PASCAGOULA RIVER LOW FLOW MANAGEMENT STUDY

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INTRODUCTION

The Pascagoula River and its tributaries combine to form one of the largest drainage systems in Mississippi covering approximately 9,700 square miles. The basin is approximately 164 miles long with a maximum width of 84 miles. The main stem of the river is formed by the confluence of the Leaf and Chickasawhay Rivers in northern George County, Mississippi. At River Mile (RM) 17.3, above the mouth, the Pascagoula River divides into the Pascagoula River and the West Pascagoula River (Figure 1). Both of these streams flow southward and eventually empty into the Mississippi Sound. Maximum tidal influence in the Pascagoula River extends inland to about RM 42, where under low flow conditions, tidal fluctuations have been observed.

The Pascagoula River and its estuary are vital resources for the State of Mississippi. The ability of the river to support a variety of uses including water supply, wildlife habitat, recreation, and navigation, is largely due to the dynamic balance between fresh water flowing downstream into the estuary and salt water being driven upstream in the river channels by tides and wind.

A principal responsibility of the Mississippi Department of Environmental Quality (DEQ) is the protection of fresh water bodies to ensure that lakes, rivers, streams, and estuaries remain viable productive resources of the state. In particular, the Office of Land and Water Resources (OLWR), an office within DEQ, is responsible for permitting the withdrawal of fresh water from streams and lakes for beneficial uses while retaining the authority to curtail withdrawals that may impact state water quality standards or aquatic habitat.

REGULATORY

Under Section 51-3-7(2) of Mississippi Water Laws, the State Permit Board has the authority to permit the withdrawal of surface water from streams and lakes only in excess of the established minimum flow or elevations based upon records or computations by the Commission. The established minimum flow is defined in Section 51-3-3 as: "the average streamflow rate over seven (7) consecutive days that may be expected to be reached as an annual minimum no more frequently than one (1) year in ten (10) years (7dayQ10)."

The 1994 Legislature amended Section 51-3-3 to revise the definition of "Established Minimum Flow." This revision gave the Commission of EnvironmentalQuality the authority to explore alternate methods of determining minimum flows. The revised law inserts:

"... or any other streamflow rate that the Commission may determine and establish using generally accepted methodologies considering biological, hydrological and hydraulic factors. In selecting a general accepted scientific methodology, the Commission shall consult with and shall consider recommendations from the Department of Wildlife, Fisheries and Parks (DWLFP)."

"In determining and establishing the minimum streamflow rates, the Commission shall give consideration to consumptive and nonconsumptive water uses, including, but not limited to, agricultural, industrial, municipal and domestic uses, assimilative waste capacity, recreation, navigation, fish and wildlife resources and other ecologic values, estuarine resources, aquifer recharge and aesthetics" (Figure 2).

GOAL OF STUDY

The goals of the study are as follows: (1) evaluate the effect of surface water withdrawals from the Pascagoula River on the balance of fresh water and saltwater in the estuary, and(2) determine whether any changes in water quality are likely to have a detrimental effect on aquatic habitat in the estuary. In particular, the study focuses on the impact of withdrawals from the river at Cumbest Bluff, at RM 25.4, during low flow periods. It is under these conditions that the estuarine water quality is most likely to be impacted by further reductions in fresh water inflow and possible migration of the salt water wedge upstream. It is important to ascertain whether or not curtailing withdrawals when flows drop below the established minimum is likely to prevent degradation to aquatic habitats. The Jackson County Board of Supervisors is currently permitted to withdraw 100 million gallons per day (MGD) from the Pascagoula River at Cumbest Bluff for industrial uses.

MODELING

Harza Engineering Company of Chicago, Illinois, was engaged as the principal contractor to model the Pascagoula River system in 1994. The model selected for this study is the WATER QUALITY ANALYSIS SIMULATION PROGRAM-5 (WASP5) developed and supported by the U.S. Environmental Protection Agency (USEPA). The model consists of two stand-alone computer programs, DYNHYD5 and WASP5.

DYNHYD5 is used to simulate hydrodynamic conditions (flows and heads) in the study area and to generate output files describing these conditions at specific times and locations. WASP5 uses the DYNHYD output files as inputs for its simulation of water quality parameters such as salinity using the TOXI5 module of WASP5. WASP5 is the name given both to the overall modelling package used in this study and to the water quality component of that package. It is a dynamic compartment modeling system that can be used to simulate the transport and transformation of conventional and toxic pollutants. It is also used to analyze a variety of water quality problems in such diverse water bodies as lakes, streams, reservoirs, estuaries, and coastal waters.

The data chosen for the initial calibration of the model were taken from the USGS Annual Report in 1986. The 1986 observations had the advantage of having been measured at the lowest average flow (2,198 cfs), registering the greatest upstream penetration of salinity, and being the most consistent data set. Model calibration began with running DYNHYD5 using flow and tide data for dates spanning the 1986 observations. The hydrodynamic output file from this simulation was then used as input for TOXI5 modeling of the river where USGS salinity readings at RM 0 were applied to establish the downstream boundary condition. After a number of simulations, a single dispersion coefficient was selected as giving the best fit between predicted and observed values.

After calibration of the TOXI5 model to the 1986 column averaged salinity data, the model was run to determine how effectively the WASP5 package would simulate salinity observed during October 1994. For this modeling, output files from the hydrodynamic simulation for October 1994 were used as inputs for simulation of column averaged salinity. Column averaged salinities taken in October at the mouths of the Pascagoula and West Pascagoula Rivers were used as boundary salinities at these two locations. The simulated column averaged salinities compare favorably with the minimum bottom salinity recorded at RM 10.75 on the East Pascagoula and at RM 6.8 on the West Pascagoula. The higher flow in the West Pascagoula contributes to the lower salinity observed at the mouth of this channel and to the lower salinities both simulated and observed.

DATA COLLECTION

The month of October is distinguished for having a relatively predictable coincidence of at least two important factors: (1) it is characterized by high lunar tides, and (2) the time of year annual low flows are most likely to occur. Because of the likelihood of high tides coinciding with low flows, baseline field data was collected by DEQ staff in October 1994 for calibration of the Pascagoula River model and to improve the understanding of the dynamics of the river.

The data collection program was designed to address the following issues at various points in the river and estuary:

1. Determine the amplitude of water level fluctuations in response to tides.

2. Determine the time lag between high and low tides as measured at the tide gage and corresponding peaks and troughs at various upstream locations.

3. Determine water velocities and discharges at selected points.

4. Determine salinities at the mouths of the Pascagoula River and West Pascagoula River.

5. Monitor salinities at upstream points along both rivers.

The Corps of Engineers, Mobile District, operates and maintains a continuous recording tide gage in the main stem of Pascagoula River about one mile above the mouth. The DEQ staff utilized this gage to monitor the fluctuation of water levels in the river in response to the tides.

During October 1994, the Mississippi DEQ, the U.S. Geological Survey (USGS), the Mississippi DWLFP, the

Mississippi Department of Marine Resources (DMR), the Pat Harrison Waterway District (PHWD), and Harza Engineering Company collected data on the Pascagoula River and the West Pascagoula River from Wade-Vancleave bridge at RM 34.5, downstream to the Mississippi Sound. Water surface elevations and tide fluctuations were recorded by pressure transducers installed by DEQ staff at five locations in the river system. Transducer readings provided a continuous measurement of water surface elevations which were later compared with water levels generated by the Pascagoula River model. Fluctuations in recorded water surface elevations in response to tide were also correlated with readings at the Corps of Engineers tide gage to measure the time required for tidal peaks and troughs to propagate upstream.

Water velocities and discharges were measured by the USGS using a Doppler flowmeter at selected sites in the study area to determine total fresh water inflows and the distribution of flows between the Pascagoula and West Pascagoula Rivers at the divide in the river. These flow velocities and discharges were used to calibrate the model output. In addition, flowmeter output was applied in development of theoretical longitudinal dispersion coefficients used as a basis for selecting coefficients applied in modeling dispersion of salinity.

Continuous recording water quality meters were installed at five locations in the Pascagoula and West Pascagoula Rivers and programmed to monitor salinity near the channel bottom at half hour intervals during a period of about six days. Salinity measurements were also taken at five-foot intervals in the water column at locations near the two mouths of the river system for a period of over 24 hours during a complete tide cycle. Salinity measurements were also made at five-foot intervals in the water column on the two river systems at one mile interval during a low tide and also a high tide event.

During April 1994, the USGS surveyed 39 cross-sections to better define channel morphology in the rivers. These cross-sections were based on a mean sea level (MSL) datum using a Geographical Position System (GPS) to establish elevations and a thalweg profile was developed from RM 34.5 at Wade-Vancleave Bridge to the Mississippi Sound.

HISTORICAL DATA

The drought that has generated the greatest amount of information on low flows in the Pascagoula River occurred in 1963. Two reports describing the impact of the 1963 drought on movement of the salt water wedge are entitled, "STATUS OF WATER RESOURCES IN JACKSON COUNTY MISSISSIPPI" by Newcombe and Golden (1964) and "WATER RESOURCES OF THE PASCAGOULA AREA, MISSISSIPPI" by Harvey, Golden, and Jeffrey (1965).

Both reports note that on June 10, 1963, saltwater was observed at RM 17.6, with recorded flows at the Merrill gage of 1,099 cubic feet per second (cfs); no tidal stages were recorded for this date. On October 10, 1963, a salt water penetration to RM 17.7 was observed when the recorded tidal stage was 0.2 feet, and the recorded streamflow at Merrill was 773 cfs. On October 17, 1963, the recorded tidal stage was 1.0 feet, the recorded streamflow at Merrill was 743 cfs, and the saltwater wedge was observed at RM 20, the maximum upstream extent of migration ever observed.

Based on this data, on October 17 with basically the same river flows at the Merrill gage, the saltwater wedge migrated 2.3 miles further upstream than on October 10. This additional penetration is attributed to the influence of a tidal head that had increased by 0.8 feet. These findings were interpreted by Harvey and others to suggest that higher tides have a more significant effect on the migration of saltwater upstream than do streamflows.

CONCLUSIONS

The development of the WASP5 model of the lower Pascagoula River provides a tool for simulating the maximum upstream limits of salt water migration and of flow reversals likely under exceptional conditions.

Maximum upstream movement of flow reversals and of the salt water wedge is likely to occur when extreme low flows coincide with extreme high tides (neglecting tides observed during storms). To simulate this type of event, the WASP5 model was run using inflow conditions based on the 7dayQ10 flow of 917 cfs at the Merrill gage (1360 at Cumbest Bluff) and 707 cfs at the Merrill gage, the minimum flow recorded during the 1963 drought. The downstream boundary conditions for both inflows were based on data recorded at the Corps' tide gage at the mouth of the Pascagoula River during the period from September 28 through October 4, 1994. During this period, an extremely high tide, 2.96, feet was recorded on October 2, 1994.

DYNHYD5 simulations, under the 7dayQ10 condition, brief flow reversals are predicted at Cumbest Bluff at RM 25.4. Flow reversals at Cumbest Bluff are not affected greatly by pumping rates of up to 100 MGD at this location (Figure 3). The maximum upstream movement of flow reversals is approximately at RM 28.5.

Under the 1963 low flow scenario, brief flow reversals are again predicted for Cumbest Bluff with a maximum rate of reverse flow (positive values). Again, flow reversals appear to be largely independent of pumping at Cumbest Bluff up to a rate of 100 MGD (Figure 4). The upstream limit of flow reversal under this condition is estimated to occur at RM 29.5.

DYNHYD5 hydrodynamic files generated to produce the results described above were used as inputs to TOXI5 modeling of salinity movement. Salinity profiles measured as a part of this study at the mouth of the Pascagoula and West Pascagoula Rivers in October 1994 are the best observations available of downstream salinity under low flow conditions. Therefore, these data, which had been used to describe the downstream salinity boundary in simulation of 1994 conditions, were again applied as boundary salinities.

Under both the 7dayQ10 and the 1963 inflows, the maximum upstream occurrence of where salinities averaged above 500 mg/L is RM 19 (Figures 5; 6). Threshold averaged salinity readings indicate a likely maximum upstream movement of the bottom of the salt water wedge of one to two miles farther upstream. This occurrence places the farthest upstream extent of the salt water wedge between RM 20 and RM 21, which corresponds with the maximum upstream extent of salt water ever observed on October 17, 1963. As was the case with flow reversals, simulation of the maximum upstream movement of salinity is not apparently influenced by pumping rates at Cumbest Bluff.

Additional observation of salinities at the mouth of the Pascagoula Rivers will be useful in establishing salinity that is truly representative of low flow conditions. While refinements of boundary conditions, dispersion coefficients, and other input data will improve the usefulness and accuracy of the WASP5 modeling, it is unlikely that they will alter the observation that pumping rates up to 100 MGD at Cumbest Bluff have little effect on the upstream limits of flow reversal or of the salt water wedge.

Proportion of fresh water inflow and actual pumpage and permitted for pumpage at Cumbest Bluff:

Average Daily Flow at Cumbest Bluff	Percent Pumped	Percent Permitted
50,000 cfs (bank full)	0.08	0.31
16,000 cfs (average annual flow)	0.24	0.97
1,360 (7dayQ10 flow)	2.8	11.4
1,030 (1963 low flow)	3.8	15.0

The actual pumping rate is approximately 25 MGD (39cfs). The permitted pumping rate is 100MGD (155cfs).

FIELD DATA COLLECTION

DATE	AGENCY	DESCRIPTION
4/94	DEQ	Installed transducers at several locations to monitor water levels in the river.USGS Surveyed 39 cross-sections on Pascagoula River from Wade bridge at RM 34.5 to the mouth of the East and West Branch Pascagoula Rivers.
6/94	DEQ	Determined the distribution of flow in the USGS East and West Branch Pascagoula River at the split (35-65%). Measured depth integrated salinities in the East West Pascagoula River.
9/94	DEQ	Determined the distribution of flow in USGS East and West Pascagoula Rivers at the split (43-57%). Measured depth integrated salinities in the East and West Pascagoula Rivers.
10/94	USGS	Measured streamflow in the Pascagoula River using a Doppler flow meter around the clock, over two complete tide cycles from Wade Bridge at RM 34.5, to the split in the East and West Pascagoula Rivers and determined the distribution of flows between the two rivers.
	DEQ	Installed 5 Hydrolabs in the river to monitor salinity readings and other water quality parameters over at least 3 tide cycles. Measured depth integrated salinity values in the East and West Pascagoula Rivers from their mouth to the freshwater-saltwater interface. Using a roaming hydrolab, measured depth integrated salinity values around the clock at the mouths of the East and West Pascagoula Rivers to establish the boundary conditions for the model.
3/95	DEQ	Measured depth integrated salinity values in the fresh water Clark Bayou area, and found total fresh water.
9/95	DEQ	Installed transducers and measured depth USGS integrated salinity values and other water quality parameters in the East and West Pascagoula Rivers.

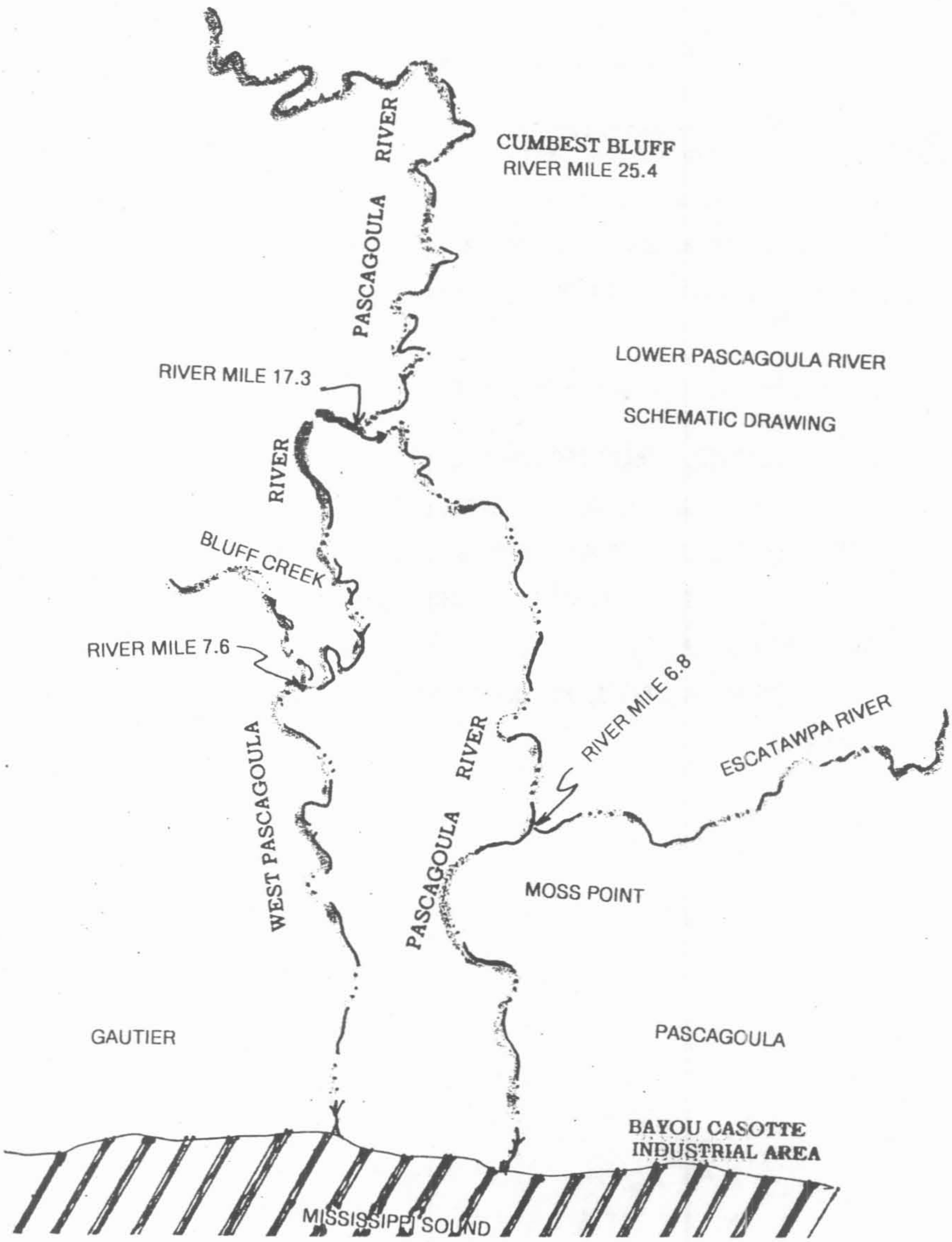

CUMBEST BLUFF
RIVER MILE 25.4
PASCAGOULA RIVER
LOWER PASCAGOULA RIVER
SCHEMATIC DRAWING
RIVER MILE 17.3
RIVER
BLUFF CREEK
RIVER MILE 7.6
RIVER MILE 6.8
ESCATAWPA RIVER
WEST PASCAGOULA
PASCAGOULA RIVER
MOSS POINT
GAUTIER
PASCAGOULA
BAYOU CASOTTE
INDUSTRIAL AREA
MISSISSIPPI SOUND

Figure 1

ESTABLISHED MINIMUM FLOW

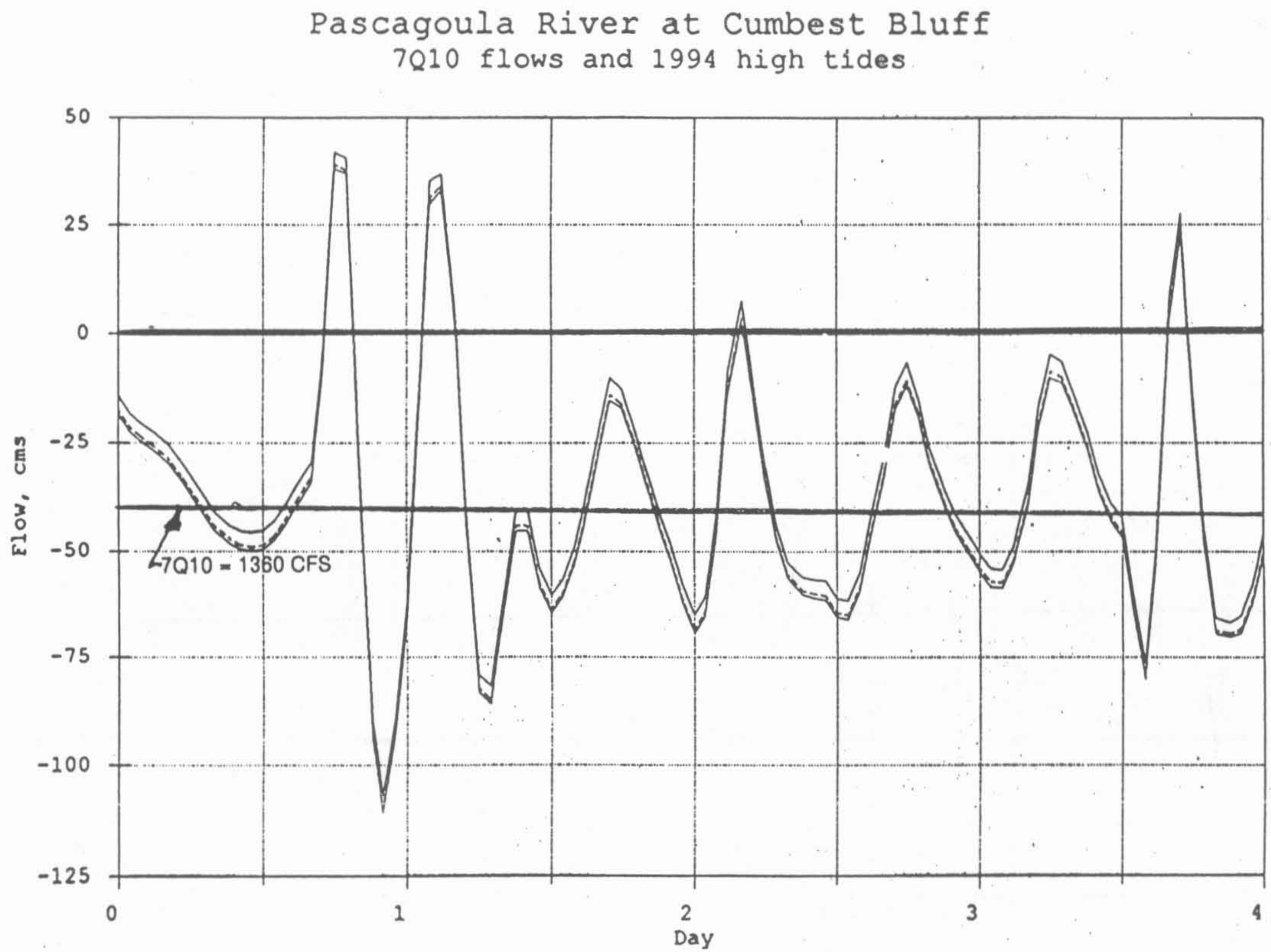
Section 51-3-3 of Mississippi Water Laws, Code of 1972 defines the "Established Minimum Flow" as:

"THE AVERAGE STREAMFLOW RATE OVER SEVEN (7) CONSECUTIVE DAYS THAT MAY NOT BE EXPECTED TO BE REACHED AS AN ANNUAL MINIMUM NO MORE FREQUENTLY THAN ONE (1) YEAR IN TEN (10),

The 1994 Legislature amended Section 51-3-3 to include:

OR SUCH OTHER STREAMFLOW RATES THAT THE COMMISSION MAY ESTABLISH USING GENERALLY ACCEPTED SCIENTIFIC METHODOLOGIES CONSIDERING BIOLOGICAL, HYDROLOGICAL HYDRAULIC FACTORS. IN ESTABLISHING THE GENERALLY ACCEPTED SCIENTIFIC METHODOLOGIES, THE COMMISSION SHALL CONSULT WITH, AND SHALL CONSIDER RECOMMENDATIONS FROM THE DEPARTMENT OF WILDLIFE, FISHERIES AND PARKS."

Figure 2



Pascagoula River at Cumbest Bluff
7Q10 flows and 1994 high tides
50
25
0
-25
-50
-75
-100
-125
Flow, cms
7Q10 = 1360 CFS
0
1
2
3
4
Day

Figure 3

Pascagoula River at Cumbest Bluff
1963 low flows and 1994 high tides

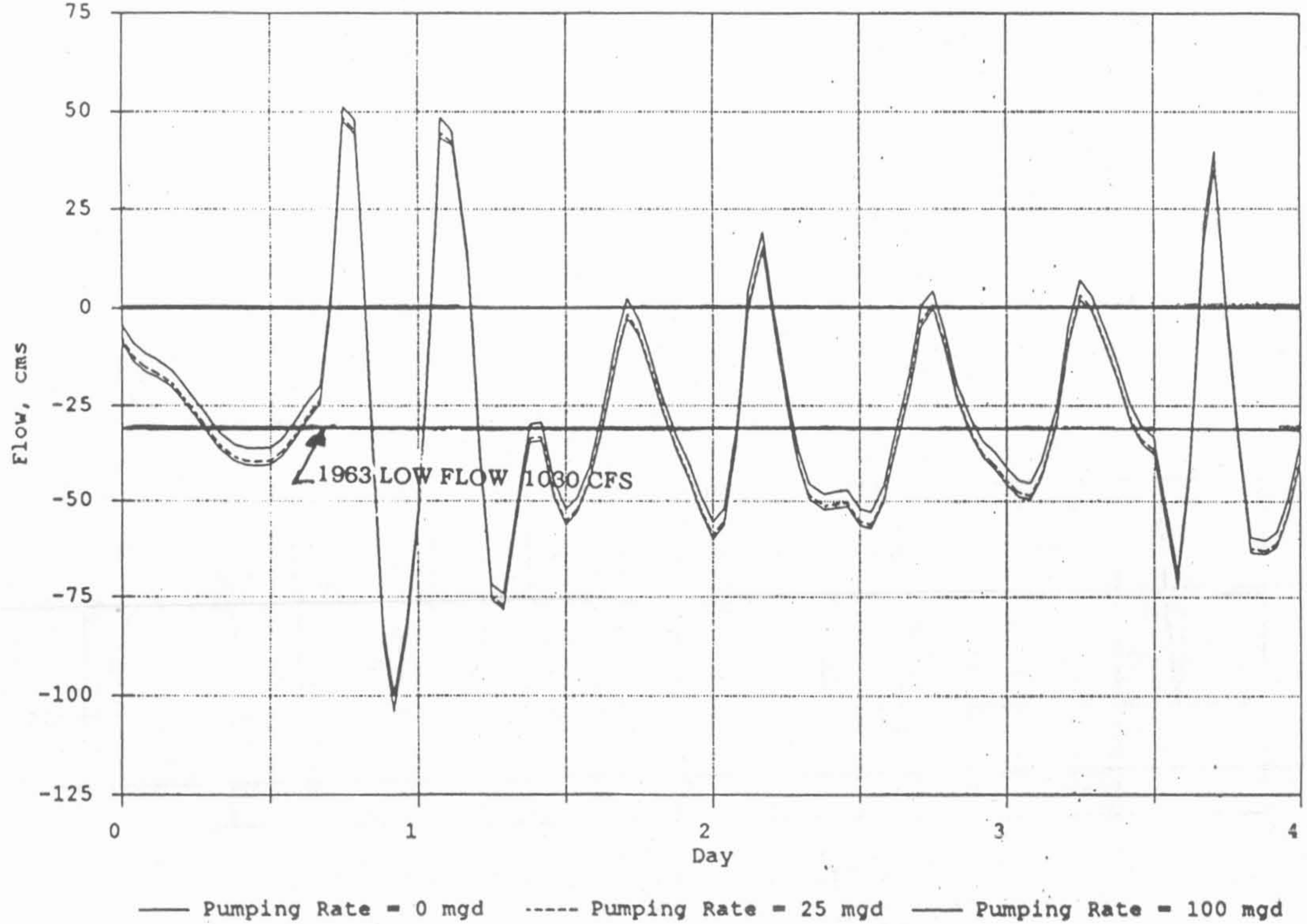


Figure 4

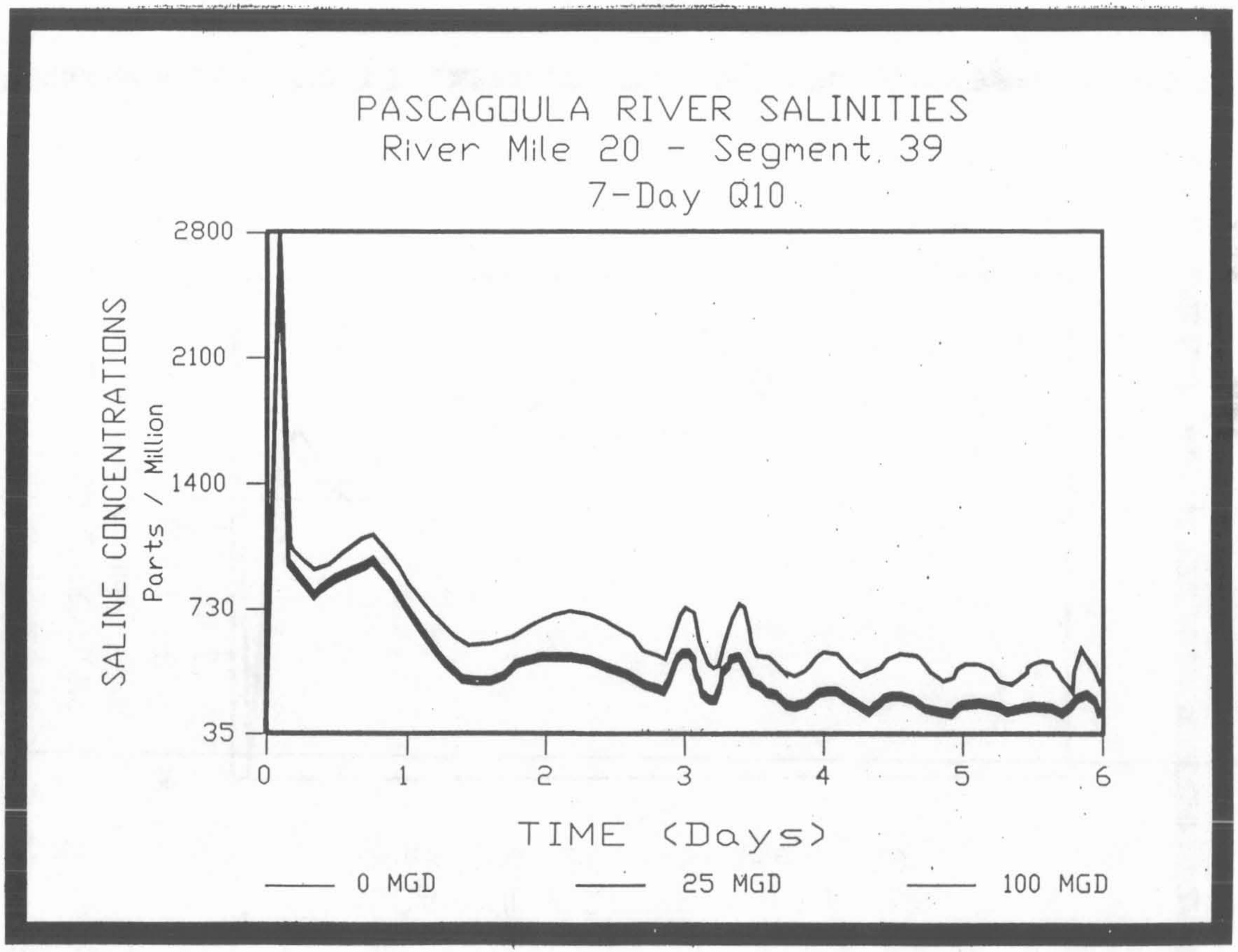

PASCAGOULA RIVER SALINITIES
River Mile 20 - Segment 39
7-Day Q10
SALINE CONCENTRATIONS
Parts / Million
2800
2100
1400
730
35
0
1
2
3
4
5
6
TIME (Days)
0 MGD
25 MGD
100 MGD

Figure 5

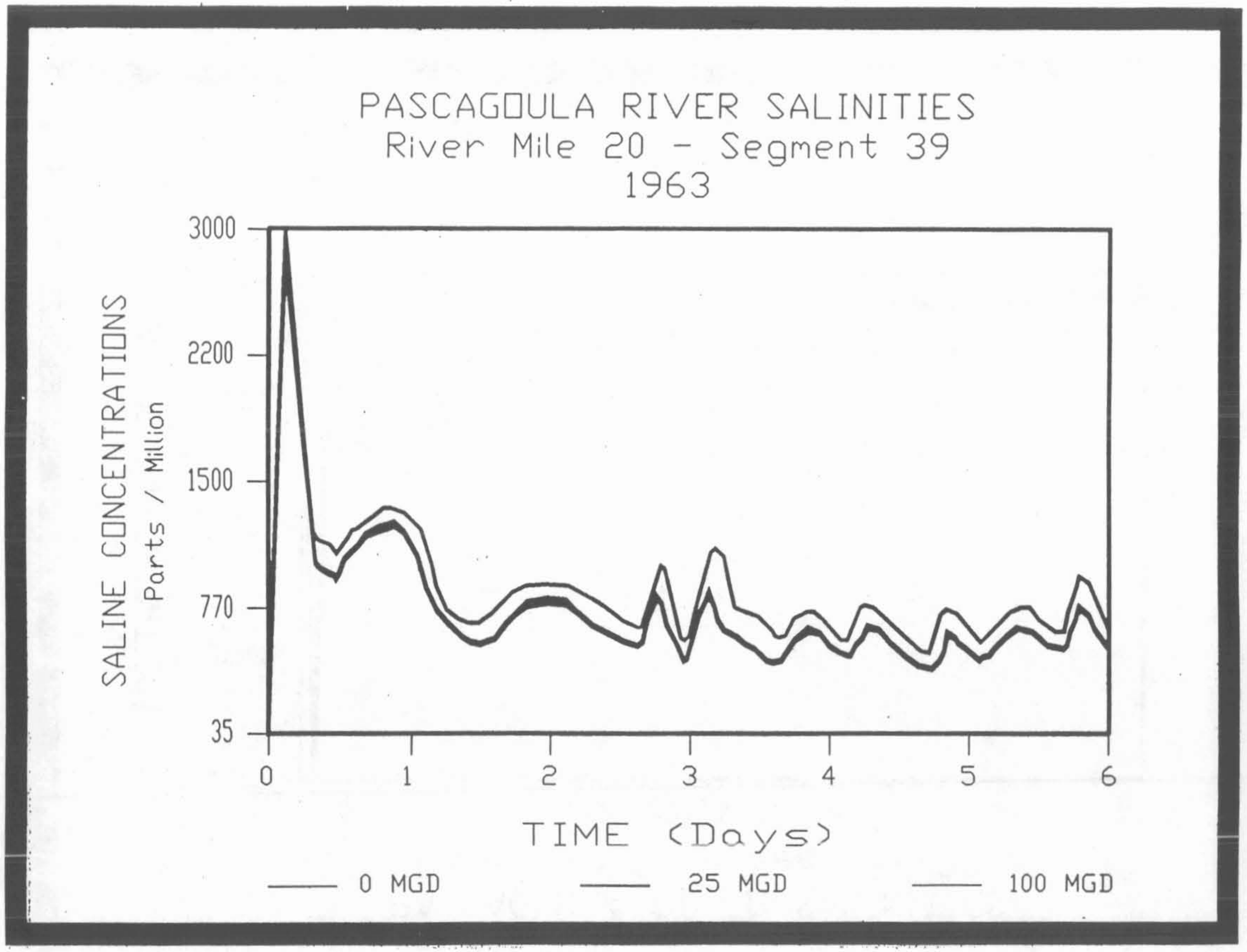

PASCAGOULA RIVER SALINITIES
River Mile 20 - Segment 39
1963
SALINE CONCENTRATIONS
Parts / Million
3000
2200
1500
770
35
0
1
2
3
4
5
6
TIME (Days)
0 MGD
25 MGD
100 MGD

Figure 6