FINAL REPORT

VOLUME VI OF VII
TWO DIMENSIONAL HYDRODYNAMIC MODEL DEVELOPMENT AND CALIBRATION

MISSISSIPPI RIVER REINTRODUCTION INTO MAUREPAS SWAMP PROJECT PO-29

Louisiana Department of Natural Resources
U.S. Environmental Protection Agency

Revised
September 29, 2006

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URS Corporation is undertaking a Hydraulic Feasibility Study to evaluate hydrologic impacts for a proposed 1,500 cfs diversion of freshwater from the Mississippi River to the Maurepas Swamp, near Garyville, Louisiana. This study is part of the Mississippi River Reintroduction into Maurepas Swamp Project (PO-29) sponsored by the U.S. Environmental Protection Agency and the Louisiana Department of Natural Resources under the federal Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA). URS has previously submitted four volumes addressing critical data collection efforts in support of the feasibility study:

- *Volume II, Secondary Benchmark GPS Static Survey;*
- *Volume III, Topographic and Bathymetric Survey;*
- *Volume IV, Hydrologic Data*; and
- *Volume V, 1D (SWMM) Model Study.*

The Maurepas Swamp is a generally freshwater cypress-tupelo forested landscape located at the upper tidal margin of the Lake Pontchartrain/Lake Maurepas estuary system (Figure 1). The swamp is threatened by episodic brackish water intrusion from Lake Maurepas, long-term subsidence, and the elimination of nutrient inputs, a consequence largely of the century-plus isolation of the swamp from the annual nourishment of Mississippi River overbank floods. The CWPPRA Phase 0 reconnaissance level study (Lee Wilson, 2001) of a reintroduction of Mississippi River water estimated the potential wetland landscape benefits to be among the most cost-effective identified to-date in Louisiana coastal restoration. The diversion concept is illustrated in Figure 2 and features a gated structure at the river, a sand/silt settling basin, a new banked diversion channel (taking the Hope Canal alignment north of US Highway 61), and outfall management structures in the swamp north of Interstate 10 to distribute diversion water within the 50,000 acre area between Reserve Relief Canal on the east and Blind River on the west.

In the Hydraulic Feasibility Study URS is focusing on the physical hydrodynamics of the diversion and the key question of "Will the water go where we want it to go?" This question reflects four important hydrologic objectives for the project:

1. No adverse impact on the stormwater drainage systems for the Garyville-Reserve communities.

2. Broad and near-uniform distribution of diversion flow, in order to deliver nutrients, fine sediments, and freshening throughout the declining forest, and to avoid exacerbating stagnant areas.

3. Reasonable retention time to facilitate the transfer of sediments and nutrients from diversion water into the swamp and avoiding short-circuiting to Lake Maurepas. [Note: direct analysis and modeling of potential water quality impacts from diversion – including salinity, nutrients, and suspended sediments – were not part of this phase of study.]

4. Modest velocities at sensitive bank locations, such as near Interstate 10, to prevent scouring.

In order to study these issues, URS has developed and calibrated a two-dimensional (2D) numerical model of physical hydrodynamic processes, using the program ADCIRC, capable of assessing swamp water elevations, circulation patterns, retention times, and channel velocities under various diversion scenarios. The 2D model development and calibration has consisted of seven tasks:

- Review of Previous Swamp Modeling Efforts
- Planning and Numerical Code Selection
- Mesh Development and Stability Testing
- Defining Key Swamp Hydrodynamic Characteristics and Model Physical Parameters
- Physical Parameter Testing
- Calibration and Validation
- Conclusions and Recommendations

This Volume describes methodologies (including quality control review) and presents results of the 2D model development and calibration. Relevant 2D model input files and output files and supporting information are given in Appendices A through E, which are included in attached DVDs.

As part of the Hydraulic Feasibility Study, URS has also developed a one-dimensional (1D) model (SWMM) of the Garyville-Reserve drainage system. This model is described in a separate report, *Volume V, 1D (SWMM) Model Study*. The 1D SWMM model will be used in conjunction with the 2D model to support the first study objective.

URS has developed a high resolution 2D ADCIRC model, which runs on a parallel high performance computer cluster. The model represents project area features with node spacing as close as 15 feet. The model represents 2D physical hydrodynamics in the project area – including channel flow, propagation of tidal signals, overbank flow, flow through bank gaps, and swamp circulation – during a variety of conditions. However, the model is limited in simulating swamp resistance. Extensive parameter testing was conducted to improve the representation of swamp resistance and this limitation has been addressed in part by raising the elevation of the swamp floor.

URS has evaluated the performance of the "High Swamp" model through calibration and validation, and determined that the model will support a feasibility analysis of the four objectives listed above. Application of the model must carefully consider the swamp resistance limitation and implications for under-representing backwater and short-circuiting. Thus, comparing relative stage and flow differences for various scenarios under near steady flow conditions will provide the most valid analysis of diversion impacts.

URS recommends proceeding with the "High Swamp" model in the feasibility study of diversion alternatives. Several model improvements have been identified that can be pursued in the future to support project engineering and diversion operation plans.

Two major studies examining hydraulic issues associated with a Maurepas Swamp diversion have been conducted under the CWPPRA program – one prior to, and the second in parallel with, the URS Hydraulic Feasibility Study:

- *Diversion into the Maurepas Swamps, A Complex Project Under the CWPPRA Program*, (Phase 0 Report); Lee Wilson & Associates, June 2001; and
- *Development Plan for a Diversion into the Maurepas Swamp: Water Quality and Hydrologic Modeling Components,* Draft Report, under the CWPPRA Program, John W. Day, G. Paul Kemp, Hassan S. Mashriqui, Robert R. Lane, and Dane Dartez, Louisiana State University (LSU), School of the Coast and Environment, Natural Systems Modeling Group, May 2004.

In the Phase 0 Study, the Hope Canal diversion was modeled using the one-dimensional (1D) UNET program by researchers at LSU. The swamp was simulated using a series of storage areas. This study found that 1,500 cfs could gravity flow from the Mississippi River nearly year-round to the project area via a banked diversion canal, at acceptable channel elevations and velocities, and would accommodate the existing Interstate 10 overpass. Based on combining the 1D results with a simplified cell model of potential nutrient benefits, the study also concluded that the diversion project warranted further feasibility study. The limitations of the 1D model pointed toward the need for further 2D analysis of diversion swamp circulation, retention time, and local drainage impacts.

In the May 2004 study, the LSU researchers developed and calibrated an RMA2 finite element model of the project area and surrounding region to further assess long-term improvements to forest productivity. Mesh design was limited by the practical capabilities of the RMA2 single-processor application and featured certain simplifying physical assumptions. These assumptions included coarse resolution of the terrain and general representation of local channels that tended to spread the diversion water, minimize backwater, and avoid short-circuiting. These model features were consistent with confirming the potential extended areal influence of a diversion. As noted below, the LSU RMA2 model did perform well in simulating key project area hydrodynamic characteristics crucial to long-term ecosystem analysis, such as capturing multi-day stage (i.e., low frequency signal) events. The LSU model was not intended for investigating critical design feasibility issues, and the coarse mesh made it generally unsuitable for this purpose.

A third study of a Maurepas Swamp diversion was performed by an LSU graduate student: *Modeling a Mississippi River Diversion into a Louisiana Wetland*, Stephan A. Capps, Louisiana State University, MS Thesis, May 2003. Capps utilized HEC-RAS, RMA2, and QUAL2E to assess the techniques of diversion modeling and the impact of diverting flow into the *existing* Hope Canal channel. Capps noted the importance of modeling channel-swamp exchange and the impact of swamp micro-topography (including the abandoned railroad embankment) in controlling the diversion.

The 2D hydrodynamic model development has been the subject of extensive discussion, planning, and cooperative decision-making among members of the Project Team. Participants in model planning have included:

- Ken Teague and Patty Taylor, USEPA;
- Chris Williams, Russ Joffrion, and Luke Lebas, LDNR;
- Mike Patorno, Bob Jacobsen, Chris Reed, and Nathan Dill, URS Corporation;
- Joannes Westerink, University of Notre Dame, and Rick Luettich, University of North Carolina, co-authors of the ADCIRC model;
- Elizabeth Valenti and Ben Jelley (WorldWinds, Inc.), computing; and
- Paul Kemp, Hassan Mashriqui, and Dane Dartez, LSU (who were engaged in a parallel research effort of the Maurepas diversion sponsored by CWPPRA).

Based on the results of the Phase 0 Study, the Project Team agreed to focus the 2D feasibility study model domain on the 50,000 acre swamp north of US Highway 61 (Airline Highway), which surrounds the Hope Canal/Dutch Bayou waterway, as shown in Figure 3. The purpose of the 2D modeling, established by the Project Team, was to support conceptual design and evaluation of four diversion objectives:

1. The planned diversion and associated outfall management features should have no adverse impact on the stormwater drainage systems for the Garyville-Reserve communities. The existing system operates under gravity is sensitive to tailwater conditions in the swamp.

2. Broad and uniform flow distribution should be achieved to deliver nutrients, fine sediments, and freshening throughout the declining forest, and to avoid exacerbating stagnant areas.

3. The diversion water should be retained in the swamp for a reasonable time and short-circuiting to Lake Maurepas should be avoided.[1]

[1] Investigation of the particular swamp water quality processes related to the diversion – such as salinity changes and nitrate removal and fate – as well as water quality impacts to Lake Maurepas, are not a subject of this phase of work but are expected to be addressed in future studies.

4. Diversion velocities should be modest to prevent scouring, particularly at sensitive bank locations, such as near Interstate 10.

As part of planning, the Project Team evaluated RMA2 and ADCIRC, along with several other 2D hydrodynamic model codes, for use in addressing feasibility study objectives.

3.1 RMA2 EVALUATION

During the pre-project development of the scope of work and post-award planning the Project Team initially agreed on the use of RMA2 for the 2D hydrodynamic modeling. This choice was based on three primary factors:

1. The RMA2 model has an established national and LDNR record as a 2D wetland model in engineering applications[2];

2. The RMA2 model met key selection requirements (see Table 1); and

3. As noted previously, an RMA2 model (albeit with a coarser mesh) was being developed in parallel by LSU for investigating long-term ecological benefits of the diversion. The Project Team thought the ecological and feasibility modeling efforts would benefit synergistically from sharing the same model platform.

Initial work on RMA2 mesh development proceeded concurrently with the completion of comprehensive field and data collection efforts. These efforts were, in turn, planned to support a careful delineation of the wetland topography/bathymetry, and collection of time series stage/velocity data for model calibration. Specific data collection activities included:

- Establishment of a high quality survey benchmark control network;
- Surveying of more than 70 feature cross sections;
- Ground-truthing of over 200 miles of linear topographic and bathymetric features – channels, sloughs, natural and artificial banks – and swamp elevations;

[2] RMA2 had been previously selected by LDNR after an extensive review of 2D hydrodynamic models to simulate wetland circulation in the Barataria Basin under a separate CWPPRA study (Moffatt & Nichol, 2000.]

- Installation of 12 continuous stage level recorders and a velocity recorder, along with operation for 10 months, in conjunction with Louisiana State University;

Table 1
Initial 2D Hydrodynamic Code Selection Criteria

Criteria	Description
1. Finite Element	The unstructured mesh supported by finite element solutions allows for a more realistic representation of long narrow features within large flat areas with lower computational nodes. Although Finite Element methods do not provide for local conservations of mass, this limitation can typically be managed within acceptable tolerances for physical hydrodynamic analysis with adequate mesh resolution. Investigation of water quality dynamics typically requires greater emphasis on local conservation of mass.
2. Depth-Averaged	A 2D depth-averaged solution is a valid approximation since it has been determined that three-dimensional effects of salinity gradients, salt wedge dynamics and associated two-layer flows are insignificant in the swamp domain.
3. Time Dependent (Unsteady or Dynamic)	Time dependent solutions are critical in this application. The forcing conditions at the Lake are highly variable and the model calibration data are time-dependent. Also, the eventual need to consider time-dependent response to diversion start-up and shut-downs require a time-dependent solution.
4. Wetting and Drying	The inundation (wetting) and drainage (drying) of the swamp by the channels has been well established and is an important characteristic requiring representation in the model.
5. Culvert Flow	Culverts, particularly those that equalize stages across I-10, provide conveyance through roads that otherwise block the flow. These are important, especially during the simulation of the diversion and the analysis of circulation and backwater.
6. Graphical User Interface	Support by Windows-based pre- and post-processing platform with a graphical user interface (GUI), such as Surface water Modeling System (SMS), provides an efficient means to generate the model mesh and analyze results.

- Evaluation of 1m (4 GByte) and 5m (300 MByte) LIDAR data;
- Processing and evaluating of high resolution (40 GByte) aerial photography; and
- Development of Oracle-based Spatial Data Engine and an ArcIMS web-enabled project GIS to Project Team collaboration.

After some initial mesh development and testing URS determined that the mesh resolution for properly represent the swamp geometry required a significant increase in the number of nodes, beyond the level that could be effectively handled by RMA2.

The project swamp area is characterized by relatively flat terrain with a network of narrow channels and micro-topographic features (e.g., natural channel banks, spoil banks, abandoned railroad embankment, etc.) that affect conveyance throughout the project area (see *Volume III, Topographic and Bathymetric Survey*). In many areas mesh resolutions finer than 20 feet are required. Using this fine resolution for many features within a total model domain of 50,000 acres requires an overall mesh size well over 100,000 nodes.

The initial RMA2 mesh contained about 20,000 nodes, which is considered a large mesh for the application. The RMA2 model, running on a single high-end Intel processor, had a very long run-speed (ratio of simulation or "wall clock" time to the time simulated), worsening as resolution was increased. Model development (particularly resolving stability problems) thus became unwieldy due to extremely slow simulation turnaround. A complete discussion of limitations of the RMA2 model is presented in the November 2004 Project Memorandum included in Appendix A.

It should be re-emphasized that LSU's long-term ecological modeling objectives allowed different model performance features than the hydraulic engineering feasibility issues. The ecological model primarily focused on the low frequency (weeks-to-months) signals and the LSU RMA2 model simulated these signals well. On the other hand, the feasibility model also needed to capture the high (daily tidal) frequency signals in the channels and swamps, particularly as a function of stage. This characteristic is critical to accurately evaluating channel-swamp exchange and the issues of backwater, circulation, and short-circuiting. A high density mesh which resolves key swamp geometry features is thus crucial to simulating this exchange.

3.2 ADCIRC EVALUATION

The Project Team therefore chose to investigate parallelized hydrodynamic codes capable of handling larger mesh sizes[3]. Parallelized codes run on common high performance computer platforms consisting of tens (if not hundreds) of standard microprocessors arranged in parallel. The parallelized codes decompose the mesh into sub-domains and manage the individual processor assignments, the exchange of model information at sub-domain boundaries, and compiling of full domain results. By simultaneously solving equations at each sub-domain, parallel processing can reduce simulation times by factors approaching the number of processors.

URS reviewed existing parallelized codes (see Appendix A, November 2004 Memorandum), and the parallelized version of the ADCIRC code was chosen on the basis of:

- Technical compatibility with initial swamp 2D simulation requirements (see Table 1);
- Significant demonstrated experience in coastal Louisiana with the US Army Corps of Engineers;
- Proven, local, high performance computers with ADCIRC experience, and available capacity; and
- Prior working relationships among the URS lead modeler, Dr. Chris Reed, and the model authors and users.

In recent years ADCIRC has become established as the pre-eminent finite element coastal hydrodynamic code, particularly for modeling coastal storm surge. As part of both pre- and post-Katrina surge modeling for coastal southeastern Louisiana, extensive stability and parameter testing has been conducted by the authors and independent reviewers. A summary of ADCIRC program features is given in Table 2.

However, it is significant to note that prior to the Maurepas project the code authors had limited experience in applying the model to low-to-moderate turbulent conditions within very shallow wetting/drying regimes.

[3] The RMA2 code has not been parallelized, and due to advances in finite element algorithms parallelization of RMA2 in the future is not likely.

Table 2
Key Features of ADCIRC Code

See *ADCIRC User's* Manual, Introduction, http://www.unc.edu/ims/ccats/adcirc/document/Introduction.html

ADCIRC is a highly developed computer program for solving the equations of motion for a moving fluid on a rotating earth. These equations have been formulated using the traditional hydrostatic pressure and Boussinesq approximations and have been discretized in space using the finite element (FE) method and in time using the finite difference (FD) method.

ADCIRC can be run either as a two-dimensional depth integrated (2DDI) model or as a three-dimensional (3D) model. In either case, elevation is obtained from the solution of the depth-integrated continuity equation in Generalized Wave-Continuity Equation (GWCE) form. Velocity is obtained from the solution of either the 2DDI or 3D momentum equations. All nonlinear terms have been retained in these equations.

ADCIRC can be run using either a Cartesian or a spherical coordinate system.

The GWCE can be solved using either a consistent or a lumped mass matrix (via a compiler flag) and an implicit or explicit time stepping scheme (via variable time weighting coefficients). If a lumped, fully explicit formulation is specified, no matrix solver is necessary. In all other cases the GWCE is solved using the Jacobi preconditioned iterative solver from the ITPACKV 2D package.

The 2DDI momentum equations are lumped and therefore require no matrix solver. In 3D, vertical diffusion is treated implicitly and the vertical mass matrix is not lumped, thereby requiring the solution of a complex, tri-diagonal matrix problem over the vertical at every horizontal node.

ADCIRC boundary conditions include:

- specified elevation (harmonic tidal constituents or time series)
- specified normal flow (harmonic tidal constituents or time series)
- zero normal flow
- slip or no slip conditions for velocity
- external barrier overflow out of the domain
- internal barrier overflow between sections of the domain
- surface stress (wind and/or wave radiation stress)
- atmospheric pressure
- outward radiation of waves (Sommerfield condition)

ADCIRC can be forced with:

- elevation boundary conditions
- normal flow boundary conditions
- surface stress boundary conditions
- tidal potential
- earth load/self attraction tide

ADCIRC includes a least squares analysis routine that computes harmonic constituents for elevation and depth averaged velocity during the course of the run thereby avoiding the need to write out long time series for post processing.

ADCIRC has been optimized by unrolling loops for enhanced performance on multiple computer architectures. ADCIRC includes MPI library calls to allow it to operate at high efficiency (typically better than 90 per cent) on parallel computer architectures.

Version PADCIRC 45.09 was used for project parameter testing and calibration simulations (earlier versions were used during model development and stability testing). This version allowed for the specification of depth-independent spatially-varying drag coefficients. The capability to spatially vary the drag coefficient was an important consideration for the Maurepas 2D modeling, due to expected variability of bottom and vegetative resistance conditions between the deeper channels and the shallow swamp.

Following the initiation of ADCIRC model development several follow-on planning reviews occurred:

- June 2005 Plan for ADCIRC simulations;
- August 2005 A review of ADCIRC modeling scope, schedule, and budget following mesh development; and
- June 2006 Plans for finalizing calibration.

Documentation of these milestones is also included in Appendix A.

Following code selection, development of the 2D Maurepas Swamp ADCIRC model entailed three steps:

- Mesh formulation;
- Establishment of boundary conditions; and
- Model stability testing.

4.1 MESH FORMULATION

The ADCIRC mesh[4] was developed with the following guidelines, which are based on discussions with the code authors, considerations of node economy, the need to properly resolve many small linear features, and the stability characteristics of the ADCIRC model.

- The mesh element size was constrained by the Courant stability condition (based on the shallow water wave celerity):

$$L \geq f * T_S \sqrt{gH}$$

where:

f = *Factor for numerical stability*
L = *Distance between nodes*
T_S = *Model time step*
g = *Gravity*
H = *Depth of water*

URS initially developed mesh size consistent with a target simulation time step of 1 second and a general stability factor of two. This initially limited node spacing to greater than 20 feet in shallow sloughs and larger spacing in the deeper channels. Greater depths associated with the tropical storm scenario were considered the limiting case. Further mesh refinements and other subsequent stability considerations necessitated reducing mesh sizes (to less than 15 feet in some areas), as well as lowering the time-step. The stability factor for some elements was allowed to approach 1.5.

[4] The term mesh typically applies to irregular node arrangements typically used in finite element and finite volume models, while the term grid applies to regular rectangular or curvilinear node structures used in finite difference models.

- Mesh stretching was generally limited so that the increase in element area for adjacent elements is kept to 50 percent.
- Sliver triangle elements were avoided, with interior angles maintained above 20 degrees.
- Bathymetric slopes within elements were kept mild to minimize wetting/ drying instability.
- A node budget of about 150,000 nodes was developed for the mesh. This budget allowed for practical runtime simulations for the calibration periods based on the initially targeted 1 second time step and the computational speed of the parallel cluster dedicated to the project.
- Channel banks and man-made levees were represented by the ADCIRC weirs. The need for mild bathymetric slopes in part dictated the use of weirs to represent banks in order to avoid unrealistically wide features. This approach enhanced model stability and eliminated the need for additional small elements to represent the banks.
- All explicitly represented channels and other drainage features were at least three elements wide. This guideline is used to enhance model stability and was based on discussions with the code authors. With node spacing generally limited to 20 feet, the model was restricted to drainage features wider than 60 feet, although a few channels smaller than 60 ft in key locations were included (and thus over represented).
- Gaps in the banks or man-made features were represented using bathymetry.

In order to facilitate mesh development URS used the various field survey data sources, as well as LIDAR data to construct a detailed digital terrain model (DTM) of the project area swamp (see *Volume III, Topographic and Bathymetric Survey*). The DTM included a complete set of vertices and edges generated with Land Development Desktop 3D tools to represent linear features, transitions, intersections. The DTM encompassed over 2.5 million vertices, and 175 miles of linear features within the 50,000 acre swamp area. DTM swamp points were generated as random elevations between 0 and +1 foot, consistent with swamp surveys.

The mesh was developed in two phases. In the first phase, a set of nodes representing the channels, natural banks, spoil banks, roads, and other linear features were prepared. Table 3 documents how bathymetric cross-section data (width, area, and wetted perimeter) for each major channel were converted to an equivalent ADCIRC cross-section. Land Development Desktop (LDD) 3D, a terrain modeling tool, was then used to construct equivalent cross-sections along actual channel alignments. In this way a complete set of channel nodes was generated (see Figure 4). Transitions and intersections of channel nodes were also created in LDD. The system of nodes representing the channels was then imported into the Surface-Water Modeling System (SMS) software for the final mesh development. ADCIRC weirs were used to represent natural and artificial banks, interrupted with bank gaps represented by bathymetric nodes. Bank elevations and gap widths and inverts, were set to values consistent with the *Volume III, Topographic and Bathymetric Survey*.

The nodes within each feature were connected to form finite elements. The outer edges of the features were then converted to map arcs (within the SMS system). This process created a series of polygons formed by the intersection of each drainage or levee feature, as shown in Figure 5. The mesh within the interior of these polygons was then generated using the SMS mesh generation tools. The mesh was "stretched" from the higher resolution, smaller elements along each feature into lower resolution, larger elements within the swamp and lake interior. This stretching process provided the high resolution needed to resolve the thin features, and simultaneously reduced the total number of nodes (and elements) within the mesh.

Field and LIDAR data showed the swamp floor elevation ranging between 0 and +1 foot elevation (NAVD-88, LDNR) throughout the area, (which is below the average water level in the swamp). Coherent variations in the swamp floor within this range, such as shallow undulations and ponds, could not be identified. The first approach to representing the swamp floor was to generate mesh elevations with random variations between 0 and 1 foot throughout the swamp interior. However, during the initial modeling simulations it was determined that random gradients in bottom elevation caused an excessively "noisy" wetting and drying and led to numerical instability problems.

URS adopted a second approach of using a uniform swamp floor, and the value was initially set at 0.5 feet. This approach eliminated the numerical instabilities and was used as the mesh configuration during the remaining stability testing. Because the swamp floor elevation is a key control for swamp storage volume and channel-swamp exchange this value is considered an important physical parameter that could be adjusted – within a reasonable range – during model parameter testing (see Section 6).

Table 3
Correlation of DTM Cross Section to ADCIRC Cross Sections

Channel	Cross Section	Detailed Terrain Model--Ref. El. -0.5				ADCIRC Terrain Model Channel--Ref. El. -0.5											% Diff in Area
		Width	Area	WP	Invert	Width	No. Elements	Avg Spacing	BL1	BL2	BL3	BL4	BL5	BL6	Area	WP	
AIRLINE CANAL	C25	103.8	755.0	107.0	-11.3	100	3	33.3	-0.5	-11.0	-12.0	-0.5			733.3	103.6	2.9%
ALLIGATOR BAYOU	N3	85.2	269.0	86.0	-6.4	90	3	30	-0.5	-6.0	-4.0	-0.5			270.0	90.8	-0.4%
AMITE DIVERSION	DIVERSION	361.9	7708.0	372.0	-37.0	360	4	90	-0.5	-24.0	-40.0	-24.0	-0.5		7785.0	368.9	-1.0%
BAYOU BEC CROCHE	N20	53.6	102.0	54.0	-3.9	60	4	15	-0.5	-2.5	-4.0	-2.0	-0.5		105.0	60.4	-2.9%
BAYOU SECRET	N10	75.3	251.0	77.0	-6.5	72	3	24	-0.5	-5.0	-7.0	-0.5			264.0	73.4	-5.2%
BAYOU SECRET	N9	64.2	275.0	67.0	-8.5	72	3	24	-0.5	-5.0	-7.0	-0.5			264.0	73.4	4.0%
BAYOU TENT	N16	126.2	311.0	127.0	-6.5	120	5	24	-0.5	-3.0	-7.0	-3.0	-2.0	-0.5	312.0	120.9	-0.3%
BAYOU TENT	PO8	79.4	218.0	80.0	-5.0	80	5	16	-0.5	-3.0	-5.0	-5.0	-3.0	-0.5	224.0	80.6	-2.8%
BLIND RIVER	N2	480.9	8710.0	489.0	-29.2	480	5	96	-0.5	-18.0	-30.0	-30.0	-15.0	-0.5	8736.0	484.6	-0.3%
BLIND RIVER	N5	361.8	9547.0	387.0	-51.5	360	5	72	-0.5	-22.0	-50.0	-40.0	-22.0	-0.5	9504.0	374.4	0.5%
BLIND RIVER	N7	231.4	3125.0	245.0	-32.4	240	5	48	-0.5	-10.0	-30.0	-20.0	-10.0	-0.5	3264.0	247.9	-4.4%
BLIND RIVER	PO10	429.5	9099.0	439.2	-37.0	430	5	86	-0.5	-20.0	-38.0	-30.0	-20.0	-0.5	9116.0	437.2	-0.2%
BLIND RIVER	PO14	410.8	9776.0	421.0	-39.5	410	5	82	-0.5	-20.0	-40.0	-40.0	-20.0	-0.5	9676.0	419.4	1.0%
BLIND RIVER	PO15	214.1	2465.0	219.0	-19.0	220	5	44	-0.5	-10.0	-20.0	-20.0	-10.0	-0.5	2552.0	224.3	-3.5%
BLIND RIVER	PO16	231.7	1450.0	233.0	-11.5	220	5	44	-0.5	-6.0	-12.0	-12.0	-6.0	-0.5	1496.0	221.5	-3.2%
BLIND RIVER	PO17	105.0	990.0	111.0	-15.5	100	5	20	-0.5	-10.0	-16.0	-16.0	-10.0	-0.5	1000.0	106.0	-1.0%
BOUGERE BAYOU	N21	28.9	22.0	29.0	-2.0	30	2	15	-0.5	-2.0	-0.5				22.5	30.1	-2.3%
BOUGERE CANAL	C20	2.4	0.3	2.5	-0.8	30	1	20	-0.5	-0.5					0.0	20.0	100.0%
BOUGERE CANAL	C4	1.9	0.3	2.0	-0.8	30	1	20	-0.5	-0.5					0.0	20.0	100.0%
BOURGEOUS CANAL	N12	85.5	354.0	87.0	-7.4	90	3	30	-0.5	-6.0	-8.0	-0.5			390.0	91.5	-10.2%
BOURGEOUS CANAL	N8	97.6	406.0	97.0	-8.1	90	3	30	-0.5	-6.0	-8.0	-0.5			390.0	91.5	3.9%
CANAL	N17	64.1	207.0	65.0	-5.8	60	2	30	-0.5	-6.0	-0.5				165.0	61.0	20.3%
CANAL	N17B	49.7	160.0	51.0	-5.8	60	2	30	-0.5	-6.0	-0.5				165.0	61.0	-3.1%
COCO BAYOU	N25	58.8	19.0	59.0	-1.0	60	2	30	-0.5	-1.0	-0.5				15.0	60.0	21.1%
CROSS OVER CANAL	C13	19.5	6.9	19.6	-1.0	30	2	15	-0.5	-1.0	-0.5				7.5	30.0	-9.0%
DITCH	C1	8.5	3.2	8.7	-1.0	30	1	20	-0.5	-0.5					0.0	20.0	100.0%
DITCH	C3	11.7	1.6	11.7	-0.7	30	1	20	-0.5	-0.5					0.0	20.0	100.0%
DUTCH BAYOU	N18	130.2	633.0	132.0	-10.8	130	5	26	-0.5	-4.0	-11.0	-8.0	-4.0	-0.5	650.0	131.9	-2.7%
DUTCH BAYOU	PO4	132.5	1030.0	135.0	-12.5	130	5	26	-0.5	-8.0	-13.0	-12.0	-8.0	-0.5	1014.0	132.9	1.6%
DUTCH BAYOU	PO9	129.5	458.0	131.0	-7.0	130	5	26	-0.5	-4.0	-7.0	-5.0	-4.0	-0.5	468.0	130.7	-2.2%
EAST MARATHON CANAL	C17	14.7	15.7	15.2	-2.2	20	2	10	-0.5	-2.0	-0.5				15.0	20.2	4.6%
GODCHEAUX CANAL	C14	39.4	91.0	41.0	-5.1	40	2	20	-0.5	-5.0	-0.5				90.0	41.0	1.1%
GODCHEAUX CANAL	C8	33.6	36.0	34.0	-2.0	40	2	20	-0.5	-2.0	-0.5				30.0	40.1	16.7%
HOPE CANAL	C2	49.7	108.0	50.0	-4.0	50	5	10	-0.5	-3.0	-4.0	-4.0	-2.0	-0.5	110.0	50.7	-1.9%
HOPE CANAL	C21	61.5	133.0	62.0	-4.1	60	5	12	-0.5	-3.0	-4.0	-4.0	-2.0	-0.5	132.0	60.6	0.8%
HOPE CANAL	N13	55.8	137.0	57.0	-5.0	55	5	11	-0.5	-3.0	-5.0	-4.0	-3.0	-0.5	143.0	55.8	-4.4%
HOPE CANAL	PO5	119.3	362.0	121.0	-5.0	120	5	24	-0.5	-4.0	-5.0	-5.0	-3.0	-0.5	360.0	120.5	0.6%
HOPE CANAL	PO6	51.0	135.0	52.0	-4.5	50	5	10	-0.5	-3.0	-5.0	-5.0	-3.0	-0.5	140.0	51.0	-3.7%
HOPE CANAL	PO7	84.5	384.0	87.0	-7.5	85	5	17	-0.5	-5.0	-8.0	-8.0	-4.0	-0.5	391.0	86.7	-1.8%
MISSISSIPPI BAYOU	C30	35.4	41.0	36.0	-2.4	35	5	7	-0.5	-2.0	-3.0	-2.0	-1.0	-0.5	42.0	35.4	-2.4%
MISSISSIPPI BAYOU	N19	124.7	512.0	126.0	-8.0	125	5	25	-0.5	-5.0	-8.0	-6.0	-4.0	-0.5	525.0	126.0	-2.5%
MISSISSIPPI BAYOU	N24	48.2	95.0	49.0	-3.5	50	5	10	-0.5	-2.0	-4.0	-4.0	-2.0	-0.5	100.0	50.6	-5.3%
MISSISSIPPI BAYOU	PO11	63.1	196.0	64.0	-5.3	65	5	13	-0.5	-3.0	-6.0	-5.0	-3.0	-0.5	195.0	66.0	0.5%
MISSISSIPPI BAYOU	PO12	30.1	24.0	30.0	-2.1	30	5	6	-0.5	-1.0	-2.0	-2.0	-1.0	-0.5	24.0	30.2	0.0%
MISSISSIPPI BAYOU	PO13	137.5	423.0	139.0	-5.0	140	5	28	-0.5	-4.0	-5.0	-5.0	-3.0	-0.5	420.0	140.4	0.7%
NORTH OILFIELD CANAL	PO2	102.5	510.0	104.0	-8.4	105	3	35	-0.5	-8.0	-8.0	-0.5			525.0	106.6	-2.9%
NUMBER 12 CANAL	N11	63.6	167.0	65.0	-6.3	60	3	20	-0.5	-6.0	-3.5	-0.5			170.0	61.1	-1.8%
RESERVE RELIEF CANAL	C10	92.4	231.0	93.0	-5.2	90	5	18	-0.5	-3.0	-5.0	-4.0	-3.0	-0.5	234.0	90.5	-1.3%

Channel	Cross Section	Detailed Terrain Model--Ref. El. -0.5				ADCIRC Terrain Model Channel--Ref. El. -0.5												% Diff in Area
		Width	Area	WP	Invert	Width	No. Elements	Avg Spacing	BL1	BL2	BL3	BL4	BL5	BL6	Area	WP		
RESERVE RELIEF CANAL	C9	71.7	160.0	72.0	-4.6	75	5	15	-0.5	-2.0	-5.0	-4.0	-2.0	-0.5	165.0	75.6		-3.1%
RESERVE RELIEF CANAL	N27	164.8	873.0	167.0	-10.8	160	5	32	-0.5	-5.0	-11.0	-9.0	-5.0	-0.5	896.0	161.5		-2.6%
RESERVE RELIEF CANAL	PO1	176.5	1027.0	178.0	-10.3	175	5	35	-0.5	-5.0	-11.0	-11.0	-5.0	-0.5	1050.0	176.6		-2.2%
RESERVE RELIEF CANAL	PO3	147.1	962.0	150.0	-12.5	150	5	30	-0.5	-5.0	-13.0	-11.0	-5.0	-0.5	960.0	152.4		0.2%
SOUTH BAYOU	N15	73.1	131.0	74.0	-3.2	75	3	25	-0.5	-3.5	-3.0	-0.5			137.5	75.3		-5.0%
SOUTH BAYOU	N15B	28.8	47.0	30.0	-3.2	30	2	15	-0.5	-3.5	-0.5				45.0	30.6		4.3%
SOUTH OILFIELD CANAL	N26	91.1	341.0	93.0	-7.6	90	3	30	-0.5	-8.0	-5.0	-0.5			360.0	91.4		-5.6%
WEST BAYOU	N14	54.3	76.0	55.0	-2.4	60	2	30	-0.5	-3.0	-0.5				75.0	60.2		1.3%
WEST INTERSTATE CANAL	N29	215.2	1405.0	217.0	-11.0	210	3	70	-0.5	-11.0	-10.0	-0.5			1400.0	211.4		0.4%

Figure 6 presents the complete mesh domain with the bathymetry/topography. This complete mesh included over 168,000 nodes and 290,000 elements. Detailed features of the ADCIRC mesh are shown in a sequence of figures, Figure 7a through 7i.

4.2 ESTABLISHMENT OF BOUNDARY CONDITIONS

The ADCIRC mesh boundaries are illustrated in Figure 3. Several model boundaries follow actual physical features which act as real flow or water surface elevation (head) constraints. The interior of Lake Maurepas was set as a constant head boundary across the northeast corner of the domain. The boundary within the Lake was located sufficiently far from the mouths of Dutch Bayou, Blind River, and Reserve Relief Canal to allow free flow into those features. Airline Highway and the series of local man-made levees and roads, which generally exceed an elevation of 6 feet, form a no-flow boundary along the southern portion of the domain.

There are no obvious physical boundaries to the east and west, and model boundaries were chosen to minimize the mesh area and number of nodes, while limiting their influence on the solution. An initial set of boundaries were developed by extending the mesh a short distance to the west of Blind River and to the east of Reserve Relief Canal. The concept in setting these boundaries is that both of these larger channels have significant conveyance and they are not greatly influenced by the exchange with the adjacent swamp (the conceptual model of swamp hydrodynamics is discussed in Section 5). This placement is considered sufficient for the project modeling since these two large channels will tend to intercept and divert flows to the Lake. This assumption was subsequently tested and found to be valid (see Section 6.2.5). Model boundary forcing consists of surface elevations at the Lake boundary and discharges into the numerous channels that enter from the southern boundary or from the west, such as Blind River, Conway Canal, and the Amite River Diversion Canal (ARDC). In simulations of observed conditions, the Lake stage boundary was typically set using the gage data at S-3 (the mouth of Reserve Relief Canal). Project area flow input locations used in the model are shown in Figure 3. Descriptions of these inputs and typical flows are provided in the URS *Volume IV, Hydrologic Data*. The input flow time series for the southern Garyville-Reserve locations for each simulation were developed using a SWMM model of the upland urban and agricultural areas. The details of the SWMM model are available in *Volume V, 1D (SWMM) Model Study*. Input flows from the west were based on estimated run-off and USGS flow gages on the ARDC at Port Vincent.

4.3 STABILITY TESTING

URS performed stability testing of the model hydrodynamics in two phases: initial and follow-on. During initial stability testing – which featured only model forcing from the Lake boundary using an early hydrograph from gage S-4 (Dutch Bayou at Lake Maurepas) – the mesh went through eight basic revisions (Version 1 through 8, each with numerous sub-revisions). The mesh required considerable smoothing and refinement in element size and bathymetric variations, taking more than 20 stability trials over an 18 week period. The first phase culminated with a stable run of a 20-day simulation using a preliminary mesh consisting of over 120,000 nodes.

Performing full mesh simulations on a single serial processor was impractical – with serial run-speeds on the order of 1:4 (actual simulation/"wall-clock" time versus the model period time being simulated). URS occasionally constructed a partial mesh of key features to conduct limited in-house stability trials. The majority of initial stability runs were performed using a full mesh on a parallel computer cluster consisting of 16 Athlon P2100 processors operated by WorldWinds, Inc. (located in Stennis, Mississippi). At the 0.5 second time step (see below) simulations achieved run-speeds approaching 3:1, or about 12 times faster than a serial run. Often a simulation would run for several days (wall-clock) before going unstable. Due to the challenging nature of identifying and resolving mesh instabilities, simulation output was saved at routine intervals. Following crashes, simulations would be restarted at the previous saved time-step and re-run with more frequent output to aid in diagnosing the source of instabilities.

Appendix B provides a Simulation Log and includes descriptions of the Maurepas diversion ADCIRC model stability tests. URS prepared input files in accordance with ADCIRC requirements (Luettich and Westerink, 2005, Online User Manual), primarily using the SMS and ADCIRC-PREP (a code for parallelizing the simulation). Model output was post-processed using SMS, primarily to prepare observed versus modeled hydrographs. [Due to the very large file sizes (typically over 500 MB for the combined input and output files) and the extensive number of initial and follow-on stability tests (approaching 50) URS has not included file copies of these stability simulations with this Volume. Digital copies can be made available.]

In addition to mesh refinement, during the first phase testing URS evaluated and determined settings for several ADCIRC stability parameters[5]:

Time-step, (0.5 and 0.25 seconds). Time-steps are the small increments of time over which the numerical solution is performed. As noted above, the time-step must be consistent with the length between nodes for the Courant stability condition. In addition, wetting and drying and other model operations often require further reduction of the time-step. While the time-step can theoretically be lowered to any value to improve stability, practical considerations of simulation time normally dictate making other model changes to "optimize" model performance. URS initially targeted a time-step of 1 second. However, after many iterative mesh and numerical parameter adjustments URS determined that a high resolution mesh would require a time step of 0.5 seconds in order to maintain stability for most simulations. A time-step of 0.25 seconds was necessary to simulate conditions with very high water elevations, such as the tropical storm scenario.

Tau_0 , (0.03). Tau_0 is a numerical parameter which weights the relative contribution of the primitive and wave portions of the GWCE.

= 0, the GWCE is a pure wave equation.

> 0, the GWCE becomes a pure primitive continuity equation. The authors suggest setting Tau_0 to equal the largest expected value of speed*friction coefficient/depth. Typical values for Tau_0 are in the range of 0.001 to 0.01.

< 0, uses a depth-dependent variable Tau_0 scheme. If the depth is >=10 Tau_0 is set to 0.005, if the depth is < 10, Tau_0 is set to 0.020.

A significant number of trials were expended to determine that a Tau_0 value of 0.03 was needed to keep the model stable under a range of forcing conditions.

Convergence criteria and maximum number of iterations, (1×10^{-8} and 35). These numerical parameters constrain the solver used for the GWCE.

[5] ADCIRC Parameter Definitions: http://www.marine.unc.edu/C_CATS/adcirc/document/parameter_defs.html

DRAMP, (0.5 days.) This numerical parameter is used to compute the ramp function that ramps up ADCIRC forcings from zero.

H0 , (0.02 feet). This numerical parameter establishes the minimum depth of water that must be present at a node for it to be active. This parameter helps to keep nodes/elements from repeatedly turning on and off during the wetting/drying process. Raising the value of H0 increases node resistance to wetting. The ADCIRC manual notes that a typical value might be 0.01 to 0.1 m. Due to the shallow water depths in the Maurepas project, URS used a value slightly below this range.

VELMIN, (0.02 feet/second). This numerical parameter establishes the minimum velocity for wetting. A dry node wets if a water surface slope exists that would drive water from a currently wet node to the dry node and the steady-state current velocity that resulted would have a velocity > VELMIN. This parameter helps to keep nodes from repeatedly turning on and off during the wetting process. Raising the value of VELMIN increases node resistance to wetting. The ADCIRC manual notes that a typical value might be 0.05 m/s. Due to the shallow water depths and low velocities in the Maurepas project, URS used a value slightly below this range.

Horizontal eddy viscosity, (10 feet^2/second). Horizontal eddy viscosity is a physical parameter which represents the diffusion of momentum and is generally a function of the characteristics of the local flow regime. In numerical modeling, eddy viscosity values can also depend on the scale of the mesh, with higher values being appropriate for large mesh spacing. For a given mesh size, increasing eddy viscosity can increase the numerical stability of models. However, artificially raising eddy viscosity values to achieve numerical stability can produce a physically unrealistic model. With extensive mesh editing, URS was able to achieve stable results with a horizontal eddy viscosity value of 10 feet^2/second, which is considered physically reasonable (Martin and McCutcheon, 1999). In their RMA2 model the LSU researchers used an eddy viscosity value of 400 pound-seconds/feet^2. This value equates to a value of 206 feet^2/second – a factor of 20X the URS ADCIRC value – and is indicative of the larger LSU mesh elements (although not nearly 20X the ADCIRC mesh) and stability challenges in developing a Maurepas mesh.

Following the initial stability simulations the WorldWinds, Inc. parallel cluster was upgraded to 32 Xeon 64-bit processors (Intel 7520 dual-core 3.0GHz with, 2GB DIMM). The dual core processors allow for the assignment of 64 sub-domains. The resulting run speed approached 10:1 using the 0.5 second time step and 5:1 for a 0.25 second time step. URS then undertook an additional 20-plus stability trials (through mesh Version 31, see Appendix B) over a 20 week period (delayed by Hurricane Katrina and the cluster upgrade) in order to complete the model mesh. These tests primarily served to further refine the channel and swamp bathymetry and bank weir features in the preliminary mesh and to assess stability under various forcing conditions.

The version of ADCIRC used by URS during the initial and follow-on stability analysis did not support a spatially variable drag coefficient (see Section 5.2.1 below). This feature was under development by the code authors and release was delayed by Hurricane Katrina until early 2006. Therefore, until this version was released URS conducted model stability tests using a spatially constant drag coefficient and added cross-channel weirs (e.g., at gaps, channel intersections, and channel-swamp dead-end openings) to aid in controlling channel-swamp exchange. Some experimentation with the weir coefficients during the stability tests facilitated the mesh refinement. During the last rounds of stability tests URS removed these cross-channel weirs, added the spatially variable drag coefficient values, and completed the mesh refinements.

The comprehensive hydrologic data captured by URS and LSU (presented in the *Volume IV, Hydrologic Data*) illustrate that the Maurepas Swamp physical hydrodynamics encompass a complex range of conditions and characteristics. This section provides a summary of these characteristics, which comprise a *conceptual model* of the swamp hydrodynamics, along with the key ADCIRC physical parameters used to model them.

5.1 SUMMARY OF MAUREPAS SWAMP HYDRODYNAMIC CHARACTERISTICS

Stage data were collected for twelve months at key swamp locations shown in Figure 8. (Information on each gage is presented in the *Volume IV, Hydrologic Data*, Table 3.) The hydrologic data includes stage hydrographs for three critical data periods, organized by the five project area waterbodies; (Lake Maurepas, Blind River, Reserve Relief Canal, Hope Canal, and Mississippi Bayou; fifteen figures – one for each waterbody for each of the three periods – are provided as Figures 11 through 25 in the *Volume IV, Hydrologic Data*). The periods are:

- December 26, 2003 to January 25, 2004, which covers the period used by the LSU researchers to calibrate their RMA-2 model;
- April through June 2004, during which the project period low occurred on Lake Maurepas, followed by a modest flood on the ARDC and Blind River; the period also included the 3-day 5-inch Garyville rain event.
- September through October 2004, which saw the passage of *three* tropical storms: Hurricane Ivan (as it passed to the east of Louisiana toward a northwest Florida landfall); Tropical Storm Ivan (when the storm regenerated in the Gulf of Mexico and passed to the south of Louisiana); and Tropical Storm Matthew, which passed directly over the project area.

Velocity data were collected using an Acoustic Doppler Current Profiler (ADCP) at S-9 (Dutch Bayou, just downstream of the confluence of Tent and Mississippi Bayous.) Velocity hydrographs for these same three periods are given in the *Volume IV, Hydrologic Data* (Figures 26, 27, and 28).

The hydrographs illustrate conditions under which stage and velocities within the project area are controlled by 1) direct precipitation and evapo-transpiration, 2) rainfall runoff flow from the network of drainage channels to the south and west, and 3) Lake Maurepas[6]. Drainage inflows are routed through the swamp to the Lake via Hope Canal/Bayou Tent and Mississippi Bayou, which join to form Dutch Bayou. The Blind River and Reserve Relief Canal channels on the west and east edges of the project area convey much larger drainage flows than the Hope Canal/Mississippi Bayou system. Lake Maurepas introduces diurnal tidal (high frequency) impacts into the swamp, as well as multi-day (low frequency) stage/velocity events. Lake signals are carried into the project area via Dutch Bayou and the surrounding Blind River and Reserve Relief Canal, and then propagated in interior channels such as Bayou Tent/Hope Canal, Mississippi Bayou, and numerous other smaller natural and man-made tributaries.

Table 4 presents a detailed listing of the physical hydrodynamic characteristics of the Maurepas Swamp illustrated by the observed hydrographs. In addition to surface water gradient and velocity properties common to flat wetlands, the hydrographic data exhibit characteristics associated with diurnal tidal signal propagation (over-banking elevation signatures) and multi-day signal propagation (channel-swamp resistance). As stated in the *Volume IV, Hydrologic Data*:

> …tidal signals are typically propagated up the project area channels only at low stages. However, as stages rise and channels flow into adjacent swamps, tidal signals are lost. Over-banking occurs in two phases: 1) as stages reach the inverts of bank gaps, limited flow is exchanged via the small openings; and 2) with further stage increase channels overflow their entire banks. After stages fall below bank level, the tidal signal is once again seen. Thus, the characteristics of high frequency signal propagation in the channel hydrographs reflect the elevation of gaps and banks, which control the stage-dependent exchange between the channels and swamp.

The elevation of gaps and banks are described in the *Volume III, Topographic and Bathymetric Survey* and *Volume IV, Hydrologic Data* and have been incorporated into the basic model mesh (as described in the previous Section) with very high resolution and reasonable accuracy.

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[6] Surface water in the Maurepas project area is not influenced by two-phased density flow. Data collected by LSU in 2002-2003 showed project area salinity generally below 0.5 PSU (Day et. al., 2004). During the 2000 drought levels in Dutch Bayou reached 5 PSU (Lee Wilson, 2001).

The *Volume IV, Hydrologic Data* goes on to state:

> The low frequency signatures of the system—including both the incoming (or filling/ wetting) and outgoing (or draining/drying) phases of the events—are important indicators of several "resistance" factors which control the extent/rate of channel-swamp exchange:
>
> - Bottom friction, or shear stress, in the swamp,
> - Vegetation form drag in the swamp,
> - The bottom friction and drag for the gaps and banks, and
> - The "effective" floor elevation and exchangeable volume of interior swamp areas,

Friction and drag parameters are discussed in the following sub-section. As noted in Section 4.1, the "effective" swamp floor elevation can vary several tenths of feet from the mean value of 0.5 feet, and this value also serves as a model physical parameter.

5.2 KEY PHYSICAL PARAMETERS

The ADCIRC Maurepas Swamp model entails the specification of two empirical resistance parameters: a drag coefficient ($C_{D\text{-}ADCIRC}$) for each mesh node (channels, swamp, and gaps), and a weir coefficient (C_{WEIR}) at all banks represented as weirs.

5.2.1 Drag Coefficient

In ADCIRC node drag resistance is parameterized using the quadratic expression for turbulent flow bottom boundary shear stress:

$$\tau_0 = C_{D-ADCIRC} \quad \rho V^2$$

where:

τ_0 = *shear stress*

ρ = *density of water*

V = *velocity*

Table 4
Summary of Physical Hydrodynamic Characteristics of the Maurepas Swamp

Water Surface Gradients and Velocity ▪ Channel water surface slopes within the project area are typically very mild, consistent with the very flat project area topography and bathymetry. From Hope Canal at Airline Highway to the mouth of Dutch Bayou the water surface slope averages 5 x 10^{-6}, with maximum gradients in either direction of about 1 to 3 x 10^{-5} ▪ Along Bougere Canal/Bayou, gradients are slightly steeper in the Central Swamp than the North Swamp, due to the greater hydrologic isolation of the Central Swamp. ▪ There is typically a slight gradient in the North Swamp from Hope Canal towards Blind River. ▪ The typical slope of the surface water within the swamp interior is likely to be very low—less than 1 x 10^{-6}. At very low gradients the flow is stagnant and critical thresholds for turbulence may not be reached. [Velocities are orders of magnitude lower under laminar conditions than under turbulent conditions.] ▪ The average velocity of Dutch Bayou (at gage S-9, just downstream of the confluence of Tent and Mississippi Bayous) is 0.18 feet per second (fps). The maximum downstream (toward Lake) and maximum upstream velocities are 1.2 and 1.1 fps, respectively. ▪ During rainfall events, and for a few days after, drainage from the upland areas to the south, and from the Blind River and ARDC to the west, dominates the hydrographs in the channels.
Tidal Signal Propagation and Channel Over-banking ▪ As shown in the LSU Calibration Period tidal signals are easily propagated up the larger, more efficient boundary channels, Blind River and Reserve Relief Canal. Due to the size of these channels, lags are very short (at most a few hours), with shorter lags and minor dampening at low channel flow and low interfering winds. When stages rise above 1.5 ft on the Blind River and about 1.2 ft on Reserve Relief Canal, tidal signals are lost. Similarly, tidal signals return when stages return to these elevations. ▪ Tidal signals are also propagated up Dutch Bayou to S-9 with minor lags and dampening, with signal loss at about 1.5 ft ▪ Upstream to Hope Canal and Mississippi Bayou at I-10 (S-7 and S-11) signal propagation is clear only when the stage is well below 1 foot, with delays of several hours and dampening on the order of 50 percent. As stages approach 1 ft, exchange with the low swamp via bank gaps occurs and signals are lost. ▪ Tidal signals are further delayed and dampened through Upper Hope Canal (S-5). The total lag from the Lake exceeds five hours and magnitudes are dampened over 50 percent, with over-banking occurring at stages below 1 ft. ▪ Tides propagate into the North Swamp (S-23) but are much more dampened than in the channels. Tides do not appear to propagate into the isolated central swamp (S-25). ▪ Comparison of the velocity and stage hydrographs at S-9 shows that the tidal velocity and stage signals are generally in phase.

Table 4 Continued

Summary of Physical Hydrodynamic Characteristics of the Maurepas Swamp

Low Frequency Signal Propagation and Channel-Swamp Exchange Resistance

- Low frequency propagation characteristics are stage dependent, indicating that resistance factors vary with water depth, which is consistent with the physical nature of shear stress, drag, and swamp storage. [Low gradient conditions may also induce very low turbulence.]
- For small 1-to-2 foot Lake signals (e.g., Hurricane and TS Ivan), propagation is influenced by prior overall area stages. The Lake signals for Hurricane and TS Ivan were nearly identical (2.6 and 2.7 ft at S-3). However, the Hurricane Ivan signal took much longer to advance through the system due to the prior low stage (about 1.0 throughout the area), whereas the Tropical Storm Ivan surge followed within a week of the Hurricane Ivan surge when the area was already at elevation 1.5.
- Signals typically propagate up the more efficient Reserve Relief Canal and Blind River faster than the two main interior channels, Hope Canal and Mississippi Bayou, and with less dampening.
- A noticeable exception is the TS Matthew surge at S-16 (Blind River and I-10) which may have been impacted by rainfall.
- Propagation of the TS Ivan event up Mississippi Bayou and Hope Canal showed a lag of about 30 hours and dampening of about 20 percent. These results were slightly shorter and lower than for Hurricane Ivan (reflecting the prior setup of the area.)
- The same comparisons can be drawn for signal delay and reduction at Hope Canal at Airline Highway (S-5) and in the north and central swamps (S-23 and S-25).
- Signal lags and peak reductions were lower for TS Matthew—possibly due to the interference of rainfall. However, lower lags and dampening would also be consistent with reduced resistance for a higher surge.
- Propagation up Mississippi Bayou to I-10 is slightly faster than Hope Canal, consistent with the former being a slightly more efficient channel.
- During the drawdown after high events, the channels, particularly upper (north) reaches, remain slow to drain for some period of time, showing evidence of continued recharge from swamp storage areas. However, as general water elevations decline, recharge from the swamp falls off dramatically and channel levels fall more rapidly, indicating either:
  1. Resistance to flow in the swamps and gaps has significantly increased with falling depth/gradient, and/or
  2. The capacity for recharging the channels from the swamp is exhausted—i.e., the residual swamp storage volume becomes isolated.

  This effect is seen in all three periods, with the hydrographs showing a decline in recharge occurring below 1.5 ft.
- The rates of swamp elevation change in response to low frequency events are sluggish, with rates generally below 0.4 ft/day range. Only with the high surge of TS Matthew did swamp water stage changes approach 1 ft/day.

For uniform, turbulent, steady flow, across a wide, shallow cross-section, the quadratic shear stress formulation yields a quadratic expression for the water surface gradient as a function of velocity:

$$S_f = \frac{C_{D-ADCIRC} \quad V^2}{gH}$$

$$\begin{aligned} &where: \\ &S_f = water\ surface\ slope \\ &g = gravity \\ &H = water\ depth \end{aligned}$$

In this case the ADCIRC quadratic drag coefficient can also be equated to the more traditional Darcy-Weisbach friction factor (*f*) and Manning's *n*

$$C_{D-ADCIRC} = \frac{f}{8} = g\left(\frac{n}{1.49R_h^{\frac{1}{6}}}\right)^2$$

$$\begin{aligned} &where: \\ &R_h = Hydraulic\ Radius \approx H\ for\ wide\ channels \end{aligned}$$

$C_{D\text{-}ADCIRC}$ values thus vary with the square of Manning's *n* . Higher values of $C_{D\text{-}ADCIRC}$ are indicative of greater resistance and will yield lower velocities for a given depth and gradient. The ADCIRC quadratic drag coefficient can also be used to represent a form drag coefficient (C_D) such as for vegetation:

$$C_{D-ADCIRC} = \frac{C_D a^* H}{2}$$

$$\begin{aligned} &where: \\ &a^* = total\ frontal\ obstructed\ area\ per\ unit\ volume \end{aligned}$$

Thus, values of $C_{D\text{-}ADCIRC}$ can be used to represent "lumped" considerations of bottom shear and form drag, much like experimental values of Manning's *n* are developed for a wide variety of hydraulic conditions. Typical literature values for Manning's *n* and the equivalent value for $C_{D\text{-}ADCIRC}$ at depths of 5 and 1 feet are given in Table 5. Values will vary both spatially – according to the character of channel/swamp geometry, bottom material, and protruding vegetation – and with the depth of water.

However, the Table 5 values reflect fully turbulent flow, such as for flood conditions. Experimental values of Manning's *n* for low turbulent flow through dense brush have exceeded 0.5 (Freeman, et. al., 2000), equivalent to a $C_{D\text{-}ADCIRC}$ of 3.6 for a depth of one foot. At depths below one foot, under very low turbulence, the Manning's *n* may be many times higher.[7] Thus, to properly account for swamp conditions ranging from full turbulence to near stagnant movement, $C_{D\text{-}ADCIRC}$ values may need to vary four orders of magnitude.

In their RMA2 model the LSU researchers fixed Manning's *n* values of 0.03, 0.025, and 0.035 for the Lake, channels, and swamp, respectively. The channel values are slightly lower than those indicated in Table 5, and the swamp values even more so, particularly if swamp flow conditions are in a low turbulent range. However, these values may have provided a reasonable fit given the RMA2 mesh design and other parameters (such as eddy viscosity).

5.2.2 Weir Coefficient

For overtopping of linear features represented as weirs (e.g., natural and man-made banks) under supercritical flow, ADCIRC uses the equation for a broad-crested weir. ADCIRC defines flow as supercritical when the height of water above the weir on the low side (H_L) is <u>less than or equal to</u> 2/3 the height of water above the weir on the high side (H_H). The ADCIRC formula is:

$$q = C_{WEIR-SUPERCRITICAL}\left(\frac{2H_H}{3}\right)^{3/2}\sqrt{g}$$

where:

q = *flow per unit length of weir*

[7] While researchers have identified "point values" for quadratic resistance parameters under low turbulence, application of these values is limited to the particular channel properties, water depth, and velocity of the observation. Theoretical studies have suggested that because the resistance relationship transitions from a quadratic to a linear one as turbulence declines, a velocity dependent parameter may be needed to better account for transitional conditions.

A traditional expression is $Q = C_{WEIR} (H_H)^{3/2}$, where the other factors are incorporated into the coefficient. Using this expression the Corps recommended a value of about 1 for large channel levee overtopping (see US Army Corps of Engineers, IPET Report, June 2006, Volume VI, Appendix 4, page 19). This translates into a ADCIRC $C_{WEIR\ -SUPERCRITICAL}$ of about 0.32. The code authors suggested using $C_{WEIR\ -SUPERCRITICAL}$ values on the order of 0.5.

ADCIRC also provides an equation for subcritical flow of the weir when the height of water above the weir on the low side (H_L) reaches an elevation greater than 2/3 the height of water above the weir on the high side (H_H).

$$q = C_{WEIR-SUBCRITICAL} H_L \sqrt{2g(H_H - H_L)}$$

Unlike the drag coefficients, a higher value of either C_{WEIR} value indicates a higher flow.

Table 5
Typical Values for Manning's *n* and Equivalent ADCIRC Drag Coefficient

Description	Manning's *n*[8]	Equivalent $C_{D\text{-}ADCIRC}$[9] 5-ft Depth	Equivalent $C_{D\text{-}ADCIRC}$[9] 1-ft Depth
Earthen Channel			
Straight, with some grass	0.026	0.006	0.010
Winding, no vegetation	0.030	0.008	0.013
Winding, weedy banks	0.050	0.021	0.036
Winding, very weedy and overgrown	0.080	0.054	0.093
Overbank Area			
Tall grass	0.035	0.010	0.018
Winter brush and some trees	0.050	0.021	0.036
Summer brush and some trees	0.060	0.031	0.052
Winter dense brush and some trees	0.070	0.042	0.071
Summer dense brush and some trees	0.100	0.085	0.145
Cleared land with stumps and dense new growth	0.060	0.031	0.052
Dense stands of large trees, water below branches	0.100	0.085	0.145
Dense stands of large trees, water reach branches	0.120	0.122	0.209

8 Roberson and Crowe (1993); applicable for fully turbulent flow.

9 For wide channel assume Hydraulic Radius (R_h) equals Water Depth (H).

During completion of the stable model mesh, URS identified physical parameter issues for further investigation. URS subsequently undertook simulations to evaluate the influence of the node drag coefficient, the weir coefficient, and the swamp floor elevation on modeling the Maurepas Swamp hydrodynamics. The test results have been critical to understanding the performance and limitations of the ADCIRC Maurepas Swamp model.

6.1 PHYSICAL PARAMETER ISSUES

Qualitative inspection of the results of final stability tests illustrated that the 2D ADCIRC model was simulating many characteristics of the Maurepas Swamp hydrodynamics. The model captured the effect of downstream Lake stage and upstream flow forcings on the project area locations and the impact of high resolution linear topographic and bathymetric features on circulation. The model also represented some effects on the amplitude and phase of propagated forcing signals. Selected hydrographs comparing the stability model results versus observed LSU period data are given in Figure 9.

The stability test results duplicated both the high and low frequency observed signals at the Lake gages (S-3, Reserve Relief Canal at Lake Maurepas; S-4, Dutch Bayou at Lake Maurepas; and S-10, Blind River near Lake Maurepas). The model also faithfully replicated the tidal signal, and reasonably represented the low frequency signal, in the larger, more hydraulically efficient channels, (i.e., S-16, Blind River, S-24, Reserve Relief, and S-9 lower Mississippi/Dutch Bayou). The results for these gages showed that the higher resolution ADCIRC model significantly improved capturing of stage dependent tidal signals compared to the LSU RMA2 model (Day et. al., 2004). However, the results for the upper interior channels (e.g., Hope Canal at gages S-5 and S-7 and Mississippi Bayou at S-11) showed a significant dampened response on the LSU Period low frequency draining signal.

The LSU Period “under-draining” in the upper (especially interior) channels indicated that either the conveyance in these channels was overly restricted or the modeled swamp-channel connection was too high (i.e., there was an “over-draining” of the swamp). Thus, URS proceeded with parameter tests focusing on improving the model resistance – either in the channels or swamp (in the drag or weir coefficients) or in the effective swamp floor elevation, or in some combination of these factors. URS utilized the updated ADCIRC code version that supported spatial variance of the node drag coefficient in the parameter testing and subsequent simulations.

6.2 APPROACH TO PARAMETER TESTING

The hydrodynamic resistance factors impact the flow within channels and swamp, as well as the exchange between the channels and swamp areas. Resistance factors therefore affect

- The degree to which a diversion will aggravate the backwater constraint on upland gravity stormwater drainage;
- The broad and uniform distribution of diversion water through the swamp;
- The diversion water retention time and the potential for short-circuiting of diversion flows to Lake Maurepas; and
- The potential for scouring velocities at concentrated flow locations.

Thus, all four diversion objectives are impacted by the representation of resistance.

URS tested various values for the resistance parameters in order to better understand the ADCIRC model performance and limitations, and to find representative values for the intended model application. This last point is crucial because no model is perfect, and models are usually better suited for some purposes more than others. In approaching model parameterization the Project Team considered evaluating diversion impacts to the Garyville/Reserve drainage be the most important for this phase of 2D modeling.

For the purpose of resistance testing (and subsequent calibration and validation) URS selected three shorter sub-periods from the hydrographs described in Section 5.1. The sub-periods were selected to represent a range of stage and resistance conditions while enabling a more efficient utilization of the cluster.

- The latter 15 days of the 30-day LSU calibration period (January 7, 2004 through January 22, 2004). There are two elevation peaks corresponding to minor rainfall events and frontal passages, one on January 9th, with Lake Maurepas reaching an elevation of 1.2 feet, and one on January 18th, reaching an elevation of 1.35 feet. These rises barely exceeded the channel bank elevation and the average Lake elevation of 1.1 ft. The Lake dropped to zero elevation in-between the peaks.

- The most significant rise portion of the ARDC/Blind River Flood period (May 8 2004 through May 24, 2004) during which the stage in the lower Blind River reached close to 3 feet.
- The Tropical Storm Matthew period (October 4, 2004 through October 24, 2004), during which Lake Maurepas exceeded 4 ft NAVD-88, LDNR, and water entered the swamp both through the channels and by overtopping the ridge along the Lake edge.

URS employed all three periods at one time or another during parameter testing – with the ARDC/Blind River Flood and TS Matthew Periods being used to assess model performance during higher stages and flows likely to be more representative of diversion conditions.

However, greater emphasis was placed on the "under-draining" portion of LSU. As indicated by the stability result, this period was highly sensitive to hydrodynamic resistance. URS also expected this period to reflect generally higher swamp resistance values, given very low stages and low turbulence in the swamp. The LSU Period was therefore considered to be the most suitable for developing resistance parameters to which diversion backwater impacts would be sensitive. All three periods were used for final calibration/validation testing (see Section 7).

Over a 13-week period URS conducted more than 40 simulations as part of resistance parameter evaluation (see Appendix B, Simulation Log, for a description of the tests). Appendix C provides a disk copy of input and output files and Table 6 summarizes the parameter values for several key simulations.

6.3 RESISTANCE PARAMETER TESTING RESULTS

The resistance parameter evaluation was conducted in five parts:

- Channel resistance;
- Bank/gap resistance;
- Swamp resistance factors;
- Extended swamp draining; and
- The sensitivity of diversion hydrodynamics to resistance parameterization.

Figures 10 and 11 present stage hydrographs of the simulated results versus the observed data.

Table 6
Summary of Values for Key Parameter Tests

Test	Simulation Number	Simulation Period	$C_{D\text{-}ADCIRC}$ Z, Bathymetry (ft)	C_{WEIR}	Swamp Elevation
Stability	31.0	LSU Period	0.7 Z>0 0.15 0>Z>-1 0.05 -1>Z>-3 0.025 -3>Z>-6 0.005 Z≤-6	0.02 Banks 0.04 Gaps	Flat at 0.5 ft
Glass Wall – Test Channels	32.1	LSU Period	Same as above	0.005	Interior gradually sloped from 0.5 ft to 1.1 ft.
Glass Wall – Test Weirs	32.9	TS Matthew	Same as above	0.005	Base at 0.5 ft; interior stepped at 0.7, 0.9, to 1.1 ft.
Typical Weir Coefficient	40.0	TS Matthew	Same as above	0.5	Flat at 0.92
High Swamp 1	40.1	LSU Period	Same as above	0.5	Flat at 0.92
High Swamp 2	41.0	LSU Period	Same as above	0.5	Added interior area at 1.3 ft; low areas behind gaps at 0.5 ft
High Swamp 3	42.0	LSU Period	Same as above	0.5	Expanded interior area at 1.3 ft
High C_D	BR C03_05	LSU Period	10 Z>1 5 1>Z>0 1 0>Z>-1 0.1 -1>Z>-2 0.05 -2>Z>-3 0.01 -3>Z>-6 0.005 Z≤-6	0.5	Flat at 0.6 ft.
Extended Swamp Draining	BR C04_03 ED	LSU Period, Extended	0.5 Z>0 0.1 0>Z>-1 0.05 -1>Z>-3 0.01 -3>Z>-6 0.005 Z≤-6	0.5	Expanded interior area at 1.1 ft.
Typical Swamp Diversion	BRgrid_D02	LSU Period	1 Z>0.5 0.15 0.5>Z>-0.2 0.05 -0.2>Z>-2.2 0.025 -2.2>Z>-5.2 0.005 Z≤-5.2	0.5	Flat at 0.6 ft.
High Swamp Diversion	BRgrid_D04	LSU Period	Same as above	0.5	Flat at 0.9 ft.

6.3.1 Channels

In order to isolate the resistance parameterization issue URS first conducted an LSU Period simulation in which channel-swamp exchange was severely restricted. This simulation essentially limited the propagation of forcing signals to the channels. This was accomplished by artificially lowering all weir coefficients (C_{WEIR}) to 0.005, including temporary weirs that were located at bank gaps and channel ends. Compared to a typical value of 0.5 this lower value reduces weir overflow, and channel-swamp exchange, one-hundred-fold.

The results of the "Glass Wall" simulation, are shown in Figure 10. The simulation produced a very reasonable draining of the upper interior channels. The model results show the re-acquiring of the tidal signal as the channel stage drops. The channel $C_{D\text{-}ADCIRC}$ values were in the range for turbulent, winding, muddy channels and those used by the LSU researchers for the RMA2 model.

These results, combined with the reasonable agreement with observed data for the larger channels (Blind River, S-16 and S-10, and Reserve Relief, S-24, and the lower Mississippi/ Dutch Bayou, S-9), indicated that model channel conveyance was behaving properly. The results also indicated that improving the draining performance for the smaller, upper interior channels required reducing swamp outflow into these channels.

6.3.2 Banks and Gaps

To evaluate the effect of the weir coefficient in controlling bank overflow, URS conducted a TS Matthew simulation with the lower, "glass wall," weir coefficient value of 0.05 (compared to the typical bank weir coefficient values of 0.5 used in the earlier tests). This simulation (see Figure 11) revealed that the 0.005 value was too restrictive and failed to allow propagation of the surge across the Lake shore into the interior gages (S-5, S-7, S-23, and S-25) as indicated in the observed data. A subsequent simulation with the 0.5 weir coefficient value, however, produced surges into the swamp (see Figure 11). This test indicated that the 0.5 weir coefficient parameter was more likely to be reasonable. The weir coefficient test did indicate that a slightly higher bank height could be justified in order to improve propagation of the surge signal to the upper channels.

Given that the under-draining of the model was occurring below a stage of 1 foot (the typical bank height) the representation of flow through bank gaps was considered. Bank gaps, which have inverts below elevation 1 foot, were included in the final mesh as very narrow, short, shallow channels. The gaps were assumed to have drag coefficients similar to other small, shallow channels in the mesh. To account for some unique turbulence properties of the gaps, a slight reduction of the gap inverts was considered acceptable and included in the model. (However, the sensitivity of the model to this change was not tested). To the extent that channel resistance had been investigated and shown to be reasonable, this investigation indicated that the bank gap drag coefficients were also likely to be reasonable. Furthermore, with the exception of the under-draining issue, the model channels and gaps appeared to behave reasonably during the other portions of the LSU Period and during the ARDC/Blind River Flood and Tropical Storm Periods.

The combined evaluation of channel, bank, and gap resistance parameters indicated that these facets of the Maurepas ADCIRC model were acceptable, and further pointed toward assessing the swamp interior parameters in order to improve the under-draining issue (i.e., the excess flow from the swamp into the channels).

6.3.3 Swamp Resistance Factors

The LSU Period draining event showed a roughly one foot drawdown in the upper channels (e.g., S-5, S-7, and S-11) over the span of six days, from an elevation close to mean water level down to about one-foot below mean water level. While the interior swamp gages (S-23 and S-25) were not operable during this event, the full hydrographic record indicates that water remains trapped in the swamp (particularly south of Interstate 10) when the upper channels undergo significant draining. As noted in the *Volume IV, Hydrologic Data*, the swamp exhibits extremely sluggish water movement (see Figure 29 of *Volume IV, Hydrologic Data*), indicating a limit to the swamp-channel connection.

A 0.1 ft/day change in the average water elevation across the north and central swamps corresponds to about 1,500 and 1,000 cfs, respectively. Since upper Hope Canal and Mississippi Bayou typically support flows less than 50 cfs each, only a very small drawdown of the swamp interior is needed to maintain stages in the smaller upper interior channels. However, the LSU Period draining event data show that replenishment of the upper channels from the swamp interior is not occurring to a significant degree at this low water stage. URS investigated the role of both the swamp floor elevation and swamp node drag coefficient in modeling the-restricted emptying of the swamps and the proper draining of the upper channels.

Swamp floor elevation is understood to be variable between 0 and 1 foot with an average of about 0.5 ft. This variable bathymetry allows for extensive areas of trapped (or ponded) water. To evaluate this condition URS conducted several "High Swamp" simulations with areas of the swamp interior bottom raised above the mean 0.5 ft elevation.[10] Table 6 summarizes the parameters for three key tests of swamp elevation and results are included on Figure 10. The results for High Swamp 3 in which swamp elevations for large areas were raised above 1 foot show a moderate improvement at S-5, S-7, and S-11, although the swamp resistance still appears to be well under-represented. Based on this modest improvement, URS incorporated higher swamp floor elevations into the model.

URS also experimented with higher values of the swamp node drag coefficient. In the High C_D test the drag coefficient value in the swamp was raised to 5. Increasing the drag coefficient to this degree did not show a significant improvement in the under-draining of the upper channels so values consistent with turbulent flow conditions shown in Table 5 were adopted[11].

6.3.4 Extended Swamp Draining

The model's modest response to the increases in the swamp floor elevation pointed towards another possible explanation for the under-draining of the upper interior channels (or over-draining of the swamp): the ADCIRC code might not be capable of drying – or "turning off" – swamp mesh nodes to the degree needed to eliminate very small quantities of drainage out of the swamp and into the channels[12]. To further clarify the role of the wetting/drying code

[10] Raising the interior swamp floor can also be considered a crude surrogate for simulating areas that experience the increased resistance of low turbulent conditions. However, a disadvantage of raising the swamp floor is that it restricts conveyance at all levels of turbulence and water elevations, and can over-represent resistance under higher flow conditions.

[11] While the latest ADCIRC code provides for a spatially varying $C_{D\text{-}ADCIRC}$, with some depth dependence, a formulation is not available to support a velocity dependent range of values approaching several orders of magnitude. Therefore, values of $C_{D\text{-}ADCIRC}$ largely reflecting the turbulent range were selected.

[12] Wetting/drying algorithms in hydrodynamic codes are not true physical models but rather rely on a series of rule-based statements and threshold parameters to "turn nodes on and off." These algorithms are an important source of resistance, particularly for very shallow flow. They can be somewhat optimized for different applications but can be difficult to refine with finite element codes, which do not maintain a local conservation of mass. In general, limitations – such as an errors in flow at a drying front – are exhibited for the more "extreme" conditions under which the model is applied, as is the case with the low water of the LSU Period draining event.

in under-draining the upper channels in this particular test period, URS undertook a simulation to artificially extend the event. The period following the "bottoming-out" of the draining event was extended with a Lake hydrograph that dropped to -0.5 feet over two days, and then remained at that level for an additional seven days. By setting the Lake boundary at this low value, and with no flow inputs, the simulation attempted to force the model to drain the upper interior channels.

The results for this simulation for several interior channel stations are shown in Figure 12. The hydrographs clearly illustrate that the upper interior channel stages do not drain. Additional analysis of the modeled velocities in Hope Canal showed a continuous flow of about 200 cfs. This value was clearly erroneous and – coupled with observed high flows at swamp gaps and instabilities at swamp wet/dry fronts – indicated a numerical mass balance limitation at the wet/dry front.

The presence of a numerical "drying" limitation in the ADCIRC model is supported by the observation that draining errors are most noticeable in the smaller, upper interior drainage features such as Hope Canal and Mississippi Bayou. The downstream Dutch Bayou, as well as the Blind River and Reserve Relief, are larger channels and the numerical error associated with "under-drying" of the swamp does not cause the same degree of "under-draining."

This numerical limitation also explains why only a moderate improvement was seen with the high swamp floor modification. Raising the swamp floor reduced the total area of wet-dry instabilities to a smaller portion of the swamp; however, this area of instability was still sufficient to "under-dry" the model.

URS discussed the numerical drying limitation with the ADCIRC code authors, who in turn conducted several independent tests to verify the issue. Following their testing, the authors agreed that the observed numerical performance limitation of the drying algorithm could be expected with the Maurepas mesh.[13] The authors indicated that increasing swamp mesh resolution for the high swamp floor, requiring a doubling or more of mesh nodes and extended stability testing, might improve the drying stability limitation. Alternatively, using the realistic swamp floor elevation in combination with a new velocity and depth dependent formulation for low turbulent drag resistance might be pursued. However, the Project Team agreed that these efforts could be deferred if the performance of the model as-developed was acceptable for the current objectives.

6.3.5 Diversion Simulation

Given the numerical drying limitation and the approaches used to represent swamp resistance in the model, URS undertook a test of the effect of the high swamp floor on simulating a diversion a 1,500 cfs diversion. The diversion feature was created by removing the Hope Canal mesh upstream of Interstate 10 and adding a constant diversion flow into Hope Canal just north of the Interstate 10 crossing. The simulations consisted of 20 days of constant 1,500 cfs diversion flow with a constant Lake level of 0.8 feet. The 20 day period was found to be sufficient for the flow in the swamp to reach near steady conditions. The two simulations differed only in the swamp bathymetry, with the floors set at 0.6 and 0.9 ft (see Table 6).

Stage hydrograph results of the diversion simulations are shown in Figure 13, with the Day 20 stage provided in Table 7. Neither diversion scenario showed a significant increase in stage versus the Lake elevation at stations close to the Lake, with increases at S-4, and S-10 of 0.03 feet or less. The differences between swamp elevation scenarios at S-4 and S-10 were also negligible.

The impact of diversion and differences between scenarios are most evident in the interior gages, particularly at S-25 and the Airport Station. South of Interstate 10 the diversion test showed the water stage raised by as much as 1.35 feet versus the Lake, and the higher swamp floor produced a 0.3 foot increase. On a percentage basis the scenario increase was as high as 33 percent. A similar impact is seen in the interior swamp north of Interstate 10 at S-23. [Note: these results are only intended for a relative comparison of the impact of the swamp floor scenarios. The actual impact of diversion on stages in the swamp is the subject of model simulations conducted following calibration and validation, which is to be the subject of a subsequent volume.]

Lower increases in diversion stage versus the Lake, and lower differences between scenarios, are seen at the interior channels north of Interstate 10. At S-9 (Dutch Bayou) and S-11 (Mississippi Bayou) the diversion raises stage about 0.5 feet, while the higher swamp floor increases stage 0.15 feet.

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[13] At the time of this report, the code authors are researching improvements to the wetting/drying numerical limitations of ADCIRC.

In the two larger, near-boundary channels both diversion scenarios produced small stage increases above the Lake elevation: 0.08 feet at S-16 (Blind River at Interstate 10), and 0.25 feet at S-24 (Reserve Relief Canal at Airline Highway). These low increases versus the Lake are consistent with the greater conveyance capacity of the larger channels and support the location of the model boundaries just outside these two large channels. The larger conveyance of these channels also resulted in the change in swamp floor having a negligible impact.

Table 7
Sensitivity of Diversion Stage to Swamp Floor Elevation

Station	Maximum Water Surface Elevation (feet)		Difference	
	Typical Swamp Floor (Elev. 0.6 feet)	High Swamp Floor (Elev. 0.9 feet)	Versus Lake*	Between Simulations
Near Lake				
S-4	0.83	0.83	0.03/0.03	0.00
S-10	0.81	0.82	0.01/0.02	0.01
Near-Boundary Channels				
S24	1.05	1.05	0.25/0.25	0.00
S16	0.85	0.88	0.05/0.08	0.03
Interior				
S9	1.22	1.32	0.42/0.52	0.10
S11	1.15	1.3	0.35/0.50	0.15
S23	1.6	1.85	0.80/1.05	0.25
S25	1.85	2.15	1.05/1.35	0.30
Swamp north of the airport	1.7	2.0	0.90/1.20	0.30

* Stages are at Day 20 of the simulation, which approximates fully developed, steady flow
** The Lake boundary water elevation was a steady 0.8 feet.

In addition to the potential stage impact at the interior locations, the higher swamp floor also modifies the diversion flow pattern. Figure 14 illustrates the flow patterns at Day 10 for the two scenarios. The two flow patterns compare ten “instantaneous” streamlines[14] starting at the same location and a travel-time factor associated with each streamline. The figures show that the higher swamp floor simulation has noticeable short-circuiting through preferential minor channels and significantly reduced travel-time factors. Both of these consequences are consistent with reducing the general conveyance of the swamp.

Thus, the results of the diversion simulations show that the model is sensitive to adjustments of swamp elevation.

6.4 EVALUATION OF MODEL PERFORMANCE AND LIMITATIONS

As previously noted the final stability test results showed that the 2D ADCIRC model had achieved several performance milestones, including simulation of tidal and flow forcings, propagation of tidal signal amplitude and phase, and representation of the effects of high resolution features on circulation. However, the stability testing also revealed that the model “under-drained” the upper interior channels under a low, falling stage condition. The results of resistance parameter tests assessing this issue have yielded additional key insights into the performance and limitations of applying the existing model to assessing the diversion feasibility:

- The resistance formulations for channels, banks, and bank gaps appear to be reasonable.
- The “under-draining” of the upper interior channels during low stages is indicative of a swamp resistance issue.
- Results show that under-draining is aggravated by wetting/drying code numerical limitations at near-dry water depths. However, under diversion conditions the swamp is not expected to be near-dry.

[14] These “instantaneous streamlines” are different from true cumulative particle path-lines. The former reflect paths that would be followed if velocity field “snapshot” at 10-day was a steady-state field. The travel-time factor is based on integrating the simultaneous travel-time over the length of the instantaneous streamline, from the initial diversion to final discharge into a major channel. With the instantaneous streamlines this travel-time factor is not a true retention time but does provide a means of comparing circulation patterns.

- "High Swamp" floor elevation values provide some improvement to representing swamp resistance and reducing the LSU Period "under-draining" of the upper interior channels.
- Raising the swamp floor elevation values can be expected to increase swamp resistance under conditions of higher swamp water depth and flow, such as diversion. The effects of a "High Swamp" could well be non-linear – with higher relative resistance impacts at higher stages and flows.
- Testing showed a 33 percent increase in interior swamp stage, for a 1,500 cfs diversion, when the swamp floor elevation was increased 0.3 foot.
- While the parameter tests indicated that the "High Swamp" model significantly increases swamp resistance, and is more accurate for simulating the LSU Period draining event, the results also showed that the swamp resistance was still under-represented.
- Under-representation of swamp resistance will have some effect on estimating diversion impacts on tailwater controlled drainage and diversion retention time and circulation.

During the course of parameter testing, the Project Team discussed the results and findings, as well as options for further model development and testing (see Section 8, Conclusions and Recommendations). The Project Team decided to proceed with a calibration/validation evaluation of the "High Swamp" model to determine if it would be suitable for completing the current study.

The combined results of model development, stability testing, and parameter testing were used to finalize a 2D ADCIRC "High Swamp" feasibility study model. This model was then used to complete calibration and validation simulations using the three periods described in Section 6.1. The input and output files for the calibration and validation simulations are provided in Appendix D, and animations are included in Appendix E.

7.1 FINAL "HIGH SWAMP" MODEL

The final "High Swamp" model consists of the following features, (Figures 6 and 7 depict the final mesh and bathymetry):

- Channels and Lake bathymetry remained essentially the same as they had for all simulations. Slight refinements of the bathymetry of mouths of Blind River and Dutch Bayou were introduced during parameter testing.
- Upper interior bank elevations were raised slightly (by 0.2 feet) to address more rapid propagation of the storm surge to the upper channels.
- Bank gap inverts were set at elevations of 0.7 feet.
- The general swamp elevation was set at elevation 1.1 feet north of the Pipeline Right of Way.
- Small portions of the swamp – adjacent to swales and banks, were assigned an elevation of 0.9 feet.
- A spatially variable drag coefficient was used with values dependent on the swamp or channel bottom elevation. The swamp/channel bottom ranges and drag coefficient values were:

Bathymetry Elevation Range (feet)	$C_{D\text{-}ADCIRC}$
z < -6	0.005
-6 < z < -3	0.01
-3 < z < -1	0.05
-1 < z <0	0.1
z > 0	0.5

- The weir coefficient for all bank weirs was set at 0.5.
- All numerical parameters were set as described in Section 4.3.

7.2 CALIBRATION

The results for the calibration using the LSU Period are shown in stage hydrographs, Figure 15a – 15i, and in the velocity hydrograph, Figure 15j. Each figure shows the time series of the measured and simulated stage for each station and a scatter plot showing the differences in the observed and simulated values at 30 minute intervals. In some instances the station gages were not operable during the selected period and therefore no measured data is available for comparison.

The results for the calibration show a good agreement between the measured and simulated stages for the larger drainage systems (Blind River – S-10 and S-16; Reserve Relief – S-3 and S-24) and for the downstream (and wider) sections of Dutch Bayou (S-4 and S-9). The "under-draining" effect is again slightly evident at S-9 and more so at the upper, interior gages: S-5, S-7 and S-11.

The model to measured data comparisons are summarized in Table 8, which shows the RMS error for water elevation at each measurement station. The RMS errors are also reported as a percentage of the range of elevations for each station during the simulation period. This tabulation was completed because the absolute RMS values are seemingly small, with maximums on the order of a few inches, but the full range of stage variations are also small, on the order of 1 to 1.5 feet for this period.

The magnitude of the RMS error reflects the degree to which the "under-draining" error influences the simulation results. The large drainage systems (S-10, S-4, and S-3) have errors on the order of less than 0.1 feet, or a few percent of the full elevation range. The medium size drainage features (S-9, S-16, and S-24) have RMS errors on the order of 0.1 to 0.2 tenths of a foot, or 10 to 15 percent of the full range. The smaller segments (S-5, S-7, and S-11) have RMS errors on the order of 0.3 feet, or 25 to 30 percent of the full range.

Table 8
Summary of Final Calibration Results for the LSU Period

Gage	RMS Error (ft)	% of Range
S3	0.041	2.99
S-4	0.01	0.74
S-5	0.281	25.67
S-7	0.294	27.37
S-9	0.169	13.59
S-10	0.044	3.12
S-11	0.341	35.54
S-16	0.136	9.85
S-23	N/A	N/A
S-24	0.193	14.07
S-25	N/A	N/A
S-9 ADCP	0.16 ft/sec	15.84

The relative percentage error for the modeled versus observed velocity data at S-9 is close to the same range as the relative percentage error for the stage data.

7.3 VALIDATION – ARDC/BLIND RIVER FLOOD

The results for the ARDC/Blind River Flood validation are shown in Figure 16a – 16i, and in the velocity hydrograph, Figure 16j. The measured Lake levels (S-3 and S-4) peak at about 2.5 feet, whereas the measured Blind River stage (S-10) peaks at about 3 feet. This is due to the high flows discharging from the ARDC into Blind River. The results at S-10 indicate that the simulated peak is higher than the observed data and may be due to over-estimating the Blind River flows used as input flow boundary conditions.

A review of the other station hydrographs indicates that peak stages are also over-predicted, on the order of 0.5 feet or 20 percent. This may be occurring either because of an over-estimation of the Blind River flow inputs or possibly due to too high a conveyance across the swamp in the model. The high water elevation occurring in the Blind River produces a flood wave that propagates across the swamp (see animation in Appendix E), and if the Blind River elevations are over-predicted then it is likely that the peaks at other stations in the path of the flood wave will also be over predicted.

The results for S-24 show that prior to the over-estimated peak the simulated results lag response to the gage rise. This is likely due to flow inputs to Reserve Relief Canal that are too low. The instabilities in the observed data reflect the cycling of the pump station at the head of the canal.

A summary of the RMS errors for each station are provided in Table 9. Overall they are slightly larger than those of the calibration period, which in a formal validation simulation can be expected. However, the dynamics of this simulation period are more complex, with the combination of large river inflows and rising Lake levels both contributing to the stage response in the channels and swamp.

Table 9
Summary of Final Validation Results for the High Blind River Period

Gage	RMS Error (ft)	% of Range
S-3	0.18	8.31
S-4	0.05	2.54
S-5	0.41	32.60
S-7	0.41	30.18
S-9	0.18	8.81
S-10	0.16	6.18
S-11	0.34	29.73
S-16	N/A	N/A
S-23	N/A	N/A
S-24	0.42	18.68
S-25	0.30	27.69
S-9 ADCP	0.18 ft/sec	17.9

7.4 VALIDATION – TS MATTHEW

The results of the TS Matthew validation are shown in Figure 17a – 17k, and in the velocity hydrograph, Figure 17l. The measured data show that the stages in Blind River, Reserve Relief Canal and in Dutch Bayou (S-9) peak at about 4 to 4.5 feet. The northern swamp station (S-23) also shows an observed peak of about 4 feet. The upper interior stations (S-5, S-7, S-11 and S-25) show lower peaks, on the order of 3 to 3.5 feet.

The simulated results generally follow this same pattern, and peak stages at each station are well represented in magnitude and phase. However, the simulation results at the eastern, western, and northern major channels (S-10, S-16, S-24 and S-9) show signs of too much attenuation. The modeled peaks are lower than the observed values, generally by less than 0.5 feet, and the rising portion of the signal tends to initiate later than indicated in the observed data. On the other hand, at the stations in the North and Central Swamp (S-23 and S-25) the simulated results tend to over-predict the peak with a slight phase lag. These trends could be due to the model providing too much swamp conveyance and exchange with the channels, i.e., the "High Swamp" model swamp resistance may still be underestimated.

The S-9 modeled velocity tends to be attenuated at the extreme events compared to the observed data. This indicates that the resistance of the deeper channels is over-estimated, and is consistent with the attenuation of the stage signal in the upstream portion of the major channels.

The RMS errors for the Tropical Strom validation are summarized in Table 10. The errors tend to be on the order of 0.3 to 0.4 feet or less, and in terms of the full range of stage values, show the best performance of all three simulation periods.

Table 10
Summary of Final Validation Results for the Tropical Storm Period

Gage	RMS Error (ft)	% of Range
S3	0.228	5.76
S4	0.162	4.09
S5	0.303	12.54
S7	0.271	6.88
S9	0.225	5.00
S10	0.303	7.30
S11	0.239	8.67
S16	0.276	8.06
S23	0.252	8.18
S24	0.395	10.75
S25	0.411	17.61
S-9 ADCP	0.29 ft/sec	12.91

The results of the calibration and validation, taken together with the parameter testing, have been used to assess the 2D ADCIRC model's capability to support the Hydraulic Feasibility Study objectives and priorities, and to develop recommendations for the model's application and further development.

8.1 CONCLUSIONS

Calibration and validation simulations using the "High Swamp" model have added to the findings presented in Section 6:

- The calibration/validation stage and velocity hydrographs generally demonstrated reasonable model behavior at the appropriate water elevations. The results of the TS Matthew validation in particular show the ability of the model to simulate a low frequency event at above normal stage, similar to the nature of a diversion pulse.
- With the high resolution geometry of channels, banks, and gaps, the tidal signals are well represented in the model.
- The animations of the three simulations depict high resolution two-dimensional circulation patterns that are consistent with the domain bathymetry and model forcings.
- The amplitude and phase of certain low frequency signals in all three simulations – under-draining during low stage of the calibration, propagation of the ARDC flood wave across the swamp, and under-representation of the TS Matthew surge peak in the channels – indicate that swamp conveyance and exchange with the channels in the "High Swamp" model is still too high.
- Raising the swamp floor elevation in the "High Swamp" model – as a means to improve the representation of swamp resistance – has not resulted in an overall overly resistive model. The results of calibration and validation indicate that the 2D model should be regarded as under-representing swamp resistance.
- This finding must be tempered by 1) the uncertainty in the boundary flow inputs, which may also be contributing to some distortion in signal amplitude, and 2) evidence from the velocity hydrographs that the resistance in the major channels may be over-represented.

- Under-representation of swamp resistance in the 2D model (i.e., excess swamp conveyance) implies that diversion backwater values, particularly in the Central Swamp, and short-circuiting may be under-represented.
- The ADCIRC "High Swamp" model is unlikely to be significantly impacted by wetting/drying numerical limitations except at very low, near-dry stages, when errors can overwhelm the solution. The parameter testing indicates that diversion conditions will not be near-dry and that the drying algorithm will not be an issue. (The exception would be for very low, extended Lake stages which could produce some swamp drying.)
- The calibration and validation results are consistent in their depiction of the swamp resistance issue, which, combined with a similar general level of accuracy among the simulations, indicate that the model is robust and reliable.
- The relative percentage error for the calibration and validation results is consistent with a feasibility study level hydrodynamic model.

Thus, with the understanding that backwater and short-circuiting may be under-represented, the model performance shows that it can be considered appropriate for a feasibility-level analysis of diversion alternatives and their achievement of the four diversion objectives.

8.2 RECOMMENDATIONS

The 2D ADCIRC "High Swamp" model can be used to evaluate alternative diversion flows, outfall management options, backwater impacts, diversion circulation, short-circuiting, and scouring locations. URS recommends proceeding with the feasibility study of these aspects of a Maurepas Diversion with the following five considerations:

1. Diversion results should be carefully interpreted consistent with the findings of model development and testing. Most importantly, allowances should be made for the model's under-representation of swamp resistance.
2. Analyzing diversion alternatives at "fully developed" flow conditions (i.e., near steady flow) and comparing results between simulations should provide the most validity. Non-steady results are likely to be subject to the most complex effects of swamp resistance under-representation. In addition, the effects of swamp resistance under-representation may be minimized by examining relative differences between scenarios. Swamp resistance under-

representation may be non-linear and relative results should not be considered totally free of resistance inaccuracies.

3. Absolute values for unsteady scenarios – e.g., an assessment of advanced shutdown scenarios ahead of an approaching tropical storm – should be considered the least accurate.

4. While scenarios that involve near-drying conditions in the swamp will probably not be evaluated in the feasibility study, the potential for numerical errors suggest that if they are, the potential numerical errors must be considered.

The various findings point towards six alternatives for improving the 2D Maurepas Swamp model, some of which can be used in combination.

1. Undertake additional simulation tests to *further increase* swamp elevations to better match the ARDC/Blind River Flood and TS Matthew swamp resistance observations. This option, however, could result in a model that is physically unrealistic and unsuitable for diversion analysis and is not recommended.

2. Revert to observed swamp elevations and "tune" the swamp drag coefficient using the TS Matthew Period for calibration and the ARDC/Blind River Flood for validation. The two surge events prior to TS Matthew in the Tropical Storm Period, as well as the minor rises in the LSU Period, can also be used. This is a practical approach and is consistent with the way most model calibrations are conducted. However, the approach relies on evaluating a very wide range of drag coefficient values (four orders of magnitude or more) and could yield extremely high swamp drag coefficient values (e.g., over 100) which might not be realistic to apply uniformly for all flow and depth scenarios.

3. Revert to observed swamp elevations, but modify the ADCIRC code to support a combination velocity and depth dependent $C_{D\text{-}ADCIRC}$ values.[15] However, low turbulent, velocity dependent drag coefficients have not been experimentally evaluated. This option would require time-consuming development and testing of modifications to the ADCIRC code.

[15] This option could also include a code change to allow for a depth variable swamp "porosity." This feature is included in RMA2 and helps address wetting/drying numerical stability.

4. Assess the nature of bank gap resistance in more detail. The flow and turbulence characteristics of bank gaps are much more complicated than for the small narrow channels. For example, these gaps may contain regions of much higher eddy viscosity. However, the lack of data specific to gap head losses meant that further evaluation of this issue would require an additional investigation effort. Given the very short length of the gaps, the possible impact on the overall flow regime could be minor.

5. Investigate lower resistance values in the major channels. The calibration/ validation data, particularly the velocity results, suggest further tuning of the drag coefficient for the deeper channel nodes.

6. Develop and test a parallelized finite volume code with the existing mesh (or finite difference code using a grid derived from the mesh), modified as required. Finite volume and finite difference codes maintain local conservation of mass.[16] However, developing a new model may take many months, and other, possibly more significant, code limitations may apply. Furthermore, changing code alone will not resolve the Maurepas Swamp resistance issue, as all 2D codes require better parameterizing of swamp resistance for low turbulence.

URS recommends that these options for further model development be considered, depending on the needs for post-feasibility study modeling. Should project engineering and/or environmental impact assessment require a more rigorous analysis of diversion backwater, circulation, short-circuiting, and water quality processes, these options may prove worthwhile.

As part of any future model development, URS also recommends conducting a formal, structured series of sensitivity tests to demonstrate the effect of resistance parameters on diversion results. These tests can be done using incremental adjustments within a range of values to better quantify the limitations of the model.

[16] The nature of finite volume and finite element codes makes them more suitable for detailed water quality studies where local mass conservations is critical to the numerical modeling of constituent transport and fate.

ADCIRC Parameter Definitions: http://www.marine.unc.edu/C_CATS/adcirc/document/parameter_defs.html

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FIGURES

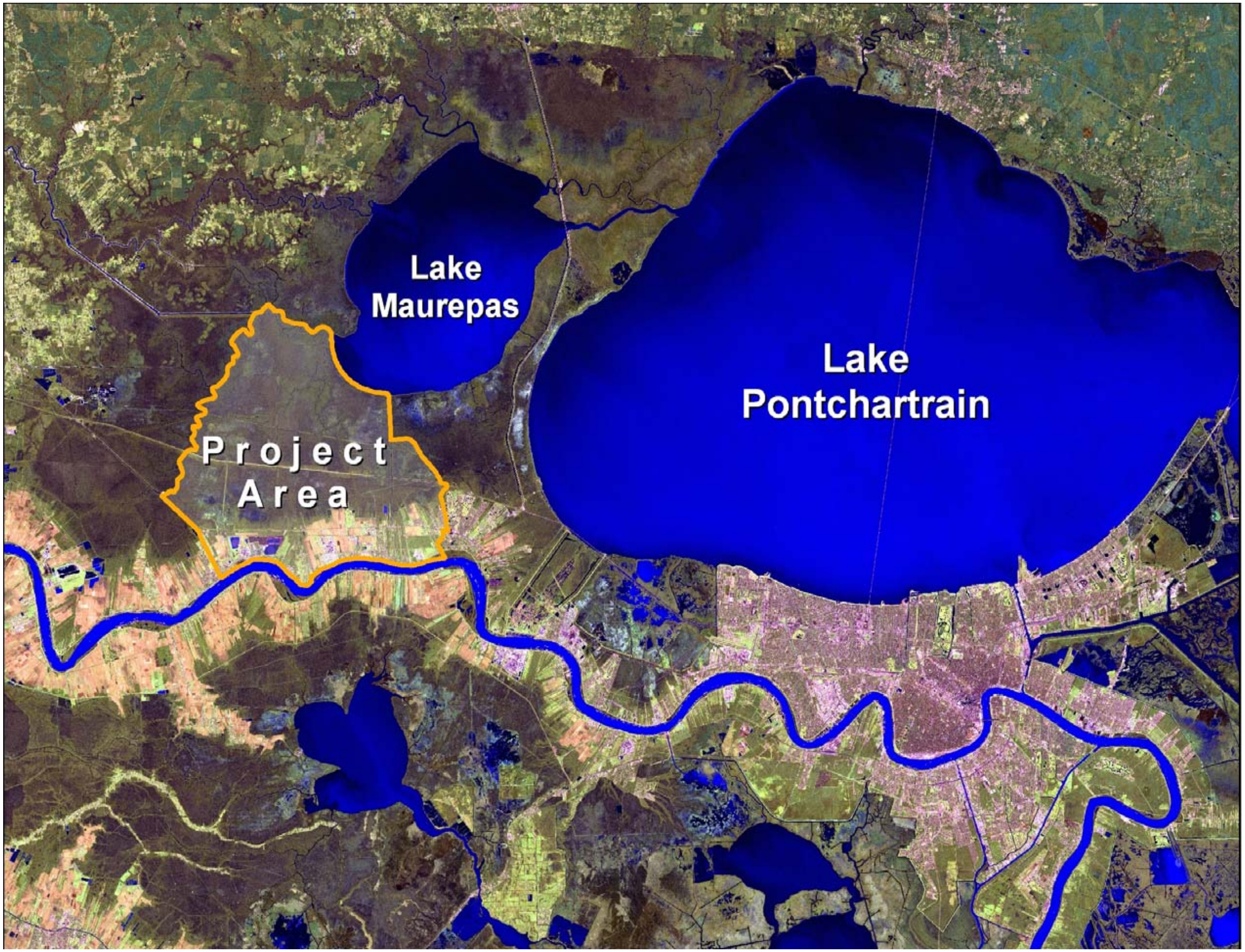

Figure 1. Project Location

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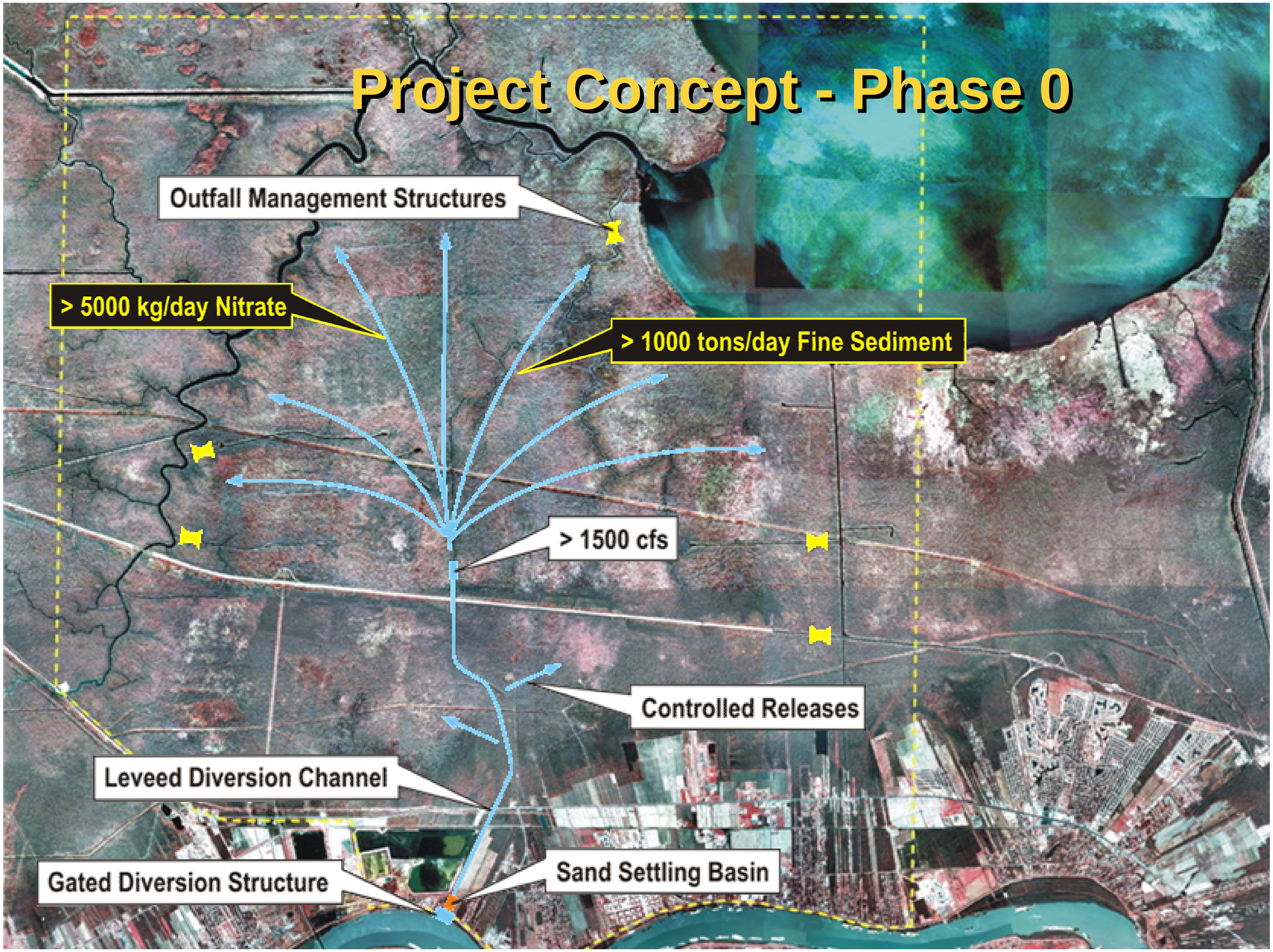

Figure 2. Diversion Schematic

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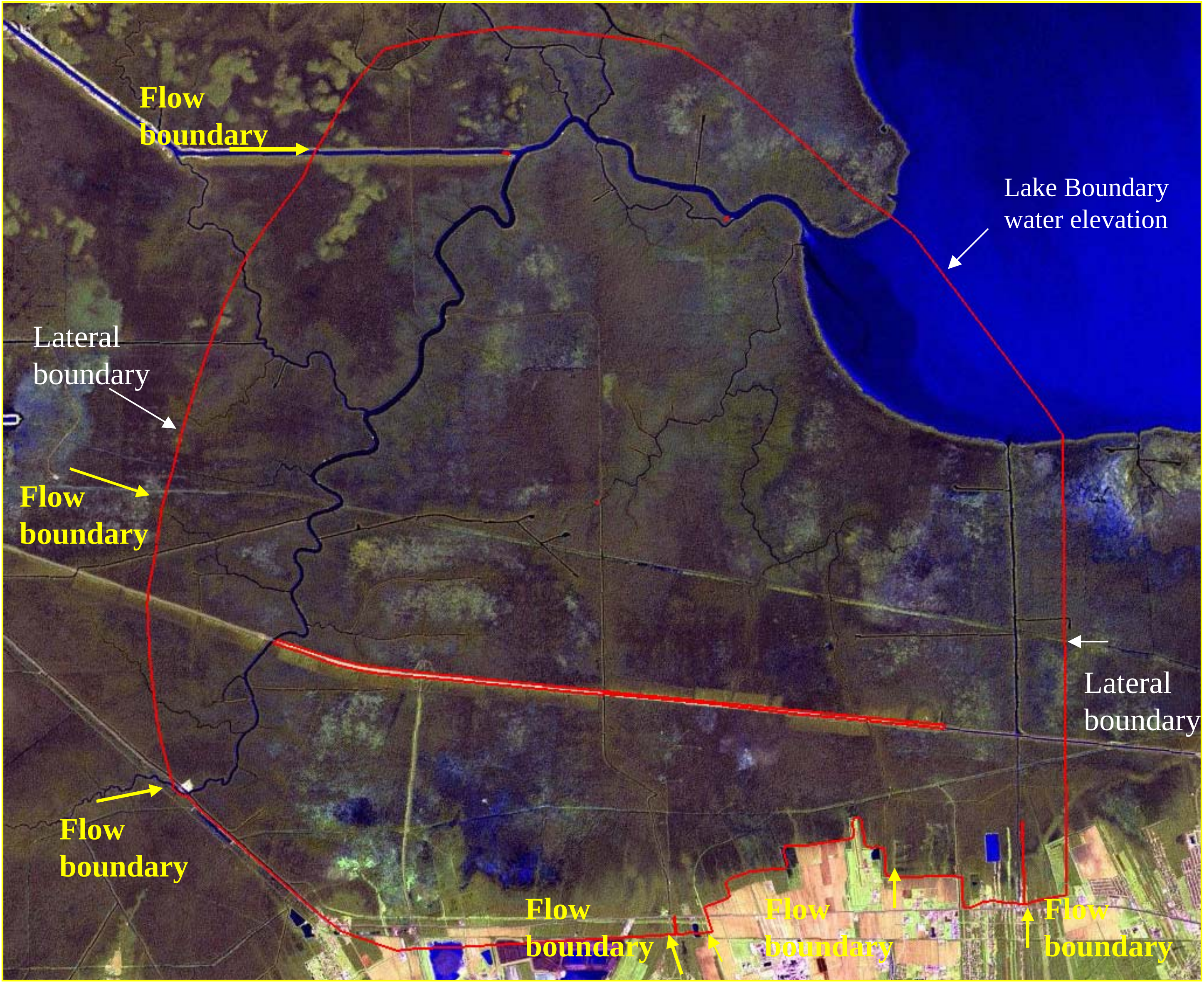

Figure 3. Model boundaries

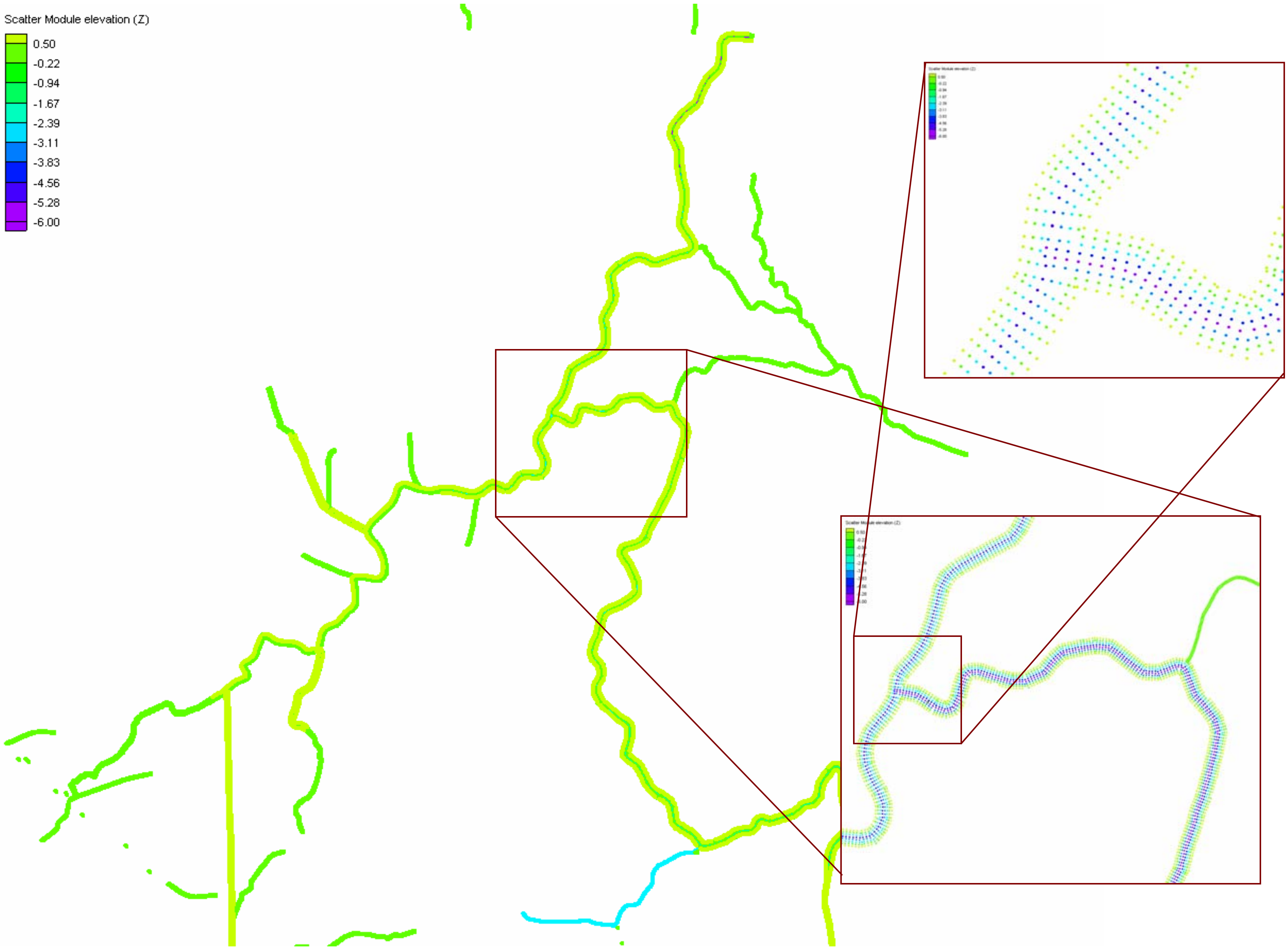

Figure 4. Example Channel Nodes

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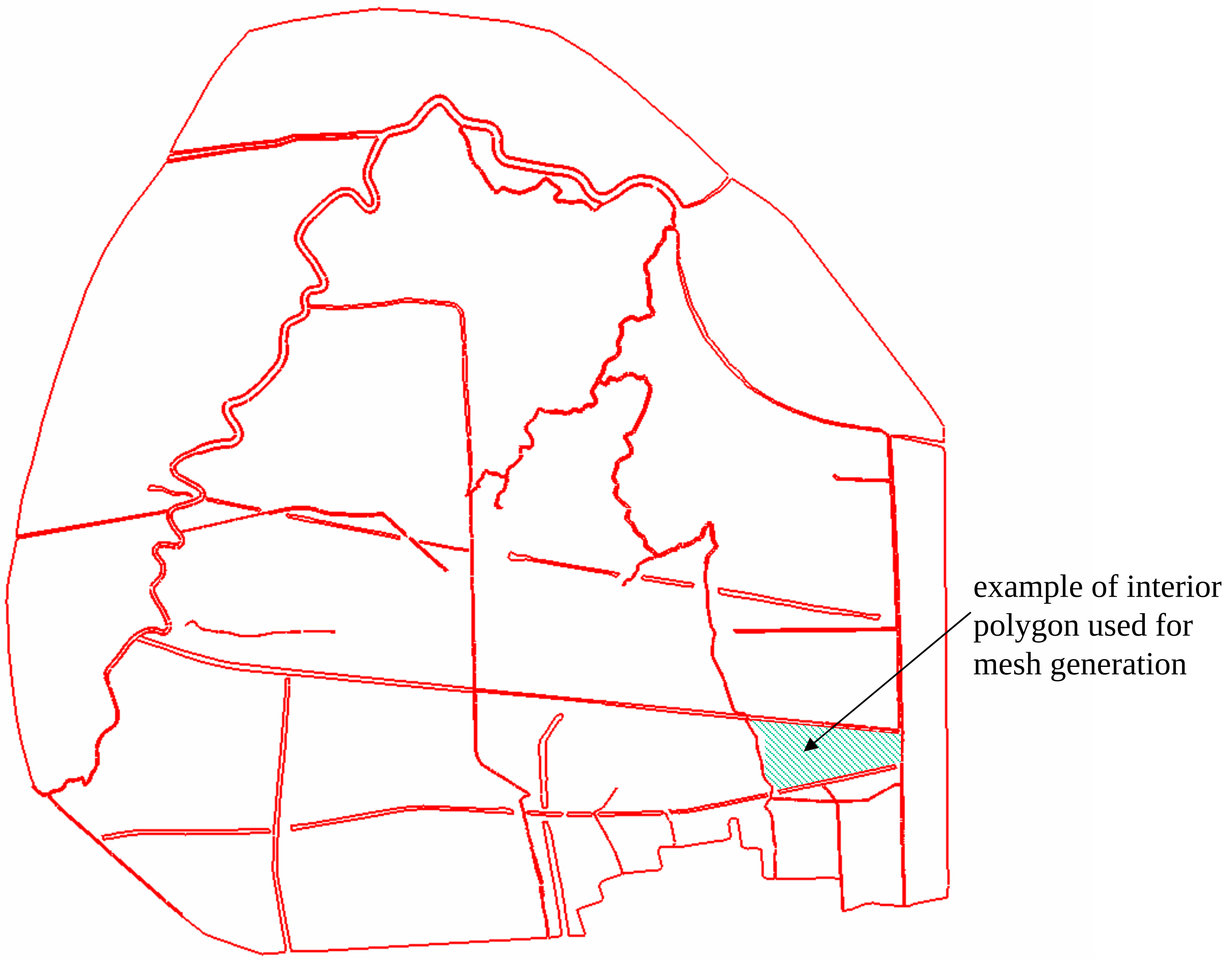

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Figure 5. Example Internal Polygons

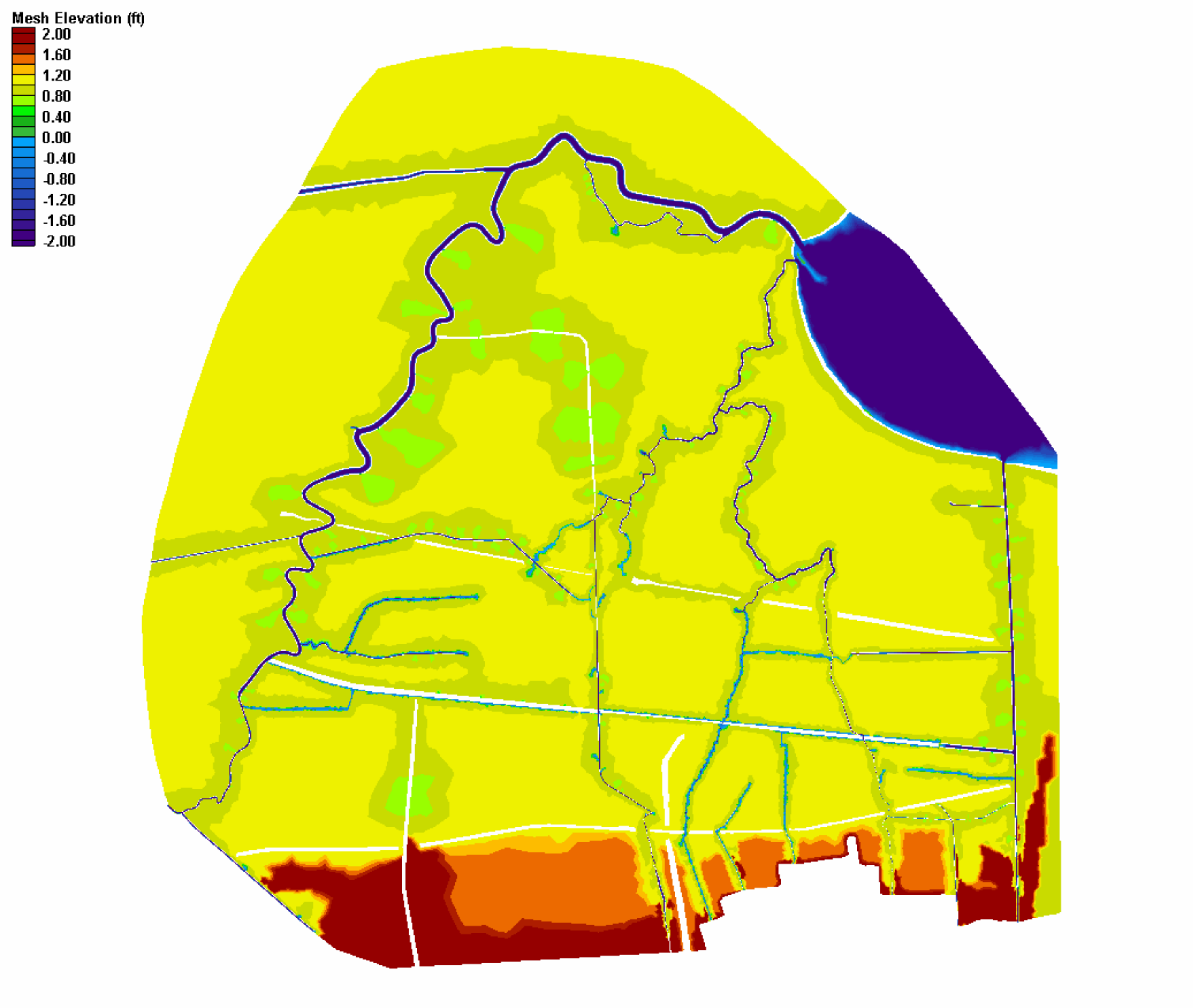

Figure 6. Final Mesh Bathymetry and Topography

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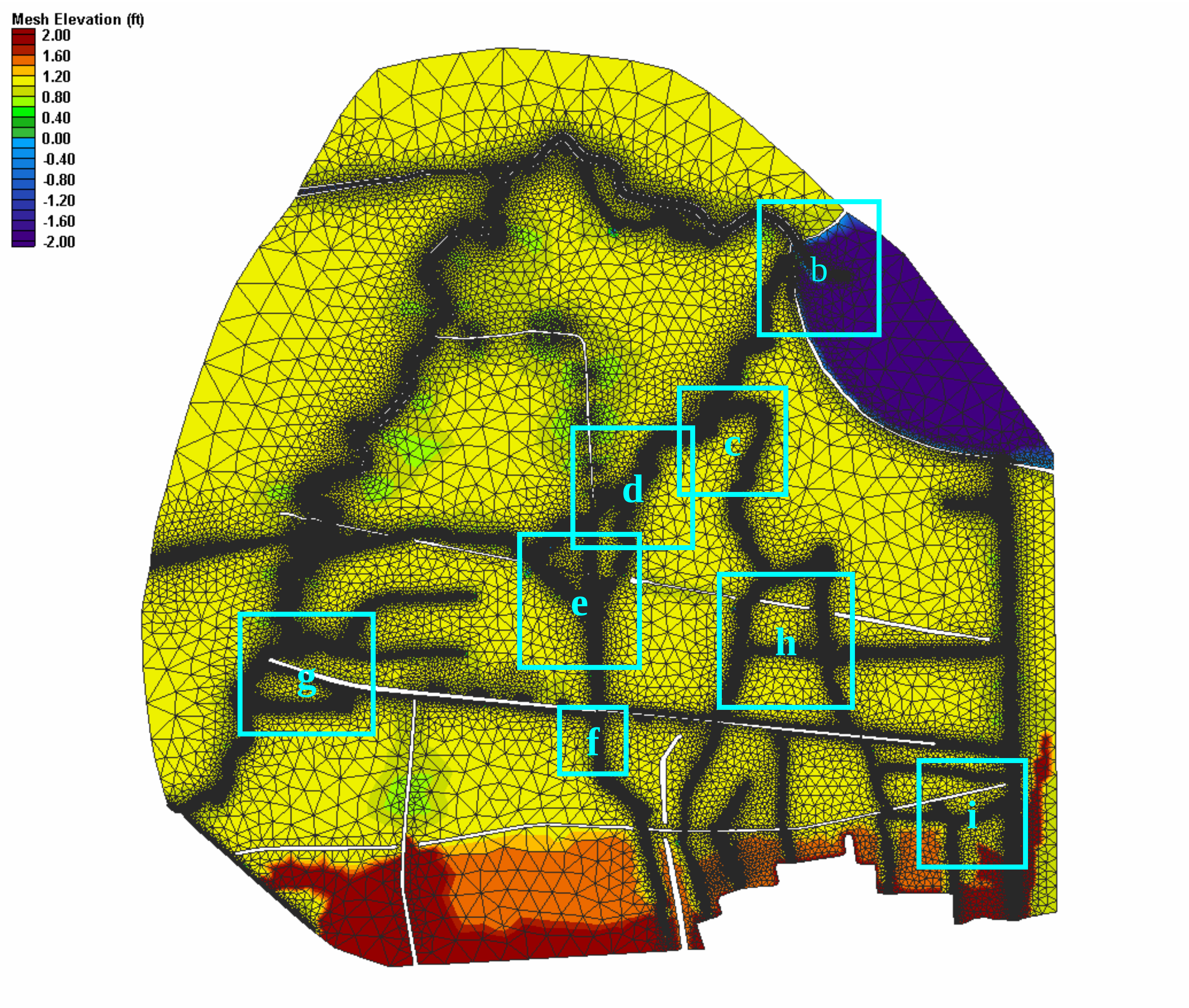

a) Index

Figure 7. Mesh Details

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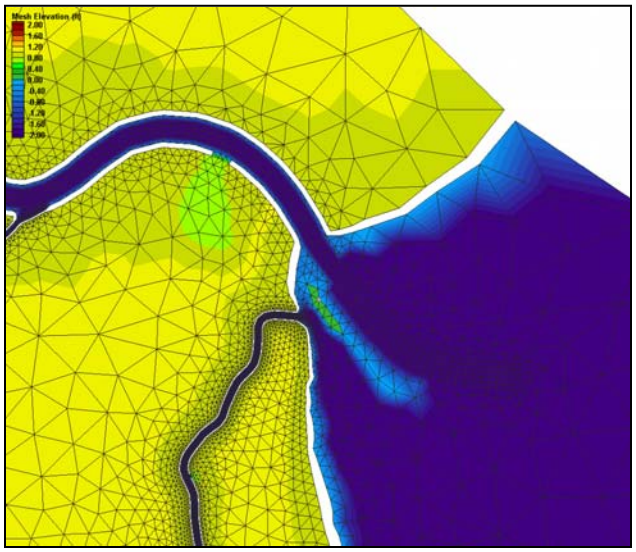
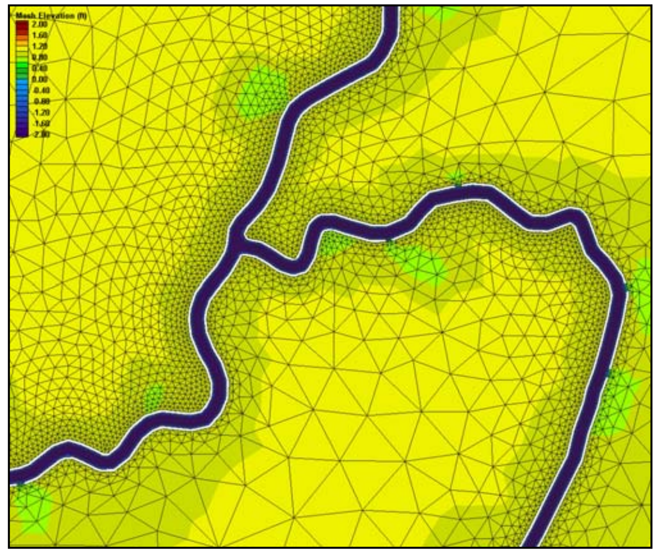
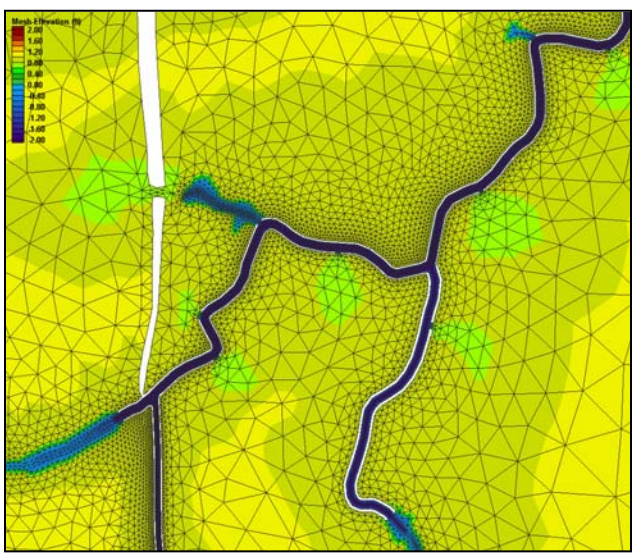


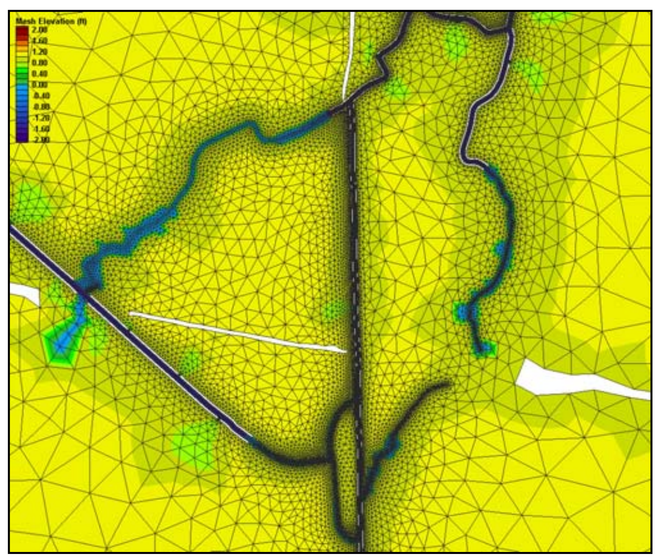
b) Mouth of Blind River and Dutch Bayou



c) Intersection of Tent, Mississippi and Dutch Bayous



d) Hope Canal, Old Railroad, and Tent Bayou



e) Hope Canal and Sloughs to Bourgeois Canal

Figure 7. Mesh Details

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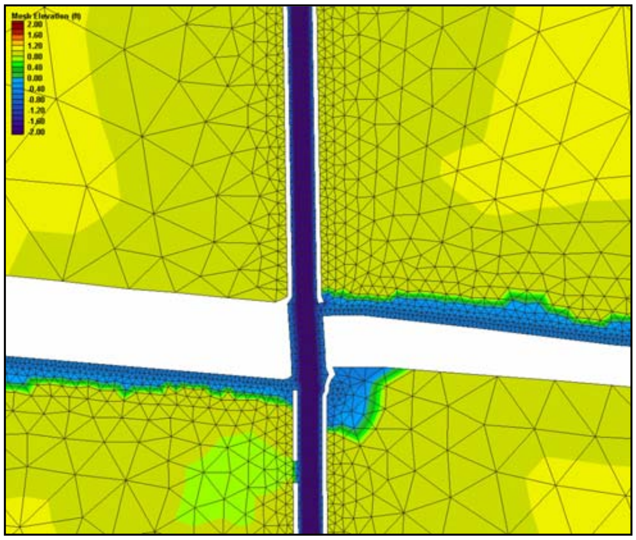
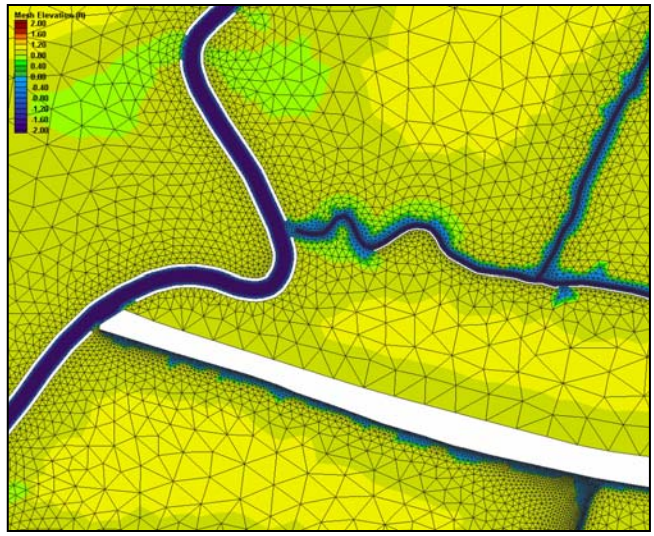
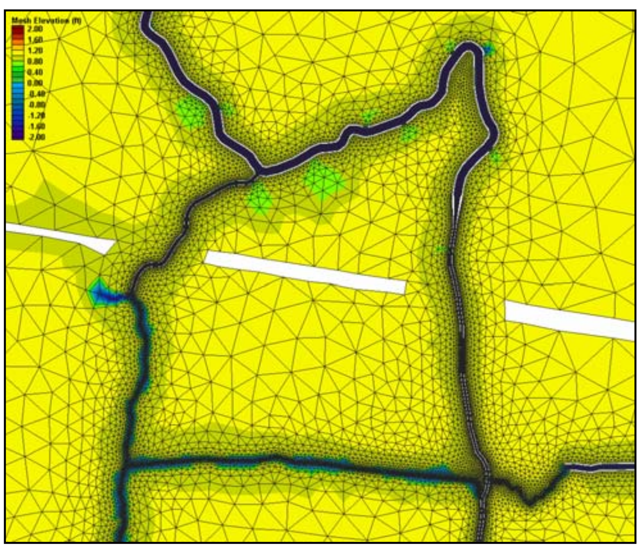


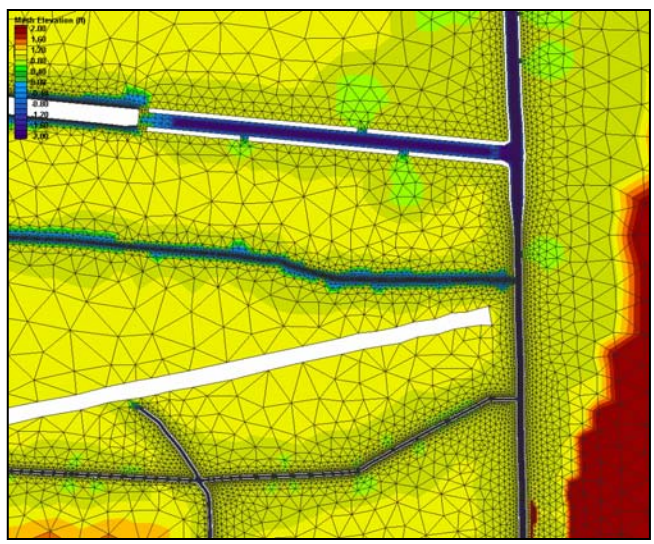
f) Hope Canal at I-10



g) Blind River at I-10



h) Bougere and Mississippi Bayous at Transmission Line Row



i) I-10 Canal at Reserve Relief Canal

Figure 7. Mesh Details

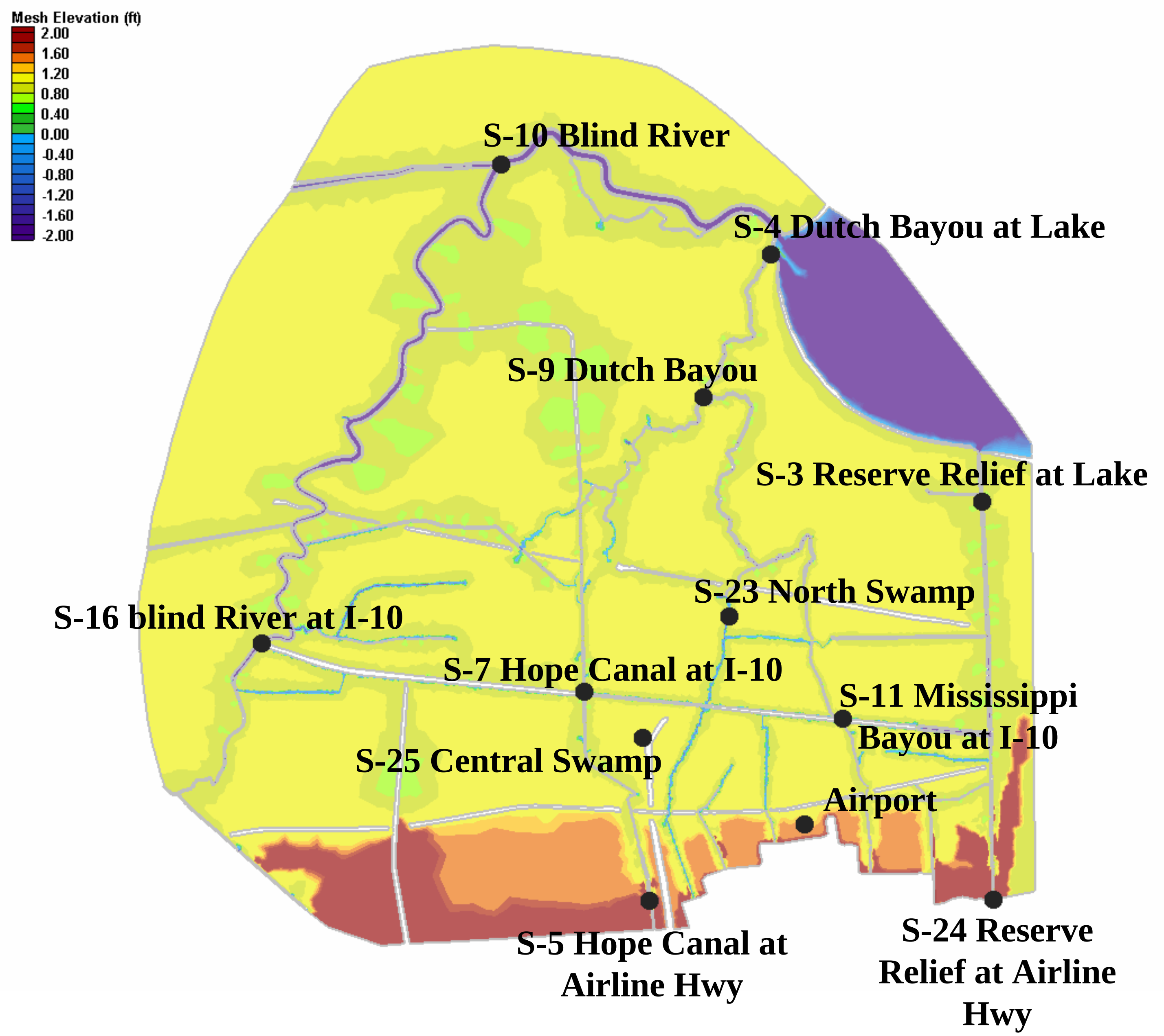
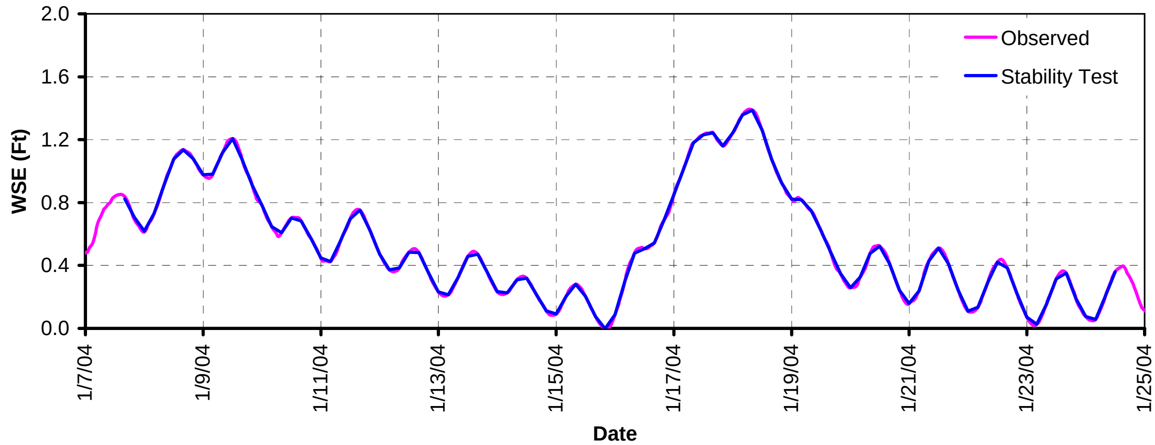
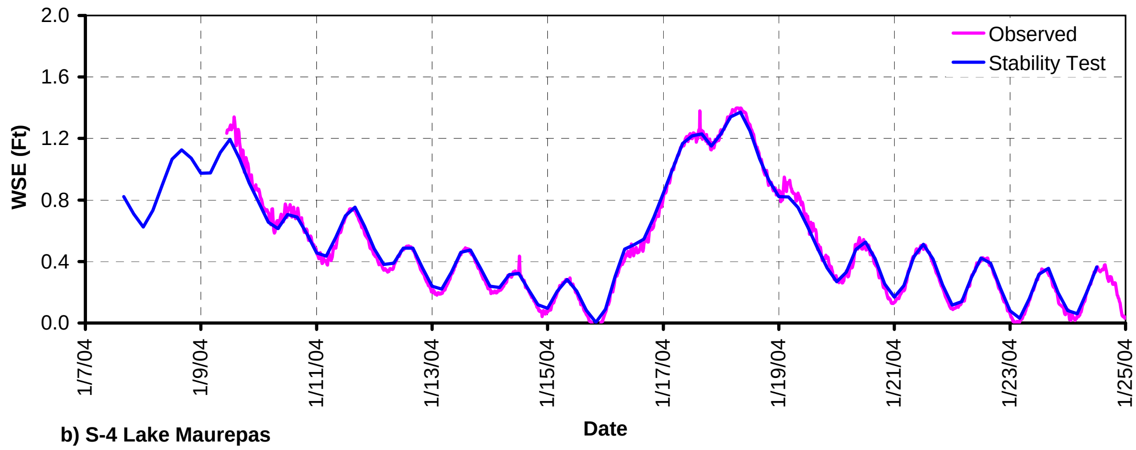


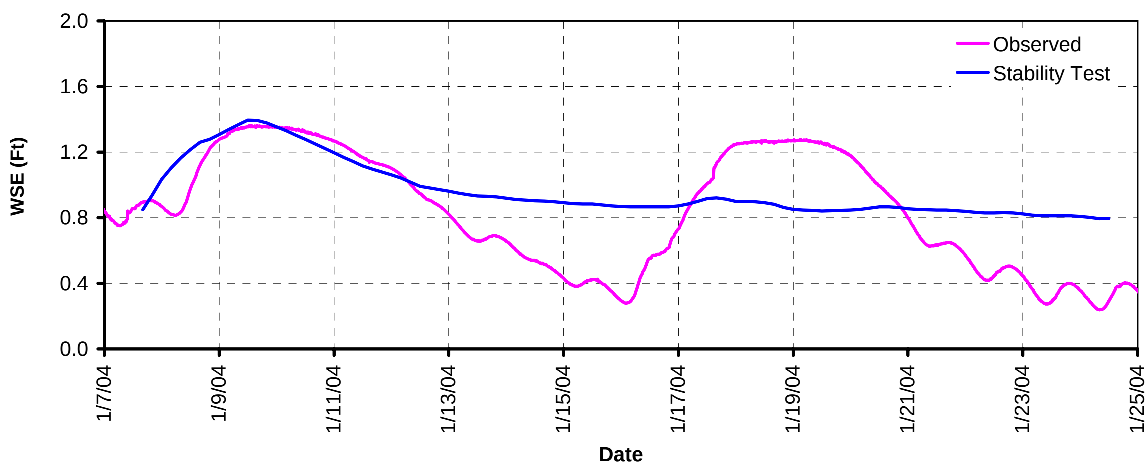
Figure 8. Hydrograph Locations



a) S-3 Dutch Bayou at Lake

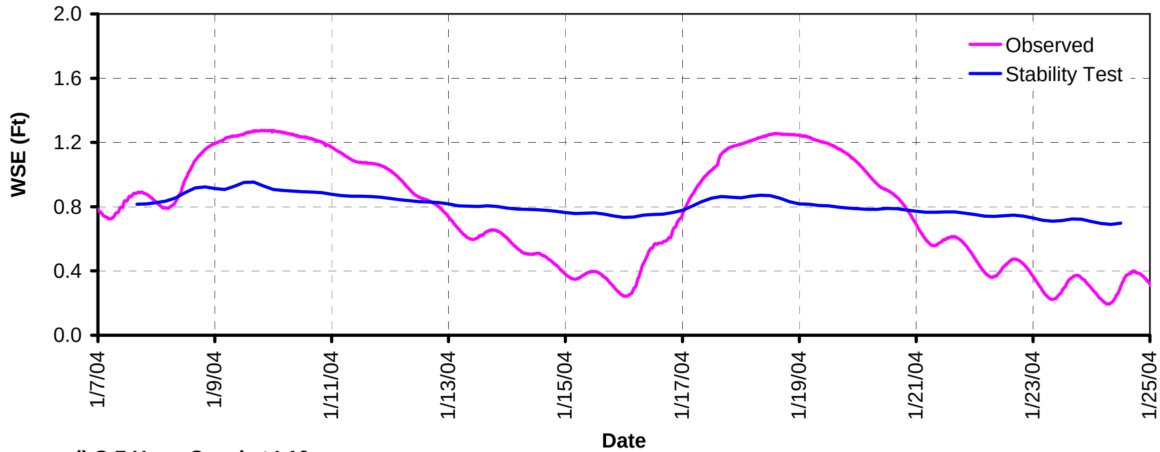


b) S-4 Lake Maurepas

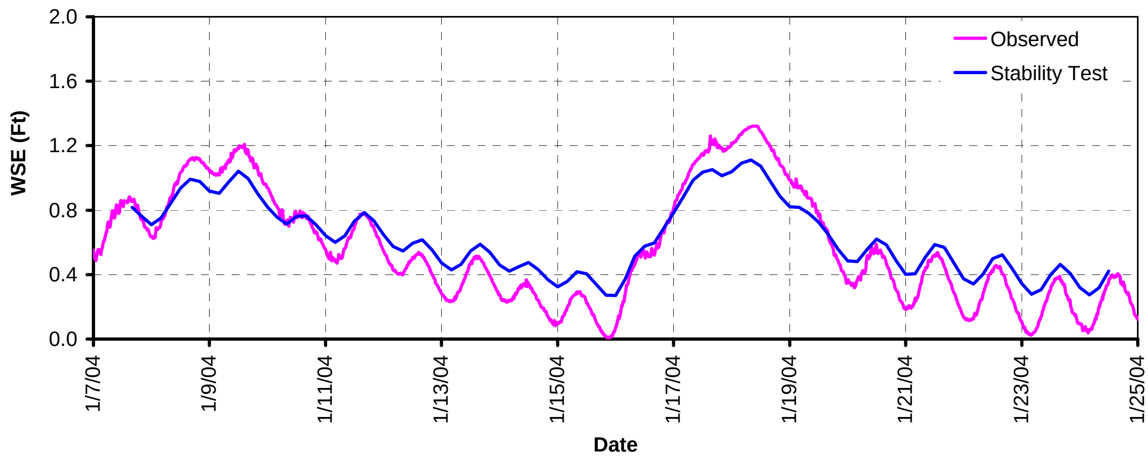


c) S-5 Hope Canal at Airline Hwy.

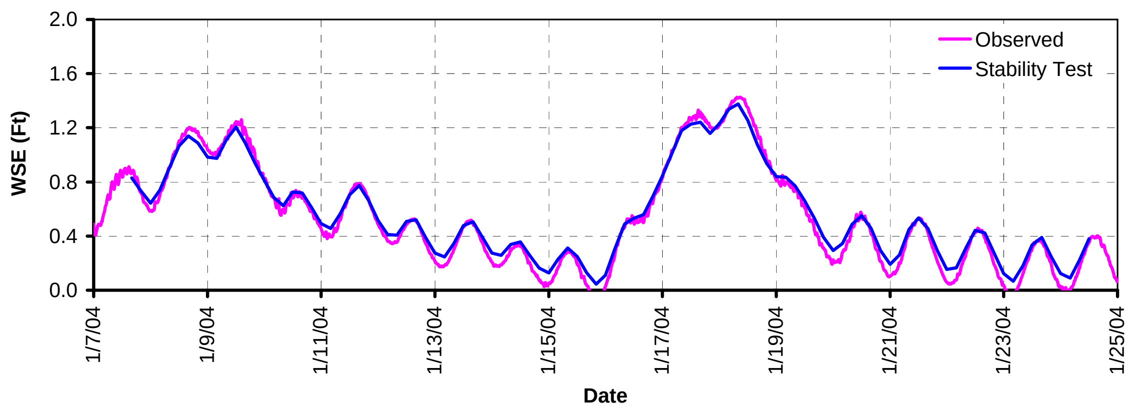
Figure 9. Stability Test Stage Hydrographs (a through c)



d) S-7 Hope Canal at I-10

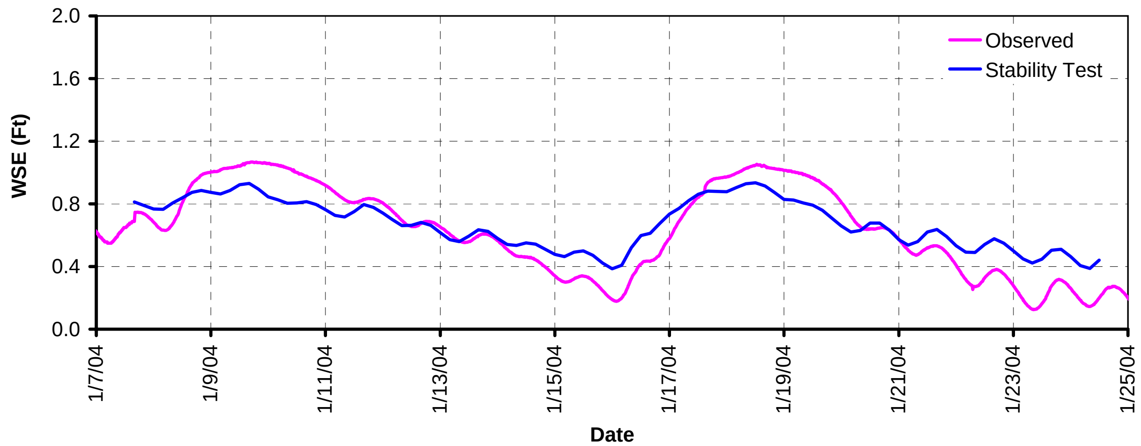


e) S-9 Dutch Bayou

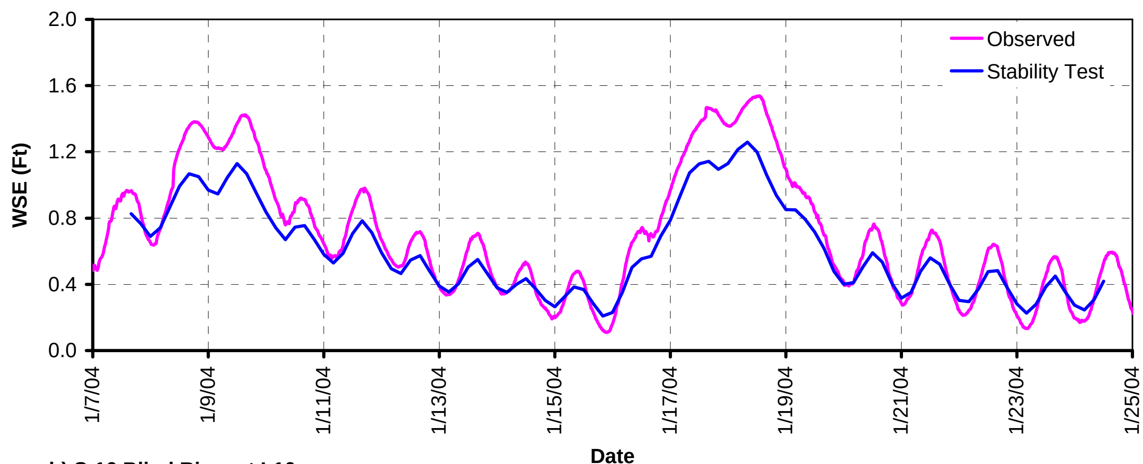


f) S-10 Blind River

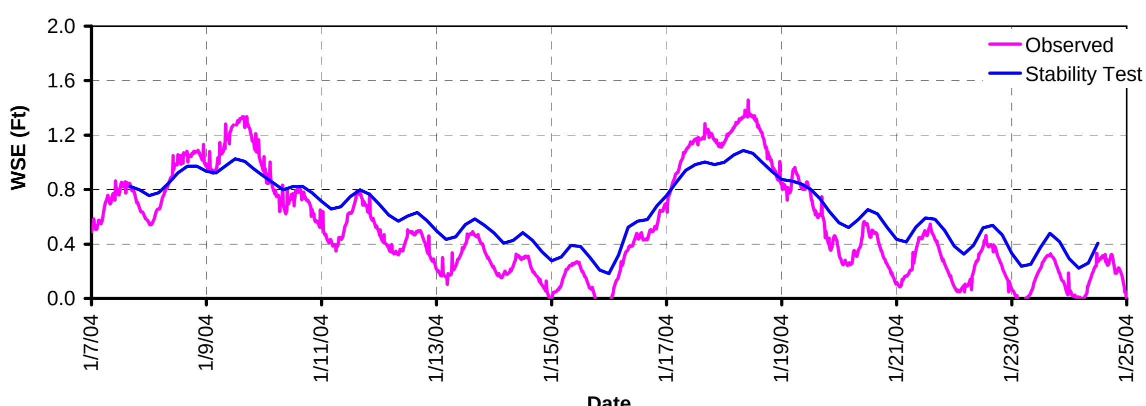
Figure 9. Stability Test Stage Hydrographs (d through f)



g) S-11 Mississippi Bayou at I-10

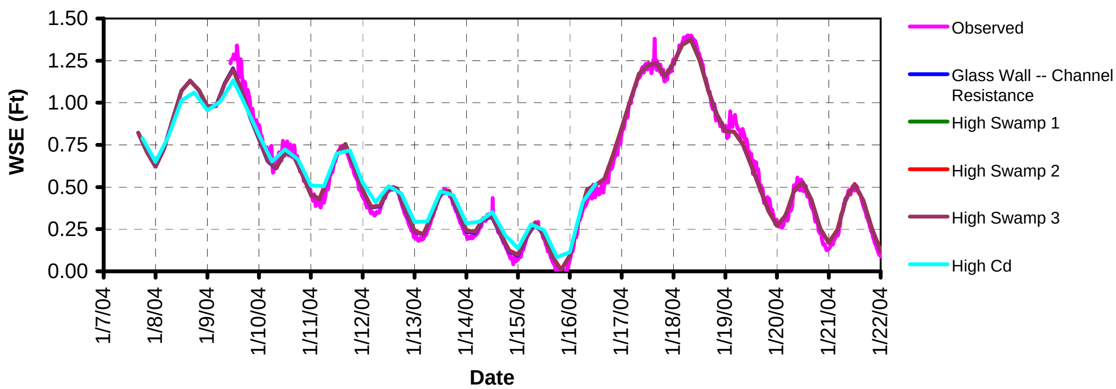


h) S-16 Blind River at I-10

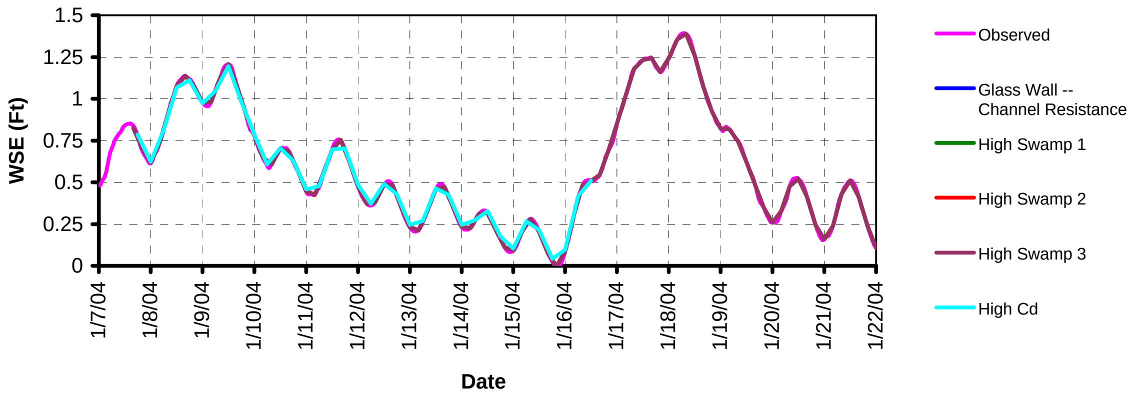


i) S-24 Reserve Relief at Airline Hwy.

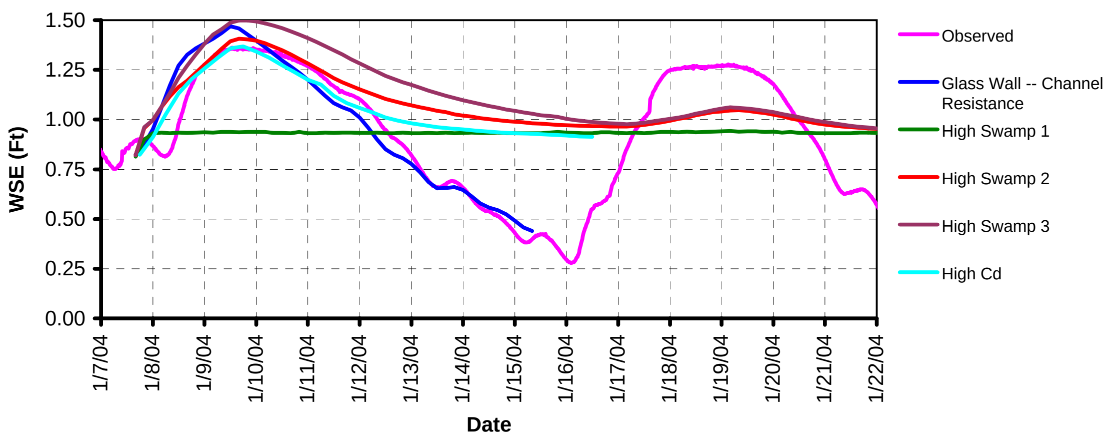
Figure 9. Stability Test Stage Hydrographs (g through i)



a) S-3 Reserve Relief at Lake



b) S-4 Dutch Bayou at Lake



c) S-5 Hope Canal at Airline Hwy.

Figure 10. Parameter Test Stage Hydrographs, LSU Period (a - c)

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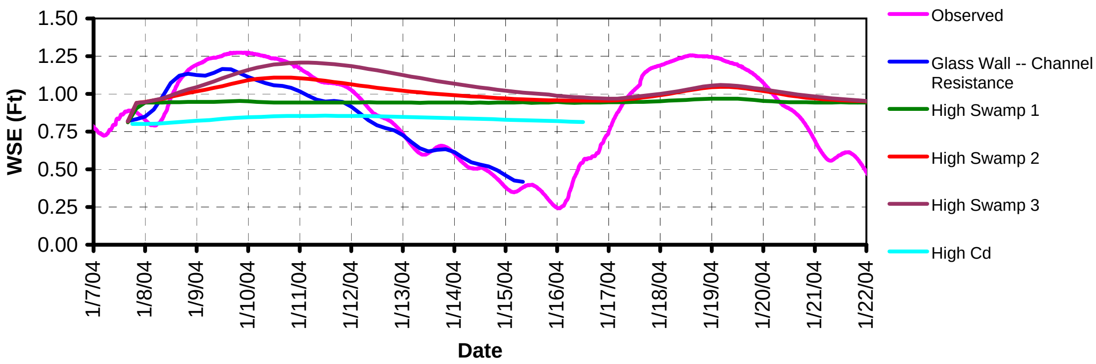
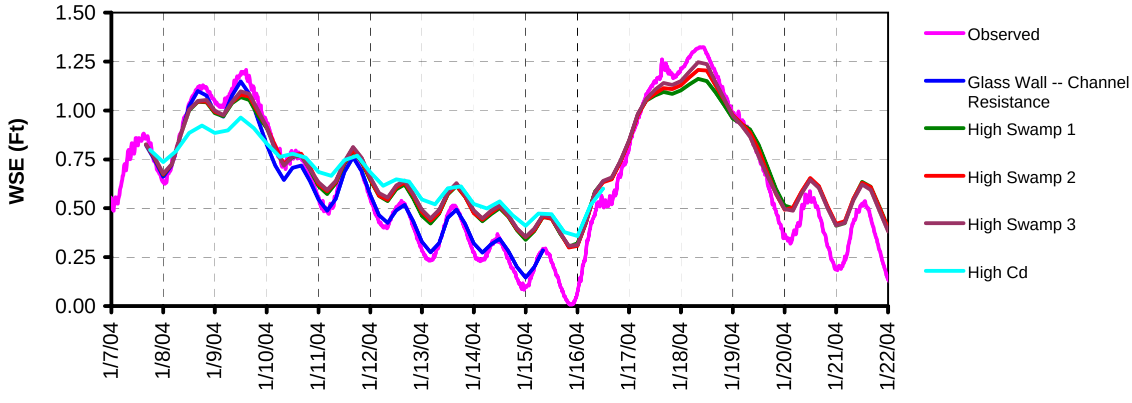
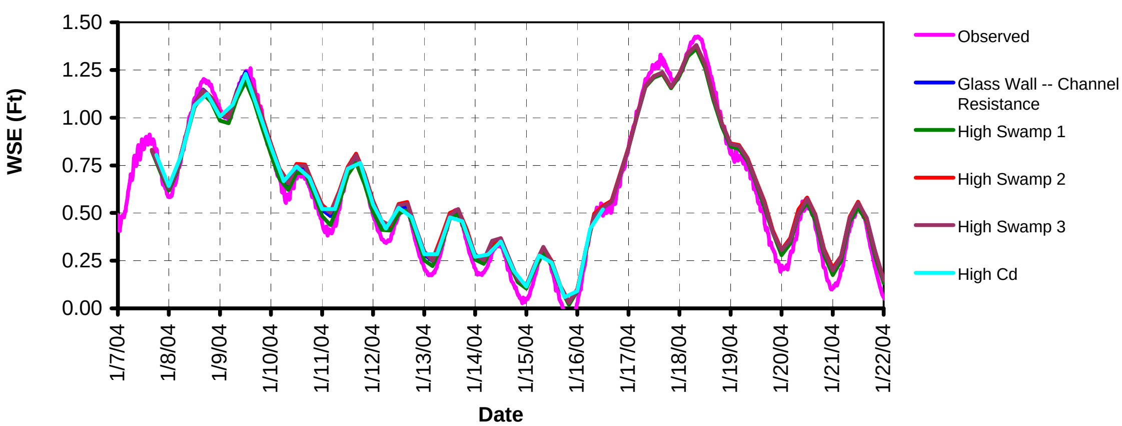


d) S-7 Hope Canal at I-10

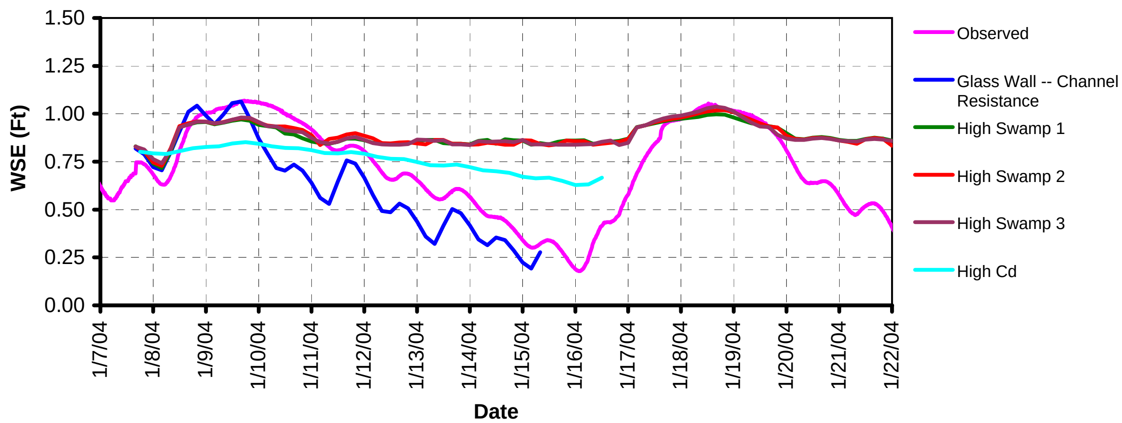


e) S-9 Dutch Bayou

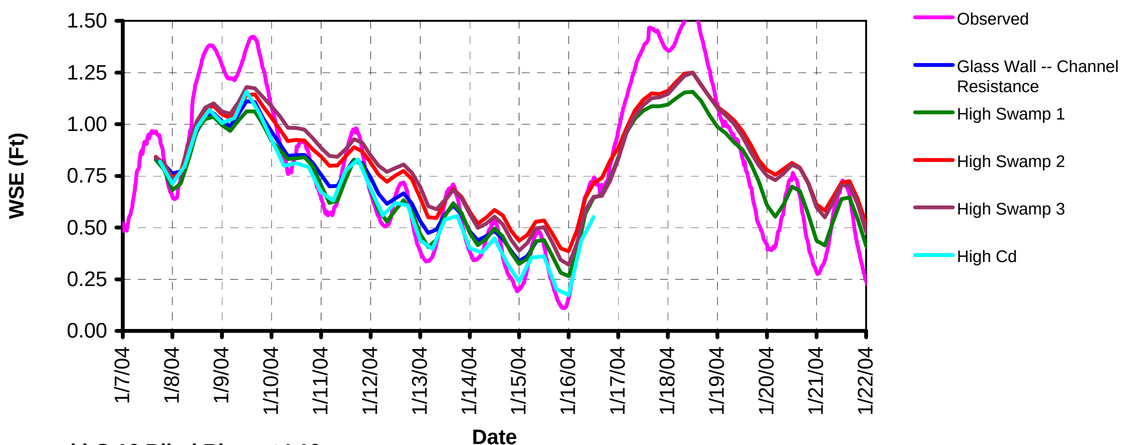


f) S-10 Blind River

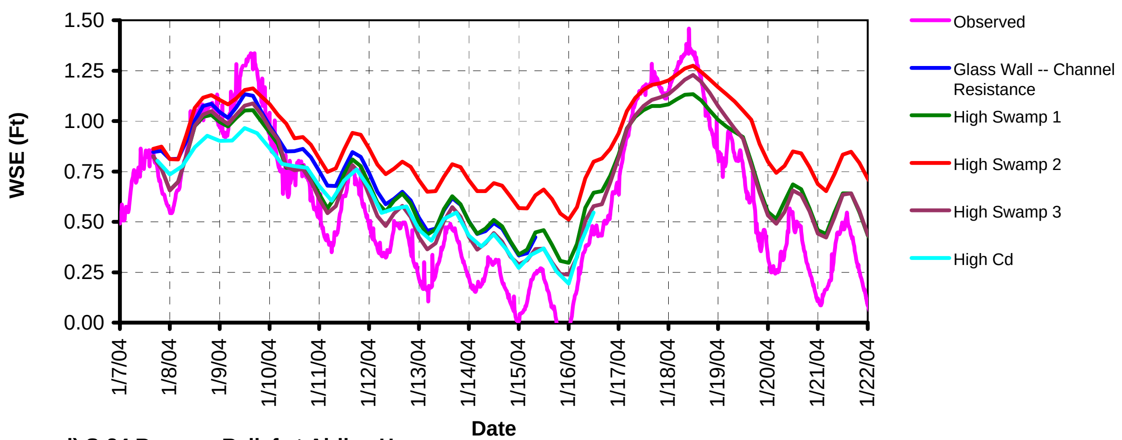
Figure 10. Parameter Test Stage Hydrographs, LSU Period (d - f)



g) S-11 Mississippi Bayou at I-10

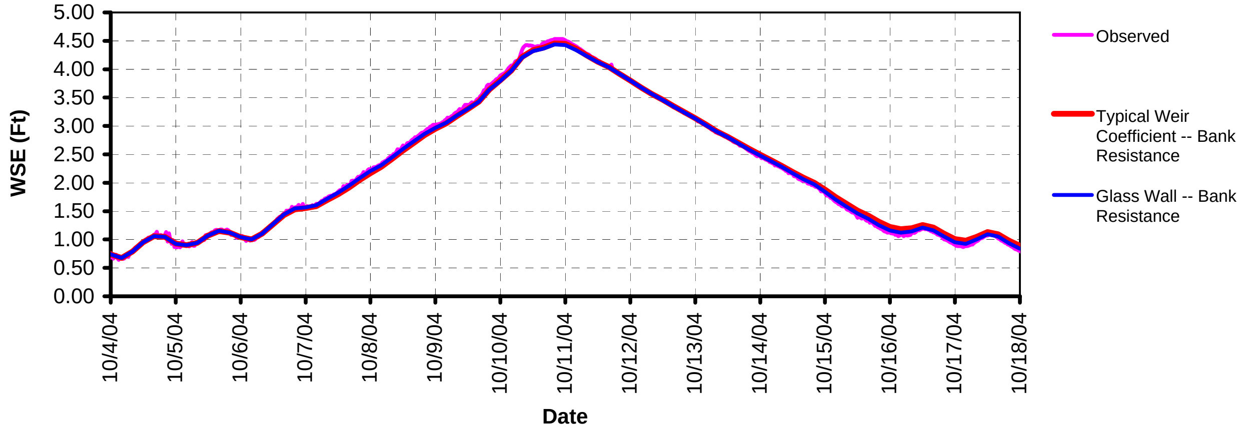


h) S-16 Blind River at I-10

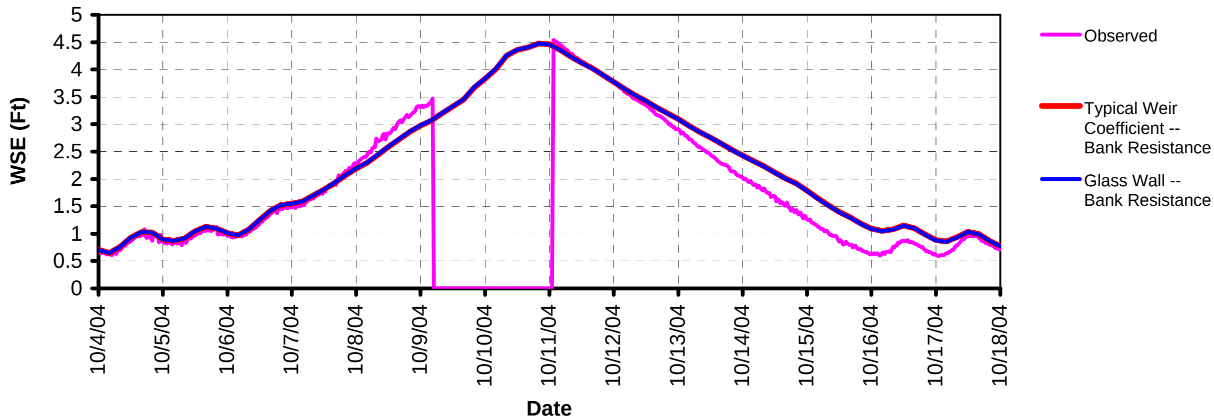


i) S-24 Reserve Relief at Airline Hwy.

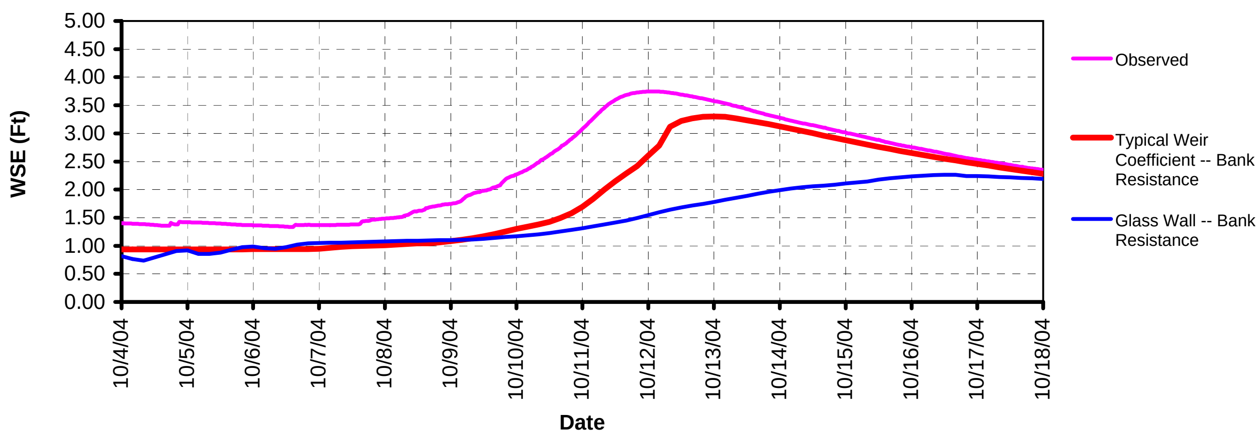
Figure 10. Parameter Test Stage Hydrographs, LSU Period (g - i)



a) S-3 Reserve Relief at Lake



b) S-4 Dutch Bayou at Lake



c) S-5 Hope Canal at Airline Hwy.

Figure 11. Parameter Test Stage Hydrographs, TS Mathew (a - c)

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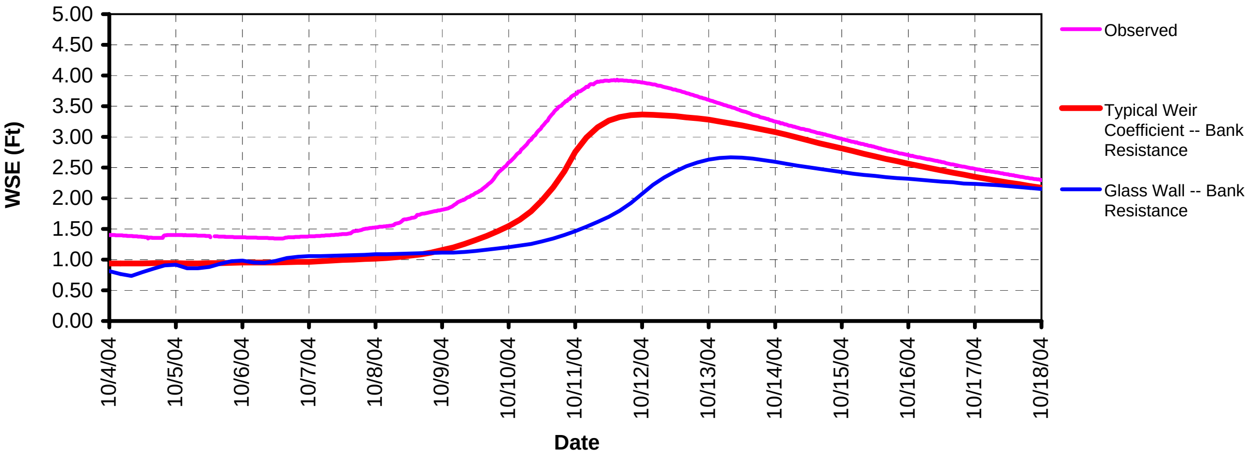
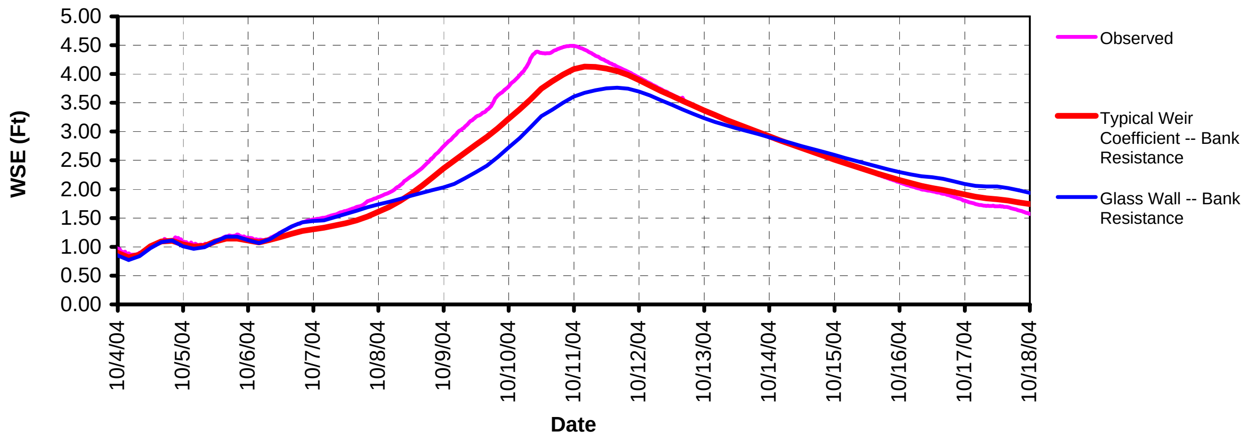
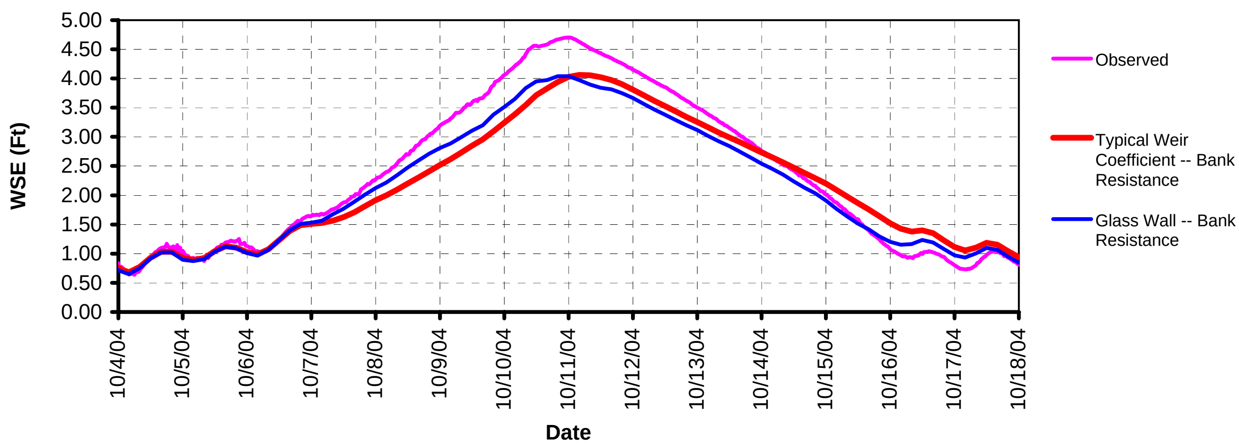


d) S-7 Hope Canal at I-10

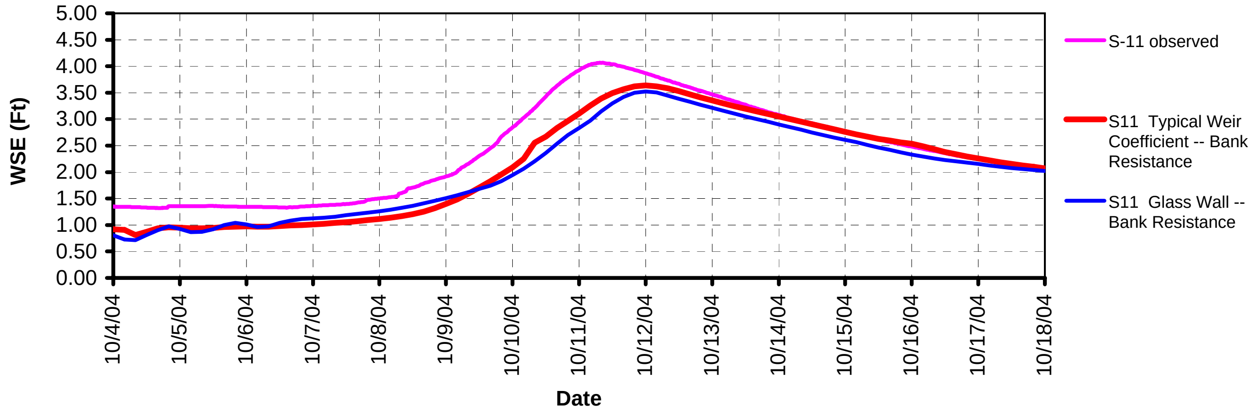


e) S-9 Dutch Bayou

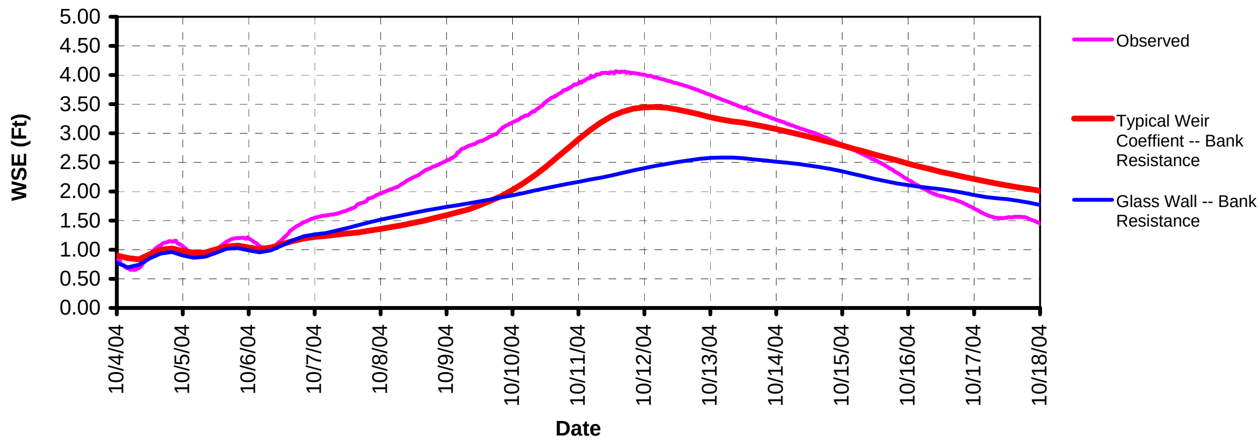


f) S-10 Blind River

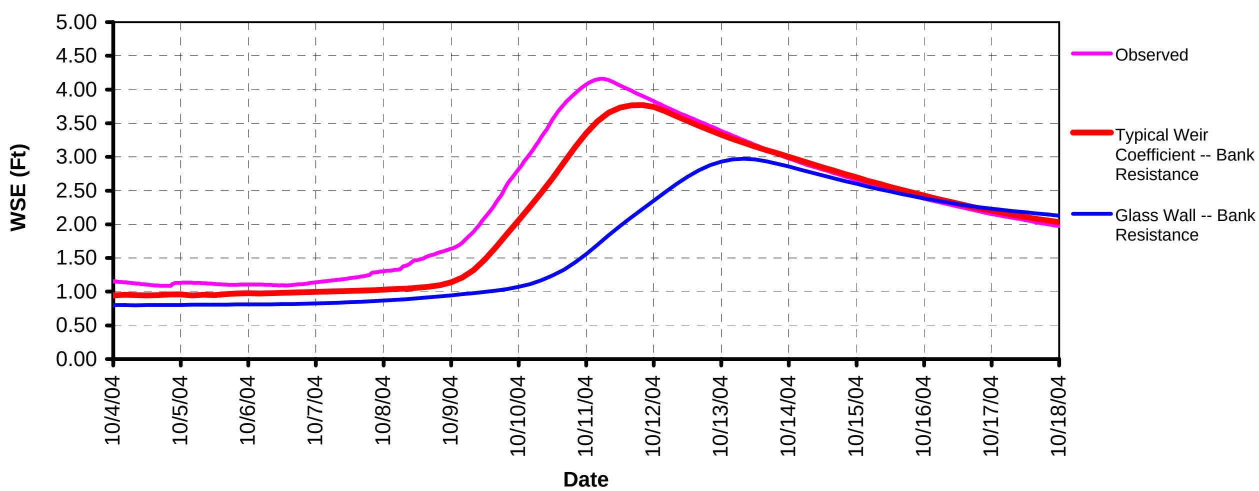
Figure 11. Parameter Test Stage Hydrographs, TS Mathew (d - f)



g) S-11 Mississippi Bayou at I-10

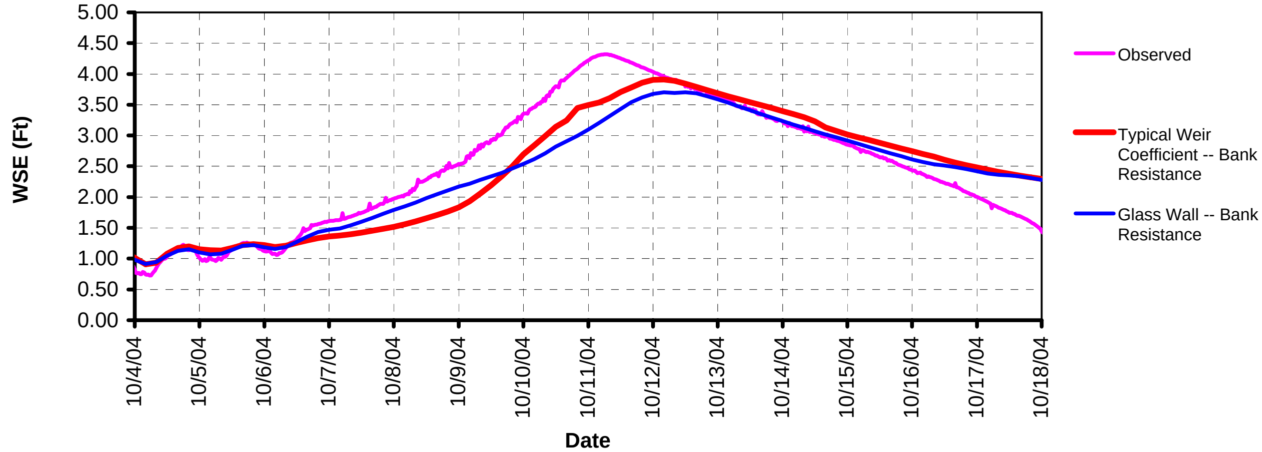


h) S-16 Blind River at I-10

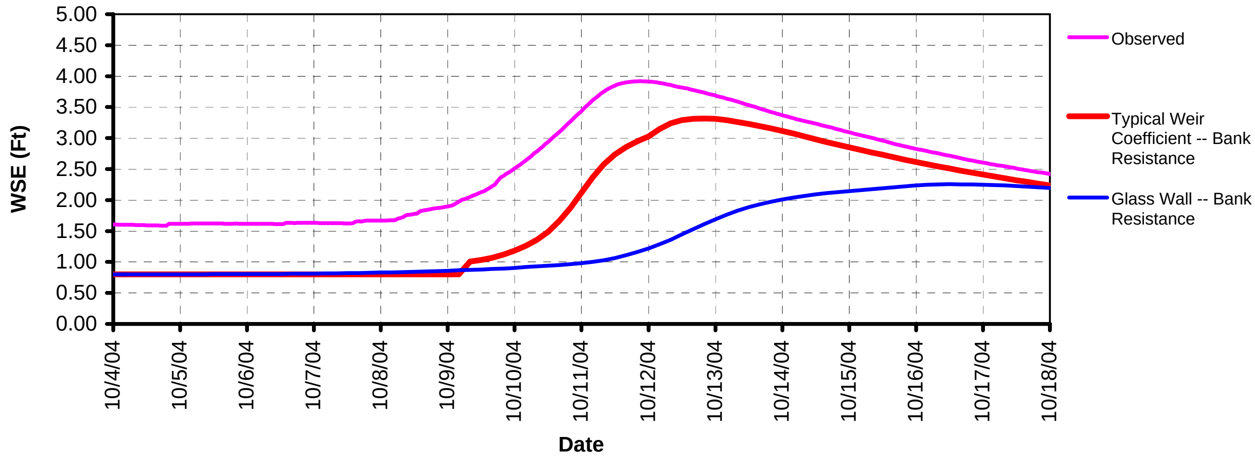


i) S-23 North Swamp

Figure 11. Parameter Test Stage Hydrographs, TS Mathew (g - i)



j) S-24 Reserve Relief at Airline Hwy.



k) S-25 Central Swamp

Figure 11. Parameter Test Stage Hydrographs, TS Mathew (j - k)

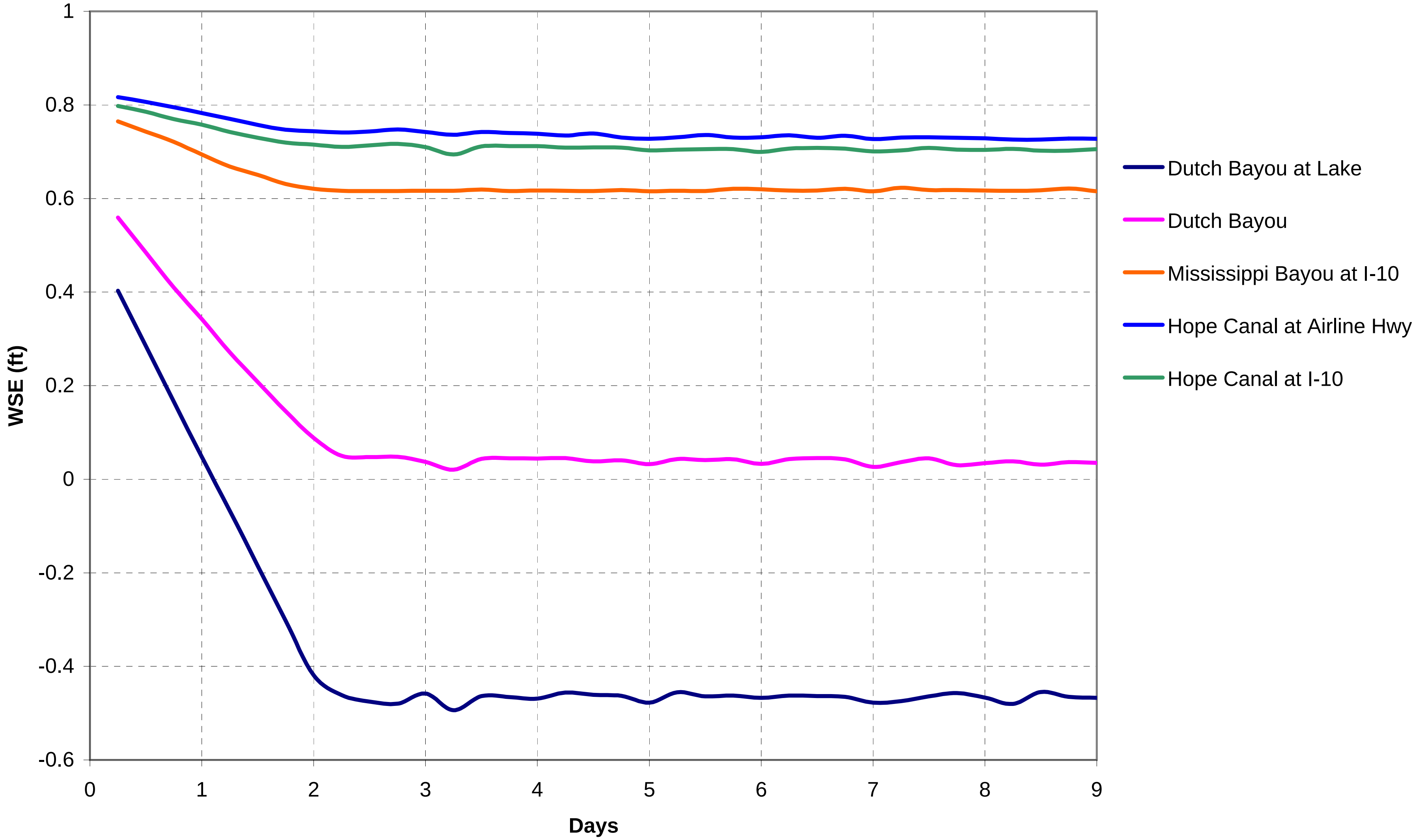
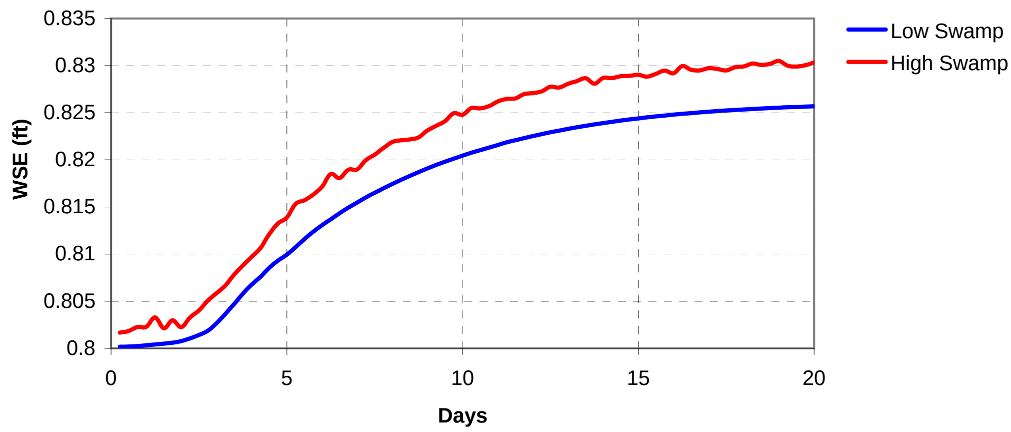
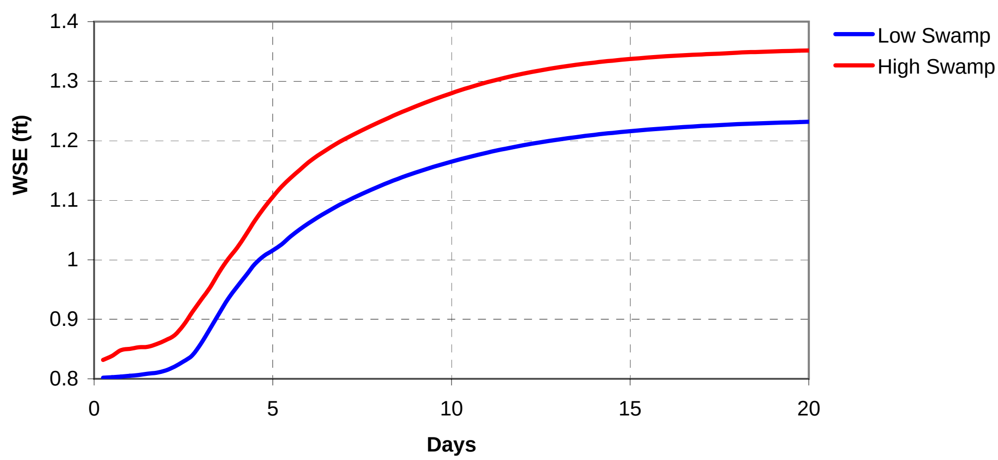


Figure 12. Extended Swamp Draining Test Stage Hydrographs

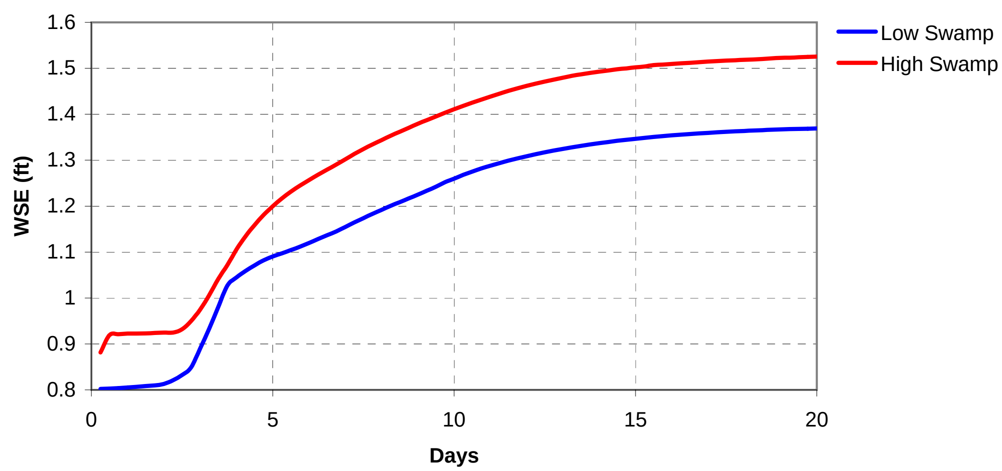
URS



a) S-4 Dutch Bayou at Lake



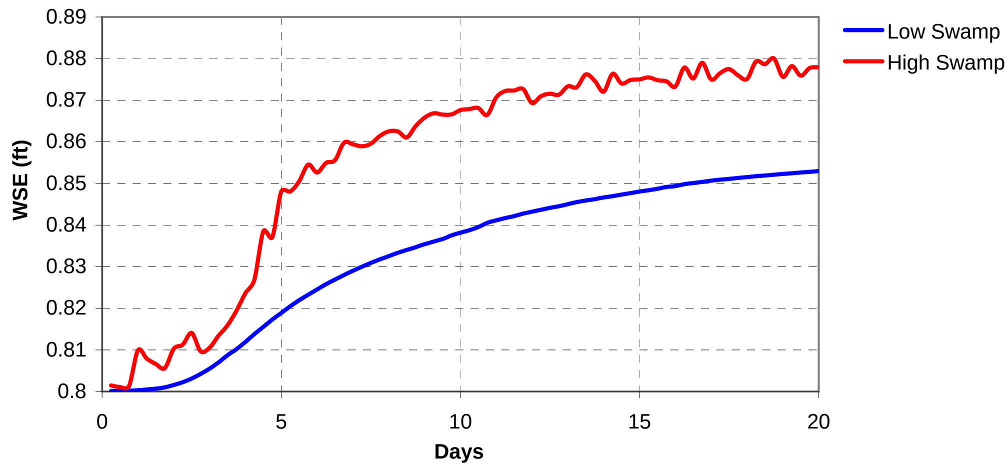
b) S-9 Dutch Bayou



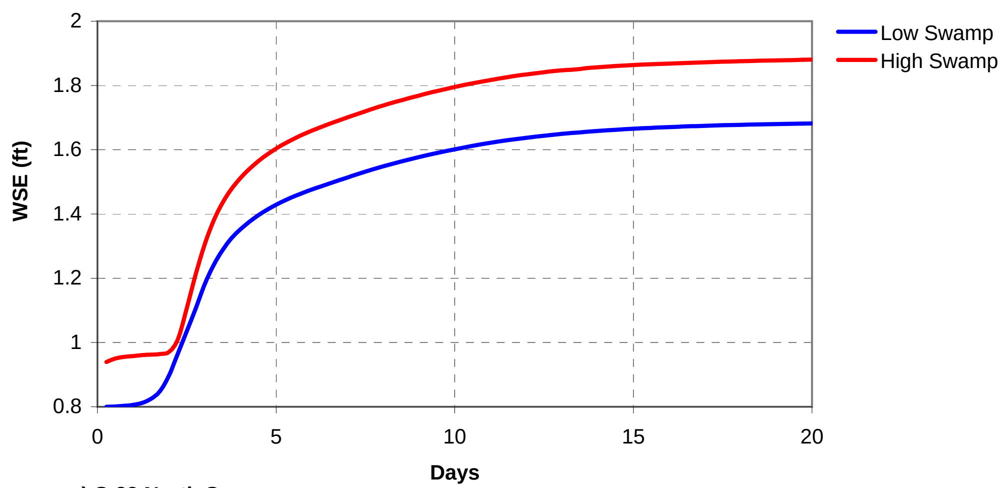
c) S-11 Mississippi Bayou at I-10

Figure 13. Diversion Test Stage Hydrographs (a - c)

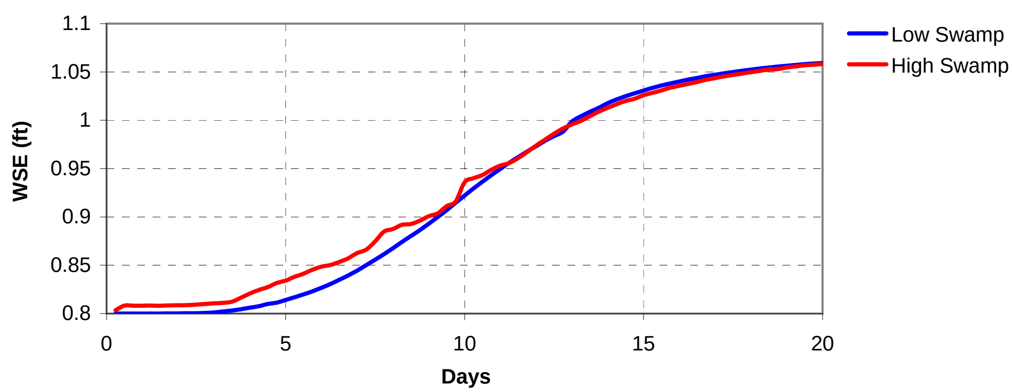
URS



d) S-16 Blind River at I-10



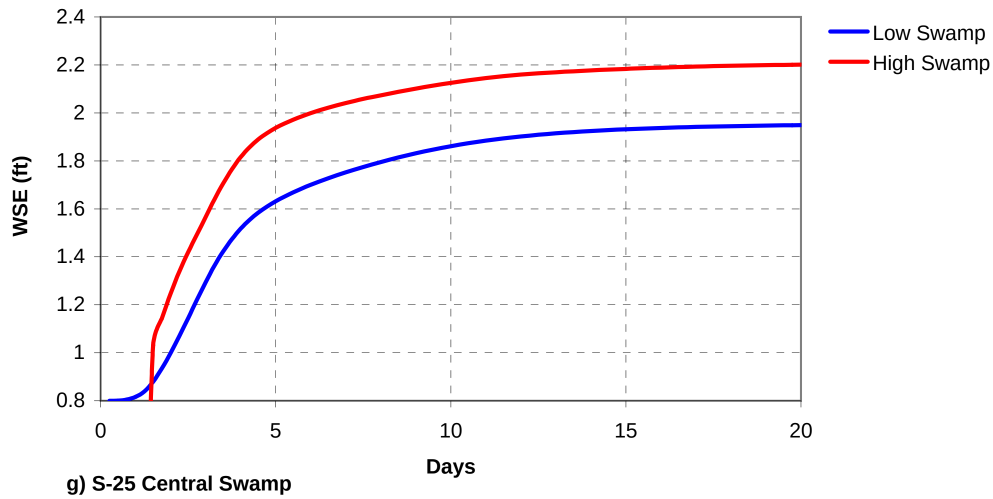
e) S-23 North Swamp



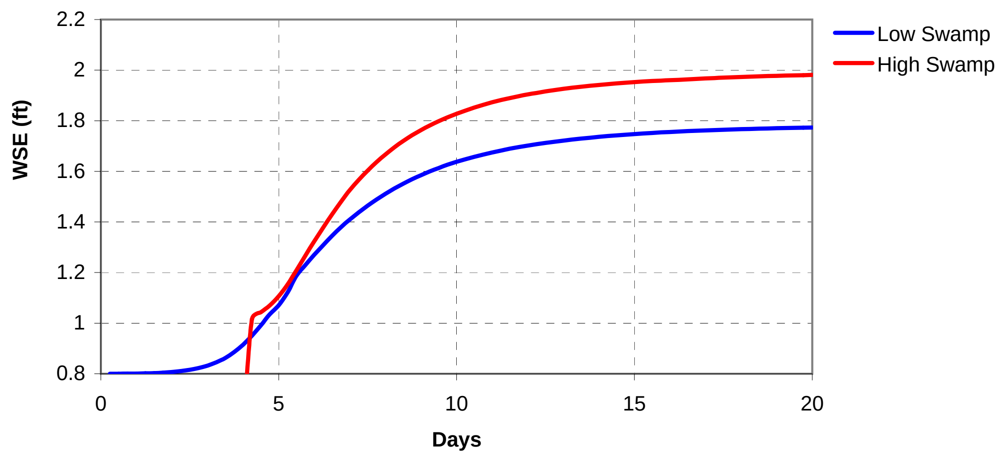
f) S-24 Reserve Relief at Airline Hwy.

Figure 13. Diversion Test Stage Hydrographs (d - f)

URS

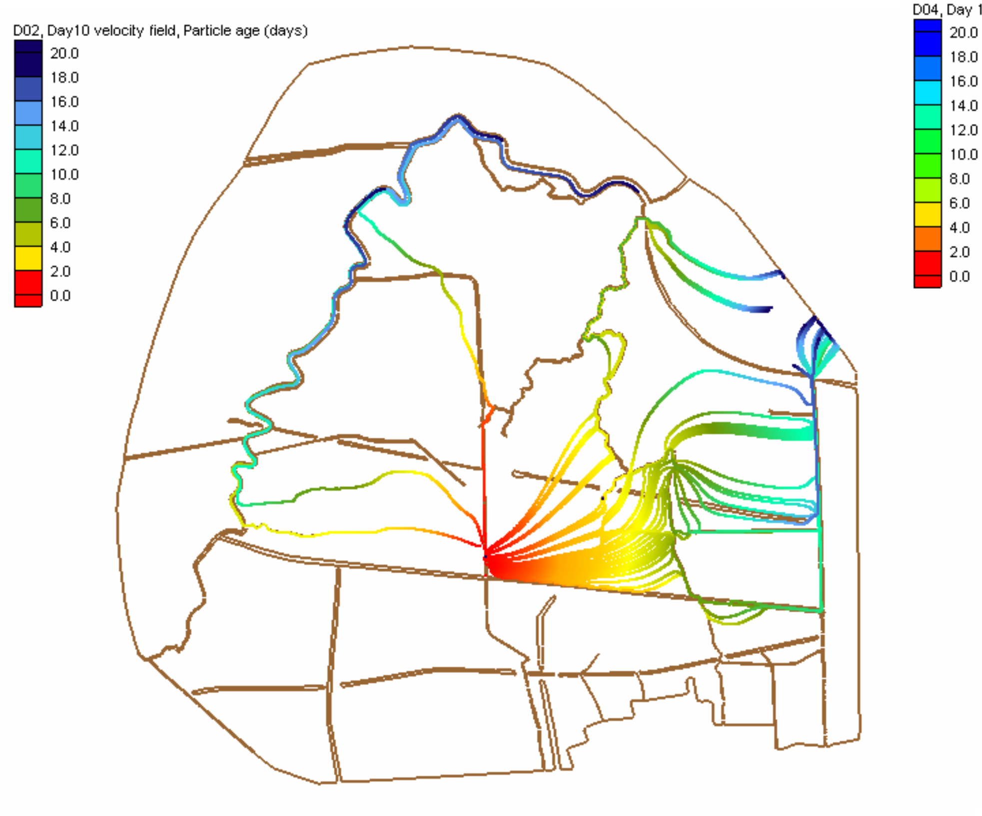


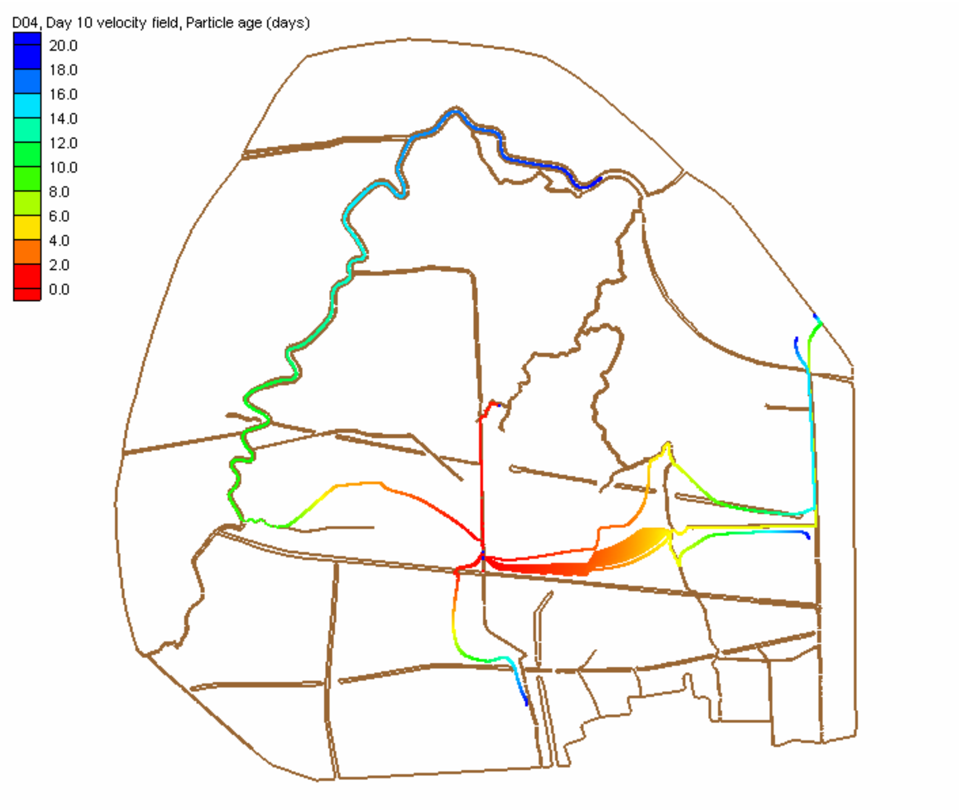
g) S-25 Central Swamp



h) Swamp North of Airport

Figure 13. Diversion Test Stage Hydrographs (g - h)



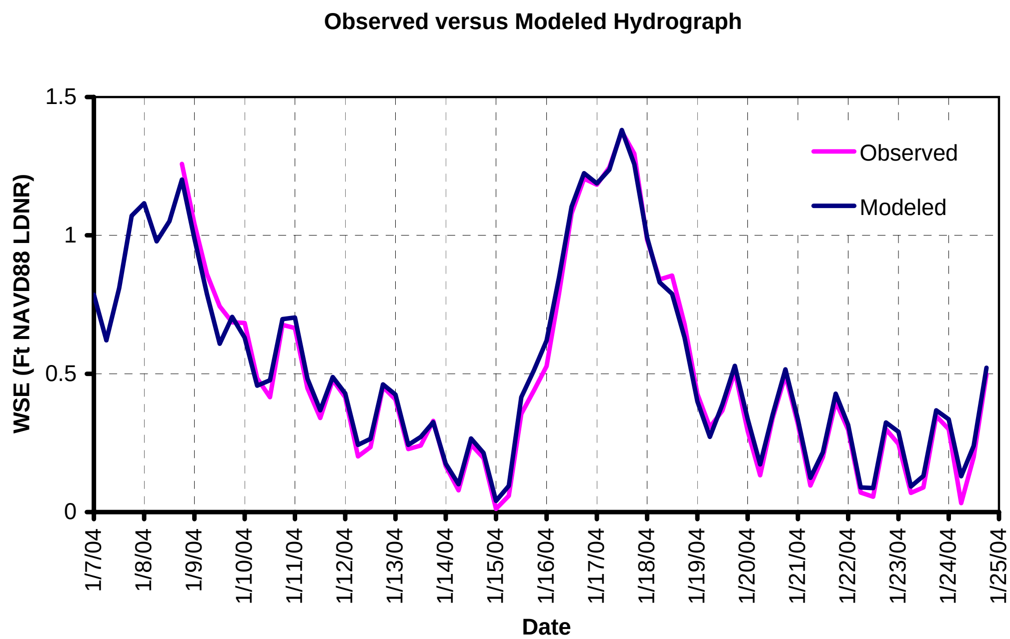


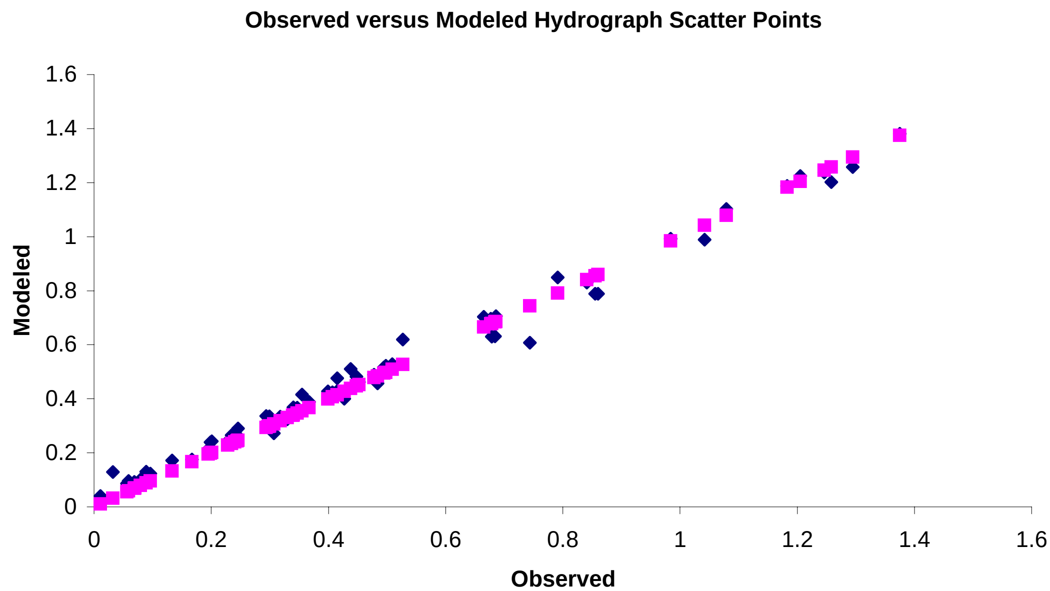
a) Typical Swamp Diversion (10.7 day mean)

b) High Swamp Diversion (7.1 day mean)

Figure 14. Diversion Test Flow Patterns.

URS

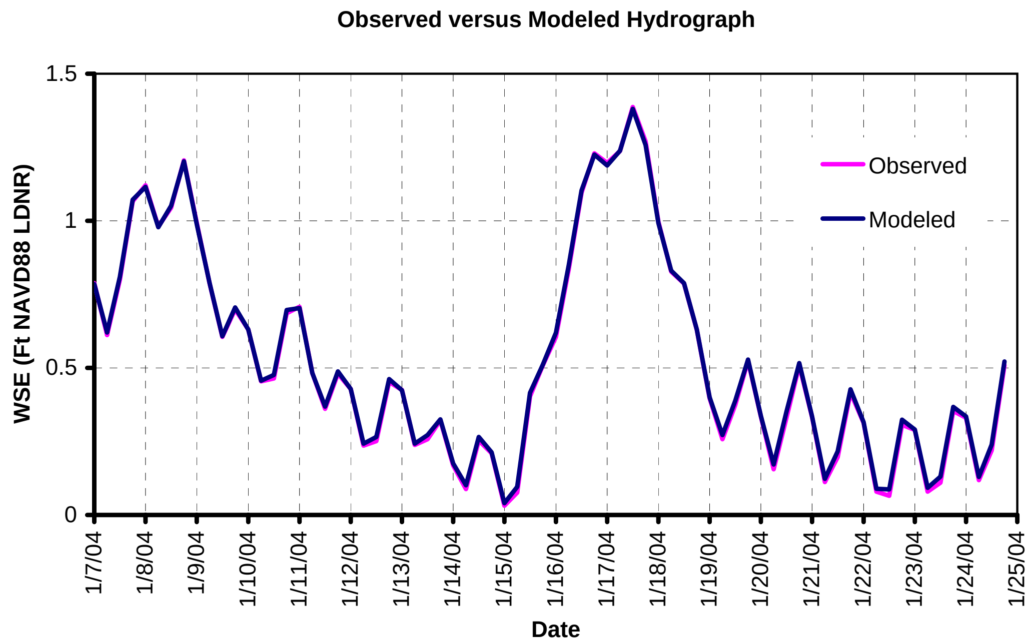


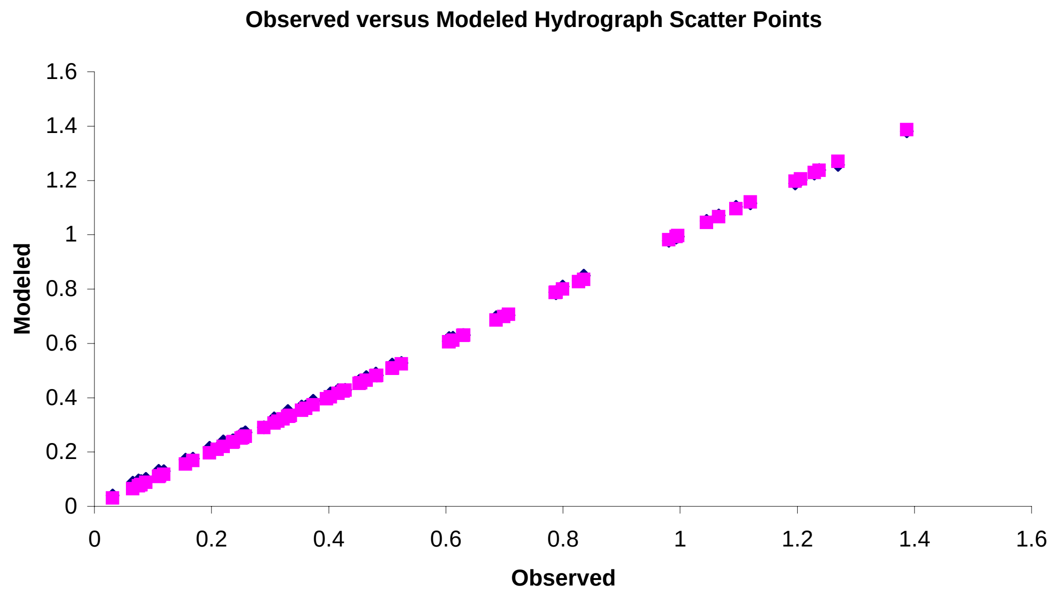


a) S-3 Reserve Relief at Lake

Figure 15. Calibration Stage Hydrograph, LSU Period

URS



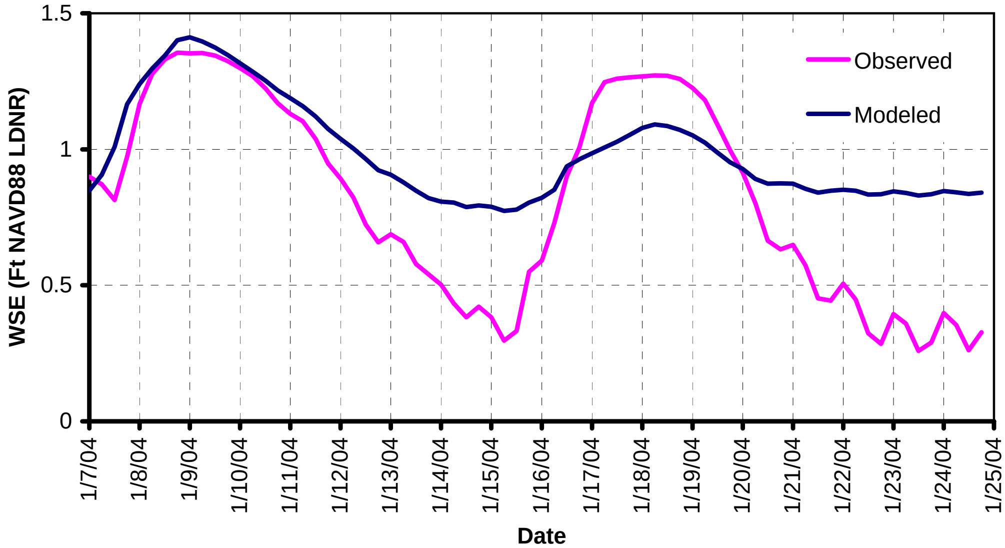


b) S-4 Dutch Bayou at Lake

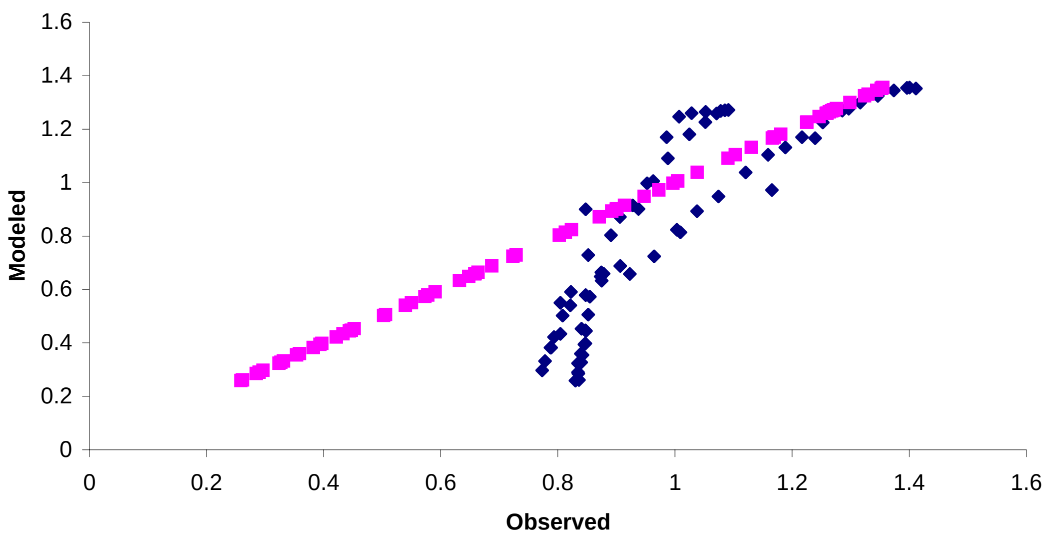
Figure 15. Calibration Stage Hydrograph, LSU Period

URS

Observed versus Modeled Hydrograph

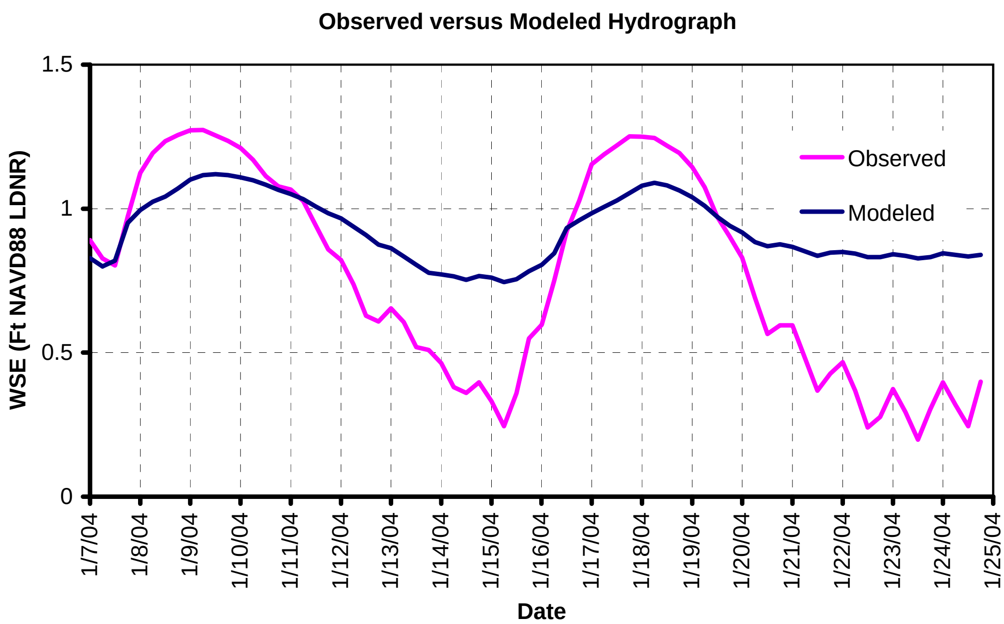


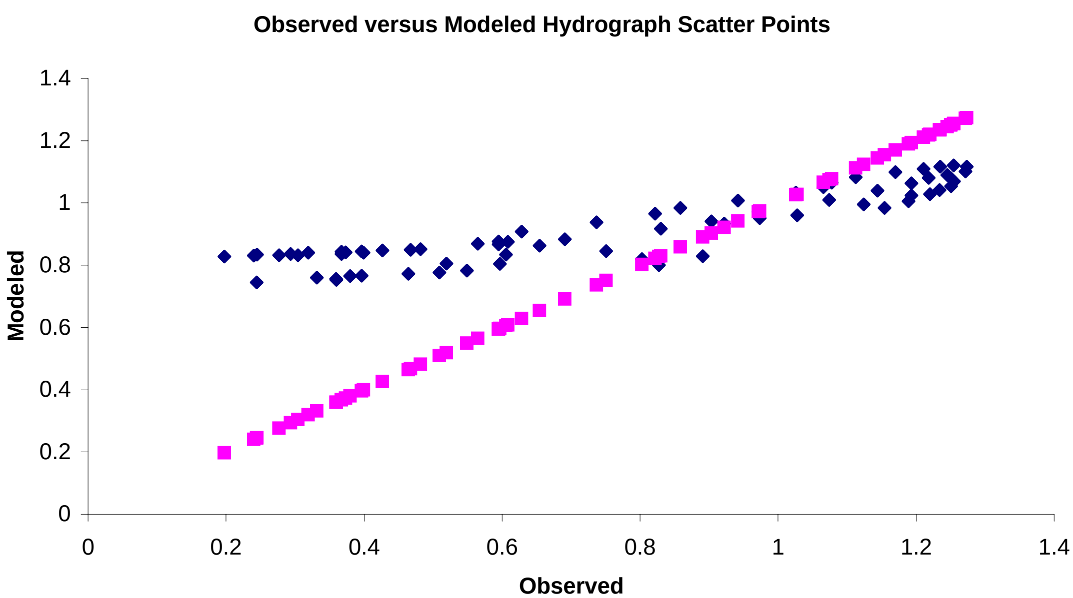
Observed versus Modeled Hydrograph Scatter Points



c) S-5 Hope Canal at Airline Hwy.

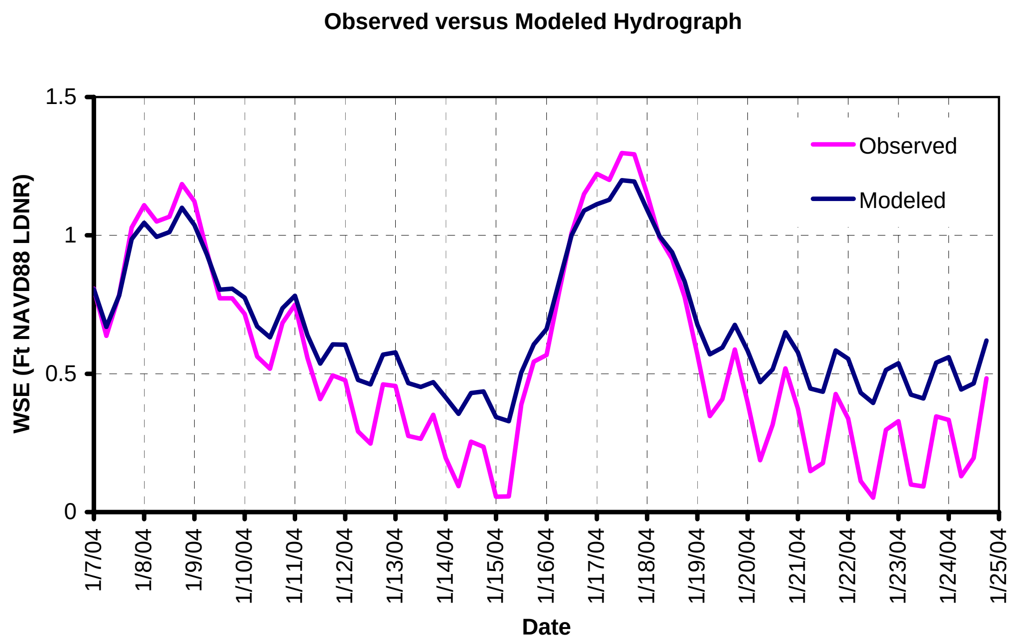
Figure 15. Calibration Stage Hydrograph, LSU Period

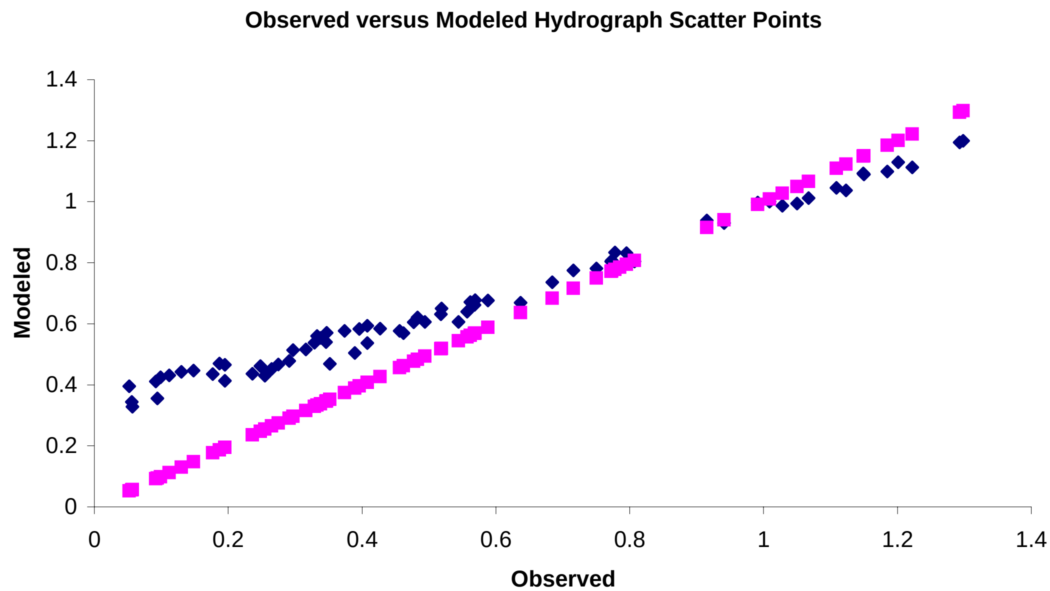




d) S-7 Hope Canal at I-10

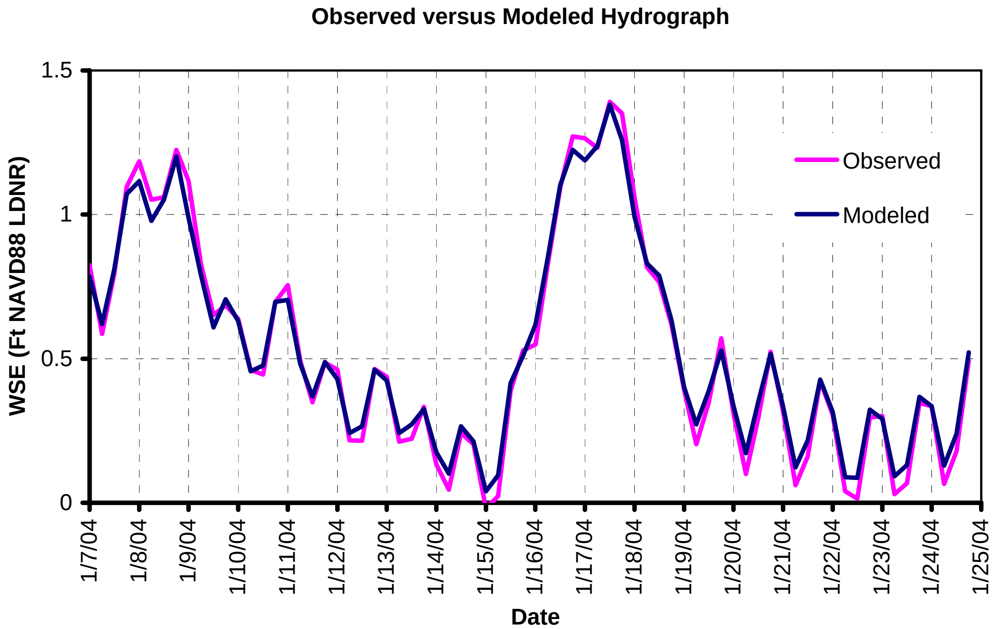
Figure 15. Calibration Stage Hydrograph, LSU Period

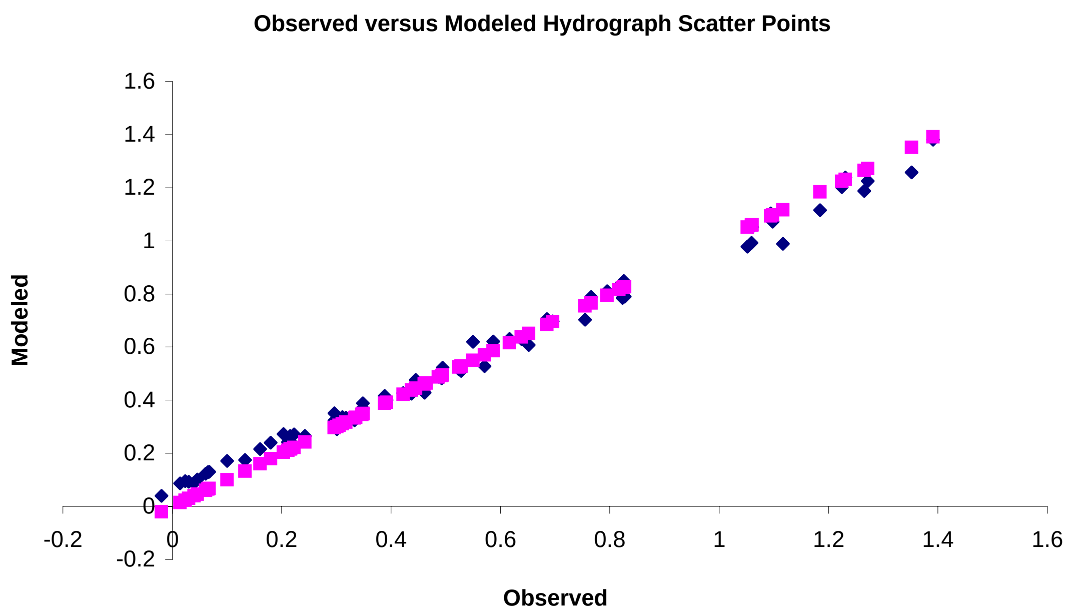




e) S-9 Dutch Bayou

Figure 15. Calibration Stage Hydrograph, LSU Period

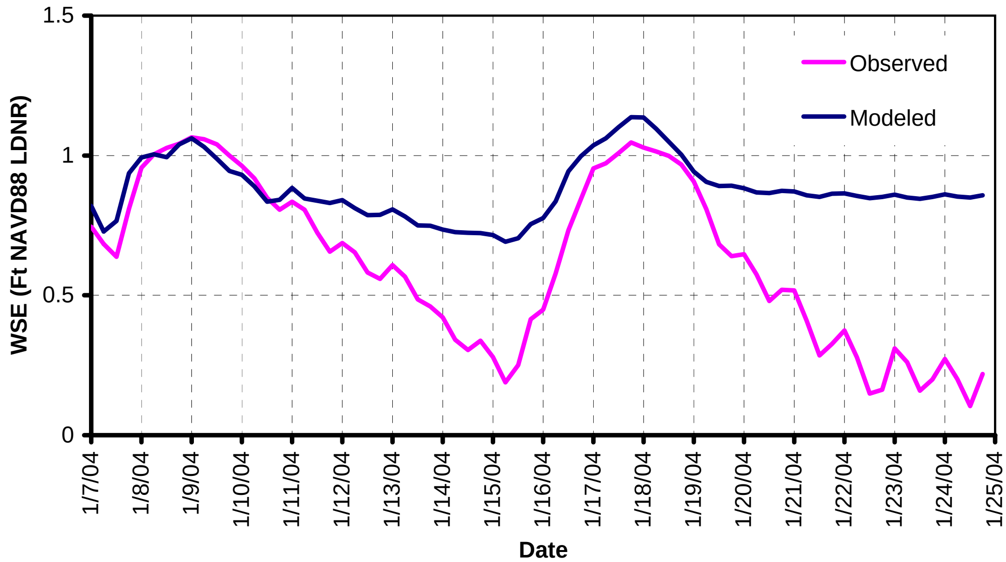




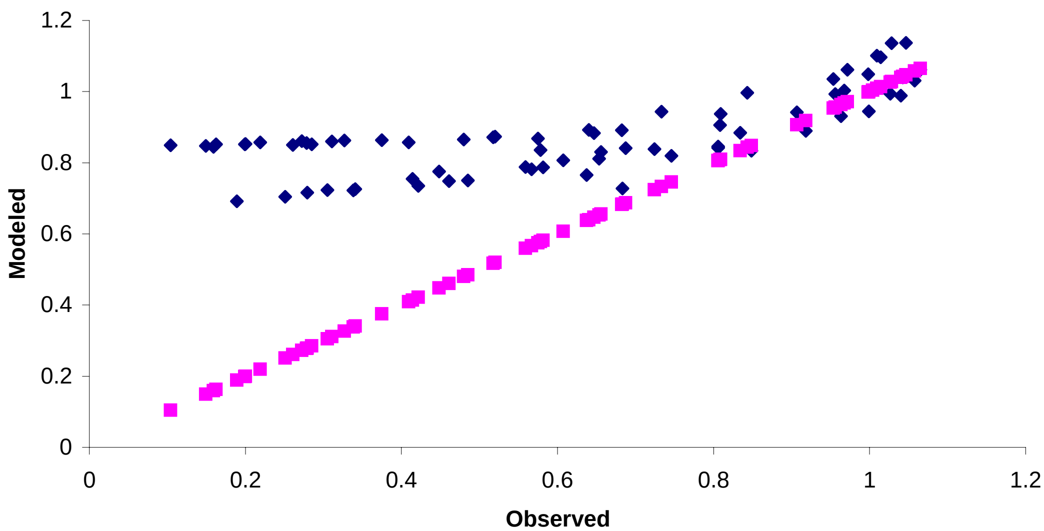
f) S-10 Blind River

Figure 15. Calibration Stage Hydrograph, LSU Period

Observed versus Modeled Hydrograph



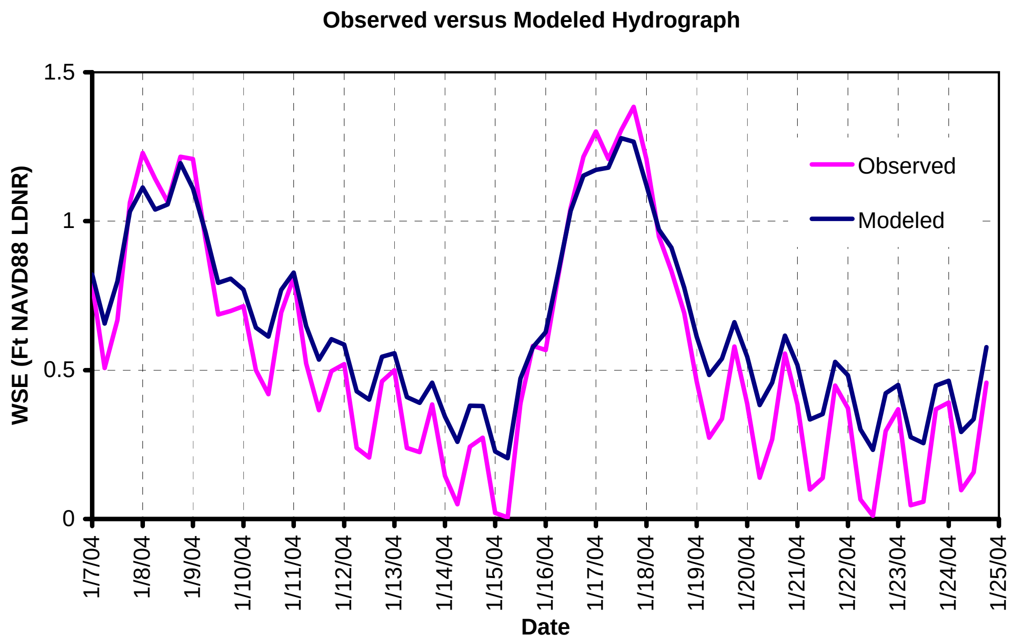
Observed versus Modeled Hydrograph Scatter Points

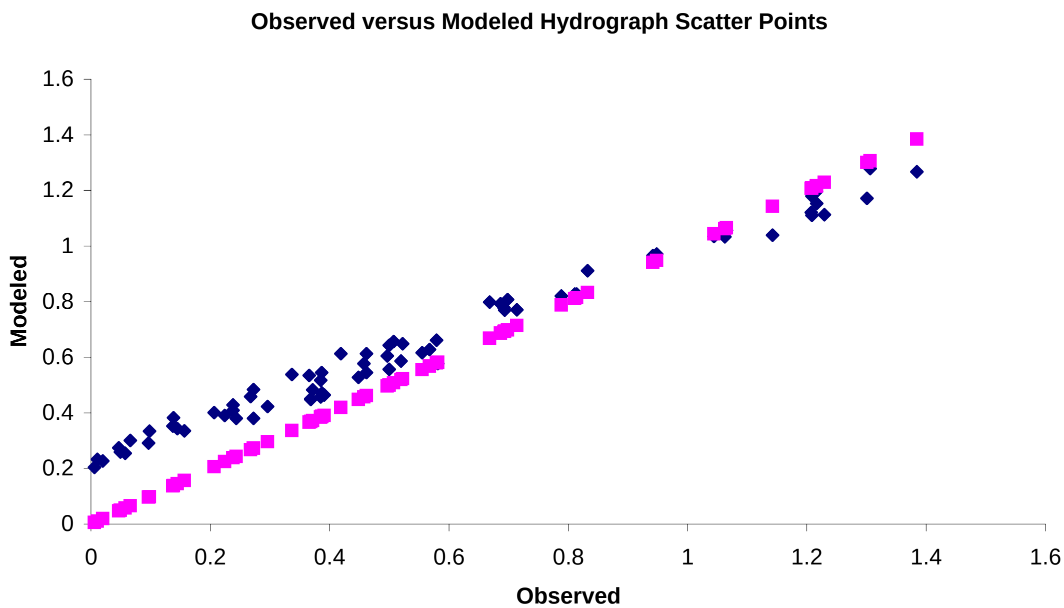


g) S-11 Mississippi Bayou at I-10

Figure 15. Calibration Stage Hydrograph, LSU Period

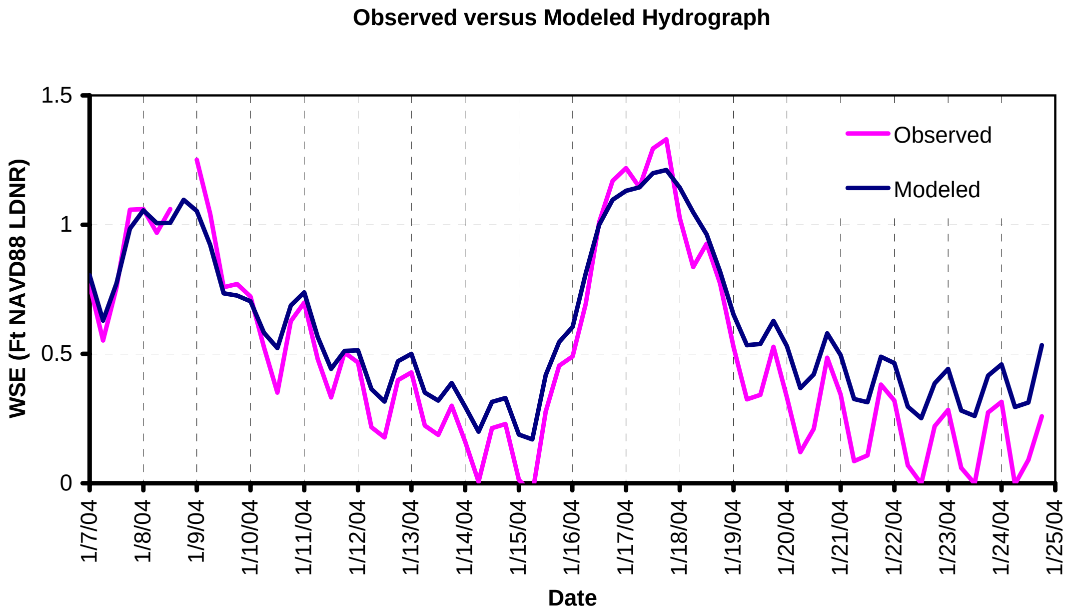
URS

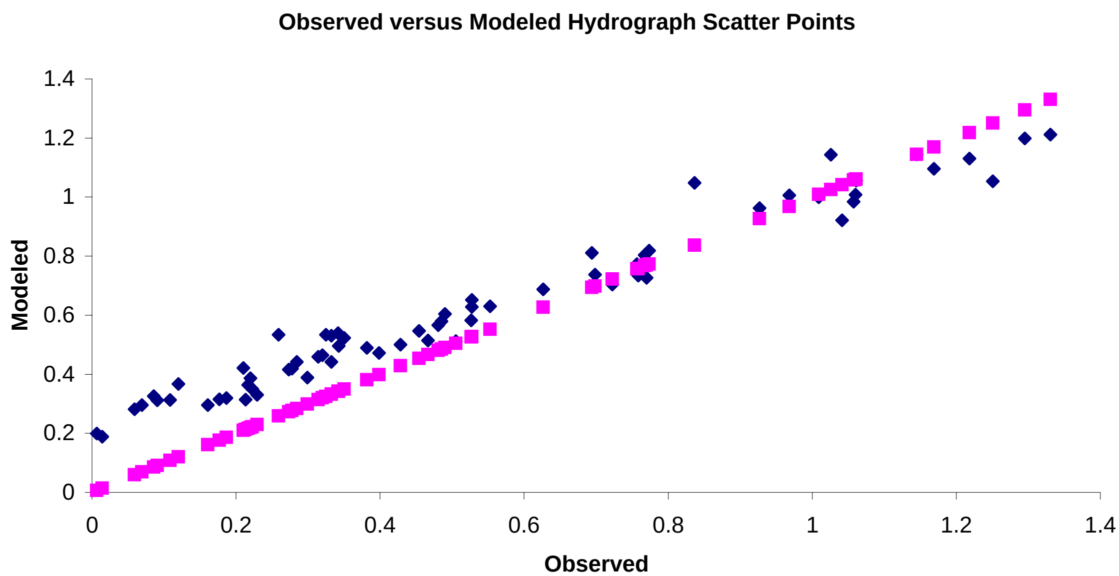




h) S-16 Blind River at I-10

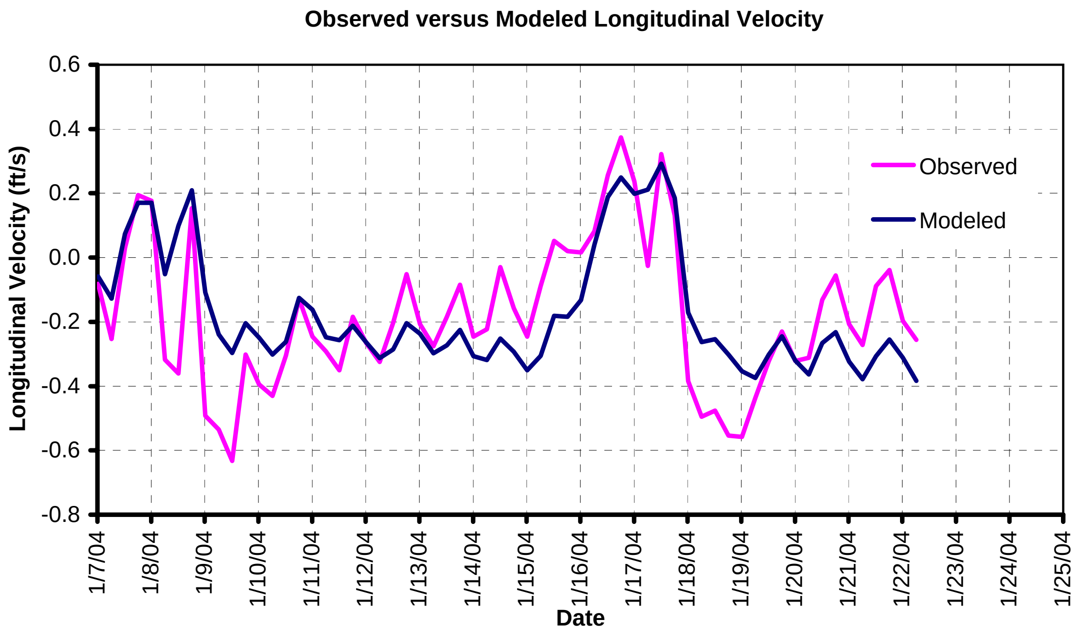
Figure 15. Calibration Stage Hydrograph, LSU Period

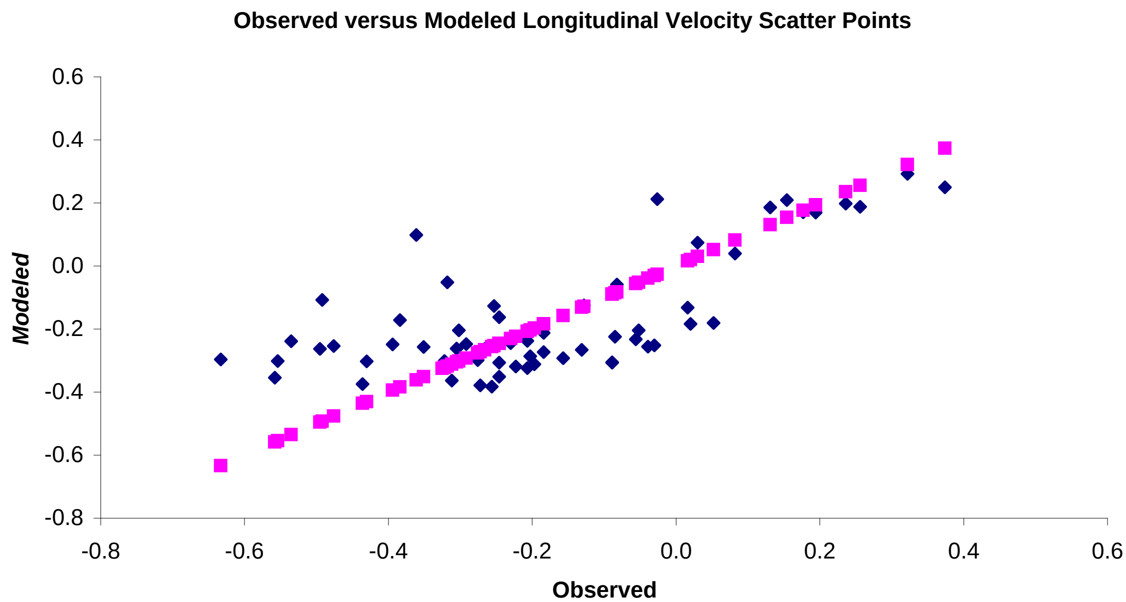




i) S-24 Reserve Relief at Airline Hwy.

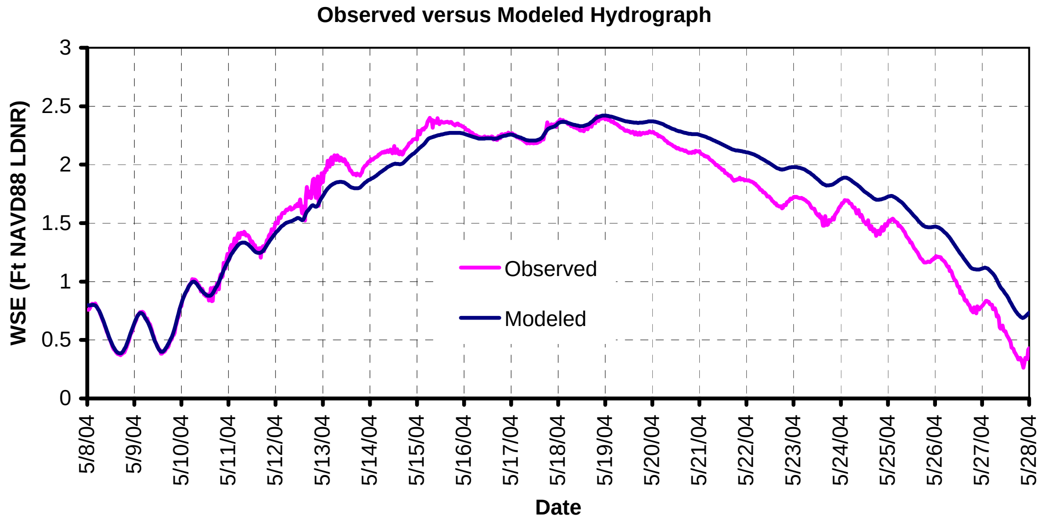
Figure 15. Calibration Stage Hydrograph, LSU Period

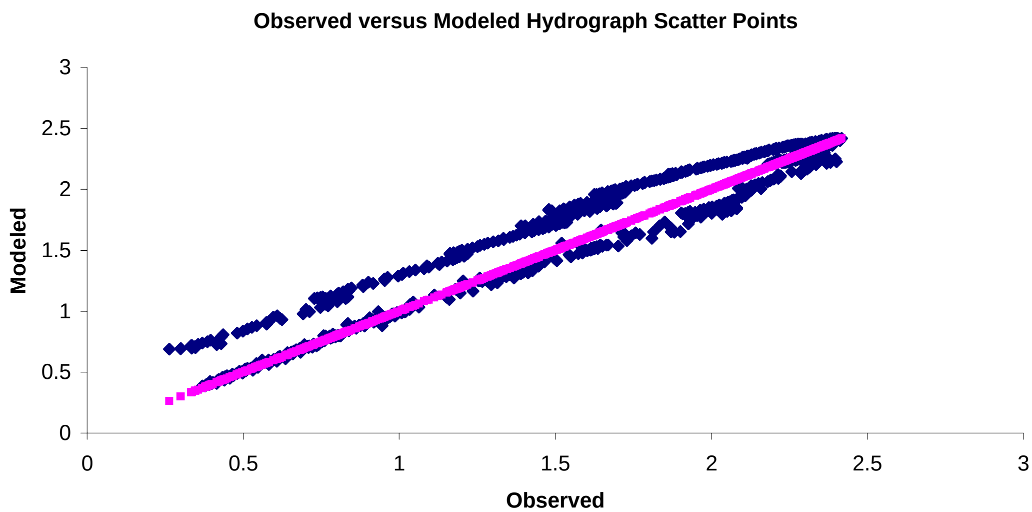




j) S-9 Dutch Bayou

Figure 15. Calibration Longitudinal Velocity, LSU Period

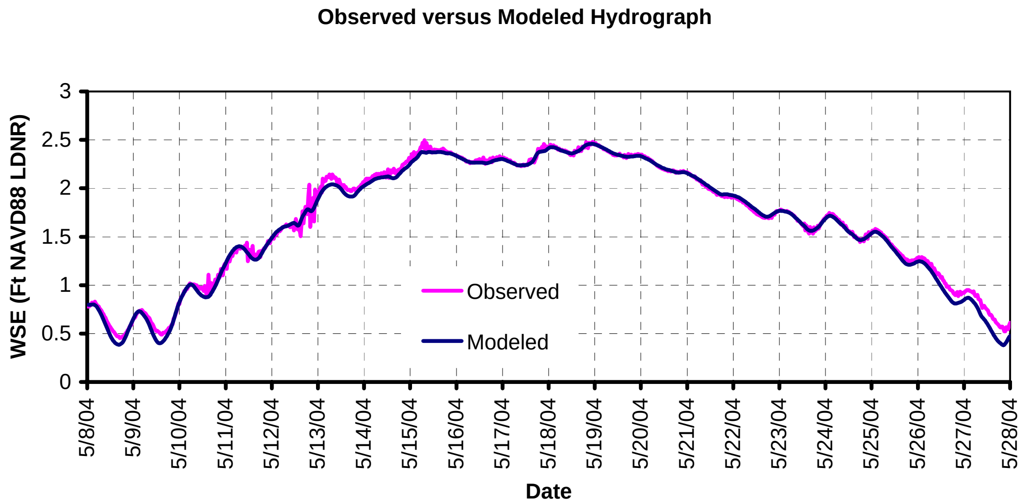


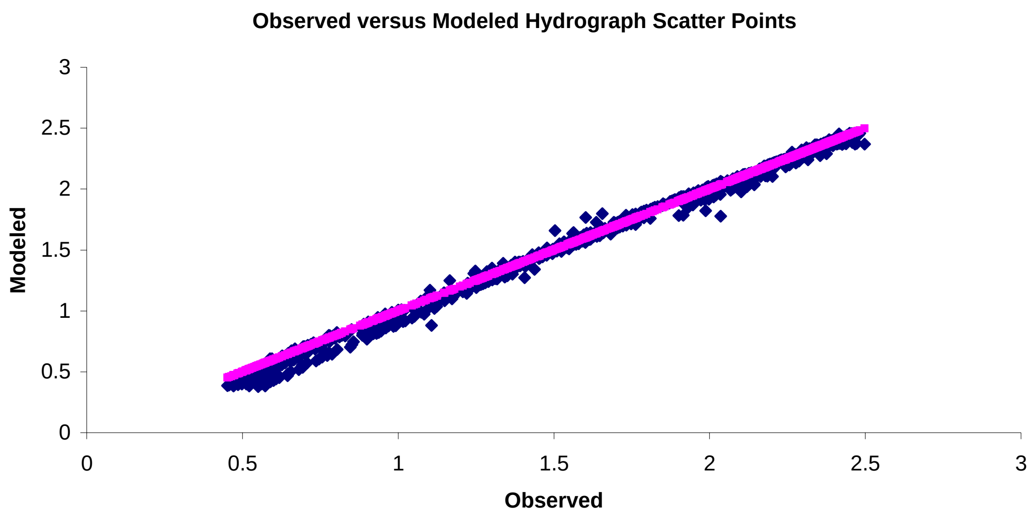


a) S-3 Reserve Relief at Lake

Figure 16. High Blind River Calibration Period

URS



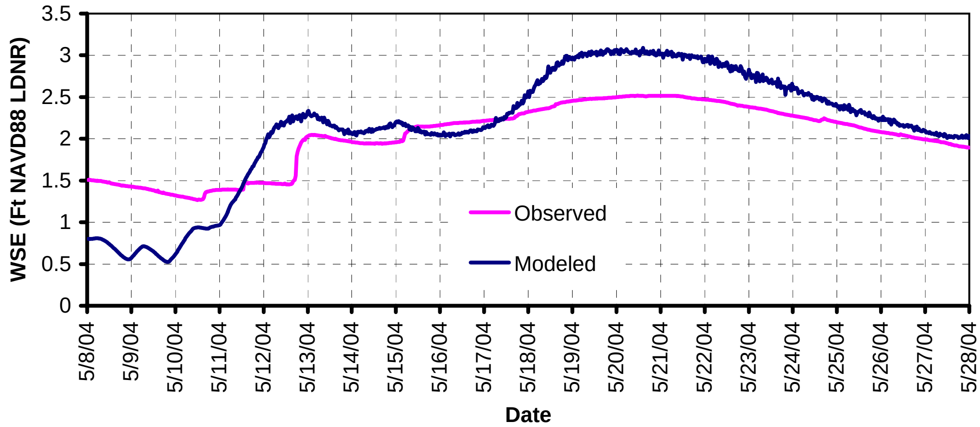


b) S-4 Dutch Bayou at Lake

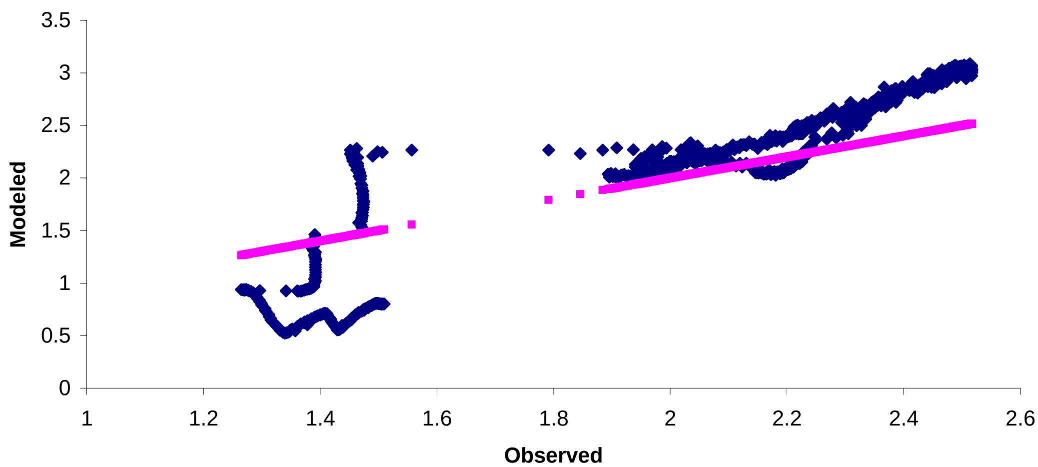
Figure 16. Validation Stage Velocity Hydrographs, ARDC/Blind River Flood

URS

Observed versus Modeled Hydrograph

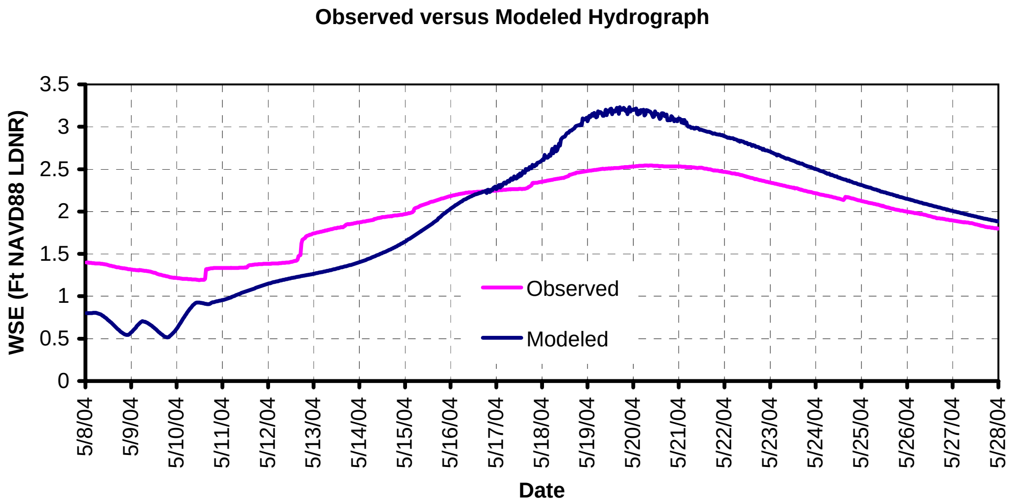


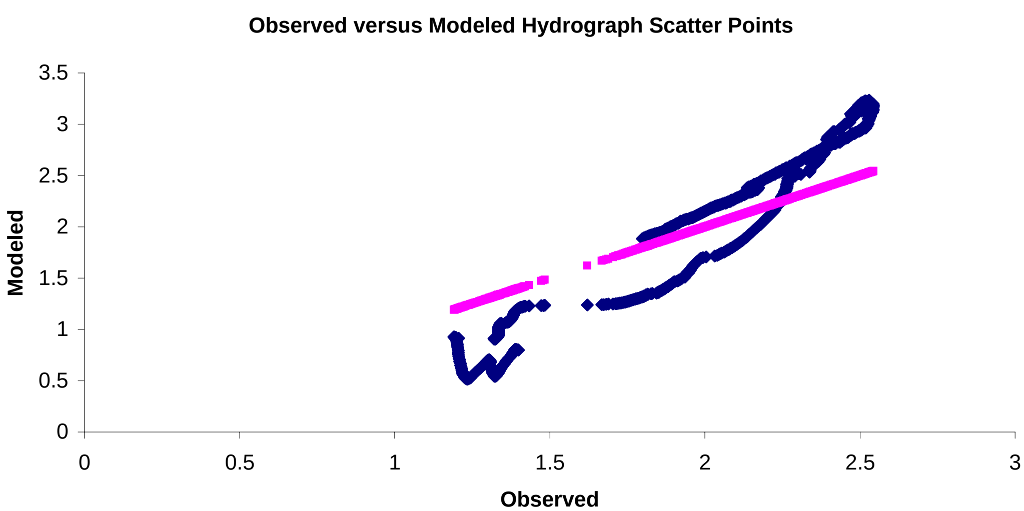
Observed versus Modeled Hydrograph Scatter Points



c) S-5 Hope Canal at Airline Hwy.

Figure 16. Validation Stage Velocity Hydrographs, ARDC/Blind River Flood

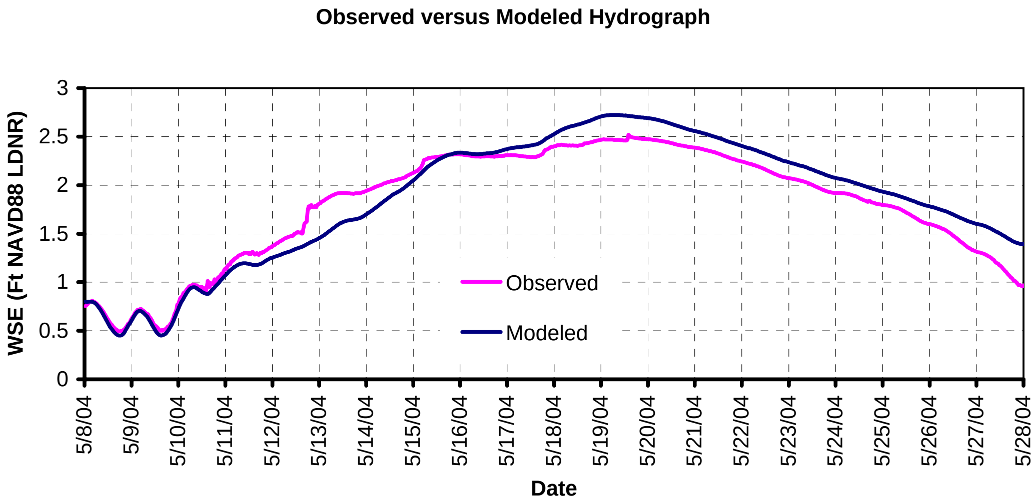


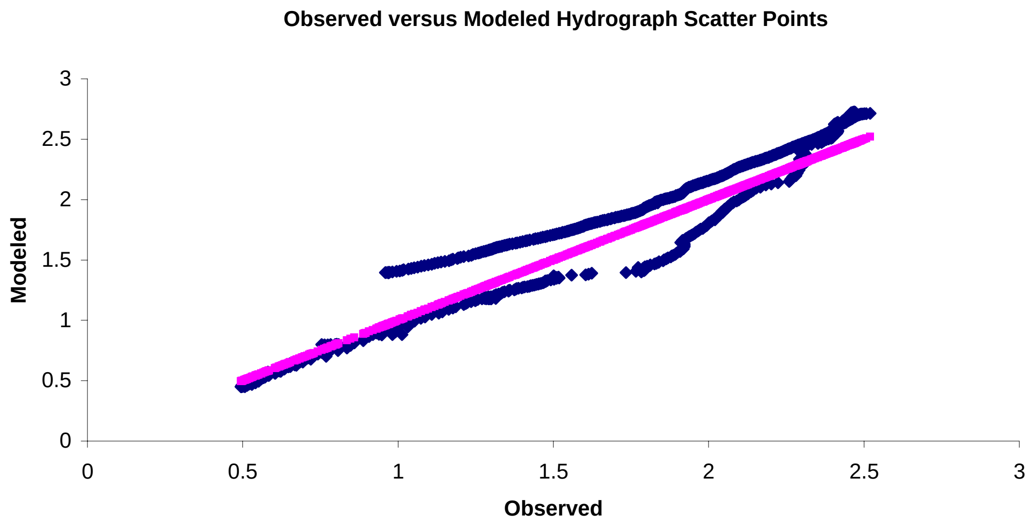


d) S-7 Hope Canal at I-10

Figure 16. Validation Stage Velocity Hydrographs, ARDC/Blind River Flood

URS



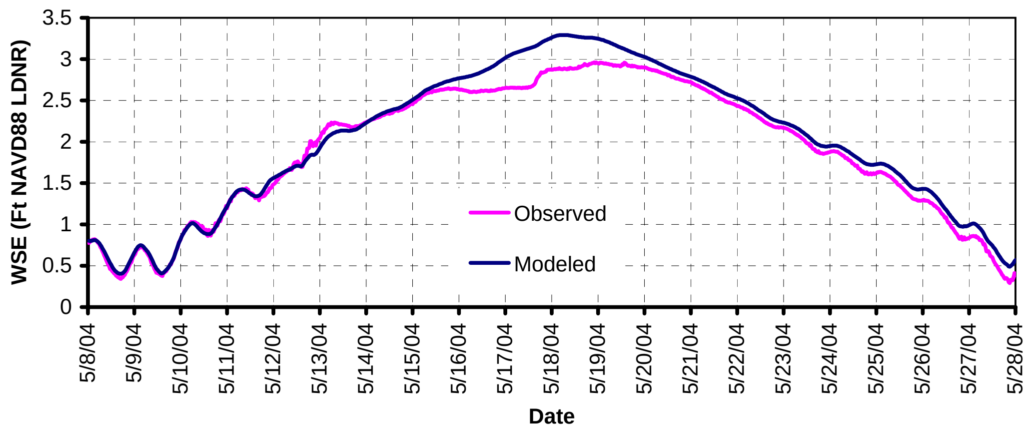


e) S-9 Dutch Bayou

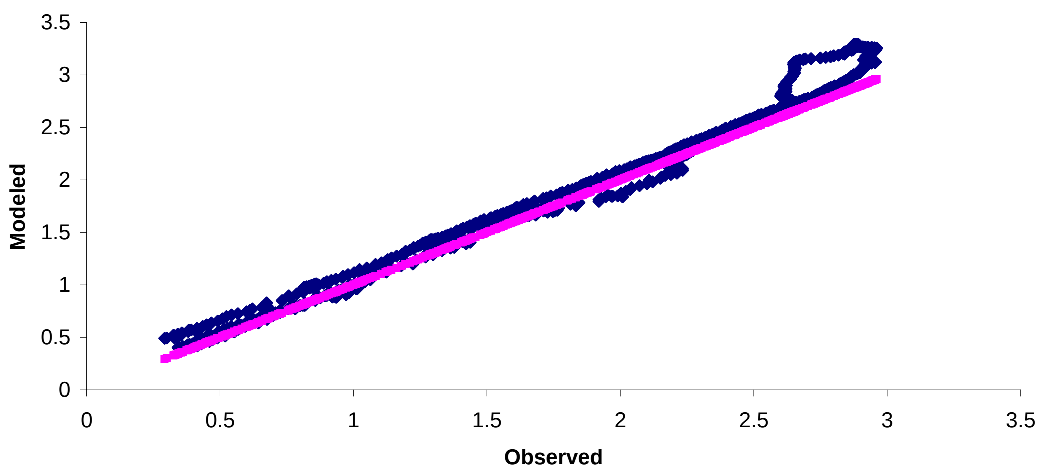
Figure 16. High Blind River Calibration Period

URS

Observed versus Modeled Hydrograph

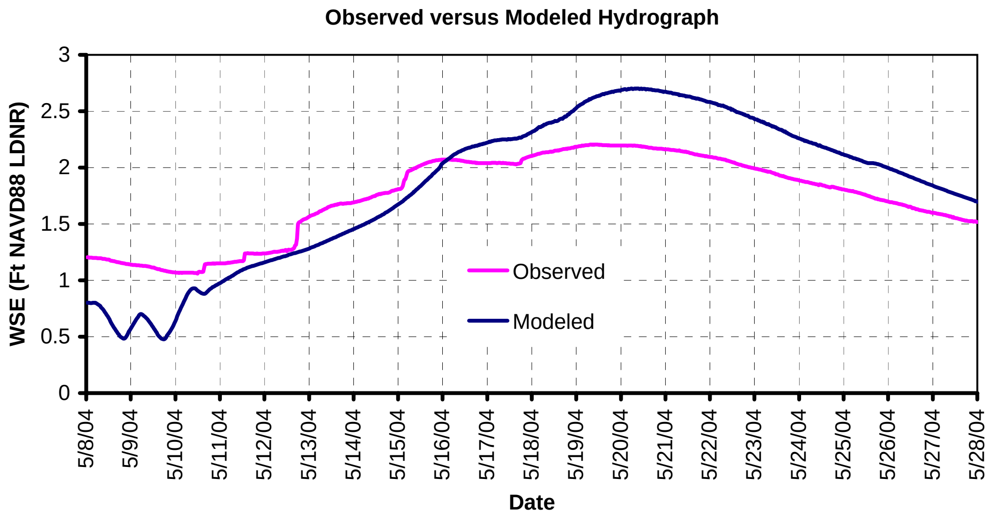


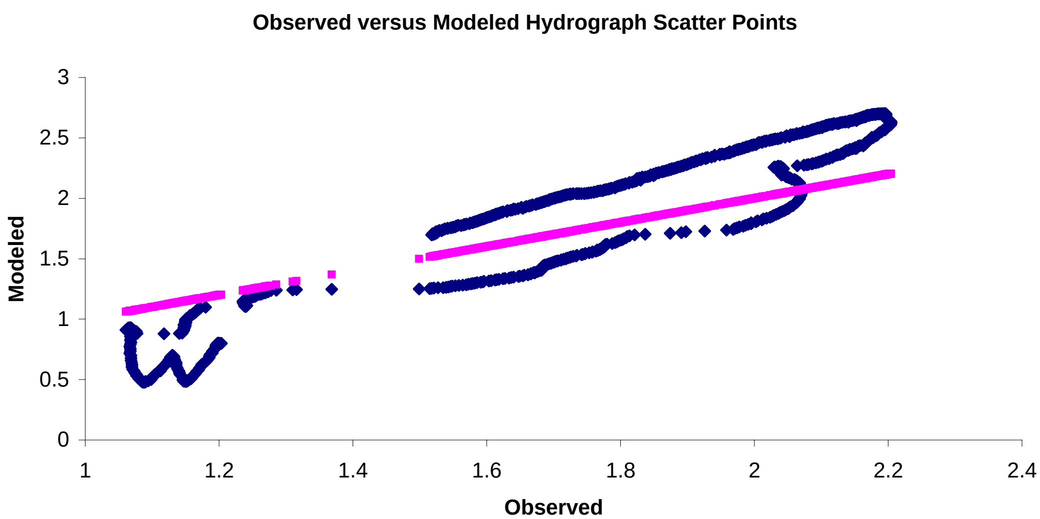
Observed versus Modeled Hydrograph Scatter Points



f) S-10 Blind River

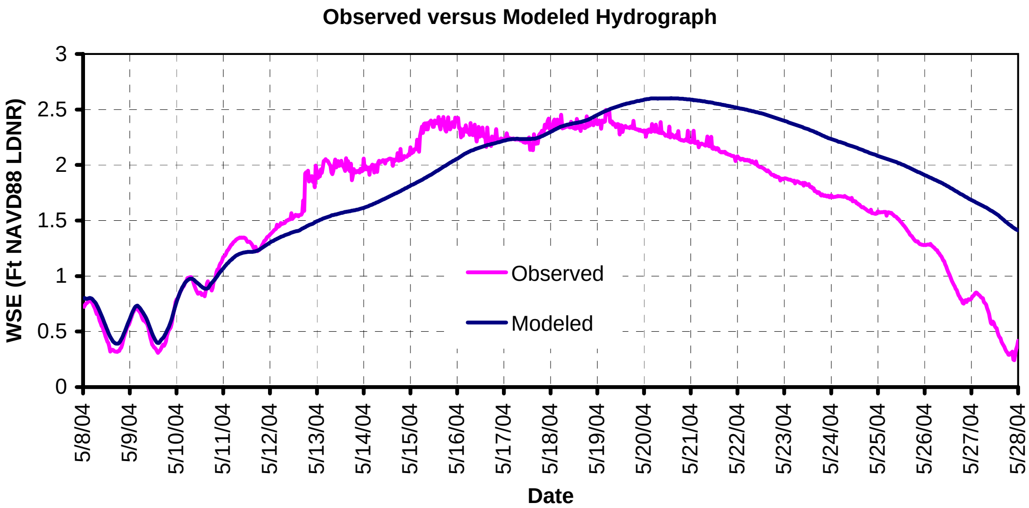
Figure 16. Validation Stage Velocity Hydrographs, ARDC/Blind River Flood

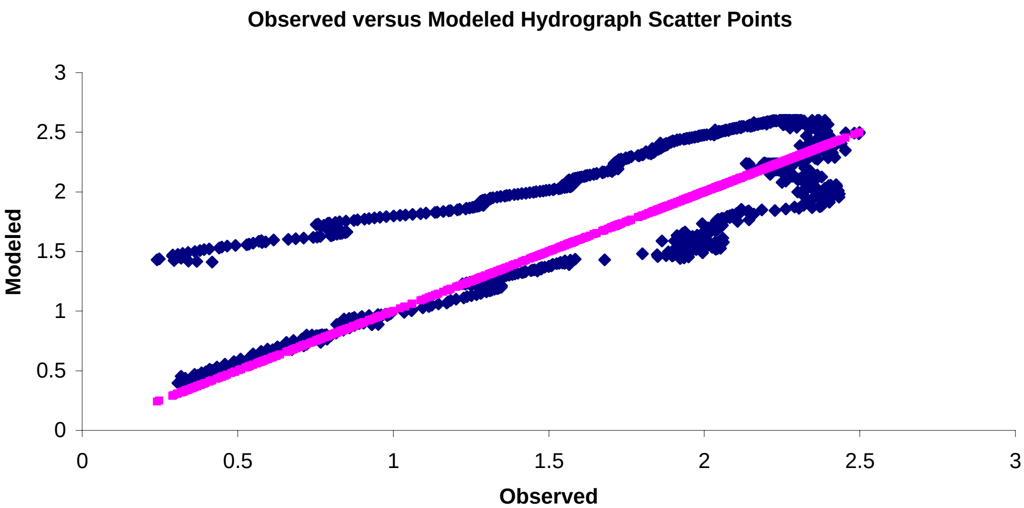




g) S-11 Mississippi Bayou at I-10

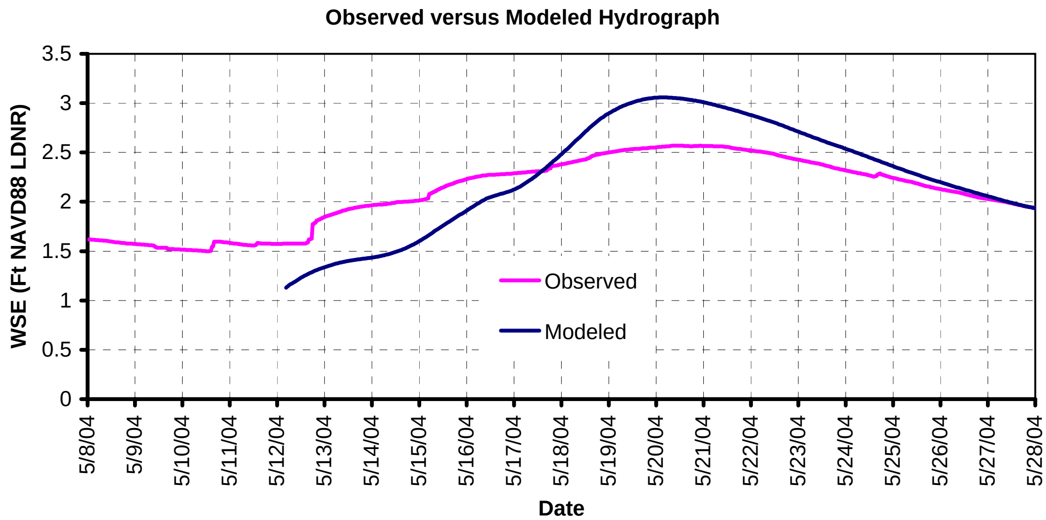
Figure 16. Validation Stage Velocity Hydrographs, ARDC/Blind River Flood

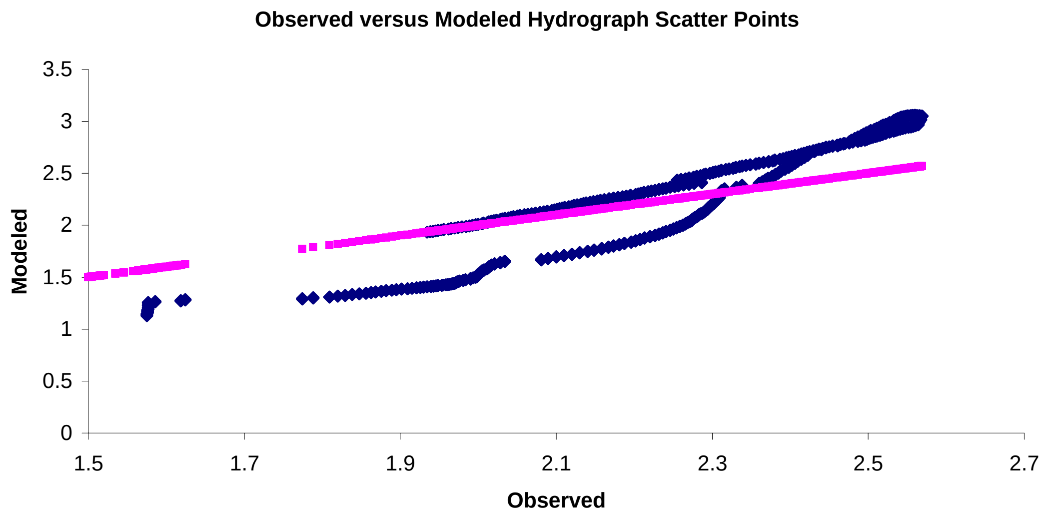




h) S-24 Reserve Relief at Airline Hwy.

Figure 16. Validation Stage Velocity Hydrographs, ARDC/Blind River Flood



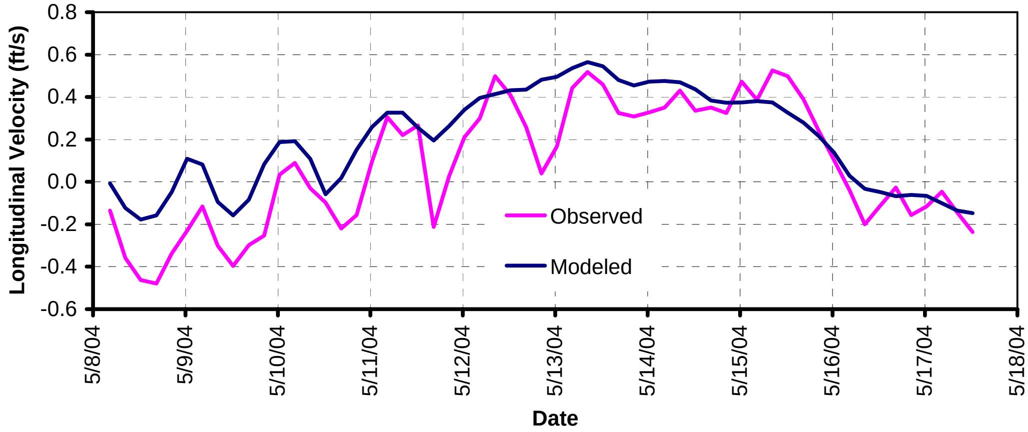


i) S-25 Central Swamp

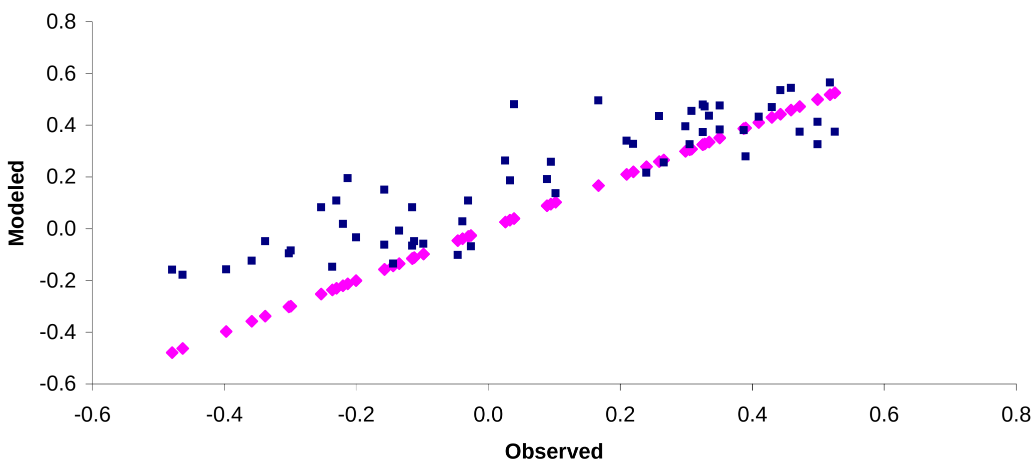
Figure 16. Validation Stage Velocity Hydrographs, ARDC/Blind River Flood

URS

Observed versus Modeled Longitudinal Velocity

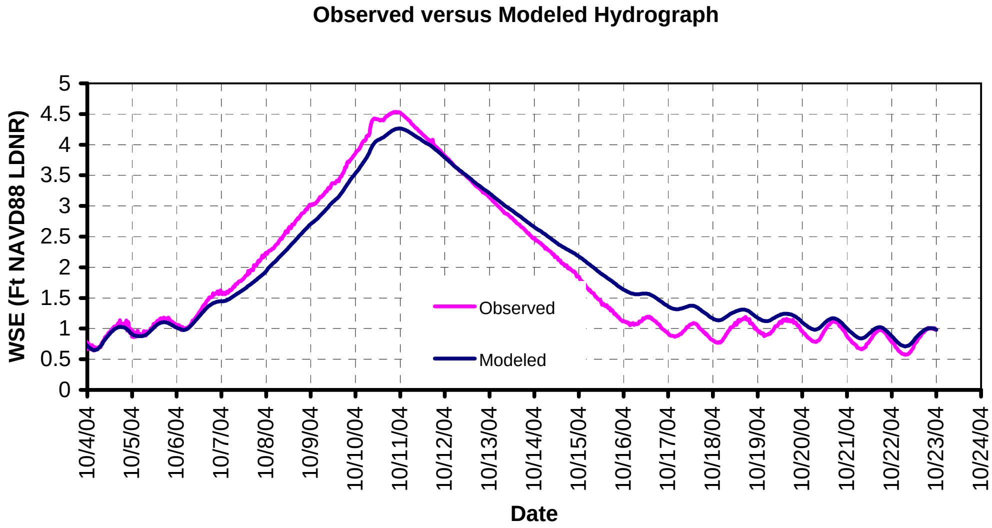


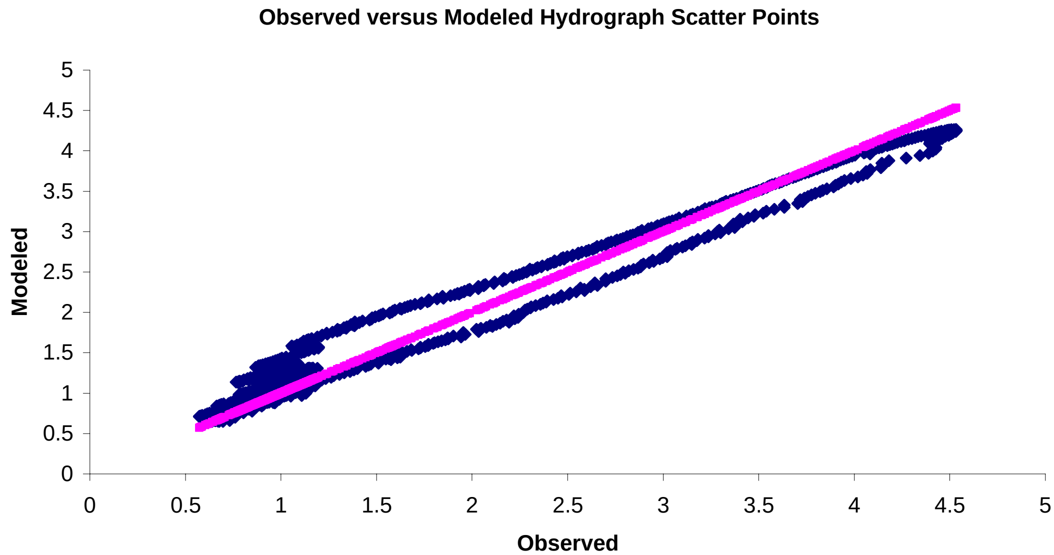
Observed versus Modeled Longitudinal Velocity Scatter Points



j) S-9 Dutch Bayou

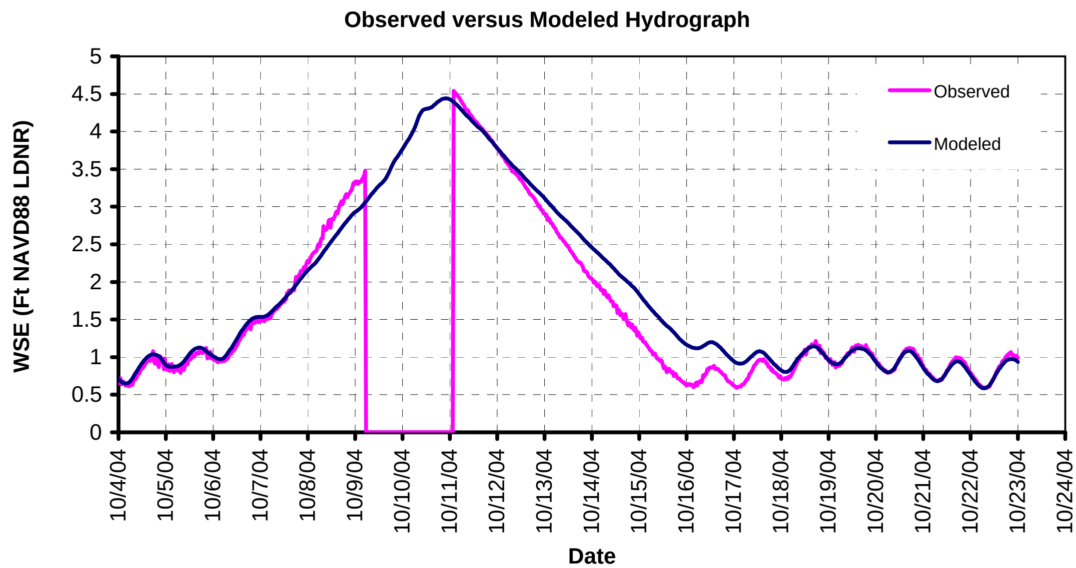
Figure 16. Validation Velocity Hydrograph, ARDC/Blind River Flood

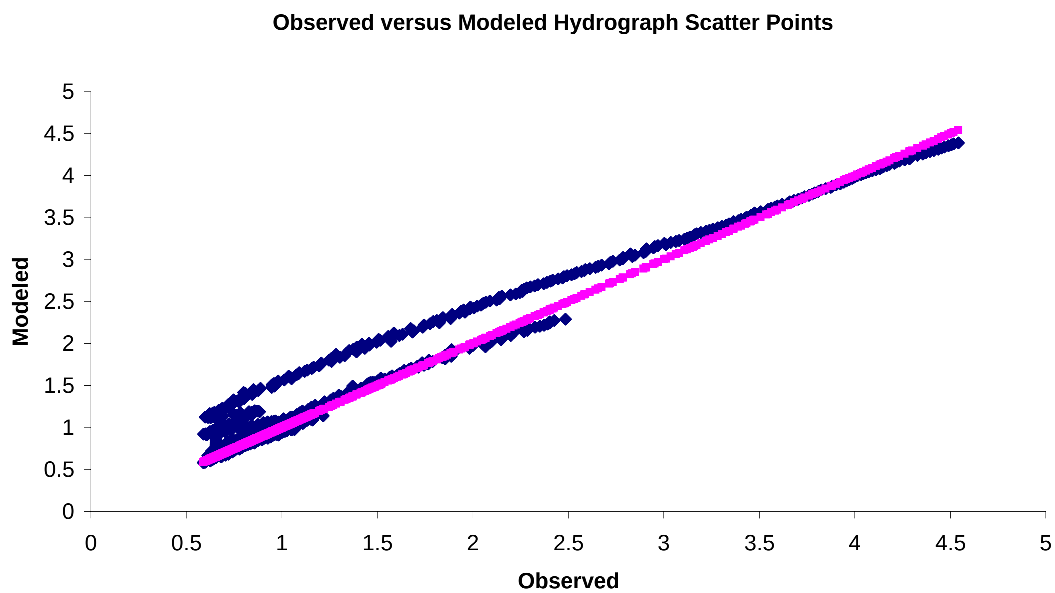




a) S-3 Reserve Relief at Lake

Figure 17. Tropical Storm Calibration Period

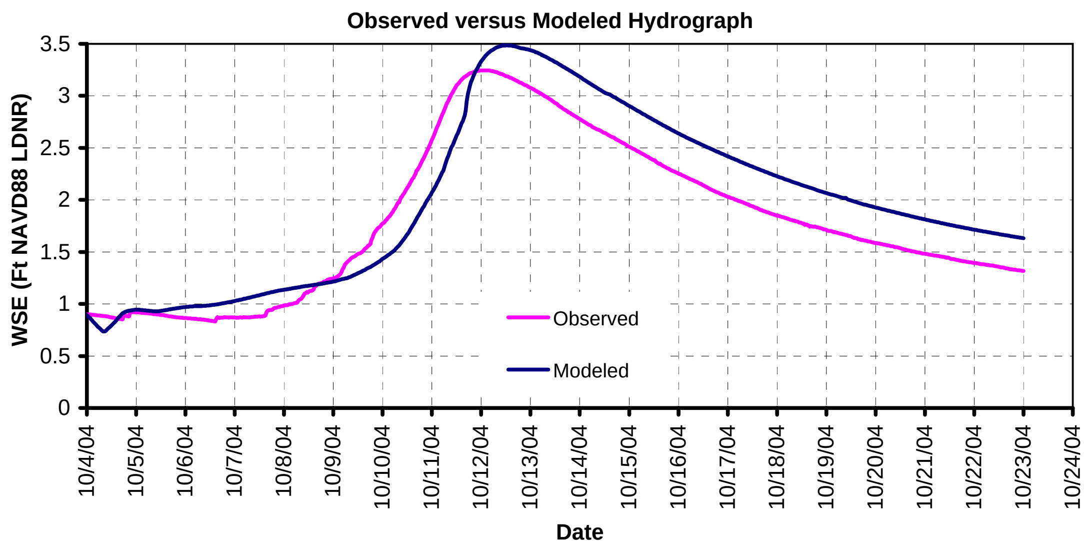


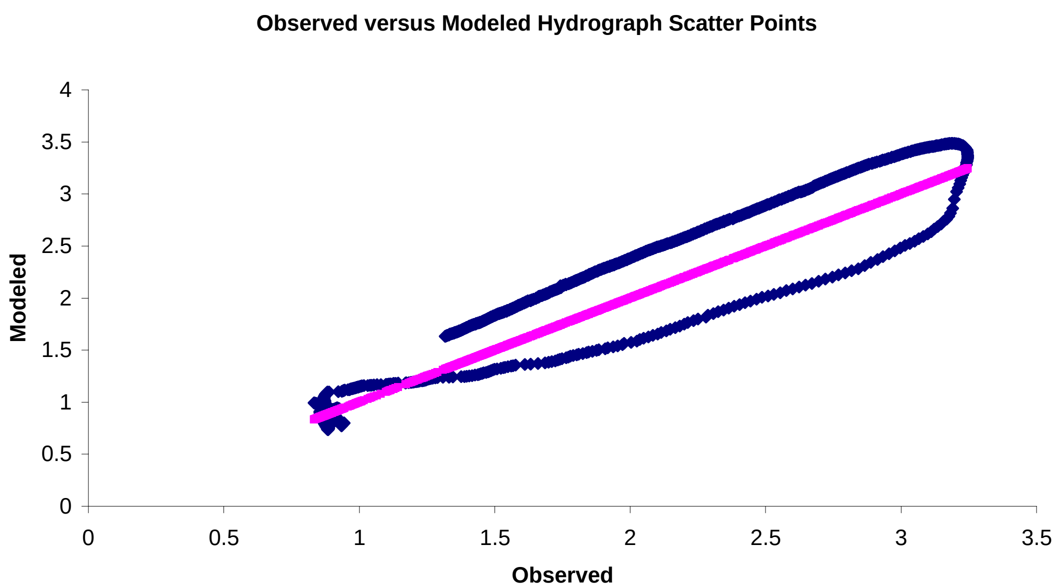


b) S-4 Dutch Bayou at Lake

Figure 17. Validation Stage Hydrograph, TS Matthew

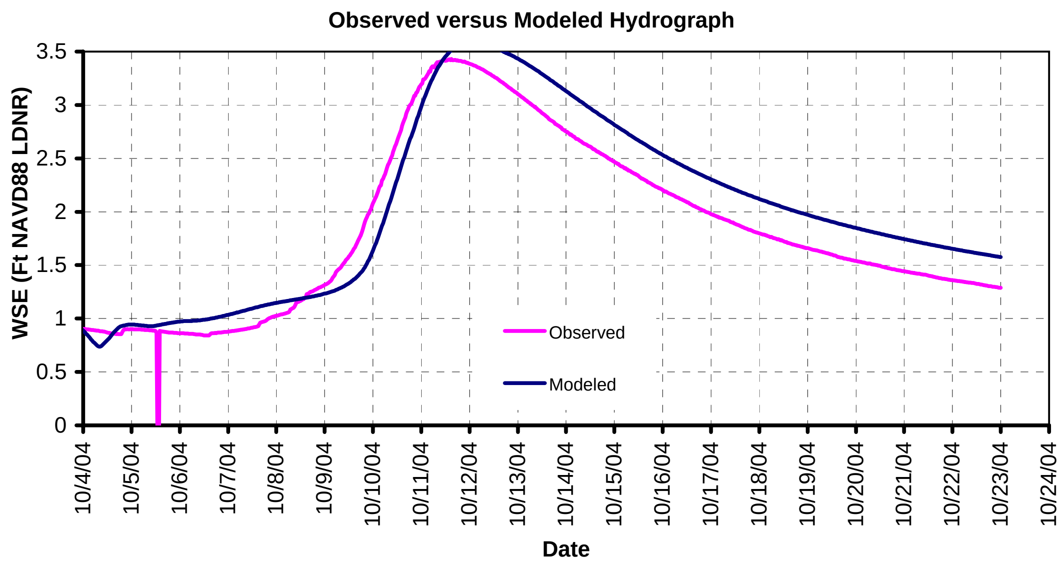
URS

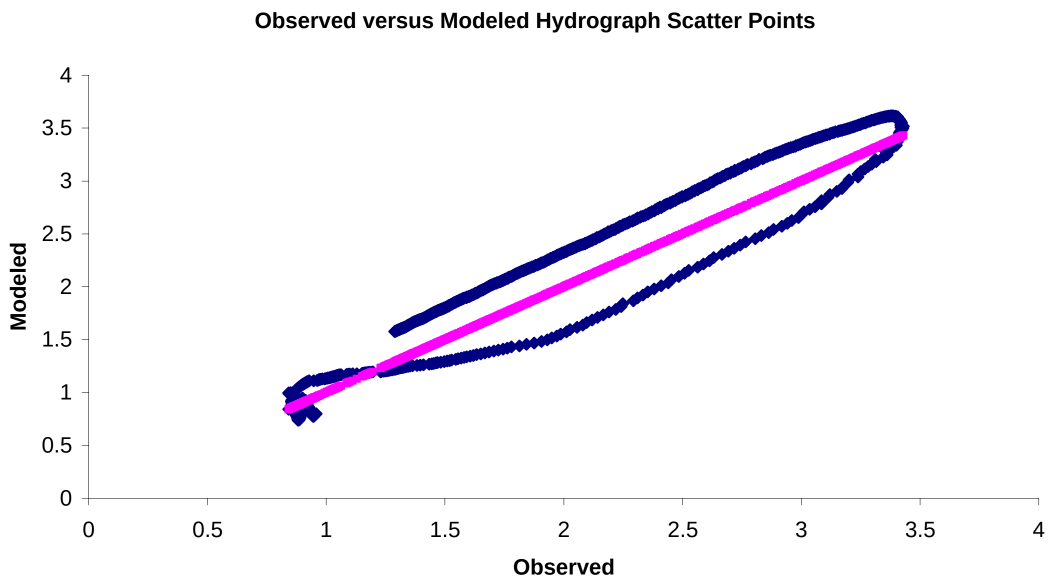




c) S-5 Hope Canal at Airline Hwy.

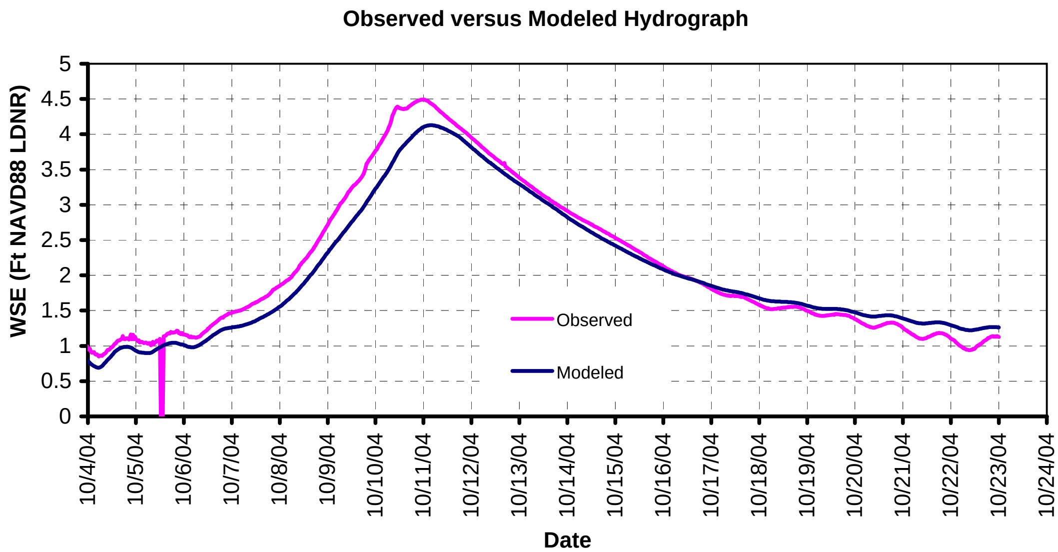
Figure 17. Validation Stage Hydrograph, TS Matthew

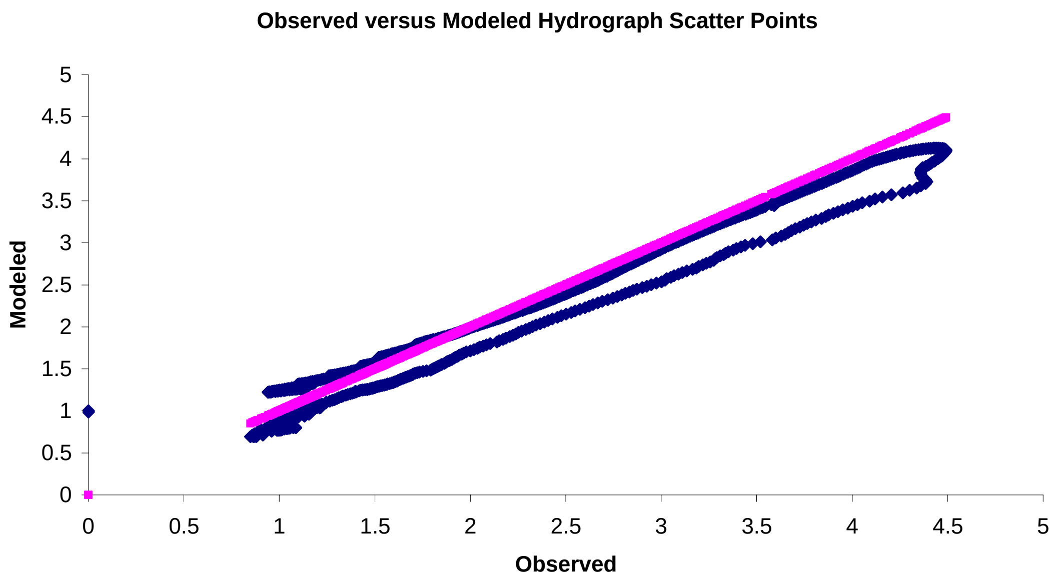




d) S-7 Hope Canal at I-10

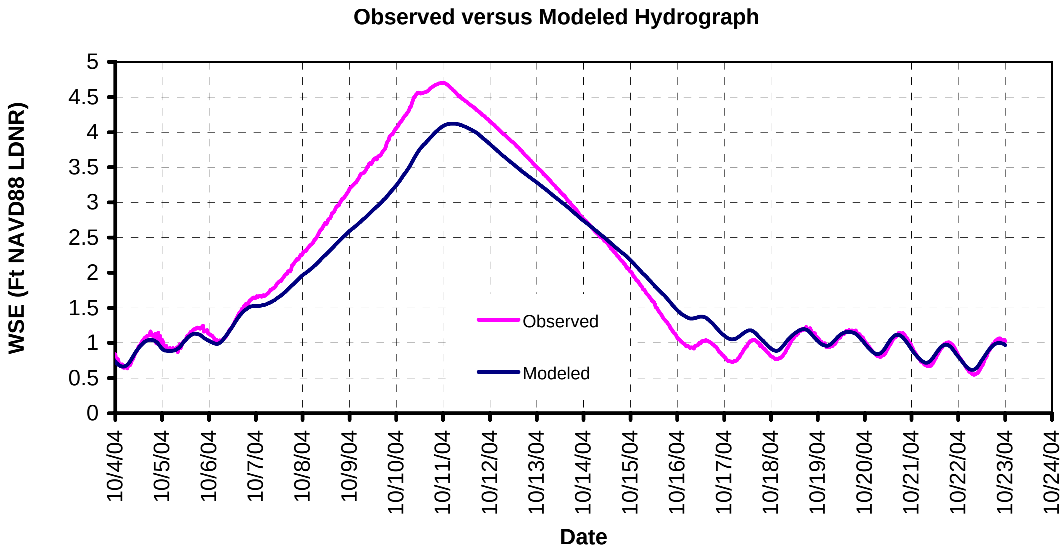
Figure 17. Validation Stage Hydrograph, TS Matthew

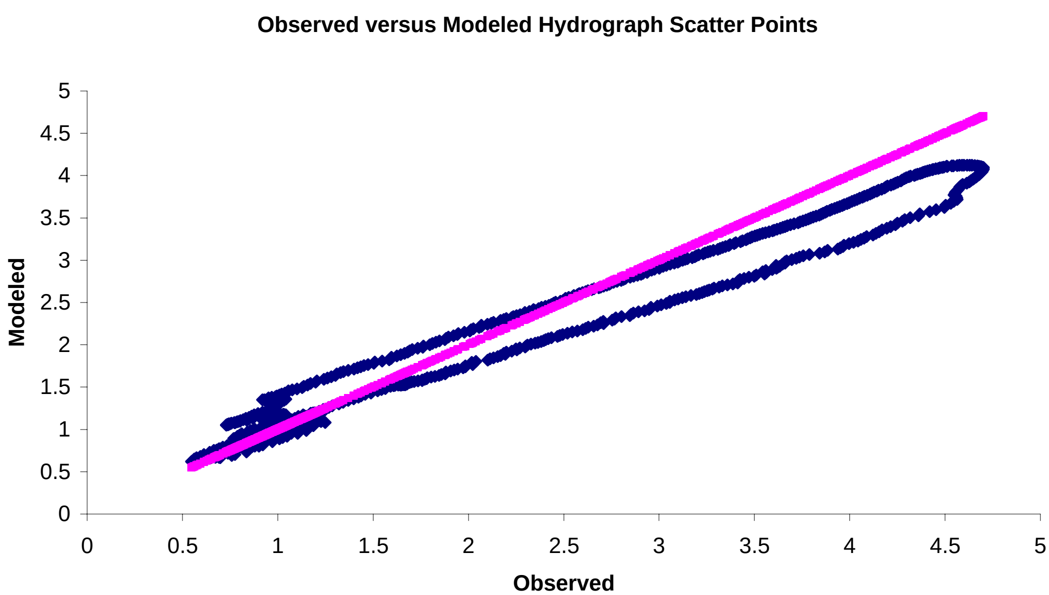




e) S-9 Dutch Bayou

Figure 17. Tropical Storm Calibration Period

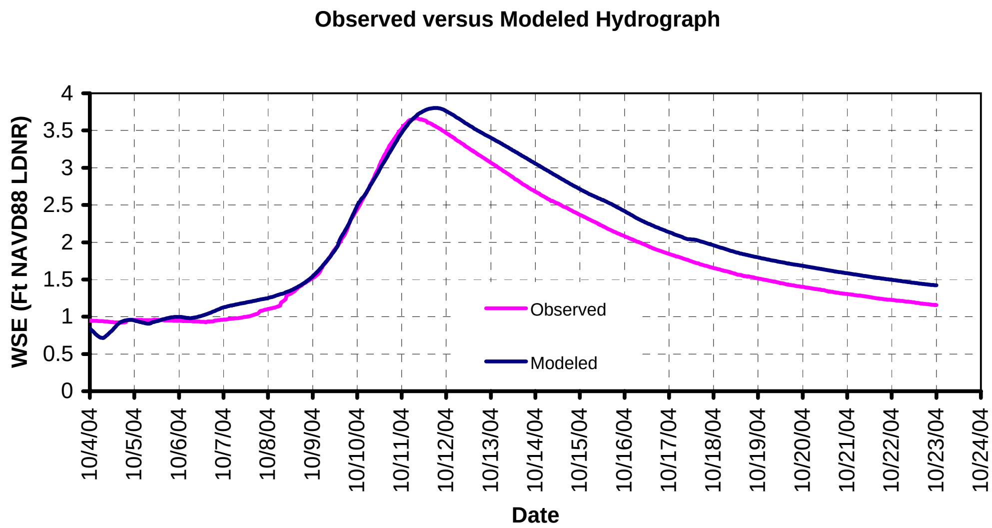


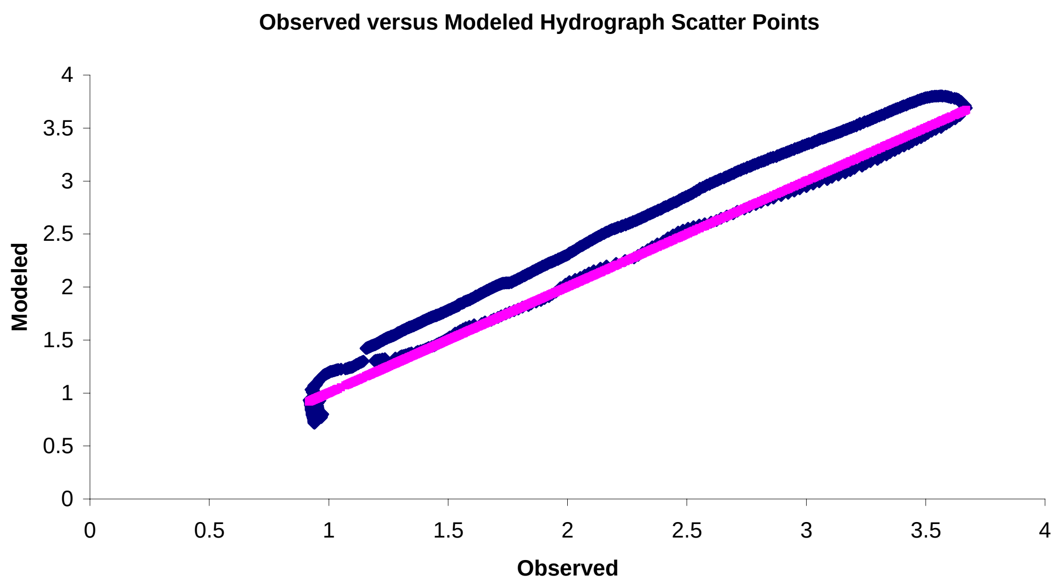


f) S-10 Blind River

Figure 17. Validation Stage Hydrograph, TS Matthew

URS

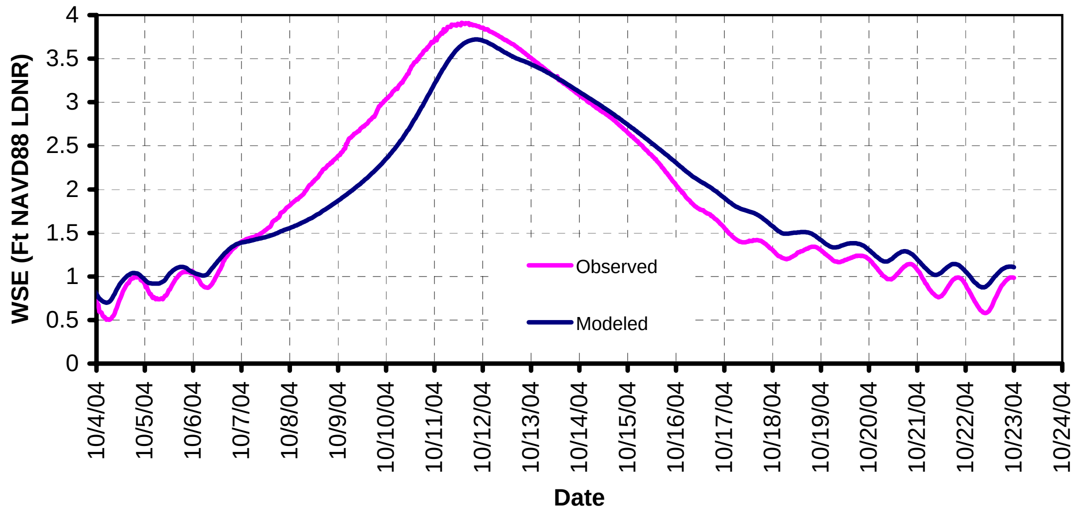




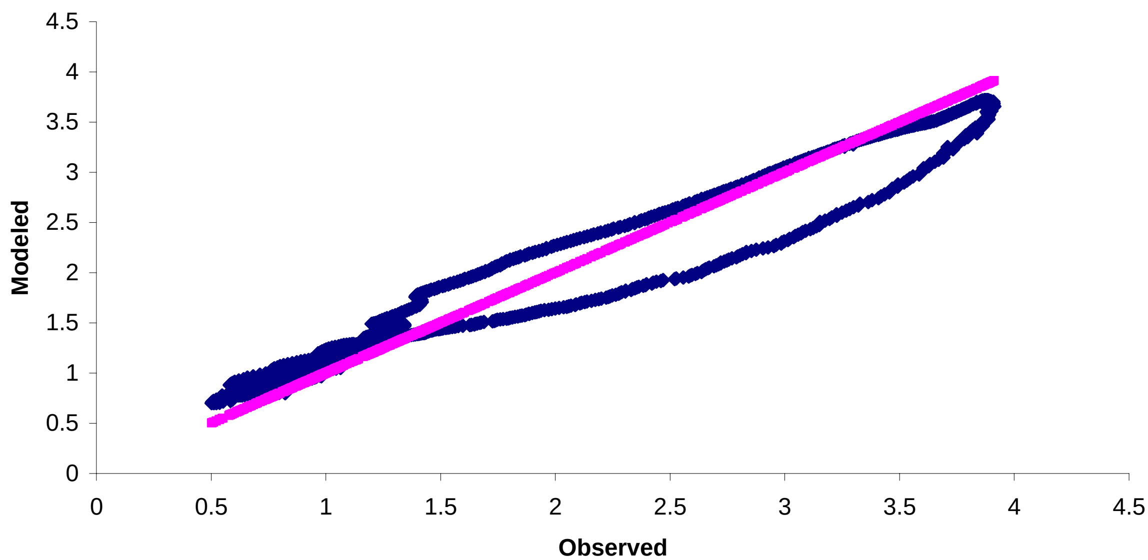
g) S-11 Mississippi Bayou at I-10

Figure 17. Validation Stage Hydrograph, TS Matthew

Observed versus Modeled Hydrograph

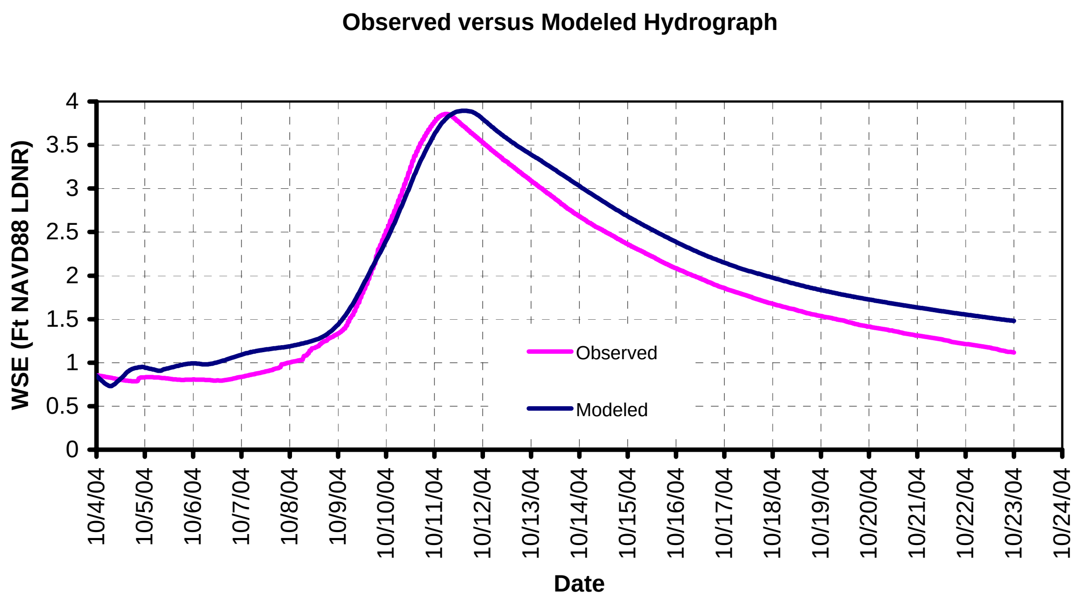


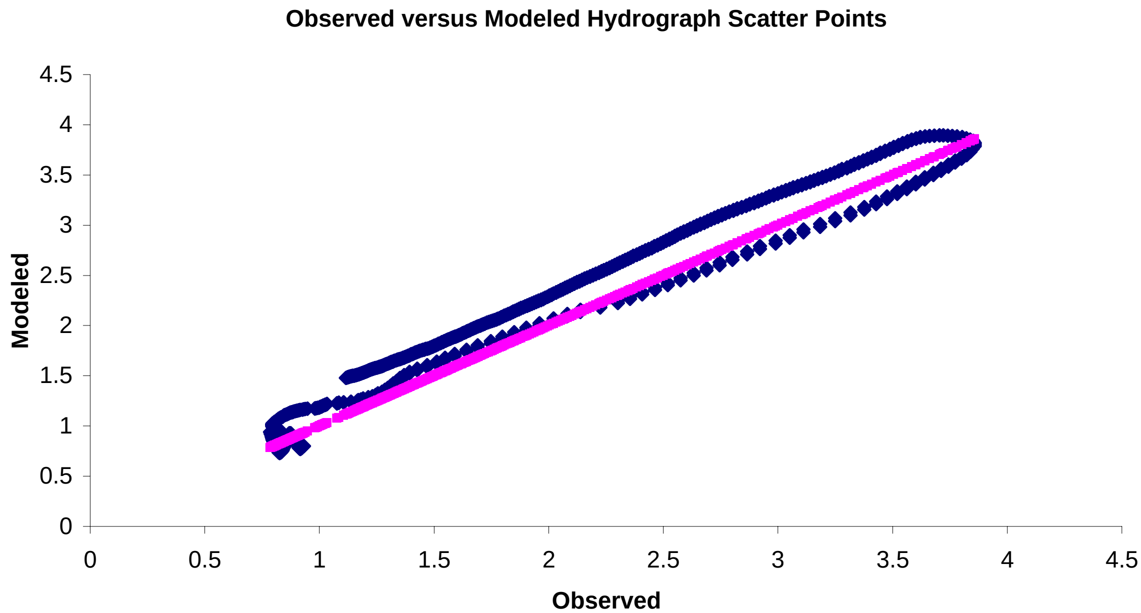
Observed versus Modeled Hydrograph Scatter Points



h) S-16 Blind River at I-10

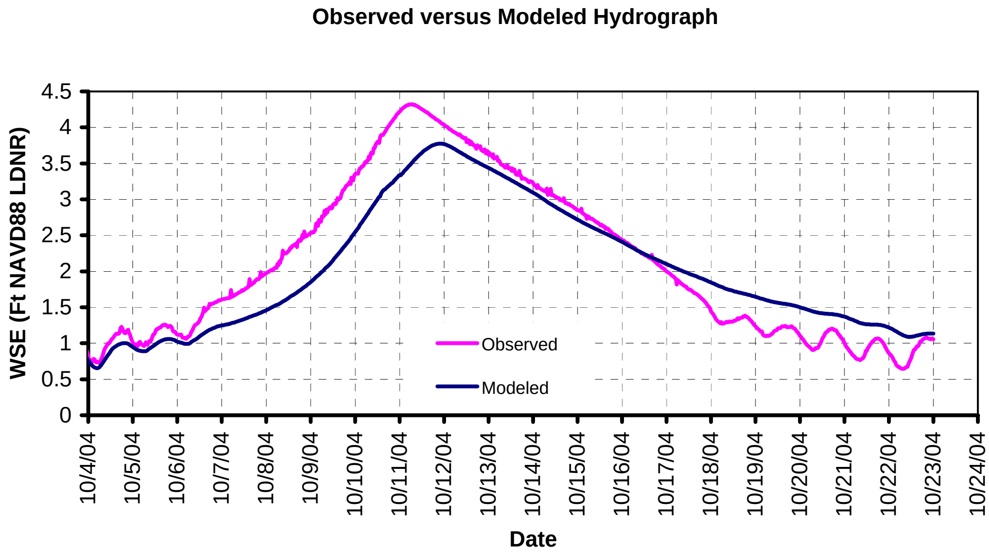
Figure 17. Validation Stage Hydrograph, TS Matthew

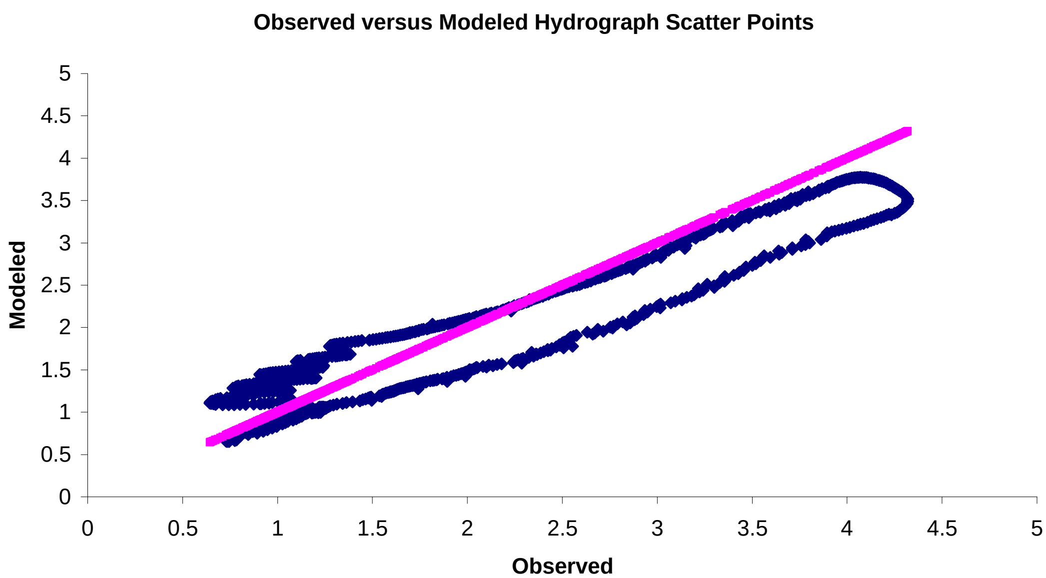




i) S-23 North Swamp

Figure 17. Validation Stage Hydrograph, TS Matthew

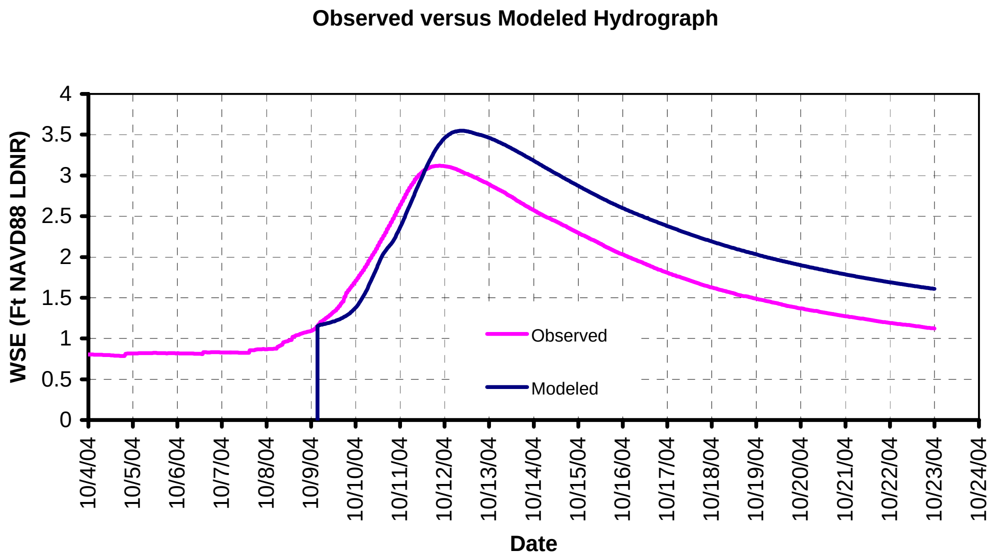


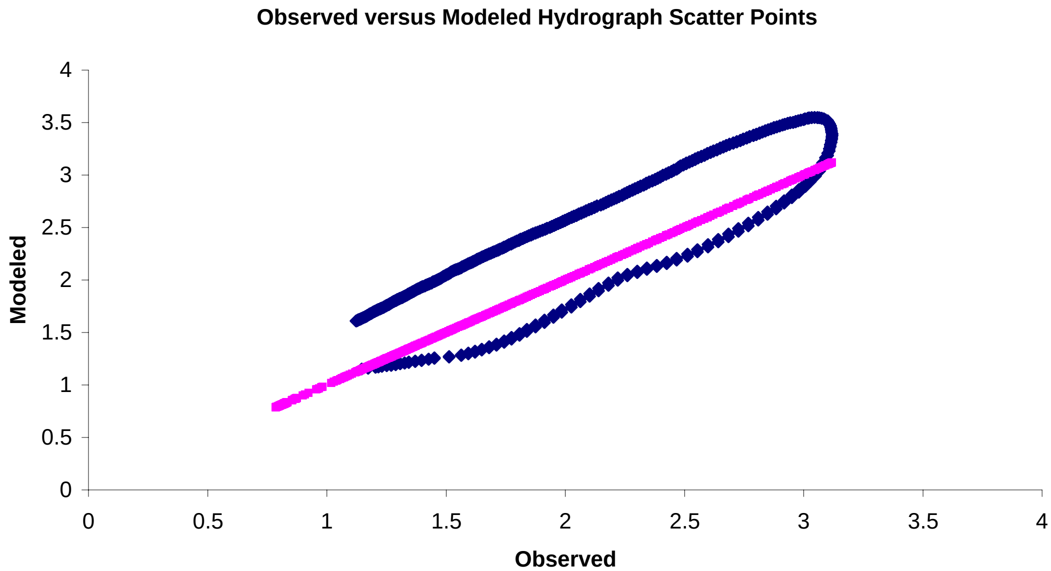


j) S-24 Reserve Relief at Airline Hwy.

Figure 17. Validation Stage Hydrograph, TS Matthew

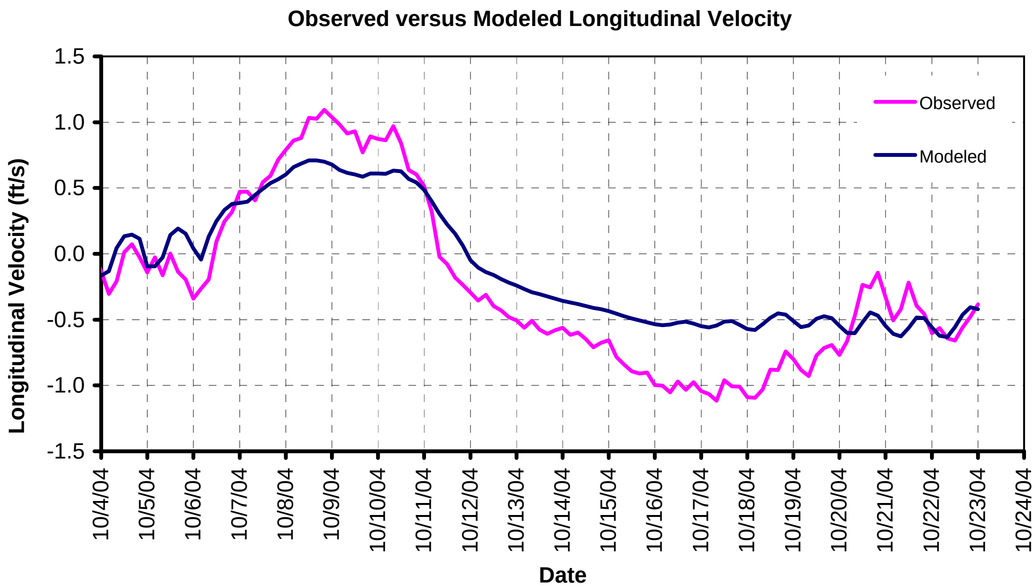
URS

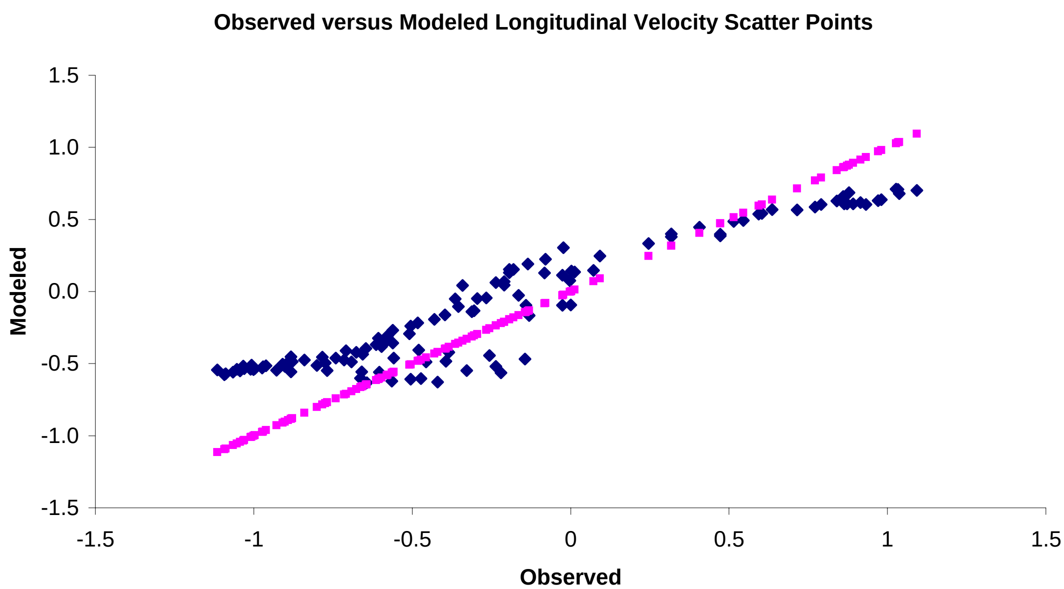




k) S-25 Central Swamp

Figure 17. Validation Stage Hydrograph, TS Matthew





l) S-9 Dutch Bayou

Figure 17. Validation Velocity Hydrograph, TS Matthew

URS

APPENDIX A

KEY CORRESPONDENCE ON ADCIRC MODEL DEVELOPMENT AND CALIBRATION

PROJECT MEMORANDUM

To: Chris Williams, Project Manager
Luke Lebas, Engineer Manager
Russ J. Joffrion, Project Engineer
From: URS Corporation
Date: November 29, 2004
Subject: Revised 2D Swamp Hydrodynamic Modeling Approach

Review of 2D Modeling Objectives

As part of a *Hydraulic Feasibility Study for Mississippi River Re-Introduction into Maurepas Swamp* URS has been contracted to develop a 2D hydrodynamic model for use in assessing issues related to diversion water swamp circulation and potential backwater and flooding impacts. Due to the complexity of these issues, and the interest of numerous stakeholder agencies (parish, state, and federal) as well as local property-owners and resource users, the Study and supporting modeling results are expected to receive intense scrutiny.

In order to provide proper engineering analysis of these issues, URS completed an intensive field survey of the diversion receiving area—including detailed cross sections of every major and minor channel and slough, and ground-truthing of natural and artificial banks and swamp elevations. In conjunction with Louisiana State University (LSU) ten months of continuous stage data were collected from thirteen locations throughout the area. Continuous Acoustic Doppler Current Profiler (ADCP) readings have been recorded by LSU along a Dutch Bayou, just downstream of the confluence of Mississippi Bayou and Dutch Bayou. [This location was recommended by LSU and agreed to by URS as desirable for supporting calibration since 1) Dutch Bayou is expected to be the major outlet for Diversion flow to Lake Maurepas and 2) velocity/flow values are expected to have a fairly wide range due influence of upstream flow from Mississippi Bayou and Hope Canal and downstream control by tides in Lake Maurepas.] Moreover, numerous area point-velocity measurements were also obtained.

Based on our evaluation of the Diversion area terrain and hydrology, URS has recommended that the 2D model address four critical physical features:

1. Encompass a large horizontal scale—some 50,000 acres of wetlands surrounding the diversion area and extending to the east, west, and south to the potential limits of hydraulic impact (i.e., the area between Blind River and Reserve Relief Canal and from Airline Highway northward to Lake Maurepas);

2. Accurately represent the controlling micro-topography and bathymetry of the swamp (i.e., the relatively small elevation changes—1 to 3 feet—associated with numerous minor sloughs, and channel banks and cuts which control water flow);
3. Simulate the timing and amplitude of tidal wetland wetting-drying throughout the study area with reasonably good calibration to observed data (see Page 2 of Attachment 1; simulation of tidal signal amplitude in the upstream locations is an indication that the channel conveyance has been properly modeled); and
4. Capture the circulation and conveyance effects of the 180 miles of narrow linear features, to the best ability of current modeling tools available. (Table 1 lists some of the significant Swamp linear features.) The model should incorporate as many of these features as possible to support accurately simulating a "realistic" picture of how the diversion water will circulate in the Swamp (area of affect, residence time, stagnation areas, etc.) and what backwater impacts may occur

These four requirements, taken together, have taxed the accuracy, reliability and efficiency of the desktop model originally selected for this project, RMA2 (see Attachment 1.) As a result of RMA2 limitations for this project, URS recommended to LDNR/EPA that alternative models—which have emerged over the last two years with improved capabilities for complex estuarine hydrodynamic simulation—be evaluated for use.

Alternative Models to RMA2

Table 2 presents a list of basic model program features that are needed for the Maurepas project. During the last two years several models have emerged within the academic community with the capability to effectively and efficiently model large-scale, high resolution, estuarine tidal wetting and drying scenarios. A key feature of these models is their development for application on high performance computer (HPC) platforms. The common platform of choice is a cluster of parallel commodity (inexpensive off-the-shelf) microprocessors (also referred to as a Beowulf Cluster). The "parallelized" codes allow for distribution of the model domain (i.e. mesh) over more than one processor. This allows each processor to handle a particular region of the mesh—solving of the various equations—during each time step. This speeds up the time required to solve the total mesh for each time step. The speed-up can be close to 1:1—with a 16 processor cluster achieving a runtime reduction of almost 16-fold. This is a clear advantage for running a model which would otherwise take several days to execute. (LSU researchers have utilized "Super Mike" for some 2-D hydrodynamic modeling applications.)

Table 1 List of Significant Swamp Linear Features

	Length (miles)
Primary Channels and Associated Banks	
Reserve Relief Canal	6.2
Blind River	18.3
Mississippi Bayou	8.6
Hope Canal	6.1
Bayou Tent	2.6
Dutch Bayou	3.2
Subtotal	**45.1**
Secondary Channels and Associated Banks	
Mississippi Bayou, above Cross-Over	1.0
Godchaux Canal	1.7
Cross Over Canal	1.8
West Interstate Canal	1.0
South Oilfield Canal	2.2
East Marathon Canal	1.7
Alligator Bayou	3.1
Bourgeous Canal	3.9
SW-NE leg of Bourgeous Canal	0.4
Number Twelve Canal	2.2
West Bayou	0.2
Bayou Secret	2.4
Tennessee Williams Canal	1.9
Airline Canal	2.4
Tchackchou Bayou	1.9
South Bayou	0.5
North Oilfield Canal	0.8
Subtotal	**29.0**
Sloughs and Associated Banks	
East-West between Reserve Relief MS Bayou	2.2
Slough from Mississippi Bayou to South Oilfield Canal	0.3
Branch Tenth	1.3
Hard Time Canal	1.4
Bougere Bayou	3.7
Sawgrass Bayou	3.0
N-S between Blind R and Alligator Bayou	0.6
Peter's Run	2.3
N-S trend, west of L Maurepas embankment	2.1
NW-SE trend, between Dutch Bayou and L Maurepas embankment	0.8
E-W trend, between Dutch Bayou and Mississippi Bayou	1.1
N-S trend, between Blind R and Old RR embankment	1.4
south of Old RR embankment	1.9
SW-NE trend at west end of West Bayou	0.9
13 Mainline	0.0
East-West Mainline	1.0

Table 1 List of Significant Swamp Linear Features (cont'd)

	Length (miles)
Bougere Canal	3.7
E_W east side of Hope Canal	1.0
East-West Mainline	1.1
Coco Bayou	0.7
Lower South Bayou	0.7
East of Reserve Relief Canal	0.9
Between Mississippi Bayou and East Marathon Canal	0.7
South of Old RR embankment	1.9
West of Bayou Tent	0.0
South of Bayou Secret	0.6
Subtotal	**35.1**
Ditches and Associated Banks	
Colonial Canal	1.7
Northside of Airline Highway to Hope Canal	2.3
I-10 northside	9.2
I-10 southside	9.2
Bougere Canal	1.2
West of Bougere Canal	1.2
West of Bougere Canal	1.1
West Marathon Canal	1.7
East of East Marathon Canal	1.4
Subtotal	**28.8**
Total Channels	**138.0**
Additional Embankments	
Pipeline ROW	10.7
Transmission Line ROW	9.3
Old Railroad Embankment	4.5
Lake Maurepas Natural Levee	4.4
South Boundary Levee	5.6
Hope Canal Road	2.6
Total Additional Embankments	**37.2**

Table 3 lists six parallelized 2D hydrodynamic models which are potentially available for use on the Maurepas project. All six codes would provide a great improvement in efficiency and effectiveness over the current RMA2 option. As of today only P-ADCIRC is commercially available and non-proprietary. Commercial licensing of FVCOM may be available in late 2004. The FVCOM developer is making the code widely available in the academic community. The other four parallelized models can be utilized only through teaming with the model developer.

Dr. Chris Reed (URS) co-authored the serial M2D code and has a working relationship with the leader of the parallelizing effort at Florida Institute of Technology (FIT). [A very preliminary test with the serial version indicated a much smoother handling of Swamp wetting and drying.] However, access to parallelized M2D (P-M2D), which is still under development, is restricted to FIT.

Serial ADCIRC has been widely used for several years and sold commercially with the SMS pre/post processor for over a year. A parallelized version of ADCIRC (P-ADCIRC) has been developed by the ADCIRC authors, Westerink and Luettich (at the Universities of Notre Dame and North Carolina), under contract to the Corps Coastal and Hydraulics Laboratory (CHL), Engineering Research and Development Center (ERDC) in Vicksburg, Mississippi. [P-ADCIRC is essentially the same code, only parallelized to allow for faster runtime on a cluster.] The code was parallelized in order to run a 200,000-plus element coastal model for simulating hurricane scenario impacts to Southeast Louisiana. P-ADCIRC is being released to the modeling community. LSU (Drs. Kemp and Mashriqui) and the University of South Alabama are using P-ADCIRC to study hurricane storm surge modeling.

P-ADCIRC has been licensed to a commercial firm—WorldWinds, LLC in Stennis Mississippi—for use on a private cluster for simulation of synthetic hurricane storm surge along the Mississippi Gulf Coast. WorldWinds operates a 16-node (32 processors) cluster which allows a 90-hour simulation of a 230,000 element model to be performed in five hours.

URS has existing professional relationships with the P-ADCIRC user community. The URS modeling group is familiar with the serial version of ADCIRC and has a working relationship with the model developers as a result of past efforts with CHL-ERDC. To-date, the developers of P-ADCIRC have been closely involved with all of the application projects and their continued support is a key asset of any P-ADCIRC effort. Of course URS has been coordinating extensively with the LSU P-ADCIRC users on the Maurepas RMA-2 application.

[Note: During our scope development (Fall 2002) the Project Team did not consider the potential need for a parallelized model primarily because parallelized models were not commercially available. Moreover, the need for a very high resolution model for the Maurepas Swamp had not been determined.}

Recommended Alternative and Implementation Schedule

Given that P-ADCIRC is currently being applied to Louisiana coastal modeling, and that there is existing commercial availability, accessibility to several cluster sources, and ready developer support, P-ADCIRC provides clear advantages over the other alternative models. To provide additional verification that critical Maurepas issues could be addressed using P-ADCIRC, URS initiated development and testing of mesh segments with the serial ADCIRC, with support from the developers. These results have so far proven successful and *URS therefore recommends that the project 2D modeling be conducted with ADCIRC.*

The following steps and schedule are proposed to complete hydrodynamic modeling:

<u>Revised 2D Hydrodynamic Modeling Schedule</u>

Proceed with developing a revised ADCIRC mesh using SMS and serial ADCIRC with support from the model developers.	October 25 to December 15
As model size dictates, initiate P-ADCIRC mesh testing with support from the model developers and LSU (using university clusters).	December 15 to December 31
Conduct model calibration simulations on commercial cluster (URS/WorldWinds)	January 1, 2005 to February 1
Conduct initial Diversion simulations on commercial cluster (URS/WorldWinds) and test for additional feature sensitivity; finalize simulation mesh.	February 1 to March 1
Conduct various With versus Without Diversion simulations scenarios on commercial cluster (URS/WorldWinds)	March 1 to April 1
Submittal of Draft FS Report	May 1, 2005

This schedule assumes that authorization to proceed is obtained from LDNR by December 15.

URS intends to continue to develop the 2D Maurepas Swamp model under the direction of Dr. Chris Reed. URS currently has serial ADCIRC (under SMS) and has initiated preliminary mesh tests with ADCIRC. Dr. Reed will utilize the model developers, Drs. Johannes Westerink and Rick Luettich, as primary technical support in "debugging" and "troubleshooting"' model runs, particularly during initial development and calibration.

Drs. Kemp and Mashriqui will be utilized for additional expertise "as-needed" in the development and troubleshooting of the model as the mesh is expanded to a size more suitable for P-ADCIRC. Their access to several LSU clusters provides us with a fairly rapid and local support for testing out the full-scale model as it is being developed. In addition they will be used as back-up support for "de-bugging" the model and in evaluating the "goodness of fit" of the calibrations. They have additional expertise in coastal Louisiana hydrodynamic simulation and since earlier this year have been using P-ADCIRC on simulations.

Discussions to-date have indicated that the LSU clusters will only be available on a limited basis—such as for initial model testing. Therefore URS has identified two options for gaining access to a commercial cluster for executing model runs.

1. WorldWinds, LLC maintains an 8 node (16 processor) cluster (Athlon P2100s) in Stennis Louisiana. They have recently installed ADCIRC and run a series of hurricane storm surge simulations under contract to NASA for the Biloxi area of coastal Mississippi. WorldWinds does not provide expertise in wetland hydrodynamic modeling. They performed the above simulations. with the assistance of Drs. Johannes Westerink and Rick Luettich. URS will direct all P-ADCIRC modeling efforts for use of the WorldWinds cluster for the Maurepas project.

2. URS is considering installing an in-house cluster to meet several demands for high-end modeling services in a variety of business lines (surface water, groundwater, seismic, air dispersion). If the decision is made to proceed, we would make our cluster available (should one be installed in time to serve this project) for the same hourly fee as time on the WorldWinds "rented" cluster. [Note: if URS does install a cluster it will likely use newer, higher capacity processors that the WorldWinds cluster.]

In order to meet the demands of the project schedule URS will use whatever cluster is available and reliable.

To implement the above schedule URS subcontract consulting agreements—and LDNR approvals—must be implemented with the following parties:

- Johannes Westerink
- Rick Luettich
- G. Paul Kemp
- Hassan Mashriqui, and

Note: URS requests that LDNR waive their insurance requirements for these agreements since the anticipated subcontracted activities to these individuals are of a technical support nature, and URS will retain responsibility for all aspects of the work.

URS will also need LDNR approval to issue a standard subcontract agreement, with WorldWinds, LLC. WorldWinds will be required to provide the standard insurance certifications.

Contact information for these subcontractors is as follows:

Westerink and Luettich Consultants
c/o Environmental Hydraulics Laboratory
Department of Civil Engineering and Geological Sciences
University of Notre Dame
Notre Dame, Indiana 46556-0767
(574) 631-6475
Johannes Westerink, Ph.D and Rick Luettich, Ph.D, Project Principals
Services: ADCIRC and Parallel Cluster Modeling Support

G. Paul Kemp, Ph.D Project Principal
c/o Louisiana State University, School of the Coast and Environment
Energy, Coast and Environment Building
Baton Rouge, LA 70803
(225) 578-6316
Services: Parallel Cluster Modeling Support

Mashriqui, Ph.D, Project Principal
c/o Louisiana State University, School of the Coast and Environment
Energy, Coast and Environment Building
Baton Rouge, LA 70803
(225) 578-6316
Services: Parallel Cluster Modeling Support

WorldWinds, Inc.
Building 1103, Suite 213C
Stennis Space Center, MS 39520
(228) 688-1468
Elizabeth Valenti, President and Discipline Leader
Services: Parallel Cluster Modeling Support

Cost Estimate

The estimated breakdown of additional subcontract and expense costs for completing the above efforts are shown in Table 4. The total estimated cost is $80,000.

URS is not requesting any budget increase for our modeling group labor to complete the 2D hydrodynamic modeling.

Water Quality Modeling

As part of the discussion of 2D Maurepas Swamp modeling results in the Feasibility Study Report, URS will address considerations for further modeling of water quality parameters.

ADCIRC does not currently accommodate water quality simulation. The program does provide for particle tracking and detention time analysis—which is consistent with the current FS scope of work. 2D simulations of salinity and nutrients are expected to be available with a finite volume version of ADCIRC which is not likely to be available until late 2005. [The current finite element numerics do not provide local conservation of mass.]

If LDNR and EPA determine that water quality modeling is needed following the completion of the hydrodynamic analysis, and a water quality version of ADCIRC is not available, FVCOM is likely to be a suitable alternative. Commercial licensing of FVCOM is likely to be available by early 2005. The model mesh for P-ADCIRC should be readily transferable to FVCOM.

Table 2 List of 2D Model Program Characteristics

Requirements

- The model must be 2D depth averaged (3D model not required).
- The model must have been previously tested and verified.
- The model must be suitable for a large-scale wetland/estuary circulation application and must support detention time estimation.
- The model must be able to accommodate tidal head and flow input boundaries.
- The model must include an appropriate scheme for simulation of wetting and drying—preferably one that does not require elimination of ponding.
- *The model must be numerically stable and able to complete lengthy simulation periods (approaching one month) within a reasonable runtime (preferably less than 24 hours). Therefore, the code should be parallelized.*

Options

- The model can employ a finite element, finite difference, or finite volume numerical scheme provided it achieves the required resolution, efficiency, and stability.
  - The finite element and finite volume models use variable mesh sizes and represent features with a minimum of computational elements. Representation of the various features of the Maurepas Swamp may require over 100,000 elements.
  - Finite difference models can use regular rectilinear or curvilinear grids which have a limited degree of grid refinement. A grid for the Maurepas Swamp is likely to require several million grid cells (which are comparable to the number of mesh elements in finite element models). Curvilinear grid-based models can reduce the required number of grid cells compared to rectilinear grids but will not be able to achieve the same efficiency as a finite element model.
  - A basic trade-off exists between finite element and finite volume models—which require fewer elements but larger computational time per grid element—versus finite difference models—which will have more cells but require less time per grid cells.

Preferred

- Simulation of culverts and control structures (e.g., weirs) is a plus since it would simplify representation of these features but not is required.
- Finite difference and finite volume methodologies have the added benefit of providing for local (cell by cell) conservation of mass. These models could then be used in the future to also simulate water quality issue—such as salinity and nutrients—should it be necessary.
- Use of the model should be facilitated with an existing pre and post processor.

Table 3
List of 2D Parallelized Models

Model	Source	Type	Pre/Post-Processor	Wetting/Drying	Water Quality Modeling	Control Structures	HPC Code Available?	HPC Support
ADCIRC	Notre Dame/UNC	FE	Yes-SMS	Yes	FV version to support WQ modeling w/CE-QUAL-ICM is planned for late 2005	Culverts, Weirs, Levees	Yes; commercially available for purchase	Drs. Westerink (Notre Dame) and Luettich (UNC); Commercial cluster at WorldWinds (Stennis MS)
CH3D	Corps/ U of Florida	FDC	Yes	Yes	Yes	Not determined	Available at the University of Florida,	Dr. Peter Seng (UF)
ECOM	HydroQual/ Princeton/ Stevens Institute	FDC	Yes	Yes	Yes	No	Available at Stevens Institute	Not Yet Determined
M2D	Corps/FIT	FD	Yes-SMS	Yes	Not currently available; interface with EPA WQ Model can be developed	No	Available at Florida Institute of Technology	Dr. Gary Zarillo (FIT)
FVCOM	U Mass-Dartmouth	FV	Yes-SMS	Yes	Yes CE-QUAL-ICM;	No	Yes but currently only licensed to universities (e.g. UNO); commercial license possible by late 2004;	Dr. Changsheng Chen (UM-Dartmouth)
LSU-CWPPRA	Louisiana State	FD		Yes	Interface with EPA WQ Model being developed	No	Available at LSU	Dr. Vibhas Aravamuthan (LSU)

Table 4
Estimated Additional Subcontractor Expenses

Task	2D Modeling Expenses (ADCIRC Cluster Runs)	Unit (Hrs)	Unit Cost	SUBTOTAL COST
7.4.4	Expenses (Additional ADCIRC WORK)			
7.4.4.1	Initial ADCIRC Serial Model Development--Mesh Testing			
7.4.4.1.1	**Technical Support**			**$1,400.00**
	Westerink and Luettich (Project Principals)	10	$ 140.00	$ 1,400.00
7.4.4.2	ADCIRC Parallel Model Development--Mesh/Cluster Testing			
7.4.4.2.1	**Technical Support**			**$ 23,043.80**
	Westerink, Luettich, Kemp, and Mashriqui (Project Principals)	20	$ 140.00	$2,800.00
7.4.4.3	ADCIRC Parallel Model Development--Calibration Simulations			
7.4.4.3.1	**Technical Support**			**$ 10,121.90**
	Westerink, Luettich, Kemp, and Mashriqui (Project Principals)	40	$ 140.00	$ 5,600.00
	Pat Fitzpatrick (WorldWinds, Task Manager)	20	$ 128.00	$ 2,560.00
	Elizabeth Valenti(WorldWinds Discipline Leader)	10	$ 110.00	$ 1,100.00
	Yongzuo Li and Chuck Parker (WorldWinds, Environmental Scientist 1)	10	$ 86.19	$861.90
7.4.4.3.2	**Modeling Cluster Rental**			**$ 5,700.00**
	WorldWinds LLC or URS 8 node (16 processor) cluster	100	$ 57.00	$5,700.00

Table 4 Continued
Estimated Additional Subcontractor Expenses

Task	2D Modeling Expenses (ADCIRC Cluster Runs)	Unit	Unit Cost	SUBTOTAL COST
7.4.4.4	Initial Diversion Mesh and Simulation Runs			
7.4.4.4.1	**Technical Support**			**$8,183.80**
	Westerink, Luettich, Kemp, and Mashriqui (Project Principals)	20	$ 140.00	$2,800.00
	Pat Fitzpatrick (WorldWinds, Task Manager)	20	$ 128.00	$2,560.00
	Elizabeth Valenti (WorldWinds Discipline Leader)	10	$ 110.00	$1,100.00
	Yongzuo Li and Chuck Parker (WorldWinds, Environmental Scientist 1)	20	$ 86.19	$1,723.80
7.4.4.4.2	**Modeling Cluster Rental**			**$ 8,550.00**
	WorldWinds LLC or URS 8 node (16 processor) cluster	150	$ 57.00	$8,550.00
7.4.5.5	Various With and Without Project Simulation Runs			
7.4.4.5.1	**Technical Support**			**$5,503.80**
	Westerink, Luettich, Kemp, and Mashriqui (Project Principals)	10	$ 140.00	$1,400.00
	Pat Fitzpatrick (WorldWinds, Task Manager)	10	$ 128.00	$1,280.00
	Elizabeth Valenti (WorldWinds Discipline Leader)	10	$ 110.00	$1,100.00
	Yongzuo Li and Chuck Parker (WorldWinds, Environmental Scientist 1)	20	$ 86.19	$1,723.80
7.4.4.5.2	**Modeling Cluster Rental**			**$ 17,100.00**
	WorldWinds LLC or URS 8 node (16 processor) cluster	300	$ 57.00	$17,100.00
	Total			$79,603.30

Attachment 1
Background-Initial URS RMA2 Modeling Efforts

Why RMA-2 Was Originally Selected

The RMA2 model was originally proposed by URS for the project—following discussions with LDNR, the Corps, USEPA, and LSU—for several reasons:

1. RMA2 was been in the public domain for over 25 years and has proven to be a reliable and accurate model when applied to problems of suitable, scale, resolution, and hydrodynamic complexity;
2. The Corps, USEPA, and LDNR had selected RMA2 for other similar Louisiana applications (e.g., Barataria-Terrebone model); a review of various 2D models by another LDNR consultant had identified RMA2 as the leading model at that time.
3. RMA2 was also being utilized by Dr. Paul Kemp and Dr. Hassan Mashriqui of LSU under contract with USEPA for a long-term ecological analysis of the diversion project; the Project Team expected that a URS RMA2 effort could be coordinated with LSU model development and synergies achieved.
4. RMA2 contains the appropriate physical representations needed to model shallow tidal flows in a swamp environment, namely a) 2D depth averaged flow and b) ability to simulate drying and re-wetting of the swamp (albeit limited);
5. RMA2 runs on standard desktop computers under the Windows OS, and is supported by commercial pre and post processing software (SMS) which facilitates model configurations and results analysis; and
6. URS had considerable experience in using RMA2 for estuarine simulations.

At the time of the RMA2 model selection, the Project Team's understanding was that study area conditions which would pose challenges to RMA2 (e.g., high resolution, wetting-drying) would be handled to the best of RMA2's capabilities. Use of ADCIRC (serial) as an alternative to RMA2 was discussed by URS internally. However, at the time (fall 2002) ADCIRC was being used primarily as a regional coastal tide/scientific model. It did not readily support engineering studies. While the newer, more efficient numerical schemes of ADCIRC were becoming attractive to modelers, the model did not incorporate various control structures (e.g., weirs, culverts, etc.).

Furthermore, ADCIRC did not then (and does not yet) support water quality modeling. The option of future water quality modeling with RMA4 module was considered a significant plus for RMA2. Finally, the mesh design of ADCIRC would not facilitate coordination with the LSU RMA2 model development. [ADCIRC now incorporates some control structures.]

LSU RMA2 "Ecological" Model

The primary purpose of the LSU modeling analysis was to make long-term—50 to 100 year—assessments of diversion water levels and flows in the Swamp in order to quantify project benefits to the health of the Swamp flora. A draft report was completed in June of 2004. The LSU model incorporates roughly 5,000 elements/15,000 nodes covering the entire project area (eastward to US 51 and including the entire Lake Maurepas and surrounding swamp). The model was calibrated using stage data from various stations located throughout the swamp.

The LSU RMA2 model calibrations results presented in the draft report showed good agreement with the low frequency stage components (i.e., multi-day water level trends associated with regional wind conditions). URS agrees this calibration indicates that the LSU RMA2 model provides sufficient resolution and accuracy for the intended purposes.

However, the LSU model geometry does not include numerous project area channels and other features. Furthermore, the calibrations do not sufficiently reflect the higher frequency diurnal tidal oscillations in the channels—in particular, the model tidal signals in the upper Swamp were highly attenuated compared to the stage data. Such signal dampening is common with coarse mesh layouts and indicates that channel conveyance properties may be significantly underestimated. While not critical to ecological modeling, accurate channel conveyance is crucial to examining swamp circulation and drainage issues to the extent demanded by this project.

Current URS RMA2 Hydraulic Model

URS has developed an RMA2 model which runs on a 3 MHz Pentium processor with 1 Gigabyte of RAM. Currently the model features a mesh with 15,000 elements and 36,000 nodes. This model includes a smaller study area than the LSU model—focusing on the area between Reserve Relief Canal and Blind River. With three times the number of elements as the LSU model, it therefore represents an improved resolution of the channels/banks and other conveyance features in the Swamp (although numerous features have not been included). Initial trials with portions of the mesh demonstrate that higher resolution of channels/banks does indeed support the simulation of the high frequency stage data.

Difficulties with RMA2 Hydraulic Model

In assembling the entire project area mesh URS has included significant mesh "stretching" to control the overall model size (i.e., total number of elements/nodes). This means that the mesh transitions fairly rapidly from small/tight elements along the channels/banks to large elements in the flatter swamp interiors. Mesh stretching and controlling model size are keys to achieving reasonable model run times.

Preliminary tests with the entire mesh reveal several problems:

1. Sharper mesh transitions have led to problems of numerical instability and model crashes. This problem is alleviated by identification and relaxation of the particular mesh areas that cause model crashes.
2. The problem is exacerbated when elements are subjected to cycles of wetting and drying—as in the case of this model. RMA2 is extremely "finicky" and Swamp elements must be further reduced.
3. Fixing the mesh problems—typically by reducing the stretching and smoothing swamp contours—increases the number of elements/nodes and increases model run time. However, a comprehensive revision of the mesh to totally eliminate the problem would result in far too many elements and exceed reasonable run-time goals. Adding more detail is not possible.
4. In addition, Swamp element geometry must be adjusted to ensure that isolated ponding does not occur. RMA2's approach to wetting and drying and is limited in its ability to consider complex Swamp bathymetry. Revising the Swamp bathymetry to fit RMA2 calls into question the model's overall accuracy and integrity.
5. The model run time for a two-week simulation was at six (6) days and extensive instability problems were still being encountered when work was temporarily halted. The actual simulation run time was beyond 6 days because the model had to be continually restarted from a previous time step after being adjusted to remedy the most recently occurring instability.

We have concluded that while it may be possible to increase the mesh size and smooth variations in the element size in order to improve the reliability of the model simulations, the computer run-time for such simulations will increase to unacceptably long periods (e.g., a week or more to simulate a three week calibration period). Long-run times are extremely problematic for intensive "model tweaking" steps such as debugging, calibration, and "with project" simulations. Thus, continued use of RMA2 is likely to extend to a period of many months.

In summary, the RMA2 mesh size requirements required to provide both an accurate and numerically stable model are becoming very large and will require very long simulation times on the fastest computational platforms available for RMA2. Furthermore, mesh changes necessary to accommodate the restrictive RMA2 wetting/drying algorithm will reduce model accuracy.

Attachment 2
Response to Questions on Draft Memorandum

1. **Page 1 - (ADCP) Acoustic Doppler Current Profiler should be designated and specified next to the acronym. What is the name of the central channel specified and where is the channel located?**

   We concur. The ADCP was placed by LSU in Dutch Bayou, just downstream of the confluence of Mississippi Bayou and Dutch Bayou. This location was recommended by LSU and agreed to by URS as desirable for supporting calibration since 1) Dutch Bayou is expected to be the major outlet for Diversion flow to Lake Maurepas and 2) velocity/flow values are expected to have a fairly wide range due influence of upstream flow from Mississippi Bayou and Hope Canal and downstream control by tides in Lake Maurepas.

2. **Page 1 - Please expand on the four critical model features used to define the complexity and size of the Maurepas Swamp Diversion area.**

   The wording of the 3rd paragraph on Page 1 of the Draft is probably confusing. It should read:

   > "Based on our evaluation of the Diversion area terrain and hydrology, URS has recommended that the development of the 2D model take into consideration four critical physical features."

   Item 1 refers to the area between Blind River on the west to Reserve Relief Canal on the east and from Airline Highway on the south to Lake Maurepas on the north.

   Item 2 refers to the relatively small elevation changes (1 to 3 feet) associated with numerous minor sloughs, and channel banks and cuts which control water flow.

   Item 3 is described in Attachment 1 of the Memorandum. Simulation of tidal signal amplitude in the upstream locations is an indication that the channel conveyance has been properly modeled.

   Item 4 refers to the list in Table 1 of the Memorandum. The model should incorporate as many of these features as possible to support accurately simulating a "realistic" picture of how the diversion water will circulate in the Swamp (area of affect, residence time, stagnation areas, etc.) and what backwater impacts may occur.

3. **Page 4- What is the primary difference between the serial and parallelized version of ADCIRC? Please clarify why serial ADCIRC was not chosen initially over RAM2.**

In the parallelized version of ADCIRC the code has been modified to allow for distribution of the model domain (i.e. mesh) over more than one processor. This allows each processor to handle a particular region of the mesh--solving of the various equations---during each time step. This speeds up the time required to solve the total mesh for each time step. The speed-up can be close to 1:1---meaning if you increase the number of processor by 8, the overall runtime will fall be a factor of close to 8. This is a clear advantage for running a model which would otherwise take several days to execute.

During our scope development (Fall 2002) the Project Team did not consider the potential need for a parallelized model primarily because parallelized models were not commercially available. Experience with a handful of parallelized models was beginning to emerge in the academic literature. We were aware of research efforts at the Corps Coastal Hydraulics Lab but as of 2002 no applications had been undertaken in the consulting world. Moreover, members of the Project Team all recognized that other similar LDNR projects were moving forward with serial models (e.g. Barataria). Furthermore, the Project Team anticipated some synergies from using RMA-2 since LSU was being tasked to use RMA-2 to evaluate ecological benefits. Finally, the need for a parallelized model has only become apparent as the need for a very high geometric resolution has emerged.

4. **Page 5 - As specified in the first paragraph, PADCIRC is licensed to WorldWinds, L.L.C. in Stennis, Mississippi. If WorldWinds, L.L.C. provides URS with the PADCIRC modeling support services, what services will be provided by LSU Drs. Kemp and Mashriqui?**

   WorldWinds does not provide expertise in wetland hydrodynamic modeling, only in executing and processing of P-ADCIRC model runs. Drs. Kemp and Mashriqui will be utilized for additional expertise "as-needed" in the development and troubleshooting of the P-ADCIRC model. We expect they may be of assistance in "de-bugging" the model and in evaluating the "goodness of fit" of the calibrations. They have additional expertise in coastal Louisiana hydrodynamic simulation and since earlier this year have been using P-ADCIRC on simulations. Their access to several LSU clusters provides us with a fairly rapid and local support for testing out the model as it is being developed.

5. **Page 7 - URS anticipates the use of a private modeling cluster, which is proposed to be provided by WorldWinds, L.L.C. or developed by URS. Due to the schedule constraints for this project and the availability of PADCIRC through WorldWinds, L.L.C., LDNR recommends that the modeling services provided by WorldWinds, L.L.C. be used to complete the required tasks for this project.**

In order to meet the demands of the project schedule URS will use whatever cluster is available and reliable. URS is considering installing an in-house cluster to meet several demands for high-end modeling services in a variety of business lines (surface water, groundwater, seismic, air dispersion). We would make our cluster available (should one be installed in time to serve this project) for the same hourly fee as time on the WorldWinds "rented" cluster. It is important to note that the university clusters will not be available for extended production run use and we therefore believe it may be attractive to have an alternative to WorldWinds. Note: due to the rapid advance in processor technology, if URS does install a cluster it will likely be faster that the WorldWinds cluster.

6. **Page 7 - The addition of the services provided by Johannes Westerink and Rick Luettich, Paul Kemp and Hassan Mashriqui, and WorldWinds, L.L.C. should follow LDNR protocol for subcontractors. All services, tasks, and hourly rates for the additional work should be broken down accordingly and submitted using the existing pay scale previously approved in the original contract for this project.**

   URS will follow LDNR protocol for subcontractors. We do not expect these four subcontractors professionals to have significant hours (probably less than 200 hours combined) and they will be used primarily for senior technical support. We propose to bill them to LDNR at the rate of a Project Principal $140/hr.

   We have included a table with this letter which breaks down the detail man-hours and computer time for each task. The cost for cluster computer time has been provided as an expense to the project as allowed for many other features of this project, since there is no current rate for computer clusters. The cluster rate of $57/hour is based on the quote we received from WorldWinds. We respectfully request that this cost be allowed as an expense with the appropriate subcontracts as required by LDNR and URS.

7. **Page 7 - An amendment increasing the contract budget will not be issued at this time for the additional technical support services. A record of these additional costs associated with the technical support services should be tabulated and submitted to LDNR for review. This will provide the documentation for services provided by URS beyond the scope of the original contract, which may be required for future contract budget adjustments. However, due to the additional technical support services provided by WorldWinds, L.L.C., and L.S.U., an amendment adding the subcontractors to the contract will be required.**

   We concur with not amending the contract budget at this time and only documenting the additional cost and out of scope services. Attached with this letter is a detail list of each subcontractors official name, address and contact information. We request that an amendment adding these subcontractors be provided. Please advise us of any additional information we need to provide.

8. **Page 8 - A contingency is not usually added to an amount issued for additional work required for a contract. The additional technical services should be broken down to each specific task and estimated accordingly.**

   As noted in item 6 above, URS has provided the detail expense estimate showing tasks and hours required to accomplish the new recommended subcontract tasks. URS has not included an explicit contingency.

9. **Page 8 - Water quality modeling for the project area will not be conducted at this time. However, a development plan for the implementation of the ADCIRC data into the FVCOM and ADCIRC (finite volume) water quality models should be evaluated.**

   As part of the discussion of ADCIRC results in the Final Report, URS will address considerations for further modeling of water quality parameters.

Plan for ADCIRC 2D Swamp Hydrodynamic Model Simulations

Calibration Analysis

Calibration analysis will be undertaken following completion of a stable model geometry (topography, bathymetry, element/grid development, and boundaries) reflecting current (baseline) terrain. Given modeling objectives to rigorously assess potential drainage impacts and diversion water spreading/ detention under a variety of conditions, URS is proposing to evaluate calibration during four periods.

Calibration Periods	Rationale
December 26, 2003 to January 25, 2004	Same as LSU RMA-2 Model Calibration Period; allows calibration to address conveyance of key channels, particularly through simulation of high frequency Lake tidal signals.
April 2004	Low Lake Maurepas water elevation; allows calibration to address conditions when greatest short-circuiting is likely.
May-June, 2004	High Amite River Diversion Canal flow and Blind River water elevation (also includes a heavy Garyville rainfall event); allows calibration to address influence of these conditions on western model boundary, the connection between Blind River and Dutch Bayou, and the conveyance of Tent and Dutch Bayous under relatively high input flows.
September-October, 2004	Passage of Hurricane Ivan, Tropical Storm Ivan, and Tropical Storm Matthew (latter caused Lake water elevations to reach 4.5 ft.); allows calibration to address the influence of rapid rise and fall of tropical storm driven Lake (north boundary) conditions.

The model will be calibrated first for the LSU RMA-2 Model Calibration Period and the Low Lake Maurepas conditions. Model will then be further calibrated/validated using the High ARDC/Blind River and Tropical Storm periods. The calibration will be assessed graphically using selected continuous stage data from the 15 project area gages and the continuous ADCP velocity data at Dutch Bayou. Standard quantitative "goodness of fit" analysis (e.g. residual mean square, RMS) will be used.

Model Sensitivity and Suitability Analysis

Following calibration URS will provide the model to Drs. Kemp and Mashriqui at LSU to conduct a Sensitivity Analysis. The Sensitivity Analysis will provide an independent assessment of the model for use in the Hydraulic Feasibility Study and identify any recommendations for improving the model's suitability for future engineering studies.

Sensitivity Scenarios	Rationale
Intrinsic Parameter Sensitivity	Evaluate influence of chosen values for Manning's, Eddy Viscosity, etc. on model.
Numeric Parameter Sensitivity	Evaluate influence of Tao and other numeric parameters on model
Model Geometry Sensitivity	Evaluate influence of simplifications in topography, bathymetry, and hydraulic features (e.g., channel conveyance and banks) on model.
Boundary Condition Sensitivity	Evaluate influence of boundary location and condition assumptions for west, south, north, and eastern boundaries on model.

Baseline Scenarios

Six Baseline Scenarios (i.e., Without Project Runs) will be developed with appropriate boundary conditions (BCs) to simulate a range of important potential hydrologic events for comparison with Design Scenarios (i.e., With Project Runs).

Baseline Scenarios	Rationale
Typical BCs	A Typical BCs Scenario will incorporate routine tidal fluctuations in Lake water elevations (0.5 to 2.0 ft) and average flow inputs for Blind River, ARDC, Hope Canal, and other canals.
Moderate Rain in Garyville and Reserve with Typical Lake and Blind River BCs	This scenario will include upland drainage from a moderate, fairly frequent rain event. The scenario will utilize an annual recurrence on the order of 2 to 5 years for durations of 1 hour, 1 day, and 4 days (see attachment). The scenario will evaluate linkages of the 1D and 2D models for a moderate rainfall discharge from the developed areas of Garyville and Reserve; this scenario will assume typical Lake and Blind River conditions.

Extreme Rain in Garyville and Reserve with Typical Lake and Blind River BCs	This scenario will provide upland drainage from an extreme rain event. The scenario will utilize an annual recurrence on the order of 10 to 100 years for durations of 1 hour, 1 day, and 4 days (see attachment). The scenario will evaluate linkages of the 1D and 2D models for an extreme rainfall discharge from the developed areas of Garyville and Reserve; this scenario will assume typical Lake and Blind River conditions.
Amite River Diversion Channel/Blind River Flooding	This scenario will incorporate extreme discharge/stage levels in the Amite River Diversion/Blind River system. The scenario(s) will utilize an annual recurrence on the order of 25 to 100 years (see attachment).
Heavy Tropical Storm Scenario with Typical Blind River BC	This scenario will include a rapid rise in Lake Maurepas, in combination with high rainfall events in Garyville and Reserve.
Low Lake/Drought	This scenario will provide very low Lake water elevations and flow inputs.

Previous RMA-2 simulations by LSU suggested that the Diversion may take several weeks to reach fully-developed flow. The Typical BC Baseline Scenario will extend for up to two months and will be developed to facilitate the stability, run-time, and convenience for "hot-starting" other scenarios. BCs for the Baseline Scenarios will be developed using a combination of actual and artificial (synthetic) stages/flows to simulate the intended critical conditions.

For the Garyville/Reserve storms simulations the water elevations/durations in the drainage networks and rainfall flow inputs to the Swamp will be evaluated using the 1D model. Controlling Swamp tailwater conditions will be established by the 2D model.

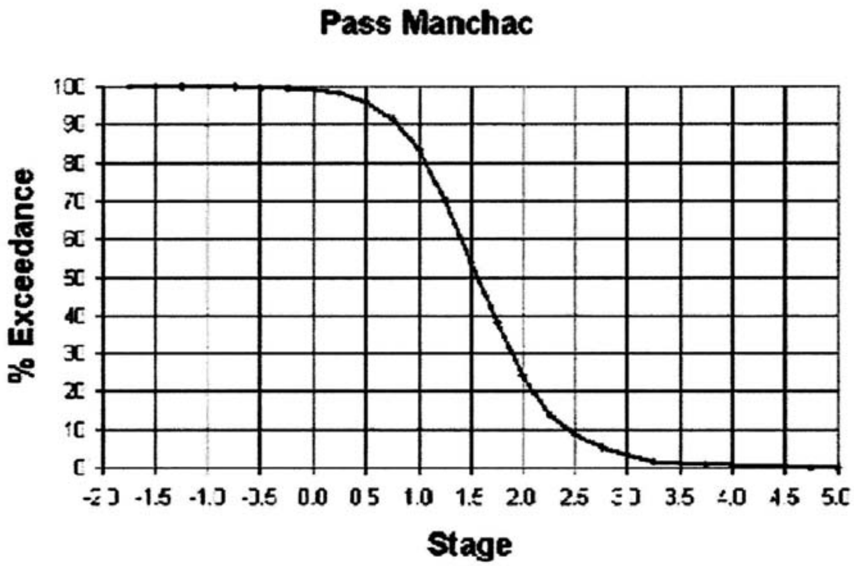
Design Scenarios

As the six Baseline Runs are completed, the following Design Scenarios (i.e., With Project Runs) will be performed.

Design Scenarios	Baseline Scenario to be Used	Scenario Rationale/Objective
Alternate Diversion Flows (1,000 to 3,000 cfs)	Use Typical Conditions to initially evaluated alternative flows; then proceed to other Baseline Scenarios to evaluate the impact of other Boundary Conditions.	Simulate the system hydraulic response to a range of possible diversion flows. Key items to evaluate are backwater impacts, scouring at I-10, diversion flow patterns in the North and Central Swamp (including overall detention time), and channel velocities. Evaluate potential maximum Diversion flow and preliminary Outfall Management requirements.
Alternate Outfall Management	Use Low Lake/Drought Scenario.	Evaluate the Diversion and Swamp response during most critical BC. Evaluate various flow restriction alternatives to reduce short-circuiting of diversion and increase retention time.
Alternate Backwater Mitigation Measures	Moderate and Extreme Rainfall Scenarios.	Simulate the system response while including various measures to reduce backwater impacts on Garyville and Reserve. One possible measure is the extension of the Pontchartrain HPL and associated pump stations.
Shutdown Response Time	Amite River Diversion Channel/Blind River Flooding and Heavy Tropical Storm Scenarios.	Evaluate if Diversion aggravates Swamp high water from extreme BC events and possible need for advanced Diversion shutdown to avoid unacceptable backwater impacts.

Attachment 1
Lake Maurepas Stage Frequency

LSU has previously developed a Stage Exceedance Curve for Lake Maurepas based on hourly data for a Corps gage at Pass Manchac. The conversion to NAVD-DNR datum is -0.5 ft.



Source: Lee Wilson, Diversion into the Maurepas Swamps, Appendix C, June 2001.

Key percentile values, converted to NAVD-DNR, from this curve are approximately.

Frequency (Percent) of Time Stage is Exceeded	Stage (ft NAVD-DNR)
1	3.0
5	2.3
10	1.9
25	1.5
50	1.1
75	0.8
90	0.3
95	0.0
99	-0.5

The stage at Pass Manchac reached 3.7 ft NAVD-DNR during late June 2003 during the passage of Tropical Storm Bill and 4.5 ft during October 2004 during Tropical Storm Matthew.   Higher levels are known to have occurred during Hurricane Juan.

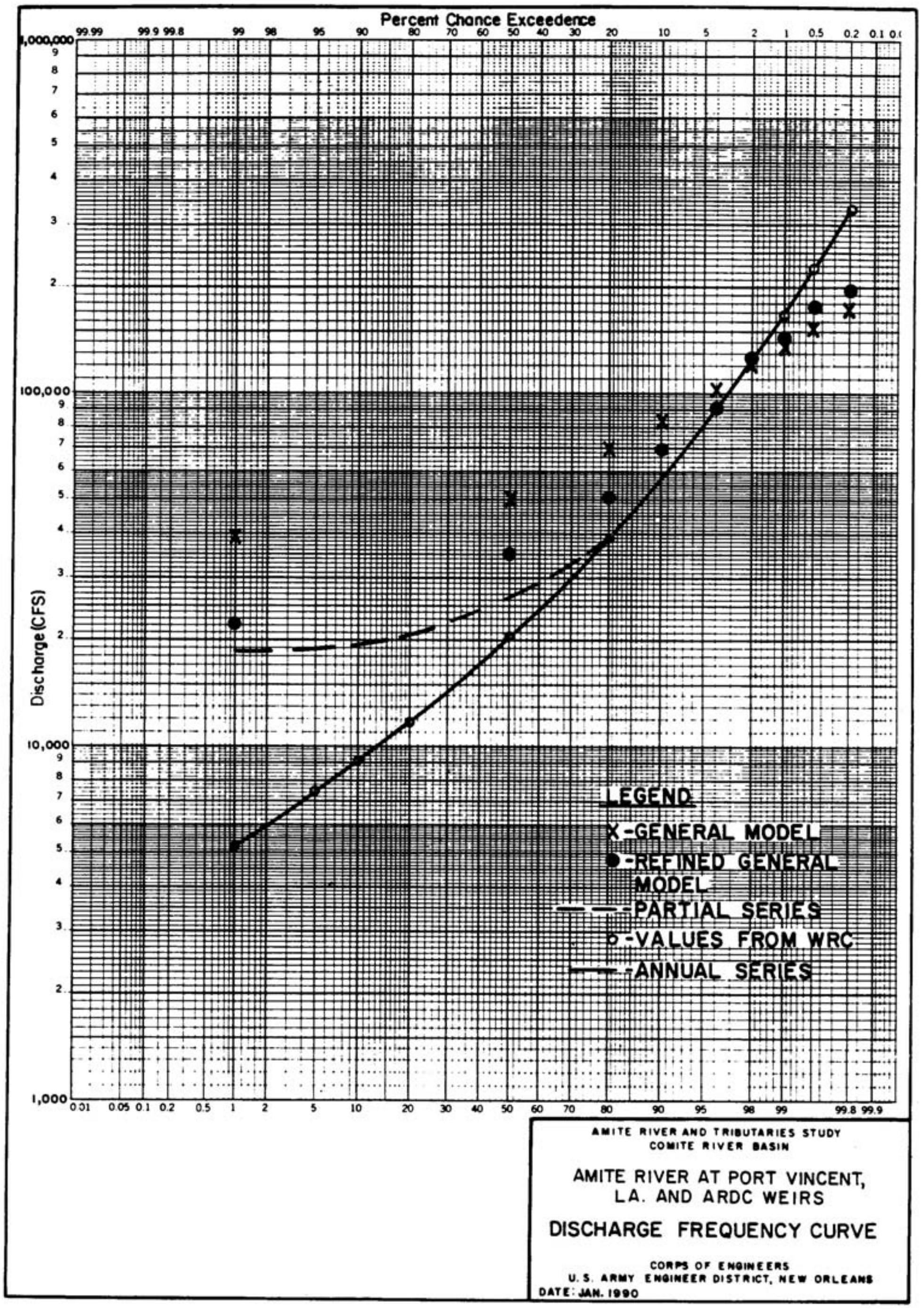
Attachment 2
Rainfall Frequency-Duration Information
Garyville-Reserve Area

Duration	Recurrence Frequency	Estimated Precipitation (in)
1 hour	100 year	4.5
	50 year	4.0
	25 year	3.7
	10 year	3.3
	5 year	2.9
	2 year	2.4
24 hour	100 year	13
	50 year	11
	25 year	10
	10 year	8.8
	5 year	7.5
	2 year	5.5
96 hour	100 year	16.5
	50 year	15
	25 year	13
	10 year	11
	5 year	9.5
	2 year	7.5

Source: USDA, Technical Paper 40 and Technical Paper 49
http://www.srh.noaa.gov/lub/wx/precip_freq/precip_index.htm

Attachment 3
Flood Frequency, Amite River Diversion Channel

The solid line on the following figure represents the Flood Frequency computed by the Corps of Engineers for the Amite River at Port Vincent.



Source: Comite River Diversion Feasibility Study, Appendix C, September 1990

The percentage of flow distributed to the Amite River Diversion Channel has been historically estimated at 2/3 during high flows, based on reported design criteria for the Diversion weir. The present distribution is probably higher than 2/3 due to settlement of the weir and is roughly estimated as follows:

ARDC Flood Frequency	Discharge (cfs)
100 year	120,000
50 year	90,000
25 year	70,000
10 year	40,000
5 year	30,000
2 year	15,000

The average flow of the Amite River at Denham Springs is reported to be about 2,000 cfs. (Corps of Engineers, Ecosystem Restoration Reconnaissance Study, Amite River System and Tributaries, July 2000). Based on this, additional contributions of flows below Denham Springs, and settlement of the weir, an average flow of 1,000 cfs is thought to be a reasonable estimate for the ARDC.

The Blind River upstream of the ARDC drains a much smaller area than the Amite River at Port Vincent, by a factor of about 6. In addition the Blind River flows are substantially retarded by much flatter topography and ARDC backwater, and are under tidal influence. Assuming Blind River flows are about 5 percent of the ARDC flows, a rough estimate of Blind River flood frequencies is as follows.

Blind River Flood Frequency	Discharge (cfs)
100 year	6,000
50 year	4,500
25 year	3,500
10 year	2,000
5 year	1,500
2 year	750

Mean flow in the Blind River prior to joining the ARDC is probably about 100 cfs.

A TS Allison (2001) high water mark at a camp near the confluence of the ARDC and Blind River was found to be at an elevation of 4 ft NAVD-DNR.

August 28, 2005

Mr. Russ J. Joffrion, P.E.
Project Engineer,
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Louisiana Department of Natural Resources
P.O. Box 94396
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RE: Mississippi River Reintroduction into Maurepas Swamp, PO-29
LDNR Contract No. 2511-03-15
Summary of Request for Amendment No. 1

In recent discussions between LDNR, EPA and URS, it has been the Project Management Team's consensus that URS has verified/justified a need to increase the budget by some $360,000 to cover the increased cost for high resolution ADCIRC 2D modeling of the swamp area. A detailed discussion of this request was forwarded to LDNR on August 15, 2005. This letter provides a brief summary of the basis for the Scope of Work change, together with a proposed budget for the change.

Background

Under the original scope of work for the 2D Modeling Subtask the Project Management Team envisioned using RMA2 model. At the time of the original scope development all agreed was a state-of-the-art application. The problems encountered with RMA2 are fully discussed in our submittal of August 15, 2005.
The gist of the problem was that RMA2 was not able to handle the complex geometry and size of the area being modeled. The size of the mesh and details of the area grew to the point where URS was forced to review other potential modeling software. The Team agreed that a switch to the parallel version of the ADCIRC model, run on high performance parallel cluster computer systems, was needed to provide a high resolution model and to accurately analyze potential backwater affects on local residents, and proper dispersion of diversion water.

Changes in 2D Modeling Subtask Scope of Work

The switch to the P-ADCIRC model has necessitated changes to the 2D Modeling Subtask Scope of Work, including modifications to Model Development and Simulations. The changes are summarized in Table 1.

Model Development

Under the original RMA2 model a grid (or mesh) with about 20,000 nodes (maximum) was originally envisioned. This mesh was expected to require 2 second time-steps. Development of the grid and a stable model version were estimated by URS to take about 12 weeks (see Table 1). These estimates were consistent with a fairly high-end, complex RMA2 model. This type of model runs on a single processor computers, the costs of which were included in the URS overhead. (URS undertook the 12 week effort to develop the RMA2 model in the summer of 2004.)

The new requirement of a high resolution P-ADCIRC model has necessitated an extensive redevelopment of the finite element model grid. The new P-ADCIRC model involves over 150,000 nodes in order to achieve the accuracy requirements. This grid requires a time-step of ½ second. ***The P-ADCIRC is therefore 30 times larger than the originally envisioned RMA-2 model*** (in terms of the number of node-steps required to simulate one day.)

The P-ADCIRC model has required 52 weeks for development and stability testing (including the 12 weeks spent on the original RMA2 model). Extensive efforts were undertaken to develop, refine, and QC a project area Digital Terrain Model and translate the DTM into a preliminary ADCIRC mesh. Many weeks of model testing, using a subcontracted parallel computer cluster, were then performed to find, diagnose, and solve a wide variety of model instability issues.

In summary, the development of the P-ADCIRC model has therefore required:

1. Extension of the model development schedule by 40 weeks;
2. Over 40 days (about 1,000 hours) utilization of a parallel computer cluster;
3. Additional labor associated with model development and cluster operation.

Simulations

Under the RAM2 scope a total schedule of about 16 weeks was originally planned. Under the current P-ADCIRC model, about 800 days of simulations are anticipated (see August 15, 2005 submittal), requiring over 100 cluster run-days, and 30 schedule weeks.

These P-ADCIRC simulations therefore require:

1. An additional 14 weeks of schedule time;
2. About 2,500 hours of parallel cluster utilization (based on the subcontractor's recently upgraded capability; a university cluster may be available to expedite the simulations); and
3. Additional labor and travel expenses associated with the expanded simulation requirements.

Budget for Changes in 2D Modeling Subtask Scope of Work

Table 2 summarizes the budget increases associated with the 2D Model scope changes. The total requested budget increase is $360,000 and key components include:

- $153,000 for computer cluster rental for Model Development ($57,000 of this is for Model Development with WorldWinds, Inc.; $66,000 is for Simulations with WorldWinds, Inc., and $30,000 is for a university cluster).
- $134,500 for URS Labor.
- $70,800 for technical support from WorldWinds, and the model authors (Westerink and Luettich) and independent technical review from experienced local university ADCIRC scientists, (Kemp, and Mashriqui).
- $1,700 in URS travel expenses.

Summary

In summation, Project Management Team now realizes that the complexities of the Swamp area require a much more robust, high resolution, and costly model. Unfortunately, the data to determine these requirements were not available until the Team was well into the project.

The good news for the project is that the ADCIRC model currently being developed will provide LDNR and EPA with a cutting edge tool. This model involves one of the largest and most complex meshes ever attempted. URS also wants to assure LDNR and EPA that we have contributed a significant number of unbilled hours to the effort of "climbing the learning curve" of a parallel ADCIRC application.

URS respectfully requests an amendment in the amount of $350,000 to the Phase I Feasibility Study budget.

Should you have any questions, or require additional information, please don't hesitate to call.

Sincerely,
URS

Michael D. Patorno, P.E.
Civil Department Manger.

Enclosures.

cc: Mr. Chris Williams, Project Manager.

June 1, 2006

Mr. Russ J. Joffrion, P.E.
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RE: Mississippi River Reintroduction into Maurepas Swamp, PO-29
LDNR Contract No. 2511-03-15
Response to Letter Dated May 25, 2006

Per the Louisiana Department of Natural Resources (LDNR) letter dated May 25, 2006 URS Corporation is providing the following information in preparation for a project team meeting.

Current Detailed Budget Summary

Table 1 presents a detailed breakdown of the tasks, contracted valued, amounts spent to-date (through May 26, 2006) and amounts remaining for the Hydraulic Feasibility Study. URS does not anticipate any changes to the current budget for the Study.

Revised Project Schedule

URS has attached a Revised Project Schedule. The schedule provides for maintaining the previous deliverable date for the Draft Hydraulic Feasibility Study Report established in the March 17, 2006 Project Schedule, with the following interim milestones:

1.	Finalize grid and input parameters	June 14
2.	Complete four calibration/validation simulations—abbreviated versions	June 25
3.	Submit Draft Hydrologic Data Report and Maurepas Swamp 2D ADCIRC Model Calibration Report	June 29
4.	Initiate Diversion Simulations	June 15
5.	Complete Diversion Simulations	August 15
6.	**Submit Draft Hydraulic Feasibility Report**	**August 29**

Calibration/Validation Status

In the previously submitted Plan for ADCIRC 2D Swamp Hydrodynamic Simulations URS identified four calibration/validation periods:

Periods	Description
"LSU Period" December 26, 2003 to January 25, 2004	Same as LSU RMA-2 Model Calibration Period; allows calibration to address conveyance of key channels, particularly through simulation of high frequency Lake tidal signals.
"Low Lake" April 2004	Maurepas water elevation; allows calibration to address conditions when greatest short-circuiting is likely.
"High Blind River" May-June, 2004	Amite River Diversion Canal flow and Blind River flood (also includes a heavy Garyville rainfall event); allows calibration to address influence of these conditions on western model boundary, the connection between Blind River and Dutch Bayou, and the conveyance of Tent and Dutch Bayous under relatively high input flows.
"Tropical Storm" September-October, 2004	Passage of Hurricane Ivan, Tropical Storm Ivan, and Tropical Storm Matthew (latter caused Lake water elevations to reach 4.5 ft.); allows calibration to address the influence of rapid rise and fall of tropical storm driven Lake (north boundary) conditions.

Earlier this year, URS completed a calibration of the 2D ADCIRC Grid to key aspects of the LSU Period. However, during follow-up validation simulations we identified discrepancies between observed hydrographs and model results for high flow exchanges between the swamp and the channels for the Tropical Storm case. Resolution of these discrepancies required reconsideration of key physical and numerical parameters. In addition a one-day field reconnaissance was also needed to confirm controlling elevation of a key grid feature identified by the modeling (i.e., the Maurepas Lake berm). Adjustments to the berm elevation and model parameters to accommodate the Tropical Storm case dramatically improved calibration of this period; however, these adjustments resulted in some worsening of the LSU Period calibration.

The issue we face involves capturing important signatures of channel-Swamp exchange over a reasonable range of water elevation/energy conditions:

- ✓ Propagation of high frequency tidal signals from the Lake to the southern swamp limits at representative channel stages;
- ✓ Over-banking from the channels to the Swamp at proper channel elevations;
- ✓ Matching high elevation/energy flooding/surge events; and
- ✓ Mimicking low elevation/energy draining events.

The current model does capture low frequency signals quite well and represents the high frequency signals under some conditions. However, a more complete matching of these exchange signatures at lower stages/flows is proving to be extremely challenging, given the extreme sensitivity of channel stages/flow to very small changes in swamp water depth.

URS has been working with LDNR to determine what constitutes an acceptable model calibration at these various Swamp-channel conditions. *The critical question is the model's ability to simulate conditions that are likely to occur during diversion, and be able to reasonably predict* <u>*significant*</u> *backwater, short-circuiting, and stagnant conditions.* These are the conditions that carry crucial risks. In the case of backwater, a small increase of tailwater elevations in the Swamp can affect drainage by a noticeable percent. In the case of short-circuiting, short residence times will result in excess nitrate loading of the Lake and eutrophication. Finally, large stagnant areas could worsen conditions in some portions of the Swamp.

We believe it has been worth the effort to improve calibration at the low stage/flow condition since this case represents the conditions for short-circuiting. Specific aspects of the model which URS has been examining closely to improve the model include:

- Grid design—
  - Swamp floor elevation and representation of “dead” storage volumee
  - Weirs and elements used to represent banks and bank gaps conveyance
- Physical parameters
  - Drag coefficients
  - Weir coefficients
- Numerical parameters
  - Changes to Tau0 (a solution blending parameter)
  - Wetting and drying threshold parameters and logic

URS has had the close cooperation and assistance of the ADCIRC model authors Rick Luettich and Joannes Westerink in the evaluation of these issues. The authors are even evaluating the ADCIRC code to identify if some minor modifications may improve handling of the physical and numerical parameters for the range of conditions typical of the Maurepas Swamp.

As of today’s date, URS has run numerous simulations under each of the calibration periods. Within the next two weeks we will finalize model grid and parameters for use in completing calibration/validation that are suitable for diversion analysis and preparing the Hydraulic Feasibility Study Report. Importantly, URS has actually conducted initial diversion test runs and determined that the crucial aspects of diversion performance can be studied with the model.

Detailed Work Plan for Completing 2D Hydrodynamic Model

To meet the milestones listed above URS will undertake the following:

- ✓ Complete trials of grid modifications and input parameters for optimizing model performance among various calibration/validation scenarios between June 1 and June 14.
- ✓ Complete four abbreviated calibration/validation simulations. The full calibration/validation simulations cover 140 days; the WorldWinds cluster is operating at about 9:1 for 0.5s time-step and 4.5:1 for 0.25s time-step; thus, the 12 day schedule for final c/v will utilize abbreviated simulation periods focusing on most critical periods.
- ✓ While LDNR is reviewing Draft Hydrologic and Calibration Reports URS can perform extended calibration/validation simulations as appropriate and as cluster availability permits.
- ✓ In addition to utilizing the WorldWinds cluster on Diversion simulations, URS is negotiating for time on clusters at LSU and ULL.
- ✓ The Draft Hydraulic Feasibility Study Report will include an Executive Summary and Diversion Simulation Report. This, combined with previous task reports, will constitute the multi-volume Final Report.
- ✓ Independent Technical Review of the Feasibility Study Report will be performed by Joseph Suhayda, PhD.

URS hopes that the above responses to LDNR's questions have addressed the concerns and we look forward to discussing them further in person. Should you have any questions, or require additional information, please don't hesitate to call.

Sincerely,
URS Corporation

Michael D. Patorno, P.E.
Civil Department Manger.

Table 1 Current Detailed Budget Summary

Task	Budget			Spent Through 5/26/2006			
	Labor	Expenses	Total	Labor	Expenses	Total	Remaining
Project Management	123,818		123,818				
Dec 05 Amend	29,900		29,900				
Subtotal	153,718	381	154,099	164,516	7,214	171,730	-17,631
Data Collection	108,904	13,816	122,720	121,980	5,960	127,940	-5,220
GIS	44,788	5,000	49,788	48,491	0	48,491	1,297
Survey							
URS				71,565	187	71,752	
E-G/3001					151,583	151,583	
2D Modeling	213,928	4,860	218,788				
Dec 05 Amend	38,400	1,640	40,040				
Subtotal	252,328	6,500	258,828	243,498	8,270	251,768	7,060
2D Support- Dec 05 Amend							
URS DTM	29,600		29,600	35,162	200	35,362	-5,762
WorldWinds/LSU	90,150	136,000	226,150	56,186	127,567	183,753	42,397
1D Modeling	272,071						
Dec 05 Amend	4,310		4,310				
Subtotal	276,381	128	276,509	269,592	1,768	271,360	5,149
Report	87,403	24,480	111,883				
Dec 05 Amend	20,000		20,000				
Subtotal	107,403	24,480	131,883	97,180	332	97,512	34,371
Total	**1,229,468**	**237,712**	**1,467,180**	**1,108,170**	**303,081**	**1,411,251**	**55,929**

APPENDIX B

SIMULATION LOG

Appendix B

Work Log

PADCIRC 2D Model for the Maurepas Swamp

Date	Comments
2/25/05	Grid V1 was handed over to WORLDWINDS and set a run for 10 days with time step of 0.25 sec. The purpose of this run was to test the WORLDWINDS system and data transfer protocols between URS and WORLDWINDS. The simulation was aborted after 5 days of simulation to save computer costs.
2/28/05	URS requested WORLDWINDS to stop the simulation after it completed 5 day simulation. Run was aborted since the grid looked stable, but it was running very slow (3:1, URS computer Vs. WORLDWINDS).
3/1/05-3/18/05	Developed Grid Version 2. Channels were revised to eliminate unnecessary small mesh cells. Levees were incorporated Grid V2 was periodically tested at URS computers (short runs). On 03/18/05, Grid V2 was handed over to WORLDWINDS for a 21 day simulation with a time step of 0.5 sec for basic calibration scenario.
3/21/05	Simulation Grid Version 2 crashed from WORLDWINDS computer. The run was set on 03/18/05 and it crashed after 90000 time steps. WORLDWINDS was unable to provide details of the instability (node number, etc.)
3/22/05	URS attempted to investigate the instability conducting two short overnight runs on two single processor machines. The grid was re-checked for mesh quality and a few small areas were adjusted prior to staging the simulations.
3/23/05	URS checked the results from overnight simulations and the results looked incorrect. After reviewing the grid, ADCIRC literature and consulting with Dr. Westerink we determined that the elevation convention used in Grid V2 was incorrect and that we needed to reverse the sign for all mesh elevations (down is positive). This was an error made by URS when creating Grid V2 and a legacy of switching form RMA2 to ADCIRC. RMA2 has the opposite convention.
3/24/05	Finished correcting Grid v2. URS wrote and test a grid pre-processor that determines minimum time step requirements for stable solutions considering both advection and diffusion. Based on the processor results, a few elements were realigned to keep the minimum time step at or above 0.5 sec time step. We also sent the revised Grid V2 to WORLDWINDS for a 6 hour simulation to test run time, outputs formats and size. Based on the results, we revised the output format from BINARY to ASCII for easier post processing and analysis.
3/25/05	Staged two simulations for 1.5 day duration to run over the weekend on URS serial machines and monitored their results periodically. Reviewed results and determined that the solution appears stable and within the expected range.
3/28/05	Delivered revised Grid V2 to WORLDWINDS for a 12 day calibration simulation and awaiting results.
3/29/05	Notified by WORLDWINDS that run was begun at approx. 8PM Monday night and as of 9am Tuesday, 3.3 days of simulation had been completed. This corresponds to a speed-up over URS serial simulations of 6.7.
3/30/05	Received notification that the simulation on WORLDWINDS crashed. URS began investigating the instability and attempted runs on their serial processor with varying tau, dt, diffusion and bottom friction.
3/31/05	Continued investigation with success. URS decided to make a smaller grid, comprised of the blind river and adjacent swamp area toreduce size and allow for more rapid assessment. The small grid had similar stability issues as the large grid and served as a good test case.
4/1/05 –	Investigated affects of dt, Tau_0, eddy viscosity, bottom friction on stability. Instabilities

4/5/05	continued.
4/6/05	After discussions with Rick Luettich, determined that the randomly generated swamp elevation (elevation between 0 and 1 ft) may be cause of instability. URS revised the small grid to have a constant swamp elevation of 0.5 feet. A simulation was launched to run over night.
4/6/05	After a few runs, it was determined that the removal of the random elevations greatly improved the simulation stability. However, the runs were still limited to dt of 0.25.
4/7/05	Investigated dt limitation with revised small grid by changing dt, Tau_0, etc. Found that an anomalous standing wave pattern evolves quickly in the main channels suddenly after about 6 seconds of simulation time. For dt of 0.25 and smaller, the pattern eventually dissipates, for larger dt (0.5 sec) it becomes unstable. This has been reported to Rick Leuttich and Joannes Westerlink and we are awaiting comments.
4/8/05	Modified large grid to remove randomly generated swamp elevations.
4/9/05	Delivered new grid and input files for revised large grid to WORLDWINDS. This simulation also included a new file for spatially variable bottom friction, to represent high friction in swamp and lower friction in channels.
4/10/05	Learned that the simulation was running, but output indicated zero forcing. After some investigation, we concluded that it is possible that the variable friction file may not be supported by the parallel version (request for comment sent to Rick and Joannes.)
4/11/05	Reverted back to constant bottom friction and launched run at WORLDWINDS. Learned that it crashed at about 58,000 time steps 11PM Monday night using dt – 0.25. Investigation of log file shows sudden (over one time step) change from stable to unstable conditions. Log file also indicates compile-type (not run-time) errors. This file has been forwarded to Rick and Joannes for comment and interpretation. WE are also running the simulation on our serial processor, and expect to get to about 58,000 time steps around 2pm EST Tuesday 4/12/05. Based on those results, we can determine if there is a machine or mesh problem.
4/13/05	Grid_V3 was handed over to WORLDWIND. After discussion with Rick and Joannes, the convergence criterion was set to 10^{-12} and the Maximum Number of Iterations was changed from 25 to 40. For parallel version of the code it was necessary to change the convergence criteria
4/14/05	Grid_V3 crashed at time step 100703. After some investigation URS decided to subdivide the whole grid to identify which portions of the Grid was causing problems. Blind River MiniGrid was detached and handed over to WORLDWINDS with a time step of 0.25 sec.
4/16/05	After running for 2 days in WORLDWIND computers and for 8.7 days of real time simulation, Blind River MiniGrid crashed. Investigation was done at URS and after few test runs in URS serial machines, hybrid bottom friction was implemented.
4/22/05	WORLDWIND was asked to run the Blind River MiniGrid again with a time step of 0.5 sec and a hybrid bottom friction. This time step was used after investigation at URS computers.
4/25/05	Blind Rriver MiniGrid crashed again. URS investigated Blind River case locally since Eddy viscosity term was noticed sensitive to model stabilization. URS decided to analyze that locally. At the same time Reserve Relief MiniGrid (RR_V3) was handed over to WORLDWIND. The time step was set 0.5 sec.
4/27/05	After running for 9.5 days, the Reserve Relief MiniGrid crashed in WORLDWINDS computer. URS analyzed the screen output locally and found that instability was occurring at the channel entrance with frequent wetting and drying.
4/29/05	URS consulted with Joannes Westerink by supplying key outputs for Blind River and Reserve Relief MiniGrid. After discussion, Eddy Viscosity term was bumped to 20 and all single-cell gaps in were changed to weir functions to eliminate jet effects. Reserve Relief entrance was modified to eliminate wetting and drying at entrance. Based on this discussion, Blind River MiniGrid was allowed to run at URS computer and Reserve Relief MiniGrid was revised and handed over to WORLDWIND.
5/02/05	URS had status call with Joannes Westerink. URS mistakenly supplied wrong Grid file on April 29. WORLDWIND was asked to abort the run and a new Grid set was supplied again.
5/03/05	WORLDWIND reported that their computers encounter a mechanical problem since the run aborted abruptly. Since the run stopped abruptly and for subsequent uses, URS decided to HOTSRAT the run since it last stopped. URS along with WORLDWIND consulted with Joannes Westerink to get HOTSTART capabilities in parallel machine.

	Reserve Relief Grid (RR_V3) was handed over to WORLDWIND again with time step of 0.5 sec. Meanwhile Blind River MiniGrid run was successful in URS computer with the model parameters adopted and URS decided to use the same model parameters throughout.
5/05/05	Reserve Relief Grid (RR_V3) successfully completed at WORLDWINDS computers. Results files were extracted for DNR presentation. URS told LDNR that results indicated that the sources of grid instability were being identified. To be consistent, the lesions from Blind river and Reserve Relief MiniGrid modifications were implemented in the full Maurepas Grid (Grid_V5) while testing those in URS serial machines. In the mean time, Hope Canal MiniGrid (HC_V5) was handed over to WORLDWINDS. Since Hope Canal has smaller size elements, this MiniGrid was thought to be the critical area for model stability.
5/06/05	Early instability was detected in Hope Canal MiniGrid and investigation was done in URS computer. Several problematic elements were found and modified. The modified MiniGrid was handed over to WORLDWIND again.
5/08/05	Again early instability on Hope Canal MiniGrid was detected. Model crashed around 50000 time steps. URS continued to investigate the causes including the time step issues and decided to run it locally before handing over to WORLDWINDS.
5/11/05	Hope Canal MiniGrid completed more than 200,000 time steps in URS computer and the MiniGrid (HC_V5) was rerun at WORLDWINDS to speed-up completion. At the same time URS allowed the run to continue in local serial machines. After getting few error messages in their computers for unknown reasons, WORLDWIND was able to launch the Hope Canal MiniGrid run
5/13/05	After running for 2 Days and 7.55 Days of simulation time, Hope Canal MiniGrid stopped in WORLDWIND computers due to mechanical reasons. The same Grid completed successfully in serial machines that was running for more than a week. So URS decided not to run the same grid again in WORLDWINDS and continued implementing identified sub-grid modifications across the Full Grid. WORLDWINDS and URS continued discussing with Westerink for HOTSTART capabilities in WORLDWINDS computers.
5/16/05	Maurepas full grid (Grid_V6) was tested in URS for a brief period of time and later the Grid was handed over to WORLDWIND. Separate minigrid testing of the remaining portion of the Grid (Mississippi Bayou) was skipped since previously identified grid modifications had been included. Grid_V6 was instable at a very early stage (51000 time steps). URS decided to investigate the grid locally and made a small version of the grid containing Mississippi Bayou (MB). The full Grid and the MB MiniGrid were allowed to run in 2 of the serial machines locally.
5/20/05	Few modifications were done in the full Grid and MB MiniGrid_V6 was handed over to WORLDWINDS.
5/22/05	Full Grid completed around 800,000 time steps and then crashed. URS continued to check the MB portion of the Grid.
5/29/05	After testing the MiniGrid in serial computers for a long period of time, MB_V7 was handed over to WORLDWIND. Time step was using 0.5 sec. This partial grid was selected since this portion of the grid was not tested fully.
5/31	WORLDWINDS had to restart MB__V7 due to node failure. Retained Hugh Roberts, Notre Dame MS CE graduate (former Westerink graduate student), to support troubleshooting the Grid.
6/03	After running for 9.43 Days, MB_V7 crashed. URS decided to test the grid in house and until now, the Grid seems to be stable in URS computer. URS considering that this crash may be due to minigrid boundary effects. WORLDWIND was asked to confirm the HOTSTART capability in their computers since this will be vital for the full grid run. While testing the MB_V7 in URS computer, full Maurepas Grid (Grid_V8) was handed over to WORLDWIND to run over the weekend. In Grid_V8 major

	changes were changing and relaxing the portions of the grids where cell size is 11 ft or less. Time step was using 0.4 sec to flush out instability problems due to Courant Condition.
6/06	After running for 2 Days (3.9 Days of simulation time), WORLDWINDS informed URS that GRID_V8 "hung up" because of unknown reasons. WORDWIND is still investigating. WORLDWIND used HOTSTART to restart the full Grid run.
6/09	After discussion with Joannes, Tau_0 has been changed to 0.02, Eddy Viscosity changed to 10 and Gamma changed from 0.33 to 1.33. WORLDWIND was asked to run Grid_V8 in their machine with a time step of 0.5 sec. At the same time, URS changed the lake levees to weirs since weirs were more stable. URS is testing the Grid in their serial machines.
6/12	After running for 6.6 Days simulation time WORLDWINDS experienced cluster hardware problem. WORLDWINDS initiating plans to upgrade LINUX kernel and master node.
6/13	Modeling resumed with HOTSTRAT from 6.25 Days, Convergence criteria was changed to 10^(-6)
6/15	Hardware problem at WORLDWINDS caused Grid_V8 model crash at 11.75 days.
6/16	Grid_V8 Model restarted and crashed at 12.5 days.
6/17	Grid_V8 Model restarted.
6/18	Grid_V8 crashed due to node problem at 15 days.
6/23	Grid_V8 Model restarted—hot start from Day 15.
6/24	Grid_V8 crashed due to node problem at 16.25 days.
6/25	Grid_V8 Model restarted—hot start from Day 16.25.
6/25	Grid_V8 Model restarted—hot start from Day 16.25.
6/26	Grid_V8 Model went unstable at Day 17.8
6/27	URS modified Tau_0 to 0.03 and Grid restarted.
6/28	Grid_V8 finished 20 day run successfully. Between 6/09 and 6/28 WORLDWINDS computers required periodic maintenance that caused significant delay in model runs.
6/29-7/1	URS reviewed the results and found attenuated signals in Hope Canal. Blind River output looked great and matched with observed data.
7/5-7/7	URS concluded that weir coefficient might be the main causes for signal attenuation.
7/8	Started calibration run with Grid V-8 with reduced weir coefficient.
7/10	Model crashed due to WORLDWINDS Hardware problem.
7/11	WORLDWIND computer crashed to machine problem
7/14	WORLDWIND computer crashed again due to machine problem with only 6 days of results. WORLDWINDS decided to upgrade their system due to frequent machine errors.
7/18	URS handed over Grid_V10 again to WORLDWINDS after making few modifications to the weirs and adopted a reduced weir coefficient while waiting for WORLDWINDS fixing their problem.
7/22	URS downloaded intermediate results (7 days) from WORLDWINDS to see the effect of lower weir coefficient. It improved the channel conveyance and decided to let WORLDWINDS proceed further.
7/25	MAUREPAS stopped suddenly at WORLDWINDS computer and after a QA/QC check on the output, WORLDWINDS found that one of their computer nodes went wrong that caused the MAUREPAS to stop rum. URS analyzed the results up to 14 days and satisfied with the behavior with reduced weir coefficient.
7/26	WORLDWINDS informed that hotstart will not be possible due to severe errors
8/04	URS asked WORLDWINDS to launch a short run with even lower weir coefficient. This is for a start-up run in an anticipation to make a MASTER start-up HOTSTART file.
8/10	WORLDWINDS still facing their hardware problems, finished the 6 day run. URS examined the result and suitability of reduced weir coefficient. Results are compared with previous weir coefficient and decided to use the present lower weir coefficient.
8/12	URS upgraded the grid incorporating railway track and I-10 with low weirs. Tested the grid in URS computer for 3 days. Decided to use a startup run for 6 day to allow swamp to get around 0.7 ft level and then proceed with a long hotstart run for calibration. URS handed over the grid (Grid_V12) to WORLDWINDS for a 6 day run around 4 pM Eastern time

8/19	After periodic hardware problems, WORLDWINDS reported that Grid_V12 went unstable due to high water elevation in the screen output. URS investigated the screen outputs and found that in the first screen output there were no signs of instability up to 3.02 days, But in the second screen output when the model needed to hoststart from 2.75 days due to hardware problems, show an instability sign at 2.75 days. This behavior is unpredicted and indicates there might be a problem in HOTSTART.
8/29 to 9/20	WORLDWINDS services interrupted due to Hurricane Katrina. URS continued to run Grid_V12 in serial machines and eliminate the cause of instability. The instability was in the forcing file (fort. 19) where proper RAMP was not used.
9/20	URS requested WORLDWINDS to run Grid_V12 with new fort.19 file.
9/20	The run was successful in WORLDWINDS computers. This was a 10 day run to build up the initialization file for subsequent usages.
9/30	URS investigated the HOTSTART results. Worked on a new grid adding few features in accordance with Bob's punch list. In the mean time, WORLDWINDS was asked to launch a HOTSTART run with the previous results. The run was set for 30 days.
10/3	Run was successful. This gives a 20 day run results after 10 day HOTSTART. URS investigated the results and found that HOPE canal signals are still attenuated. Other channels were OK. URS investigated that too much connection with MARSH and canals might cause this problem.
10/6	URS modified grid_vV12 to Grid_V13. All the low weir elevations are changed to 1.399 to deter the channel-marsh connection. WORLDWINDS was asked to launch the cold start run for 10-day. URS briefly ran the model in serial machine and it was stable.
10/9	WORLDWINDS sent the results for first half (10 days). WORLDWINDS accidentally ran the wrong (previous) grid. WORLDWINDS started to run the grid again.
10/11	WORLDWINDS completed the first 10 day run. URS investigated the results and Hope Canal conveyance—results showed no attenuation. URS asked WORLDWINDS use the Grid V13 first 10 days to HOTSTART a full run for 28 days. This will cover the full calibration period.
10/14- 10/16	WORLDWINDS completed the full run. Results were uploaded to URS computer and investigated. URS evaluated alternatives for speeding up the Uploading of results. It was noticed that channel conveyance was little bit more than the actual. URS planned to open the channel gaps again in a controlled way. All the gaps are set to 0.75 ft heights. Minimum channel bank heights are set to 1.199 ft. URS completed the Grid modification and ran the grid for a brief period of time. WORLD WINDS was asked to HOTSTART the preset grid (Starting 10 days)
10/19- 10/24	WORLDWINDS completed the run. URS investigated latest results and found that the calibration looks better. Question arose as to whether WORLDWINDS was using the latest ADCIRC version (with latest wetting/drying numerics); Rick Luettich confirmed that WORLDWINDS had the latest version and a short retest was done and provided additional confirmation.
10/24	URS modified the grid by setting minimum levee height as 1.011—named Grid V14. WORLDWINDS was started the run using the previous HOTSTART 10 day Grid V13. The run was set for 28 days.
10/26	WORLDWINDS completed 26 day run when their machine was unplugged by foreman. URS received results for 26 days. It was a significant improvement in calibration
10/27	To further improve the calibration, URS modified the grid—Grid V14—by incorporating higher friction in the channel. An inflow boundary (200 cfs) was used in Blind River. WORLDWINDS was asked to fire a 30 day run using the previously saved HOTSTART files.
10/30- 10/31	WORLDWINDS completed run. Results showed improvement from the previous runs. Channel conveyance, especially in the Hope Canal were still too much. URS made Grid V15 by reducing the Hope Canal gaps to 0.65 ft. WORLDWINDS was asked to launch the run to create a new 10-day HOTSTART file.
11/1-11/2	WORLDWINDS completed run of first 10 days. URS & WORLDWINDS then used the HOTSTART file to run a new simulation for a total of 30 days.
11/4	WORLDWINDS completed run for total of 30 days with Grid V15.
11/06	URS launched Grid V16 (Day 10-30) using previous Gird V15 HOTSTART. To improve the calibration and to improve Marsh connection, Hope Canal gap heights are set to 0.5 ft

11/7—11/8	WORLDWINDS completed run of Grid V16 (Day 10-30). WORLDWINDS was asked to start a modified Grid V16 (Day 10-30) (Note: there was a 2 day delay to debug input file)
11/11	WORLDWINDS completed modified Grid V16 (Day 10-30). URS changed the levee height at Hope Canal to 0.85 ft. At the same time weir coefficient was changed to 0.1 to increase Channel-Marsh connection. Grid V17 was started using previous V16 HOTSTART.
11/14	WORLDWINDS completed run of Grid V17 (Day 10-30). URS browsed the results and found that Hope Canal signals are attenuated because of too much channel-marsh connection. URS asked WORLDWINDS to run modified Grid V17 (Day 10-30) with a lower weir coefficient set to 0.02—using the Grid V16 HOTSTART.
12/01	WORLDWINDS cluster was busy for a while and they launched Grid_18.2 on 12/01. Meanwhile, URS tested Grid_V18 and Grid_V18.1 in the serial machine and results looked different since the weir coefficients were different. URS still suspected that something might go wrong while WORLDWIND were processing different grids in their Cluster.
12/04	Results from Grid_V18.2 were uploaded in URS computers. Again those results were found exactly same as previous results (Grid_V18 and Grid_V18.1). URS asked WORLDWINDS to check their preprocessing since results did not make any sense.
12/05	WORLDWINDS discovered their problem since they were using same old grid over and over while setting a new run.
12/06	WORLDWINDS reran Grid_V18.2 and URS checked partial results. Results looked consistent.
12/09	Results from Grid_V18.2 were uploaded in URS computers. Attenuation of Hope canal signals was observed. URS created 2 grids (Grid_V18.3), one with blind river inflow @200 cfs that incorporates fort.20 file and other without Blind river inflow. Weir coefficients were changed to 0.1 for gaps and 0.025 for levees. WORLDWINDS was asked to set a run with the river inflow.
12/11	WORLDWINDS experienced problem with their new ADCIRC processor and with the fort.20 file. URS asked to abandon river inflow case and set a run without river inflow. WORLDIWNDS successfully launched the run without river inflow.
12/13	Grid_V18.3 results were investigated. Channels signals were found attenuated due to higher weir coefficient along the channel levee. URS further reduced weir coefficient to 0.015 along levees. WORLDWINDS was asked to set a HOTSTART run for 20 days (Grid_V18.4)
12/15	URS requested WORLDWINDS to provide partial results from Grid_V18.4, data were analyzed locally and results were found very similar to the results from previous version (V18.3). WORLDWINDS was asked to stop the run for further investigation.
12/17	URS decided to double check all the results from Version 18 series and suspected that something might go wrong. URS asked WORLDWINDS to rerun Grid_V18 for few days to test whether they can reproduce previous results and it failed. Further investigation by running several previous grids throughout the weekends, URS and WORLDWINDS concluded that the results from Grid_V18 actually came from Grid_V15 runs. This was a major setback that cost more than a month simulation since all the results and interpretation from Grid_V18 series (V18.1 to 18.5) was found ineffective. URS decided to use Grid_V16 as datum and modified according to the learning from previous runs and launched Grid_V20.0
12/18	URS modified few gap elevations and levee heights to match observed data and launched Grid_V20.0. WORLDWINDS was asked to make a short HOTSTART run to test the sensitivity of the grid and signal propagation.
12/19	URS investigated partial results from Grid_V20.0 and found attenuated signal in HOPE canal and identified that swamp is receiving too much water. URS decided to increase friction in the swamp and launched Grid_V20.1 incorporating variable friction file fort.21. The objective is to provide a spatially variable friction coefficient in the model domain. Previously a hybrid friction value was used. Run was set for a COLDSTART for 10 days following a HOTSTART run for 20 days.
12/20	WORLDIWNDS experienced problems in processing variable friction file. URS changed variable friction file to constant friction (Cd= 0.5) in Grid_20.2 and handed over to WORLWINDS. The run objective was to test swamp response to higher friction value.
12/21	WORLDWINDS completed 10-day COLDSTART run. URS asked WORLDWINDS to launch a HOTSTART run with the archived HOTSTART files.
12/23	URS investigated partial results from Grid_V20.2 and found adverse effects of larger Cd values. At the same time WORLDWINDS upgraded new binaries in their system to handle variable

	friction fort.21 file properly. WORLDWINDS was asked to abandon Grid_V20.2 run. URS constructed Grid_V20.3 with variable friction file (Cd= 0.5) and asked WORLDWINDS to fire a run. Objective was to verify whether fort.21 files were handed properly or not. Verification would be accomplished if results from Grid_V20.2 and Grid_V20.3 matched with machine accuracy. At this stage, URS concluded that handling of variable friction file (fort.21) is crucial to proper model calibration.
12/24	Partial results from Grid_V20.3 were uploaded to URS computers. Results were well compared with Grid_V20.2. URS concluded that variable friction files were properly handled by WORLDWINDS. At the same time, highly damped signals were observed along most of the channels. URS planned to revise the gaps along most of the channels, Bob Jacobsen visited Tallahassee to revise the grids and gaps.
12/25	URS launched Grid_V20.4 at WORLDWIND computers. Channel gaps in grid were revised and compared with observed data. A hybrid friction file was also used. Run was divided into two sections; a 10 day COLDSTART run following a full 20 day HOTSTART run.
12/29/05	URS investigated results and detected that Blind river signals were damped especially during low flows. Weir coefficients were changed to 0.01 in Grid_V20.5 and WORODLWINDS fired a HOTSTART run.
01/05/06	During that previous week, URS investigated two grids (V20.5 and V20.6) with different weir coefficients and still unusual signals in Blind river were observed. URS investigated further and found that one levee height was wrong and might cause instability in that section. URS fixed the problem and launched Grid_V20.7 in WORLDWINDS computer. Weir coefficients were further reduced to 0.005.
01/08/06	Results from Grid_V20.7 were very good and model data matches closely with observed data at most of the stations. URS decided to add few features in the grid and also planned to include provisions for river inflow in future model runs.
01/10/06	URS launched Grid_V30.0 in WORLDWINDS cluster. This grid was modified from previous grid and new features (e.g., Transmission line & Pipeline corridor, Hope canal road) were added. Also Blind river and Amite river diversion canals were modified so that they can handle river inflow boundaries. WORLDWINDS was asked to fire a 10-day COLDSTART. Fort.20 file (river baseflow) was also included in this run.
01/16/06	URS investigated calibration results and as expected, results looked good. URS planned to go ahead and do few validation runs.
01/18/06	URS launched Grid_V30.1 in WORLDWINDS cluster. A new Lake boundary file (fort.19) was used as an attempt to first run (12/25/03-01/26/04). The run was set as a HOTSTART run for 30 days.
01/23/06	URS investigated results. All stations other than HOPE canal were good. URS decided to use rainfall generated flow in HOPE canal sections.
01/24/06	Grid_V30.2 Hot start run, minor grid changes; weir coefficient 0.02 was used.
01/27/06	Grid_V30.3 Hot start run, minor grid changes; weir coefficient 0.02 was used.
02/09/06	Grid_V31.0 launched with a few minor grid changes and changes to rainfall inputs; weir coefficient 0.02 for banks, 0.04 for gaps was used, 0.05 for a few gaps south of I-10. Cd values: 0.7 for z > 0 ft; 0.15 for z > -1 ft; 0.05 for z > -3 ft; 0.025 for z > -6; 0.005 for z<= -6.
02/11/06	URS launched 3 mini runs (Each 3.5 days duration) in WORLDWINDS computers to understand the role of weir coefficients. Results were analyzed on 02/12. URS narrowed down optimum values of weir coefficients both in gaps and levees.
02/13/06	Grid_V32.0 was launched in WORLDIWNDS computers. Storage volume in the swamp was reduced. Swamp base at 0.5 ft, interior swamp mounds step up: 0.7 ft to 0.9 ft to peaks of 1.1ft; weir coefficient of 0.02 for banks and 0.04 for gaps were used. Partial results were analyzed on 02/14 and damping signals were found. URS decided to lower the weir coefficient.
02/15/06	Grid_V32.1 was launched in WORLDWINDS computers. The objective of this run was to verify LSU calibration period with a weir coefficient of 0.005. The results of this run were analyzed on 02/16. Results looked pretty good.
02/17/06	Grid_V32.2 was launched in WORLDWINDS computers. A new Lake boundary file (fort.19) was used for second validation run (High Blind River Period starting 05/08/04). Run was set for 20 days.

02/20/06	Results from Grid_V32.2 were uploaded in URS computers. Hope Canal signals did not match with the observed data. URS investigated the cause and found that SWMM output (which is an input to the ADCIRC model) was not properly tuned. URS decided to use a higher inflow.
02/22/06	Grid_V32.3 was launched in WORLDWINDS clusters. Model uses higher inflow along Blind and Hope canal sections. Run was set for 20 days.
02/23/06	Grid_V32.3 crashed unexpectedly in WORLDWINDS cluster after 1 day of simulation. WORLDWINDS decided to troubleshoot their hardware.
02/24/06	WORLDWINDS were still experiencing the problem. Rick Luettich from University UNC gave few indications of potential network problems.
02/27/06	WORLDWINDS ran few older grids in their system and it was a success. URS investigated that fort.20 file (River inflow) could be creating problems.
03/01/06	URS made some modifications in the Grid and launched Grid_V32.5 in WORLDWINDS computers. Also, a revised SWMM output was used. The run crashed after running for a while. Expertise from Rick Luettich was sought to troubleshoot the issue.
03/08/06	Fort.20 problem was fixed. It was an ADCIRC prep error. A new preprocessor was loaded in WORLDWINDS clusters. URS did few testing on that new processor.
03/13/06	Grid_V32.8 was launched in WORLDWINDS computers. This is a verification run for High Blind River Period with modified SWMM outputs.
03/16/06	Results from Grid_V32.8 were analyzed in URS computers. Results were good and URS decided to proceed with the Tropical Storm Period in the next run
03/19/06	Results from Grid_V32.9 Tropical Storm Period were uploaded in URS computer. In most of the stations, attenuated signals were found. In order to improve the calibration, URS reduced the levee heights along Lake Maurepas to 1.5 ft and weir coefficients along that segment were doubled. Grid_V33.0 was launched in WORLDWINDS computers. Cd values same as V31.0
03/23/06	Results from Grid_V33.0 Tropical Storm Period were uploaded in URS computer. Results looked better than previous run. URS decided to fine tune parameters and geometry in order to improve the calibration. Weir coefficients along the Lake Maurepas levee were increased further. Grid_V33.1 was launched in WORLWINDS computers.
03/29/06	Grid_V33.1 crashed in WORLDWINDS computers. URS modified flow and friction files and launched a series of partial runs (5 to 10 days) in order to troubleshoot instability issues. URS identified that time step was the main reason for instability since in this particular run, lake level went pretty high (up to 4.5 ft) which could not handle a large time step. URS planned to cut down the time step to 0.25 sec and launched Grid_V33.5 in WORLDIWNDS computers. At the same time, URS increased the weir coefficients along gaps to 0.5. The idea was to divert more water into the swamp.
04/04/06	Grid_V33.5 run Tropical Storm Period was successful. URS processed the results and the results looked good. Grid_V33.6 Tropical Storm Period URS also planned to make a field trip in order to investigate the Lake Maurepas levee heights.
04/12/06	After visiting the lake levees, URS implemented few changes to the Lake Berm height in the model grid to mimic observed data. Also storage volume in the swamp was adjusted by increasing swamp interior. URS launched Grid_V40.0 Tropical Storm Period, 0.92 flat swamp floor, no mounds, weir coeff = 0.5 in WORLDWINDS computers.
4/17/06	40.1 LSU Period, 0.92 ft flat swamp, Cd same as V31.0, corrected flow input, weir coeff = 0.5
4/20/06	40.2 LSU Period, 0.92 ft flat swamp, Cd doubled in swamp; weir coeff = 0.5
4/25/06	40.3 Tropical Storm Period, 0.92 ft flat swamp, weir coeff = 1.0
???	41.0 LSU Period swamp base at 0.92, bays behind gaps at 0.5 ft, added interior swamp " flat mounds" elevated to 1.3 ; Cd at swamp was same as V40.1. **NO RECORD OF EMAILS ON THIS RUN**
4/22/06	42.0 LSU Period, swamp base at 0.92; bays behind gaps at 0.5 ft ; slightly increased area of "flat Mounds" at 1.3 ft.; Cd same as V31.0. same as V40.1.
4/30/06	42.1 Tropical Storm Period, mounds, weir coeff = 1.0
5/3/06	42.2 LSU Period, extended mounds, constant Cd = 0.02
5/6/06	42.3????
5/7/06	42.4????
5/8/06	42.5????

????	42.6 LSU Period, DT adjustment - 42.6=0.25, 42.0 = 0.50 **NO RECORD OF EMAILS ON THIS RUN**
5/12/06	43.0 LSU Period, backside of weir lowered in attempt to improve draining—no change.
5/19/06	BRgrid_D01, Diversion test with Grid V. 42, flat swamp at elev 0.92 ft. Diversion flow checked out to be 1800 cfs, Cd values: 1 for z > 0.5; 0.15 for z > -0.2; 0.05 for z > -2.2; 0.025 for z > -5.2; 0.005 for z <= -5.2. run completed successfully
5/25/06	BRgrid_D02 Diversion test with Grid V. 42, flat swamp at elev 0.6 ft. Diversion flow reduced to 1500 cfs, ,run completed successfully
5/29/06	BRgrid_C01, flat swamp at elev 0.6 ft, LSU Calibration Period, went unstable at 0.533 days, blew up near intersection of Mississippi Bayou and Crossover canal.
5/31/06	BRgrid_C01_3, C01 with all weirs converted to mesh, went unstable at 0.533 days, did not capture specific instability, discovered some bad elevation values in mesh
6/1/06	BRgrid_C01_4, Corrected bad elevation values, unstable 0.50 days, no results
6/4/06	BRgrid_D03, Hotstart of D02 with LSU period lake boundary
	BRgrid_C02, this was an intermediate saving of the grid file and was never run.
6/6/06	BRgrid_C03_3, Gaps in weir converted to elements, Swamp at elev +0.6, LSU calibration period, only run for 9 days. Cd values: 1 for z > 1.5; 0.15 for z > 0.6; 0.05 for z > -1.4; 0.025 for z > -4.6; 0.005 for z <= -4.6.
6/6/06	BRgrid_D04, 10 day run , swamp at elev +0.92, Qmax=1500, Cd same as D01
6/7/06	BRgrid_C03_4, C03_3 with gaps reduced in width, completed LSU Calibration Period
6/8/06	BRgrid_C03_5, C03_4 with weirs raised up 0.1ft, higher swamp Cd, lower channel Cd, completed. Cd values: 10 for z > 1 ; 5 for z > 0 ; 1 for z > -1 ; 0.1 for z > -2 ; 0. 05 for z > -3; 0.01 for z > -6; 0.005 for Cd <= 6.
6/9-6/11	BRgrid_C03_6, 0.25 Dt, NOLICA=NOLICAT=0, EVM=50 (initially tried 0.5 Dt and was unstable) Crashed with shorter timestep also Cd same as C03_3
6/9/06	BRgrid_C03_7, EVM=25, DT=0.5, crash
6/12/06	BRgrid_C03_8, 90% reduced inflows.
6/14/06	BRgrid_D06, hope canal below I-10 removed from C03_4, Qmax=1500cfs, Cd values: 5 for z > 1; 1 for z > 0; 0.15 for z > -1; 0.05 for z > -3; 0.025 for z > -6; .005 for z <= -6 .
6/15/06	BRgrid_D04, Hotstart and finish to 20 days
6/16/06	BRgrid_C04_1, swamp base elev at +0.9, mounds at elev +1.3, reduced minor channel conveyance, Cd values: 1 for z > 0; 0.5 for z > -1; 0.05 for z > -3; 0.025 for z > -6; 0.005 for z <= -6 .
6/17/06	BRgrid_C04_2, raised behind gaps to elev + 0.7, mounds to elev +1.1 more reduced minor channel conveyance, new Cd values: 1 for z > 0; 0.5 for z > -1; 0.1 for z > -2; 0.05 for z > -3; 0.01 for z > -6; 0.005 for z <= -6 .
6/19/06	BRgrid_C04_3, southern mounds back to 1.3, opened mouth of Dutch Bayou slightly. ran 1st 9 days of LSU calibration period. new Cd values: 0.5 for z > 0; 0.1 for z > -1; 0.05 for z > -3; 0.01 for z > -6; 0.005 for z <= -6 .
6/20/06	BRgrid_C04_3_keep Draining, Hotstart of C04_3, dropped lake over two days to elev -0.5, held constant for 7 days. Ran at UNC
6/20/06	BRgrid_C04_3, Hotstart and finish LSU period.
6/21/06	BRgrid_C04_4, High Blind R. calibration, unstable , Conway canal too shallow
6/24/06	BRgrid_C04_6, fixed Conway canal from C04_4, completed
6/28/06	BRgrid_C04_5, Tropical Storm period, completed

APPENDIX C

PARAMETER TESTING INPUT/OUTPUT FILES

ADCIRC Parameter Testing Input/Output Files

Due to the large file sizes, the ADCIRC Input/Output files for Parameter Testing have been provided separately.

APPENDIX D

CALIBRATION AND VALIDATION INPUT/OUTPUT

ADCIRC Calibration and Validation Input/Output Files

Due to the large file sizes, the ADCIRC Input/Output files for Calibration and Validation have been provided separately.

APPENDIX E

CALIBRATION AND VALIDATION ANIMATION FILES