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THE HYDROMETEOROLOGY OF DEGRAY LAKE, ARKANSAS

by

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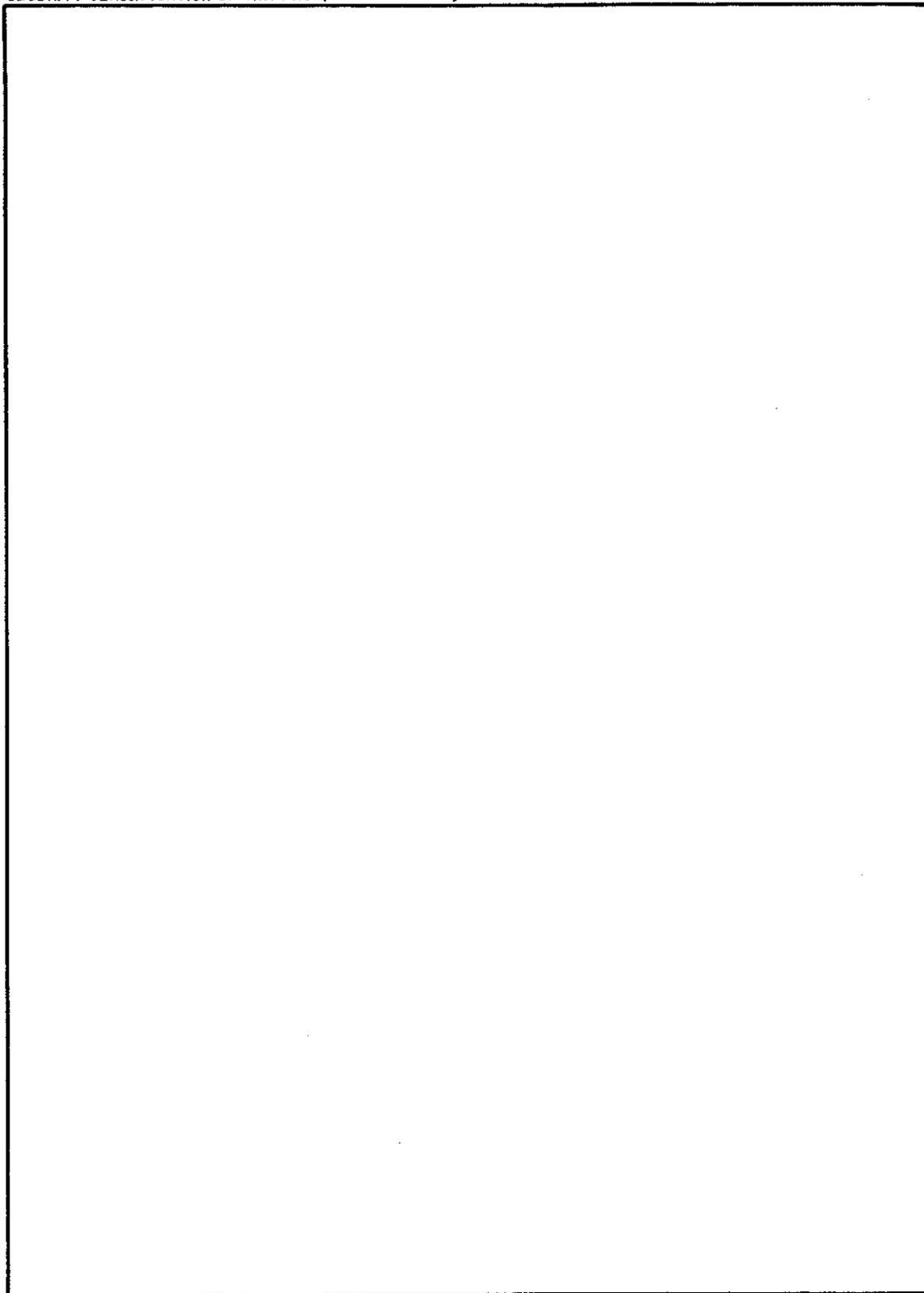


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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report documents the hydrometeorology of DeGray Lake and the sur- rounding Caddo River drainage basin to provide a self-contained document for use by other researchers in this area. This report reviews the main factors influencing stream temperatures and some of the recent stream temperature modeling techniques. Selected techniques for modeling daily temperatures are then applied to data collected from Caddo River. One model is selected to estimate temperatures to fill gaps in the measured temperatures.		

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PREFACE

This report was sponsored by the Office, Chief of Engineers (OCE), U. S. Army, as a part of the Environmental and Water Quality Operational Studies (EWQOS) Work Unit 31595 (IC.1) entitled Improve and Verify Existing One-Dimensional Reservoir Water Quality and Ecological Predictive Techniques. The OCE Technical Monitors for EWQOS were Mr. Earl Eiker, Dr. John Bushman, and Mr. James L. Gottsman.

The work was conducted during the period from September 1980 to January 1982 by the Environmental Laboratory (EL), U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., under the general supervision of Dr. J. Harrison, Chief, EL, and under the direct supervision of Mr. D. L. Robey, Chief, Ecosystem Research and Simulation Division, EL. Program Manager of EWQOS was Dr. J. L. Mahloch, EL. The report was prepared by Mr. Bryan Ford and Mr. Aaron B. Stein.

Commanders and Directors of the WES during this study and the preparation and publication of this report were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

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THE HYDROMETEOROLOGY OF DEGRAY LAKE, ARKANSAS

PART I: INTRODUCTION

Background

1. In 1977, the Office, Chief of Engineers, initiated Environmental and Water Quality Operational Studies (EWQOS) to provide new or improved technology to solve selected environmental quality problems associated with Civil Works activities of the Corps of Engineers in a manner compatible with authorized project purposes. An integral part of EWQOS is the long-term reservoir field studies for which DeGray Lake was selected as one of four intensive study sites. The following were the four major objectives of the EWQOS reservoir field studies:

- a. Define the cause-and-effect relationships between reservoir design and operation and water quality.
- b. Provide information needed for development and verification of predictive techniques.
- c. Provide information for demonstration of various management techniques.
- d. Provide guidance in the proper design of water quality sampling programs.

2. In 1972, DeGray Lake and the Caddo River drainage basin in west-central Arkansas were selected as field study sites for research on water quality modeling being conducted under the Corps' Environmental Impact Research Program. The objectives of the research are to: develop a data base for model development and verification, develop data collection and handling techniques suitable for field office use, and demonstrate management techniques for solving environmental problems. DeGray Lake was chosen because of pre- and postimpoundment baseline data, a multilevel outlet structure, pumped storage hydropower capability, and the opportunity for cooperative interagency involvement (Westerdahl et al. 1975).

3. The hydrometeorology of DeGray Lake was not studied

specifically in either of the above research programs; however, its interpretation and documentation is essential to the field study objectives.

Purpose

4. The objectives of this report are to document the hydrometeorology of DeGray Lake and the surrounding Caddo River drainage basin and to review the main factors influencing stream temperatures and some of the recent stream temperature modeling techniques. Selected techniques for modeling daily temperatures are then applied to data collected from the Caddo River. One model is selected to estimate temperatures to fill gaps in the measured temperatures.

PART II: STUDY AREA

DeGray Project

5. DeGray Dam was authorized by Congress in the River and Harbor Act of 1950. Project objectives were modified by the Water Supply Act of 1958 and the Federal Water Pollution Control Act Amendments of 1961. The Corps of Engineers began construction of the dam in 1963 and completed the project in 1972. Impoundment of the river began in August 1969 and reached normal pool in December 1971.

6. The dam is 12.7 km upstream of the mouth of the Caddo River at latitude $34^{\circ}12'50''$; longitude $93^{\circ}6'40''$. Major project purposes of DeGray Lake include flood protection, power generation, recreation, water supply, and low-flow augmentation of the Ouachita River for water quality control and navigation. Power is generated through a 40,000-kw conventional unit and a 28,000-kw reversible turbine. The reversible turbine, in conjunction with the regulation pool downstream, can pump water back into the reservoir during periods of low power demand to augment peak power demands. Recreation facilities include DeGray State Park which has a lodge, golf course, beach, marina, and camping and picnic facilities. In addition, the Corps of Engineers maintains numerous recreation areas and boat ramps.

7. DeGray Dam is an earthfill structure with a crest elevation of 138 m above mean sea level (msl). Water is withdrawn through four 6.4-by 6.4-m portals in the intake tower. Interchangeable baffle gates and trash rack at each portal allow the water to be withdrawn from three levels. The center-line elevations of the three levels are: 120.4 m msl, 115.8 m msl, and 108.4 m msl. At conservation pool, the maximum discharge capacity is $170 \text{ m}^3/\text{sec}$. Water levels above 129 m msl are passed over an uncontrolled broad-crested emergency spillway (U. S. Army Engineer District, Vicksburg (Vicksburg District) 1969).

8. At conservation pool (124.4 m msl), DeGray Lake has a volume of $8.08 \times 10^8 \text{ m}^3$ and a surface area of 54.3 km^2 . The 32-km-long reservoir has a mean depth of 14.9 m with a maximum depth of 60 m and 333 km of

shoreline (Table 1). The shoreline development index of 12.8 reflects the dendritic shape of DeGray Lake.

9. A reregulating dam 5 km downstream of DeGray Dam holds water to pump back to the main reservoir and to regulate downstream flows. This earth-fill dam has a concrete gravity spillway with a crest elevation of 67.4 m msl. Its five 1.52- by 2.74-m sluice gates have an invert elevation of 60.05 m msl to pass water below the spillway crest (Vicksburg District 1969). Normal pool elevation is 67.4 m msl with volume $4.44 \times 10^6 \text{ m}^3$ and surface area 1.74 km^2 (Table 2). During high flows, the water may rise a metre or more above the spillway.

Watershed

10. The Caddo River drains the south flank of the Ouachita Mountains in south-central Arkansas and enters the Ouachita River just north of Arkadelphia, Arkansas (Figure 1). It flows in a generally southeast

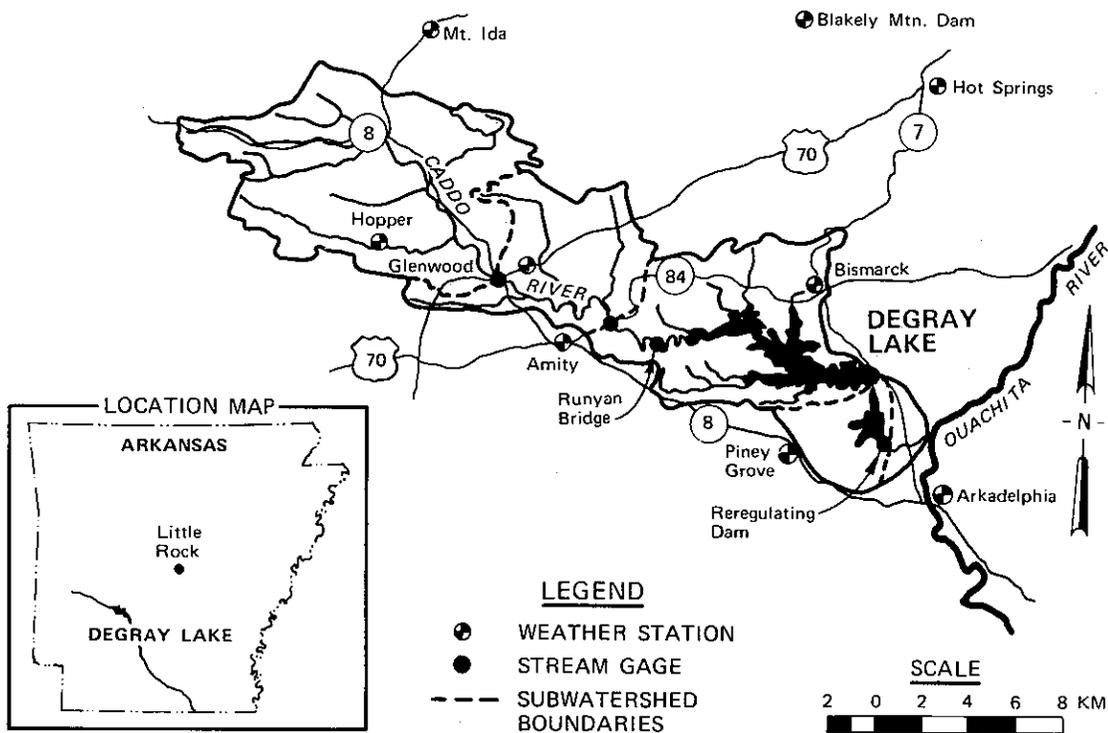


Figure 1. Caddo River watershed, Arkansas

direction for 125 km. From headwaters at over 400 m msl, the river falls to 165 m msl at Glenwood, to 130 m msl at Highway 84, and to 54 m msl at its confluence with the Ouachita River (Figure 2) (Perrier et al. 1977). It has a drainage area of 1269 km² of which 1173 km² are controlled by DeGray Dam; an additional 70 km² are controlled by the re-regulating dam (Vicksburg District 1969).

11. To the northwest of the dam, the watershed lies within two subsections of the Ouachita Mountain section of the Ouachita physiographic province. Above Glenwood, the Novaculite Uplift region is characterized by long, eastward-trending, even-crested mountains and flat intermontane basins. Ridges in the Caddo River region exceed 600 m msl. Southeast of Glenwood, the Caddo River passes through the Athens-Fiedmont Plateau. This area is characterized by nonmountainous east-west ridges rising 75 m above the intervening valleys (Albin 1975). Below the dam, the Caddo River enters the Gulf Coastal Plain, which is characterized by a rolling-to-hilly terrain over unindurated sedimentary materials.

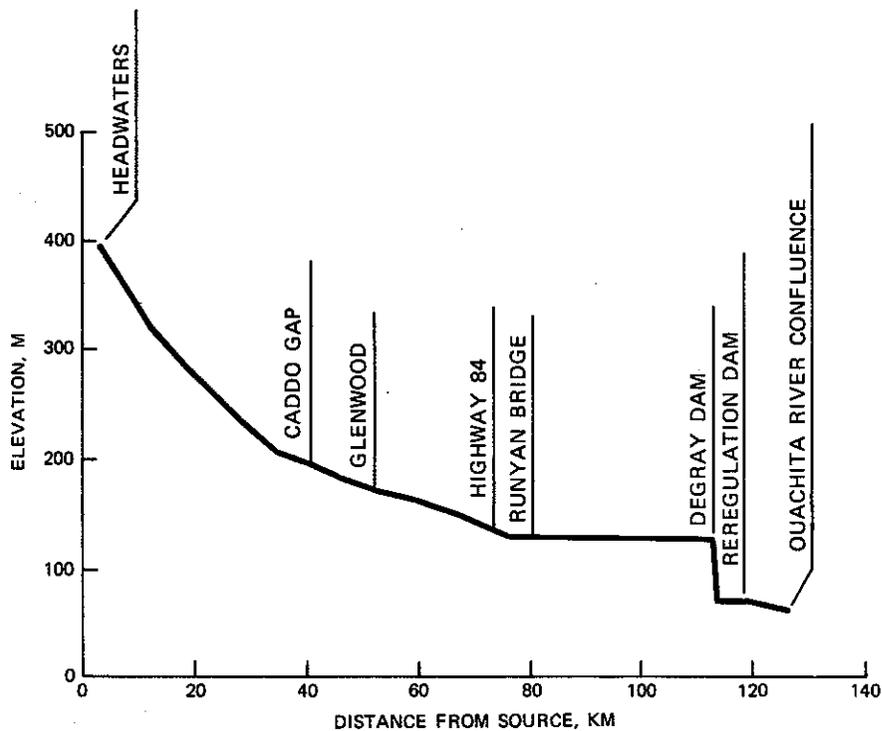


Figure 2. Profile of Caddo River

12. The predominant soil associations in the Novaculite Uplands region are Pickens and Carnasaw, with areas of Pickwick near the streams (Figure 3). These well-drained, acid soils range from shallow on the slopes to moderately deep on the ridge tops and floodplains. Usually brown loam surface soils overlie yellowish silty clay loam or yellow-red silty clay subsoils which grade into clay. Gravel may occur on the slopes and in the valleys. The bedrock is usually steeply inclined fractured shale or sandstone. Outcrops of chert, slate, novaculite, and limestone also appear (Perrier et al. 1977).

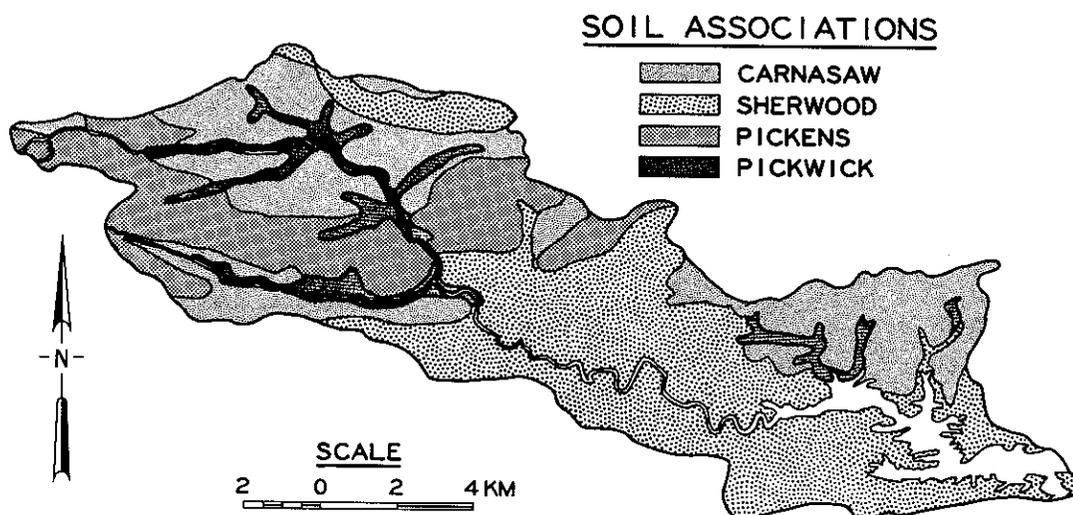


Figure 3. Soil association map of Caddo River watershed

13. In the Athens-Piedmont Plateau region, the Sherwood and Carnasaw associations predominate. Well-drained, acid soils have dark grayish brown to brown loam or fine sandy loam that is gravelly in some areas. These overlie yellow-red or red sandy clay loam or clay loam subsoil. This region is primarily underlain by shales bounded by beds of sandstone. These formations are thick and generally impermeable (Perrier et al. 1977).

14. The Caddo River watershed is mainly rural, with only about 1 percent urban or developed (Figure 4). About 30 percent is classified as agricultural, mostly pastures in the Caddo River flood plain and tributary valleys. Crops include corn, soybeans, and hay. The remainder of the watershed is forested: 50 percent deciduous-mixed and 18 percent

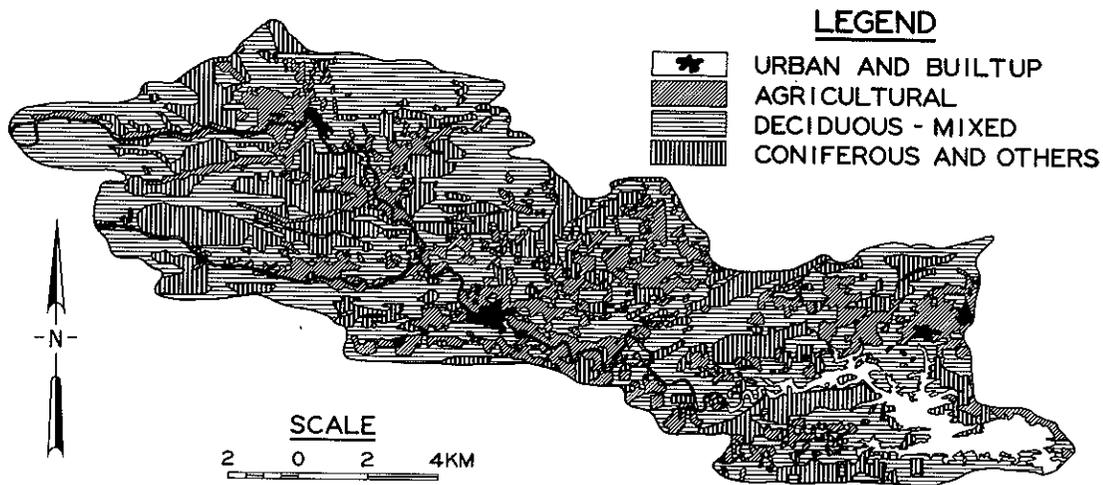


Figure 4. Land use map of Caddo River watershed

coniferous and others. This includes areas which have been clearcut and block planted (Perrier et al. 1977).

Climate

15. No National Weather Service stations record temperature within the Caddo River watershed (see Figure 1). Daily temperature extremes are recorded at Arkadelphia, about 12 km south of the dam and 60 m below the reservoir surface in elevation. Nearby Malvern and Hot Springs, both about 30 km from the reservoir, and Mount Ida, about 50 km from the reservoir but only 7 km outside the upper watershed, also have recorded temperature extremes. Temperature and other meteorological data are recorded at the Little Rock Airport every 3 hr.

16. DeGray Lake is exposed to a modified continental climate. Warm, humid air from the Gulf of Mexico causes the summers to be long and humid with temperatures occasionally exceeding 40°C. Winters are generally short and mild but often influenced by polar air masses which have dropped the temperature as low as -20°C (Reinhold 1966, 1969). Mean monthly temperatures at Arkadelphia range from 6°C in January to 28°C in July, with a mean annual temperature of 17°C (Table 3). Temperatures in the upper watershed should be comparable to those at Mount Ida,

whose monthly averages are 1 to 1.5°C lower than those at Arkadelphia.

17. The average wind speed is greatest in late winter and early spring and least in mid- to late summer. Winds from the southwest to south predominate, especially during the summer months. During the winter a more even distribution prevails. The average barometric pressure is about 4 mb higher in the summer than in the winter (Table 4).

18. On a long-term average, precipitation is fairly well distributed throughout the year. About one-third of the annual precipitation falls from March through May. The spring and winter precipitation is mainly associated with frontal systems from the northwest. Summer rains are mostly scattered showers and thunderstorms which are brief but often heavy. During summer and autumn there may be long periods of little or no rain. Precipitation usually increases in the late fall. Some winter precipitation falls as freezing rain, sleet, or snow. Snow falls from one to four times per year but rarely stays on the ground more than a few days (Reinhold 1966).

19. The average annual precipitation in the Caddo River area ranges from 134 cm per year at Arkadelphia to 140 cm per year near Glenwood. The greater rainfall at Glenwood is attributed to the condensing of moisture in the air as it is lifted over the Ouachita Mountains. In the mountains to the west and north of Glenwood, the rainfall decreases slightly.

Hydrology

20. While streamflow is intrinsically related to precipitation, many other factors are also involved. Depending on the season, antecedent soil moisture, and groundwater conditions, runoff may vary from 15 to 90 percent for individual storms. Annually about 43 percent of precipitation falling in the Caddo River drainage area enters the Caddo River. During the late spring and summer, the lower watershed contributes the larger portion of streamflow to DeGray Lake, while in late fall and winter the upper watershed contributes more runoff (Perrier et al. 1977). Hines (1965) indicates that a significant amount of streamflow

in the Caddo River is maintained by the discharge of groundwater from storage during periods of little precipitation. The typical period of low flow is from June through November. However, large storms are not uncommon in June and November.

21. River stages have been recorded at several locations on the Caddo River (see Figure 1). At the site of the old Runyan Bridge near Amity, continuous records date from 1946 through 1971 when the site was inundated by the rising waters of DeGray Lake. Another gage with records from 1946 to the present is at Glenwood, 29.4 km upstream from the Runyan Bridge site. Since April 1975, a gage has recorded river stages at the Highway 84 bridge near Amity, 7.8 km upstream from the Runyan Bridge site. Several other gages were located on the upper Caddo River briefly during the mid-1970s. Measurements have been made at or near the damsite since 1960. Gage sites on the Caddo River are listed in Table 5.

22. These measurements of water surface elevations are transformed into streamflows by rating curves developed by measuring flow velocities and stream cross-sectional areas at different elevations. Occasionally, for one reason or another, gaps appear in the streamgage records. These may be for only a few hours or for several days. They often occur during storm events. Missing mean daily flows can usually be estimated from the records of nearby gages and precipitation.

23. The presence of several gages on the river allows a more detailed hydrologic examination of storm events. An important factor affecting the flow patterns during storm events is the spatial and temporal distribution of precipitation over the watershed. For example, in the storm event depicted in Figure 5, the heaviest precipitation fell over the lower watershed. The streamflow at the Highway 84 bridge, in addition to being much larger than at upstream stations, rose and receded quickly. In the storm event depicted in Figure 6, the precipitation was greatest in the upper watershed, and the streamflow at Highway 84 rose and receded comparatively slowly. The figure shows the two streamflow peaks merging as the flow travels downstream.

24. These different types of storms also affect the water quality.

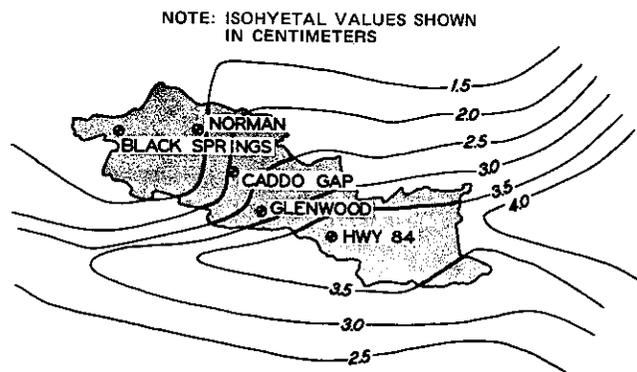
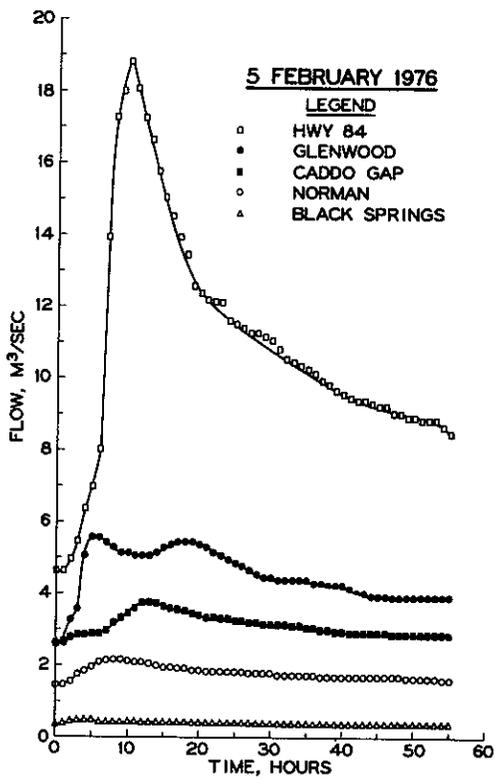


Figure 5. Storm event on Caddo River, 5 February 1976

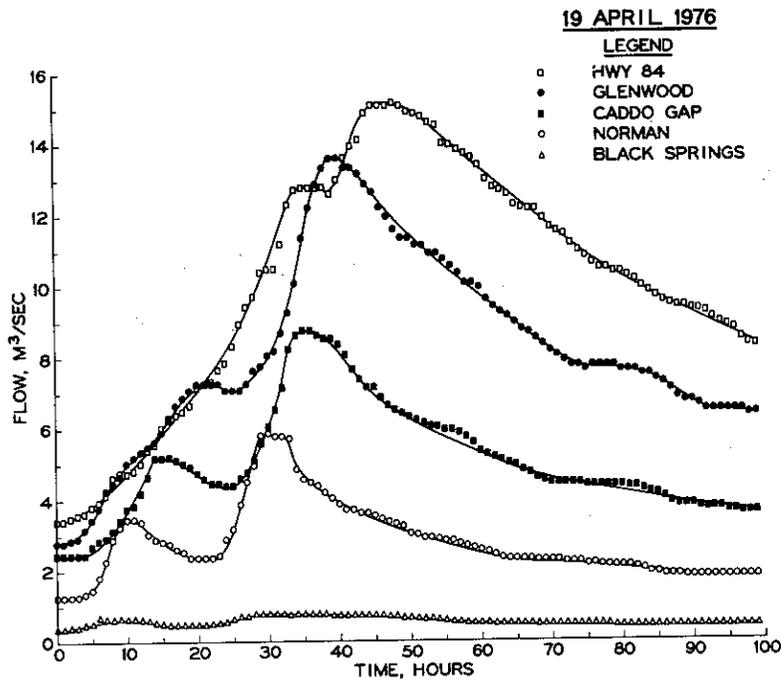
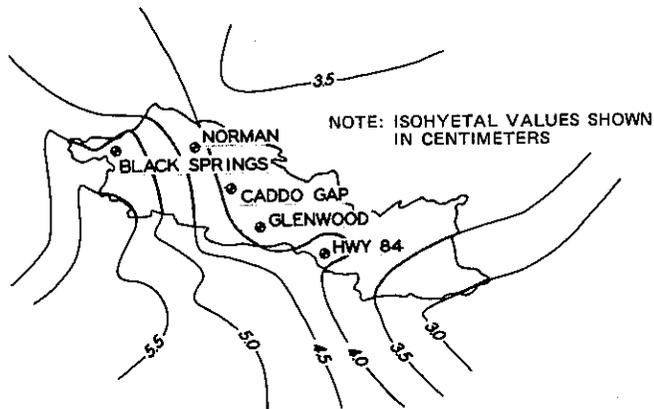


Figure 6. Storm event on Caddo River,
19 April 1976

Washoff constituents in the runoff from different locations are likely to vary with soil types, land use, and other factors. Also water from the upper watershed, having been in the river several hours, may experience temperature changes as well as chemical and biological reactions of its chemical constituents.

Hydraulic Residence Time

25. The hydraulic residence time is an estimate of the time the average water particle remains in the reservoir. It is defined as the ratio of the volume of water in the reservoir to the rate of flow of water through the reservoir, usually the outflow. Large flow rates yield short hydraulic residence times and low flow rates, long ones. Calculated from monthly inflows, the hydraulic residence time can vary from a fraction of a year to several years (Table 6) (Ford 1981). For instance, a large storm occurred in late April 1974, but release was held back until the beginning of May (Table 11 and Figure 7). The residence time calculated for April is about 9 years, while that for May is less than half a year. Had the water been released directly or had the entire process happened a week earlier, the residence time for April would have been closer to 1 year as would the residence time for May. In contrast, a large storm event in early June was entirely released by the end of the month with a consequently small residence time.

26. Turbidity plume studies during storm events indicate that a short-circuiting can take place yielding an actual residence time of

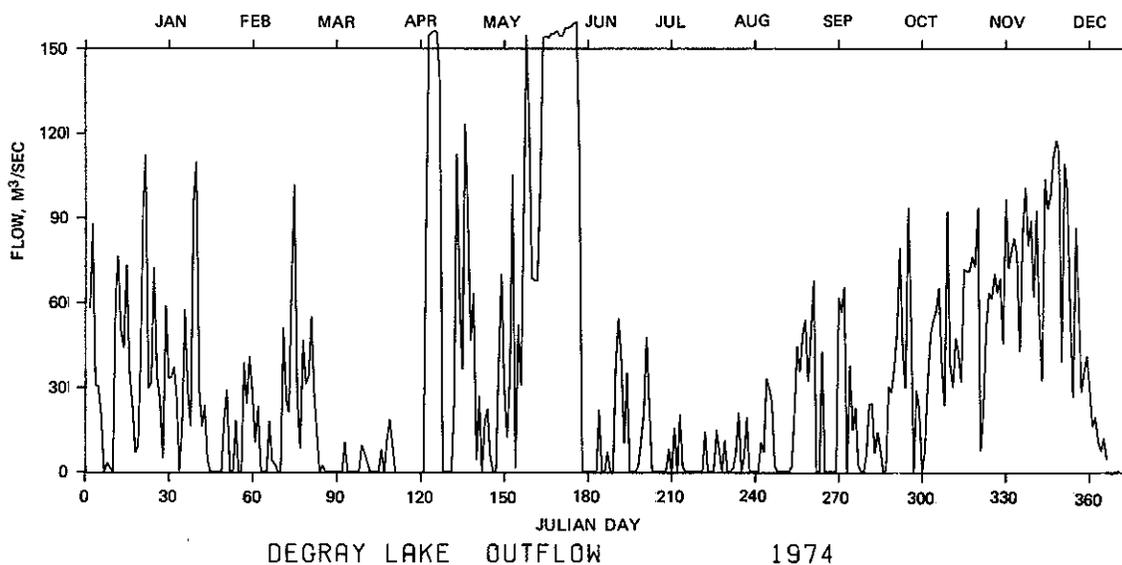


Figure 7. Flow from DeGray Lake, 1974

less than a week (Ford 1981). During storm events, the storm water follows the center of the reservoir to the outlet. While this zone of conveyance is flushed out, the branches of the reservoir remain relatively unaffected unless upset locally by the storm event. This zone of conveyance has been estimated to be about 65 percent of total reservoir volume at normal pool elevation.

PART III: WATER BALANCE

27. A water balance (or water budget) accounts for the various components of water entering and leaving a given body of water. It can be used to estimate an unknown component when all other components are known. These estimates are usually very rough because of the accumulated estimation errors in the other components. The water balance can be used to check for errors in the estimates of the components of the hydrologic cycle. If errors are found, manipulations can then be made to correct them. A correct water balance is important in many studies ranging from simple nutrient balances to complex reservoir models.

28. In accordance with the data available for DeGray Lake, the following form of the water balance is used:

$$\frac{dV}{dt} = (P - E)*A + I - O \pm G \quad (1)$$

where

$\frac{dV}{dt}$ = change in reservoir volume per unit time, unit volume per unit time

P = precipitation on the reservoir, unit length per unit time

E = evaporation from the reservoir, unit length per unit time

A = surface area of the reservoir, unit area

I = inflow into the reservoir, unit volume per unit time

O = outflow from the reservoir, unit volume per unit time

G = groundwater flow from or into the reservoir, unit volume per unit time

29. Each term in the water balance is subject to error. Errors can arise in the measurements and in the interpretation of the measurements. When there are several components of error for a measurement, the maximum error is approximated by the sum of the component errors. However, the probable error will likely be somewhat less. Errors tend to compensate more over longer periods of time. Thus, the uncertainty of long term averages is generally less than that of short-term averages (Winter 1981). Some sources of error will be discussed for the different components of the water balance.

Precipitation

30. Precipitation on the watershed is accounted for by runoff and streamflow into the reservoir. Only that precipitation falling directly on the reservoir surface need be considered separately. Precipitation was measured at several nonrecording gages near the reservoir by the National Weather Service and the Corps of Engineers. The Thiessen polygon method, which weights the influence of each rain gage on a given area by dividing the area into polygonal subareas using rain gages as centers, showed the normal DeGray Lake surface to be influenced by only three nearby gages. About 5 percent of the area was covered by a gage west of the reservoir near Amity. The remainder was evenly split between a gage north of the reservoir near Bismarck and a Corps gage near the dam.

31. For nonrecording precipitation gages measured daily, common measurement errors due to evaporation, adhesion, splash, etc., usually are less than 2 percent in a well-maintained gage. Error due to wind, usually a deficit, may be 80 percent during strong winds and light rains but should be much less for monthly accumulations. Errors associated with the areal averaging of rainfall depend on the density of the gages and the terrain (Brakensiek et al. 1979). For DeGray Lake, the error is probably 20 percent or greater.

Inflow

32. Inflow into DeGray Lake may be divided into two parts. The major portion comes from the Caddo River. The remainder comes from small, ungaged streams which drain the land around the reservoir. (This will be discussed later.) The actual point of inflow varies with the rise and fall of the reservoir surface. For practical purposes the inflow should be assumed to enter DeGray Lake just above the backwater at normal pool elevation. The Runyan Bridge gage was situated near this point until it was inundated by the filling of the reservoir in 1971. Since then, the gages at Glenwood and the Highway 84 bridge near Amity have been the nearest gages, successively.

33. The problem of obtaining streamflows for the Runyan Bridge site can be solved by using techniques ranging from simple regression to elaborate rainfall/runoff models. With all these techniques there is the question of whether the period of flow which is to be predicted is representative of the period on which the model was based. There has been minimal development in the watershed above the reservoir; therefore, the main differences in streamflow should be those associated with weather and climate. Monthly streamflows for Glenwood and Runyan Bridge are shown in Tables 7 and 8, respectively.

34. The average monthly streamflows for Glenwood and Runyan Bridge for the period 1962 through 1971 are shown in Figure 8. There are two distinct seasons: a period of high flow from December through May and a period of low flow from June through November. The streamflow at Glenwood for 1974 through 1977 was generally low except for a few large

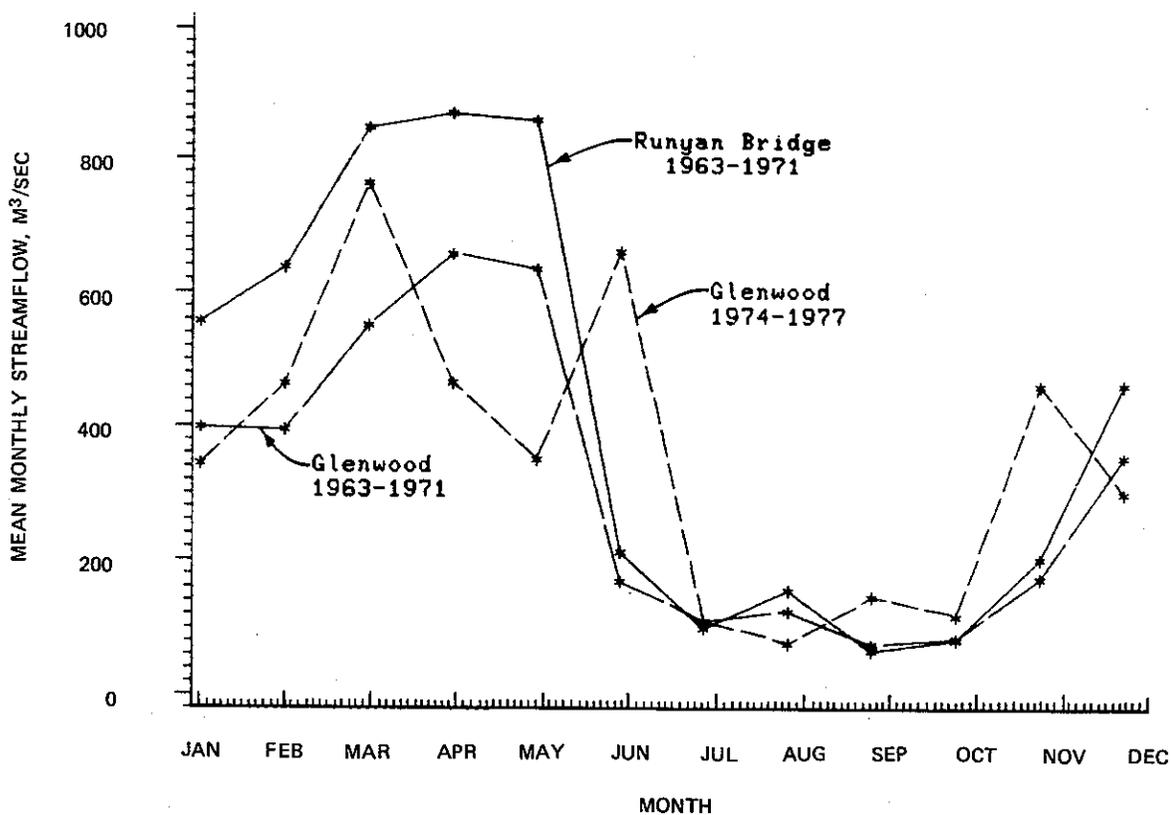


Figure 8. Mean streamflow at Glenwood and Runyan Bridge

storms. Thus, the mean streamflow for this period looks somewhat different from that for the 1963-1971 period.

35. Monthly streamflows at Runyan Bridge were estimated by least squares regression techniques using the streamflow at Glenwood for the period July 1962 through November 1971. The following equation for streamflows at Runyan Bridge (Q_{rb}) and Glenwood (Q_g) was developed using all the data:

$$Q_{rb} = 1.347Q_g + 0.12 \quad (2)$$

where the units are m^3/sec . The coefficient of determination was 0.96. The data was then divided into two seasons representing periods of high and low flows. For high flows (December-May) the equation was

$$Q_{rb} = 1.308Q_g + 1.55 \quad (3)$$

with a coefficient of determination of 0.96. For low flows (June-November) the equation was

$$Q_{rb} = 1.235Q_g - 0.35 \quad (4)$$

with a coefficient of determination of 0.85. The improvement gained by using two regressions was statistically insignificant. It should be noted that during periods of low flow, the flow may be less at Runyan Bridge than at Glenwood. Whether this is due to loss of water between the two sites or error in streamflow estimation is unknown. In either case, it illustrates a possible problem when simple regressions are used.

36. Records at the Highway 84 bridge began in April 1975. During periods of low flow, the streamflows at Highway 84 are higher than those regressed to Runyan Bridge. Overall, the use of Highway 84 streamflow yields a slightly higher inflow into DeGray Lake than the use of the regressed Runyan Bridge streamflow would have. The Highway 84 streamflows were used as inflows to DeGray Lake. Streamflow records at Highway 84

from the beginning of 1974 to April 1975 were regressed from Glenwood, using the equation

$$Q_h = 1.2569Q_g^{1.09656} \quad (5)$$

where Q_h and Q_g are in m^3/sec . Mean daily streamflows at Highway 84 are given in Appendix A.

37. Mean monthly streamflows at Highway 84 are shown in Table 9. The 1975-1980 period was, except for 1979, rather dry. Twenty-one percent of the average annual streamflow was in March, while February, April, and May each had 12 to 13 percent of annual flow. These records show that streamflow was less than the mean annual streamflow, $13 m^3/sec$ 78 percent of the time, but that this represented only 34 percent of the total flow during this period (Table 10).

38. Errors in streamflow estimation can come from many sources. Current meters used in stream velocity measurements have been found to vary 10 percent between calibrations during extensive use. Errors in measurement due to velocity distributions have been estimated to be as much as 5 percent in both vertical and horizontal directions; errors of several percent can also be caused by short-term velocity variations in the stream. Cross-sectional areas are usually accurate to within a few percent; however, the total error in a discharge measurement can be 10 percent or higher. A good stage-discharge relationship should yield less than 10 percent error (Winter 1981). However, for the station at Glenwood, which was gaged infrequently and showed a propensity to vary, the error is probably greater. The Highway 84 gage is located at an unstable site. Correlation of flow from one gage to another can yield widely varying estimates.

Ungaged Inflow

39. In addition to streamflow into the reservoir through the Caddo River, there is flow from a number of small, ungaged streams as well as from land which drains directly into the reservoir. From the

Highway 84 bridge to the DeGray Dam, there are 360 km² of ungaged land representing 32 percent of the watershed above the dam. The runoff into the reservoir from this ungaged area can be estimated from precipitation or from the Caddo River inflow. The latter method has the advantage of having such losses as evapotranspiration already removed and of using data already available. It also assumes that the rainfall/runoff ratio from the land surrounding the reservoir is the same as that from the area above the stream gage, which may not be true. Two simple methods to account for this ungaged area may be tried. First, streamflow was increased in proportion to the additional runoff area below the stream-gage, which would increase the inflow into DeGray Lake by 47 percent. Second, streamflow was increased in proportion to the additional length of stream channel. Using the thalweg, this method would increase the inflow by 67 percent; however, using the path of conveyance, which is approximately the center line of the reservoir, the increase is 50 percent, which is close to that obtained from the area-proportion method.

40. The regionalization of runoff from gaged to ungaged watersheds, as was done to estimate the ungaged runoff into DeGray Lake, can have errors of over 100 percent during periods of low flow. However, for humid regions such as Arkansas, errors in the range of 10 to 15 percent annually can be expected (Winter 1981).

Outflow

41. Outflow from DeGray Lake recorded in the daily operation reports of the dam is estimated from the following components:

- a. Estimated turbine leakage of about 0.4 m³/sec when the turbines are idle.
- b. Discharge through the turbines to generate power.
- c. Discharge through the flood-control outlet.
- d. Volume that is pumped back to the main reservoir from the reregulating reservoir during low power-demand periods.

Mean daily outflows are listed in Appendix B.

42. Discharge is also measured at the reregulating dam by

estimating discharges through the sluices and over the spillway. The flow from the reregulating dam can provide a check for the estimated outflows from DeGray Dam.

Evaporation

43. Evaporation is measured daily near the dam and recorded in the daily operation reports of the dam.

44. Evaporation from pans varies with the size, construction material, insulation, color, and placement of the pans, with variances of up to 30 percent for each of the different characteristics. When compared to the energy-budget method of calculating evaporation, which is generally considered the most accurate method (within 15 percent for monthly values), pan measurements tend to be lower in the summer and higher during the spring and autumn. Since evaporation pans do not represent those conditions in the lake, a pan-to-lake coefficient is used to relate the pan evaporation to lake evaporation. Studies have shown pan coefficients to vary from 0.35 in the spring to over 2.0 in the fall. These extreme values were in desert areas, and DeGray Lake should experience milder variations, probably from 0.5 to 1.1. Monthly pan coefficient errors of 50 percent or more are likely when applying 0.7 as the pan coefficient (Winter 1981).

Groundwater

45. Groundwater flow in the DeGray Lake region is virtually unknown. Although there is certainly some movement into the reservoir from upstream and some seepage beneath the dam, gains and losses are unknown. It has been assumed that net movement is negligible, and it will be lumped with other errors.

Storage

46. The storage (i.e., the volume of water in the reservoir) can

be estimated from the elevation of the water surface of the reservoir as measured near the intake structure. Local water-level fluctuations at the intake structure during release that are not representative of the reservoir as a whole may introduce substantial errors. These can be minimized by using measurements taken several hours after release has ceased. Mean daily pool elevations are given in Appendix C. These elevations have been converted to volumes (see Appendix D) using the design curves from the Vicksburg District design memorandum for DeGray Lake. Due to the inherent inaccuracies of measurements, shore erosion, and sedimentation, it is possible that there is a substantial error in this conversion. Within the normal pool elevation range (122-124.4 msl), an error in elevation of 0.15 m will produce about 1 percent error in reservoir volume.

Discussion

47. The water balance for DeGray Lake was calculated using monthly averages. Results are shown in Tables 11-17 and Figures 9-15, and an annual summary is shown in Table 18 and in Figure 16. The error shown in the tables is the difference between the change in storage, i.e. volume, obtained from the pool elevation (see paragraph 46) and the change in storage calculated from Equation 1. Analysis failed to indicate a relation between the errors and any of the water balance constituents.

48. While residual errors are probably associated with all the water balance constituents in proportions which vary from month to month, the ungaged inflow is the most likely source of error. Better estimates of monthly inflow could be made by using a detailed hydrologic model or by examining individual storm isohyets, as shown in Figures 5 and 6, to adjust the weighting of runoff below Highway 84. Monthly isohyets would require less work than a model and might suffice. A simpler method for achieving a year-by-year balance is to use the annual water balance to derive a factor F for adjusting the ungaged inflow so that the residual error disappears. See Table 19 for a list of factors for 1974-1980.

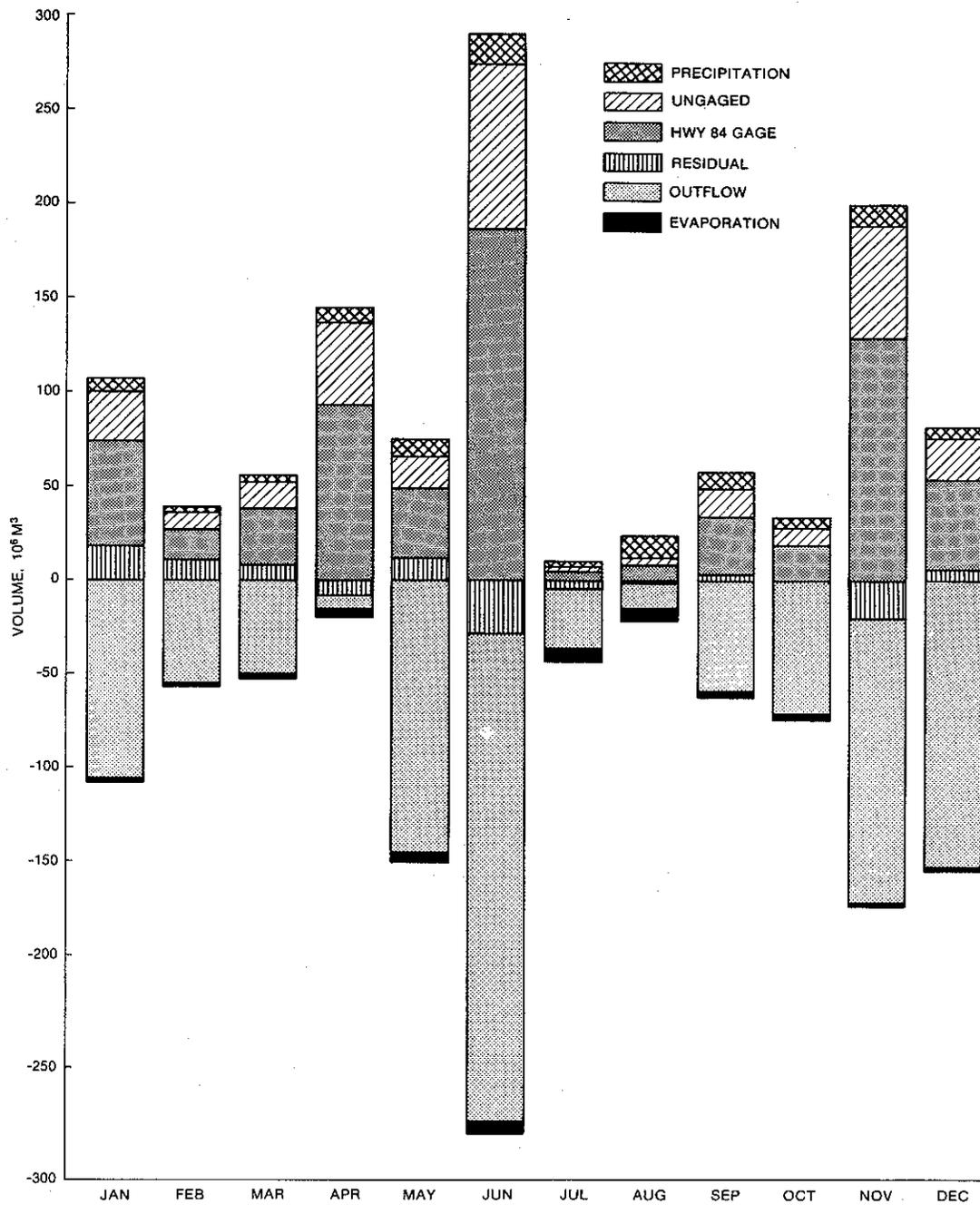


Figure 9. Water budget for DeGray Lake, 1974

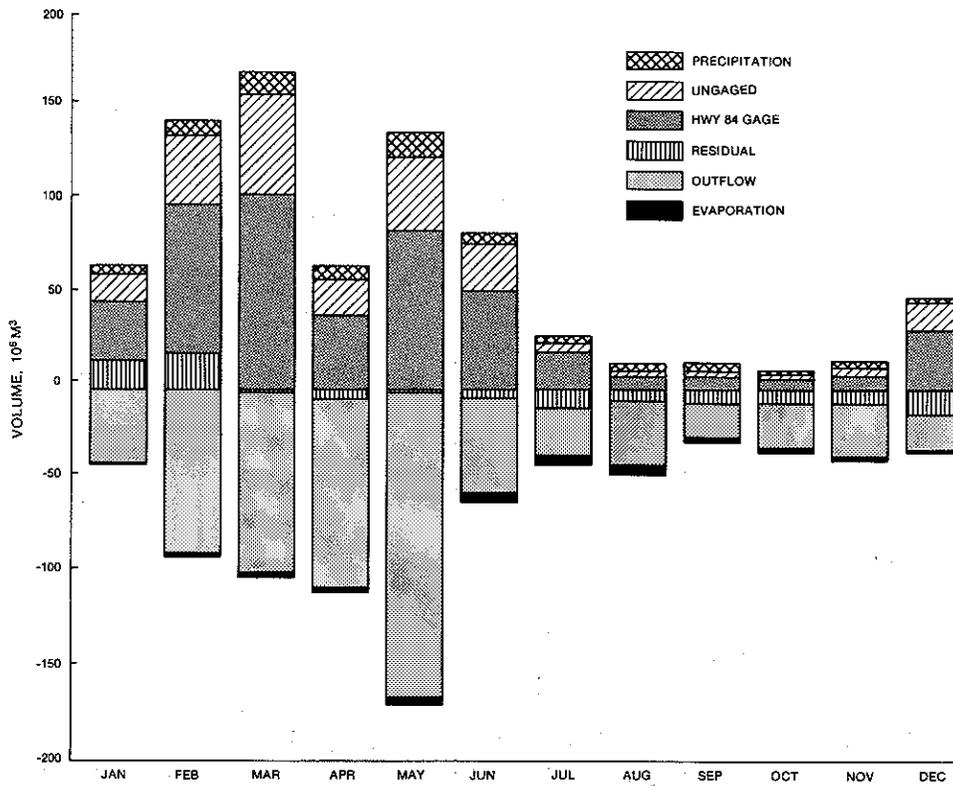


Figure 10. Water budget for DeGray Lake, 1975

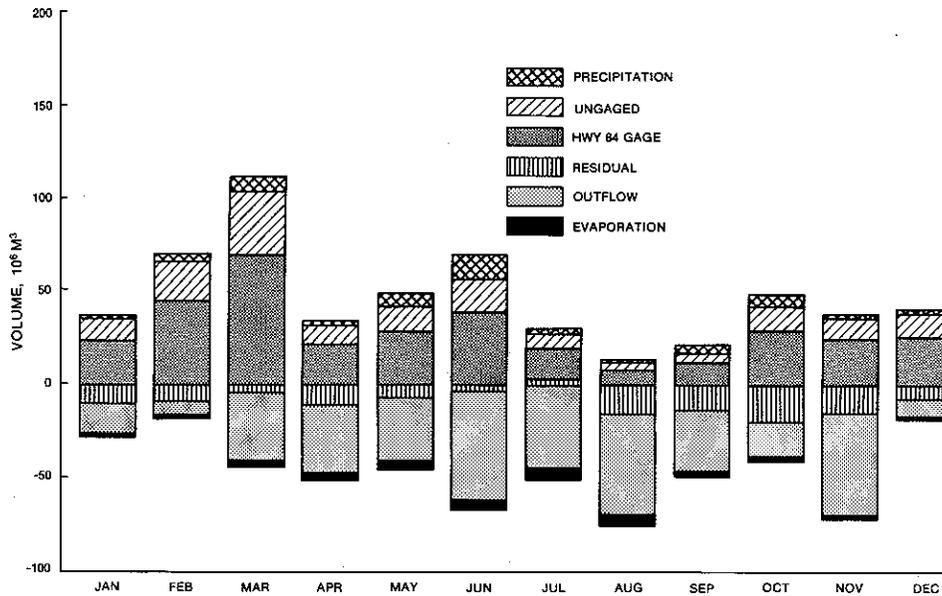


Figure 11. Water budget for DeGray Lake, 1976

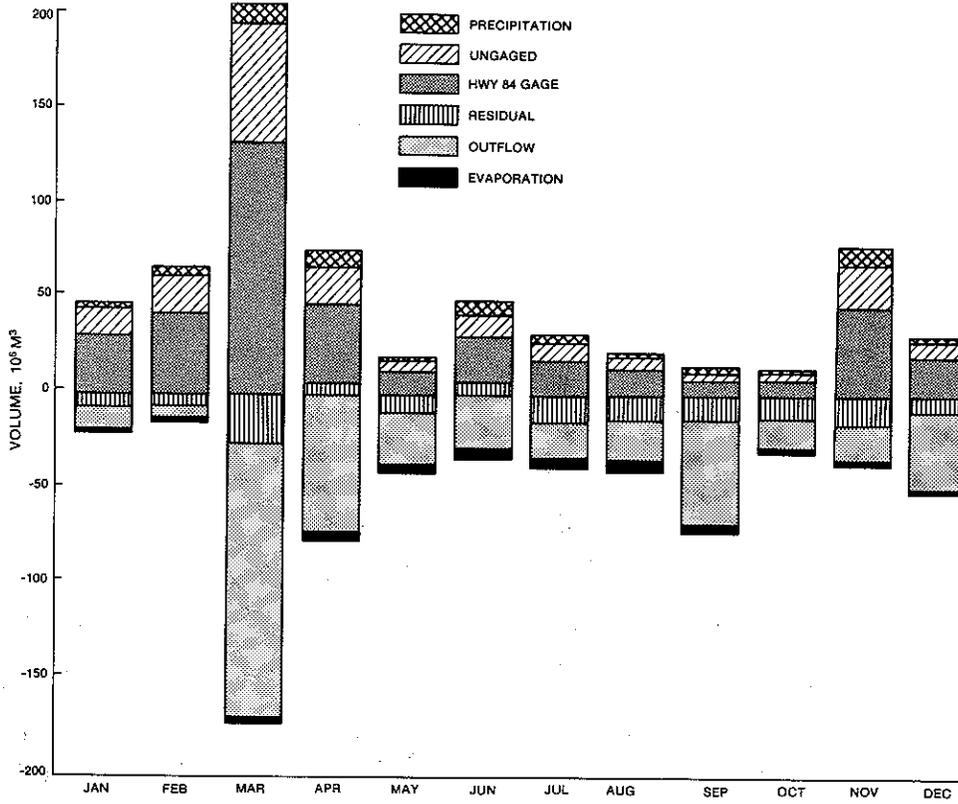


Figure 12. Water budget for DeGray Lake, 1977

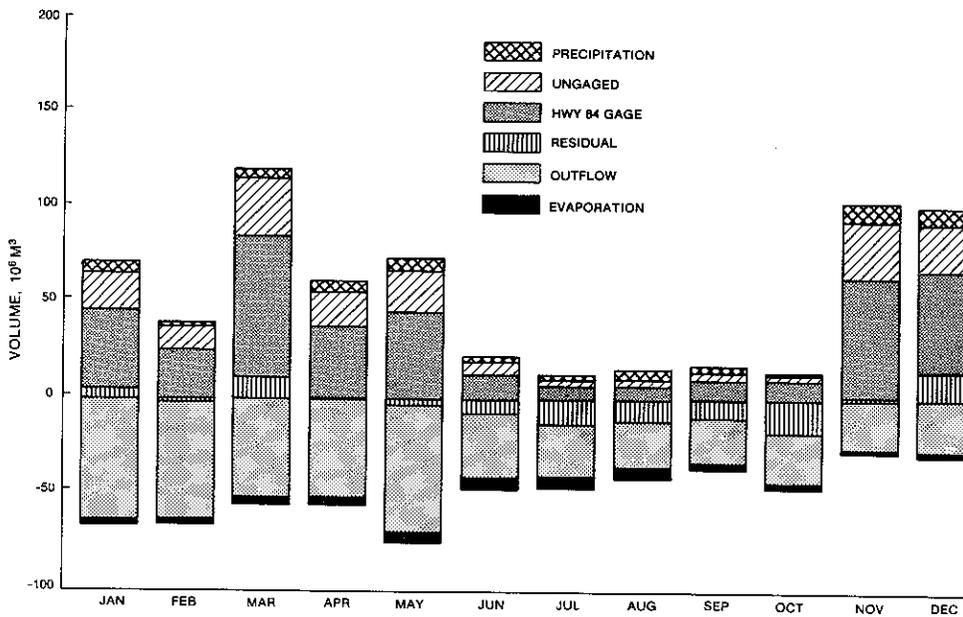


Figure 13. Water budget for DeGray Lake, 1978

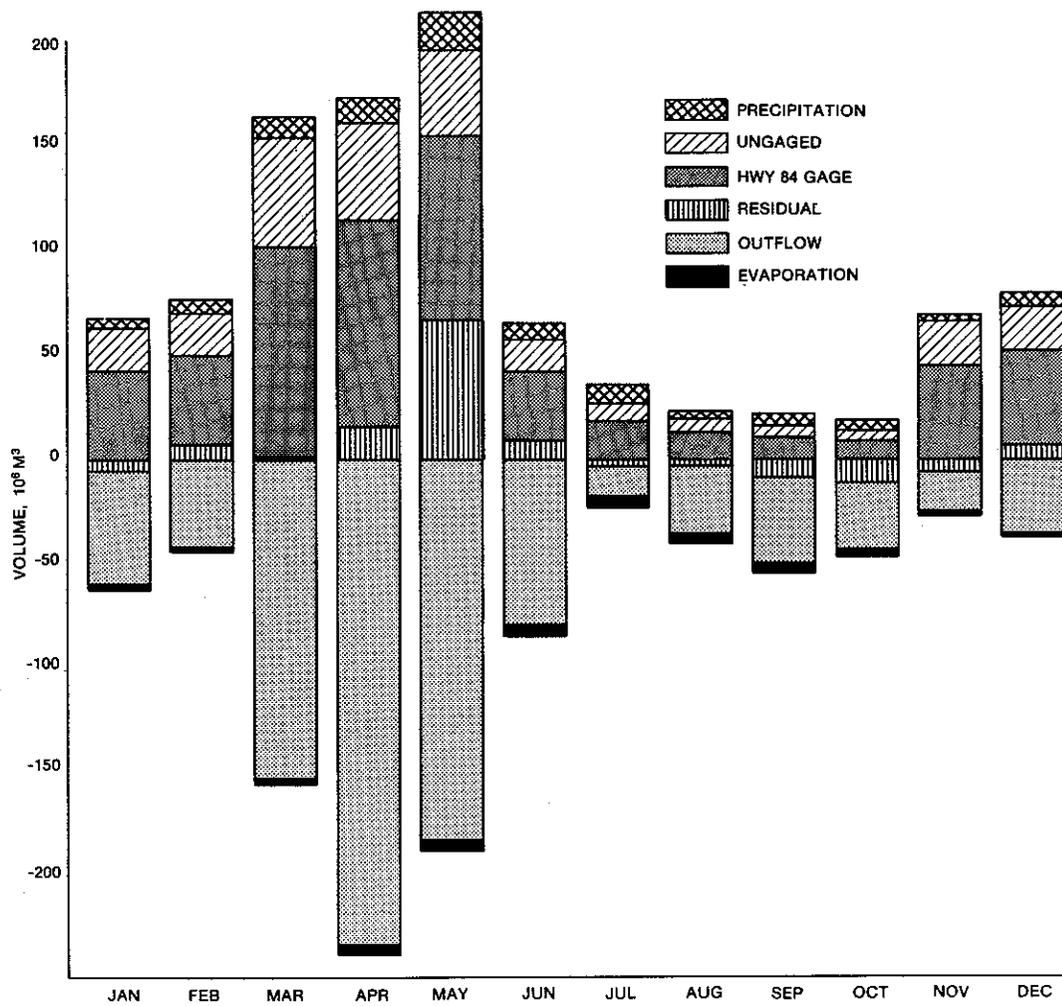


Figure 14. Water budget for DeGray Lake, 1979

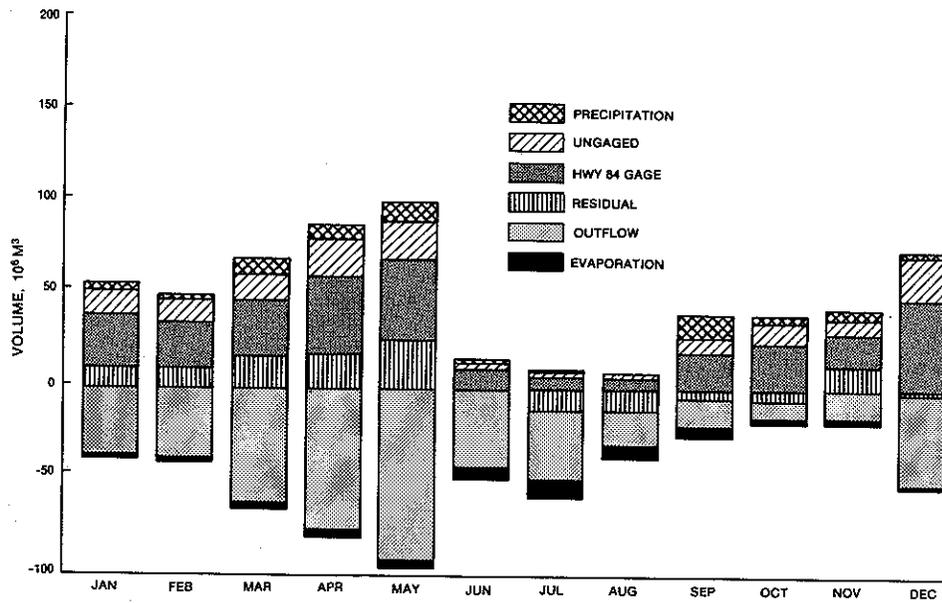


Figure 15. Water budget for DeGray Lake, 1980

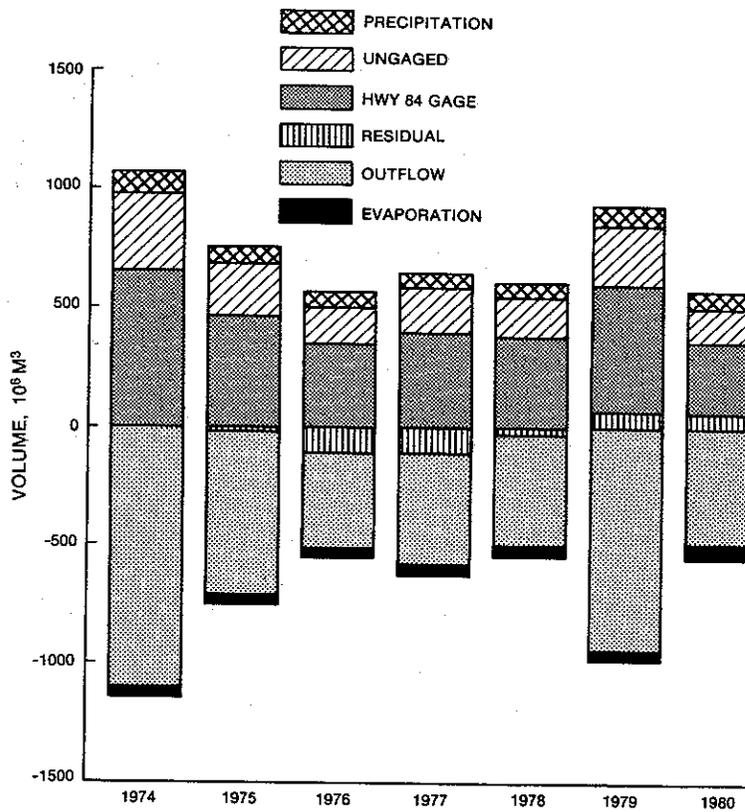


Figure 16. Water budget for DeGray Lake, annual summary for 1974-1980

PART IV: STREAM TEMPERATURES

49. The temperature of stream water is necessary to many studies. For example, the temperature of the inflowing water is an important factor in the hydrodynamics of a reservoir, determining largely at what level in the reservoir the incoming water will flow. However, temperature records, where available, are often incomplete. Methods of synthesizing stream temperature histories from incomplete data are available. Some techniques such as heat or energy balances require extensive instrumentation not normally available except in special studies. Other methods use more widely available meteorological data.

Heat Balance

50. A brief discussion of the components of the heat balance, or heat budget, of a body of water is instructive in describing those physical factors which affect stream temperature. More detailed discussions may be found in numerous other reports (e.g., Raphael 1962, Tennessee Valley Authority (TVA) 1972). A heat balance must account for the heat present in a water body and all heat fluxes to and from that body. The initial heat content of a water body is determined by the water temperature, the amount of water, and the thermal characteristics of water. Some of the major types of heat flux are discussed below.

51. A significant component of the heat budget of a body of water is the absorption of incoming solar radiation. Seasonal and diurnal temperature changes are direct results of changes in the solar altitude. The amount of solar radiation reaching the water surface can be significantly reduced by cloud cover, shading by topographic features, and by bank vegetation. A portion of the solar radiation reaching the water surface is reflected; the reflected portion increases with increased angle of incidence.

52. Longwave radiation emitted by the atmosphere is the major thermal input to a water body at night and on cloudy days. This radiation depends primarily on the temperature and moisture content of the

air column above the water. The proportion of atmospheric radiation reflected by the water is almost constant. Longwave radiation is also emitted by nearby topographical features and by bankside vegetation.

53. Longwave radiation emitted by the water is a significant source of heat loss from a water body and depends on the temperature of the water at and just below its surface. This radiation is often largely offset by the longwave radiation emitted by the air above the water.

54. Evaporation removes heat from a water body (a) by using energy to change the state of water from liquid to gas and (b) by removing the water itself. The rate of evaporation increases with higher temperatures, reduced vapor pressure, lower barometric pressure, increased air movement over the water surface, and increased surface area. Evaporation can be a significant factor in the heat budget of a water body. Its opposite, condensation, though usually minor and occurring at night, can add energy to the water body.

55. Energy as sensible heat is conducted across the air-water interface. The temperature gradient at the interface determines the rate and direction of heat exchange. Air and water movement help to maintain the gradient as heat exchange progresses. Since the diurnal temperature changes of the air are usually greater than those for water, heat is generally conducted from air to water during the day and from water to air during the night, with the net daily heat exchange by conduction usually small compared to other means.

56. Heat conduction across the water-bottom interface depends on the temperature gradient there. A storage effect has been noted on a seasonal basis in lakes and on a diurnal basis in a small rock-bottom stream (Brown 1969). However, little is currently known of this form of heat transfer, and it is usually considered small (Jackman and Yotsukura 1977).

57. Advected heat, that coming from water entering the system at a different temperature through precipitation, tributary streams, or groundwater flow, may be significant in small streams but becomes less important in larger ones. Advected heat transfer is usually difficult to assess.

Factors Affecting Stream Temperatures

58. In summary, the major factors affecting water temperature are solar radiation, wind velocity at the water surface, air temperature, vapor pressure, and the water temperature itself. The effectiveness of each of these may be modified by the depth of the stream, the discharge, the degree of mixing, impurities in the water, shading from vegetation or land masses, the temperature of surface and subsurface inflows, the temperature of the surrounding land mass, and the orientation of the stream.

59. From their origins, stream waters begin exchanging heat with the surrounding environment, trying to reach an equilibrium. Streams originating from mountain snowmelt or from deep aquifers will have a nearly constant temperature, but away from their source they will begin to experience diurnal and other changes in temperature. The variation in temperature of streams with a high percentage of groundwater inflow will be damped.

60. Since small streams have less capacity for heat storage than larger ones, they are more strongly influenced by meteorological conditions and environmental features such as bankside vegetation and surrounding topography. In Oregon, for example, diurnal fluctuations of over 10°C were measured in small exposed streams with low summer flows, while the Willamette River fluctuated only about 1°C (Brown 1969). In general, the larger the stream, the slower the heating and cooling and the less the diel temperature range and maximum temperature.

61. Bankside vegetation has a significant effect on streams. Macan (1974) found a stream temperature to be as much as 7.5°C cooler after flowing about 1 km through a wood. Brown (1969) found that a small forested stream section varied diurnally only about 1°C, while two unforested stream sections varied about 9°C with minimums about 1°C lower and maximums 7 to 8°C warmer than the forested section. In an analysis of the mean monthly temperatures of some 70 sites in Louisiana, Calandro (1973) found the temperatures of smaller streams generally to be 3 to 5°C cooler than larger streams which had wide, relatively

shallow, unshaded areas exposed to solar radiation. In general, streams exposed to solar radiation will have larger diurnal variations in temperature, often becoming much warmer on sunny afternoons and somewhat cooler at night than protected streams. While the diel and seasonal extremes may be reduced by forest cover, the annual mean temperature is apparently not significantly affected (Johnson 1971).

62. The strong correlation which exists between air and water temperatures is one of the relationships most cited and most convenient to use in the study of water temperatures. Both, being driven by solar radiation, follow the same seasonal and nonseasonal patterns. However, water with its much higher thermal capacity and slower response time usually varies less in its fluctuations, an inertial effect which is greater for larger bodies of water.

63. One notable exception to this generally good temperature correlation occurs when water temperature approaches the freezing point. Since large amounts of latent heat are absorbed or released without temperature change when water changes its state at 0°C , a water-ice mixture is relatively insensitive to temperature changes and will remain at or near 0°C even while air temperatures may be considerably lower or higher. The freezing of water thus also constrains the diel temperature range of water near freezing conditions (Song and Chien 1978).

Equilibrium Temperature

64. An attractive concept for predicting changes in the temperature of a water body is that of equilibrium temperature. The equilibrium temperature is a hypothetical temperature of the water surface at which there is no net heat exchange with the atmosphere (Edinger et al. 1974). The temperature of the water surface is continuously being driven toward the equilibrium temperature at a rate proportional to the difference between the two. The equilibrium temperature responds strongly to solar radiation but tends to approach the dew-point temperature when the sun is not shining. Edinger et al. (1974) outlined an iterative method for calculating the equilibrium temperature from meteorological parameters.

Stream Temperature Models

65. Stream temperatures are subject to many fluctuations ranging from long-term climatic changes to minute-to-minute fluctuations caused by a myriad of interactions among the processes described previously. Three cycles are most prominent: seasonal, synoptic, and diel. A time series of water temperatures in a temperate climate is dominated by an annual cycle caused by seasonal solar heating variations. Less periodic fluctuations on the order of several days are caused by meteorological variations and storm runoff. Diurnal variations also occur. Water temperatures are slower to respond to changes than are air temperatures and usually display a more moderate range; this is especially true of large bodies of water. Shading can significantly reduce the diurnal variation in small streams. Several models which predict daily stream temperatures over one year have been investigated and are described below.

66. A simple model proposed by Ward (1963) predicts the annual cycle as a smooth sinusoidal curve:

$$T(t) = \bar{T} + a \sin (\omega t + \theta) \quad (6)$$

where

$$\begin{aligned} T(t) &= \text{stream temperature on day } t \\ \bar{T} &= \text{mean annual stream temperature} \\ a &= \text{amplitude of the harmonic variation of } T \\ \omega &= 2\pi/P = \text{fundamental frequency} \\ P &= \text{period} \\ \theta &= \text{phase angle} \end{aligned} \quad (7)$$

For the annual cycle, the period is 365 or 366 days. Ward found that this function explained an average of 96 percent of the variance in stream temperatures for 37 stream locations in Arkansas. This equation can also be written as

$$T(t) = \bar{T} + a \cos (\omega t + \theta') \quad (8)$$

where only the phase angle is changed

$$\theta' = \theta - \frac{\pi}{2} \quad (9)$$

Or it can be written as

$$T(t) = \bar{T} + A \cos \omega t + B \sin \omega t \quad (10)$$

where

$$A = a \sin \theta \quad (11)$$

and

$$B = a \cos \theta \quad (12)$$

The equation can be solved in this form using least squares regression; then

$$a = \left(A^2 + B^2 \right)^{1/2} \quad (13)$$

and

$$\theta = \arctan A/B \quad (14)$$

67. Thomann (1967) and Kothandaraman (1971) showed Equation 10 to be the first harmonic of the Fourier series

$$T(t) = \frac{A_0}{2} + \sum_{n=1}^M (A_n \cos n\omega t + B_n \sin n\omega t) \quad (15)$$

where

$$A_n = \frac{2}{N} \sum_{t=1}^N (f_t \cos 2 \pi n t / N) \quad (16)$$

and

$$B_n = \frac{2}{N} \sum_{t=1}^N (f_t \sin 2 \pi n t / N) \quad (17)$$

For N observations over the given period and considering only the first M harmonics, f_t is the observation at time t . The n th term of the Fourier series has a period of $365/n$ days. A_0 is equal to $2\bar{T}$.

68. Thomann (1967) found that the first harmonic accounted for 92 to 98 percent of the total variance of water temperature at several sites on the Delaware River, while the second through fifth harmonics accounted for an additional 1 to 1.5 percent. Similarly, Kothandaraman (1971) found that the first harmonic term accounted for an average of 95 percent of the stream temperature variance at a site on the Illinois River for 4 years, while the second through tenth harmonics accounted for only 2 to 3 percent of the total variance. He also found that the first harmonic term accounted for about 80 percent of the variance in air temperatures at a nearby site, while the second through tenth harmonics accounted for about 4 percent. He concluded that adding additional harmonics beyond the first is an inefficient way to improve the model.

69. Since models cannot reproduce the observed temperatures exactly, there remains a residual or error term for which the model does not account. Various methods have been proposed for reducing this term.

70. Kothandaraman (1971) addressed the nonseasonal variations through regression analysis of the residuals; i.e., the remainder after the harmonic approximation has been removed from the time series. Citing work by others who found that air temperature has a significant influence on water temperature, Kothandaraman regressed the water temperature residuals against different series of lagged air temperature residuals:

$$R_w(t) = a + \sum_{i=0}^M b_i R_a(t - i) \quad (18)$$

where

$R_w(t)$ = water temperature residual

$R_a(t)$ = air temperature residual

a, b_i = regression coefficients

He found the multiple correlation coefficients to increase from 0.51 for

M = 0 to 0.79 for M = 5 . However, lags beyond 2 days failed to increase significantly the correlation coefficient. The regression using two lags was found to explain about 60 percent of the variance in the water temperature residuals. Thus his final equation was of the form

$$T(t) = \bar{T} + A \cos wt + B \sin wt + b_0 R_a(t) + b_1 R_a(t - 1) + b_2 R_a(t - 2) \quad (19)$$

71. Song, Pabst, and Bowers (1973), using data from several Minnesota rivers, regressed water temperature residuals from the air temperature residuals. They concluded that the small improvement gained from including lagged terms was insufficient to warrant keeping more than a 1-day lag in their model. They also suggested the option of using the air temperatures directly in the regression rather than their residuals; with the appropriate coefficients, this option should give the same results. These authors also showed that the inclusion of a random component in the model will produce results with statistical characteristics similar to those of the actual time series but that this will decrease the accuracy of the individual predictions. Therefore, the inclusion of a random term in the model should depend on criteria set to define the quality of the fit.

72. Cluis (1972) lagged the stream temperature residuals in Markov fashion to utilize the thermal inertia of water and the same-day air temperature residual:

$$R_w(t) = a_1 R_w(t - 1) + a_2 R_w(t - 2) + K R_a(t) \quad (20)$$

where

a_1 and a_2 = second order Markov process coefficients based on the autocorrelation coefficients of $R_w(t)$

K = exchange coefficient

which is optimized by minimizing the discrepancies between the predicted and measured temperatures for a sample of the data.

73. McMichael and Hunter (1972) suggested applying an

autoregressive, integrated moving average (ARIMA) model to stream temperature data. They determined that for data from the Ohio River at Wheeling, West Virginia, a first-order autoregressive model was sufficient when combined with a first-order harmonic model:

$$T(t) = pT(t - 1) + (1 - p)\bar{T} + b \cos (\omega t + c) - pb \cos [\omega(t - 1) + c] + a(t) \quad (21)$$

where

p = autoregression coefficient

$a(t)$ = normal, independently distributed random values with zero mean and homogeneous variance

This method accounted for 85 percent of the variance remaining in the residuals after the harmonic component had been removed.

74. Edinger et al. (1968) suggested using the equilibrium temperature to predict the water temperature:

$$T(t) = \bar{T}_e + T_u \sin (\omega t + \theta - \alpha) + e^{-kt/h} F(0) \quad (22)$$

where

\bar{T}_e = mean equilibrium temperature

$$T_u = T_i \left/ \sqrt{1 + \left(\frac{\omega h}{k}\right)^2} \right. \quad (23)$$

T_i = amplitude of the harmonic variation of the equilibrium temperature

h = depth of the water column

k = ratio of the thermal exchange coefficient to the product of the specific heat of water and the density of water

$$\alpha = \arctan (\omega h)/k, \quad 0 < \alpha < \pi/2 \quad (24)$$

$F(0)$ = function dependent on the initial conditions

75. During the winter, water temperatures will hover near freezing while air temperatures may drop much lower. To eliminate this bias caused by the inability of water temperatures to respond freely to air

temperature during the winter months, Kothandaraman (1971) regressed residuals for only 9 months of data, excluding December through February. This explained about 75 percent of the variance in the residuals for the 9-month period as compared to 60 percent when the entire year was used (see paragraph 70). Song, Pabst, and Bowers (1973) also calculated their models on the nonfreezing period only, stopping their computations when the stream temperature fell below freezing.

76. Tasker and Burns (1974) adjusted the period (Equation 7) to be less than 1 year if the amplitude of the harmonic function was greater than the mean; i.e., the period was decreased until the amplitude equaled the mean. This produced sharper summer peaks and no temperatures below freezing; the temperatures for the intervening winter months were assumed to be 0°C. In 24 of 27 New England stations, this method yielded smaller root mean square deviations than using a standard 1-year period. The periods of the remaining three stations were unaffected.

77. Drummond and Robey (1975), studying a period from April to September, used a different approach to regress stream temperatures directly from air temperatures since air temperatures contain the basic seasonal variations. Various combinations and lags of air temperature, streamflow, and equilibrium temperature were tested. They determined the best equation for Allegheny River data was

$$T(t) = a + bA(t) + cA(t - 1) + dA(t - 2) + eA(t - 3) - fQ(t) \quad (25)$$

where

A = air temperature

Q = streamflow

Because spring snowmelt depressed the stream temperatures, they developed two equations: one for the period of snowmelt and one for the summer. The two equations accounted for 93 and 89 percent, respectively, of the total variance during these times.

Regionalization

78. The stream temperature measurements necessary to carry out the preceding analyses are available at only a few locations. To estimate stream temperature at other sites on the same river or a similar river nearby calls for an extrapolation of data from one site to another. This regionalization involves finding similar properties at the different locations with which stream temperatures may be correlated. Song, Pabst, and Bowers (1973) approximated the coefficients for their water temperature model using the coefficients derived for the corresponding air temperature model and the size of the drainage area. Tasker and Burns (1974) used regression analysis to relate various stream temperature characteristics to basin characteristics for several New England sites. They developed equations for estimating the mean annual temperature and harmonic amplitude from the station elevation and latitude, the day of maximum temperature from elevation and drainage area, and the harmonic period from the latitude.

Sampling Frequency

79. Often the stream temperatures that are available are not mean daily values but periodic spot measurements. Collins (1968) concluded that 10 to 12 spot-temperature measurements well-spaced throughout the year produced an adequate solution to the basic harmonic curve, Equation 6. Gilroy and Steele (1972) compared weekly, biweekly, and monthly sampling frequencies with daily sampling and concluded that a less-than-daily sampling frequency may provide an adequate estimate of the seasonal temperature pattern. The important factor is even representation during all seasons.

Caddo River Temperatures

80. The stream temperatures used in this study came from continuous recording instruments located at the Highway 84 bridge site. Over the

years, several recorders have been placed in the stream and left, often for weeks at a time. Occasionally, records were completely lost because of storms or vandalism; in addition, problems with the timer or with temperature calibration have rendered some of the information useless or questionable. Unexplainable variations have appeared in the records from time to time. Thus, a far-from-complete record of stream temperatures is available. Where possible, obvious errors in temperature calibration have been corrected. Other measurements have been made at the same location which include frequent sampling during some storm events and spot samples taken weekly, biweekly, or less often. Since for 90 percent of the time the daily stream temperatures have varied less than 3°C, such samples can be used to check for possible errors. They can also be used to check the annual harmonic equation.

81. In Figure 17, mean daily stream temperatures are plotted for the period 1976-1979; records were begun in March 1976. These plots show an incomplete record. For 1976, there are about 70 days of missing

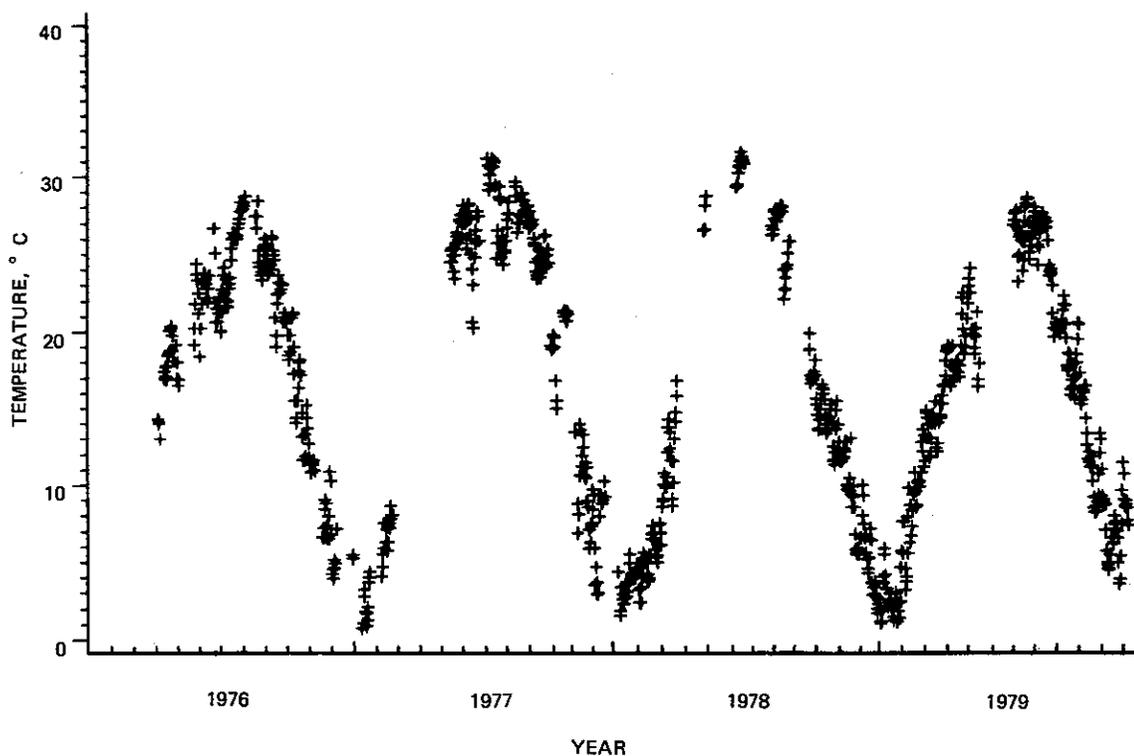


Figure 17. Daily stream temperatures at Highway 84, 1976-1979

data scattered throughout the year. One apparent anomaly is the cool temperatures recorded for June and early July closely followed by rapidly warming temperatures. For 1977, there is a 16-day data lapse beginning in late January, then an 80-day lapse beginning in late February. Some abnormally high temperatures in October were discarded. For 1978, records are missing from early April to mid-August except for a few days in mid-May and late June. There is a month's worth of missing data in late September and early October. For 1979, there are about 50 days with no records from early June to mid-July. The records for the first half of 1979 were measured by a different type of recorder a short distance downstream from where the other measurements were taken. See Appendix E for mean daily stream temperatures taken at the Highway 84 bridge or estimated from air temperatures.

82. Mean daily air temperatures available from Little Rock are complete for the period of interest (Figure 18). In 1976, there was a

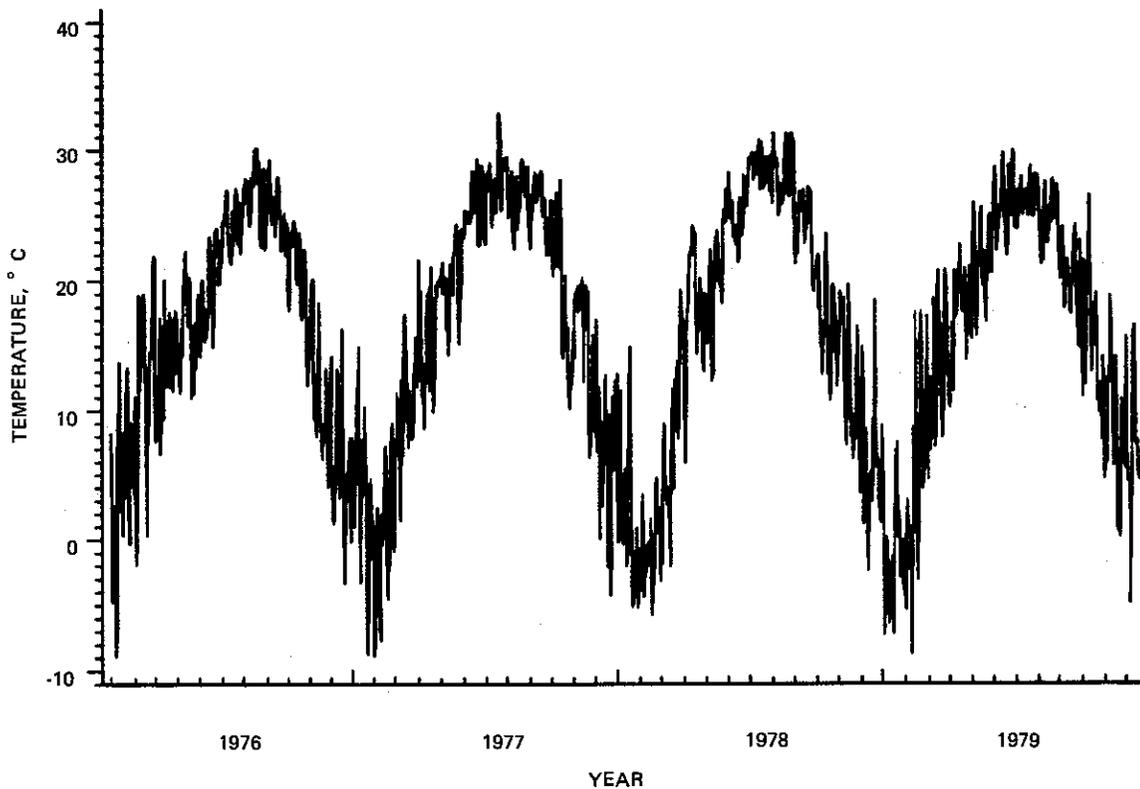


Figure 18. Daily air temperatures at Little Rock, 1976-1979

cool period in May and June followed by a warmer July, but the change is not so dramatic as that in the stream temperatures; since elsewhere the stream and air temperatures agree well, there may be reason to question this period of stream records. For 1977, the air and stream temperatures matched well except for October when high stream temperatures were measured. The first winter comparison of air and stream temperatures can be made for late 1977, and it demonstrates the freezing constraints on water temperatures. For 1978 and 1979, the winter freezing constraint on stream temperatures is again apparent. The May 1978 stream temperatures measured several degrees higher than the air temperatures. For 1979, there is a steady decrease in stream temperature as compared to air temperatures beginning around the first of April and continuing until the gage was discontinued in June. Since, except for the aforementioned cases, the stream and air temperatures tend to match one another, there is reason to suspect some of this stream temperature data (Figure 17) to be inaccurate.

Seasonal Temperature Cycle

83. The annual temperature cycle predicted by the harmonic model described in Equation 6 is a smooth sinusoidal curve. The recorded temperatures fluctuate about this curve. Several features are evident about the equation. The value for \bar{T} should equal the mean annual measured temperature M when calculated from a complete year of uniformly spaced records. This occurs with the air temperature (Table 20), but it is impossible to know the true water temperature mean since so many records are missing or questionable; the mean of the available records may be quite different from the true mean and from the calculated \bar{T} . The magnitude and direction of error depend on how many records are missing and for what periods. The means of the available stream temperature records appear too high for 1976 and 1977 and too low for 1978 and 1979. Generally the curves fit the data well as evidenced by the correlation coefficients of over 0.90 for 1977-1979 (Table 20). However, 1976 with a correlation coefficient of only 0.86 appears much affected by the cool June.

84. The coefficients of seasonal harmonic curves for the 1976 to 1979 Caddo River stream temperatures and for the average over that period are shown in Table 20. The values show considerable variation among years. It should be noted that while the minimum of the curve $\bar{T} - a$ is about the same each year, the maximum $\bar{T} + a$ varies almost 4°C . Therefore, it is not advisable to use data indiscriminately from one year to model another year. The seasonal harmonic for 1979 is compared to the measured data in Figure 19.

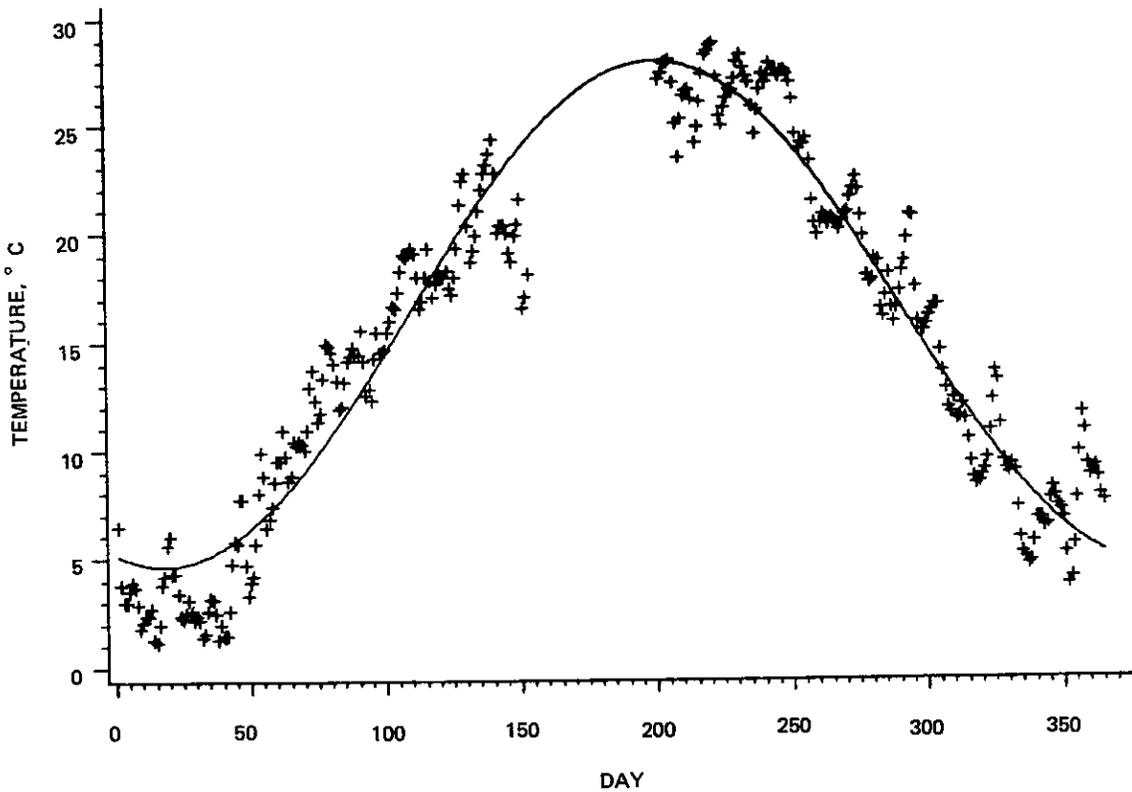


Figure 19. Stream temperatures at Highway 84, 1979

Residuals

85. Subtracting the seasonal cycle from the recorded temperatures leaves residuals which, ideally, should fluctuate randomly about zero. The residual structure of the air temperature series is shown in Figure 20. Two trends are consistent throughout the data. First, the

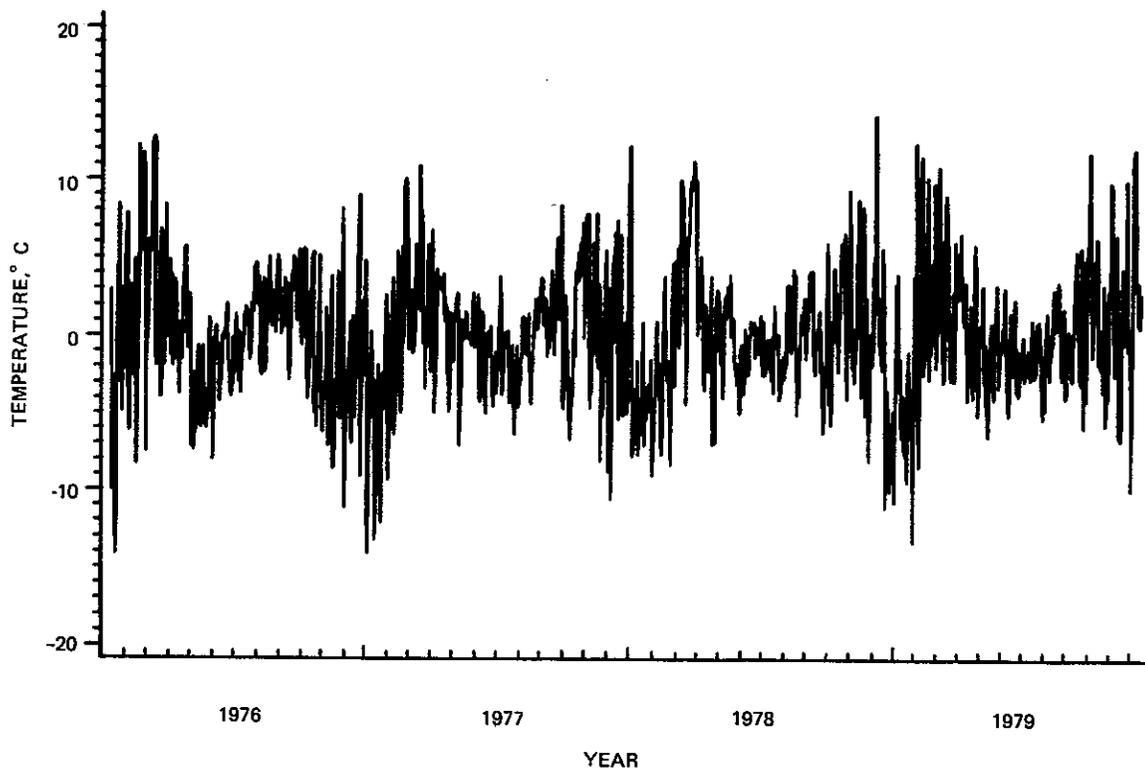


Figure 20. Air temperature residuals, 1976-1979

magnitude of the fluctuations is smaller in summer than during the rest of the year. Second, there appear to be other cycles in the residuals. At the beginning of each year, the residuals are consistently negative, indicating that the seasonal curves do not drop low enough in winter. A sharp rise in temperature in February or March makes the ensuing residuals largely positive. They tend to be slightly negative during the summer, then slightly positive for the remainder of the year, indicating a cycle with a period of about one-half year. Removal of this cycle, however, only marginally improves the results since the day-to-day temperature fluctuations may be several times larger than the amplitude of the cycle.

86. Trends in the stream temperature residuals, because of the limited data, are more difficult to discern (Figure 21). In general, the day-to-day fluctuations (2-4°C) tend to be only about one-fourth as large as those for air temperatures, but no seasonal trend in magnitude is apparent. For 1979, the stream temperature residuals follow the same

pattern as the air temperature residuals, but for the other years they do not.

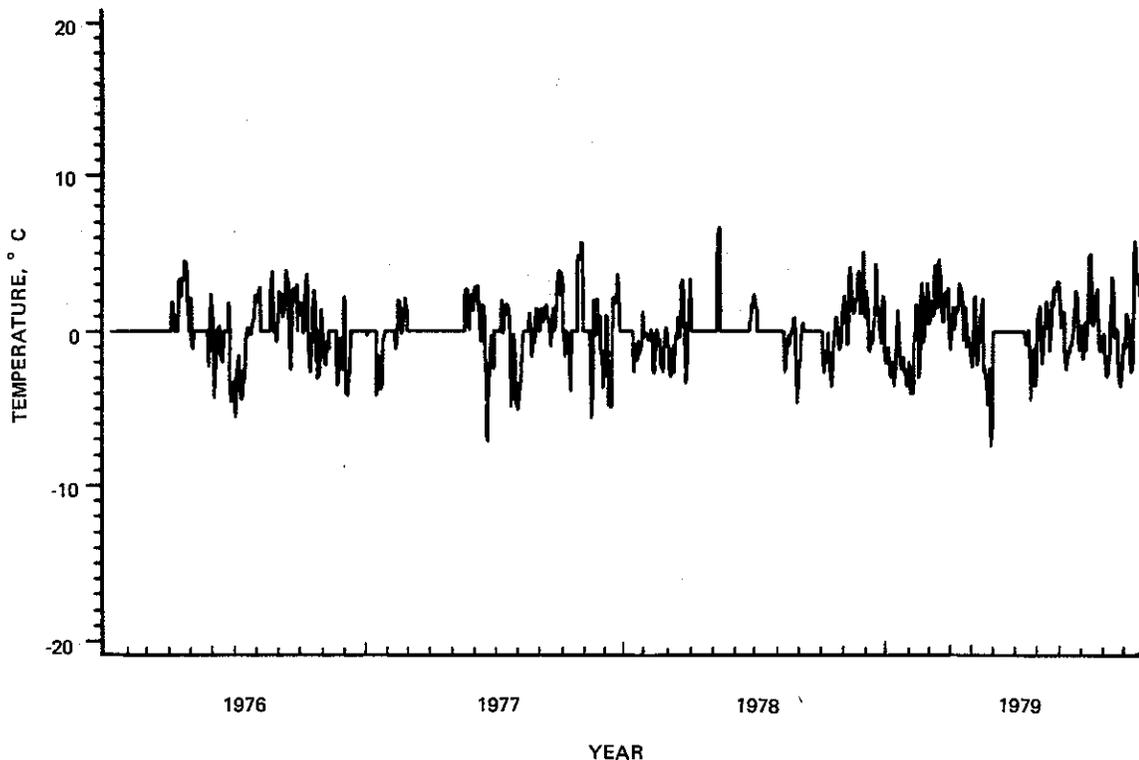


Figure 21. Stream temperature residuals, 1976-1979

Results and Discussion

87. The models developed for 1978 and 1979 are listed in Table 21. In model 1 for both years, the stream temperatures are regressed directly from air temperatures. Improvement in the coefficient of determination R^2 by adding streamflow or additional lags was insignificant, although equations with an R^2 only a fraction lower could have been developed using other combinations of lagged air temperatures. This possibility applies to all the equations in which lagged values were used. One combination was chosen over others because it offered a slightly higher R^2 , although the difference may be insignificant.

88. Models 2, 3, and 4 for both years separate the seasonal curve and regress on the residuals. Model 2 used only lagged air temperature

residuals R_a ; model 3 included streamflow; model 4 used a lag of the stream temperature in a Markov fashion as well as air temperature residuals.

89. From the R^2 's (Table 22), it would appear that model 4 is more accurate than the others for both 1978 and 1979. The R^2 's also show that while including streamflow in model 3 (Equation 3) improves it slightly over model 2, the improvement is small. The R^2 's imply all the models are very good.

90. In order to evaluate which model is the most accurate predictor of stream temperatures, the residuals between the values generated by the models and those measured in the Caddo River were calculated. Then the percentiles of the residuals were calculated (Table 22). As an example, for 1979 50 percent of the values generated by model 1 were within 2.17°C of the measured values, while for model 2, 50 percent were within 0.94°C. The percentiles show models 2 and 3 to be equally good, while model 1 has the largest spread.

91. Figures 22-29 compare the values generated by the four models for 1978 and 1979 (shown as a continuous line) with the measured values (indicated by crosses). Immediately noticeable is the large fluctuation occurring with model 1 (Figures 22 and 23). While the temperatures generated with model 1 follow the measured values quite well in the summer and early fall, elsewhere the fluctuations are too large, implying that the model is too responsive to fluctuations in the air temperatures; the negative values generated early in the year should be corrected. The temperatures predicted by model 2 (Figures 24 and 25) resemble the measured values more closely except perhaps in the summer when they do not pick up the large fluctuations. The model 3 temperatures (Figures 26 and 27) are essentially the same as those from model 2; however, there are some fine differences, such as around day 140 in 1979. It should be noted that the occurrence of a very large storm during a period for which there are no stream temperature records could cause a conspicuous error which, however, would be readily caught by inspecting a graph of the generated data.

92. Autoregressive model 4 (Figures 28 and 29) also reproduces

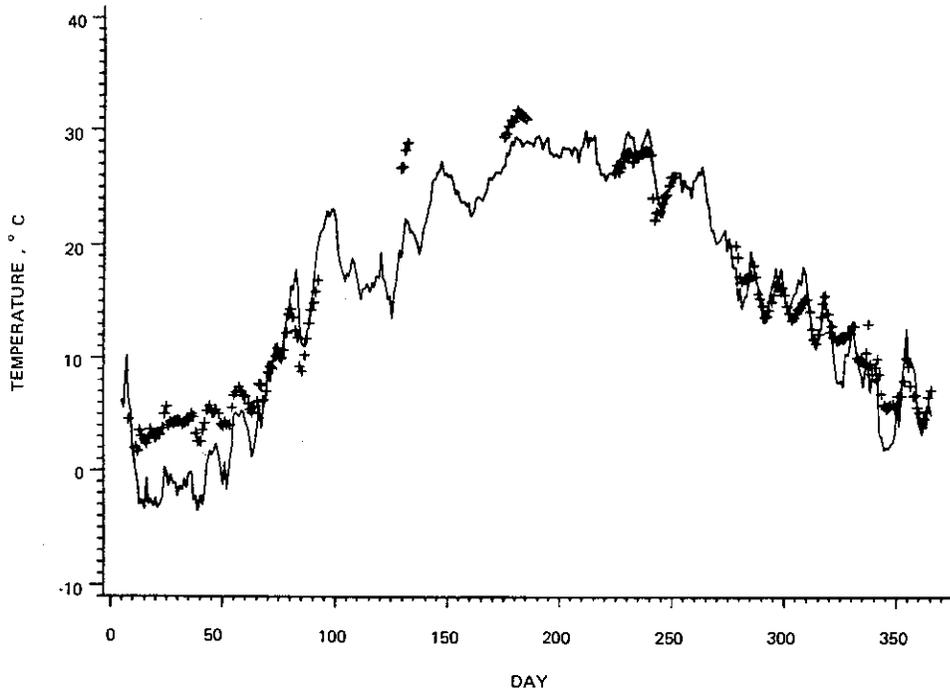


Figure 22. Temperatures generated by model 1, 1978

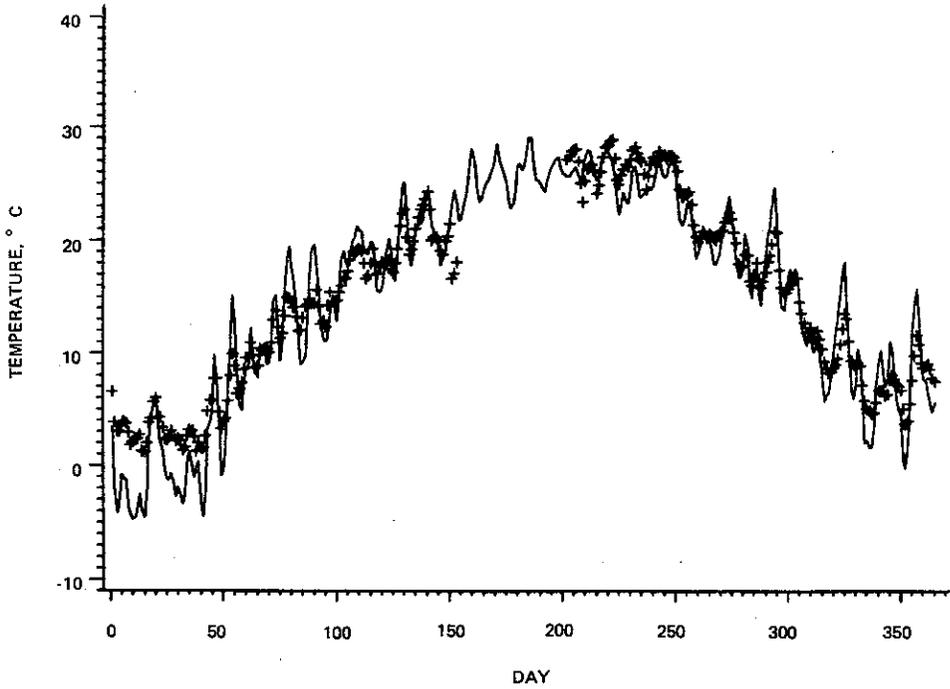


Figure 23. Temperatures generated by model 1, 1979

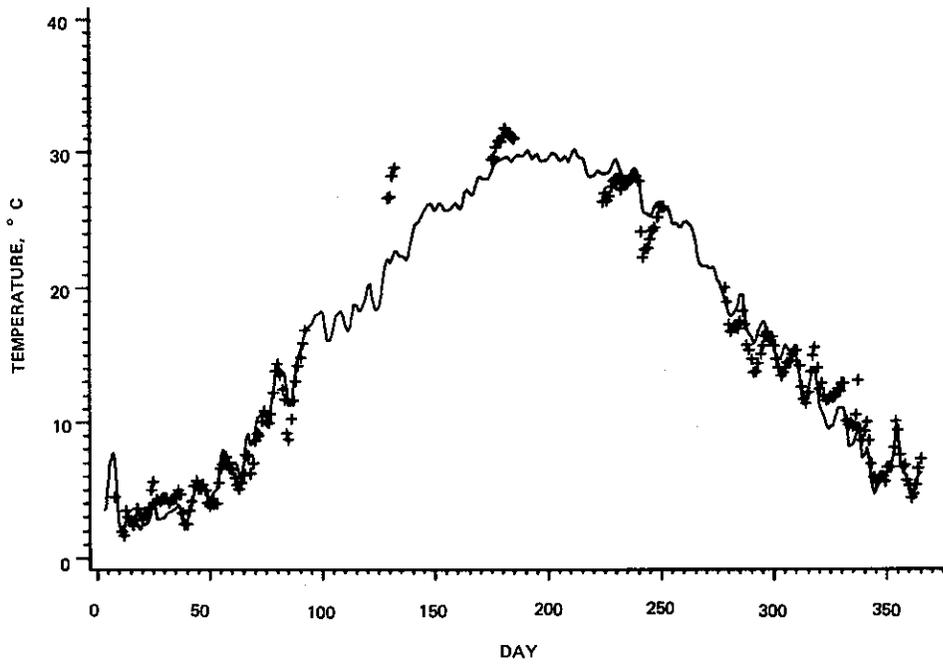


Figure 24. Temperatures generated by model 2, 1978

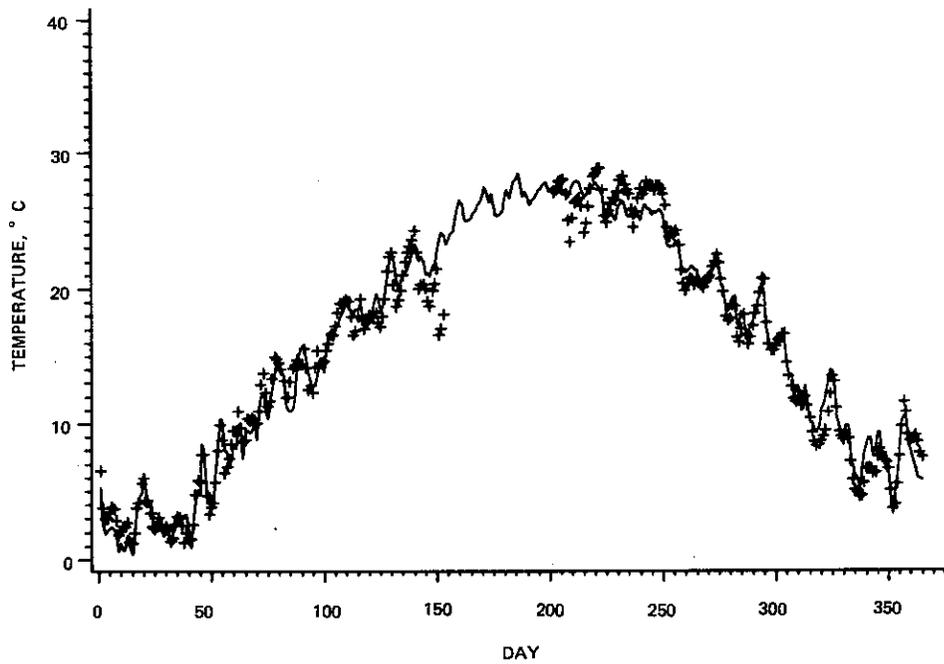


Figure 25. Temperatures generated by model 2, 1979

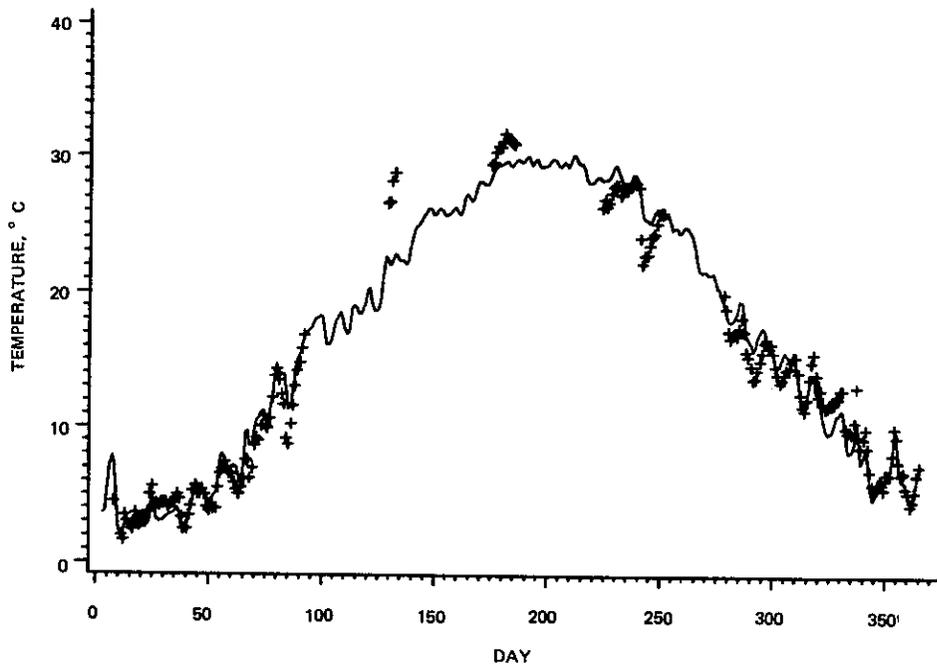


Figure 26. Temperatures generated by model 3, 1978

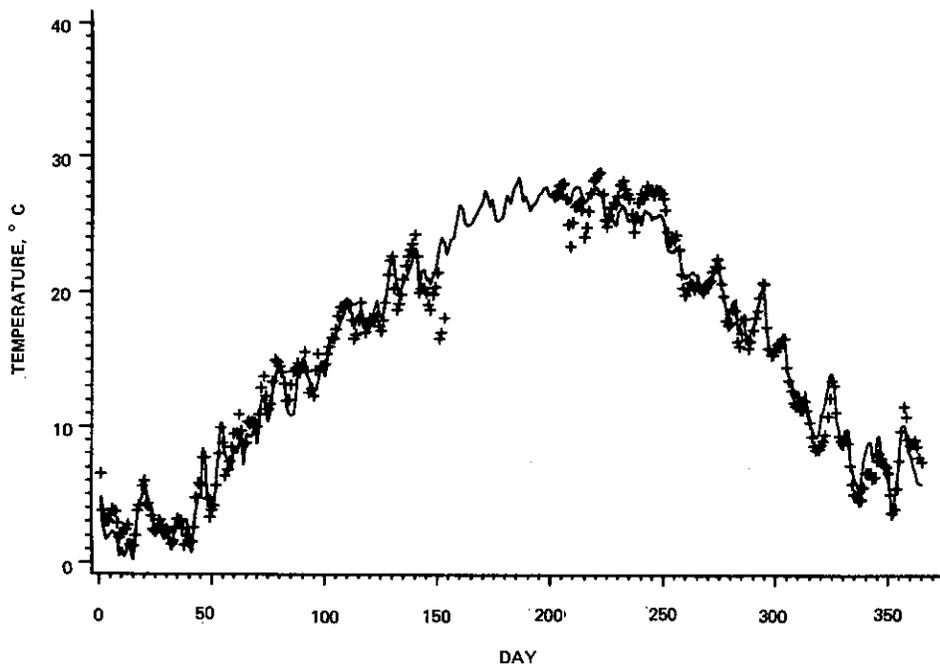


Figure 27. Temperatures generated by model 3, 1979

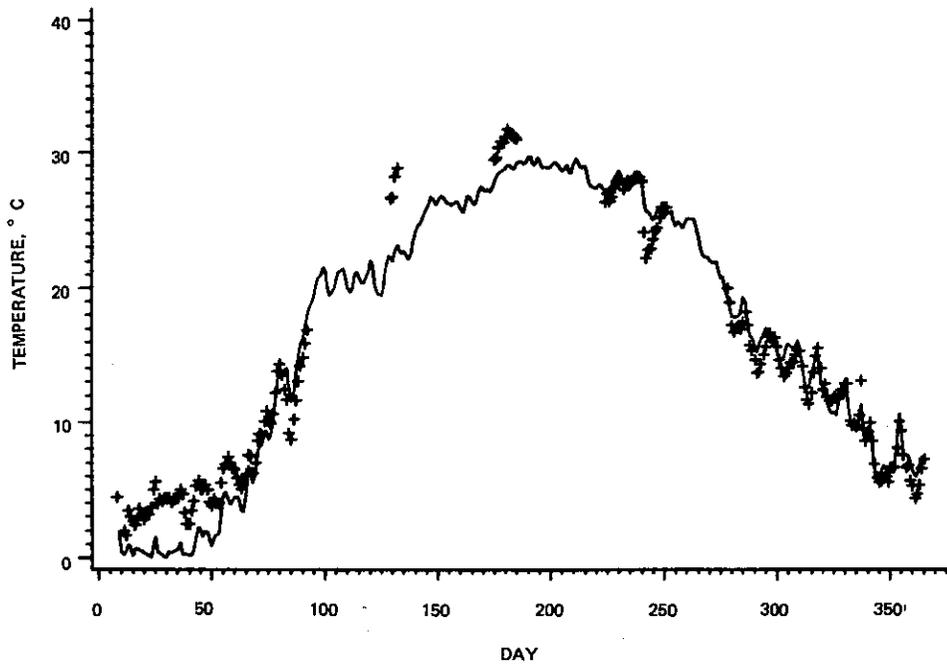


Figure 28. Temperatures generated by model 4, 1978

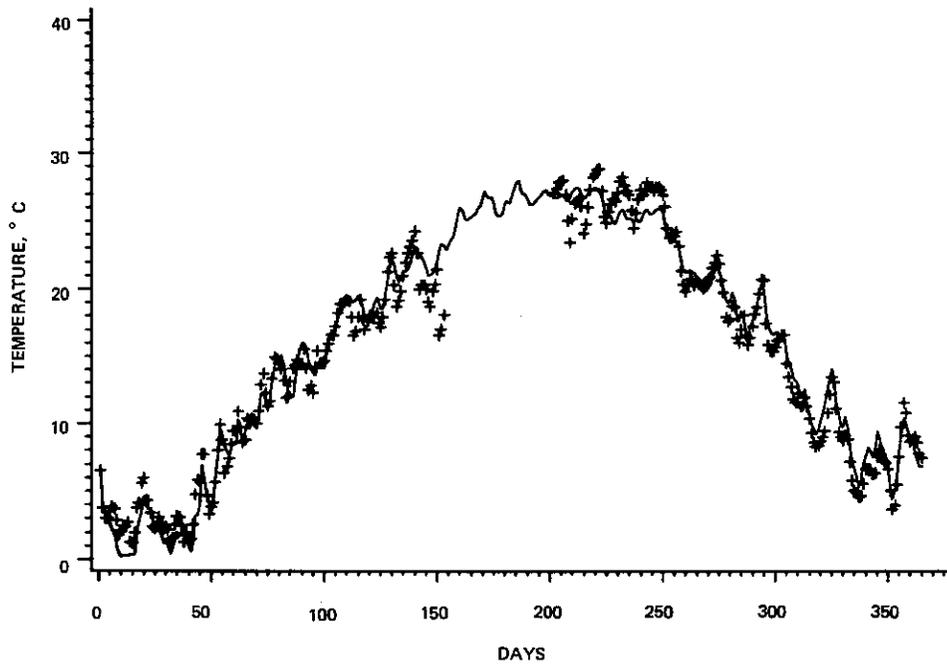


Figure 29. Temperatures generated by model 4, 1979

the measured temperatures well; close examination shows that it gives smaller fluctuations than the other models, which is not unexpected. A shortcoming of autoregressive models is shown in Figure 28: the initial temperature for 1978 put into the model was too low, and the error carried through into March before it was eliminated.

PART V: CONCLUSIONS AND RECOMMENDATIONS

93. This report is intended to document some of the work on DeGray Lake and provide reference for future work. The main conclusions follow.

94. The hydraulic residence time of a reservoir can vary considerably during any given time in a manner inversely proportional to outflow. For the period 1974 through 1980, the annual hydraulic residence time of DeGray Lake ranged from 0.7 to 2.0 years. The average over this period was 1.4 years.

95. The stream gage at the Highway 84 bridge near Amity measures the runoff from only 68 percent of the watershed controlled by DeGray Dam. On an area-proportion basis, the streamflow at Highway 84 should be multiplied by 1.47 to approximate the total inflow into DeGray Lake. However, for any given year this may leave an error as large as 20 percent of the estimated inflow. To eliminate the error in the water balance for the years 1974-1980, the Highway 84 streamflow should be increased by the factors in Table 19.

96. While stream temperatures have been recorded on the Caddo River for several years, the recorded data have many gaps. Selection of a model to fill in the gaps was based on several factors. The stream temperature data limited the choice of models to those which could be developed from a discontinuous data set. Of those models which were equally acceptable, the simplest, model 2, was chosen. The model equations selected for 1976 through 1980 are given in Table 23. The mean daily stream temperature records with gaps filled in are presented in Appendix E.

97. A sinusoidal curve generally gives a good approximation of the seasonal temperature cycle in temperate climates. Exceptions occur with long freezing or near-freezing winters. These conditions have been modeled with modified or partial sinusoidal curves. Long periods of abnormal temperatures can also decrease the correlation for any given year in areas where the correlation is normally high, as for the Caddo River in 1976. There is significant variation in the temperature cycle from

year to year, and attempts to model one year from another year's data or from an average of several years can increase expected errors.

98. Day-to-day temperature fluctuations are also significant. There is currently no method for the "accurate" prediction of stream temperatures at most stream sites given the type and quality of hydrologic and meteorologic data commonly available. Acceptable temperatures can usually be estimated, the quality depending on the quality of the available data.

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Table 1
Morphometric Characteristics of DeGray Lake

<u>Characteristic</u>	<u>Flood-Control Pool</u>	<u>Conservation Pool</u>	<u>Minimum Pool</u>
Elevation, m msl	128.9	124.4	111.9
Surface area, km ²	68.5	54.3	25.8
Volume, 10 ⁶ m ³	1087	808	322
Shoreline, km	362	333	209
Maximum depth, m	64.5	60.0	47.5
Mean depth,* m	15.9	14.9	12.5
Reservoir length, km	37	32	24
Shoreline Development Index**	12.3	12.8	11.6
Volume of conveyance, 10 ⁶ m ³		541	
Hydraulic residence time, year		1.38	

* Mean depth = lake volume/surface area.

** Shoreline Development Index
= length of shoreline / (2 · √π · surface area) .

Table 2
Morphometric Characteristics of DeGray Reregulating Dam

<u>Characteristic</u>	<u>Spillway Crest Elevation</u>	<u>Minimum Pool</u>
Elevation, m msl	67.4	63.7
Surface area, km ²	1.74	0.365
Volume, 10 ⁶ m ³	4.44	0.740
Maximum depth, m	7.9	4.2
Mean depth, m	2.55	2.03
Length, km	4.6	2.7

Table 3
Arkadelphia Meteorological Data

<u>Month</u>	<u>Temperature 1948-1979, °C</u>	<u>Precipitation 1941-1979, cm</u>
Jan	5.8	11.1
Feb	8.3	10.3
Mar	12.3	13.0
Apr	17.6	14.3
May	21.6	14.5
Jun	25.5	10.9
Jul	27.6	9.7
Aug	27.1	8.3
Sep	23.6	10.3
Oct	17.8	9.0
Nov	11.2	11.7
Dec	7.1	11.0
Average	16.6	
Total		134.1

Table 4
Little Rock Meteorological Data Average, 1949-1979

<u>Month</u>	<u>Cloud Cover</u>	<u>Pressure mb</u>	<u>Temperature, °C</u>		<u>Wind Speed m/sec</u>	<u>Predominant Wind Direction</u>
			<u>Dry Bulb</u>	<u>Dew Point</u>		
Jan	0.61	1013.7	4.51	-0.75	3.94	NNE
Feb	0.57	1012.6	6.82	0.58	4.11	SW
Mar	0.58	1011.5	11.22	3.89	4.44	S
Apr	0.56	1012.4	16.93	9.61	4.14	S
May	0.54	1013.4	21.44	15.01	3.53	S
Jun	0.47	1014.6	25.67	19.10	3.28	SW
Jul	0.49	1016.3	27.16	21.11	3.06	SW
Aug	0.44	1016.2	26.45	20.14	2.97	SW
Sep	0.45	1015.5	22.81	16.86	3.03	NE
Oct	0.41	1015.4	17.08	10.52	3.19	SW
Nov	0.50	1014.4	10.63	4.21	3.69	SW
Dec	0.56	1013.4	6.24	0.60	3.81	SW
Average	0.52	1014.1	16.41	10.07	3.60	SW

Table 5
Selected Caddo River Streamgage Sites

Site	Elevation m msl	Drainage Area km ²	Distance from		Period of Continuous Records
			Confluence Thalweg km	Following Path of Conveyance km	
Glenwood	159	497	83.8	70.8	1947-date
Highway 84 bridge	130	759	62.2	49.2	1975-date
Runyon Bridge	121	808	54.4	41.4	1946-1971
DeGray Dam	66	1173	12.7	12.7	1960-date
Reregulating Dam	61	1243	7.7	7.7	1971-date
Confluence	55	1269	0	0	No previous record

Table 6
Theoretical Hydraulic Residence Time (Years) Calculated from
Monthly Inflows, DeGray Lake, Arkansas

Month	1974	1975	1976	1977	1978	1979	1980	Average
Jan	0.62	1.68	4.10	4.99	1.04	1.20	1.83	1.40
Feb	1.21	0.75	8.97	10.1	1.07	1.58	1.75	1.59
Mar	1.31	0.68	1.80	0.46	1.28	0.41	1.07	0.76
Apr	8.97	0.65	1.85	0.81	1.59	0.28	0.87	0.80
May	0.45	0.40	1.96	2.39	0.99	0.34	0.72	0.64
Jun	0.25	1.29	1.14	2.36	2.00	0.83	1.57	0.84
Jul	2.07	2.46	1.49	3.52	2.34	4.51	1.85	2.31
Aug	4.60	1.88	1.22	2.88	2.74	2.03	3.55	2.29
Sep	1.11	3.55	1.97	1.19	2.84	1.58	4.42	1.87
Oct	0.93	2.72	3.56	4.53	2.45	2.05	7.57	2.36
Nov	0.44	2.28	1.29	3.52	2.54	3.51	4.42	1.48
Dec	0.43	3.37	6.63	1.63	2.45	1.84	1.35	1.38

Table 7
Monthly Streamflow at Glenwood, m³/sec

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1963	2.7	2.7	18.1	4.0	2.2	1.2	1.4	1.1	1.1	0.7	1.7	1.7
1964	1.1	3.3	19.0	33.0	3.7	1.9	1.7	6.3	3.3	1.7	3.8	3.0
1965	19.7	25.3	8.3	3.8	4.0	6.3	2.8	1.2	5.4	1.6	1.6	2.2
1966	10.1	11.7	2.5	38.3	12.4	1.0	1.2	11.0	1.5	1.4	1.7	8.2
1967	2.6	2.8	12.7	20.4	41.2	5.9	3.0	1.5	1.7	1.8	3.5	19.3
1968	11.0	8.0	34.5	24.5	85.2	6.9	3.2	2.5	1.7	1.3	8.9	19.5
1969	35.9	21.1	12.5	5.4	5.7	13.0	9.7	2.6	1.6	3.0	15.5	19.7
1970	9.7	12.5	25.4	32.4	4.6	5.2	2.4	2.7	2.2	8.8	6.0	7.3
1971	8.8	13.1	7.5	5.4	3.1	1.8	2.9	3.1	0.8	1.6	1.6	44.7
1972	7.1	4.0	1.5	1.5	9.5	0.8	0.9	0.8	7.3	21.0	31.7	14.5
1973	19.4	12.8	53.2	46.8	5.4	11.2	3.5	1.8	6.1	23.8	27.8	22.4
1974	17.1	7.2	9.8	25.6	11.8	51.4	2.0	3.1	10.8	4.2	34.5	15.4
1975	10.6	26.2	33.9	11.4	20.4	10.3	2.6	1.8	2.2	1.6	2.6	9.6
1976	4.3	8.9	14.1	4.7	5.2	8.0	3.0	1.2	2.5	6.8	6.9	6.3
1977	7.0	10.1	28.5	11.1	2.4	5.2	4.8	2.8	1.2	1.0	8.5	2.8
Mean	11.1	11.3	18.8	17.9	14.4	8.7	3.0	2.9	3.3	5.4	10.4	13.1
Percent of total means	9	9	16	15	12	7	2	2	3	4	9	11

Table 8
Monthly Streamflow at Runyan Bridge, m³/sec

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1960	27.9	15.6	20.5	4.7	25.9	8.9	4.2	1.4	1.7	2.3	7.3	40.6
1961	12.5	27.5	53.3	21.0	48.7	3.4	2.5	3.6	8.1	2.4	19.0	24.4
1962	34.9	39.3	26.8	16.4	10.0	3.0	1.5	1.0	6.4	15.1	6.6	5.2
1963	5.6	5.4	33.4	7.8	4.1	1.7	1.6	1.2	1.4	0.7	2.8	2.4
1964	1.6	6.9	35.8	55.8	5.0	1.1	0.8	5.7	3.6	2.0	4.7	6.3
1965	26.5	35.2	16.0	7.2	4.8	6.9	3.1	1.0	4.6	1.4	1.7	2.2
1966	11.0	21.3	4.5	44.3	15.9	1.1	1.0	20.0	2.1	2.0	2.4	9.5
1967	5.7	5.2	17.0	23.1	61.4	8.0	4.3	1.4	1.6	1.7	4.3	23.2
1968	15.3	13.6	42.9	28.5	110.6	9.8	2.6	3.0	1.7	1.4	10.0	30.5
1969	49.9	30.0	17.8	7.6	6.9	17.0	8.6	2.2	0.9	1.4	13.6	21.1
1970	14.2	27.5	35.8	40.3	6.9	7.2	1.1	1.2	0.9	8.8	9.9	10.3
1971	12.3	17.5	13.0	6.9	3.2	1.4	2.5	3.5	0.7	1.9	2.6	0.0
Mean	18.1	20.4	26.4	22.0	25.3	5.8	2.8	3.8	2.8	3.4	7.1	14.6
Percent of total means	12	13	17	14	17	4	2	2	2	2	5	10

Table 9
Monthly Streamflow at Highway 84, m³/Sec

<u>Year</u>	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Jul</u>	<u>Aug</u>	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>	<u>Dec</u>
1975	11.57	32.75	42.75	15.42	31.55	20.60	3.84	2.52	2.67	2.17	3.07	12.01
1976	8.86	18.02	26.13	8.57	10.63	15.06	6.32	3.22	4.67	10.66	9.63	9.76
1977	11.62	17.69	49.46	16.03	4.56	9.55	6.96	5.24	3.25	3.13	18.30	7.89
1978	15.55	10.62	23.96	14.60	17.12	5.11	2.59	2.78	3.98	2.68	23.94	19.70
1979	15.97	17.69	41.60	38.23	42.55	12.84	6.82	4.87	4.15	3.39	5.41	16.90
1980	10.48	10.34	11.77	16.01	16.06	4.13	2.68	2.31	8.05	8.74	6.70	18.28
Mean	12.34	17.85	32.61	18.14	20.41	11.21	4.87	3.49	4.46	5.13	11.18	14.09
Percent of total means	8	11	21	12	13	7	3	2	3	3	7	9

Table 10
Highway 84 Streamflow Estimates

<u>Total Streamflow (Q), m³/sec</u>	<u>Percent of Time Flow Is Less Than Q</u>	<u>Percent of Flow Less Than Q</u>
5	42	11
10	71	27
13*	78	34
15	81	37
20	87	44
25	90	50
50	96	66
100	98	77
200	99.5	88
300	99.8	95

* Mean annual streamflow.

Table 11
Water Balance for DeGray Lake in 1974, 10⁶ m³

Month	Direct Precipitation	Highway 84 Inflow	Ungaged Inflow	Outflow	Evaporation	Error	Volume Change
Jan	7.32	55.69	26.18	106.29	1.78	18.15	-0.73
Feb	2.90	18.32	8.61	54.70	2.23	11.42	-15.68
Mar	4.13	29.98	14.09	50.28	3.03	8.53	3.43
Apr	7.72	92.68	43.56	7.35	4.88	-7.93	123.80
May	9.15	36.65	17.23	145.23	5.32	12.41	-75.11
Jun	16.71	187.11	87.94	260.82	6.32	-27.78	-3.16
Jul	3.27	4.95	2.33	31.78	6.73	-3.84	-31.81
Aug	11.45	8.38	3.94	14.34	5.53	-1.21	2.69
Sep	9.09	31.04	14.59	59.27	3.33	2.74	-5.13
Oct	5.81	19.15	9.00	70.70	2.73	-0.64	-40.10
Nov	11.19	128.74	60.51	150.58	1.98	-20.25	27.65
Dec	5.79	47.60	22.37	152.62	1.52	6.21	-72.17
Year	94.53	660.29	310.35	1103.96	45.38	-2.19	-86.36

Table 12
Water Balance for DeGray Lake in 1975, 10⁶ m³

Month	Direct Precipitation	Highway 84 Inflow	Ungaged Inflow	Outflow	Evaporation	Error	Volume Change
Jan	3.93	30.99	14.57	39.18	1.80	15.91	24.42
Feb	6.86	79.23	37.24	87.99	2.23	19.41	52.53
Mar	11.25	114.50	53.81	97.20	3.43	-1.14	77.79
Apr	6.47	39.96	18.78	101.21	3.62	-4.66	-44.28
May	13.30	84.51	39.72	163.98	4.86	-0.99	-32.29
Jun	6.63	53.40	25.10	51.09	5.66	-4.40	23.98
Jul	3.43	10.29	4.84	26.75	6.29	-9.04	-23.98
Aug	2.98	6.75	3.17	35.02	5.21	-5.94	-33.27
Sep	4.20	6.91	3.25	18.57	3.85	-6.62	-14.68
Oct	0.97	5.81	2.73	24.25	3.09	-7.04	-24.86
Nov	3.65	7.97	3.74	28.93	2.09	-7.17	-22.83
Dec	2.54	32.17	15.12	19.55	1.63	-13.00	15.66
Year	66.21	472.49	222.07	693.72	43.76	-24.68	-1.38

Table 13
Water Balance for DeGray Lake in 1976, 10⁶ m³

<u>Month</u>	<u>Direct Precipitation</u>	<u>Highway 84 Inflow</u>	<u>Ungaged Inflow</u>	<u>Outflow</u>	<u>Evaporation</u>	<u>Error</u>	<u>Volume Change</u>
Jan	2.46	23.73	11.15	16.07	1.87	-10.09	9.30
Feb	4.43	45.14	21.22	7.35	1.98	-8.86	52.60
Mar	8.96	69.99	32.90	36.52	2.81	-4.02	52.60
Apr	2.95	22.21	10.44	35.64	4.29	-10.60	-14.92
May	7.90	28.46	13.38	33.68	5.05	-6.36	4.65
Jun	13.49	39.03	18.34	57.92	5.27	-2.89	4.77
Jul	2.83	16.93	7.96	44.20	6.61	3.53	-19.57
Aug	2.03	8.63	4.06	53.98	5.97	-15.44	-60.68
Sep	4.45	12.10	5.69	33.40	3.26	-12.85	-27.28
Oct	7.22	28.56	13.43	18.53	2.74	-18.93	9.01
Nov	2.45	24.96	11.73	54.75	2.19	-14.74	-32.54
Dec	2.95	26.14	12.29	9.94	1.75	-7.19	22.51
Year	62.12	345.88	162.59	401.98	43.79	-108.26	16.54

Table 14
Water Balance for DeGray Lake in 1977, 10⁶ m³

<u>Month</u>	<u>Direct Precipitation</u>	<u>Highway 84 Inflow</u>	<u>Ungaged Inflow</u>	<u>Outflow</u>	<u>Evaporation</u>	<u>Error</u>	<u>Volume Change</u>
Jan	2.26	31.13	14.63	13.22	1.98	-6.64	26.18
Feb	4.40	42.80	20.12	6.50	2.40	-5.58	52.85
Mar	9.87	132.49	62.27	143.66	3.75	-25.65	31.57
Apr	10.46	41.55	19.53	81.86	4.82	6.16	-8.99
May	2.28	12.22	5.74	27.56	5.38	-9.08	-21.77
Jun	7.62	24.74	11.63	27.88	5.77	6.54	16.88
Jul	4.40	18.65	8.77	18.72	5.73	-13.97	-6.61
Aug	2.30	14.02	6.59	22.86	5.45	-12.46	-17.86
Sep	3.33	8.42	3.96	55.35	3.75	-12.00	-55.39
Oct	1.41	8.37	3.93	14.54	2.79	-11.56	-15.17
Nov	9.63	47.42	22.29	18.72	2.26	-14.33	-44.04
Dec	2.62	21.13	9.93	40.51	1.82	-7.99	-16.64
Year	60.58	402.94	189.39	471.38	45.90	-106.56	29.07

Table 15
Water Balance for DeGray Lake in 1978, 10⁶ m³

Month	Direct Precipitation	Highway 84 Inflow	Ungaged Inflow	Outflow	Evaporation	Error	Volume Change
Jan	6.44	41.64	19.57	63.45	1.96	4.60	6.85
Feb	2.00	25.69	12.07	61.63	2.38	-1.68	-25.93
Mar	5.57	64.18	30.16	51.60	3.31	10.78	55.78
Apr	6.08	37.85	17.79	41.52	4.28	-0.26	15.66
May	6.56	45.86	21.55	66.61	4.91	-3.19	-0.73
Jun	2.50	13.25	6.23	33.01	5.80	-7.63	-24.47
Jul	3.22	6.95	3.26	28.12	6.56	-12.78	-34.03
Aug	5.49	7.46	3.50	24.04	5.61	-11.02	-24.22
Sep	4.23	10.32	4.85	23.23	3.38	-9.19	-16.39
Oct	0.77	7.18	3.37	26.85	2.53	-17.18	-35.23
Nov	12.45	62.06	29.17	25.98	1.48	1.83	78.05
Dec	8.67	52.77	24.80	26.85	2.19	15.25	72.46
Year	63.98	375.21	176.32	472.89	44.39	-30.47	67.80

Table 16
Water Balance for DeGray Lake in 1979, 10⁶ m³

Month	Direct Precipitation	Highway 84 Inflow	Ungaged Inflow	Outflow	Evaporation	Error	Volume Change
Jan	4.69	42.77	20.10	55.03	2.10	-4.83	5.60
Feb	7.01	42.79	20.11	41.85	2.21	7.82	33.27
Mar	10.21	111.41	52.36	162.65	3.59	0.08	7.83
Apr	12.21	99.08	46.57	232.60	4.09	15.95	-62.88
May	17.72	113.96	54.56	192.14	4.87	30.12	18.35
Jun	7.43	33.27	15.64	79.19	5.07	8.61	19.30
Jul	8.55	18.27	8.59	14.61	5.58	-3.01	12.22
Aug	3.53	13.05	6.13	32.54	4.85	-2.99	-17.67
Sep	5.65	10.75	5.05	41.82	4.38	-8.28	-33.03
Oct	4.70	9.08	4.27	32.21	3.30	-11.13	-28.60
Nov	3.08	14.02	6.59	18.79	2.60	-5.94	-3.64
Dec	6.55	45.26	21.27	35.87	1.78	7.13	42.56
Year	91.33	553.71	261.24	939.30	44.42	33.53	-44.91

Table 17
Water Balance for DeGray Lake in 1980, 10⁶ m³

Month	Direct Precipitation	Highway 84 Inflow	Ungaged Inflow	Outflow	Evaporation	Error	Volume Change
Jan	4.49	28.07	13.19	36.04	1.73	11.10	19.08
Feb	2.93	25.50	11.98	37.68	2.42	10.21	10.52
Mar	8.55	30.19	14.19	61.46	2.98	16.90	5.38
Apr	8.04	42.41	19.93	75.56	4.75	18.61	8.69
May	11.30	43.10	20.26	92.05	4.43	26.48	4.67
Jun	2.76	10.94	5.14	41.93	5.95	0.00	-29.04
Jul	1.24	7.18	3.37	35.59	8.75	-11.02	-43.57
Aug	0.00	6.20	2.92	18.55	6.97	-11.02	-27.42
Sep	12.75	19.01	8.93	14.92	4.98	-4.16	16.64
Oct	4.16	24.97	11.74	8.71	3.25	-5.17	23.73
Nov	7.42	17.38	8.17	14.92	2.14	11.72	27.64
Dec	2.86	49.37	23.20	48.87	1.81	-1.07	23.01
Year	66.50	304.32	143.02	486.28	50.16	62.58	39.33

Table 18
Water Balance for DeGray Lake, Annual Summary, 10⁶ m³

Year	Direct Precipitation	Highway 84 Inflow	Ungaged Inflow	Outflow	Evaporation	Error	Storage Change
1974	95	660	310	1104	45	-2	-86
1975	66	472	222	694	44	-23	-1
1976	62	346	163	402	44	-109	16
1977	61	403	189	471	46	-107	29
1978	64	375	176	473	44	-30	68
1979	91	554	260	939	44	33	-45
1980	67	304	143	486	50	64	42
Average	72	445	209	653	45	-25	3

Table 19
Factors for Adjusting the Ungaged
Inflow into DeGray Lake to
Eliminate Water Imbalances*

<u>Year</u>	<u>F</u>
1974	0.47
1975	0.42
1976	0.16
1977	0.21
1978	0.39
1979	0.53
1980	0.68

* Corrected ungaged inflow
= factor F × Highway 84
inflow.

Table 20
Coefficients for Seasonal Harmonic Curves $T(t) = \bar{T} + a \sin (wt + \theta)$
for Stream and Air Temperatures*

<u>Year</u>	<u>M</u>	<u>\bar{T}</u>	<u>a</u>	<u>θ</u>	<u>$\bar{T} - a$</u>	<u>$\bar{T} + a$</u>	<u>R</u>
<u>Highway 84 Stream Temperature</u>							
1976	19.42	15.69	10.51	-1.83	5.18	26.20	0.86
1977	19.32	17.15	12.37	-1.83	4.78	29.52	0.93
1978	12.25	17.12	12.82	-1.87	4.30	29.94	0.95
1979	14.66	16.24	11.60	-1.88	4.64	27.84	0.93
<u>Little Rock Air Temperature</u>							
1976	15.57	15.57	10.31	-1.74	5.26	25.88	0.75
1977	16.73	16.73	12.38	-1.78	4.35	29.11	0.83
1978	16.07	16.07	13.49	-1.88	2.58	29.56	0.85
1979	15.74	15.74	12.17	-1.84	3.57	27.91	0.80

* M = mean of measured temperatures, °C
 \bar{T} = measured annual stream temperature, °C
a = amplitude of harmonic variation, °C
 θ = phase angle, deg
 $\bar{T} - a$ = minimum temperature of seasonal curve, °C
 $\bar{T} + a$ = maximum temperature of seasonal curve, °C

Table 21
Stream Temperature Models Tested for Caddo River at
Highway 84 Bridge for 1978 and 1979*

Model No.	Year	Model Equation
1	1978	$T(t) = 0.4487T_a(t) + 0.3011T_a(t - 2) + 0.2445T_a(t - 4)$
2	1978	$T(t) = TS(t) + 0.0894R_a(t) + 0.1962R_a(t - 1) + 0.0543R_a(t - 2)$
3	1978	$T(t) = TS(t) + 0.1068R_a(t) + 0.1588R_a(t - 1) + 0.0655R_a(t - 2) + 0.0087Q$
4	1978	$T(t) = TS(t) + 0.9519R_w(t - 1) + 0.1682R_a(t) - 0.1137R_a(t - 2)$ $TS(t) = 17.12 + 12.82 \sin(0.017214t - 1.87)$
1	1979	$T(t) = 0.4162T_a(t) + 0.3233T_a(t - 2) + 0.2478T_a(t - 4)$
2	1979	$T(t) = TS(t) + 0.1392R_a(t) + 0.2269R_a(t - 1) + 0.1141R_a(t - 3)$
3	1979	$T(t) = TS(t) + 0.1372R_a(t) + 0.2354R_a(t - 1) + 0.1221R_a(t - 3) - 0.00546Q$
4	1979	$T(t) = TS(t) + 0.8511R_w(t - 1) + 0.1674R_a(t) - 0.0727R_a(t - 3)$ $TS(t) = 16.24 + 11.60 \sin(0.017214t - 1.88)$

* $T(t)$ = predicted shear temperature on day t
 T_a = measured air temperature
 R_a^a = air temperature residual
 R_w^a = water temperature residual
 TS = averaged measured stream temperature for day t for the period of record
 Q = streamflow

Table 22
Percentiles* (P) and Coefficients of Determination (R^2)
for Stream Temperature Models

Model No.	Year	P1	P5	P10	P25	P50	P75	P90	P95	P99	P100	R^2
1	1978	0.04	0.16	0.37	0.98	2.07	3.91	6.07	7.33	8.29	8.75	0.960
2	1978	0.01	0.08	0.14	0.32	0.71	1.32	1.97	2.65	3.35	3.95	0.972
3	1978	0.01	0.08	0.15	0.34	0.70	1.32	2.09	2.67	3.37	4.00	0.973
4	1978	0.03	0.06	0.19	0.60	1.24	2.57	4.32	4.82	5.87	6.43	0.996
1	1979	0.05	0.18	0.35	1.02	2.17	4.00	6.63	8.16	9.33	10.05	0.983
2	1979	0.04	0.11	0.22	0.49	0.94	1.82	2.87	3.52	4.61	4.87	0.974
3	1979	0.02	0.12	0.24	0.52	0.95	1.87	2.86	3.54	4.43	4.80	0.975
4	1979	0.01	0.13	0.26	0.50	1.09	2.06	3.29	4.20	4.92	5.23	0.992

* Percentiles of difference between predicted and measured temperatures, °C.

Table 23
Stream Temperature Models Used for Caddo River at
Highway 84, 1976-1980

<u>Year</u>	<u>Model Equation</u>
1976	$T(t) = 15.69 + 10.506 \sin [(2\pi/366)t - 1.83064] + 0.2184$ $R_a(t) + 0.2474R_a(t - 2) + 0.1676R_a(t - 4)$
1977	$T(t) = 17.15 + 12.369 \sin [(2\pi/365)t - 1.93956] + 0.1785$ $R_a(t) + 0.2586R_a(t - 1) + 0.1540R_a(t - 3)$
1978	$T(t) = 17.12 + 12.816 \sin [(2\pi/365)t - 1.87142] + 0.0894$ $R_a(t) + 0.1962R_a(t - 1) + 0.0543R_a(t - 3)$
1979	$T(t) = 16.24 + 11.600 \sin [(2\pi/365)t - 1.87903] + 0.1392$ $R_a(t) + 0.2269R_a(t - 1) + 0.1141R_a(t - 3)$
1980	$T(t) = 17.00 + 11.426 \sin [(2\pi/366)t - 1.99452] + 0.1542$ $R_a(t) + 0.2610R_a(t - 1) + 0.1726R_a(t - 3)$

APPENDIX A: MEAN DAILY STREAMFLOW OF CADDO RIVER AT
HIGHWAY 84 BRIDGE, 1974-1980

This appendix presents mean daily streamflows in cubic metres
per second.

1974
MEAN DAILY STREAMFLOW OF CADDO RIVER AT HIGHWAY 84 BRIDGE, m³/sec

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	6.1	11.8	6.7	3.3	6.0	34.5	2.6	1.7	9.2	5.0	74.0	38.1
2	5.5	10.2	5.8	3.3	6.5	18.2	2.2	1.4	10.4	4.1	36.7	26.7
3	4.8	8.3	5.4	4.1	5.7	11.5	2.2	1.6	16.5	3.5	38.7	20.2
4	4.8	6.8	4.8	3.7	5.2	8.9	2.2	1.4	7.9	3.3	57.7	16.2
5	4.8	6.8	4.1	3.3	4.8	91.2	2.2	1.4	5.6	2.8	28.6	13.3
6	4.8	6.5	4.1	3.3	4.6	131.6	2.2	1.4	4.2	2.8	22.9	94.7
7	4.2	5.8	3.5	2.8	4.1	667.1	1.8	1.4	3.3	2.8	19.1	63.4
8	4.1	5.1	3.3	2.8	3.3	699.2	2.2	1.4	3.1	2.7	13.7	36.7
9	4.1	4.8	3.3	2.8	3.3	177.3	2.2	1.4	3.9	2.4	12.4	25.3
10	121.2	4.8	3.3	2.8	3.3	78.3	1.8	4.7	4.7	2.2	114.6	19.4
11	130.7	4.1	114.9	3.3	3.3	38.4	1.8	3.2	54.6	2.2	79.6	21.8
12	58.1	4.1	48.9	7.7	3.3	14.0	1.8	3.3	26.0	2.2	33.0	18.1
13	26.7	4.1	25.0	6.0	2.8	16.8	1.8	2.9	26.1	2.2	20.1	14.8
14	19.2	4.1	16.3	5.1	7.1	12.2	1.6	2.7	18.2	2.2	13.4	13.1
15	14.5	4.1	12.2	4.6	117.8	14.0	1.8	2.2	12.2	2.4	10.3	11.7
16	12.0	4.1	9.4	4.1	28.9	66.0	2.2	2.4	8.7	2.2	7.5	10.5
17	9.9	3.5	7.6	3.5	14.5	19.4	2.2	2.2	11.0	2.2	8.3	9.0
18	8.6	4.2	6.7	3.3	9.4	13.1	1.8	1.8	9.0	2.2	6.9	8.0
19	9.9	6.7	5.8	3.3	6.8	9.5	1.8	2.0	7.3	2.1	6.6	7.6
20	13.7	5.8	5.4	2.9	5.4	7.1	1.4	4.2	5.9	1.8	5.8	6.8
21	13.1	5.8	7.3	62.0	4.8	5.9	1.4	2.6	5.6	1.8	5.8	6.6
22	11.3	10.1	5.8	747.8	4.6	4.9	1.4	2.1	4.9	1.8	5.4	5.8
23	10.1	25.7	5.2	80.1	3.8	4.4	1.4	1.8	3.9	1.8	10.3	5.8
24	8.6	16.9	4.8	35.8	3.3	3.9	1.9	1.8	3.3	1.8	573.7	5.8
25	7.3	12.9	4.6	21.9	4.0	3.3	1.8	1.6	26.9	1.8	90.1	5.8
26	8.4	9.9	4.1	15.2	72.5	3.3	1.8	1.4	27.2	1.8	44.5	5.5
27	9.5	8.0	4.1	11.4	25.3	3.2	1.7	1.6	15.3	1.8	18.7	5.6
28	45.3	7.0	4.1	8.8	14.0	2.8	1.4	2.1	10.5	4.3	20.6	4.9
29	28.7		3.9	6.9	9.3	2.8	1.4	5.1	7.8	45.4	32.2	6.6
30	20.0		3.3	6.8	7.0	2.8	1.5	21.0	6.1	24.0	68.9	7.4
31	14.6		3.3		29.5		1.8	11.2		82.1		15.7

1975
MEAN DAILY STREAMFLOW OF CADDO RIVER AT HIGHWAY 84 BRIDGE, m³/sec

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	15.8	287.6	10.7	42.6	28.6	7.2	4.8	3.0	2.3	2.1	2.1	6.1
2	15.3	140.6	9.2	29.5	24.1	6.6	4.8	3.0	2.3	2.3	2.3	5.3
3	24.0	80.6	8.0	22.5	243.8	6.1	4.4	3.5	2.1	2.5	3.1	4.6
4	20.9	51.4	6.9	17.2	95.3	5.5	4.1	3.5	2.1	2.1	4.9	4.1
5	17.2	42.6	6.8	13.7	49.6	5.5	4.0	3.2	1.8	2.1	3.7	3.6
6	14.1	31.9	6.1	11.7	34.1	10.0	3.5	3.0	1.8	2.1	3.1	11.2
7	12.2	24.3	5.8	9.9	38.4	37.3	3.5	2.8	2.1	2.1	3.0	15.7
8	16.7	19.4	5.8	8.4	34.8	46.4	3.5	2.5	2.1	2.1	2.5	9.8
9	14.2	15.5	5.0	12.2	97.5	126.8	3.5	2.5	2.1	2.1	2.5	7.5
10	24.1	13.1	5.4	11.8	54.7	55.6	3.3	2.5	2.9	2.1	2.5	5.6
11	20.1	11.6	11.9	9.9	33.0	34.8	3.0	2.5	3.1	2.1	2.5	4.9
12	15.9	10.3	10.4	9.0	26.9	23.1	2.5	2.5	2.5	2.1	2.5	4.7
13	12.5	8.8	20.7	8.0	20.1	16.3	3.0	2.3	3.3	2.1	2.5	4.1
14	11.3	8.0	41.2	6.9	17.6	27.5	2.9	2.1	2.8	2.1	2.1	4.1
15	10.0	6.9	44.3	8.9	17.2	47.4	2.5	2.1	2.7	2.1	2.1	4.7
16	8.7	6.9	32.7	7.9	14.0	27.6	2.5	2.1	4.9	2.1	2.1	6.7
17	8.0	7.8	43.1	6.8	11.9	20.7	2.5	2.1	5.1	2.1	2.1	6.3
18	7.3	7.9	38.1	6.8	10.2	16.0	2.5	2.3	3.9	2.1	2.1	6.1
19	6.8	6.8	72.5	6.9	9.3	12.5	2.5	2.6	3.2	2.1	2.1	5.3
20	6.5	6.5	47.9	7.4	9.7	10.4	2.5	3.0	3.0	2.1	5.0	4.3
21	5.8	5.8	30.5	6.7	15.3	8.7	4.4	3.0	3.0	2.1	7.2	4.1
22	5.8	5.8	22.2	6.3	11.4	7.4	10.0	2.5	2.7	2.1	4.9	4.1
23	5.7	11.8	17.1	6.3	9.6	13.7	5.6	2.5	2.5	2.1	3.9	3.5
24	5.3	37.1	17.1	5.7	8.9	9.1	4.1	2.2	2.5	2.1	3.0	3.6
25	5.8	24.1	22.0	31.1	8.2	7.4	4.1	2.2	2.5	2.1	3.0	4.4
26	5.0	18.0	15.0	28.6	7.3	6.4	4.1	2.1	2.3	2.5	3.0	6.9
27	4.8	14.1	12.4	19.6	8.8	5.9	4.9	2.1	2.1	2.5	3.0	8.2
28	4.8	11.8	37.2	25.4	10.7	5.5	5.3	2.1	2.1	2.5	3.0	9.4
29	4.8		432.7	36.4	10.2	5.6	4.0	2.1	2.1	2.3	3.0	118.4
30	4.8		215.2	38.4	9.1	5.1	3.5	2.1	2.1	2.1	3.4	54.3
31	24.5		71.3		7.8		3.3	2.1		2.1		30.7

1976
MEAN DAILY STREAMFLOW OF CADDO RIVER AT HIGHWAY 84 BRIDGE, m³/sec

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	19.6	7.8	8.6	15.2	6.1	7.3	9.6	3.6	3.6	4.2	13.9	10.7
2	17.6	7.2	8.0	12.6	5.7	8.8	8.5	3.8	6.7	3.9	11.0	9.2
3	13.9	7.0	7.5	11.0	5.3	8.5	7.6	3.5	6.9	3.8	9.3	8.2
4	11.4	6.5	7.2	10.1	5.1	7.0	37.0	3.5	5.5	3.5	8.1	7.5
5	10.1	12.1	9.4	9.1	4.8	6.4	12.0	3.5	5.0	3.7	7.2	7.0
6	9.2	12.1	9.2	8.5	8.1	7.7	8.8	3.5	4.3	4.3	6.5	7.0
7	8.6	10.0	8.4	7.9	12.5	7.9	8.0	3.3	3.9	4.0	5.9	8.4
8	7.7	9.0	195.4	7.2	9.3	6.4	7.2	3.1	3.9	3.8	5.6	7.8
9	7.2	8.6	179.0	6.8	8.0	5.7	6.4	3.1	3.6	3.5	5.3	7.2
10	7.1	8.0	65.7	6.5	7.2	5.3	5.9	3.1	3.5	3.5	5.2	7.2
11	7.2	7.6	37.8	6.2	7.4	4.8	5.5	3.1	3.4	3.5	4.9	19.5
12	6.9	7.2	26.9	6.3	8.1	4.6	5.2	3.1	3.1	3.5	5.3	30.9
13	6.5	6.9	19.9	5.9	55.9	4.3	4.8	3.1	3.1	3.5	5.1	23.0
14	6.2	6.5	18.8	6.2	26.3	4.3	4.7	3.1	3.1	3.5	4.8	18.0
15	5.9	6.5	16.8	5.9	22.4	4.0	4.3	3.1	3.1	3.5	4.8	15.0
16	5.9	6.7	14.6	5.6	18.5	5.2	4.3	3.1	3.4	3.3	4.8	12.9
17	5.3	50.4	12.6	5.3	14.8	6.4	4.3	3.3	3.7	3.1	4.8	11.0
18	5.3	124.3	11.3	5.3	11.6	48.2	3.9	3.1	7.2	3.1	4.8	9.6
19	5.5	44.9	10.6	6.5	9.6	27.0	3.9	3.1	6.6	3.2	4.8	8.8
20	7.3	26.9	9.7	12.4	8.4	15.5	3.9	2.8	6.6	3.6	6.4	8.0
21	7.2	30.5	9.9	15.1	7.6	10.9	3.9	2.8	6.5	3.9	10.2	7.4
22	6.5	23.9	9.1	11.4	6.8	8.5	3.8	2.8	5.9	3.7	9.0	7.2
23	6.5	19.2	8.4	9.4	6.1	7.5	3.5	2.9	4.9	3.5	8.0	6.6
24	6.5	16.5	8.0	11.8	6.6	8.5	3.5	3.1	4.3	11.0	7.2	5.9
25	9.9	14.2	8.0	11.3	6.6	97.3	3.5	3.1	3.9	113.1	6.8	5.9
26	14.3	12.7	8.0	9.2	5.8	48.5	3.7	3.1	3.9	41.8	29.8	5.9
27	12.2	10.7	7.7	8.1	8.9	25.5	3.8	3.1	4.1	20.1	40.2	5.6
28	10.6	9.7	7.7	7.2	7.6	21.9	3.9	3.1	6.5	14.1	21.0	5.3
29	9.6	8.9	23.3	6.6	6.4	15.8	3.5	3.3	5.2	10.9	15.8	5.3
30	8.8		24.1	6.5	5.8	12.0	3.5	3.8	4.6	18.1	12.4	5.3
31	8.1		18.5		6.1		3.5	3.9		18.4		5.3

1977
 MEAN DAILY STREAMFLOW OF CADDO RIVER AT HIGHWAY 84 BRIDGE, m³/sec

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	4.8	7.2	13.6	20.9	6.3	3.5	3.9	32.0	2.8	3.9	107.4	24.1
2	4.8	6.7	12.3	19.4	6.1	3.4	3.5	15.5	2.8	3.5	104.9	17.9
3	4.8	10.5	412.8	22.1	6.5	3.1	3.5	10.3	2.6	3.4	27.2	14.3
4	4.8	16.7	159.9	49.2	6.0	3.1	3.5	7.8	2.5	3.1	16.4	12.0
5	4.8	14.7	63.8	26.2	5.9	3.2	3.5	6.3	2.5	3.1	11.6	10.4
6	4.8	12.5	37.5	19.7	5.3	3.5	3.1	5.5	2.8	3.1	9.3	9.0
7	5.3	11.1	26.0	16.6	5.3	3.4	3.1	5.1	3.8	3.1	7.8	7.8
8	5.3	10.0	19.5	13.9	5.0	3.1	3.1	4.7	3.8	3.1	6.8	7.2
9	6.6	9.2	17.2	11.7	5.6	3.1	3.1	4.3	3.5	3.1	7.5	6.8
10	8.6	8.8	15.1	10.1	5.2	3.1	3.1	3.9	3.1	3.1	7.1	6.2
11	8.0	22.6	14.9	9.2	4.8	3.1	3.1	3.8	3.1	3.0	6.5	5.9
12	8.0	90.4	18.2	8.5	4.8	3.1	3.1	3.5	3.0	2.8	5.9	5.5
13	11.2	43.5	14.7	7.9	4.3	4.5	3.1	3.5	3.0	2.8	5.5	6.2
14	58.6	27.2	12.4	7.2	4.3	6.3	3.1	3.5	3.9	2.8	5.3	8.8
15	37.8	20.2	11.0	7.0	4.3	4.7	2.8	3.5	3.9	2.8	4.9	8.2
16	25.0	16.6	10.0	6.5	3.9	4.3	2.8	3.5	3.6	2.8	62.8	8.0
17	18.5	14.5	9.1	6.4	3.9	126.1	2.8	3.5	3.3	2.8	28.4	8.0
18	16.0	12.5	8.8	12.9	3.9	26.3	2.8	3.5	3.1	2.8	16.2	7.7
19	12.8	11.0	8.0	19.8	3.9	14.3	2.8	3.2	3.1	2.8	12.0	7.2
20	11.6	9.7	7.8	26.7	3.9	9.8	8.0	3.1	3.1	2.8	9.9	6.7
21	10.3	8.8	7.2	44.5	3.9	7.6	8.5	3.1	3.0	2.8	12.6	6.2
22	9.3	8.3	7.1	26.8	3.9	6.3	7.5	3.1	2.8	2.8	11.4	5.9
23	8.8	16.1	6.5	19.1	4.7	5.5	6.2	3.1	2.8	2.8	9.4	5.7
24	10.1	20.8	6.5	15.4	4.3	4.8	4.2	3.1	2.8	2.8	8.4	5.3
25	9.8	16.5	6.5	12.3	3.9	4.7	3.9	3.1	2.8	3.8	7.3	5.2
26	9.1	15.7	6.4	10.2	3.9	4.3	4.2	2.8	3.8	4.3	6.6	4.8
27	8.8	18.0	71.9	8.9	3.6	5.2	10.8	2.8	3.9	3.6	6.0	4.8
28	8.8	15.6	366.4	8.0	3.5	4.8	11.4	2.8	4.0	3.4	5.9	4.8
29	8.0		89.6	7.2	3.5	4.3	8.1	2.8	4.1	3.1	6.2	4.4
30	8.0		45.0	6.6	3.5	3.9	23.0	2.8	4.2	3.1	11.7	4.8
31	7.2		27.7		3.5	60.3		2.8		3.7		4.8

1978
 MEAN DAILY STREAMFLOW OF CADDO RIVER AT HIGHWAY 84 BRIDGE, m³/sec

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	4.7	11.5	9.4	8.8	9.6	4.8	2.8	2.7	3.0	2.8	2.7	10.0
2	4.3	10.2	12.5	7.6	8.6	4.8	2.8	2.7	2.9	2.8	2.7	9.3
3	4.3	9.4	19.8	7.4	34.4	4.3	2.8	2.7	2.8	2.8	2.7	66.5
4	4.3	8.6	17.8	7.2	34.6	4.3	2.8	2.7	2.8	2.7	2.7	34.1
5	4.3	8.0	15.3	7.2	28.6	6.7	2.8	2.7	2.7	2.7	2.7	18.4
6	4.3	8.0	13.5	6.8	26.2	16.5	2.8	2.7	2.7	2.7	2.8	51.3
7	4.3	8.0	93.7	6.5	42.8	13.4	2.8	2.7	2.6	2.6	2.9	59.2
8	4.3	7.7	65.3	6.1	83.3	9.4	2.6	2.7	2.6	2.6	2.9	37.3
9	4.2	7.2	37.2	5.9	38.6	7.5	2.5	2.6	2.6	2.6	2.9	26.5
10	3.9	7.2	25.5	5.9	23.5	6.2	2.5	2.6	2.7	2.7	2.8	20.3
11	4.1	7.2	20.1	11.7	18.0	5.3	2.5	2.6	2.7	2.7	2.8	15.6
12	4.7	7.8	16.9	10.4	16.7	4.8	2.5	2.6	2.8	2.7	2.8	13.7
13	4.8	22.1	26.3	8.6	16.3	4.8	2.5	2.7	20.2	2.7	2.8	12.5
14	4.8	21.2	36.7	7.6	11.8	4.6	2.5	2.8	11.4	2.7	2.9	10.9
15	4.8	17.4	24.8	7.0	9.8	4.2	2.5	2.7	6.2	2.6	10.7	9.4
16	19.5	15.1	19.5	6.5	8.4	3.9	2.5	2.6	4.9	2.6	294.9	8.5
17	41.6	13.0	16.3	6.3	8.2	3.9	2.5	2.6	4.2	2.6	130.7	7.7
18	25.2	12.2	13.7	38.3	8.0	3.7	2.5	2.6	3.5	2.6	35.4	7.1
19	18.9	10.9	11.6	22.1	7.0	3.5	2.5	2.6	3.3	2.6	18.6	6.7
20	15.4	10.2	10.2	15.7	6.5	3.8	2.5	2.6	3.2	2.6	13.2	6.4
21	12.8	10.3	23.0	12.3	11.3	3.8	2.4	3.3	3.1	2.6	10.2	6.0
22	11.1	9.6	22.5	12.5	16.4	3.5	2.2	3.0	3.0	2.6	9.3	5.7
23	9.9	9.6	18.0	86.6	12.2	3.5	2.2	2.8	3.0	2.6	8.9	5.4
24	21.3	9.0	44.4	30.8	9.3	3.5	2.5	2.7	3.1	2.6	7.7	5.8
25	70.8	8.8	35.6	27.6	7.6	3.4	2.5	2.6	3.0	2.6	6.9	5.8
26	64.4	8.8	24.3	19.1	6.4	3.1	2.7	2.5	3.0	2.8	32.5	5.3
27	34.2	8.8	19.2	14.9	5.9	3.1	2.8	2.5	2.9	2.8	49.8	5.0
28	23.5	9.5	16.0	11.6	5.3	3.1	2.8	2.7	2.9	2.9	22.7	4.9
29	18.3		13.1	9.9	5.5	3.1	2.7	3.9	2.9	2.8	15.7	6.0
30	15.8		11.1	9.2	5.2	2.9	2.7	3.7	2.8	2.7	12.0	15.1
31	13.2		9.5		4.8	2.7	2.7	3.4	2.8	2.7		114.4

1979
 MEAN DAILY STREAMFLOW OF CADDO RIVER AT HIGHWAY 84 BRIDGE, m³/sec

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	105.0	8.3	22.2	209.9	8.0	15.6	4.3	7.0	5.2	3.4	7.9	4.4
2	39.0	8.2	29.5	189.6	7.6	44.5	4.2	6.2	5.5	3.3	5.8	4.3
3	23.0	9.5	217.7	61.3	39.6	73.0	4.1	8.3	4.6	3.3	4.9	4.1
4	17.0	9.4	70.1	36.9	137.2	36.3	4.0	8.9	4.2	3.2	4.4	4.0
5	14.0	9.3	37.4	23.8	52.2	22.5	3.9	6.7	4.0	3.1	4.1	3.9
6	13.0	9.7	24.3	18.0	27.8	20.2	3.9	5.6	3.8	3.1	4.0	3.9
7	12.0	10.7	18.3	14.8	18.6	20.1	4.2	5.0	3.9	3.0	3.8	3.8
8	12.0	10.0	14.7	28.5	13.6	14.5	4.3	4.6	4.1	3.0	3.7	3.7
9	11.0	9.0	12.4	20.0	10.9	11.6	4.2	4.3	3.8	3.0	4.1	3.7
10	10.0	8.6	10.7	16.3	9.4	9.7	7.6	4.1	3.6	3.0	5.9	3.6
11	9.3	9.4	9.4	27.0	51.7	8.4	5.2	6.8	3.5	3.0	5.1	3.6
12	8.7	15.2	8.5	59.9	57.4	7.5	4.5	4.9	3.4	3.0	4.6	8.1
13	8.0	20.4	7.9	28.1	28.4	6.8	4.6	4.4	3.3	3.0	4.3	22.9
14	7.4	17.7	7.4	18.2	18.2	6.4	4.1	4.1	3.3	2.9	4.1	14.4
15	6.8	15.1	6.8	14.2	13.7	5.9	4.0	4.0	3.2	3.0	4.0	10.6
16	6.4	12.4	6.6	11.8	11.1	5.6	4.1	4.7	3.1	3.0	3.9	9.0
17	6.4	10.8	6.4	10.2	9.3	5.3	4.4	4.5	3.1	3.1	3.8	7.7
18	6.5	10.2	6.1	8.9	8.2	5.1	4.0	4.1	3.1	3.3	3.7	6.6
19	11.8	10.0	12.7	8.1	7.4	4.9	3.8	3.9	3.3	3.4	3.7	6.0
20	23.9	10.4	127.2	7.5	6.9	4.7	3.7	3.7	3.9	3.3	3.8	5.6
21	23.3	19.0	54.8	7.5	69.9	4.6	3.6	3.6	7.4	3.2	6.2	5.3
22	17.9	28.0	30.3	18.0	320.0	4.8	3.5	3.6	7.8	3.3	14.7	8.5
23	16.7	29.0	25.1	136.3	130.8	4.9	3.4	3.5	5.7	3.7	10.2	97.2
24	13.8	42.0	18.4	66.9	54.1	6.8	3.4	4.4	4.8	3.5	8.2	160.4
25	11.7	47.0	14.6	34.8	27.9	9.5	3.4	4.0	4.3	3.3	7.0	40.8
26	11.9	41.0	12.5	21.6	18.9	6.5	3.5	3.7	4.0	3.3	6.2	21.7
27	11.9	36.0	15.0	15.7	30.2	5.4	14.9	3.6	3.8	3.2	5.6	16.0
28	10.1	29.0	14.2	12.6	41.0	4.9	54.3	5.0	3.6	3.2	5.2	12.4
29	9.1	29.0	16.3	10.9	42.0	4.7	16.3	5.5	3.6	3.7	4.8	10.4
30	9.0		291.7	9.5	27.0	4.4	10.2	4.3	3.5	3.8	4.6	9.2
31	8.4		140.3		20.0		7.9	4.0		8.5		8.1

1980
MEAN DAILY STREAMFLOW OF CADDO RIVER AT HIGHWAY 84 BRIDGE, m³/sec

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	7.5	7.0	4.8	15.2	20.3	7.6	2.8	2.6	2.4	14.4	5.2	5.4
2	6.7	6.6	4.7	12.2	17.8	6.6	2.8	2.5	2.4	10.2	4.9	5.2
3	6.2	6.4	4.6	10.6	18.8	5.8	2.8	2.5	2.8	7.9	4.6	4.9
4	6.1	6.1	4.6	9.0	14.7	5.3	2.8	2.5	2.7	6.4	4.3	4.8
5	5.8	5.9	4.4	7.9	12.0	4.9	2.7	2.4	2.5	5.5	4.1	4.7
6	5.4	5.8	4.3	7.2	9.8	4.5	2.6	2.4	2.4	4.9	4.0	4.7
7	5.3	5.6	4.2	6.7	8.2	4.4	2.5	2.4	2.4	4.4	3.9	4.5
8	5.0	21.5	4.2	6.6	7.5	4.2	2.5	2.4	2.4	4.1	3.8	141.0
9	4.8	37.9	4.1	6.3	6.6	4.1	2.5	2.4	2.4	3.9	3.7	179.6
10	4.7	22.5	4.0	5.9	5.9	4.0	2.5	2.4	2.4	3.7	3.7	45.9
11	5.0	17.3	4.0	6.5	5.4	3.8	2.4	2.3	2.4	3.5	3.7	24.9
12	4.8	15.5	8.3	12.2	11.9	3.6	2.4	2.3	2.4	3.4	3.7	17.6
13	4.5	14.3	7.5	35.0	15.9	3.5	2.4	2.3	2.4	3.3	3.6	13.7
14	4.4	13.2	6.3	56.6	10.2	3.4	2.4	2.3	2.3	3.1	9.5	11.3
15	4.5	13.1	5.8	33.4	10.4	3.3	2.4	2.2	2.3	3.0	10.6	10.1
16	5.6	11.9	23.3	21.4	72.7	3.3	2.3	2.2	2.3	3.1	9.3	8.9
17	6.2	10.4	31.8	16.3	38.5	3.3	2.3	2.2	2.2	54.8	15.7	7.8
18	5.9	9.3	20.9	16.3	21.0	3.3	2.3	2.2	2.3	36.3	15.1	7.2
19	5.7	8.6	16.5	13.0	14.5	4.4	2.4	2.3	2.3	15.0	12.1	6.6
20	5.9	8.1	13.7	11.0	11.8	5.4	2.4	2.2	2.3	10.3	10.0	6.0
21	28.4	7.5	11.8	9.6	17.4	4.8	2.4	2.2	2.3	8.5	8.5	5.6
22	61.0	6.9	10.2	8.4	28.6	4.3	2.4	2.2	2.3	7.1	7.6	5.3
23	35.5	6.5	15.6	7.5	26.0	4.0	2.4	2.2	2.4	6.0	7.2	5.2
24	20.3	6.1	27.8	6.8	15.6	3.8	2.4	2.2	2.4	5.3	6.7	5.0
25	14.3	5.7	18.5	54.6	11.4	3.3	2.4	2.2	2.9	4.7	6.1	4.8
26	11.5	5.3	13.6	28.7	8.5	3.2	3.7	2.2	3.1	4.4	5.8	4.6
27	9.9	5.1	11.4	19.5	8.7	3.0	4.7	2.2	3.2	6.5	6.3	4.5
28	9.2	5.0	10.8	14.2	14.3	3.0	3.7	2.2	85.0	8.4	6.1	4.4
29	8.7	4.9	13.7	11.8	13.6	2.9	3.1	2.2	66.0	7.0	5.8	4.3
30	8.3		29.1	10.0	10.9	2.8	2.9	2.3	23.8	6.1	5.5	4.2
31	7.8		20.5		8.9	2.7	2.7	2.4		5.6		4.1

APPENDIX B: MEAN DAILY OUTFLOW FROM DEGRAY LAKE,
1974-1980

This appendix presents mean daily outflows, in cubic metres per second, adapted from daily operation reports of DeGray Power Plant, U. S. Army Engineer District, Vicksburg.

1974
MEAN DAILY OUTFLOWS FROM DEGRAY LAKE, m³/sec

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	58.5	26.6	11.0	0.4	87.9	105.7	0.4	2.2	29.8	15.1	65.3	85.2
2	88.0	0.8	23.5	10.8	155.2	1.6	22.2	0.4	25.2	22.9	39.5	101.0
3	31.1	17.3	0.4	0.4	156.1	52.4	0.4	0.4	2.5	2.6	24.0	80.6
4	30.6	57.8	0.4	0.4	156.6	31.0	0.4	0.4	0.4	0.4	92.5	89.2
5	20.8	29.8	0.4	0.4	156.0	95.7	7.4	0.4	0.4	0.4	38.5	62.2
6	0.4	16.6	18.2	0.4	138.7	155.0	0.4	0.4	0.4	6.9	30.3	92.7
7	3.6	95.6	4.1	0.4	0.4	122.0	0.4	0.4	0.4	24.3	47.6	53.9
8	1.8	110.0	3.0	9.8	0.4	68.8	39.2	0.4	0.4	24.6	42.6	32.6
9	0.4	29.5	0.4	7.1	0.4	68.2	54.5	14.5	2.2	7.3	32.1	104.1
10	61.7	16.4	0.4	3.9	0.4	68.0	40.1	0.4	21.5	14.5	72.1	93.6
11	76.7	23.7	51.1	0.4	24.9	102.1	10.6	0.4	44.8	8.2	71.4	98.3
12	50.8	4.5	26.0	0.4	113.2	154.2	35.4	0.4	35.8	0.4	71.4	112.1
13	44.4	0.4	21.5	0.4	62.9	154.7	0.4	15.0	49.1	1.1	76.5	117.6
14	73.5	0.4	66.8	0.4	36.8	154.2	0.4	7.7	54.1	30.6	72.9	113.8
15	35.7	0.4	101.9	8.2	123.5	155.7	0.4	0.4	32.4	28.5	94.1	39.2
16	23.7	0.4	27.4	0.4	89.9	155.8	2.2	11.5	49.7	37.2	7.9	109.4
17	7.3	0.4	8.7	11.9	47.1	156.5	10.9	0.4	68.0	50.4	22.7	99.2
18	9.5	19.2	46.8	18.8	63.6	154.8	21.3	0.4	0.4	79.7	51.5	54.7
19	40.9	29.3	31.5	9.9	4.8	154.8	48.1	1.6	0.4	43.5	63.6	26.8
20	94.5	0.4	34.5	0.0	27.2	157.5	24.1	7.2	42.8	30.1	61.7	86.7
21	112.6	0.4	55.2	0.0	0.4	157.8	0.4	21.4	0.4	93.9	70.3	59.4
22	29.9	18.6	28.9	0.0	18.5	158.1	0.4	0.4	0.4	53.9	63.9	28.5
23	32.1	0.4	14.1	0.0	22.6	159.2	0.4	6.1	0.4	0.4	68.7	35.7
24	72.6	0.4	0.4	0.0	6.0	159.7	0.4	19.6	0.4	29.2	45.8	41.1
25	34.3	38.9	2.6	0.0	0.4	113.0	0.4	0.4	0.4	22.5	96.8	29.6
26	25.5	24.5	0.4	0.0	0.4	0.4	0.4	0.4	62.0	0.4	72.6	16.6
27	5.3	40.9	0.4	0.0	38.5	0.4	8.3	0.4	56.9	8.1	78.7	19.8
28	59.0	29.1	0.4	0.0	70.3	0.4	0.4	0.4	65.7	32.6	82.9	11.0
29	33.7		0.4	0.0	30.1	0.4	16.0	10.7	0.4	49.1	77.1	7.8
30	33.8		0.4	0.0	12.7	0.4	0.4	7.4	37.9	54.1	43.1	12.5
31	37.4		0.4		34.8		20.7	33.4		57.4		5.0

1975
 MEAN DAILY OUTFLOWS FROM DEGRAY LAKE, m³/sec

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	14.7	80.2	9.2	158.1	8.9	0.4	26.3	0.4	17.1	15.0	0.4	32.5
2	37.4	43.1	5.7	158.2	23.9	19.5	1.5	0.4	37.8	0.4	0.4	2.5
3	12.3	111.0	26.8	157.7	74.3	3.7	28.1	0.4	22.5	0.4	1.5	2.4
4	14.3	101.0	3.3	40.0	52.6	15.7	15.1	0.4	16.5	0.4	0.4	0.4
5	0.4	102.3	46.7	13.1	118.4	1.2	28.4	6.9	5.6	0.4	8.7	3.3
6	18.0	112.8	43.7	12.3	155.1	5.2	0.4	7.7	0.4	0.4	3.1	0.4
7	12.1	129.0	8.8	41.3	114.9	0.4	18.7	7.8	0.6	8.4	1.6	0.4
8	9.0	4.7	18.8	85.0	103.8	0.4	26.2	7.3	0.4	10.9	3.6	0.4
9	14.1	15.4	4.7	41.2	108.8	17.5	18.1	0.4	0.4	26.9	0.4	10.8
10	42.1	48.3	44.6	36.0	105.4	89.3	0.4	0.4	1.4	29.8	0.4	12.4
11	6.1	13.6	32.4	34.5	40.5	1.4	0.4	16.6	0.4	2.9	4.6	6.4
12	42.8	12.6	37.3	16.1	100.4	2.2	0.4	46.7	0.4	0.9	9.6	0.4
13	40.3	11.9	26.7	3.3	83.0	0.4	0.4	27.0	9.0	38.6	59.6	0.4
14	8.2	9.4	30.6	30.0	94.1	39.1	0.4	16.5	0.4	19.2	9.5	0.4
15	19.2	15.8	13.9	9.9	107.7	65.3	0.4	22.5	16.3	28.4	18.0	0.4
16	14.8	0.4	5.7	12.3	67.6	65.9	10.1	17.5	0.4	4.6	0.4	9.5
17	30.4	9.9	32.8	36.3	16.7	31.9	0.4	0.4	0.4	3.3	0.4	28.2
18	0.4	5.6	25.9	40.2	9.6	63.9	0.4	17.8	14.5	0.4	6.9	61.1
19	0.4	8.6	46.9	0.4	104.9	53.3	0.4	22.2	24.8	0.4	13.1	17.1
20	36.2	10.1	25.0	15.6	84.7	66.2	8.3	26.9	0.4	8.4	9.6	0.4
21	30.2	9.3	12.1	0.4	106.4	0.4	15.8	25.5	0.4	0.4	18.1	0.4
22	9.1	23.0	10.4	6.3	101.7	0.4	26.4	16.8	0.4	1.6	0.4	1.4
23	22.7	42.8	29.6	24.6	102.7	0.9	17.6	16.0	0.4	0.4	33.2	1.4
24	37.1	4.7	30.5	52.9	0.4	5.7	10.5	14.0	1.2	0.4	45.8	0.4
25	18.1	4.4	6.5	38.1	0.4	1.3	21.7	15.9	9.4	0.4	30.0	0.4
26	18.6	27.2	22.9	3.4	0.4	21.7	8.7	18.2	0.4	21.7	32.3	9.9
27	10.6	42.4	95.1	11.5	0.4	8.7	0.4	18.9	7.7	15.6	21.5	0.4
28	11.5	22.0	95.9	34.9	6.9	0.4	10.3	8.6	0.4	0.4	0.4	0.4
29	11.7	71.7	71.7	26.4	0.4	0.4	7.7	24.0	12.3	3.3	0.4	0.4
30	9.0	102.7	102.7	31.6	2.4	8.1	5.0	0.4	12.1	5.6	0.4	0.4
31	31.3	157.9	157.9		0.4		0.4	0.4		30.6		17.5

1976
MEAN DAILY OUTFLOWS FROM DEGRAY LAKE, m³/sec

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.4	0.4	2.5	97.8	0.4	4.8	39.6	0.4	47.6	17.3	34.2	5.9
2	0.4	4.7	3.9	8.8	0.4	12.0	0.4	0.4	30.2	0.4	20.4	0.4
3	11.9	1.2	3.5	24.0	12.3	0.4	0.4	9.0	26.5	0.4	51.1	1.4
4	0.9	0.4	9.2	17.7	7.8	0.4	124.7	0.4	34.2	6.7	58.0	0.4
5	13.1	9.6	6.5	0.4	0.4	0.4	105.2	0.4	35.5	7.6	49.2	0.4
6	0.4	0.4	3.3	10.8	20.4	36.0	50.3	12.9	23.4	0.4	7.4	3.4
7	34.4	0.4	0.4	10.4	0.4	0.4	8.8	0.4	1.4	0.4	4.8	3.8
8	39.6	0.4	3.2	8.9	0.4	49.8	31.9	0.4	0.4	43.2	58.5	5.3
9	19.7	11.1	6.7	6.8	0.4	18.6	0.4	8.1	0.4	0.4	22.5	0.4
10	0.4	0.4	15.3	0.4	9.1	0.4	0.4	0.4	0.4	0.4	16.4	0.4
11	0.4	0.4	113.0	0.4	0.4	0.4	0.4	17.4	0.4	49.2	73.6	0.4
12	0.4	1.9	106.7	3.3	9.3	0.4	16.3	35.1	0.4	0.4	39.4	0.4
13	0.4	21.2	4.3	13.0	95.4	15.2	25.8	32.1	7.5	0.4	8.5	0.4
14	0.4	0.4	0.4	16.5	0.4	0.4	8.9	31.5	18.3	0.4	5.5	3.6
15	0.4	0.4	0.4	14.8	68.7	0.4	0.4	45.4	0.4	0.4	32.8	1.0
16	13.0	0.4	0.4	9.2	24.6	8.4	0.4	33.8	0.4	0.4	26.0	14.1
17	0.4	0.4	0.4	0.4	8.2	3.9	0.4	38.9	0.4	0.4	12.8	0.4
18	0.4	0.4	0.4	0.4	0.4	58.6	0.4	30.1	10.2	0.4	5.9	0.4
19	0.4	0.4	6.2	39.7	8.9	40.7	0.4	31.0	0.4	0.4	13.7	0.4
20	2.8	8.8	23.5	44.6	11.9	0.4	1.2	29.3	0.4	0.4	0.8	31.3
21	8.7	0.4	0.4	53.7	70.3	28.0	21.3	24.8	10.8	0.4	0.4	7.2
22	0.4	0.8	0.4	0.4	5.5	0.4	0.4	28.9	33.8	20.2	0.4	0.4
23	11.9	1.7	19.4	13.2	0.4	24.2	10.1	33.5	13.1	0.4	0.4	0.4
24	0.4	0.4	16.4	8.4	10.7	21.9	14.7	26.8	45.0	0.4	0.4	0.4
25	0.4	6.6	0.9	6.3	0.4	123.2	0.4	29.2	36.4	10.6	0.4	0.4
26	1.8	0.4	0.4	0.4	8.5	105.8	37.7	31.5	2.5	15.9	0.4	0.4
27	8.5	5.4	0.4	0.4	5.6	47.9	0.4	47.3	3.4	16.9	5.0	0.4
28	9.1	0.4	0.4	0.4	0.4	57.4	8.2	5.9	0.4	10.1	4.6	16.7
29	3.3	4.8	10.1	0.4	0.4	0.4	0.4	0.4	0.4	0.4	72.1	0.4
30	0.4		11.5	0.4	0.4	9.0	0.4	24.0	1.5	1.8	8.0	0.4
31	0.4		51.8		6.8		0.4	14.9		6.8		13.2

1977
MEAN DAILY OUTFLOWS FROM DEGRAY LAKE, m³/sec

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.4	3.9	7.8	145.3	22.0	10.0	0.4	25.2	46.1	53.2	0.4	20.5
2	0.4	4.2	13.5	27.1	6.5	10.7	0.4	13.4	24.0	2.3	0.4	14.3
3	0.4	3.9	84.8	60.5	0.8	0.4	0.4	12.7	29.0	0.4	21.2	14.5
4	0.4	8.1	72.8	100.3	40.8	0.4	0.4	11.7	20.4	0.4	0.4	23.2
5	3.3	0.4	103.4	4.7	38.7	0.4	0.4	0.4	20.5	0.4	0.4	52.6
6	4.7	0.4	157.5	38.7	3.1	0.4	11.8	8.5	29.3	0.4	0.4	50.2
7	0.4	0.4	158.8	39.2	33.2	0.4	0.4	5.7	29.3	4.0	8.7	52.6
8	9.8	12.1	159.0	6.3	0.4	12.5	3.6	8.4	25.7	5.3	8.6	38.6
9	0.4	0.4	42.4	26.9	26.5	0.4	0.4	10.9	0.4	0.4	7.4	45.0
10	43.6	0.4	86.7	0.4	35.3	0.7	0.4	0.7	0.4	4.3	8.7	55.7
11	9.1	10.0	96.3	0.4	12.8	17.4	11.2	0.4	0.4	6.6	6.2	8.6
12	0.4	0.4	0.4	0.4	5.5	0.4	14.2	0.4	0.4	3.0	4.6	14.0
13	1.2	0.4	0.4	19.8	9.5	0.4	24.5	0.4	28.8	6.5	0.4	0.4
14	0.4	0.7	0.4	12.2	0.4	0.4	19.5	0.4	0.4	9.1	8.8	0.4
15	0.4	6.3	8.3	43.8	0.4	13.3	10.2	29.8	28.2	4.0	8.0	0.4
16	0.4	5.3	7.6	23.1	0.4	0.4	0.4	27.4	24.0	0.4	14.6	0.4
17	16.8	1.4	0.4	14.8	10.2	99.8	0.4	0.4	16.9	8.9	11.9	7.8
18	10.1	0.4	8.0	14.7	1.7	54.0	21.2	0.4	6.1	0.4	20.2	0.4
19	32.9	0.4	0.4	69.9	16.3	0.4	24.9	0.4	6.1	5.8	5.6	7.4
20	0.4	0.4	0.4	104.0	0.4	2.2	13.7	0.4	29.6	5.3	6.6	10.6
21	3.2	0.4	0.4	112.2	0.4	14.8	11.4	0.4	34.2	8.7	4.4	18.4
22	0.4	0.4	0.4	31.7	0.4	11.6	0.4	0.4	51.0	0.4	3.6	0.4
23	0.4	0.4	0.4	0.4	0.4	0.4	0.4	14.1	32.3	0.4	8.5	0.4
24	0.4	0.4	6.9	0.4	0.4	0.4	0.4	0.4	33.3	5.0	0.4	0.4
25	2.7	8.2	0.4	30.3	20.7	0.4	0.4	15.5	38.3	0.4	0.4	0.4
26	0.4	0.4	0.4	0.4	19.0	43.0	0.4	7.0	26.0	0.4	28.7	0.4
27	0.4	0.4	102.2	11.8	0.4	15.3	10.9	2.0	11.8	15.9	5.7	5.7
28	4.0	4.4	114.8	0.4	0.4	0.4	0.4	0.4	24.9	1.0	16.9	3.7
29	0.4	0.4	110.7	6.6	0.4	0.4	13.1	0.7	6.1	0.4	4.0	11.5
30	0.4	0.4	158.9	0.4	10.9	10.6	19.2	14.4	16.5	7.7	0.4	9.2
31	4.0		157.6	0.4	0.4		0.4	50.8		6.6		0.4

1978
MEAN DAILY OUTFLOWS FROM DEGRAY LAKE, m³/sec

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.4	24.2	50.1	10.5	17.9	12.5	0.4	4.9	9.9	10.0	10.0	10.0
2	0.4	24.9	37.6	11.0	15.3	0.4	14.7	8.8	0.4	10.0	10.0	10.0
3	19.9	4.2	33.6	40.0	5.4	0.4	38.0	0.4	0.4	10.0	10.0	10.0
4	0.4	0.4	29.5	30.5	56.7	0.4	0.4	0.4	0.4	10.0	10.0	10.0
5	0.6	24.6	0.4	10.8	59.0	10.1	0.4	0.4	25.1	10.0	10.0	10.0
6	0.4	46.6	0.4	14.3	32.1	24.1	10.8	0.4	22.6	10.0	10.0	10.0
7	0.4	72.6	23.1	17.0	92.1	27.4	0.4	0.4	0.4	10.0	10.0	10.0
8	13.4	32.8	25.0	4.7	53.1	23.0	24.6	13.3	0.4	10.0	10.0	10.0
9	46.9	30.0	0.4	2.6	67.5	0.4	3.6	16.8	0.4	10.0	10.0	10.0
10	31.1	20.5	0.4	14.4	12.0	0.4	14.2	15.3	0.4	10.0	10.0	10.0
11	73.5	28.1	0.4	12.0	14.6	0.4	12.2	12.8	0.4	10.0	10.0	10.0
12	52.1	3.4	0.4	3.7	15.0	27.4	8.8	0.4	0.4	10.0	10.0	10.0
13	83.1	46.4	11.3	0.4	21.5	29.3	10.0	0.4	22.4	10.0	10.0	10.0
14	62.1	28.7	35.5	0.4	0.4	0.4	0.4	0.4	0.4	10.0	10.0	10.0
15	17.9	56.0	30.4	7.8	25.1	0.4	0.4	37.1	0.4	10.0	10.0	10.0
16	7.9	20.4	30.8	0.4	23.2	0.4	11.5	24.1	36.4	10.0	10.0	10.0
17	33.5	35.5	29.3	63.7	22.7	33.4	16.5	18.1	0.4	10.0	10.0	10.0
18	46.1	20.4	11.0	82.5	23.5	0.4	30.9	26.0	53.0	10.0	10.0	10.0
19	17.4	0.4	15.5	3.0	33.5	2.5	0.9	0.4	40.1	10.0	10.0	10.0
20	9.6	28.3	17.0	0.4	2.4	17.1	22.7	0.4	28.0	10.0	10.0	10.0
21	8.5	42.4	49.8	5.2	0.4	34.3	0.4	24.2	0.4	10.0	10.0	10.0
22	0.4	32.5	40.6	0.4	0.4	0.4	0.4	14.7	0.4	10.0	10.0	10.0
23	7.2	20.8	38.7	0.4	25.3	7.6	0.4	24.0	0.4	10.0	10.0	10.0
24	0.4	19.1	23.6	48.5	24.3	32.2	2.3	15.7	2.8	10.0	10.0	10.0
25	28.9	1.2	14.2	33.8	38.0	18.2	26.8	15.7	4.6	10.0	10.0	10.0
26	68.2	0.4	9.7	9.9	33.4	31.7	11.0	0.4	0.4	10.0	10.0	10.0
27	20.8	24.7	31.1	9.6	33.8	19.2	0.4	0.4	0.4	10.0	10.0	10.0
28	29.1	23.8	2.2	0.4	0.4	17.5	27.3	0.4	0.4	10.0	10.0	10.0
29	10.3		0.4	0.4	1.0	9.4	20.2	0.4	6.3	10.0	10.0	10.0
30	17.1		0.8	41.6	13.9	0.4	4.2	0.4	10.0	10.0	10.0	10.0
31	26.3		4.1	7.3	7.3	10.0	10.0	0.4	10.0	10.0	10.0	10.0

1979
MEAN DAILY OUTFLOWS FROM DEGRAY LAKE, m³/sec

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	10.0	10.0	36.9	94.4	48.8	65.1	0.4	0.4	0.4	37.0	8.6	0.4
2	10.0	10.0	36.9	62.4	30.4	50.8	0.4	0.4	0.4	27.7	6.1	2.1
3	41.1	10.0	36.9	83.5	41.9	141.0	28.6	19.8	0.4	38.3	0.4	29.6
4	63.8	10.0	36.9	97.4	87.3	129.5	0.4	29.5	21.7	10.5	7.6	10.4
5	51.5	10.0	72.3	154.2	81.8	62.7	0.4	14.8	14.7	17.3	2.0	21.5
6	36.9	10.0	151.6	59.4	102.5	55.3	0.4	51.6	27.1	0.4	8.4	0.4
7	36.9	10.0	151.6	10.0	86.1	69.4	0.4	44.6	72.8	0.4	26.8	8.2
8	36.9	10.0	151.6	10.0	83.4	49.2	0.4	32.5	58.8	39.8	0.4	0.4
9	20.1	10.0	151.6	62.4	70.0	48.4	0.4	20.7	65.3	0.4	0.4	0.4
10	10.0	10.0	151.6	155.2	61.6	0.4	17.6	21.5	13.5	0.4	8.4	4.4
11	10.0	10.0	151.6	156.1	28.9	18.8	0.4	0.4	39.6	0.4	21.4	15.1
12	10.0	10.0	63.3	157.3	27.1	27.1	0.4	0.4	52.7	0.4	13.7	4.2
13	10.0	10.0	8.8	157.1	47.7	18.6	0.4	1.8	0.4	0.4	25.9	7.6
14	10.0	10.0	7.5	157.4	39.7	0.4	0.4	0.4	0.4	5.8	22.1	4.4
15	10.0	10.0	10.0	158.5	38.9	0.4	0.4	0.4	0.4	42.8	15.4	0.4
16	10.0	10.0	10.0	157.7	35.4	0.4	2.7	0.4	0.4	29.8	1.6	0.4
17	10.0	10.0	10.0	139.2	69.3	1.2	14.2	1.7	0.4	0.7	0.4	22.8
18	10.0	10.0	10.0	89.6	0.4	28.3	0.4	8.0	0.4	12.2	0.4	5.4
19	10.0	10.0	10.0	75.3	0.4	55.3	0.4	2.5	0.4	0.4	0.4	2.3
20	10.0	10.0	10.0	62.4	0.4	30.0	0.4	0.4	0.4	0.4	0.4	2.2
21	10.0	25.4	31.0	10.6	23.2	0.4	0.4	34.3	12.9	11.0	9.9	8.2
22	10.0	36.9	66.7	10.2	139.6	3.3	17.3	0.4	0.4	30.9	0.4	14.2
23	10.0	36.9	66.7	88.8	138.3	0.4	0.4	0.4	0.4	0.4	0.4	20.6
24	10.0	36.9	66.7	93.6	143.1	0.4	10.6	0.4	23.1	8.0	0.4	81.4
25	21.5	36.9	66.7	84.5	81.0	0.4	0.4	0.4	41.3	0.4	0.4	31.6
26	36.9	36.9	66.7	81.6	138.4	13.1	0.4	0.4	1.2	0.4	8.6	21.1
27	36.9	36.9	66.7	68.0	141.8	8.3	0.4	0.4	0.4	0.4	9.1	29.6
28	36.9	36.9	31.3	61.5	137.2	18.9	0.4	11.5	31.2	0.4	0.4	60.7
29	26.8		6.2	59.3	135.2	18.3	5.2	39.2	0.4	17.8	6.2	0.4
30	10.0		49.7	34.4	131.2	0.4	43.9	25.0	1.7	33.7	10.7	2.3
31	10.0		95.0		32.8		19.5	11.6		3.7		2.2

1980
MEAN DAILY OUTFLOWS FROM DEGRAY LAKE, m³/sec

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	24.4	26.1	28.3	36.6	13.2	14.8	2.4	0.4	0.4	0.7	8.2	0.4
2	20.3	0.4	32.6	66.5	39.0	53.1	13.6	0.4	10.7	0.4	22.7	10.5
3	55.8	0.4	32.3	33.3	40.6	29.4	0.4	0.4	1.7	0.4	0.4	1.3
4	1.8	22.8	28.5	0.4	49.2	38.2	0.4	5.9	1.1	0.4	0.4	4.0
5	22.5	21.5	15.5	0.4	56.6	77.1	0.4	10.8	6.8	0.4	0.4	0.4
6	8.6	25.1	16.3	17.0	27.9	51.0	0.4	0.4	0.4	0.4	0.4	0.4
7	2.6	68.5	23.8	17.4	0.4	65.9	36.8	0.4	2.0	1.9	0.4	0.4
8	5.6	24.7	6.1	39.9	0.4	0.4	40.2	5.2	14.9	6.3	0.4	1.3
9	0.4	6.1	12.0	14.3	0.4	0.4	31.2	0.4	18.3	0.4	0.4	117.4
10	15.1	14.4	0.4	3.0	0.4	12.4	17.1	17.1	5.1	0.4	6.7	117.0
11	0.4	24.8	0.4	18.1	0.4	0.9	35.5	30.2	0.4	0.4	10.1	63.5
12	4.3	11.3	31.0	0.4	63.7	0.4	16.3	19.6	0.4	16.0	2.4	33.8
13	1.4	14.7	23.7	17.1	31.1	0.4	11.2	39.1	17.5	0.4	0.4	22.5
14	4.2	20.1	0.4	91.5	9.9	0.4	69.5	0.4	0.4	1.7	0.4	6.0
15	7.6	0.4	0.4	76.1	81.3	0.4	29.0	23.1	20.7	0.4	0.4	25.1
16	21.5	24.7	0.4	84.3	88.0	0.4	29.0	0.4	14.3	12.6	0.4	10.8
17	31.8	27.2	0.4	84.1	81.1	13.2	0.4	0.4	0.4	2.9	0.4	18.8
18	36.6	21.9	36.0	68.2	54.5	0.4	0.4	2.3	0.4	0.4	52.3	10.2
19	0.4	12.5	78.2	0.4	10.5	1.7	0.4	21.9	1.4	0.4	25.3	0.4
20	0.4	4.8	2.4	2.5	32.6	0.4	0.4	10.6	0.4	0.4	0.4	12.8
21	0.4	11.6	7.2	31.0	40.9	0.4	0.4	15.2	8.3	7.7	7.3	16.7
22	11.5	0.4	0.4	25.8	70.1	0.4	11.2	0.4	30.2	0.4	0.4	33.2
23	0.4	0.4	42.7	5.8	37.0	0.4	0.4	1.8	0.4	13.4	0.4	0.4
24	9.5	0.4	80.6	18.6	37.1	14.1	6.7	0.4	0.4	0.4	6.4	11.8
25	7.1	14.7	18.8	12.9	40.6	17.5	0.4	4.5	0.4	0.4	2.9	24.7
26	7.8	35.4	22.4	7.5	0.4	21.0	0.4	0.4	0.4	0.4	11.0	0.4
27	10.8	0.4	65.2	24.1	16.7	35.6	0.4	0.4	0.4	10.0	0.4	0.4
28	9.1	0.4	30.4	8.6	37.3	0.4	0.4	0.4	0.4	6.1	0.4	11.4
29	14.8	16.9	37.7	25.7	93.1	0.9	23.1	0.4	0.4	0.4	0.4	8.4
30	16.5		19.7	10.4	0.4	0.4	33.0	0.4	13.6	0.4	0.4	0.4
31	63.4		43.0		32.8		0.4	13.3		9.2		12.1

APPENDIX C: MEAN DAILY SURFACE ELEVATION OF DEGRAY LAKE,
1974-1980

This appendix presents mean daily surface elevation measurements, in metres above mean sea level (msl), adapted from daily operation reports of DeGray Power Plant, U. S. Army Engineer District, Vicksburg. Note that the base of DeGray Dam is 64.0 metres msl.

1974

MEAN DAILY SURFACE ELEVATION OF DEGRAY LAKE, m msl

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	123.71	123.72	123.42	123.50	125.70	124.36	124.33	123.74	123.81	123.69	122.98	123.47
2	123.59	123.74	123.41	123.50	125.50	124.36	124.32	123.74	123.81	123.68	123.01	123.39
3	123.50	123.77	123.41	123.50	125.26	124.39	124.30	123.74	123.82	123.66	123.03	123.28
4	123.47	123.73	123.43	123.51	125.05	124.36	124.30	123.74	123.84	123.66	123.09	123.17
5	123.44	123.67	123.44	123.51	124.83	124.35	124.30	123.73	123.85	123.66	123.06	123.08
6	123.45	123.67	123.45	123.51	124.60	124.37	124.29	123.73	123.87	123.67	123.07	123.10
7	123.47	123.59	123.44	123.51	124.50	124.79	124.29	123.73	123.87	123.64	123.05	123.22
8	123.49	123.44	123.45	123.52	124.51	126.14	124.27	123.72	123.87	123.61	123.02	123.28
9	123.51	123.30	123.46	123.51	124.51	127.11	124.20	123.72	123.91	123.59	122.98	123.24
10	123.57	123.28	123.47	123.50	124.52	127.31	124.11	123.71	123.91	123.58	123.05	123.11
11	123.83	123.25	123.56	123.51	124.54	127.31	124.07	123.72	123.90	123.56	123.27	123.03
12	123.94	123.24	123.72	123.54	124.39	127.17	124.03	123.75	123.90	123.55	123.31	122.90
13	123.97	123.25	123.79	123.57	124.29	126.99	123.99	123.77	123.92	123.55	123.26	122.74
14	123.95	123.26	123.81	123.60	124.25	126.80	123.99	123.75	123.88	123.56	123.19	122.56
15	123.90	123.28	123.70	123.60	124.31	126.60	123.99	123.75	123.85	123.54	123.08	122.46
16	123.90	123.29	123.60	123.60	124.28	126.45	123.99	123.75	123.81	123.49	123.00	122.35
17	123.92	123.30	123.60	123.60	124.24	126.29	123.99	123.75	123.74	123.43	123.02	122.17
18	123.95	123.32	123.57	123.59	124.18	126.09	123.96	123.76	123.68	123.32	122.98	122.05
19	123.95	123.31	123.53	123.57	124.12	125.87	124.91	123.76	123.70	123.19	122.92	122.02
20	123.92	123.30	123.50	123.56	124.11	125.65	123.84	123.78	123.70	123.13	122.85	121.99
21	123.78	123.36	123.47	123.62	124.10	125.41	123.80	123.77	123.67	123.02	122.77	121.88
22	123.68	123.44	123.41	124.72	124.12	125.17	123.80	123.74	123.68	122.87	122.69	121.85
23	123.68	123.47	123.39	125.36	124.10	124.92	123.80	123.74	123.68	122.82	122.69	121.80
24	123.63	123.53	123.39	125.50	124.07	124.65	123.81	123.72	123.69	122.80	123.00	121.81
25	123.55	123.53	123.40	125.57	124.08	124.40	123.81	123.70	123.80	122.76	123.31	121.81
26	123.54	123.49	123.41	125.62	124.28	124.33	123.81	123.70	123.87	122.74	123.43	121.80
27	123.56	123.47	123.42	125.65	124.39	124.33	123.81	123.70	123.83	122.73	123.39	121.83
28	123.65	123.43	123.44	125.68	124.35	124.33	123.80	123.70	123.79	122.76	123.31	121.83
29	123.52		123.46	125.70	124.30	124.33	123.79	123.73	123.73	122.85	123.28	121.83
30	123.72		123.47	125.72	124.28	124.34	123.78	123.76	123.67	122.84	123.41	121.91
31	123.73		123.48		124.33		123.77	123.80		122.83		121.97

1975

MEAN DAILY SURFACE ELEVATION OF DEGRAY LAKE, m msl

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	122.04	122.76	123.52	124.84	124.16	123.51	123.96	123.53	122.86	122.58	122.07	121.58
2	122.06	123.47	123.54	124.64	124.22	123.51	123.93	123.52	122.82	122.56	122.07	121.54
3	122.11	123.64	123.52	124.42	124.69	123.50	123.91	123.54	122.76	122.55	122.10	121.54
4	122.18	123.66	123.52	124.29	125.06	123.49	123.88	123.56	122.72	122.55	122.11	121.54
5	122.22	123.63	123.50	124.28	125.08	123.47	123.85	123.56	122.70	122.55	122.11	121.55
6	122.28	123.56	123.43	124.28	124.91	123.48	123.82	123.55	122.72	122.55	122.11	121.57
7	122.31	123.39	123.40	124.25	124.82	123.57	123.80	123.54	122.72	122.55	122.11	121.59
8	122.37	123.35	123.40	124.21	124.73	123.70	123.77	123.53	122.72	122.53	122.10	121.62
9	122.42	123.39	123.39	124.14	124.75	123.97	123.73	123.52	122.72	122.53	122.10	121.64
10	122.48	123.37	123.39	124.12	124.73	124.15	123.71	123.51	122.72	122.44	122.11	121.63
11	122.52	123.36	123.35	124.09	124.70	124.15	123.68	123.50	122.72	122.40	122.10	121.62
12	122.56	123.37	123.34	124.08	124.65	124.20	123.71	123.46	122.73	122.40	122.10	121.61
13	122.53	123.38	123.40	124.08	124.54	124.24	123.70	123.69	122.73	122.38	122.05	121.62
14	122.52	123.39	123.51	124.10	124.44	124.27	123.70	123.34	122.72	122.32	121.96	121.63
15	122.54	123.40	123.59	124.08	124.34	124.30	123.69	123.31	122.71	122.27	121.93	121.66
16	122.53	123.41	123.68	124.08	124.21	124.27	123.68	123.27	122.69	122.23	121.91	121.66
17	122.53	123.44	124.06	124.08	124.16	124.27	123.67	123.25	122.69	122.22	121.90	121.64
18	122.53	123.45	123.90	124.03	124.15	124.18	123.67	123.25	122.69	122.22	121.90	121.57
19	122.57	123.46	124.03	124.01	124.09	124.11	123.66	123.22	122.68	122.22	121.88	121.49
20	122.55	123.46	124.08	124.02	123.95	124.03	123.65	123.20	122.68	122.21	121.89	121.47
21	122.52	123.46	124.13	124.01	123.84	123.96	123.65	123.16	122.68	122.20	121.87	121.47
22	122.49	123.47	124.17	124.03	123.68	123.97	123.64	123.12	122.68	122.19	121.85	121.48
23	122.49	123.49	124.18	124.02	123.51	123.98	123.61	123.09	122.67	122.19	121.84	121.48
24	122.47	123.50	124.19	123.98	123.41	124.00	123.59	123.06	122.67	122.19	121.76	121.48
25	122.46	123.55	124.20	123.97	123.41	124.00	123.57	123.03	122.66	122.21	121.68	121.52
26	122.47	124.57	124.20	124.00	123.43	123.99	123.55	123.00	122.65	122.20	121.63	121.53
27	122.46	123.54	124.19	124.05	123.45	123.97	123.55	122.96	122.65	122.16	121.59	121.53
28	122.47	123.51	124.30	124.05	123.46	123.97	123.55	122.93	122.64	122.14	121.56	121.55
29	122.48		124.96	124.08	123.48	123.98	123.55	122.91	122.63	122.14	121.56	121.66
30	122.47		125.13	124.11	123.50	123.98	123.53	122.88	122.60	122.13	121.60	121.86
31	122.50		125.01		123.51		123.53	122.88		122.09		121.93

1976
MEAN DAILY SURFACE ELEVATION OF DEGRAY LAKE, m ms1

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	121.97	122.14	123.20	124.44	124.22	124.31	124.37	124.02	122.82	122.28	122.47	121.80
2	122.02	122.15	123.21	124.36	124.23	124.31	124.34	124.02	122.75	122.26	122.44	121.81
3	122.04	122.15	123.22	124.36	124.22	124.31	124.34	124.01	122.73	122.26	122.39	121.83
4	122.04	122.15	123.23	124.35	124.21	124.32	124.63	124.00	122.71	122.25	122.30	121.83
5	122.05	122.19	123.25	124.34	124.20	124.32	124.45	123.99	122.65	122.25	122.20	121.84
6	122.05	122.24	123.24	124.35	124.23	124.34	124.36	123.98	122.60	122.26	122.15	121.88
7	122.06	122.26	123.25	124.34	124.24	124.34	124.32	123.96	122.57	122.25	122.15	121.89
8	121.99	122.28	123.49	124.34	124.25	124.34	124.32	123.96	122.56	122.22	122.09	121.90
9	121.93	122.29	124.09	124.33	124.27	124.28	124.29	123.95	122.56	122.18	122.02	121.90
10	121.92	122.30	124.31	124.32	124.28	124.26	124.29	123.93	122.56	122.15	121.99	121.92
11	121.93	122.31	124.33	124.33	124.28	124.26	124.29	123.92	122.56	122.14	121.91	121.98
12	121.94	122.33	124.21	124.33	124.29	124.26	124.29	123.87	122.56	122.09	121.79	122.06
13	121.95	122.33	124.15	124.33	124.34	124.25	124.27	123.81	122.54	122.09	121.76	122.12
14	121.96	122.31	124.19	124.33	124.33	124.24	124.24	123.75	122.53	122.09	121.75	122.17
15	121.96	122.32	124.23	124.31	124.36	124.24	124.23	123.69	122.51	122.09	121.72	122.21
16	121.95	122.33	124.27	124.29	124.33	124.27	124.23	123.62	122.50	122.08	121.68	122.23
17	121.94	122.38	124.29	124.28	124.33	124.26	124.23	123.56	122.51	122.08	121.63	122.24
18	121.94	122.64	124.31	124.29	124.34	124.32	124.23	123.49	122.52	122.08	121.62	122.26
19	121.95	122.80	124.33	124.28	124.36	124.34	124.22	123.43	122.51	122.08	121.61	122.28
20	121.98	122.88	124.34	124.23	124.36	124.34	124.22	123.36	122.52	122.08	121.63	122.29
21	121.98	122.96	124.33	124.19	124.33	124.35	124.20	123.31	122.52	122.08	121.65	122.25
22	121.98	123.02	124.34	124.15	124.24	124.34	124.18	123.26	122.31	122.06	121.66	122.25
23	121.99	123.06	124.35	124.15	124.24	124.33	124.17	123.20	122.46	122.04	121.67	122.25
24	121.98	123.10	124.33	124.17	124.25	124.32	124.14	123.15	122.41	122.05	121.69	122.26
25	122.02	123.13	124.32	124.19	124.24	124.43	124.13	123.09	122.33	122.19	121.70	122.28
26	122.06	123.14	124.34	124.19	124.24	124.47	124.10	123.04	122.29	122.35	121.74	122.29
27	122.08	123.16	124.36	124.19	124.27	124.37	124.06	122.97	122.28	122.38	121.82	122.30
28	122.09	123.17	124.37	124.20	124.29	124.39	124.05	122.90	122.28	122.38	121.88	122.30
29	122.09	123.19	124.43	124.21	124.29	124.35	124.04	122.90	122.28	122.40	121.87	122.28
30	122.11		124.51	124.22	124.30	124.38	124.03	122.89	122.29	122.44	121.80	122.29
31	122.12		124.53	124.22	124.30	124.03	124.03	122.86	122.29	122.47		122.28

1977

MEAN DAILY SURFACE ELEVATION OF DEGRAY LAKE, m msl

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	122.27	122.81	123.94	124.39	124.34	123.93	124.25	124.17	123.76	122.68	122.46	123.31
2	122.27	122.81	123.95	124.31	124.33	123.90	124.25	124.17	123.69	122.61	122.80	123.33
3	122.27	122.84	124.26	124.32	124.34	123.89	124.25	124.17	123.64	122.61	122.91	123.36
4	122.28	122.88	124.95	124.31	124.32	123.89	124.25	124.15	123.59	122.61	122.93	123.36
5	122.29	122.90	124.04	124.31	124.25	123.89	124.25	124.15	123.56	122.60	122.96	123.34
6	122.29	122.93	124.91	124.29	124.22	123.89	124.25	124.14	123.52	122.60	122.97	123.25
7	122.30	122.96	124.72	124.32	124.21	123.89	124.24	124.14	123.49	122.59	122.98	123.16
8	122.29	122.88	124.50	124.31	124.18	123.88	124.23	124.13	123.45	122.59	122.99	123.09
9	122.31	122.98	124.36	124.32	124.18	123.86	124.22	124.11	123.42	122.59	123.00	123.03
10	122.29	123.00	124.30	124.31	124.15	123.86	124.23	124.10	123.42	122.58	122.98	122.95
11	122.26	123.04	124.18	124.32	124.11	123.84	124.22	124.10	123.42	122.57	122.98	122.90
12	122.26	123.24	124.13	124.34	124.09	123.82	124.21	124.09	123.42	122.55	122.97	122.89
13	122.29	123.39	124.15	124.34	124.08	123.84	124.18	124.09	123.40	122.54	122.97	122.90
14	122.38	123.48	124.18	124.33	124.07	123.84	124.14	124.09	123.38	122.53	122.96	122.92
15	122.49	123.54	124.20	124.31	124.07	123.84	124.10	124.07	123.37	122.51	122.95	122.93
16	122.57	123.57	124.21	124.26	124.06	123.84	124.08	124.03	123.33	122.50	122.99	122.95
17	122.60	123.60	124.20	124.24	124.06	124.15	124.08	124.00	123.29	122.48	123.08	122.97
18	122.63	123.63	124.22	124.26	124.05	124.28	124.07	124.00	123.27	122.48	123.09	122.97
19	122.62	123.66	124.22	124.34	124.04	124.29	124.02	123.99	123.26	122.47	123.10	122.98
20	122.60	123.68	124.23	124.36	124.02	124.31	123.98	123.99	123.23	122.46	123.11	122.99
21	122.62	123.69	124.24	124.31	124.02	124.32	123.97	123.98	123.16	122.45	123.16	122.97
22	122.64	123.71	124.26	124.25	124.02	124.31	123.97	123.98	123.09	122.44	123.18	122.95
23	122.66	123.75	124.26	124.28	124.02	124.30	123.97	123.97	123.00	122.44	123.20	122.95
24	122.69	123.79	124.26	124.32	124.02	124.30	123.98	123.95	122.93	122.43	123.21	122.96
25	122.71	123.83	124.26	124.34	124.01	124.30	123.99	123.94	122.87	122.43	123.22	122.97
26	122.73	123.86	124.27	124.32	123.98	124.31	123.99	123.92	122.82	122.43	123.21	122.97
27	122.75	123.89	124.29	124.34	123.96	124.28	123.99	123.91	122.79	122.42	123.19	122.98
28	122.77	123.92	124.63	124.34	123.96	124.26	124.00	123.92	122.77	122.41	123.17	122.98
29	122.77		124.91	124.34	123.97	124.26	124.00	123.91	122.75	122.40	123.20	122.98
30	122.79		124.80	124.34	123.96	124.26	124.01	123.90	122.73	122.40	123.24	122.97
31	122.80		124.61		123.94		124.07	123.86		122.40		122.96

1978
MEAN DAILY SURFACE ELEVATION OF DEGRAY LAKE, m msl

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	122.97	123.09	122.54	123.68	123.97	123.96	123.48	122.82	122.33	121.97	121.22	122.87
2	122.97	123.08	122.50	123.69	123.95	123.95	123.47	122.80	122.32	121.96	121.19	122.86
3	122.97	123.08	122.49	123.67	124.00	123.95	123.45	122.79	122.32	121.93	121.17	122.94
4	122.95	123.10	122.47	123.63	124.06	123.95	123.40	122.79	122.32	121.90	121.15	123.14
5	122.95	123.11	122.49	123.60	124.05	123.96	123.40	122.78	122.31	121.88	121.12	123.21
6	122.97	123.05	122.53	123.59	124.06	123.98	123.39	122.78	122.26	121.86	121.11	123.25
7	122.97	122.96	122.70	123.58	124.04	123.98	123.37	122.78	122.23	121.83	121.10	123.37
8	122.98	122.88	122.88	123.57	124.09	123.97	123.35	122.76	122.22	121.80	121.08	123.72
9	122.93	122.84	122.98	123.57	124.14	123.95	123.32	122.74	122.22	121.78	121.05	123.94
10	122.85	122.81	123.07	123.58	124.14	123.95	123.30	122.70	122.22	121.75	121.02	124.02
11	122.77	122.79	123.14	123.57	124.17	123.96	123.27	122.67	122.22	121.73	121.00	124.07
12	122.69	122.77	123.18	123.57	124.19	123.95	123.25	122.65	122.22	121.71	120.98	124.09
13	122.58	122.79	123.26	123.58	124.20	123.92	123.22	122.65	122.23	121.68	120.95	124.11
14	122.45	122.77	123.36	123.59	124.20	123.89	123.21	122.65	122.24	121.66	120.93	124.11
15	122.37	122.75	123.39	123.61	124.21	123.89	123.20	122.62	122.26	121.63	121.00	124.11
16	122.41	122.71	123.41	123.61	124.19	123.88	123.20	122.56	122.25	121.60	121.62	124.10
17	122.51	122.70	123.40	123.59	124.31	123.86	123.17	122.82	122.21	121.58	122.28	124.09
18	122.54	122.70	123.41	123.54	124.15	123.82	123.12	122.47	122.18	121.55	122.46	124.08
19	122.56	122.70	123.43	123.52	124.12	123.82	123.08	122.44	122.08	121.52	122.52	124.07
20	122.58	122.70	123.43	123.54	124.10	123.81	123.06	122.44	122.01	121.50	122.55	124.05
21	122.60	122.68	123.43	123.56	124.11	123.77	123.03	122.42	121.97	121.48	122.56	124.04
22	122.61	122.62	123.42	123.58	124.13	123.74	123.02	122.38	122.03	121.45	122.58	124.01
23	122.64	122.61	123.40	123.80	124.15	123.73	123.01	122.34	122.03	121.43	122.59	123.99
24	122.72	122.59	123.43	123.93	124.13	123.71	123.01	122.29	122.03	121.40	122.59	123.98
25	122.88	122.58	123.51	123.93	124.09	123.65	122.99	122.26	122.03	121.37	122.60	123.96
26	122.99	122.59	123.56	123.94	124.04	123.61	122.96	122.25	122.03	121.36	122.62	123.93
27	123.03	122.59	123.58	123.96	124.00	123.56	122.94	122.24	122.03	121.34	122.76	123.91
28	123.06	122.58	123.58	123.97	123.97	123.53	122.93	122.23	122.03	121.31	122.83	123.89
29	123.08		123.61	124.00	123.98	123.50	122.88	122.29	122.02	121.29	122.86	123.87
30	123.10		123.65	124.00	123.98	123.49	122.84	122.33	122.00	121.27	122.87	123.90
31	123.11		123.67	123.97	123.97	123.49	122.83	122.33	122.00	121.24	122.87	124.04

1979

MEAN DAILY SURFACE ELEVATION OF DEGRAY LAKE, m msl

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	124.40	124.34	124.95	125.19	123.95	124.31	123.97	124.19	123.86	123.19	122.65	122.58
2	124.54	124.33	124.94	125.68	123.90	124.33	123.97	124.20	123.87	123.13	122.65	122.58
3	124.58	124.34	125.42	125.84	123.90	124.41	123.95	124.23	123.88	123.08	122.65	122.55
4	124.52	124.35	125.70	125.87	124.28	124.34	123.93	124.24	123.87	123.04	122.65	122.51
5	124.46	124.35	125.75	125.74	124.43	124.29	123.93	124.22	123.84	122.99	122.64	122.49
6	124.43	124.35	125.64	125.60	124.36	124.25	123.95	124.19	123.81	122.97	122.64	122.47
7	124.43	124.39	125.45	125.61	124.30	124.23	123.96	124.11	123.73	122.97	122.61	122.47
8	124.40	124.40	125.25	125.68	124.22	124.18	123.96	124.04	124.23	122.95	122.58	122.47
9	124.36	124.40	125.04	125.75	124.13	124.13	123.98	124.00	123.51	122.90	122.60	122.47
10	124.36	124.40	124.82	125.61	124.04	124.11	124.03	123.97	123.45	122.90	122.61	122.47
11	124.36	124.40	124.59	125.44	124.09	124.11	124.02	123.95	123.42	122.89	122.59	122.46
12	124.35	124.42	124.40	125.34	124.27	124.10	124.04	123.95	123.33	122.89	122.56	122.49
13	124.35	124.45	124.39	125.20	124.33	124.07	124.05	123.95	123.26	122.89	122.54	122.61
14	124.34	124.49	124.39	125.01	124.35	124.05	124.06	123.95	123.25	122.88	122.49	122.67
15	124.32	124.51	124.39	124.80	124.33	124.06	124.06	123.95	123.25	122.84	122.45	122.70
16	124.30	124.52	124.38	124.57	124.31	124.06	124.07	123.96	123.24	122.76	122.44	122.74
17	124.29	124.53	124.38	124.34	124.25	124.07	124.07	123.96	123.24	122.73	122.44	122.75
18	124.27	124.54	124.37	124.19	124.20	124.05	124.06	123.95	123.24	122.73	122.44	122.74
19	124.30	124.54	124.38	124.07	124.21	124.00	124.05	123.94	123.25	122.72	122.44	122.74
20	124.36	124.54	124.50	123.97	124.22	123.92	124.05	123.94	123.28	122.72	122.44	122.75
21	124.43	124.56	124.69	123.93	124.26	123.91	124.05	123.93	123.34	122.72	122.46	122.76
22	124.45	124.55	124.70	123.97	124.69	123.93	124.04	123.93	123.33	122.69	122.51	122.77
23	124.49	124.57	124.68	124.20	124.96	123.93	124.02	123.93	123.33	122.67	122.54	122.84
24	124.50	124.60	124.63	124.36	124.96	123.97	124.02	123.93	123.34	122.66	122.57	123.21
25	124.50	124.77	124.56	124.34	124.86	124.02	124.01	123.94	123.31	122.66	122.59	123.37
26	124.48	124.87	124.48	124.28	124.77	124.03	124.02	123.94	123.26	122.66	122.60	123.41
27	124.45	124.92	124.41	124.20	124.61	124.02	124.05	123.94	123.26	122.66	122.60	123.44
28	124.41	124.94	124.37	124.13	124.52	124.01	124.17	123.93	123.24	122.66	122.60	123.40
29	124.36		124.38	124.06	124.49	123.98	124.24	123.91	123.21	122.66	122.60	123.37
30	124.66		124.54	124.00	124.37	123.97	124.23	123.86	123.21	122.62	122.58	123.40
31	124.35		125.03	124.33	124.33	124.19	123.83			122.64		123.41

1980

MEAN DAILY SURFACE ELEVATION OF DEGRAY LAKE, m msl

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	123.42	123.78	123.98	124.09	124.28	124.34	123.72	122.86	122.27	122.72	123.11	123.68
2	123.40	123.76	123.93	124.06	124.32	124.32	123.70	122.85	122.25	122.75	123.11	123.69
3	123.36	123.78	123.87	124.00	124.34	124.26	123.68	122.84	122.24	122.77	123.08	123.68
4	123.32	123.77	123.84	124.00	124.35	124.22	123.67	122.83	122.23	122.78	123.08	123.68
5	123.31	123.76	123.82	124.01	124.29	124.14	123.67	122.81	122.22	122.79	123.08	123.69
6	123.30	123.75	123.79	124.04	124.25	124.05	123.66	122.79	122.20	122.79	123.09	123.69
7	123.30	123.68	123.77	124.03	124.25	123.95	123.64	122.79	122.20	122.79	123.10	123.70
8	123.30	123.64	123.75	124.00	124.26	123.88	123.57	122.78	122.18	122.79	123.11	123.78
9	123.30	123.75	123.75	123.96	124.27	123.88	123.49	122.77	122.15	122.79	123.11	124.27
10	123.30	123.84	123.73	123.95	124.29	123.87	123.45	122.75	122.11	122.79	123.11	124.30
11	123.30	123.87	123.73	123.96	124.29	123.86	123.40	122.70	122.13	122.79	123.11	124.27
12	123.30	123.90	123.76	123.98	124.32	123.86	123.34	122.65	122.13	122.79	123.10	124.23
13	123.30	123.93	123.75	124.08	124.31	123.86	123.31	122.59	122.12	122.76	123.10	124.24
14	123.30	123.95	123.74	124.22	124.32	123.85	123.24	122.54	122.09	122.76	123.34	124.25
15	123.31	123.98	123.74	124.22	124.29	123.85	123.13	122.52	122.07	122.76	123.34	124.25
16	123.31	123.79	123.80	124.18	124.31	123.84	123.08	122.49	122.03	122.75	123.39	124.24
17	123.28	124.00	123.97	124.11	124.34	123.83	123.04	122.48	122.01	122.78	123.49	124.24
18	123.24	123.98	124.04	124.03	124.31	123.82	123.03	122.47	122.00	122.94	123.54	124.23
19	123.21	123.98	124.02	124.00	124.30	123.85	123.03	122.45	121.99	123.01	123.51	124.22
20	123.22	123.99	124.00	124.03	124.32	123.87	123.02	122.41	121.98	123.04	123.52	124.22
21	123.29	124.01	124.03	124.03	124.31	123.88	123.01	122.39	121.97	123.06	123.54	124.21
22	123.46	124.00	124.04	124.02	124.29	123.89	122.99	122.36	121.94	123.07	123.55	124.18
23	123.63	124.02	124.08	124.01	124.30	123.89	122.97	122.37	121.90	123.07	123.58	124.15
24	123.73	124.03	124.09	124.01	124.31	123.86	122.96	122.34	121.90	123.08	123.60	124.16
25	123.78	124.05	124.06	124.06	124.29	123.84	122.94	122.33	121.93	123.08	123.61	124.14
26	123.82	124.01	124.09	124.18	124.27	123.81	122.94	122.32	121.93	123.08	123.62	124.11
27	123.85	123.99	124.08	124.23	124.29	123.77	122.96	122.47	121.94	123.08	123.62	124.11
28	123.86	123.99	124.04	124.24	124.31	123.73	122.96	122.31	122.16	123.11	123.64	124.11
29	123.88	123.99	124.04	124.25	124.34	123.73	122.95	122.30	122.54	123.11	123.65	124.11
30	123.89		124.07	124.25	124.32	123.72	122.90	122.30	122.68	123.11	123.66	124.10
31	123.85		124.09		124.35		122.86	122.29		123.11		124.10

APPENDIX D: DEGRAY LAKE AREA-CAPACITY TABLE

The data herein were adapted from "Ouachita River Basin, DeGray Dam and Reservoir, Caddo River, Arkansas," Supplement A, Design Memorandum No. 1, Hydrology and Hydraulic Analysis. January 1962. U. S. Army Engineer District, Vicksburg. Note that the base of DeGray Dam is 64.0 metres above mean sea level (msl).

DeGray Lake Area-Capacity Table

<u>Elevation</u> <u>m msl</u>	<u>Surface Area</u> <u>hectares</u>	<u>Volume</u> <u>10 m</u>
114.0	2974.4	382.0
114.3	3031.1	391.1
114.6	3091.8	400.5
114.9	3148.5	410.0
115.2	3209.2	419.6
115.5	3269.9	429.5
115.8	3330.6	439.5
116.1	3391.3	449.7
116.4	3456.0	460.1
116.7	3516.7	470.7
117.0	3581.5	481.6
117.3	3650.3	492.5
117.6	3715.0	503.8
117.9	3783.8	515.2
118.3	3852.6	526.8
118.6	3921.4	538.8
118.9	3990.2	550.9
119.2	4063.0	563.2
119.5	4135.9	575.7
119.8	4208.7	588.4
120.1	4281.6	601.3
120.4	4354.4	614.5
120.7	4431.3	627.8
121.0	4508.2	641.5
121.3	4585.1	655.3
121.6	4662.0	669.4
121.9	4742.9	683.7
122.2	4823.9	698.3
122.5	4908.8	713.1
122.8	4993.8	728.1
123.1	5078.8	743.4
123.4	5163.8	759.1
123.7	5252.8	774.9
124.0	5341.8	791.0
124.4	5430.9	807.6
124.7	5519.9	824.2
125.0	5608.9	841.2
125.3	5702.0	858.5
125.6	5791.1	876.1
125.9	5884.1	893.9
126.2	5977.2	912.0
126.5	6070.3	930.3
126.8	6167.4	949.0
127.1	6260.5	967.9
127.4	6357.6	987.0
127.7	6454.7	1006.6
128.0	6555.9	1046.6
128.6	6758.2	1067.1
128.9	6859.4	1087.8

APPENDIX E: MEAN DAILY STREAM TEMPERATURE OF CADDO RIVER AT
HIGHWAY 84 BRIDGE, 1976-1980

This appendix presents mean daily stream temperature of the Caddo River in degrees Celsius. When data were unavailable, stream temperatures have been estimated using available air temperatures; these estimated temperatures are indicated with a cross.

1976 CADDO RIVER TEMPERATURES AT HIGHWAY 84 BRIDGE, °C

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	+5.5	+6.2	+11.9	+12.1	+14.6	23.3	22.5	+27.9	23.8	18.7	11.4	4.6
2	+6.8	+5.9	+13.1	+13.5	+15.9	23.2	22.1	+27.1	24.0	19.8	11.5	4.7
3	+6.5	+6.0	+14.6	+13.2	+16.4	23.8	23.4	+25.8	24.0	20.9	11.7	5.2
4	+4.9	+4.9	+15.5	+14.4	+16.2	23.4	21.7	+25.2	24.3	21.2	11.0	5.0
5	+2.5	+6.2	+16.3	+15.0	+16.3	23.1	21.6	+24.6	26.0	21.1	+11.1	+6.1
6	+1.3	+6.9	+14.3	17.0	+17.8	22.2	22.0	+25.0	26.1	19.0	+9.3	7.2
7	+1.8	+4.2	+11.1	17.4	+17.9	22.0	22.8	+26.1	25.2	17.3	+10.1	+6.9
8	+1.7	+3.6	+10.7	17.7	+17.5	22.8	23.1	+26.2	24.6	15.5	+11.0	+6.1
9	+0.7	+3.7	+9.1	17.1	+17.1	23.6	23.5	+25.3	24.9	14.1	+9.5	+4.3
10	+1.1	+5.7	+8.4	16.9	+16.9	+23.3	24.6	+24.9	20.9	14.4	+10.5	+4.8
11	+1.2	+8.5	+9.3	17.8	+16.9	+23.8	25.4	+24.8	19.0	15.5	+12.6	+5.7
12	+3.3	+10.2	+10.1	18.5	+18.0	+24.1	26.0	+24.9	19.8	16.4	+10.1	+6.0
13	+3.8	+9.3	+11.9	18.6	+19.0	+24.5	26.4	+25.7	21.8	17.4	+8.1	+6.3
14	+5.9	+11.8	+10.8	18.8	+18.9	+24.8	26.4	27.4	22.4	18.0	+7.3	+6.5
15	+7.8	+11.3	+9.2	20.1	+18.9	+25.1	26.1	26.7	23.6	18.2	+5.8	+4.7
16	+4.1	+11.6	+11.1	20.2	+18.6	26.7	26.0	27.4	23.2	17.2	6.7	+6.7
17	+6.2	+13.7	+9.7	20.4	+18.2	25.1	26.1	28.4	22.5	14.7	6.7	+5.5
18	+3.9	+13.0	+9.5	19.8	+18.4	21.9	26.0	25.2	22.7	13.2	7.3	+6.9
19	+2.9	+12.6	+11.1	18.8	19.2	20.6	26.2	24.5	23.1	+13.6	8.5	+8.8
20	+4.9	+11.6	+12.8	18.1	20.2	20.7	26.7	24.2	23.0	11.7	9.1	+10.0
21	+4.7	+11.1	+14.3	+18.4	21.8	21.5	27.0	24.2	+22.6	11.7	8.9	+8.9
22	+3.8	+8.1	+13.8	+17.7	23.7	21.2	27.3	23.6	20.7	11.9	7.4	+4.9
23	+5.7	+6.0	+12.5	19.2	24.4	21.2	27.7	23.3	20.7	13.3	6.6	+3.9
24	+6.4	+8.2	+13.0	18.0	23.3	22.2	28.3	23.9	21.2	14.4	6.6	+3.7
25	+8.3	+7.5	+12.1	17.0	22.5	20.0	28.3	24.5	20.9	15.2	8.0	+3.2
26	+9.1	+10.1	+13.0	16.5	21.2	20.1	27.9	25.4	20.6	13.7	10.9	+4.8
27	+7.6	+10.8	+14.1	16.9	+20.5	21.3	28.3	26.0	20.6	12.7	10.3	+5.9
28	+4.7	+11.6	14.3	+15.2	18.4	22.7	28.1	25.4	19.8	11.8	6.8	5.5
29	+5.0	+11.8	14.2	+14.6	20.2	23.6	28.3	25.6	18.5	11.4	4.3	5.3
30	+5.2		14.0	+14.0	21.8	24.2	28.7	24.9	18.2	10.8	4.0	+6.5
31	+5.7		13.0	23.1	23.1		+27.6	24.1		10.9		+6.1

1977 CADDO RIVER TEMPERATURES AT HIGHWAY 84 BRIDGE, °C

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	+0.1	+0.9	+8.0	+12.6	+19.1	27.2	+27.4	25.1	28.1	25.3	+18.9	7.4
2	+1.3	+3.0	+7.6	+14.6	+19.0	27.0	+26.6	25.2	28.0	24.4	+17.7	7.6
3	+0.4	+3.9	+8.1	+14.0	+19.1	28.1	+27.3	25.8	27.7	+21.5	+16.3	8.5
4	+2.0	+5.7	+8.9	+12.3	+20.0	27.5	+27.6	26.7	27.7	+20.3	+16.5	9.8
5	+3.6	+5.6	+8.1	+13.4	+20.2	27.1	+28.3	27.2	26.7	+19.7	+17.7	9.4
6	+3.9	+4.3	+8.1	+11.6	+21.1	27.6	+29.2	27.6	26.8	+19.8	+17.4	6.0
7	+3.4	+3.5	+8.2	+13.9	+21.3	27.0	+30.2	28.3	27.1	+19.5	+18.1	3.6
8	+3.6	4.2	+8.9	+15.1	+21.6	25.3	31.1	+29.2	27.2	+19.6	+18.0	4.8
9	+2.5	4.8	+10.0	+15.4	+20.8	26.0	30.7	+29.3	27.2	19.8	+16.6	3.8
10	+0.1	5.6	+10.9	+16.6	+19.5	27.2	29.1	+29.5	26.9	19.6	+13.4	3.0
11	+0.9	6.0	+11.8	+16.9	+18.1	28.1	29.5	+29.2	26.0	19.0	+12.6	3.1
12	0.8	7.6	+11.3	+16.9	+18.5	28.2	30.1	+28.5	25.7	16.8	8.9	6.0
13	1.1	7.6	+11.2	+17.0	+18.7	27.3	30.5	+28.5	25.5	15.5	7.0	8.0
14	2.9	7.2	+12.3	+17.3	+20.0	26.2	31.1	+28.4	24.5	15.0	8.2	9.5
15	3.3	6.4	+13.2	+17.4	+21.4	25.0	31.1	+28.2	23.9	+16.3	10.7	9.4
16	1.9	5.8	+13.4	+17.5	+21.7	24.0	31.0	29.6	23.4	+15.9	14.0	8.9
17	1.8	6.4	+11.8	+18.0	24.5	20.6	30.6	29.3	23.6	+15.9	13.6	8.9
18	1.0	7.4	+14.0	+17.8	24.5	20.2	30.9	28.7	24.7	+16.8	11.3	9.1
19	1.4	7.6	+12.8	+17.6	25.2	23.0	29.4	27.0	25.3	+17.1	12.0	10.3
20	2.2	7.3	+11.3	+18.0	25.4	24.8	27.2	26.4	23.9	+16.7	13.3	10.3
21	3.8	7.9	+12.0	+17.6	24.9	25.7	24.7	27.0	23.5	+17.6	12.5	9.3
22	4.1	8.7	+10.9	+18.2	23.9	26.5	25.7	27.5	23.8	+18.5	10.7	9.3
23	4.5	8.1	+9.9	+17.3	23.4	27.4	26.5	27.0	24.2	+18.5	10.5	8.7
24	+3.4	8.1	+11.1	+16.7	24.9	27.7	28.6	27.4	24.6	21.2	11.5	+7.3
25	+4.0	+12.0	+10.9	+16.4	25.7	27.4	29.3	28.4	25.1	21.4	11.2	+6.8
26	+4.6	+11.6	+12.6	+15.3	26.1	25.8	28.5	28.9	26.1	21.0	9.0	+4.9
27	+5.6	+9.6	+13.7	+16.0	26.4	+26.4	25.7	28.4	26.2	20.7	8.6	+4.9
28	+4.1	+8.2	+14.6	+17.1	25.9	+26.6	24.8	27.7	24.9	20.7	7.2	+3.5
29	+2.3		+15.2	+18.3	25.7	+26.7	26.1	+27.7	24.2	21.3	6.0	+3.5
30	+1.9		+15.5	+18.6	27.1	+26.8	25.1	+27.7	24.9	21.1	6.4	+3.9
31	+1.8		+14.4		27.5		24.3	+27.9		+18.9		+5.3

1978 CADDO RIVER TEMPERATURES AT HIGHWAY 84 BRIDGE, °C

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	+5.0	4.1	6.5	15.8	+20.2	+26.1	31.3	+29.6	22.8	+21.0	14.0	9.7
2	+4.4	4.3	5.9	16.8	+19.2	+25.9	31.1	+29.4	23.5	+20.4	14.4	10.5
3	+3.5	4.4	5.4	+16.9	+18.3	+25.6	31.0	+29.4	24.1	+20.3	14.5	13.1
4	+3.7	4.4	5.1	+17.1	+18.3	+25.6	30.8	+29.0	24.3	+19.8	15.0	9.5
5	+5.4	5.0	5.5	+17.3	+18.5	+25.6	+29.6	+28.3	25.1	19.9	15.3	8.6
6	+7.0	4.7	6.1	+17.7	+19.3	+25.8	+29.6	+28.0	25.8	18.9	15.3	9.3
7	+7.7	3.3	7.6	+18.0	+20.6	+26.0	+29.5	+28.0	25.8	17.2	14.2	10.0
8	4.5	2.5	7.5	+18.0	+21.8	+26.1	+29.5	+28.1	25.8	16.7	12.6	8.6
9	+4.7	2.5	6.2	+18.2	+22.1	+25.9	+29.8	+28.3	+25.7	17.0	11.7	6.9
10	+2.5	3.5	7.0	+18.1	+21.8	+25.6	+30.0	+28.5	+25.7	17.1	11.4	5.9
11	2.0	4.2	8.6	+17.1	+22.0	+26.1	+29.6	+28.3	+25.2	16.9	12.2	5.6
12	1.7	5.3	9.2	+16.1	+22.6	+26.9	+29.3	26.2	+24.6	17.4	13.7	5.7
13	3.5	5.7	9.0	+16.0	+22.5	+27.1	+29.6	26.8	+24.6	18.2	14.9	5.9
14	3.0	5.1	10.1	+16.5	+22.2	+26.9	+29.7	26.3	+24.6	17.2	15.5	6.0
15	2.7	5.1	10.8	+17.2	+22.3	+26.7	+29.3	26.6	+24.3	15.7	14.0	5.6
16	2.4	5.4	10.1	+17.8	+22.2	+26.8	+29.1	27.3	+24.4	15.3	12.4	6.7
17	2.8	5.0	9.9	+18.1	+22.0	+27.4	+29.2	27.7	+24.7	14.6	12.9	6.7
18	3.6	4.1	10.6	+18.2	+22.2	+28.0	+29.2	27.9	+24.8	13.6	11.9	6.7
19	3.2	3.9	12.2	+17.9	+23.1	+28.1	+29.4	27.9	+24.7	13.7	11.6	8.1
20	2.9	4.3	13.8	+17.2	+24.1	+27.9	+29.6	27.1	+24.5	14.3	11.7	10.1
21	3.2	4.0	14.3	+16.8	+24.6	+27.9	+29.8	27.6	+24.1	15.0	11.9	9.4
22	3.2	4.0	13.5	+17.1	+24.7	+27.9	+29.7	27.7	+23.2	15.6	11.8	7.6
23	3.7	5.5	12.4	+18.0	+24.9	+28.1	+29.5	27.6	+22.2	16.4	11.9	6.7
24	5.0	6.6	11.7	+18.7	+25.3	29.3	+29.2	27.8	+21.7	16.6	12.4	6.8
25	5.6	6.9	9.2	+18.6	+25.6	29.5	+29.2	28.0	+21.5	16.0	12.3	5.7
26	4.0	7.4	8.7	+18.3	+25.8	30.2	+29.5	28.1	+21.5	16.3	12.9	5.3
27	4.3	7.0	10.2	+18.3	+26.1	30.7	+29.4	28.0	+21.5	15.6	12.9	4.4
28	4.2	6.6	11.6	+18.6	+26.0	30.6	+29.1	27.7	+21.4	14.6	10.1	4.7
29	4.4		13.0	+19.2	+25.6	31.0	+29.5	24.0	+21.3	14.0	9.8	5.4
30	4.4		14.2	+20.1	+25.6	31.6	+30.0	22.1	+21.4	13.4	9.9	6.6
31	4.4		14.8		+25.9		+30.0	22.7		13.6		7.3

1979 CADDO RIVER TEMPERATURES AT HIGHWAY 84 BRIDGE, °C

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	6.5	1.4	9.5	14.4	15.6	+24.0	+26.5	26.5	27.4	22.4	14.5	5.1
2	3.8	1.6	9.5	12.9	15.6	+23.8	+27.1	26.0	27.4	21.8	13.5	4.9
3	3.0	2.6	10.9	11.3	15.9	+23.2	+27.7	24.0	27.1	20.6	12.7	4.6
4	3.0	3.2	9.7	11.6	15.0	+23.5	+27.8	24.7	27.4	19.7	11.8	4.7
5	3.5	3.1	8.6	11.0	14.7	+23.9	+28.3	25.9	27.4	17.9	11.6	5.6
6	3.9	2.5	8.8	12.9	15.5	+24.1	+27.5	27.2	27.2	17.6	12.3	6.7
7	3.7	1.3	10.4	14.1	16.7	+25.0	+26.6	28.1	26.8	17.7	11.3	6.7
8	2.9	2.0	10.2	13.1	18.7	+25.8	+27.0	28.3	26.0	18.7	11.4	6.7
9	1.8	1.5	10.4	13.1	19.7	+26.3	+26.5	28.6	24.4	18.6	12.0	6.3
10	2.1	1.5	10.3	13.1	20.0	+26.1	+26.0	28.7	23.7	16.4	11.3	6.4
11	2.4	2.6	10.0	13.9	17.6	+25.1	+26.4	27.1	24.0	16.0	10.4	7.6
12	2.4	4.8	10.9	14.4	15.9	+24.9	+26.5	25.2	23.9	17.0	9.3	8.1
13	2.7	5.8	12.9	15.0	16.4	+24.9	+26.8	24.8	24.2	18.0	8.6	7.7
14	1.3	5.7	13.7	14.9	17.0	+25.1	+27.1	25.6	23.1	16.5	8.3	7.3
15	1.2	7.7	12.3	15.6	18.1	+25.5	+27.2	26.1	21.3	15.8	8.4	7.1
16	2.0	7.7	11.3	16.5	19.1	+25.6	+27.5	26.5	20.3	16.4	8.7	6.7
17	3.8	4.7	11.7	17.2	19.7	+26.0	+27.7	26.4	19.8	17.2	9.0	5.1
18	4.2	3.3	13.3	17.0	20.1	+26.3	+27.2	27.0	20.3	18.1	9.5	3.7
19	5.6	3.9	14.9	17.2	20.6	+26.7	+27.0	27.8	20.7	18.6	10.8	4.0
20	6.0	4.2	14.8	17.4	21.2	+27.4	+27.2	28.1	20.5	19.6	12.2	5.5
21	4.3	5.7	14.5	17.1	19.6	+27.0	27.0	27.5	20.2	20.7	13.5	7.6
22	4.3	8.0	14.0	16.0	16.8	+26.2	27.3	27.1	20.5	20.6	13.1	9.8
23	3.4	9.9	13.2	14.5	17.1	+26.8	27.7	26.8	20.4	17.4	11.1	11.6
24	2.4	8.8	11.9	14.8	17.1	+26.1	27.8	25.7	20.2	15.8	9.4	10.8
25	2.3	6.4	12.0	15.9	16.7	+25.3	27.9	24.4	20.0	15.4	9.0	9.2
26	2.5	6.8	13.1	17.1	15.8	+25.2	26.8	25.5	20.4	15.4	8.8	8.7
27	3.1	7.4	11.7	15.6	15.4	+25.4	24.9	26.5	20.7	15.7	9.2	8.9
28	2.6	8.5	11.9	14.9	16.5	+25.6	23.3	27.2	20.8	16.1	8.9	9.1
29	2.2		12.2	15.4	17.0	+26.5	25.1	26.8	21.5	16.3	7.2	8.6
30	2.4		13.4	15.8	18.0	+27.1	26.2	27.1	21.9	16.6	5.8	7.8
31	2.2		13.3		+20.8		26.4	27.7		16.6		7.5

1980 CADDO RIVER TEMPERATURES AT HIGHWAY 84 BRIDGE, °C

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	6.8	+4.2	7.0	12.5	15.4	23.7	+28.7	+29.3	27.1	19.8	12.3	9.7
2	6.7	+1.5	4.7	14.1	15.5	24.1	+28.9	+29.3	27.4	20.0	12.7	10.5
3	7.0	+2.2	4.5	16.0	15.5	24.5	+30.9	+29.1	27.0	18.7	13.2	9.0
4	6.3	+3.0	5.6	15.5	15.9	25.1	30.8	+28.6	27.1	17.7	13.8	8.8
5	6.4	+4.1	6.9	14.7	16.5	25.8	30.4	+28.5	27.3	17.5	13.5	10.4
6	6.1	+5.2	7.7	15.3	17.8	26.1	30.6	+28.5	27.2	16.9	13.7	11.6
7	6.6	+4.7	10.2	16.2	18.5	25.9	30.7	+28.8	27.1	17.0	14.1	11.9
8	5.7	+4.2	11.7	17.2	18.0	25.5	30.7	+28.9	26.8	17.8	14.5	12.3
9	5.2	+4.3	11.2	16.3	17.4	23.0	30.8	+29.1	26.4	19.1	15.4	11.7
10	5.4	+2.9	11.8	16.0	17.9	22.8	30.8	+28.7	26.6	20.1	16.5	11.0
11	7.1	+3.0	11.2	16.0	19.6	24.0	30.7	+28.9	26.7	20.2	16.2	10.3
12	6.6	+3.6	+9.1	14.3	+19.8	24.6	30.5	+29.0	26.6	18.2	14.6	10.1
13	5.5	+3.4	+10.6	10.0	+20.1	24.6	30.5	+28.8	25.8	17.1	13.5	10.1
14	5.6	+5.7	+10.0	8.6	+20.6	25.9	30.5	+28.5	25.5	16.9	13.2	9.9
15	7.3	+8.0	+9.5	10.4	+18.6	26.6	30.5	+29.6	25.9	17.9	13.0	9.6
16	9.5	+7.7	+11.1	12.6	+19.0	27.6	30.5	29.6	26.4	18.9	11.7	10.1
17	8.6	+4.9	+11.2	13.9	+20.0	27.0	30.6	29.6	26.2	19.1	10.3	9.9
18	9.0	+5.1	+10.5	14.3	+20.3	26.8	30.2	29.5	24.7	18.7	9.7	9.8
19	9.5	+5.6	+10.6	14.9	+20.7	25.3	30.2	29.2	24.6	18.0	8.7	+9.5
20	9.9	+6.8	+11.2	16.1	+20.8	25.4	30.2	29.1	25.0	16.7	8.2	+5.6
21	9.4	+8.9	11.2	17.2	+20.5	25.2	29.8	28.8	25.5	16.4	8.1	+4.0
22	9.5	+11.7	11.3	18.0	+19.6	25.6	29.5	28.6	26.0	16.4	8.1	+3.4
23	8.6	+11.1	11.0	18.3	+18.7	+24.4	28.5	28.2	25.9	16.7	9.0	+3.4
24	8.4	+11.1	9.9	18.4	18.4	+25.3	27.7	27.1	24.5	16.6	9.7	+5.0
25	8.7	+9.2	9.5	16.1	20.4	+26.5	27.3	+27.8	23.7	14.5	8.9	+3.6
26	9.5	+7.5	9.5	13.3	22.0	+27.2	27.1	27.7	22.3	13.6	8.0	+2.8
27	9.5	+7.1	10.1	12.9	22.8	+27.9	25.0	27.8	19.9	14.3	7.1	+4.4
28	8.3	+9.2	11.7	13.7	22.1	+28.3	26.7	27.0	16.6	13.9	6.9	+3.4
29	6.8	9.4	12.2	15.3	19.9	+28.6	27.6	26.4	17.2	13.1	7.3	+4.6
30	5.9		10.3	15.8	21.0	+28.5	28.5	26.1	18.8	12.1	7.8	5.5
31	5.1		10.4		22.7	+28.8		26.5		11.8		6.0