evaluate the hydrologic system of Reelfoot Lake. Long-term streamflow, rainfall, evaporation, and lake-level data were used to describe normal hydrologic conditions at Reelfoot Lake. These data were also used to assess the potential hydrologic effects of a mid-summer lake drawdown of 5.8 feet below normal pool (276.4 feet) and a late fall lake refill to 1.0 foot above normal pool (283.2 feet) on ground-water levels surrounding Reelfoot Lake.

Estimated monthly water budgets, assuming normal climatic and hydrologic conditions, were derived for Reelfoot Lake in order to determine the time required to refill the lake to normal pool and then to 1.0 foot above normal pool beginning on November 1 of a normal year. Results of these determinations indicate that a normal pool elevation of 282.2 feet would probably be achieved by mid-January, and a pool elevation of 283.24 feet by the end of January.

Ground-water level data from 31 observation wells were used to develop potentiometric contour maps for the lowest (September) and highest (December) ground-water levels during the study period. The potentiometric maps indicate ground-water flow generally is from the bluffs toward the Mississippi River and Reelfoot Lake. The direction of ground-water flow is controlled by head differences between the water-table aquifer, the Mississippi River, and Reelfoot Lake. Ground-water level data and surface-water records indicate the Mississippi River contributes to ground-water recharge and surface runoff from December to May when river stages are normally 10 to 20 feet higher than the adjacent water-table elevations and lake stages.

Ground-water level data were also used to calibrate a two-dimensional ground-water flow model for two steady-state periods (August-September 1984 and November-December 1984). The calibrated model for August-September 1984 and November-December 1984 was then used to simulate ground-water levels following a lake drawdown of 5.8 feet below normal pool and a lake refill to 1.0 foot above normal pool and to check independently the residual term (net ground-water flow into or out of Reelfoot Lake) of the water-budget equation.

Overall comparisons of the model results to observed ground-water conditions during the study period are acceptable. The model reasonably simulated ground-water conditions at Reelfoot Lake for two different ground-water and surface-water conditions, and the model may be considered as a reasonable representation of the ground-water system under equilibrium conditions. Model-calculated water levels for the two simulation periods generally are within $\pm$ 5 feet of the observed water levels for these periods.

Model-calculated ground-water inflow and outflow at Reelfoot Lake generally approximate the estimated water-budget ground-water inflow and outflow. The model-calculated ground-water inflow for the November-December period is 71.6 ft^3/s, and the estimated water-budget ground-water inflow is 95.0 ft^3/s. The model-calculated ground-water outflow for the August-September period is 11.7 ft^3/s, and the estimated water-budget ground-water outflow is 26.5 ft^3/s. The larger discrepancy for the August-September period may be due to overestimation of evapotranspiration from the wetlands, overestimation of transmissivity, underestimation of the constant flux from the bluffs, or underestimation of recharge to the flood plain. The estimated water-budget ground-water outflow could also be overestimated because of uncertainties associated with calculating ground-water flow as the residual of the water-budget equation. The potential error associated with this calculation is approximately 40 percent.

Low lake-level simulation results indicate ground-water levels may decline approximately 5.7 feet below normal in the areas immediately adjacent to the lake. The decline in ground-water levels will be less significant radially outward from the lake. High lake-level simulation results indicate ground-water levels may increase approximately 1.0 foot above normal in the areas immediately adjacent to the lake. The increase in ground-water levels also becomes less radially outward from the lake.

The calibrated model for the August-September 1984 period was used to calculate the ground-water inflow and outflow at Reelfoot Lake during the 2-month simulated drawdown period. Model-calculated ground-water flow results indicate that the net ground-water flow during this period is approximately 1.4 ft^3/s (167 acre-ft) into Reelfoot Lake. Therefore, a sustained surface-water outflow rate of approximately 1.4 ft^3/s would be required to maintain the drawdown pool level. Evapotranspiration, ground-water outflow, and controlled surface-water outflow are major discharge mechanisms during the summer months.

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