SIMULATION OF TRAVEL TIME FOR A 300 CUBIC FOOT PER SECOND DISCHARGE FROM OKATIBBEE RESERVOIR, PASCAGOULA RIVER BASIN, MISSISSIPPI

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Introduction

Background: Surface-water withdrawals in Jackson County, Mississippi, are primarily from the Pascagoula River at Cumbest Bluff near Three Rivers, Mississippi (fig. 1). Increasing water use is placing a burden on this supply, and demand can exceed supply during periods of extreme low flow. A possible solution to this problem is to augment extreme low flows with discharges of water from Okatibbee Reservoir in Lauderdale County, Mississippi. The first step in assessing the feasibility of this proposal is to estimate the travel times of flow releases as they travel the 252 mile reach from the Okatibbee Reservoir spillway to Cumbest Bluff (fig. 1). For purposes of this report, travel time is the time in days for the leading edge of an additional volume of water (in excess of base flow) to the river system to travel from one point on the reach to another. This additional discharge can be from rainfall or reservoir releases. As a result of discussions with officials from various governmental agencies, a simulated discharge of 300 feet^3/s (cubic feet per second) from Okatibbee Reservoir was used to analyze the effects of reservoir releases on the lower Pascagoula River. This paper presents the methods used in estimating the travel time, and the results of these estimates, for the flow release from Okatibbee Reservoir to travel through the Pascagoula River basin to Cumbest Bluff during low-flow conditions.

Study Area: The study area is the Pascagoula River basin with emphasis on the stream reach between Okatibbee Reservoir and Cumbest Bluff (this stream reach will be referred to as the main-stem reach for the purposes of this report). The U.S. Geological Survey (USGS) operates four continuous-record gaging stations on the main-stem reach and operates six other gaging stations near the mouths of major tributaries along the main-stem reach. These 10 stations continuously monitor the flows into and along the stream reach between Okatibbee Reservoir and Cumbest Bluff (fig. 1).

Simulation of Travel Time

The ideal method for determining travel time would be to release a trial discharge from Okatibbee Reservoir and time the resulting wave as it travels to Cumbest Bluff. However, current operating procedures of Okatibbee Reservoir do not allow for these types of releases during low-flow conditions. Consequently, an alternative procedure was used.

The procedure used in this analysis was to examine hydrographs from gaging stations within the study area and estimate travel times using flow-routing techniques based on recorded hydrographs. The ideal hydrologic conditions for this comparison of hydrographs would be steady low-flow conditions at all downstream tributaries while a small rise occurs on the main stem. Hydrographs from gaging stations in the study area indicated that these conditions occurred at least once within the past several years due to a localized storm in the upper Pascagoula River basin. The hydrographs for August 1989, shown in figure 2, illustrate the movement of the resulting discharge down the main stem. Similar hydrographs representing storm events during medium stages were also examined. The comparison of such large amounts of data was aided by the use of a computer model.

Selection of a model: CONROUT (Doyle et al. 1983), a USGS model for routing streamflow by convolution methods, was selected for this analysis. The main advantage of CONROUT is that the model has the ability to route streamflow from an upstream gaging station to the next downstream gaging station under variable hydraulic and hydrologic conditions. The routing parameters (wave speed and attenuation) can be adjusted in order to calibrate the model's output hydrographs to recorded hydrographs. The output hydrographs for CONROUT are easily tabled, statistically analyzed, and plotted (Lumb et al. 1989).

CONROUT does not account for water losses due to evaporation, transpiration, ground infiltration, and water withdrawals. Accounting for these losses was beyond the scope of this study, but they play an important role in the overall flow regime of a basin during extreme low-flow conditions.

Methods: The input hydrograph to CONROUT is convoluted with the system unit response to obtain the output hydrograph. The output hydrograph can, in turn, be used as the input hydrograph for the next reach downstream. For this reason, the main-stem reach was divided into five subreaches (numbered 1 through 5 from upstream to downstream) extending from Okatibbee Reservoir spillway to Cumbest Bluff (fig. 3).

Tributary flow into the main stem was accounted for in the model by adding an inflow hydrograph to the CONROUT control file for the subreach being examined.

Steady lowflow tributary conditions represented by relatively flat inflow hydrographs were selected because they permit a more accurate calibration of the model than would unsteady-flow conditions.

During extreme low-flow conditions, the Pascagoula River can be tidally affected as far as 53 miles upstream of the mouth (Harvey et al. 1965). At Cumbest Bluff, 25.4 miles upstream from the mouth of the river, the stage-discharge relation is affected by tides (fig. 4). The travel times of flow augmentations in subreach 5 are, therefore, affected by tidal influences from the Mississippi Sound but the complexities of tidal influences upon travel time were not addressed in this report. Although estimated travel times in subreach 5 approximate average travel times, care should be used when interpreting model results in this reach.

Calibration and verification: Each subreach has unique hydraulic and hydrologic properties that affect the characteristics of the routed hydrograph. Therefore, each subreach is treated independently with its own set of calibration factors. CONROUT was calibrated by adjusting wave speed (celerity) and dispersion coefficients for each successive subreach until the synthesized hydrographs agreed as closely as possible with actual hydrographs. The calibrated model was verified by comparing synthesized hydrographs with measured hydrographs for selected storm events independent of the calibration hydrograph.

The first and fifth subreaches are not bounded by gaging stations; this resulted in incomplete hydrographic comparisons. The calibration factors for these two subreaches were estimated using the properties of the adjoining subreaches. The estimates are assumed to be adequate because the adjoining subreach characteristics were similar. Also, travel time and wave attenuation were determined to be relatively insensitive to moderate changes in calibration factors. Travel times for the second and third subreaches were verified by comparing synthesized hydrographs with actual low-flow storm hydrographs. Calibration of the model for the fourth subreach was not verified because the storm event used in calibration was the only hydrograph available not affected by tributary storm events. In the two subreaches for which the model was verified, the estimated travel times were within 6 hours of recorded travel times which indicated that the calibrations were adequate. Because of the similarities in the subreaches, the travel times in the fourth subreach probably were also adequate.

Simulation Results

Model output for the various subreaches is in the form of hydrographs which can be superimposed on one another to evaluate wave speed and attenuation along the mainstem. The shape of the output hydrographs is dependent upon the specific hydraulic and hydrologic conditions used in calibration. Output hydrographs depicting sustained augmentations do not show wave attenuation characteristics of storm related discharge because of the constant reservoir outflow. Therefore, in the model, the flow augmentation reaching Cumbest Bluff was the same as the additional flow release from Okatibbee Reservoir.

Calibration factors, which represent a specific flow regime, limit the model to a unique unit response for the subreach being examined. The inflow hydrograph is multiplied by the unit response to obtain the outflow hydrograph. Therefore, for one set of calibration factors, estimated travel times do not vary with different discharges due to the constraints of the unit response function. For this reason, the model was calibrated to a low-flow storm event similar in magnitude to the proposed reservoir discharge of 300 $feet^3/s$.

Results from the calibrated model indicate that the time required for a low-flow augmentation of 300 $feet^3/s$ to travel from the Okatibbee Reservoir spillway to Cumbest Bluff is slightly more than 6 days (fig. 5).

Summary

Flow-routing techniques were used to estimate the time required for sustained flow augmentations to travel from Okatibbee Reservoir to Cumbest Bluff, near Three Rivers, Mississippi, during low-flow conditions. The USGS digital model CONROUT proved to be adequate in routing flows through this stream reach. For purposes of model calibration, the main-stem reach was divided into five subreaches. CONROUT was calibrated to a low-flow storm event and verified using hydrographs for other storm events in two of these subreaches. The effects of tides, ground infiltration, evaporation, transpiration, and other environmental effects were beyond the scope of this study; however, they may be significant factors in the magnitude and travel time of flow augmentations reaching Cumbest Bluff. Results from the calibrated model indicate that a travel time of about 6 days is required for flow augmentations from Okatibbee Reservoir to reach Cumbest Bluff.

References

Doyle, W.H., Jr., J.O. Shearman, G.J. Stiltner, and W.R. Krug. 1983. A digital model for streamflow routing by convolution methods: U.S. Geological Survey Open File Report 83-4160.

Harvey, E.J., H.G. Golden, and H.G. Jeffery. 1965. Water resources of the Pascagoula Area Mississippi: U.S. Geological Survey Water-Supply Paper 1763.

Lumb, A.M., J.L. Kittle, and K.M. Flynn. 1989. Users manual for ANNIE, a computer program for interactive hydrologic analyses and data management: U.S. Geological Survey Open File Report 89-4080.

Figure 1.--Location and major drainage of the Pascagoula River basin.

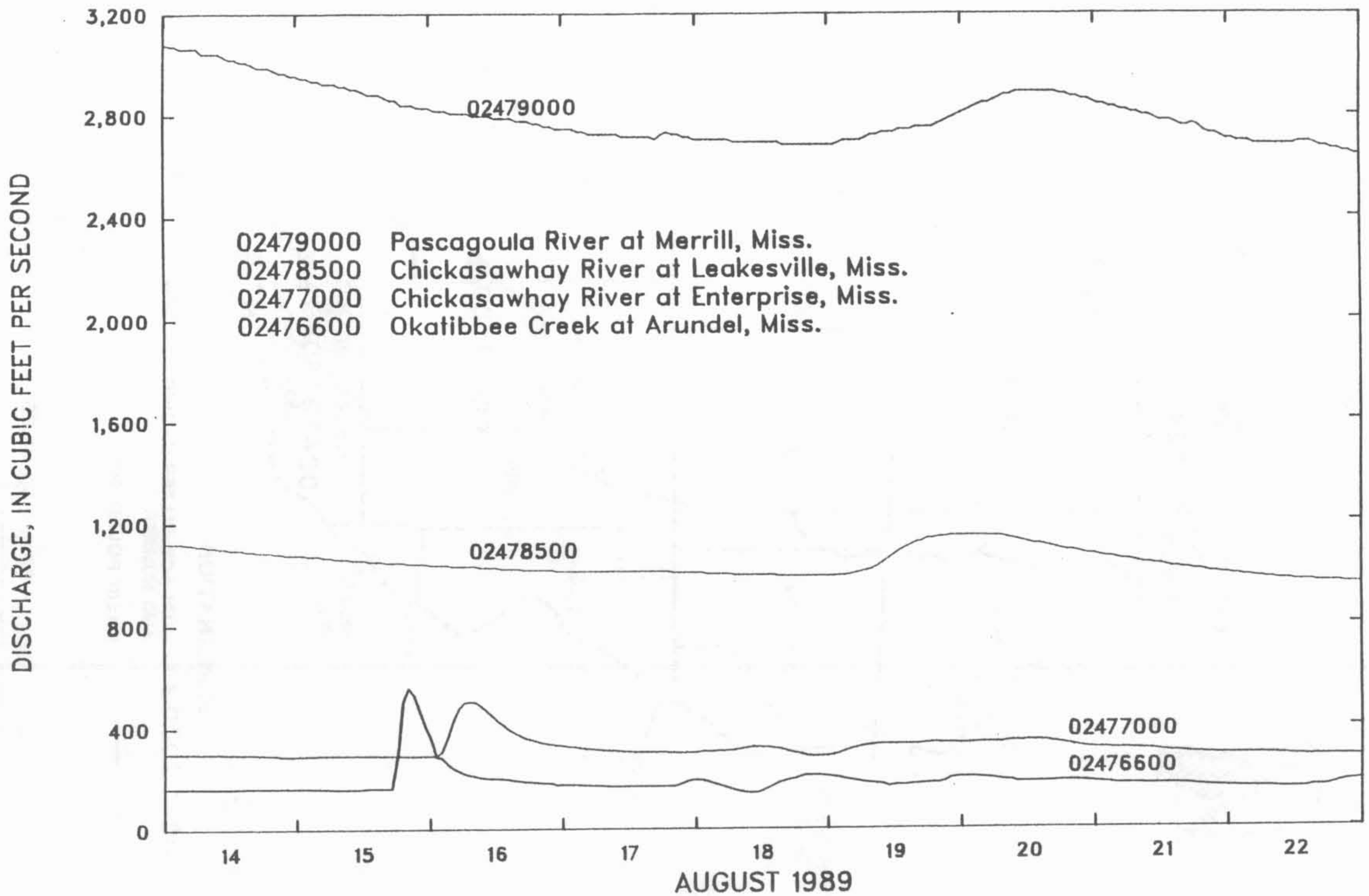

Figure 2. -- Low-flow discharge for selected sites along the main stem of the study area (August 1989).

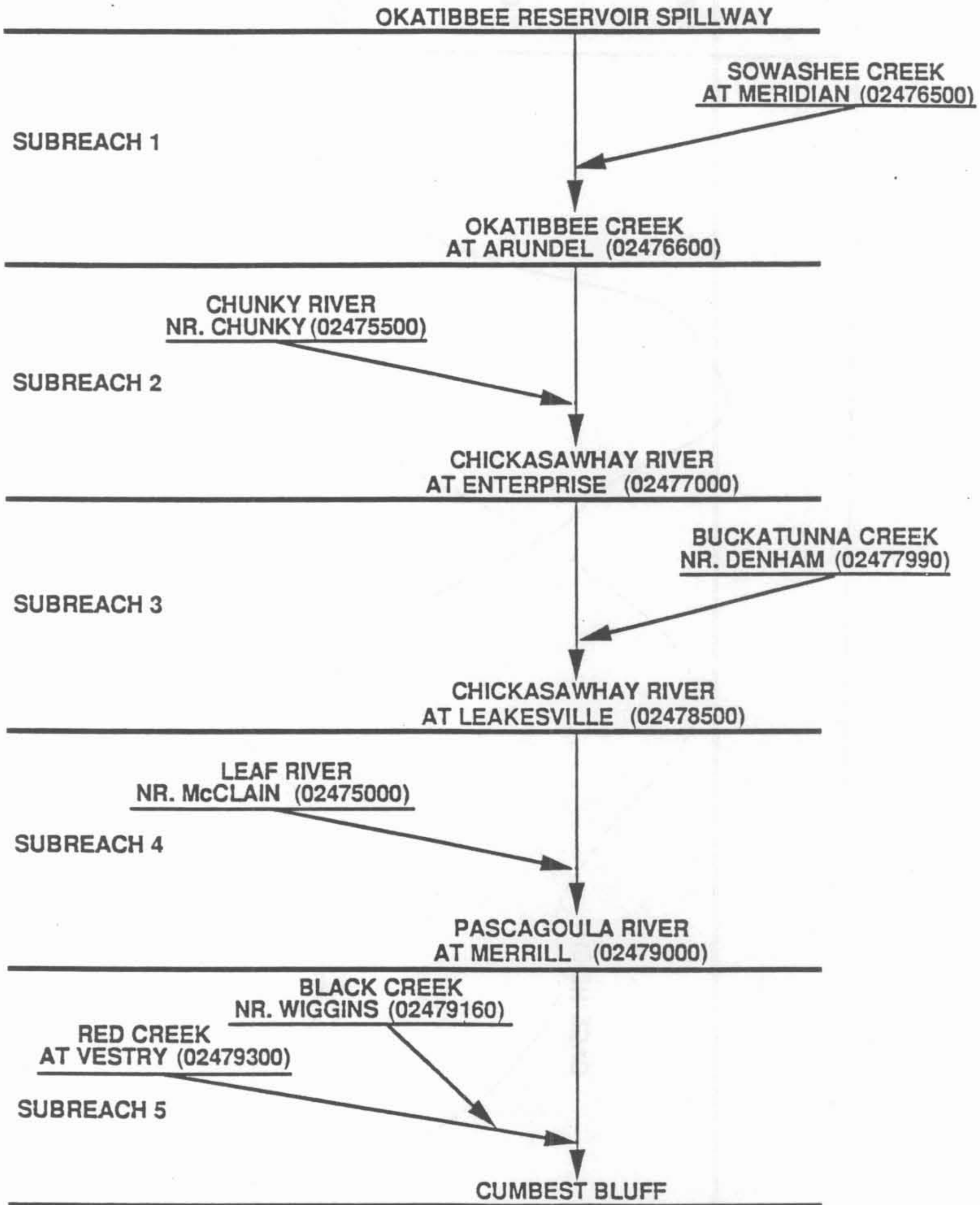

Figure 3. – Schematic representation of the study area subreaches showing locations of gaging stations (identified by 8-digit numbers).

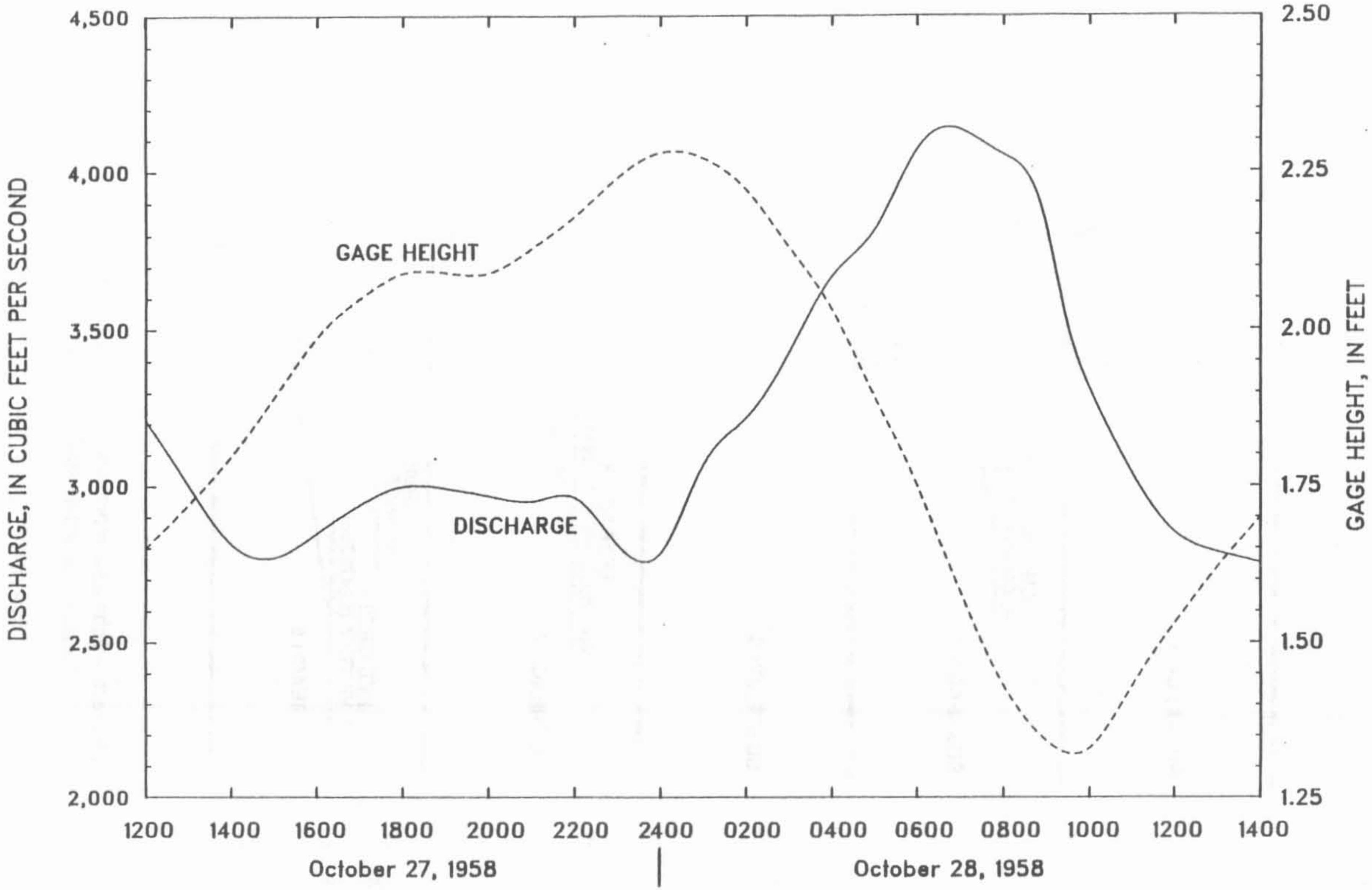

Figure 4. -- Stage-discharge relation showing tidal effects on the Pascagoula River at Cumbest Bluff (Oct. 27-28, 1958).

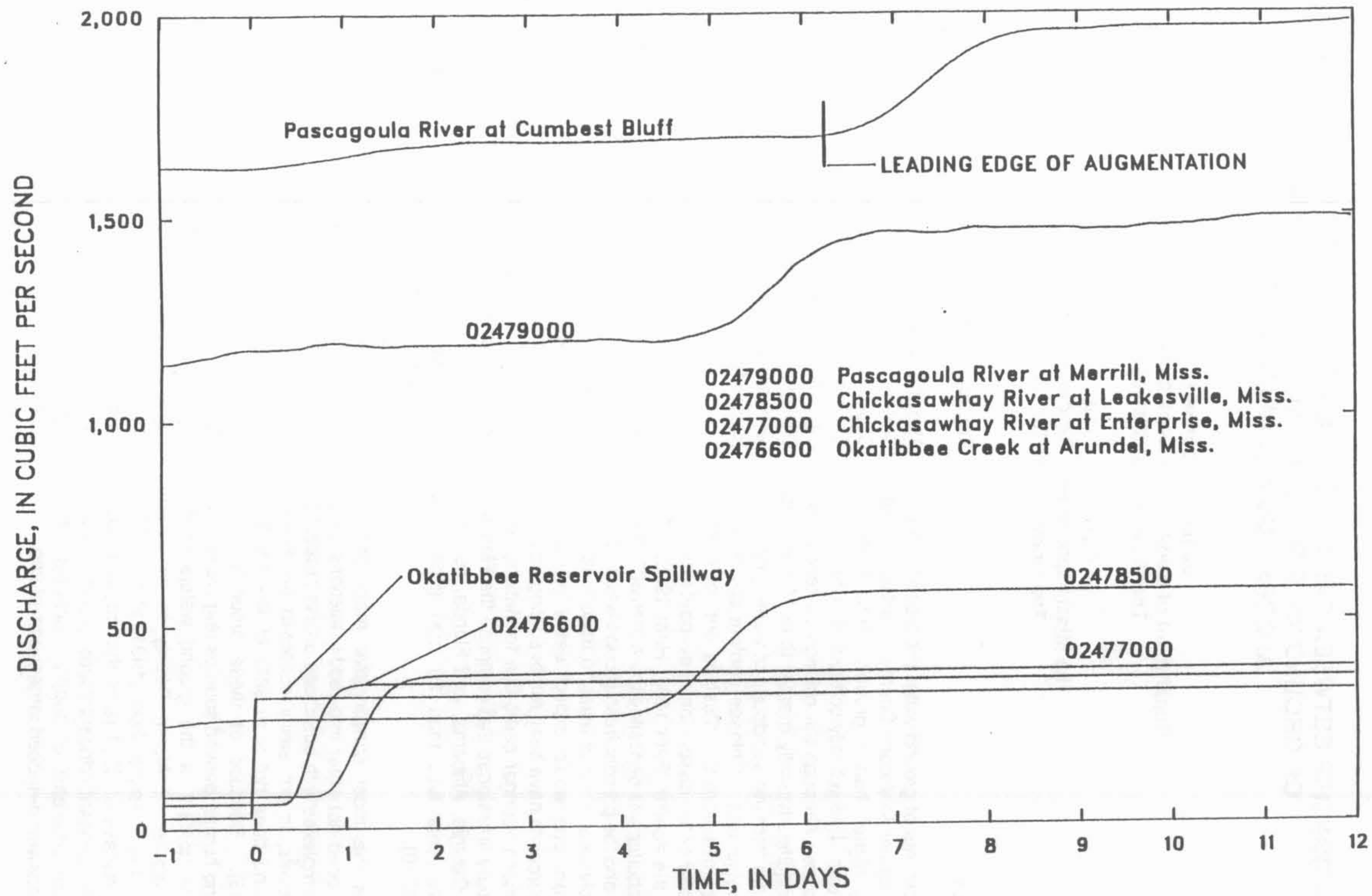

Figure 5. -- Estimated travel times of a 300 cubic foot per second discharge augmentation.