Draft Final Report

# Hydrologic Modeling to Evaluate the Potential to Divert Mississippi River Water into the Swamps South of Lake Maurepas

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## INTRODUCTION

The wetlands south of Lake Maurepas fall within the Amite/Blind River mapping unit, Region 1, of the Louisiana coastal zone as it was defined in the Coast 2050 planning effort and restoration report (Figure 1). Both the Coast 2050 restoration planning effort and the Mississippi River Sediment, Nutrient, and Freshwater Redistribution (MRSNFR) study have identified these swamps as stressed and dying, and in need of restoration. Introduction of Mississippi River water, sediments and nutrients was identified as the recommended strategy for restoration. A complex feasibility-level study was authorized under the Breaux Act, and Phase 0 funding was committed. This report covers hydrographic data acquisition and preliminary one-dimensional hydrodynamic modeling undertaken in Year 1.

Long-settled communities and industrial facilities exist along the natural levee ridge of the Mississippi River that forms the southern boundary of the study area. The natural levee grades from relatively high close to the River (20 ft NAVD 88) to lower-lying bottomland forests (3 to 5 ft NAVD 88) a few miles to the north. Much of the bottomland forests have been cleared for agriculture or other purposes, and this land is susceptible to flooding, whether caused by rainfall or high tides in Lake Maurepas. Lake Maurepas is a feature of the Pontchartrain estuary and experiences tides and salt water that originate in the Gulf of Mexico. Channels have been dredged north into the swamps (1 to 3 ft NAVD 88) that are used as outlets for storm water drained or pumped from developed areas of the natural levee. Hunting and fishing camps have been constructed along swamp waterways, generally within a mile of Lake Maurepas.

The swamp forest south of Lake Maurepas is dominated by tupelo (80 %) and cypress (20 %). Dr. Gary Shaffer of Southeastern Louisiana University (SLU) has reported that most of the tupelo trees in the interior of the Maurepas, except those along ridges associated with bayous and canals, are exhibiting signs of extreme stress, as evidenced by thinning, breaking of canopy tops and extremely low production of leaf litter. Existing cypress are not being replaced or augmented by recruitment. Over time, this lack of regeneration will lead to loss of this component of the forest as older trees die off.

Persistent swamp flooding and associated water stagnation, along with occasional intrusion of brackish water (3 to 10 ppt) is believed to stress adult cypress and tupelo trees, and to negatively affect other components of the swamp ecosystem, such as fisheries productivity. In the Manchac area between Lakes Maurepas and Pontchartrain, marshes replaced the swamps when the trees were artificially removed by logging. If cypress and tupelo trees are not artificially removed, however, they can withstand considerably deeper waters for longer periods than herbaceous species. Herbaceous plants do not appear to be spreading in the Maurepas swamp despite the increased availability of sunlight as the forest canopy thins. Therefore, it is expected that most of the dying swamp will convert to open water, rather than marsh, if a more riverine hydrology is not restored.

The overall objectives were to determine how large a diversion of Mississippi River water could be safely accommodated by the stressed swamps south of Lake Maurepas, and where it would best be located. The high initial construction cost of such a project, (as well as anticipated costs for maintenance) mandate that such a structure be of great enough capacity to do significant good. Limits to the size of such a structure, without considering cost, are determined not only by a commitment not to aggravate flooding on the margins of the natural levee, but also by other factors. While the swamps may be in need of Mississippi River sediments and nutrients, the high concentration of nitrate nitrogen in the River is a potential stimulant for undesirable phytoplankton in the Lake. Hydrodynamic modeling could provide an initial understanding of how much diverted River water might reach the Lake before nitrate was removed by passage through the swamp.

Participants in technical scoping meetings, as well as members of the Breaux Act Engineering and Environmental Workgroups, have recommended that both hydrologic and ecological modeling are needed to address essential questions in this study. The work reported here begins that effort. It was decided to initiate hydrodynamic data acquisition and modeling while ecological baseline information was collected. The first phase of the work called for implementation of a one-dimensional hydrodynamic model to investigate basic project feasibility options pertaining to where and how much water would be needed. UNET, an unsteady network model developed and supported by the Hydraulic Engineering Center (HEC) of the U.S. Army Corps of Engineers, was selected for this initial phase of work. Should Phase I be approved for funding, a two-dimensional model is under development that will be used for more detailed analysis.

**Tasks**

Provide hydrologic information that could assist in selection of an appropriate diversion location. Reconnaissance surveys were undertaken of the Blind River, Hope Canal and Reserve Relief Canal.

Assist the surveyors in establishing a master gauging network with appropriate datum controls to support the hydrologic investigation and design.

Conduct additional surveys as necessary to characterize bank geometry and breaks and additional details on bridge crossings, etc.

Acquire LIDAR topographic data from the Louisiana Oil Spill Coordinator's Office (LOSCO) for the study area and integrate this data into model development.

Build a UNET model in consultation with FTN, Inc. to make initial decisions regarding external and internal boundaries; assign reaches, define junctions and other connections; assign storage areas and characterize connections to channels.

Calibrate and validate UNET model against appropriate hydrographic time-series data acquired in the field.

Run calibrated UNET model for diversion input locations and operation schedules defined by study managers.

## METHODS

Three parallel lines of efforts were used to achieve the objectives of this study. We reviewed existing background information, conducted field surveys to gather current hydrologic and land elevation data, and finally developed an unsteady state computer model, UNET, to simulate existing hydrology and that under diversion conditions.

### Relevant Features of the Study Area

Several reconnaissance surveys were used to define a preliminary study area boundary, as well as the preferred diversion site. This served as the basis for the development of the final overall boundary of the UNET model. The preliminary study area included portions of St. John the Baptist Parish, St. James Parish, Ascension Parish, Livingston Parish and Tangipahoa Parish (Figure 2). Water generally flows north toward the Lake Maurepas but is bidirectional in most waterways, being more dominated by tides closer to the lake.

An initial hydraulic analysis of the three proposed diversion sites (Reserve Relief Canal, Hope Canal, Blind River) showed that if water was introduced at Reserve Relief Canal or Blind River, most would travel directly to Lake Maurepas (Attachment I). For this and other reasons (real estate, etc.), attention focused on a Hope Canal site. Then, the UNET model boundaries could be better refined. The study area for the Maurepas Swamp Diversion Project is now bounded on the north by Lake Maurepas, on the south by Airline Highway, on the west by the Blind River, and on the east by Interstate 55 (Figure 3). From a modeling standpoint, the study area was divided between channel and swamp storage areas.

The key water features to be included in the UNET model were then identified. The major streams, bayous and canals of this study area are the Blind River, Amite Diversion Canal, Amite Pettit River, Conway Canal, New River Canal, Hope Canal, Mississippi Bayou, Reserve Relief Canal, Interstate 55 Borrow Canal and Bayou Chene Blanc. All of these water features have been included in the UNET model scheme (Figure 4).

Interstate 10 (I-10) crosses the southern part of the study area obliquely. The twin roadways are elevated for part of this transit, but are situated on causeways for the most part with limited under road drainage via culverts. I-10 crosses the Blind River, Hope Canal and Reserve Relief Canal on twin concrete pile supported spans.

### Survey and Gaging Network

Louisiana State University scientists and engineers assisted Pyburn and Odom, Inc. surveyors (P&O) in siting twenty non-recording staff gages, and in acquiring key cross-sections once they had established horizontal and vertical controls throughout the study area (Figure 3, Appendix A). These gages provided uniform water level information to all researchers and served as a basis for zeroing additional surveys and recording gages (Figure 5).

Two continuously recording gages were installed in Blind River at the Lake and near the Amite Diversion Canal. Two others were installed in Reserve Relief Canal and in Mississippi Bayou by July 2000. These gages were set up to collect data at 15 minute intervals. It was anticipated that very high resolution temporal data would be necessary to capture the dynamic circulation of the system as well as effects of winds and tides on stage. Near synoptic velocity cross-sections were acquired at key cross-sections to link stage and observed flows.

Several surveys were conducted with GPS equipment to locate breaks in channel banks. Locations of these breaks were registered using a hand held GPS receiver and later imported into a GIS system (Figure 6). Description of the breaks in channel banks or openings in to a swamp area were noted and later used to determine the locations and parameters for lateral connections in the UNET model. Water levels recorded on relative gages at interior swamp study sites were registered to channel levels to provide reasonable estimates of swamp floor elevation.

To supplement the surveys data provide by P&O, several field visits were made by LSU. During LSU field survey additional cross section information were collected for the Hope canal, Mississippi Bayou and Alligator Bayou (Figure 7). These survey data were incorporated in the UNET model. Photographs were also taken to document the hydrology, swamp conditions and land elevations. Many photographs were taken to document swamp water interaction and determine the tree density of the swamp.

**Swamp and Land Elevation from the LIDAR data**

LOSCO supplied LSU with “bare earth” LIDAR data from 3001, Inc., earlier this year. “Bare earth” data has had trees and man-made structures removed using a filtering algorithm. LIDAR elevation data was provided in the UTM 83 Zone 15 coordinate system. The vertical datum for the elevation was NAVD 88 and elevation was measured in feet. Water level elevations during the LIDAR flights were obtained for Manchac Pass and for several locations within the study area. Post-processing of the LIDAR elevation data with the water depth measurements can provide excellent swamp and canal ground surface elevations.

LIDAR generates a huge amount of point data. Given that all data cannot be processed at once, it was decided to compare LIDAR data with the preliminary swamp elevations used in a small area within the UNET model boundary, Alligator Island near Lake Maurepas. Alligator Island was selected because it was an isolated swamp island with approximately 50,000 LIDAR points. Excellent agreement was found for this location between the 1.5 ft elevation used in UNET and the average elevation of the LIDAR data for this area (Figure 8). We found that LIDAR elevation was reliable and extremely useful to determine the swamp elevation. If the more detailed modeling planned for the next phase of the study is funded, LIDAR data will be used as the primary means to determine swamp and land elevation.

## Lake Elevation

Lake Maurepas elevation currently drives stages throughout the study area, and is a very important boundary condition for any modeling. Long-term stage data recorded at Pass Manchac was analyzed statistically to determine the frequency with which Lake surface water elevation exceeds various levels. A 1 ft elevation is exceeded 83 percent of the time, while a 2 ft stage is exceeded for about 25 percent of the record (Figure 9). Continuous data collected in this study indicate that while a 2 feet lake elevation is not rare, such exceedences typically occur only for short durations associated with wind events.

## Engineered Structures

The two interstate bridges on the Hope Canal were coded in the UNET model. This bridge is coded to determine the maximum capacity of the diversion without major modification of the bridge. The LSU team conducted a field survey to collect bridge and section information. During the survey, a hand sketch of the bridge was made and depth of water along the bridge profile was measured with a staff gage. The I-10 Bridge was coded as a normal bridge in the UNET model (Figure 10,11).

## UNET Model Construction

A description of key UNET parameters (cards) is given in Attachment II. For the purposes of developing the UNET model, storage area and swamp elevations were determined initially using USGS 30m by 30m resolution grid data. Later these elevations were adjusted on the basis of field measurements of relative water depths at monitoring sites by the SLU ecologists. Areas of the swamps were delineated using DOQQ imagery as a backdrop within the GIS system. These were later checked against a sample of LIDAR data, as has been described. Areas of the swamp storage cells were obtained using GEOMEDIA Pro 4.0 GIS system and were merged with the elevation data (Table 1).

The final UNET model was composed of 29 reaches (segments of rivers, canals and bayous) and 53 storage cells in the swamps and other areas inter-connected between water features and storage cells. Reach and storage cell numbers were assigned following UNET model development protocol (Table 2; Figures 4, 12). North-south oriented channels were assigned a northerly assumed flow direction (+), while those with an east-west orientation were assumed to flow east eventually leading to Lake Maurepas. The assumed flow direction is merely a convention as UNET quite readily accommodates bi-directional flows.

Connections between reaches (rivers, canals and bayous) and swamp cells were simulated using LA-WD cards assuming that over flow in the swamp would be adequately described by flow over a weir. GPS bank line survey information was used to define the locations, equivalent length of the weir and other parameters for the LA-WD cards for lateral flow into the swamps. Connections between storage cells were simulated using SS cards. Subdivisions of storage areas were determined from field observations of flow patterns within the swamp, field inspection of presumed ridges, and, in some cases, measurement of ridges and gaps visible on imagery (such as I-10 and the old rail road grade). These gaps and divisions governed water movement from one water feature to another across a storage cell in one modeling time step. The concept of using swamps in UNET model as storage cells and connecting those cells with LA-WD card has been accomplished successfully in previous US Army Corps of Engineers studies (USACE, 2000, FTN, 1989, FTN 1994a, FTN 1994b).

**Running, Calibrating and Validating UNET**

Several boundary condition files based on field measurements were created to run the UNET model. Upstream boundary conditions were generally given as flow in the various rivers and canals that enter the study area, while lake gage data provided downstream boundary conditions. Several tide elevations were considered during model simulation. Based on observed data it was determined that the base elevation for the lake would be 1 foot NAVD 88. This elevation was termed the 1-foot tide at the lake. Since the lake elevation varies with time, this base run will be very useful to compare the effect of diversions for other tide elevations. Several roughness values were used at the beginning of the model development and final selected "n" values varied from 0.045 to 0.020.

The UNET model was calibrated with observed data from two sites during July 2000. One gage was located at S-10 on the Blind River downstream of the mouth of the Amite Diversion Canal (Glenn Martin camp). The second gage was located at S-9 on Dutch Bayou just downstream of the mouth of Mississippi Bayou. Observed stage and UNET simulated stage for this period shows that stage dropped by 1.5 ft at S-10 (Figure 13) and 1.0 ft at S-9 (Figure 15) in the course of the month. Agreement of the model with the field record was determined by a regression analysis for the two records (Figures 14, 16). The model explained 99 percent of the variance at S-10 and 95 percent at S-9. Most deviation occurred during thunderstorms occurring between hours 100 and 200 that resulted in wind-forced oscillations that were not predicted by the model. Additional validation runs will be made if funding is approved for the next stage of work.

## RESULTS AND DISCUSSION

**Mississippi River Introduction Site**

Several field visits were made to install tide gages that would record water level in the lake as well as in the channels. During field visits, photographs were taken to document the existing conditions of the channels and vegetation growth on the banks and in the channels. Tree densities and obstructions to the possible flow in to the swamps were also noted. It was apparent from this reconnaissance that Mississippi River water introduced either into the Blind River or Reserve Relief Canal would be efficiently conveyed to the Lake under most normal conditions (Attachment I). While sufficient diversions into these channels could influence salinities in Lake Maurepas, the channels are too large to result in significant overflow to the adjacent swamp. Hope Canal is currently an inefficient channel with very limited conveyance. It is thus well suited to serve as a diversion manifold. These observations, and others (real estate, etc.), influenced the decision by the study team to center further modeling efforts on the potential of a Hope Canal diversion.

**Swamp Hydrology**

Comparison of continuous gage records show good coherence, indicating that water levels in bayous throughout the study area are governed by lake level. This is demonstrated by regressing synoptic stage measurements at Sites S-9 and S-10 and looking at the degree to which the reading at one gage can be predicted from the other (Figure 16B). Agreement between these gages for June 2000 was 95 percent. Strong winds alone can cause the water level to rise or fall 1 ft in an hour (Hours 1450 and 1600, Figure 17). Although detailed analyses have not been completed, it appears that salinity is positively correlated with the lake elevation. While this connection cannot be probed with UNET, it appears that higher Lake Maurepas levels are generally accompanied by an influx of water from Lake Pontchartrain rather than from the tributary rivers. Swamp elevation data obtained from the LIDAR survey was qualitatively found to be reliable when compared with existing survey points and will be used to determine the swamp and elevation if the next phase of the study is funded.

**Project Design**

Several UNET runs were made to identify the maximum flow that could be passed to the swamp through Hope Canal under the existing I-10 bridges without causing unacceptably high backwater stages at Airline Highway (4.5 ft NAVD 88) and without major modification of the I-10 bridge over Hope Canal. One important specification concerned the length of the proposed conveyance channel from a structure in the Mississippi River levee across the populated levee ridge to the swamp. It was found that if the conveyance channel terminated at the current head of Hope Canal, at the Airline Highway, then most diverted water would flow into the bottomland hardwoods and higher elevation swamp south of the I-10, where it could become ponded (Figure 18).

Dispersion of flow out of the natural channel at the point that it leaves the conveyance channel is demonstrated using the channel flow curve that shows discharge within the channel at various points along the course to the Lake (Figure 18). When discharge decreases, it is assumed to move into the swamp, or into distributary channels. Conversely, when flow increases, it is assumed to be returning from the swamp or being introduced from tributary channels. Accordingly, it was recommended that the conveyance channel be designed to continue north to the I-10 bridge to ensure delivery to the larger swamp area available between this point and Lake Maurepas.

To carry the diverted water past the I-10, an improved condition model was developed. In this model, it was assumed that the water would be confined within a guide levee until I-10. A single, uniform cross-section was used for these improved channel conditions (Figure 19, 20).

**A 1,500 cfs Diversion**

Once calibrated, the model predicted that up to 1,500 cfs flow could be diverted from the Mississippi river through the improved Hope Canal alignment without raising backwater above 4.5 feet at Airline Highway. With 1,500 cfs flow, model results show that maximum velocity in the I-10 bridge sections could be as high as 3.8 fps. The bridges would create a hydraulic head difference of about 2.5 feet going from south to north (upstream to downstream). In the long run, this head difference might cause seepage, piping and foundation damage. During the next phase of the study, it would be necessary to obtain structural information of the I-10 Bridge so that a reasonable permissible velocity or allowable long-term head difference at the structure could be determined. At the present preliminary stage, it is reasonable to set 1,500 cfs as the maximum allowable diversion discharge.

The UNET model was run at 1,500 cfs for higher than normal (2.0 ft) and high normal (1.0 ft) Lake Maurepas elevations. The backwater curves in Hope Canal at 7 and 30 days were plotted for these two boundary conditions (Figures 21, 22). The associated channel flow curves (Figures 23, 24) and velocity profiles (Figures 25, 26) were also made. Lake level has little effect on stage in the first 5 miles of the Hope Canal system, the improved conveyance channel that extends to the I-10 bridge. The effect after 30 days at the Airline Highway crossing is 0.2 ft (4.3 ft with a 1.0 ft lake and 4.5 ft with a 2.0 ft lake). Results of this analysis indicate that Lake Maurepas levels, at least up to 2 ft NAVD 88, should not result in a potential for backwater flooding at Airline Highway.

Similarly, the diversion at 1,500 cfs has little effect on stages close to the lake. Under the 2.0 ft Lake scenario, the entire swamp system up to the end of Hope Canal (about 6 miles from the Lake) merges hydraulically with the Lake, having a uniform 2.0 ft water elevation. After 30 days of operating a 1,500 cfs diversion with a 2.0 ft lake level, stage at the end of Hope Canal (beginning of Bayou Tent) has risen by 0.5 ft, from 1.9 to 2.4 ft. No increase after 30 days is predicted for Dutch Bayou. Most camps are located within a mile of the Lake and so should not be affected by any stage increase associated with the diversion.

The most significant effect of raising Lake level is predicted by the model to occur between the I-10 Bridge and the Power line. A rise of 0.3 to 0.5 ft is predicted for this reach.

Lake level is not affected by diversion operation and would pose a constraint only during extreme hurricane conditions when the diversion would be shut down for other reasons. The more realistic constraint will be posed by the need to evacuate the conveyance channel from the River to I-10 so that it can be used for pumped drainage during severe rain events. Hurricanes that raise Lake Maurepas water levels well above 2 ft will continue to pose a problem for low-lying developed land, with or without the diversion.

Hope Canal appears to offer in its present unaltered condition an excellent manifold for supplying Mississippi River water, sediments and nutrients to a large area of stressed swamps. The conveyance channel should be extended to the I-10 crossing. This will affect drainage in the bottomland hardwoods and higher swamps between Airline Highway and the I-10, and some compatible drainage solution will be necessary.

A 1,500 cfs diversion can be operated all year through this conveyance channel if the entrance gates are large enough and constructed with a sufficiently low sill. Mississippi River stages at the proposed diversion site got as low as 3 ft (NGVD) during 2000. At the same time, lake levels were as high as 1.5 ft (NGVD). A 1 ft head difference under these conditions would limit diversion operation at some periods when it is desired. The I-10 bridge crossings should be examined in detail to ensure that proper precautions are taken to ensure safe foundation conditions. Principal constraints on operation will be the need to shut gates in an emergency to prevent passage of materials spilled into the Mississippi River, to evacuate the conveyance channel so that it can accept pumped storm water from the adjacent developed lands, and to reduce or change input to the swamps on a seasonal or other ecological basis.

## **Depth of Water in the Swamp**

Depth of water in the swamp at 7 and 30 days were plotted for 1-foot lake elevation (Figure 27). Model results suggest that the depth of water in swamp varies from 6 to 12 inches as it reaches steady state in approximately 30 days.

## **Shutdown Scenario**

A shutdown scenario was simulated to determine the system response time. In the UNET model, a 1500 cfs diversion was suddenly shut off and corresponding drop of stages in the channel were plotted with time (Figure 28). It was observed that within 4 to 6 hours stages in the channel converged with the stage in the swamp.

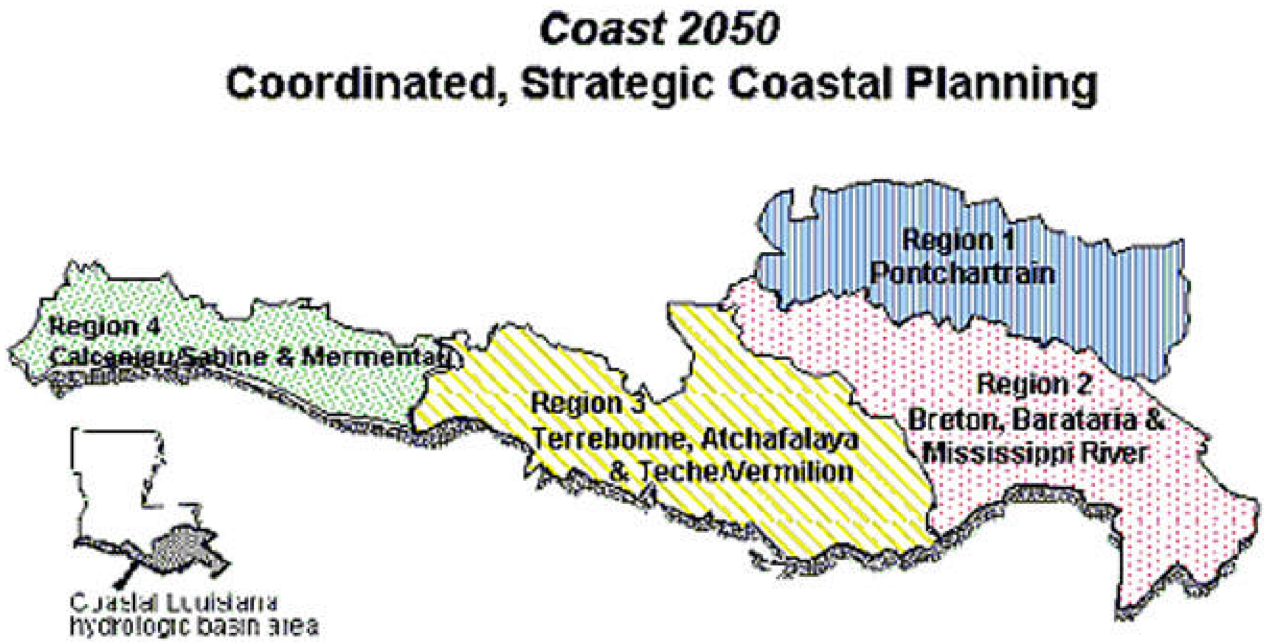



**Figure 1. Louisiana Coastal zone as it was defined in the Coast 2050 effort and restoration report.**

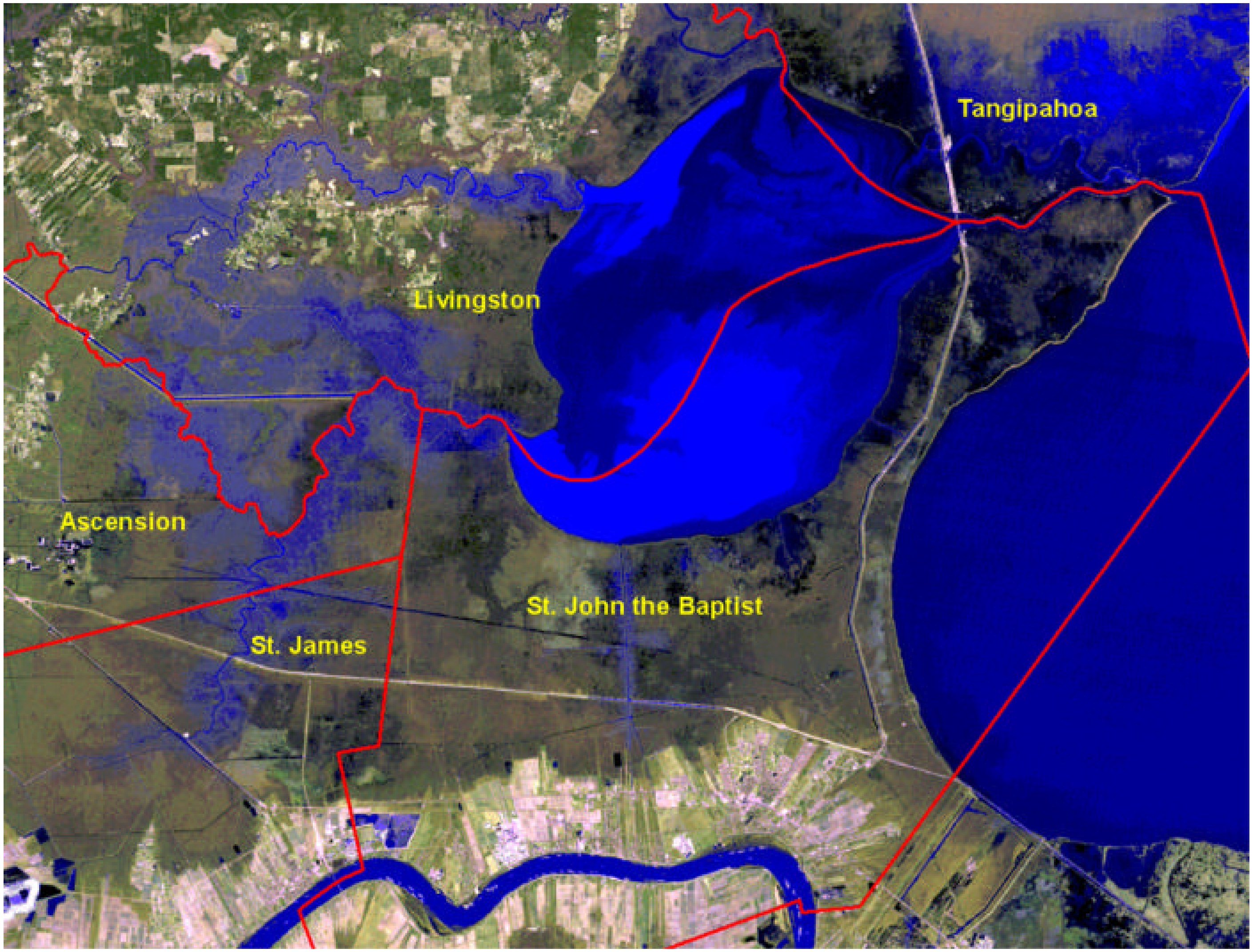



**Figure 2. Study area location.**

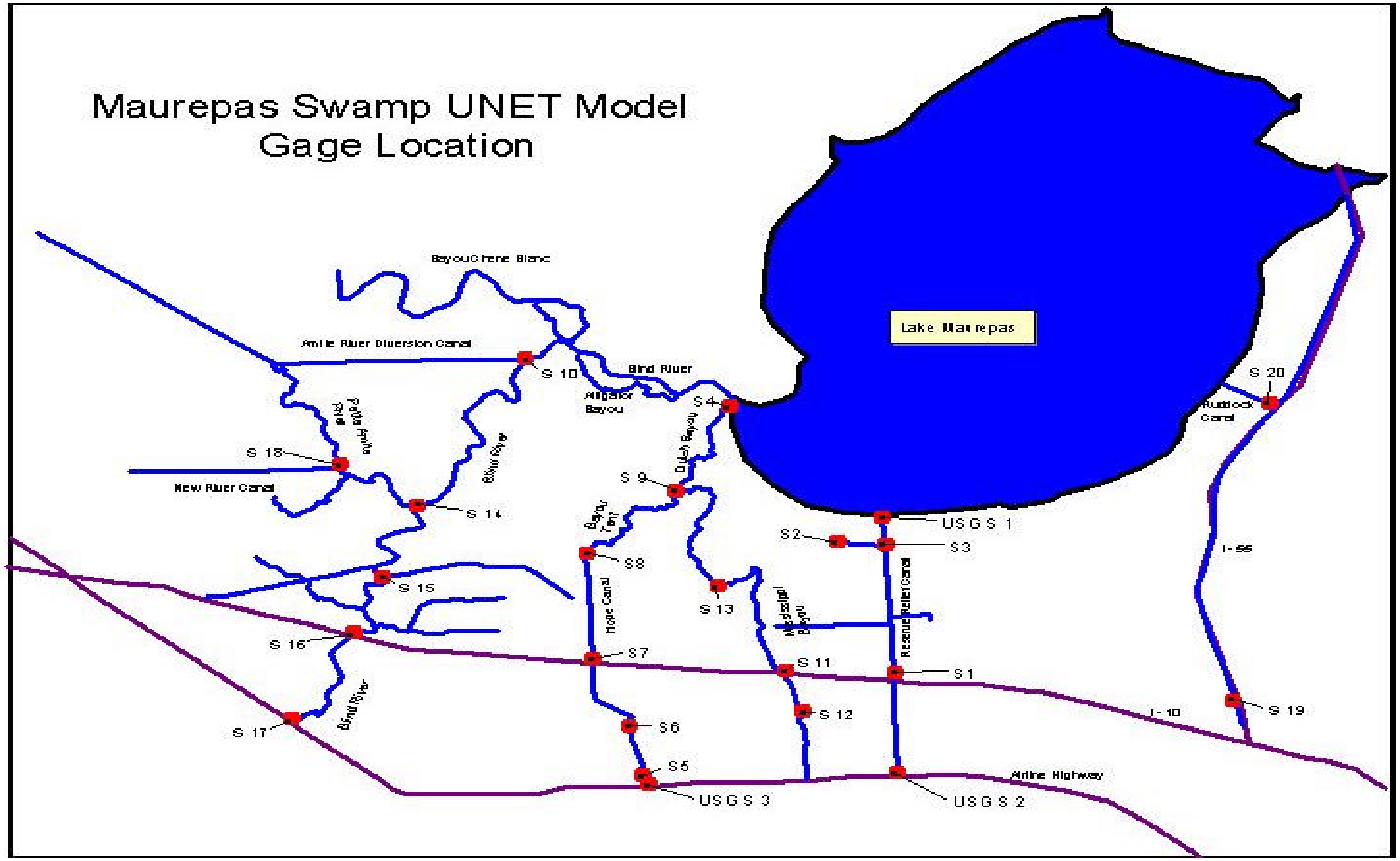



**Figure 3. Major water features within the study area. Red dots indicate survey and gage locations.**

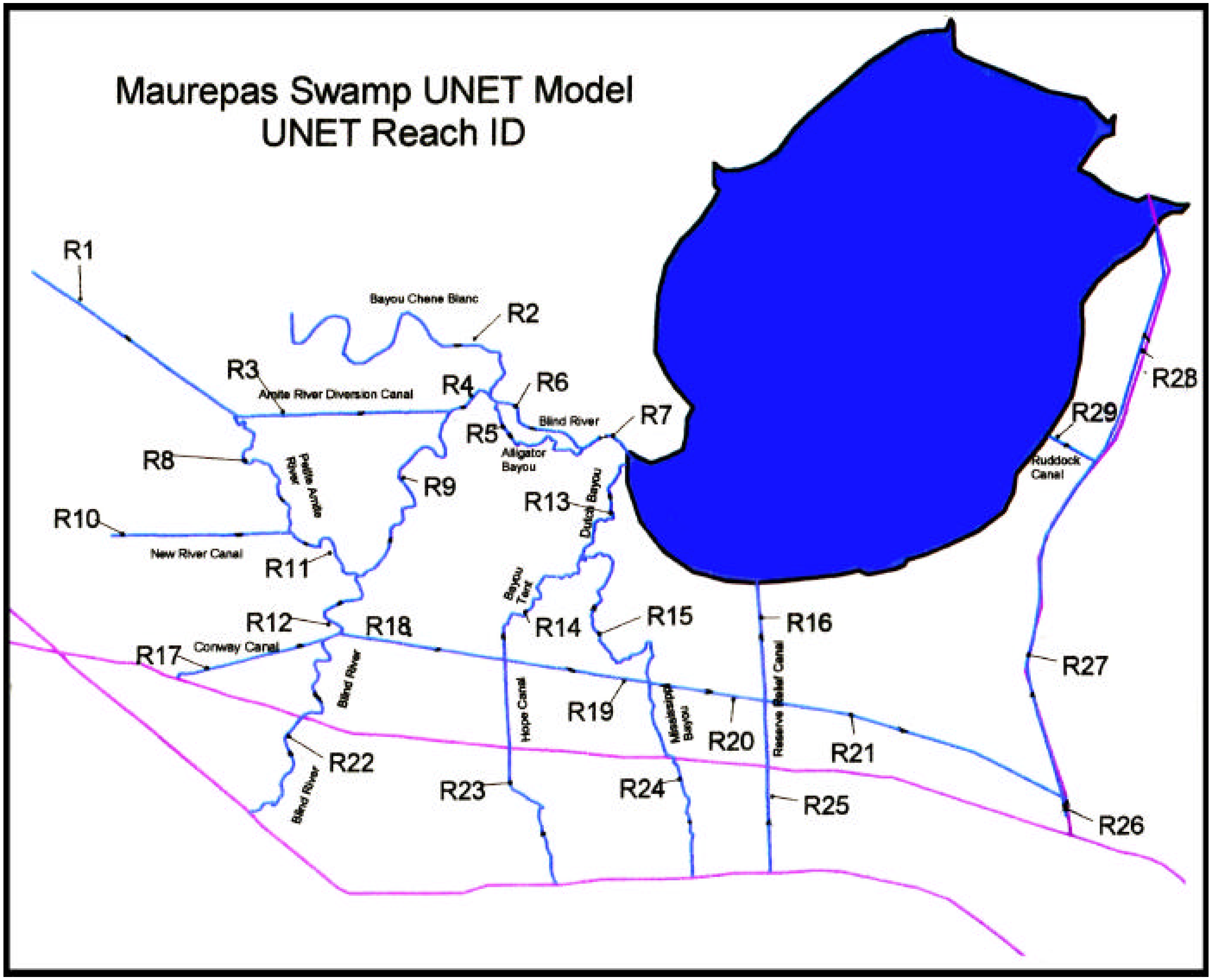



**Figure 4. UNET model scheme.**

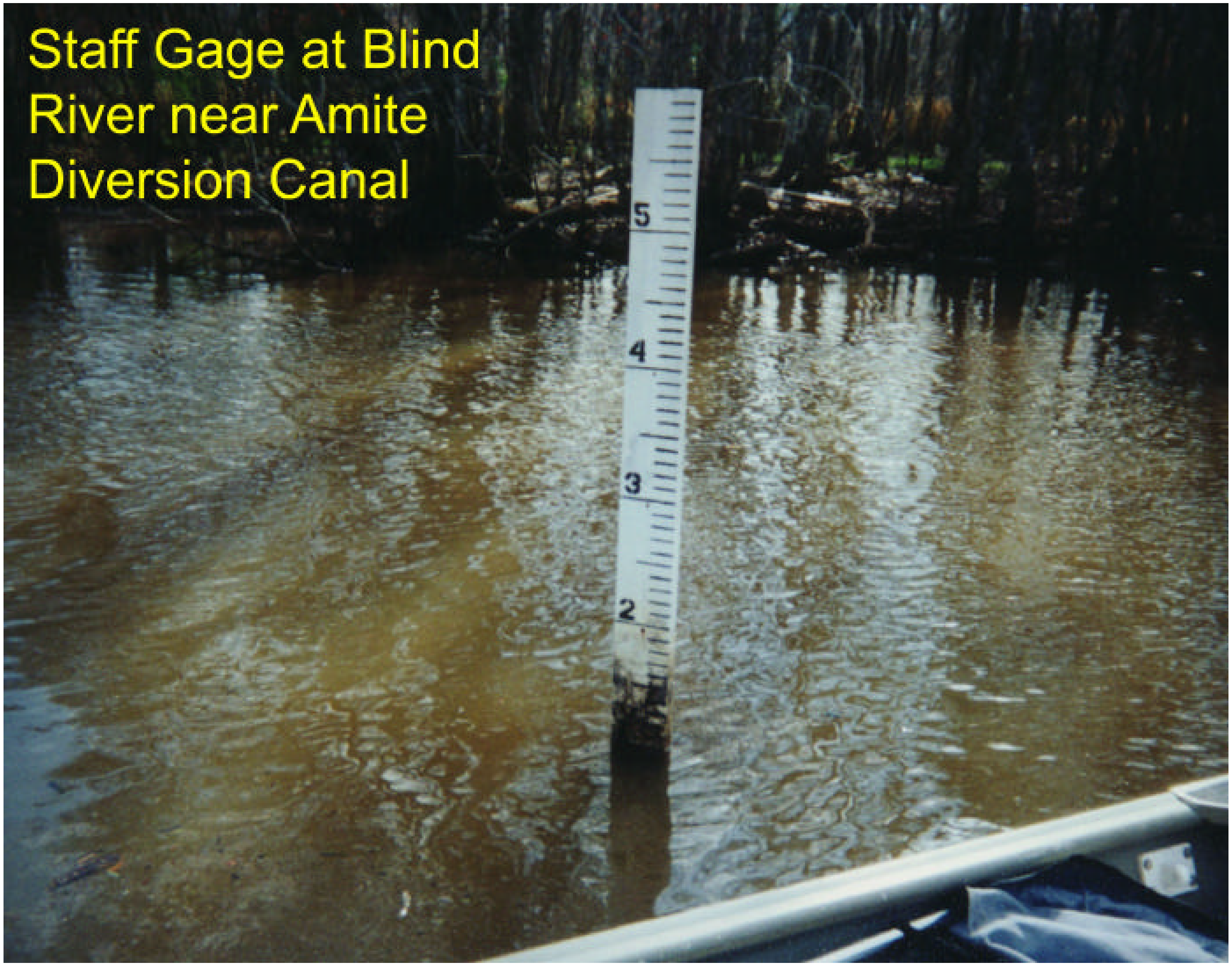



**Figure 5. Staff gage installed at Blind River near Amite Diversion Canal.**

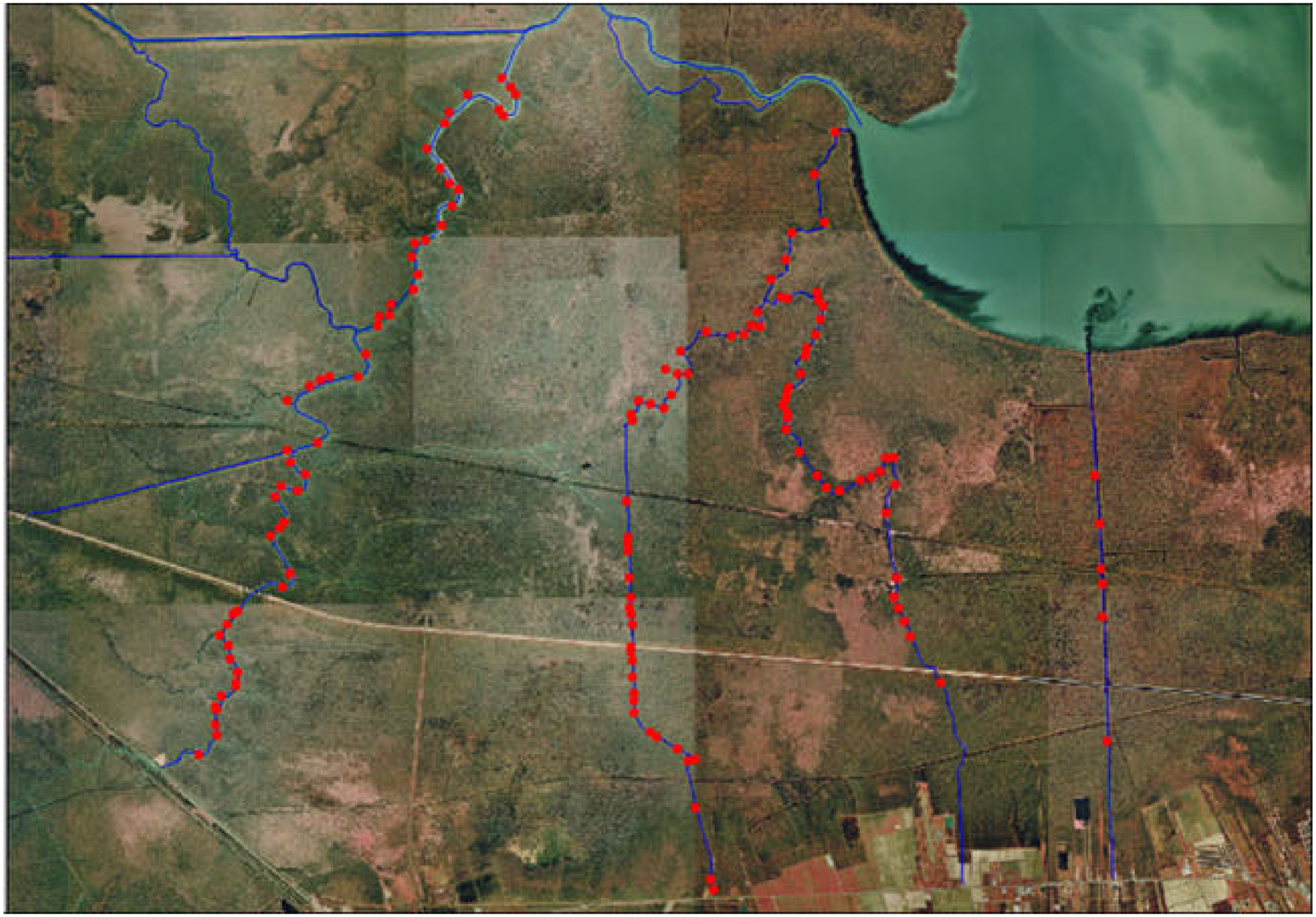


**Figure 6. Location of breaks in channel banks as identified by GPS survey. Red dots indicate the spatial location of the breaks.**


**Figure 7. Locations of LSU cross-section surveys.**

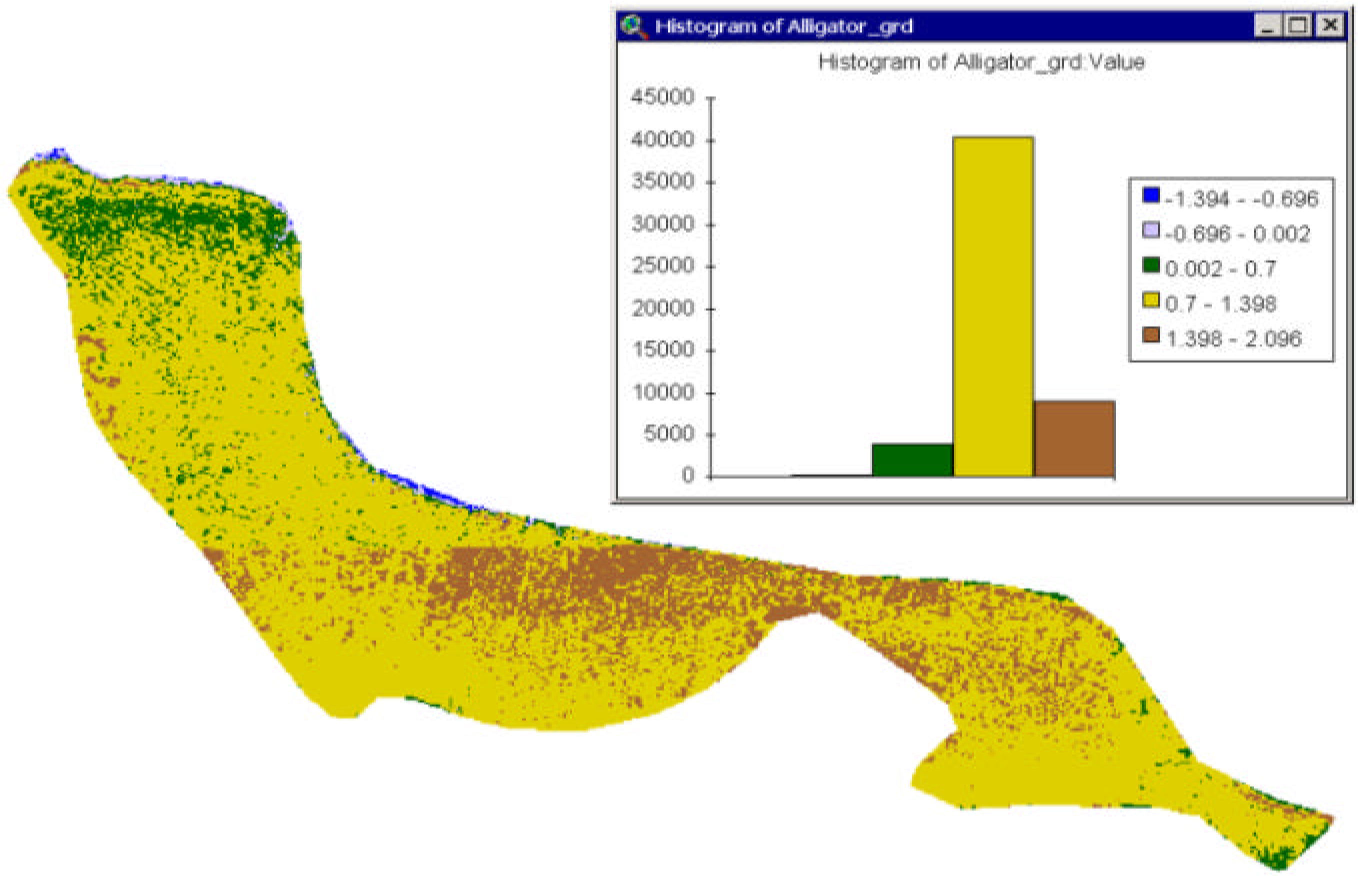



**Figure 8. Elevation of Alligator Island as constructed from the LIDAR data.**

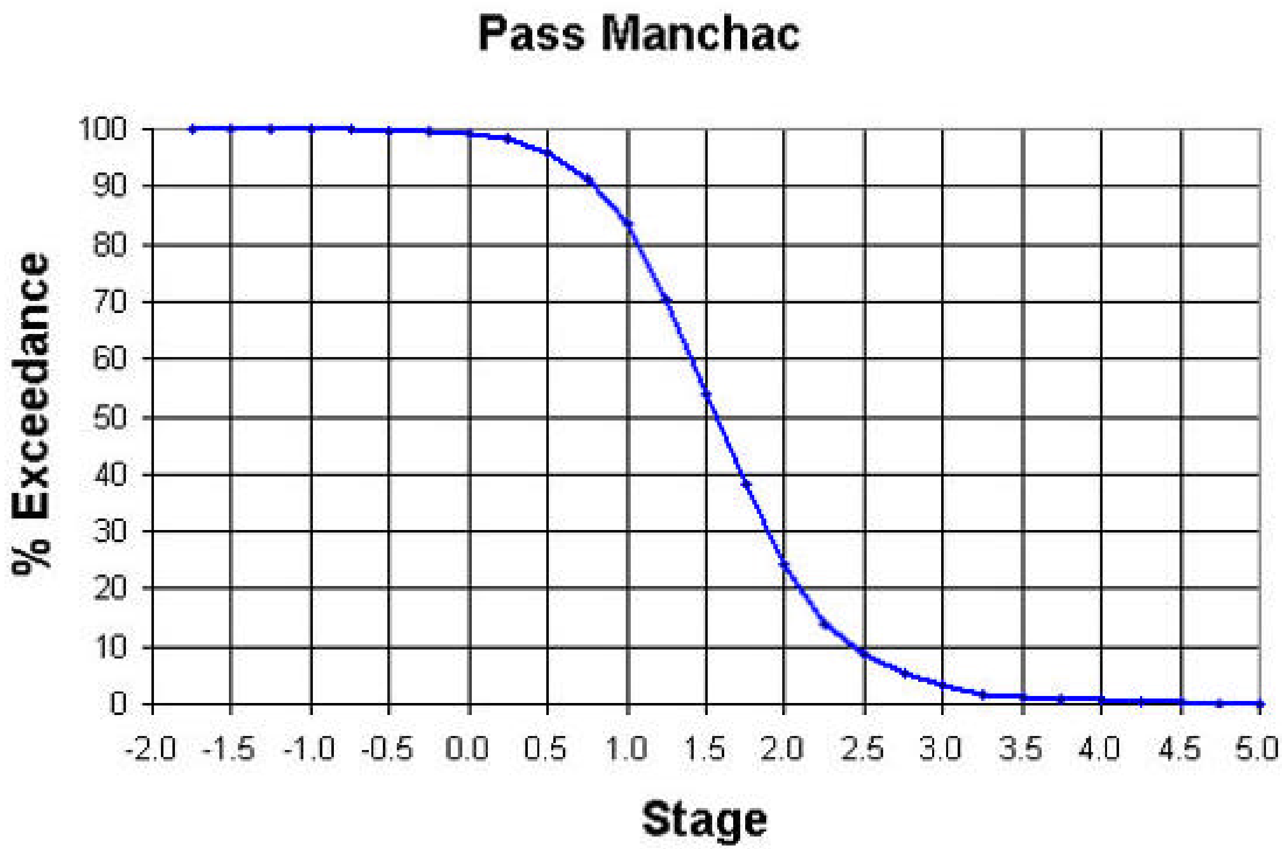



**Figure 9. Stage exceedance curve as developed for Pass Manchac.**

**Figure 10. Photo of the I-10 bridge on Hope Canal.**

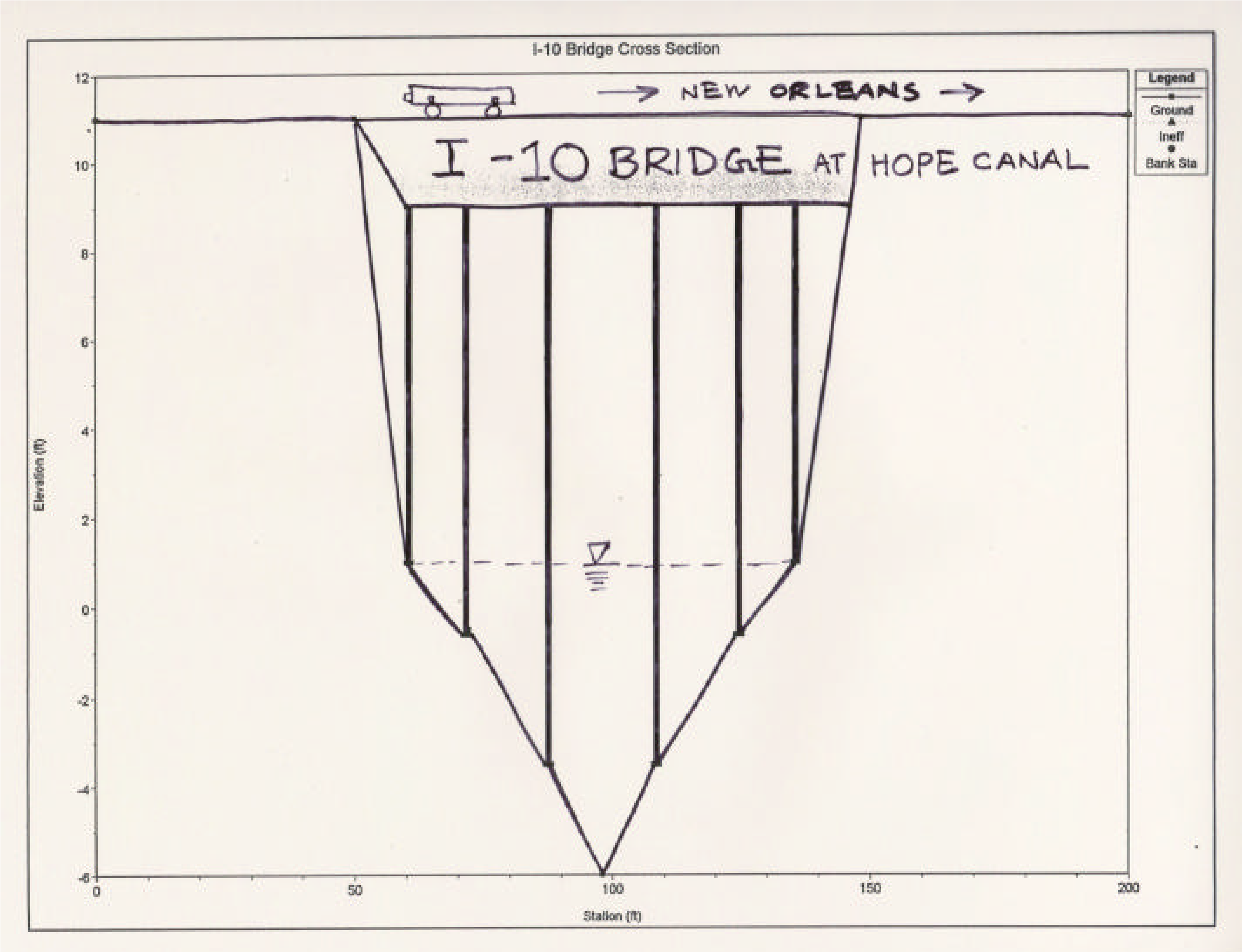



**Figure 11. I-10 bridge as developed for the UNET model.**

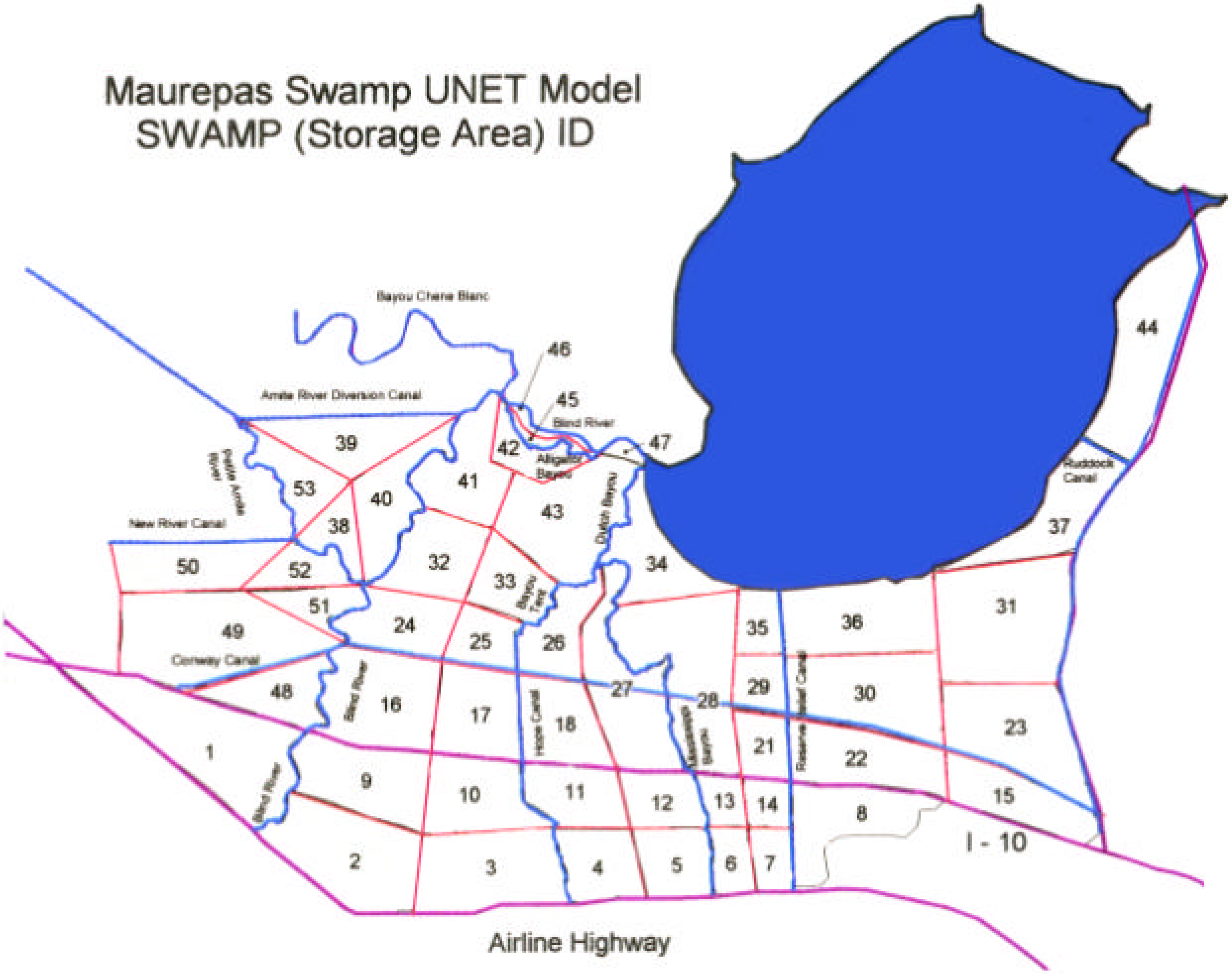



**Figure 12. Storage area ID as used in the UNET model.**

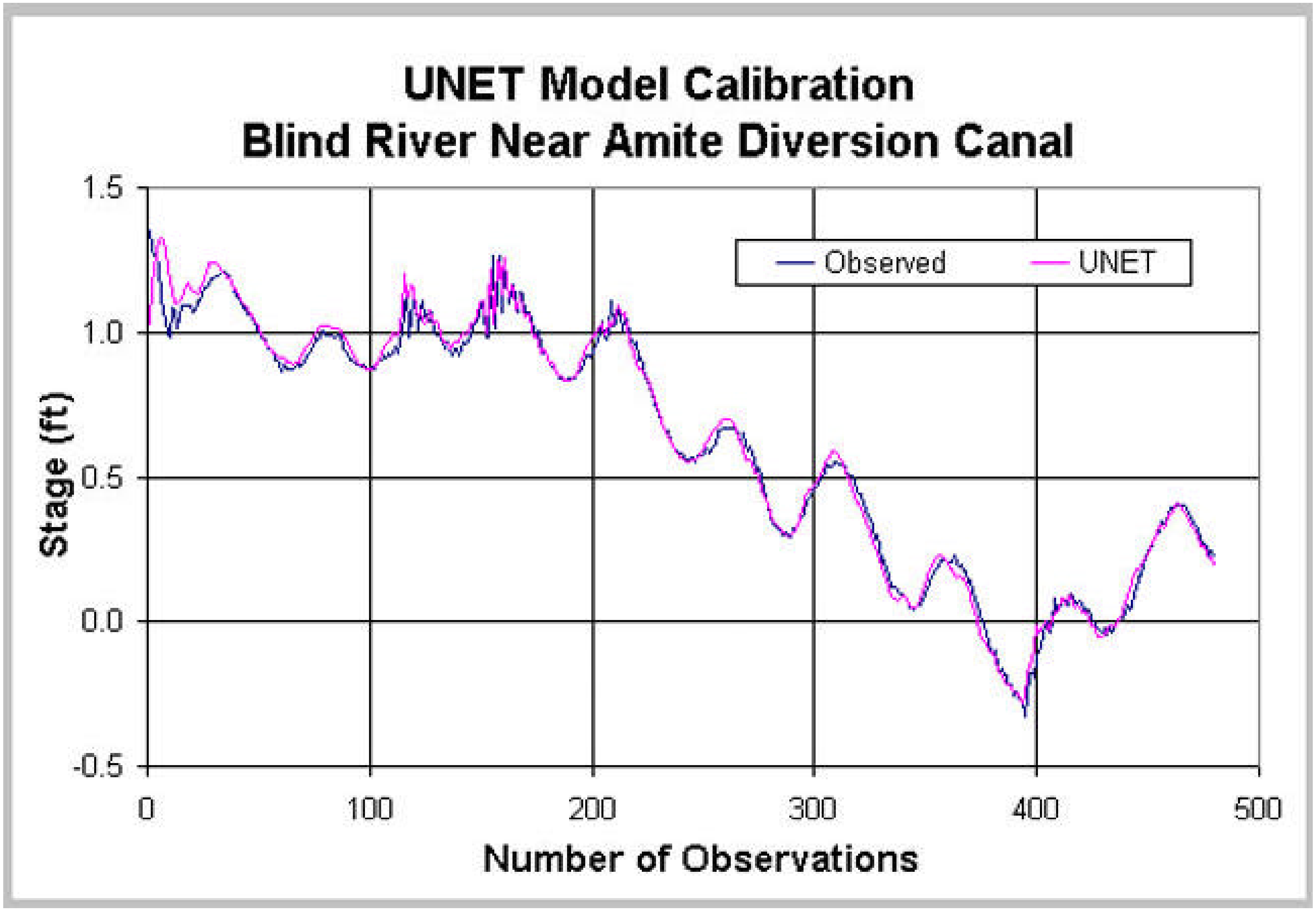



**Figure 13. Observed and simulated stages of Blind River near Amite Diversion Canal.**

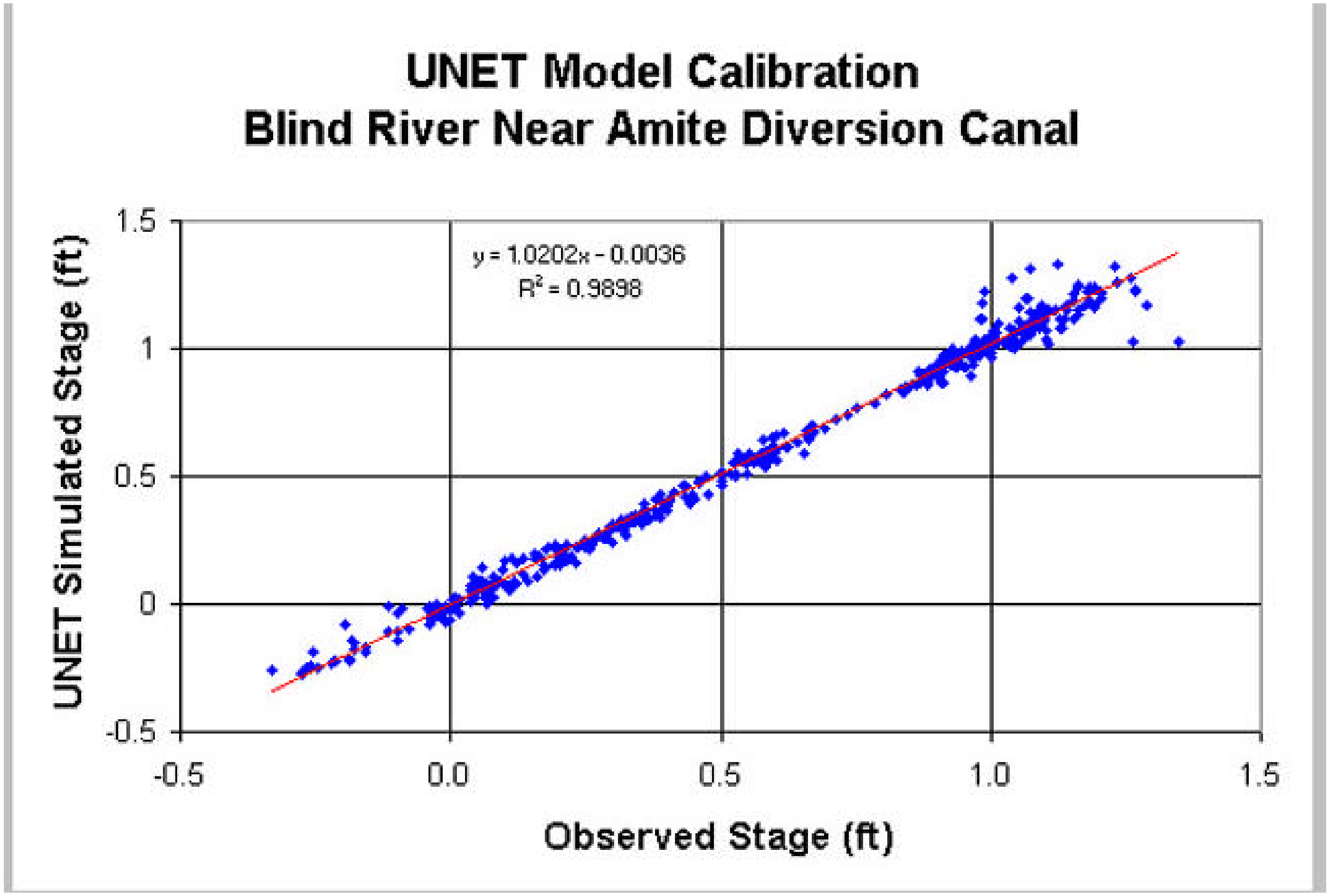



**FIGURE 14. Regression analysis of observed and simulated stages of Blind River near Amite Diversion Canal.**

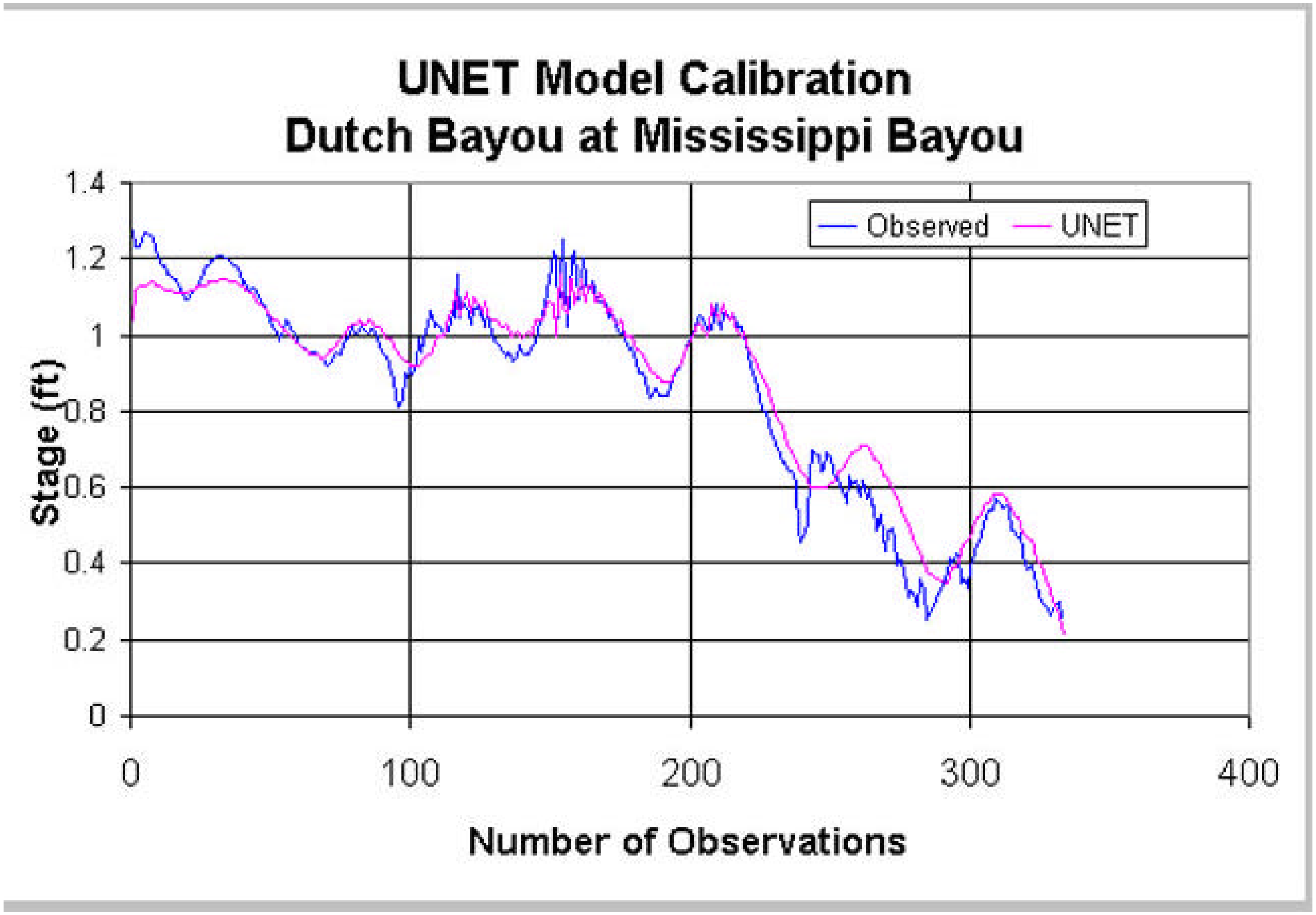



**FIGURE 15. Observed and simulated stages of Dutch Bayou near Mississippi Bayou.**

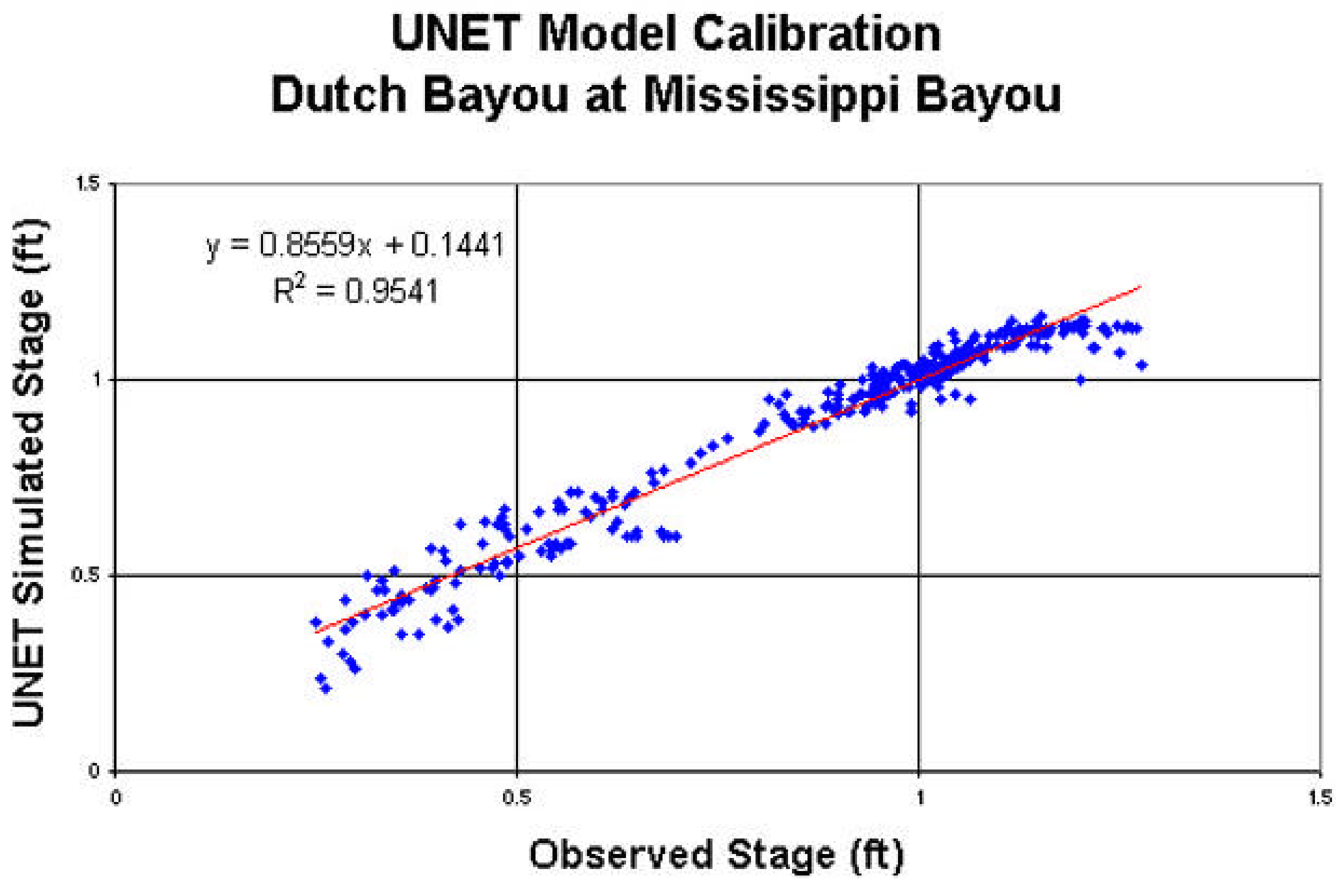



**Figure 16. Regression analysis of observed and simulated stages of Dutch Bayou near Mississippi Bayou.**

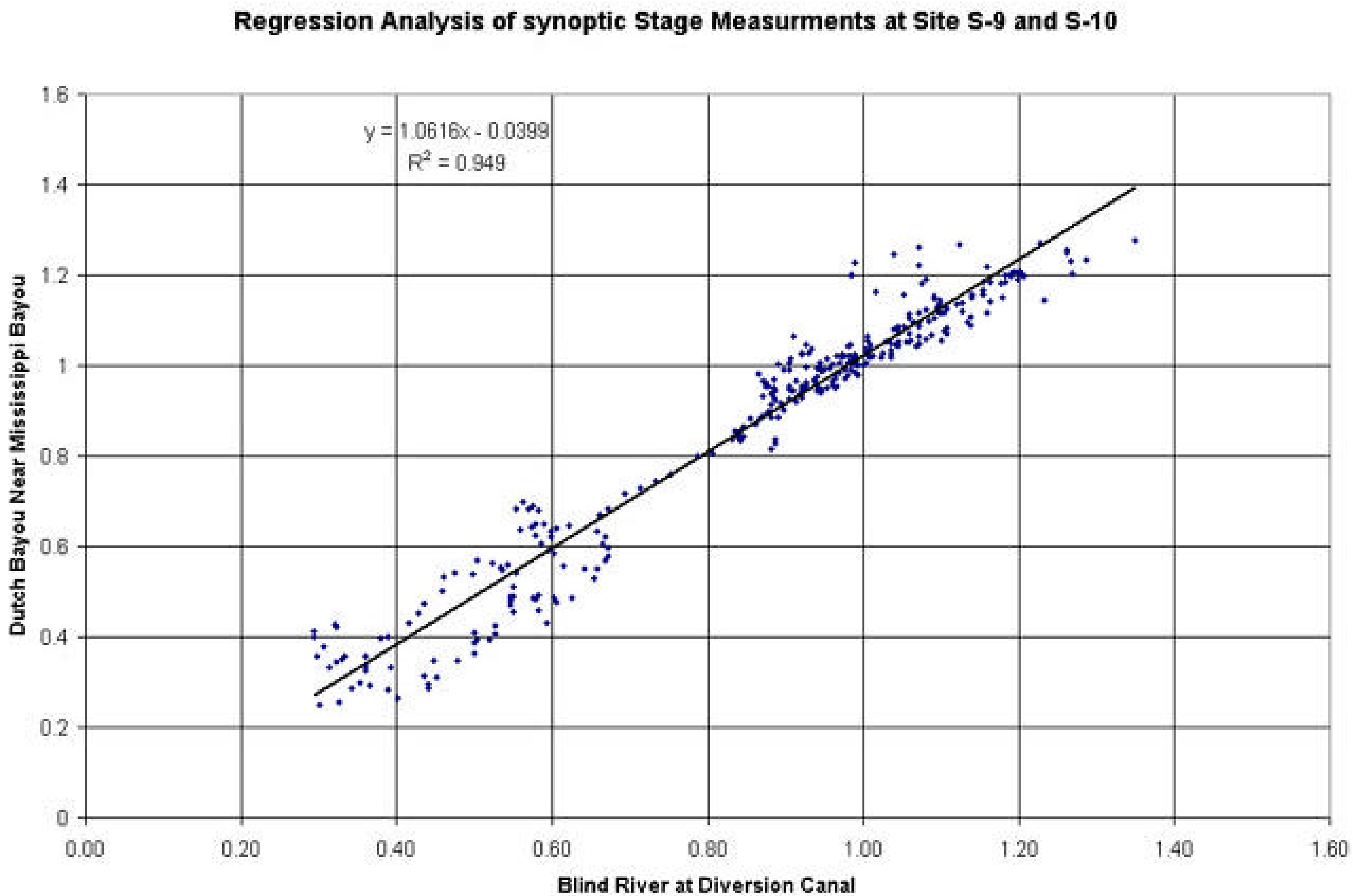



**Figure 16-B. Regression Analysis of synoptic stage measurements at site S-9 and S-10.**

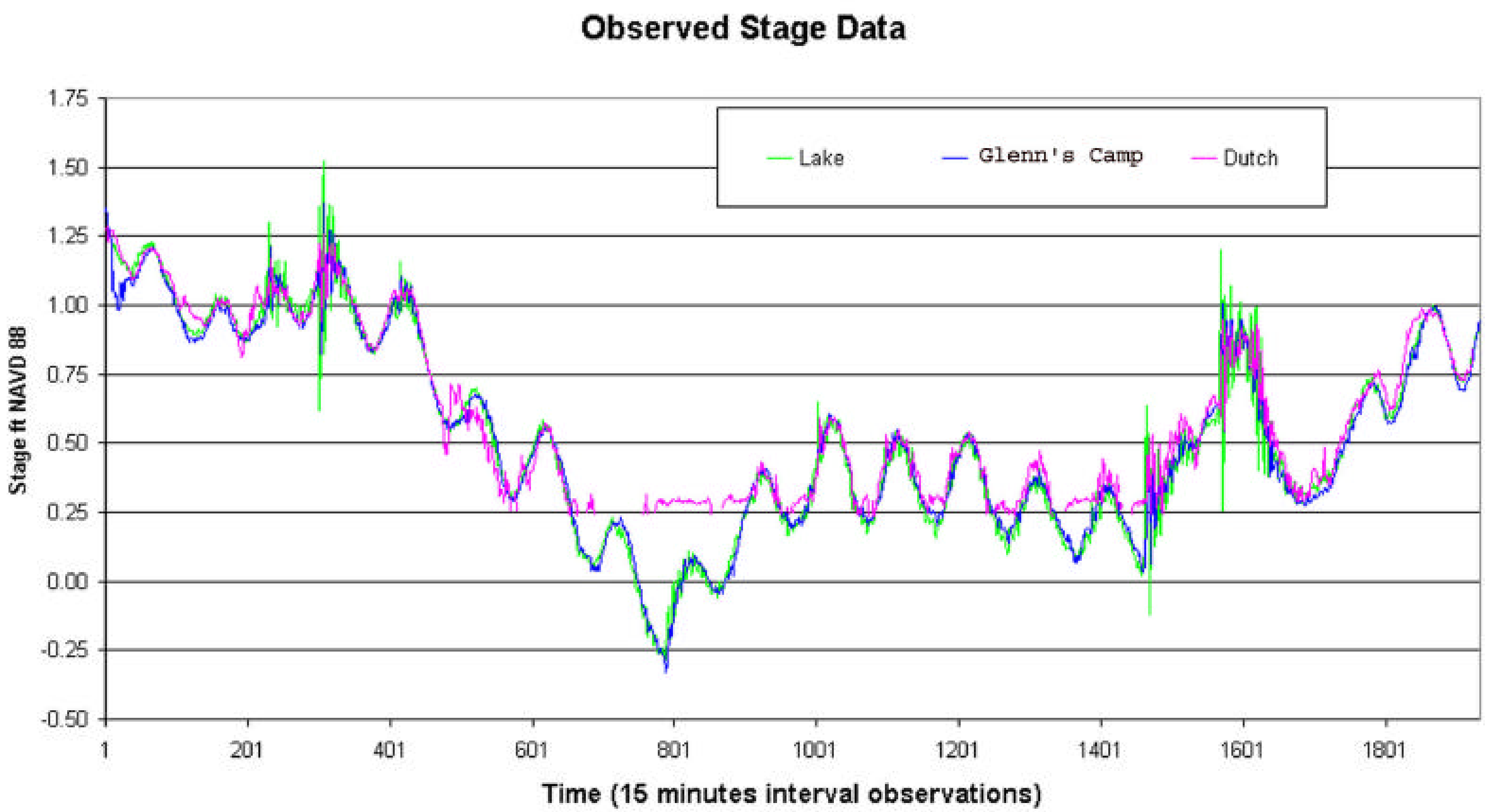



**Figure 17. Observed stage as recorded in July 2000.**

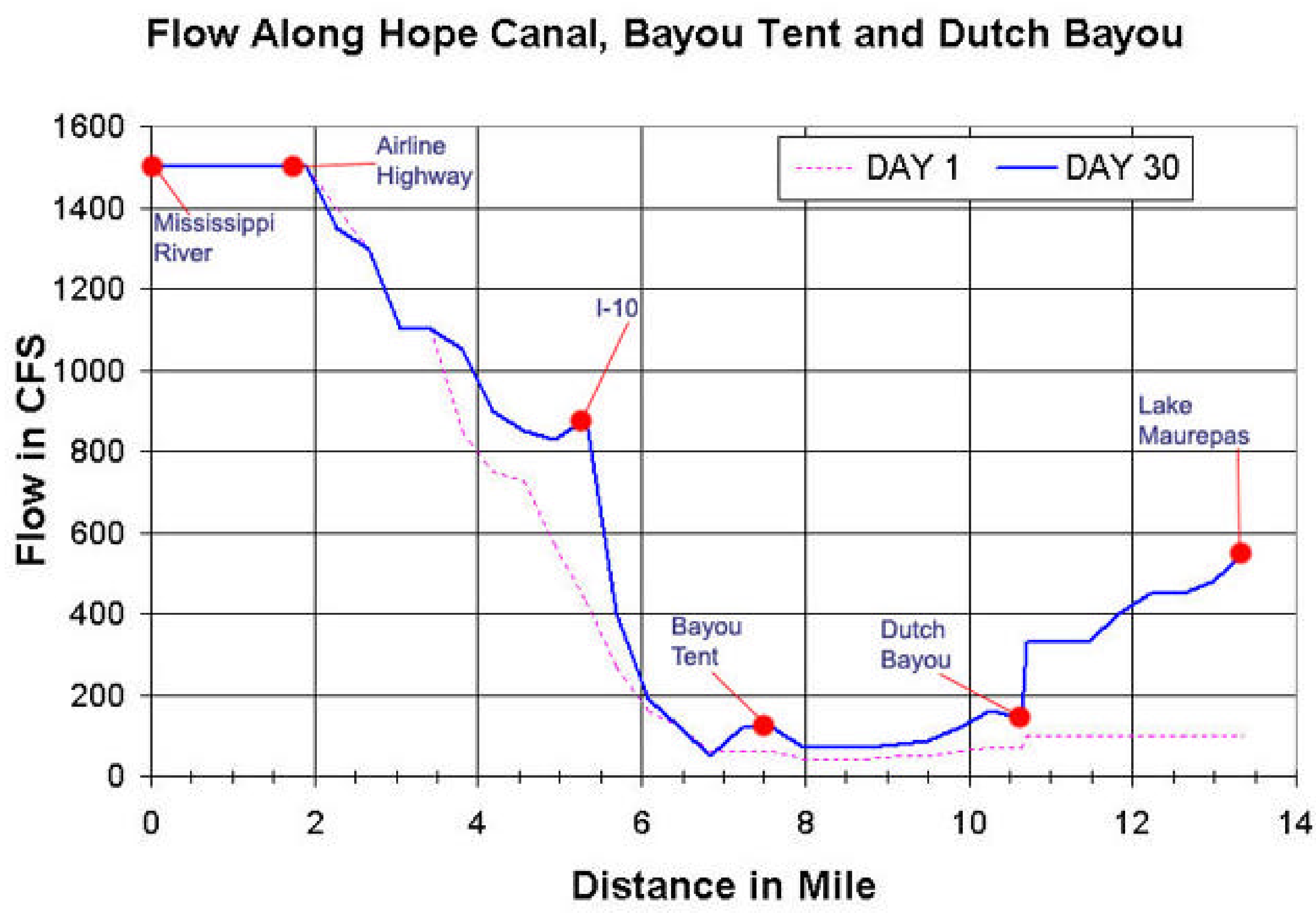



**Figure 18. Flow along Hope Canal without a guide levee between Airline highway and I-10. During simulation, a 1500 cfs diversion was assumed with a lake elevation of 1 foot.**

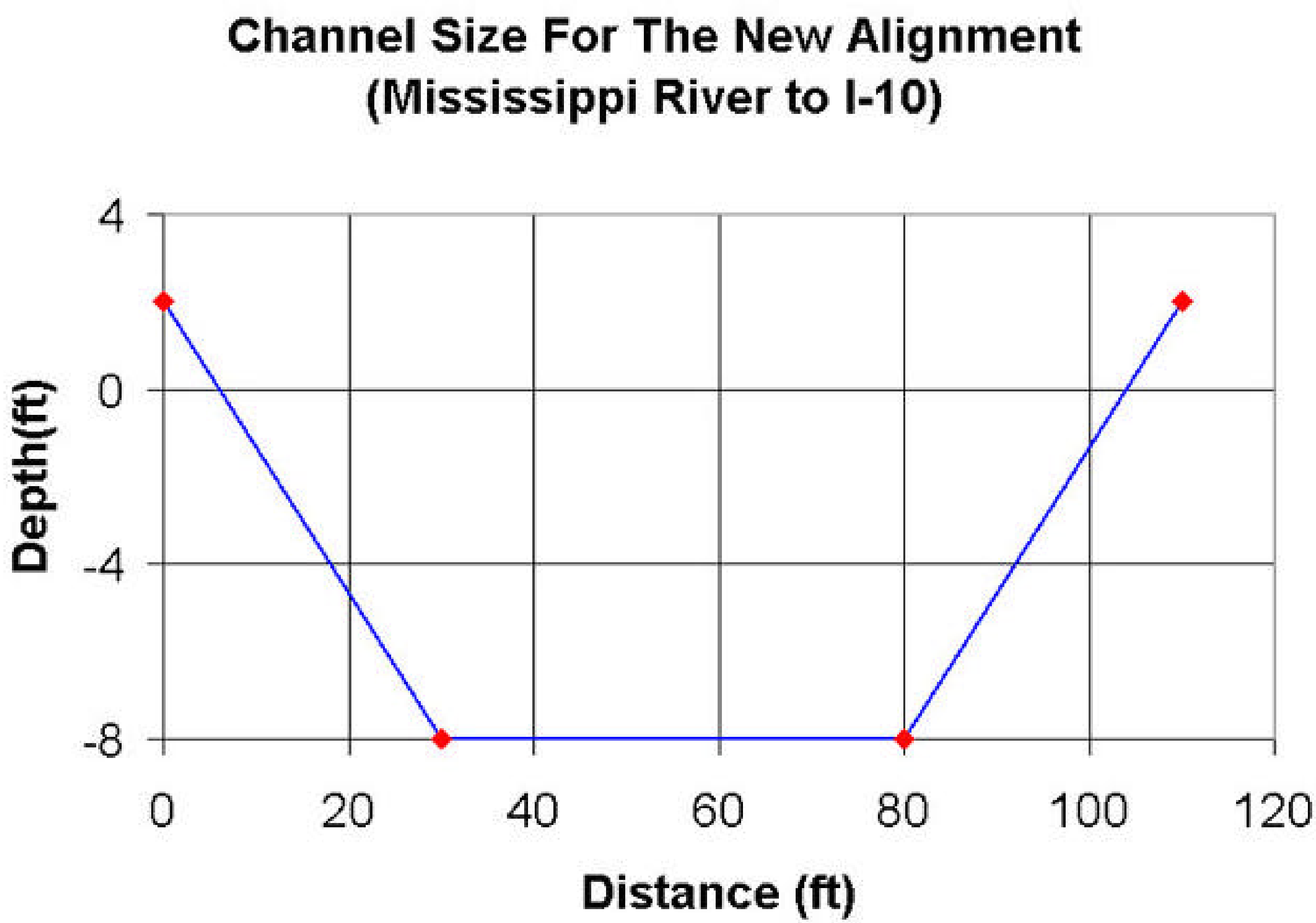



**Figure 19. Size of the cross section as used in the UNET model.**

**Figure 20. Alignment of the diversion channel from the Mississippi River up to I-10.**

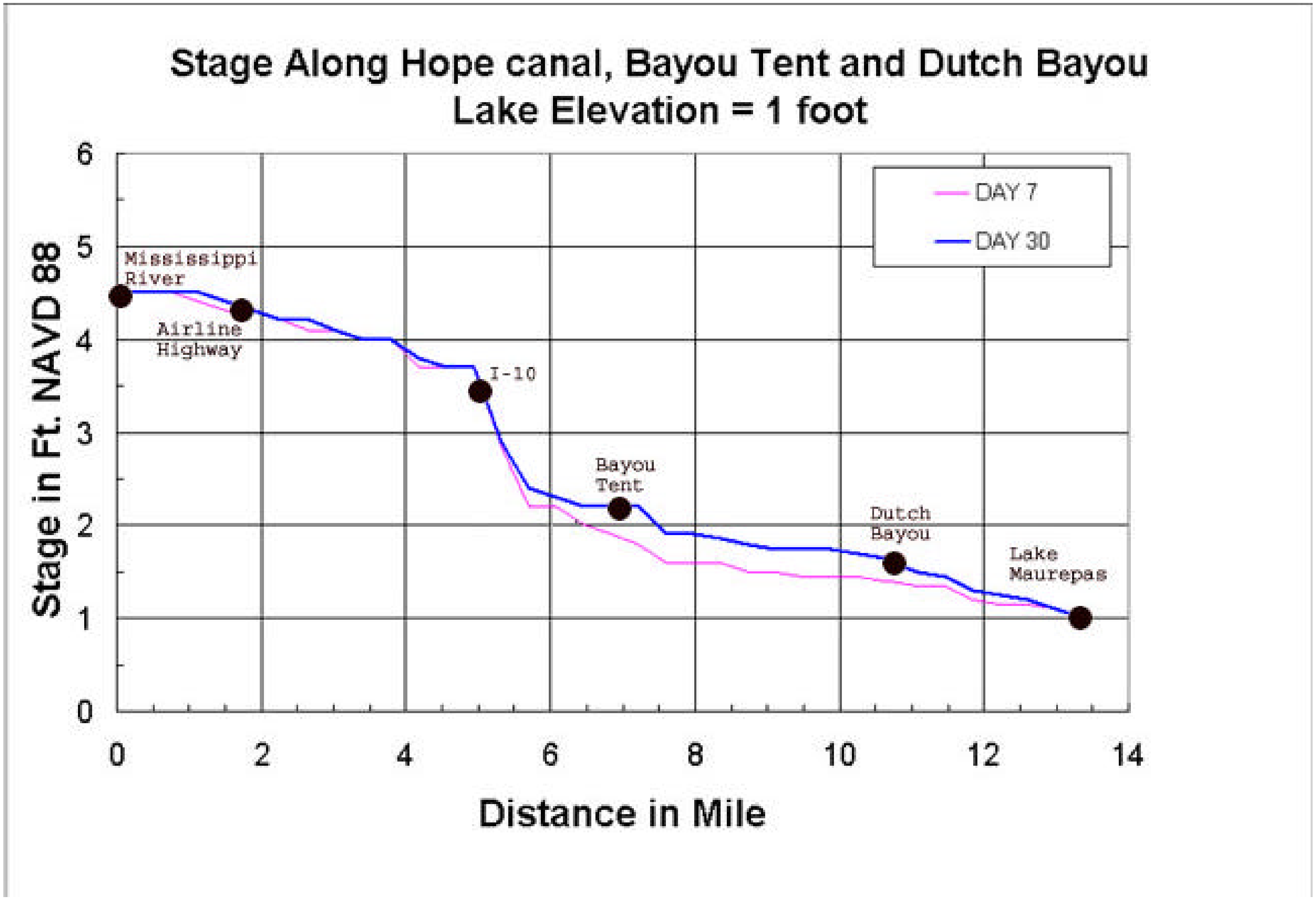



**Figure 21. Stage along Hope Canal with a guide levee between Airline highway and I-10. During simulation, a 1500 cfs diversion was assumed with a lake elevation of 1 foot.**

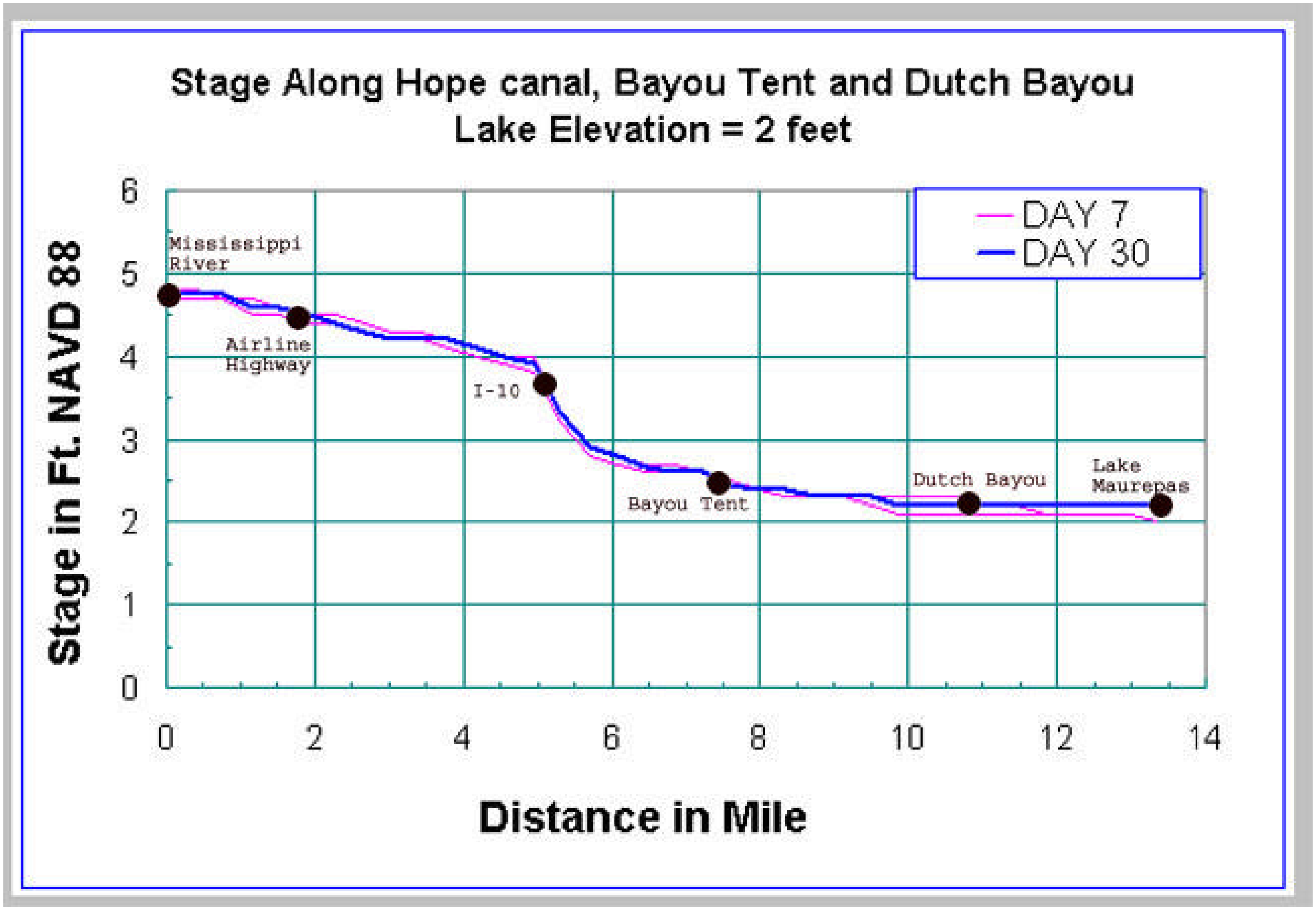



**Figure 22. Stage along Hope Canal with a guide levee between Airline highway and I-10. During simulation, a 1500 cfs diversion was assumed with a lake elevation of 2 feet.**

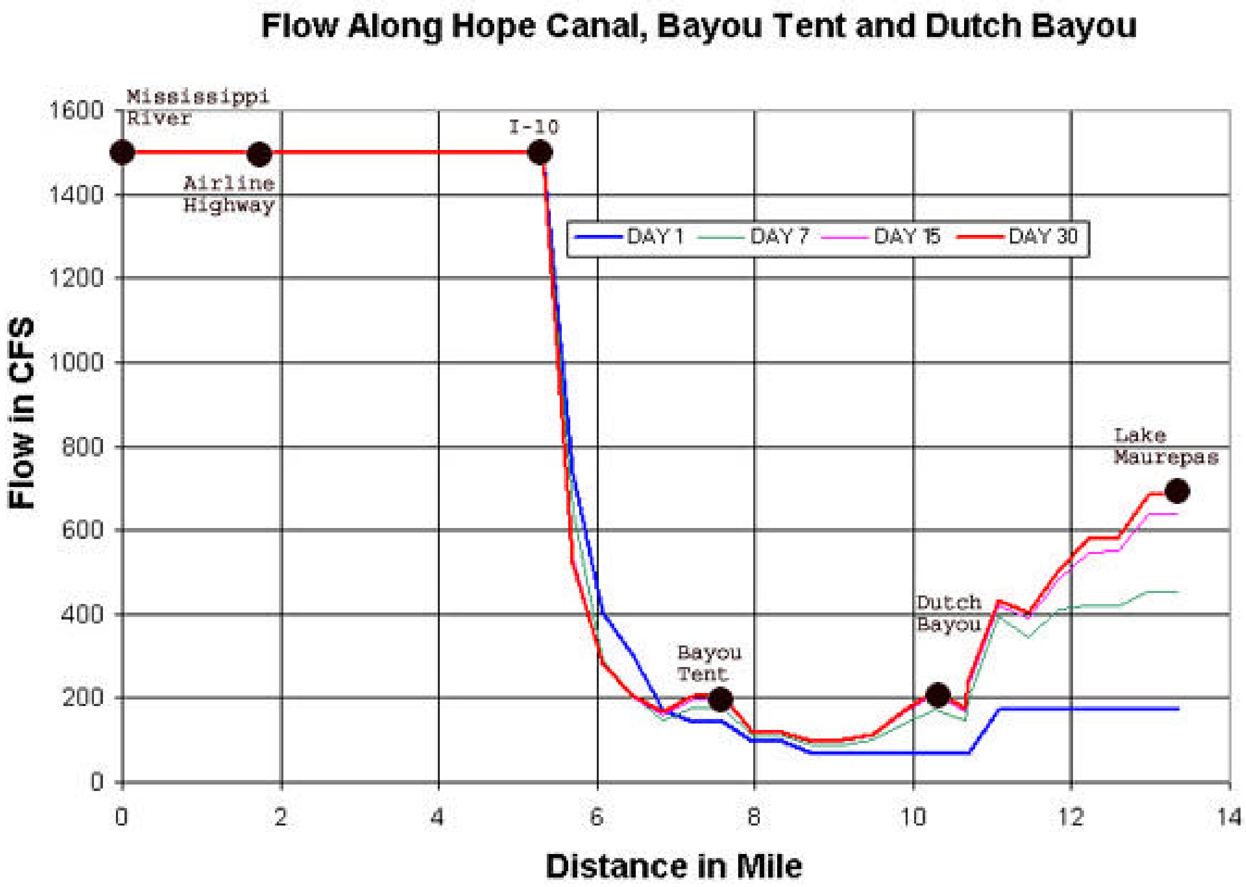



**Figure 23. Flow along Hope Canal with a guide levee between Airline highway and I-10. During simulation, a 1500 cfs diversion was assumed with a lake elevation of 1 foot.**

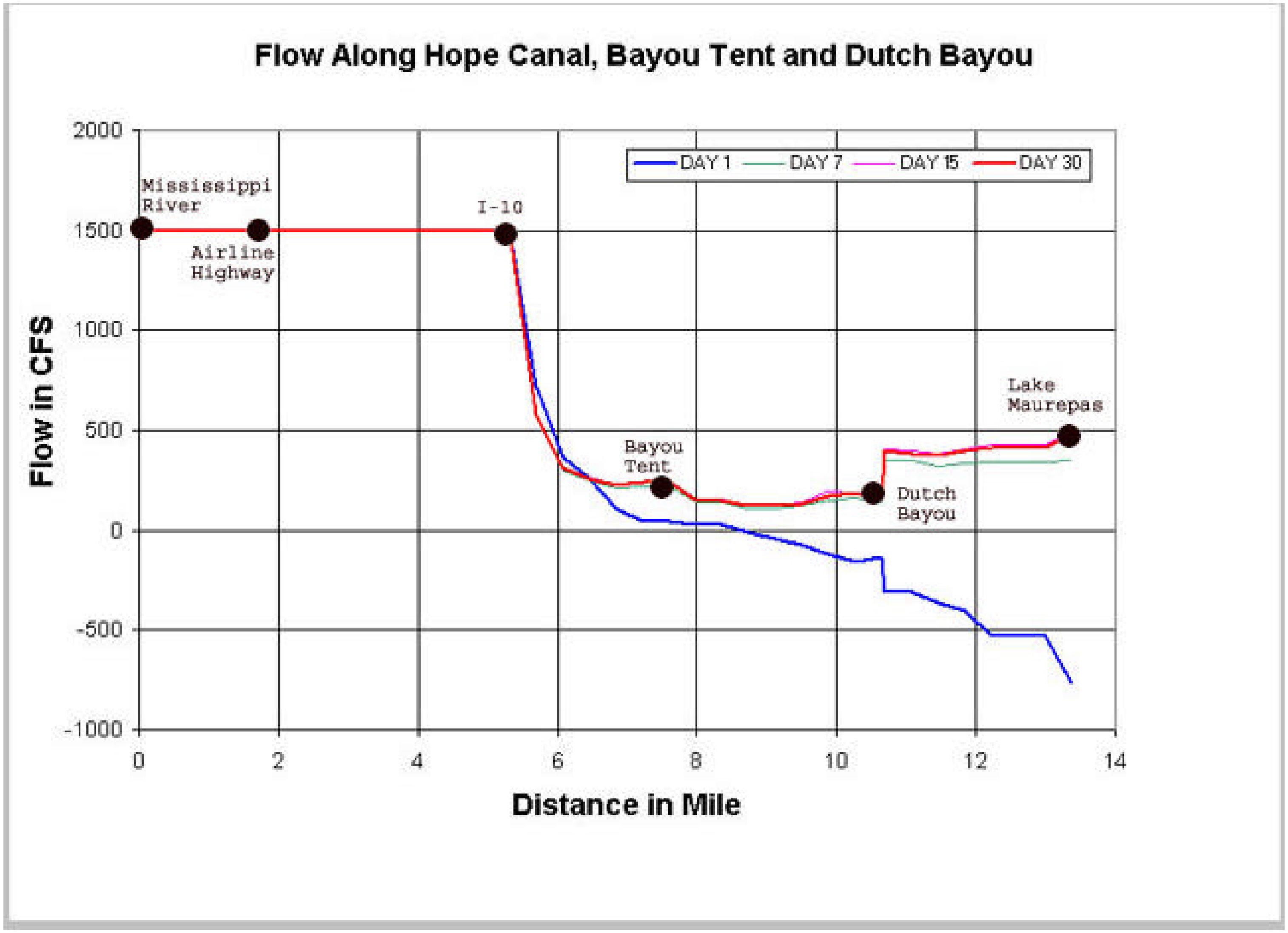



**Figure 24. Flow along Hope Canal with a guide levee between Airline highway and I-10. During simulation, a 1500 cfs diversion was assumed with a lake elevation of 2 feet.**

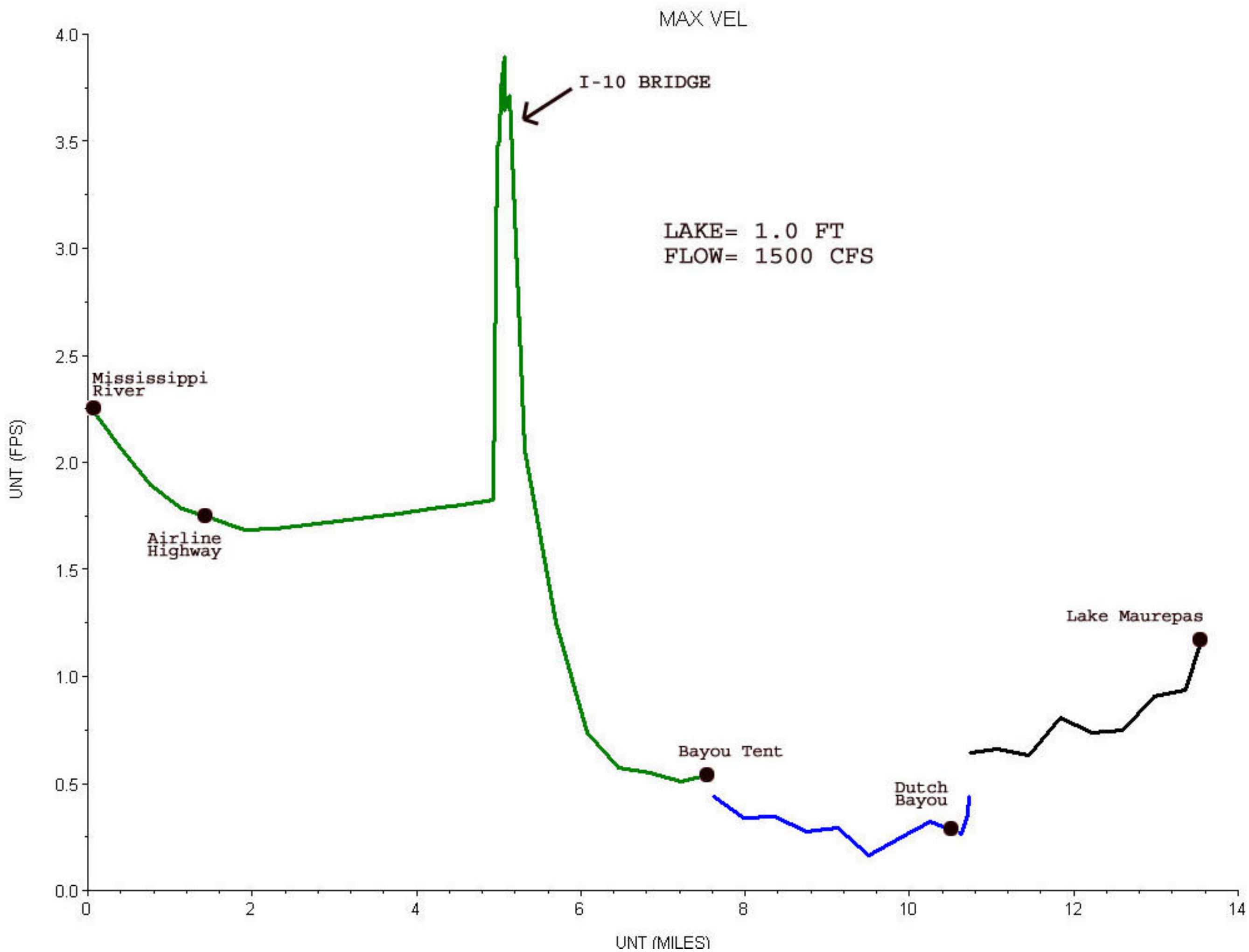



**Figure 25. Flow velocity along Hope Canal with a guide levee between Airline highway and I-10. During simulation, a 1500 cfs diversion was assumed with a lake elevation of 1 foot.**

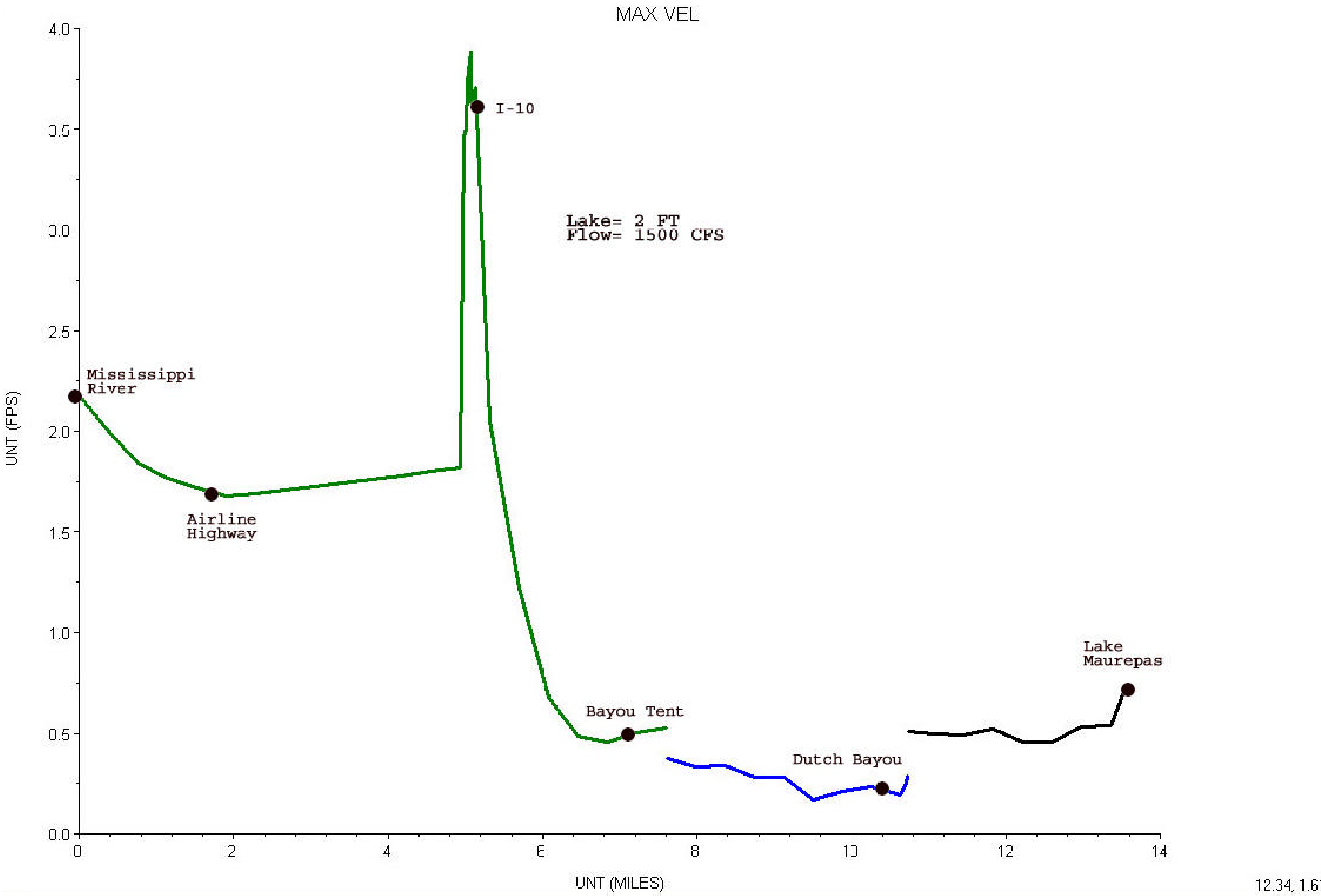



**FIGURE 26. Flow velocity along Hope Canal with a guide levee between Airline highway and I-10. During simulation, a 1500 cfs diversion was assumed with a lake elevation of 2 feet.**

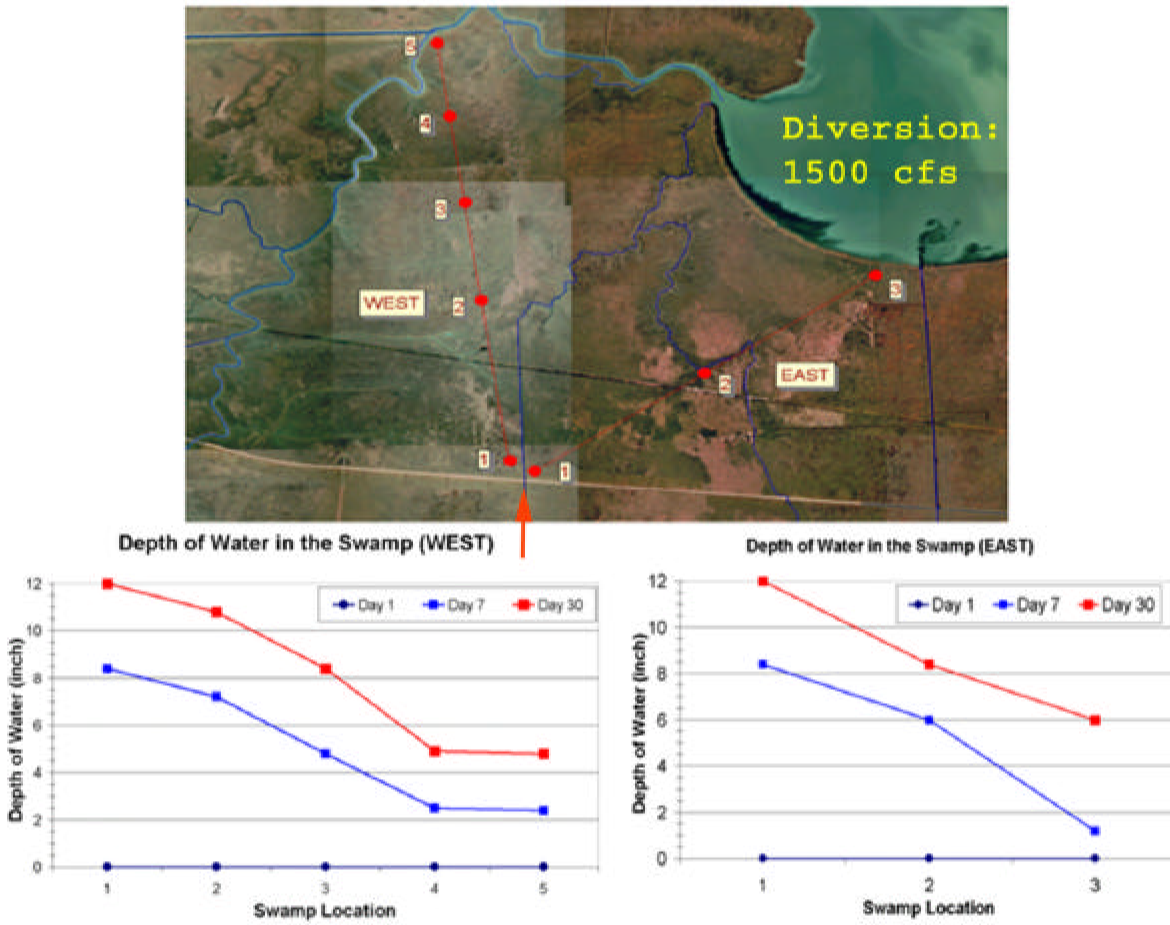



**Figure 27. Depth of water in the Swamp at 7 and 30 days.**

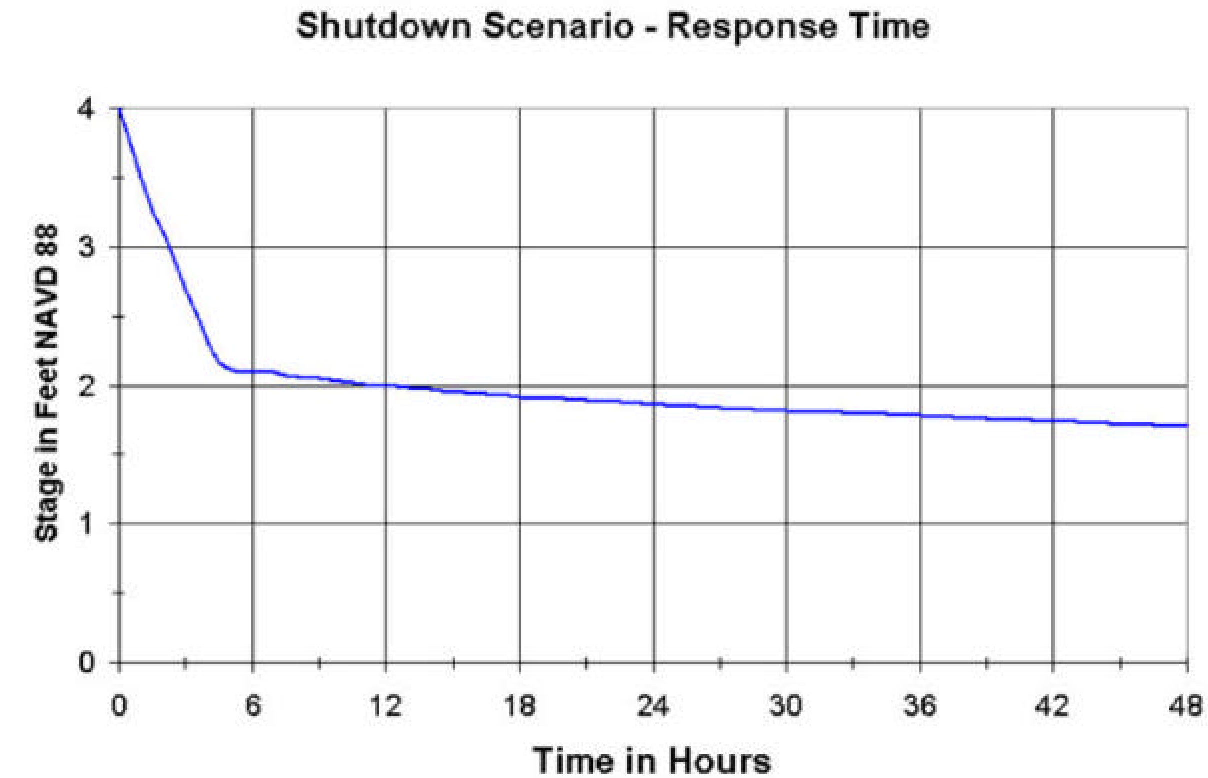



**Figure 28. Response time of the system during a shutdown scenario simulation.**

| Swamp ID | Swamp Area (Sq. Mile) | Swamp Elev (ft. NAVD 88 |
|---|---|---|
| 1 | 6.79 | 1.20 |
| 2 | 4.80 | 1.20 |
| 3 | 5.01 | 1.20 |
| 4 | 2.06 | 1.20 |
| 5 | 0.69 | 1.20 |
| 6 | 0.97 | 1.20 |
| 7 | 0.95 | 1.20 |
| 8 | 4.16 | 1.20 |
| 9 | 3.96 | 1.20 |
| 10 | 4.10 | 1.20 |
| 11 | 3.03 | 1.20 |
| 12 | 1.85 | 1.20 |
| 13 | 1.07 | 1.20 |
| 14 | 0.91 | 1.20 |
| 15 | 2.63 | 1.00 |
| 16 | 4.17 | 1.20 |
| 17 | 3.62 | 1.20 |
| 18 | 2.92 | 1.20 |
| 21 | 1.48 | 1.00 |
| 22 | 3.96 | 1.00 |
| 23 | 4.90 | 1.00 |
| 24 | 2.16 | 1.20 |
| 25 | 1.63 | 1.00 |
| 26 | 2.09 | 1.00 |
| 27 | 4.24 | 1.00 |
| 28 | 6.20 | 1.00 |
| 29 | 1.19 | 1.00 |
| 30 | 4.61 | 1.00 |
| 31 | 6.30 | 1.00 |
| 32 | 2.95 | 1.20 |
| 33 | 2.47 | 1.00 |
| 34 | 2.63 | 1.00 |
| 35 | 1.33 | 1.00 |
| 36 | 5.17 | 1.00 |
| 37 | 3.18 | 1.00 |
| 38 | 1.27 | 1.20 |
| 39 | 2.61 | 1.20 |
| 40 | 2.94 | 1.20 |
| 41 | 3.23 | 1.20 |
| 42 | 1.57 | 1.20 |
| 43 | 4.78 | 1.00 |
| 44 | 4.70 | 1.00 |
| 45 | 0.25 | 1.50 |
| 46 | 0.20 | 1.50 |
| 47 | 0.31 | 1.00 |
| 48 | 2.45 | 1.20 |
| 49 | 3.40 | 1.20 |
| 50 | 3.21 | 1.20 |
| 51 | 1.33 | 1.20 |
| 52 | 1.28 | 1.20 |
| 53 | 1.82 | 1.20 |

**TABLE 1. Swamp storage ID, area and Base elevation.**

| | River Reach ID and Approximate Length | | | |
|---|---|---|---|---|
| | | | | |
| **UNET Reach ID** | **River/Bayou Name** | **Feet Reach Length** | **Mile Reach Length** | **Meter Reach Length** |
| | | | | |
| 1 | Amite Diversion Canal | 29,500 | 5.587 | 8,992 |
| 2 | Bayou Chene Blanc | 44,000 | 8.333 | 13,411 |
| 3 | Amite Diversion Canal | 24,897 | 4.715 | 7,589 |
| 4 | Blind River | 6,000 | 1.136 | 1,829 |
| 5 | Alligator Bayou | 15,300 | 2.898 | 4,663 |
| 6 | Blind River | 13,200 | 2.500 | 4,023 |
| 7 | Blind River | 7,510 | 1.422 | 2,289 |
| 8 | Petite Amite River | 20,000 | 3.788 | 6,096 |
| 9 | Blind River | 28,500 | 5.398 | 8,687 |
| 10 | New River Canal | 21,600 | 4.091 | 6,584 |
| 11 | Petite Amite River | 12,000 | 2.273 | 3,658 |
| 12 | Blind River | 11,500 | 2.178 | 3,505 |
| 13 | Dutch Bayou | 15,500 | 2.936 | 4,724 |
| 14 | Hope Canal and Bayou Tent | 20,200 | 3.826 | 6,157 |
| 15 | Mississippi Bayou | 28,600 | 5.417 | 8,717 |
| 16 | Reserve Relief Canal | 13,400 | 2.538 | 4,084 |
| 17 | Conway Canal | 17,100 | 3.239 | 5,212 |
| 18 | Powerline | 19,100 | 3.617 | 5,822 |
| 19 | Powerline | 16,700 | 3.163 | 5,090 |
| 20 | Powerline | 13,600 | 2.576 | 4,145 |
| 21 | Powerline | 39,200 | 7.424 | 11,948 |
| 22 | Blind River | 30,800 | 5.833 | 9,388 |
| 23 | Hope Canal | 28,100 | 5.322 | 8,565 |
| 24 | Mississippi Bayou | 23,500 | 4.451 | 7,163 |
| 25 | Reserve Relief Canal | 19,700 | 3.731 | 6,005 |
| 26 | Canal Along I-55 (Upper) | 2,500 | 0.473 | 762 |
| 27 | Canal Along I-55 (Middle) | 39,800 | 7.538 | 12,131 |
| 28 | Canal Along I-55 (Lower) | 28,200 | 5.341 | 8,595 |
| 29 | Ruddock canal | 5,400 | 1.023 | 1,646 |

**TABLE 2. UNET reach ID and approximate length.**

# Attachment I

# Diversion Simulation through
Blind River and Reserve Relief Canal

A 1500 cfs Diversion through Blind River and Reserve Relief Canal

With 1500 cfs flow through Blind River, model results show that up to 1350 cfs flow would directly go to Lake Maurepas (Figure AI-1). Similarly, with a 1500 cfs flow through Reserve Relief Canal, model results show that up to 1050 cfs flow would directly go to Lake Maurepas (Figure AI-2).

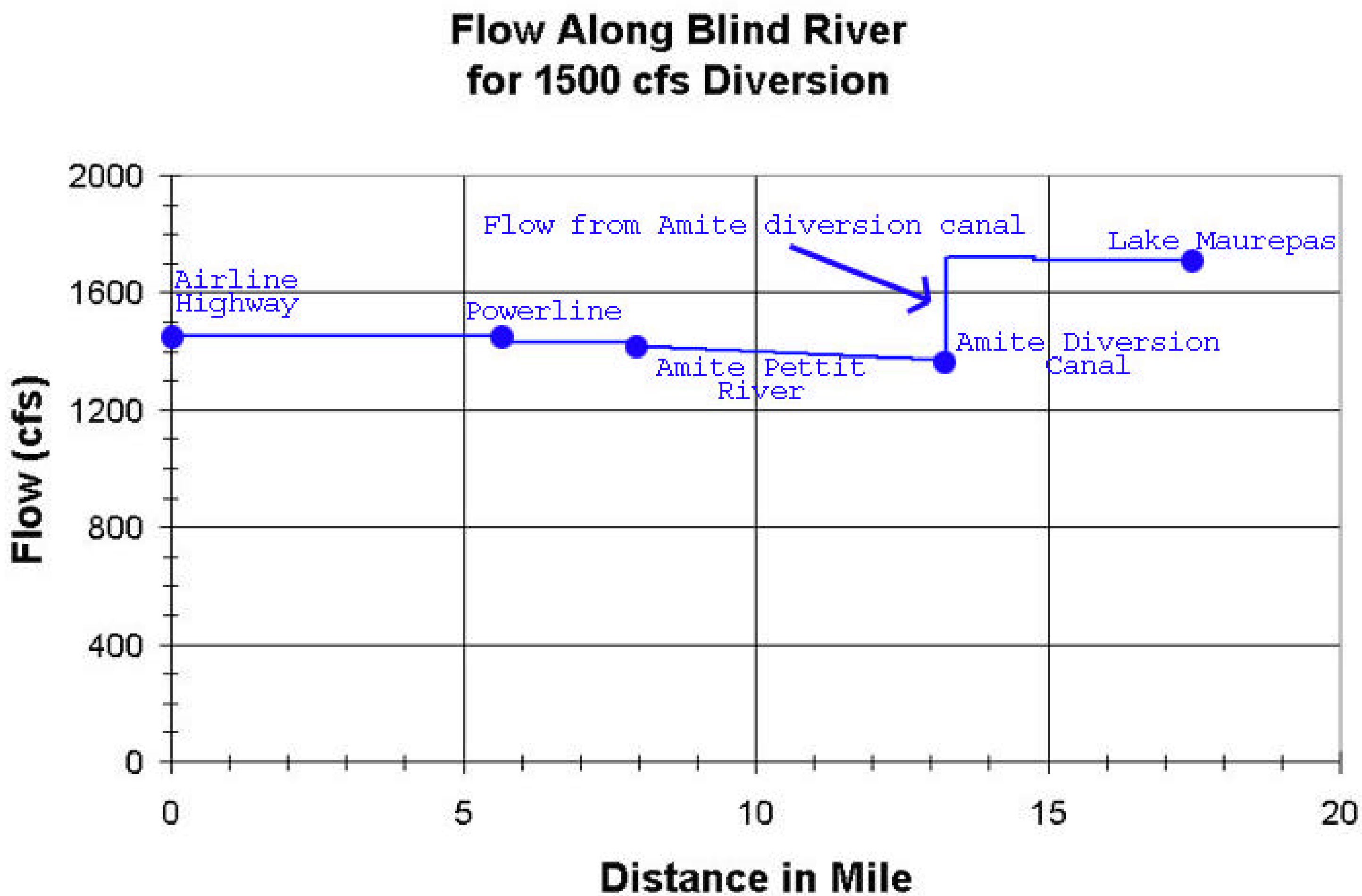



Figure AI-1. Flow along Blind River for 1500 cfs Diversion.

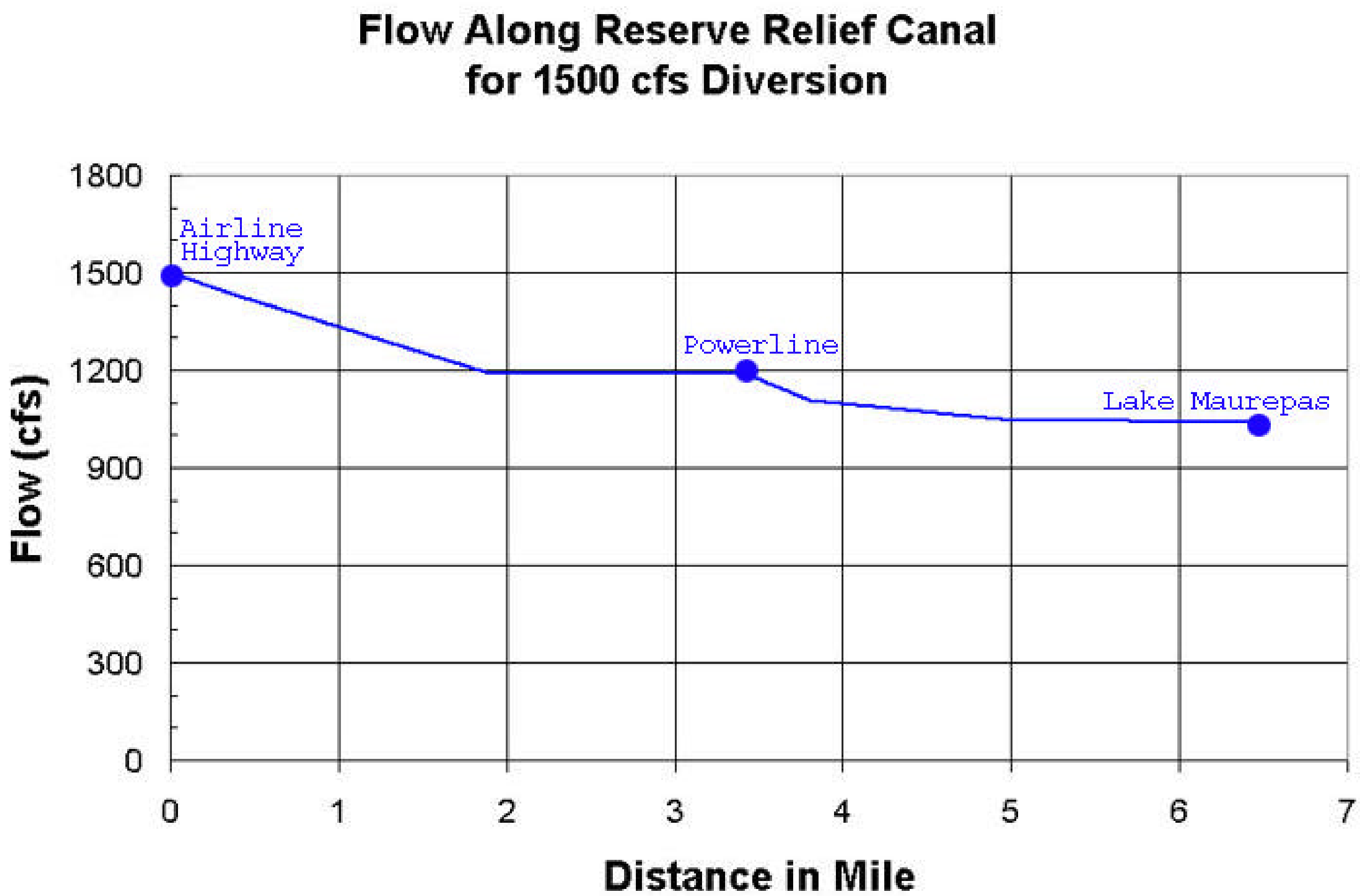



Figure AI-2. Flow along Reserve Relief Canal for 1500 cfs Diversion.

# Attachment II

# Key UNET parameters (Cards)

# LA

LA Record - Lateral Spillway Diverting Water into a Storage Area - (Optional Record)

The LA Record is used to define a lateral spillway which diverts high flows out of a reach into an adjacent storage area. The LA Record is placed just after the cross section that represents the upstream end of the spillway. The water surface elevation used in the computations is based on the average of the two cross sections that bound the spillway. Except for fields 1 and 10, the LA Record is input exactly as the SP Record. Note that the spillway width is measured along the channel, as opposed to across the channel in the case of in line (SP Record) spillways. **For spillways without gates, fields 3 through 10 are left blank. Weir sections are defined on a WD Record immediately following the LA Record.**

| Field | Variable | Value | Description |
|---|---|---|---|
| 0 | ID | LA | Record identification. |
| 1 | ICONN | + | Number of the storage area connected to the spillway. |
| 2 | ZSP | + | Elevation of crest of spillway (ft). |
| 3 | WSP | + | Width of spillway at crest (ft). This width is equal to the total width of all gates in the spillway. Width of weir sections should be described on WD Records placed immediately after the LA Record. |
| 4 | S | 0 | Compute both free and submerged flow. |
| | | 1 | Compute only free flow (use only if flow conditions are known) |
| 5 | CE | + | Discharge coefficient (rages from 0.6 to 0.8). |
| 6 | AH | + | Trunnion height (ft) (from ZSP to trunnion pivot point). |
| 7 | AHE | + | Trunnion height exponent, typically about 0.16 (for sluice gate set to 0.0). |
| 8 | BE | + | Gate opening exponent, typically about 0.72 (for sluice gate set to 1.0). |
| 9 | HE | + | Head exponent, typically about 0.62 (for sluice gate set to 0.5). |

# LA (Cont.)

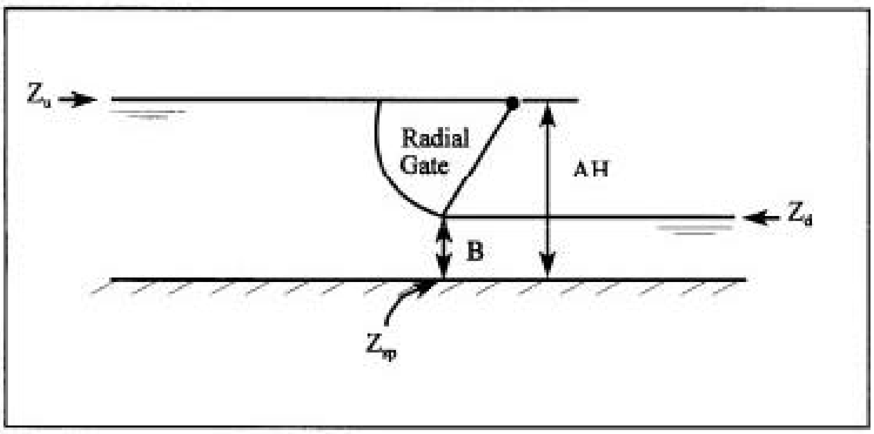
| Field | Variable | Value | Description |
|---|---|---|---|
| 10 | CSPNAME | Alpha | Name of spillway. To be used in boundary conditions file for referencing time series of gate openings. |

$$Q = CE \cdot \sqrt{2g} \cdot WSP \cdot AH^{AHE} \cdot B^{BE} \cdot H^{HE}$$

where: B = Gate opening in ft.

H = Head on the spillway

H = $Z_u$ - AVH · $Z_{sp}$ - (1 - AVH) $Z_d$



# SA

SA Record - Storage Areas - (Optional Record)

The SA Record defines a storage area. Storage areas may be connected to upstream or downstream reach boundaries, or may be filled (and drained) through a lateral spillway. The maximum number of storage areas allowed can be found in the CSECT output file under the heading "PROGRAM DIMENSIONS". A name can be attached to the storage area by placing an HS Record after the SA Record. The name placed on the HS Record will also be used as the B part of the DSS pathname. If the user does not supply an HS Record with the SA Record, the default name is SA#, where # is the user defined storage area number (IDSAENTERED).

| Field | Variable | Value | Description |
|---|---|---|---|
| 0 | ID | SA | Record identification. |
| 1 | IDSAENTERED | + | The user defined storage area number. |
| 2 | SURFA | + | The surface area of the storage in acres. |
| | | 0 | Elevation-volume relation will be defined on a subsequent SV Record. |
| 3 | Z0SA | + | Minimum elevation of storage area. |
| 4...10 | NSACON | + | Reach numbers of the reaches that use this storage area as a downstream boundary . |
| | | - | Reach numbers of the reaches that use this storage area as an upstream boundary. |

# SS

SS Record - Simple Spillway Connecting Two Storage Areas - (Optional Record)

The SS Record defines a simple spillway connection between two storage areas. The flow is defined from storage area 1 to storage area 2.

| Field | Variable | Value | Description |
|---|---|---|---|
| 0 | ID | SS | Record identification |
| 1 | ICONN1 | + | Storage area number 1. |
| 2 | ICONN2 | + | Storage area number 2. |
| 3 | ROUT12 | + | Linear routing coefficient for flow from SA 1 to SA 2 (0 < ROUTL12 ≤ 1. Generally about 0.2). |
| 4 | ROUT21 | + | Linear routing coefficient for flow from SA 2 to SA 1 (0 < ROUTLOUT ≤ 1. Generally about 0.2). |
| 5 | ZSP | + | Elevation of spillway crest. |

# WD

WD Record - Uncontrolled Overflow Weirs - (Optional Record)

The WD Record is used to define up to 25 broad-crested weir sections associated with spillway (SP, LA, LS), navigation dam (ND), Bridge (BR), and culvert (CA, CB, CC, RI) internal boundary conditions. The WD Record should immediately follow the appropriate set of the above records in the CSECT input file.

| Field | Variable | Value | Description |
|---|---|---|---|
| 0 | ID | WD | Record identification. |
| 1 | NWEIR | + | Number of weir segments (maximum of 25). |
| 2 | CWEIR | + | Broad-crested weir flow coefficient (0.0 - 4.0).* |
| 3,5,7,9 | ZWEIR | + | Elevation at crest of weir section (ft). Start with the lowest weir elevation. |
| 4,6,8,10 | WEIRL | + | Incremental width of each weir segment (ft). |

*Note: For flow over a typical bridge deck, a weir coefficient of 2.6 is recommended. A weir coefficient of 3.0 is recommended for flow over elevated roadway approach embankments. A good reference for weir coefficients is Brater and King, 1976. *Handbook of Hydraulics*, McGraw-Hill.