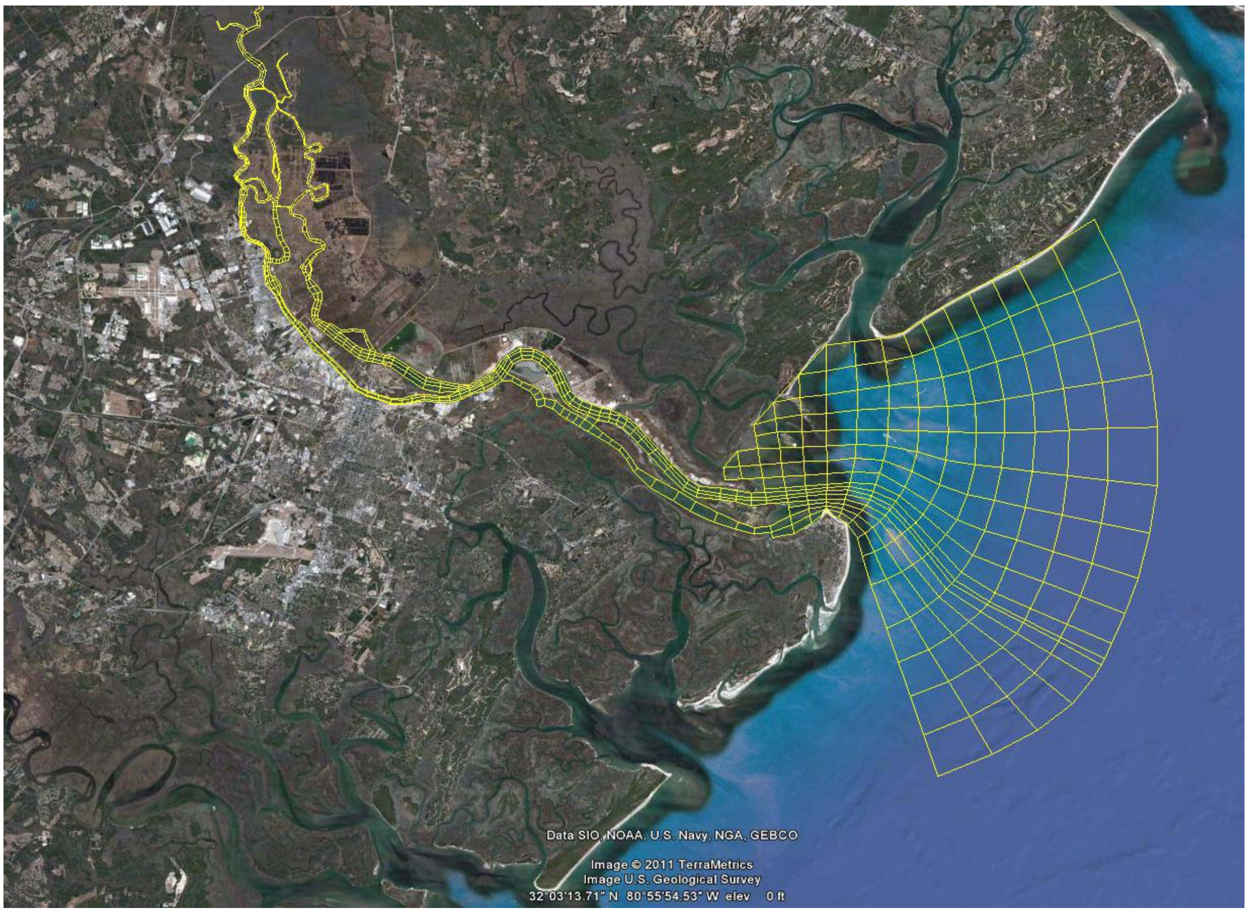
Model Comparison Report
In Support of the
Savannah Harbor Expansion Project



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Mr. Joe Hoke contributed to this report and coordinated efforts with the contractor team and the Savannah District. Mr. Wade Cantrell from the South Carolina Department of Health and Environmental Control (DHEC) assisted in the scope of this work. Mr. Steven Davie was the project manager from Tetra Tech and was supported by Mr. Jim Greenfield, Dr. Hugo Rodriguez, and Dr. Yuri Plis. Mr. Phillip Todd was the project manager for SEPI.

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1.0 INTRODUCTION

The United States Army Corps of Engineers (USACE), Savannah District is working with the Georgia Ports Authority (GPA) to evaluate the deepening of the navigation channel in Savannah Harbor. This effort is called the Savannah Harbor Expansion Project (SHEP). The project is intended to identify the impacts and mitigation strategies of deepening the harbor from its presently authorized 42-foot depth Mean Lower Low Water (MLLW), up to a depth of 48-feet MLLW.

Hydrodynamic and water quality models were developed and determined to be acceptable in March 2006 by the United States Environmental Protection Agency (USEPA), United States Fish and Wildlife Services (USFWS), Georgia Environmental Protection Division (GAEPD), and South Carolina Department of Health and Environmental Control (SCDHEC) to identify dissolved oxygen levels throughout Savannah Harbor. This set of models are called the Sigma Model. During 2007, EPA Region 4 determined a need to convert the sigma grid of the enhanced model to a Z-Grid, which was later updated with new Middle River and Back River bathymetry and recalibrated to 2009 USGS velocity and flow data. The Z-Grid model was further enhanced to be used for the Savannah harbor Chloride analysis.

It should be noted that the Sigma and Zgrid models were calibrated for different purposes. The Sigma model was calibrated on 1997 and 1999 data and was designed for SHEP impact use in a way that state and federal agencies and peer reviews deemed appropriate. The Zgrid model was refined to better handle the EPA, Georgia and South Carolina TMDL development needs and the Corp's chlorides analysis for the Upper Savannah River portion of the model. The Z-Grid model was based on the Sigma Model and then updated with 2009 USGS data. This report does not develop any conclusions about one model being better than the other but is just to illustrate the differences. However it should be noted that even though the models were developed about 10 years apart the results are remarkably similar.

The basic tasks included in this *Model Comparison Report* are as follows:

- Comparison of Z-Grid Model and Sigma Models' salinity and velocities at Houlihan Bridge
- Comparison of Z-Grid Model and Sigma Model Predictions of the Surface Salinities at the 0.5 ppt 50% Exceedance Levels
- Estimation of wetland impacts due to Harbor Deepening using the Z-Grid Model results

2.0 TECHNICAL APPROACH

This Scope is to compare the Corp's Savannah Harbor Hydrodynamic and Water Quality Models (Sigma Grid) with EPA's updated TMDL Hydrodynamic and Water Quality Models (Zgrid Grid) under baseline 1997 conditions. Both sets of models use the same hydrodynamic model linked to a water quality model. The hydrodynamic model used is the Environmental Fluid Dynamics Code (EFDC) developed and maintained by Tetra Tech (Hamrick 1992). The water quality model used is the Water Quality Analysis Simulation Program (WASP) maintained by EPA.

The Z-Grid model builds on the original harbor model. During 2007, EPA Region 4 determined a need to convert the sigma grid of the enhanced model to a Z-Grid. Hundreds of Savannah Harbor TMDL modeling runs were going to be necessary over a multiyear time period and the Sigma Grid WASP model took a day to run one year. So EPA changed to the Zgrid model which ran one year of water quality in a couple of hours. The initial grid model predictions were very similar to the Sigma model, the major changes in the Zgrid model occurred when EPA recalibrated the Middle and Back River based on new bathymetry, velocity and flow data collected by USGS in 2009.

The Z-Grid allows for varying number of vertical layers throughout the model domain. The Sigma Grid has six vertical layers with widely varying layer depths, the Z-Grid model was converted to five vertical layers in the navigation channel and one vertical layer in the Middle, Back, Little Back, and Upper Savannah Rivers allowed all the layers to be similar depths. The Z-Grid allowed for the invert of the river bottom elevation to be modified with one vertical layer going upstream from the I-95 Bridge to the Clyo USGS gage on the Savannah River. A more detailed description of the Z-Grid model is explained in a later section of this report.

The EPA Z-Grid model was updated by Tetra Tech in 2010 for use in the Corp's Chloride modeling analysis. The updates included expanding the Upper Savannah River portion of the model to include Abercorn Creek tributary. This is the Z-Grid model used for the following model comparisons.

The EFDC model is part of the USEPA TMDL Modeling Toolbox due to its application in many TMDL-type projects. As such, the code has been peer reviewed and tested and has been freely distributed for public use. EFDC was developed by Dr. John Hamrick and is currently supported by Tetra Tech for USEPA Office of Research and Development (ORD), USEPA Region 4, and USEPA Headquarters. EFDC has proven to capture the complex hydrodynamics in systems similar to that of Savannah Harbor. The EFDC hydrodynamic and sediment transport model linked with the WASP water quality model provides the most appropriate combination of features necessary for this study. EFDC is a multifunctional, surface-water modeling system, which includes hydrodynamic, sediment-contaminant, and eutrophication components. The EFDC model is capable of 1, 2, and 3-D spatial resolution. The model employs a curvilinear-orthogonal horizontal grid and a sigma, or terrain following, vertical grid. The EFDC model's hydrodynamic component employs a semi-implicit, conservative finite volume-finite difference solution scheme for the hydrostatic primitive equations with either two or three-level time stepping (Hamrick 1992).

The EFDC hydrodynamic model can run independently of a water quality model. For this Savannah Harbor application the EFDC model simulates the hydrodynamic and constituent (salinity and temperature) transport and then writes a hydrodynamic linkage file for the water quality model WASP7 code.

WASP7 is a version of WASP with many upgrades to the user's interface and the model's capabilities. The major upgrades to WASP have been the addition of multiple BOD components, addition of sediment diagenesis routines, and addition of periphyton routines. WASP is an enhanced Windows version of the USEPA Water Quality Analysis Simulation Program (WASP), nonetheless, uses the same algorithms to solve water quality problems as those used in the DOS version. WASP is a dynamic compartment-modeling program for aquatic systems, including both the water column and the underlying benthos. The time-varying processes of advection, dispersion, point and diffuse mass loading and boundary exchange are represented in the basic program.

2.1 Sigma Grid EFDC Application to the Savannah River Estuary

The Sigma Grid EFDC model was calibrated with seven years of data – from January 1, 1997 through December 31, 2003. The model grid, which includes 931 horizontal cells, extends upstream to Clyo, Georgia (~ 61 miles from Fort Pulaski) and downstream to the Atlantic Ocean (~17 miles offshore from Fort Pulaski). The model also includes marsh cells, to simulate the extensive intra-tidal marsh areas in the system, increasing the number of total cells to 947. The man-made connections affecting the system were included in the model. These included McCoy Cut, Rifle Cut, Drakie's Cut, New Cut as closed, and the sill of the Tide Gate.

Figure 2-1 shows the modeling grid. The Savannah Harbor EFDC model was calibrated with graphical time series comparisons (qualitative) and statistical calculations (quantitative). The statistical calculations included percentiles at 5% intervals. It included: water surface elevation, currents, flow, temperature, and salinity.

The calibration objectives for the hydrodynamic model were to appropriately represent the transport processes by propagating momentum and energy through the system based upon freshwater inflow from the Savannah River and tidal energy from the Atlantic Ocean. Since vertical stratification plays a major role in the water quality of the lower harbor area, it was imperative to capture the effect of tides and fresh water flows on salinity and temperature over the appropriate spatial and temporal scales. The primary objective was to simulate the salinity and temperature stratification events and to demonstrate that the duration and magnitude of the events were appropriately represented in the model. The calibration period was the summer of 1999. The confirmation period was the summer of 1997. Long-term United States Geological Survey (USGS) data was also used for confirmation. The two summer periods were both low-flow conditions with several spring/neap tide events occurring throughout the period.

The model calibration and validation results are presented in the report "Development of the Hydrodynamic and Water Quality Models for the Savannah Harbor Expansion Project", of January of 2006, prepared by Tetra Tech, Inc. for the Savannah District of USACE.

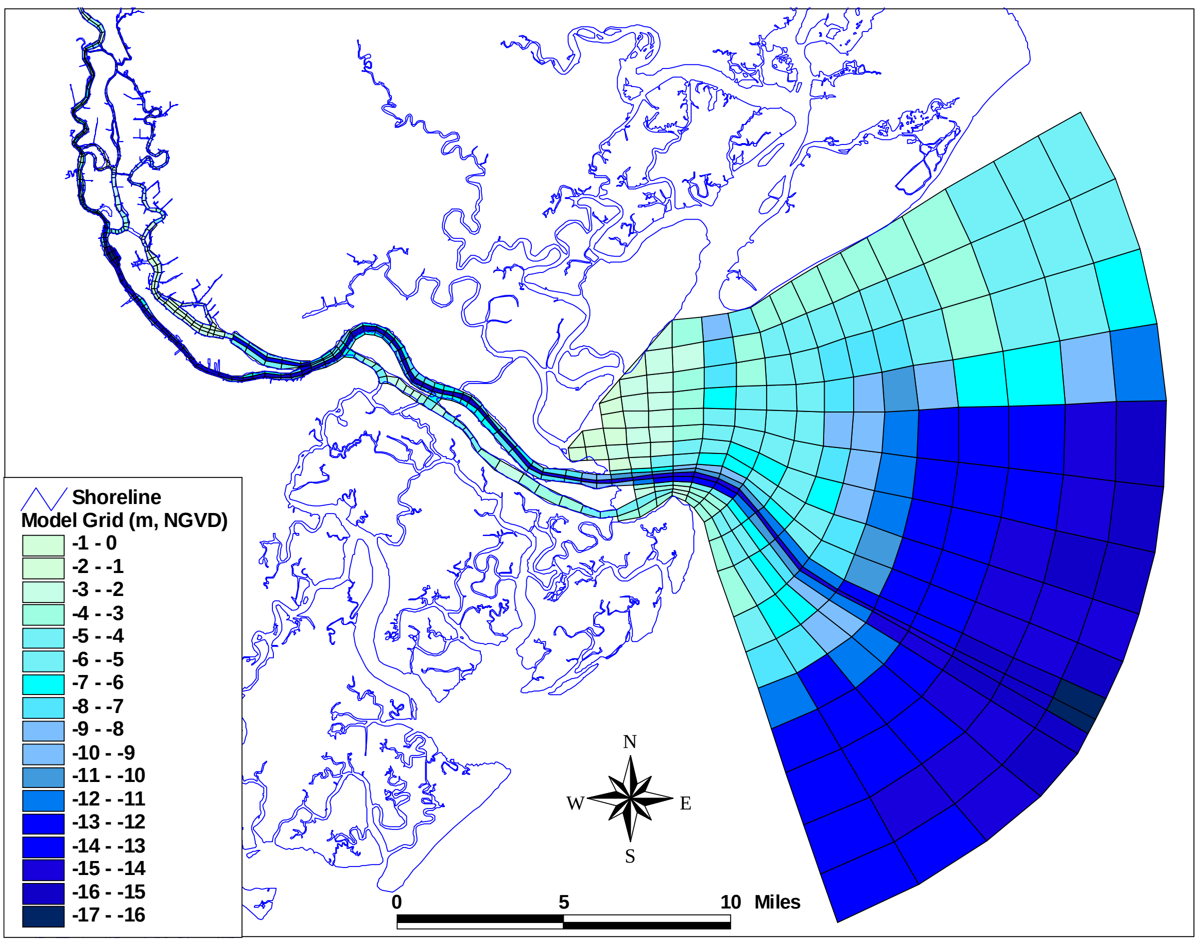

Figure 2-1 EFDC Sigma Grid

2.2 EPA Z-Grid Model Application to the Savannah River Estuary

The Z-Grid model builds on the original harbor model developed for EPA Region 4 during the development of the Total Maximum Daily Load in 2004-2005 and the enhanced model for the United States Army Corps of Engineers (USACE) finalized on January 30, 2006 (Tetra Tech 2006). During 2007, EPA Region 4 determined a need to convert the sigma grid of the enhanced model to a Z-Grid. The Z-Grid allows for varying number of vertical layers throughout the model domain. The sigma grid is six vertical layers with widely varying layer depths, while the Z-Grid has five vertical layers in the navigation channel and one vertical layer in the Middle, Back, Little Back, and Upper Savannah Rivers which allowed all the layers to be similar depths. The Z-Grid allowed for the invert of the river bottom elevation to be modified with one vertical layer going upstream from the I-95 Bridge to the Clyo USGS gage on the Savannah River. The longitudinal slope was evenly distributed from the headwater cell to above the I-95 Bridge by adjusting bottom elevations. The water surface elevation at the headwater boundary cell was raised to better match the gage height reported at the Clyo USGS gage. In addition to the Z-Grid conversion, the watershed tributary flows and marsh areas were revised.

The Z-Grid model, Figure 2-2, contains 608 horizontal cells and 1,778 total cells when including the vertical cells. The original flow, velocity, elevation and temperature predictions were calculated using the EFDC hydrodynamic model and calibrated to the extensive 1997 and 1999 data set (Tetra Tech 2006). The EFDC model inputs were updated to reflect more recent information. This information includes new flow gages by USGS in the harbor, long-term DO data at the USACE Dock, updates to the boundary conditions, connection to EPD's river model, and updates to water quality kinetics.

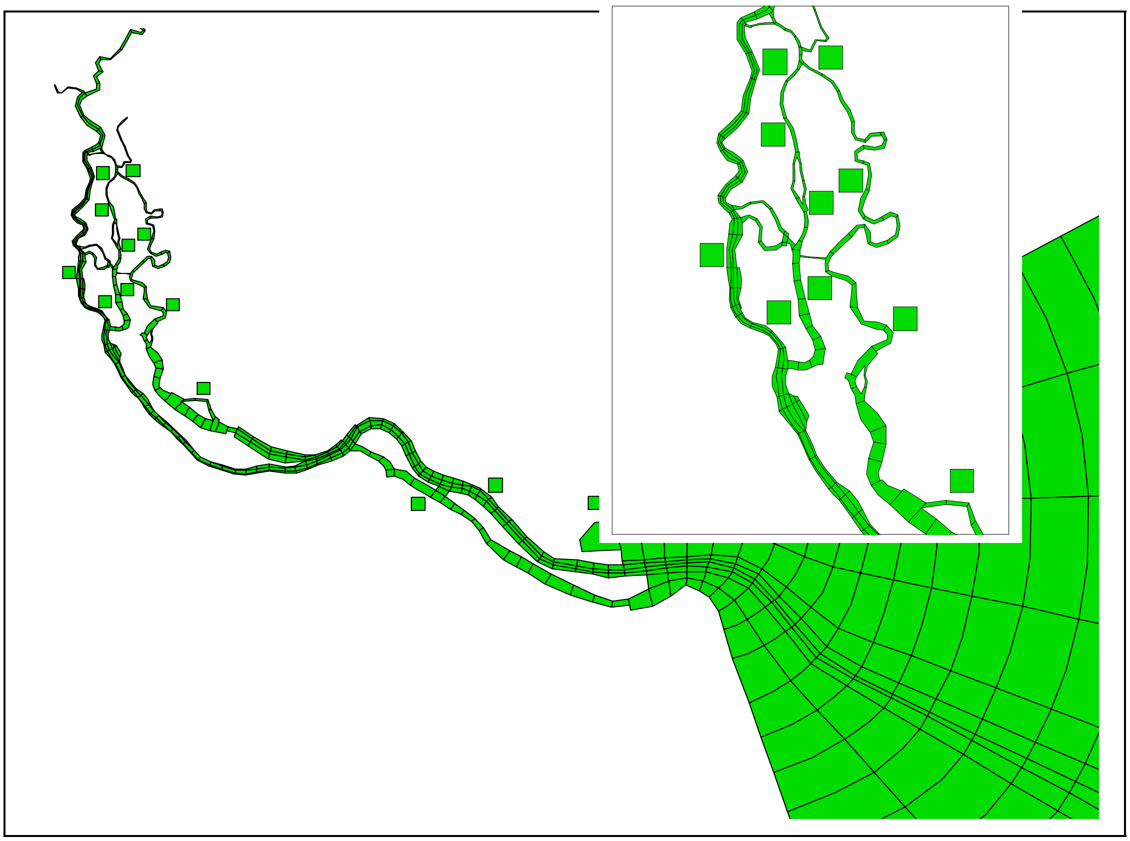

Figure 2-2 Savannah Harbor Z-Grid Model (marsh cells shown for representation)

The USGS collected detailed (15 minute) water surface elevation, velocity and flow data during the fall and winter of 2008 – 2009 at the Middle and Back Rivers near the Houlihan Bridge crossings at Stations MR-10 and LBR-15, respectively. These data were used to improve the hydrodynamic predictive ability of the model in the Middle and Back Rivers. The updates focused on improving the width and depths of the river channels in the model and changing the marsh storage areas to better reflect the movement of water through the channels so the model would better reflect the measured flows, velocities and elevations. (2010 EPA Region 4) Figure 2-3 and Figure 2-4 illustrate an example of the models predictive capabilities for gage height and flows for Little Back River at Houlihan Bridge.

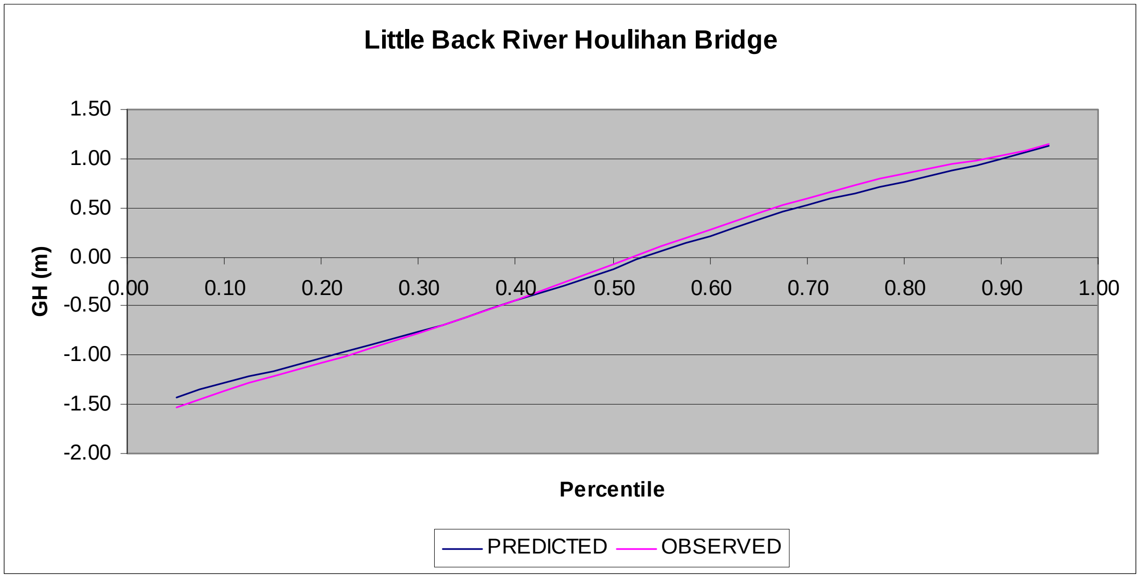

Figure 2-3 Percentile Comparison of Predicted and Measured Gage Heights

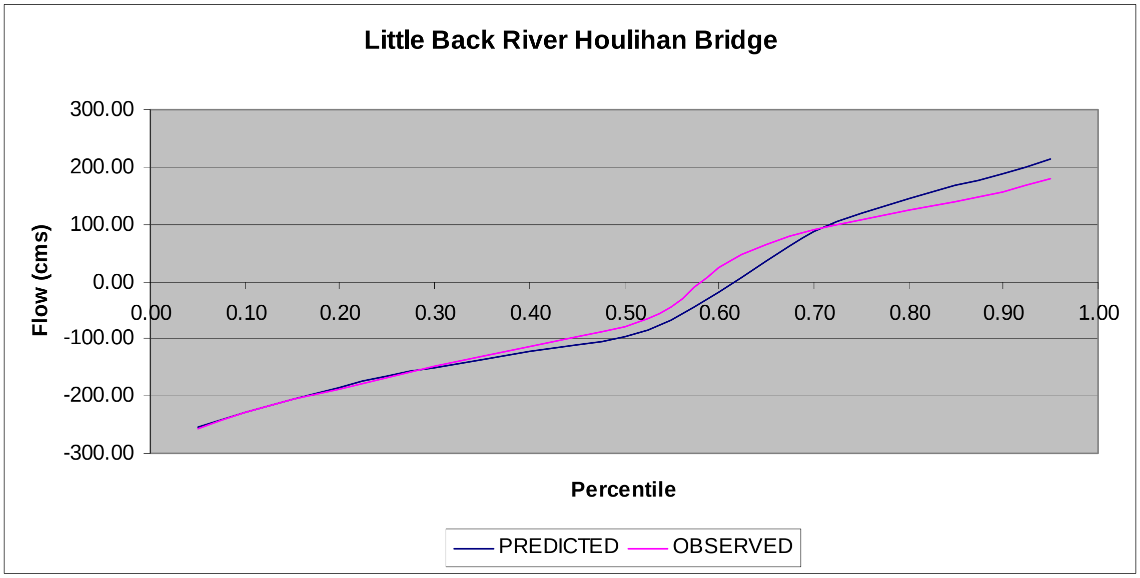

Figure 2-4 Percentile Comparison of Predicted and Measured Flows

Georgia EPD has developed a hydrodynamic and water quality model (EPDRiv1 Model) for the Savannah River from the Augusta Canal diversion dam to the USGS stage recorder (02198760) near

Hardeeville, South Carolina. This model was used to transport the oxygen demanding substances from the upper watershed to the Harbor Model. This provided a seamless connection between the Savannah River Model and the Savannah Harbor Model. The Sigma model and the original (pre 2009) Zgrid model used USGS Clyo gage flow and water quality data for the Savannah River input boundary.

The Z-Grid model, as used for TMDL development, was reviewed extensively by an EPA, States and Dischargers' Technical Advisory Group. . This group of technical experts w from or represented the Savannah Harbor Committee, Central Savannah River Area TMDL Group, USEPA, Georgia EPD and South Carolina DHEC. The Technical Advisory Groups conclusion was the River and Harbor Models as refined during 2009 subgroup work effort provide sufficient tools to develop a revised Savannah Harbor TMDL

Tetra Tech used the Z-Grid model for the 2010 chloride analysis in support of SHEP. The Z-Grid model was used because of the improved flow calibration in the upper part of the system. The Abercorn Creek, including Big Collis, Little Collis, and Bear Creeks, was added to the model domain by adding grid cells and measured depths for the bathymetry. The model was calibrated to a longterm chloride dataset at the City's intake and further validated with flow and salinity data in the harbor through 2009. The Z-Grid model was reviewed through Agency Technical Review (ATR) by Mr. John Hazelton (USACE Wilmington District) in November 2010 and Independent External Peer Review (IEPR) by Battelle Memorial Institute in February 2011.

3.0 MITIGATION PLANS FOR SALINITY AND WETLANDS

The USACE Savannah District used the EFDC (Sigma grid) to determine the appropriate measures to mitigate for salinity and wetland impacts. Plan 6A includes the following flow-altering mitigation features: McCoy Cut diversion structure; channel enlargement on McCoy Cut, and upper Middle and Little Back Rivers; submerged sill and broad berm at the mouth of Back River, closure at Rifle Cut and lower arm at McCoy Cut; and removal of the tide gate abutments and piers. These features act together to increase freshwater flows through Middle, Little Back and Back River while maintaining tidal flow access to mitigate for salinity intrusion from the deepened navigation channel.

Figure 3-1 was provided by the USACE Savannah District and depict the different features for Plan 6A.

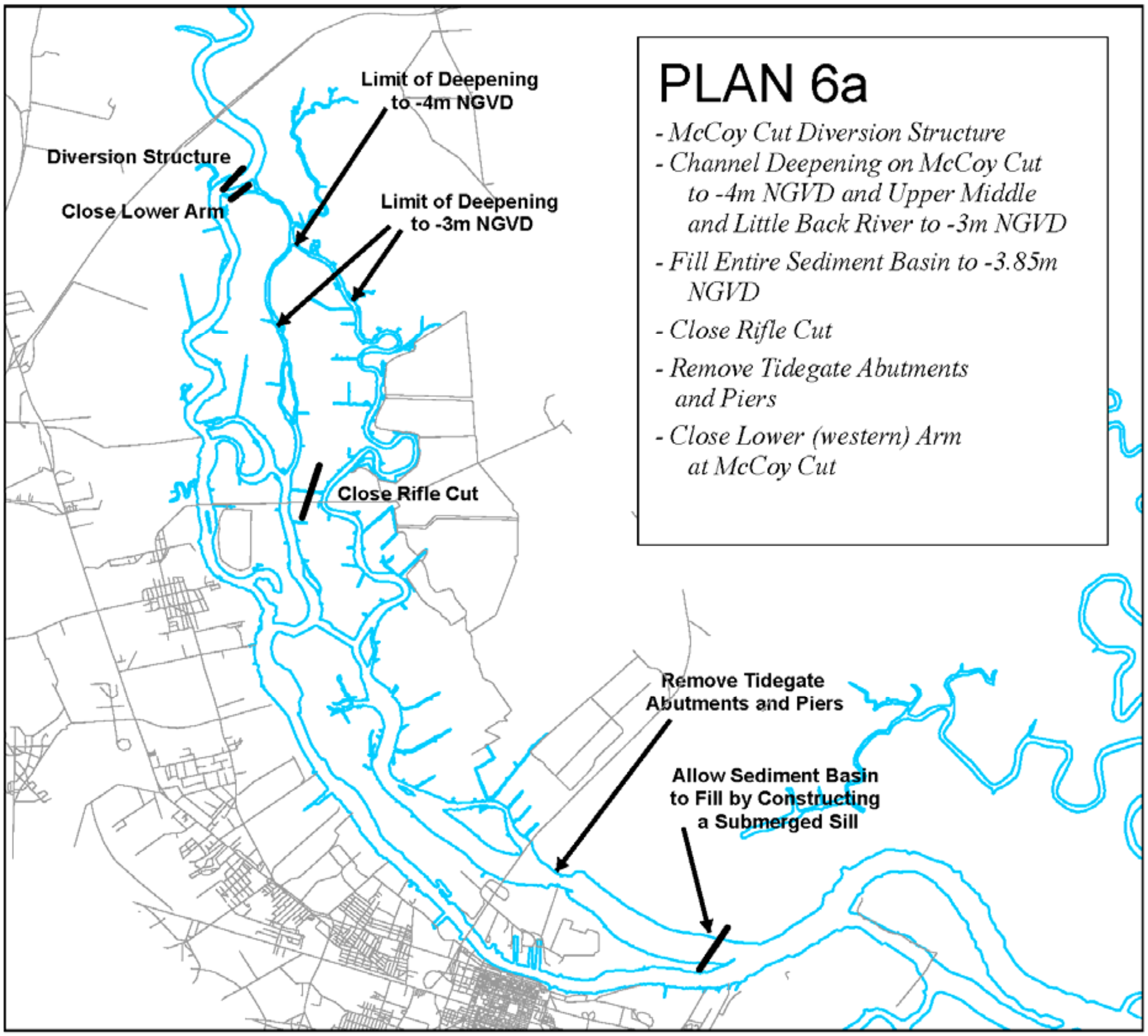

Figure 3-1 Mitigation Plan 6A (courtesy of the USACE Savannah District)

4.0 SALINITY COMPARISONS AT HOULIHAN BRIDGE FOR FRONT, MIDDLE AND BACK RIVERS.

The location where Houlihan Bridge crosses the Front, Middle and Back Rivers was selected for Salinity Comparisons between the Sigma Grid and Z-Grid Models.

4.1 Salinity Comparisons under Existing Conditions

Tables 4-1 to 4-3 and Figures 4-2 to 4-4 show the differences in salinity predictions for Front, Middle and Back Rivers. The Z-Grid model predicts salinity moving upstream slightly farther than the Sigma Grid model.

Table 4-1 Front River Salinity Comparisons

Front River Z-Grid - Sigma Grid 1997 Model Comparisons Salinity (ppt)			
Percentiles	10th	50th	90th
Sigma Grid	0.0	0.2	2.8
Z-Grid	0.03	0.78	4.0

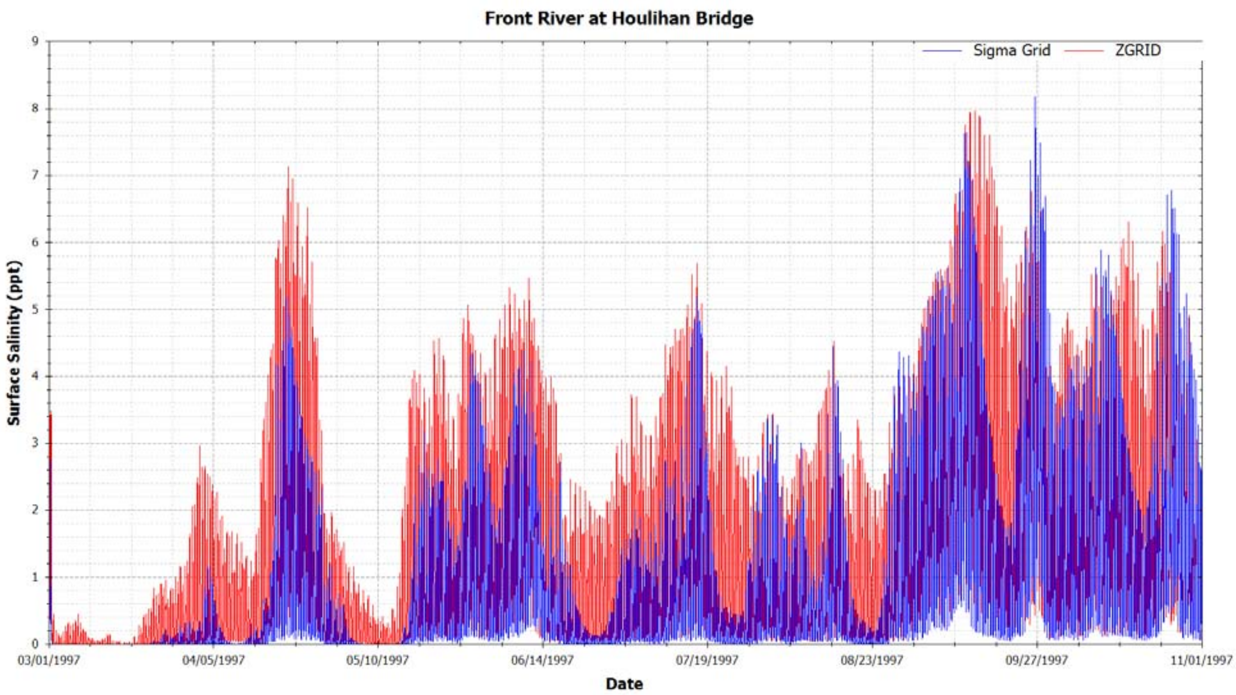

Figure 4-1 Front River Salinity Comparisons

Table 4-2 Middle River Salinity Comparisons

Middle River Z-Grid - Sigma Grid 1997 Model Comparisons Salinity (ppt)			
Percentiles	10th	50th	90th
Sigma Grid	0.0	0.37	1.9
Z-Grid	0.19	1.1	3.0

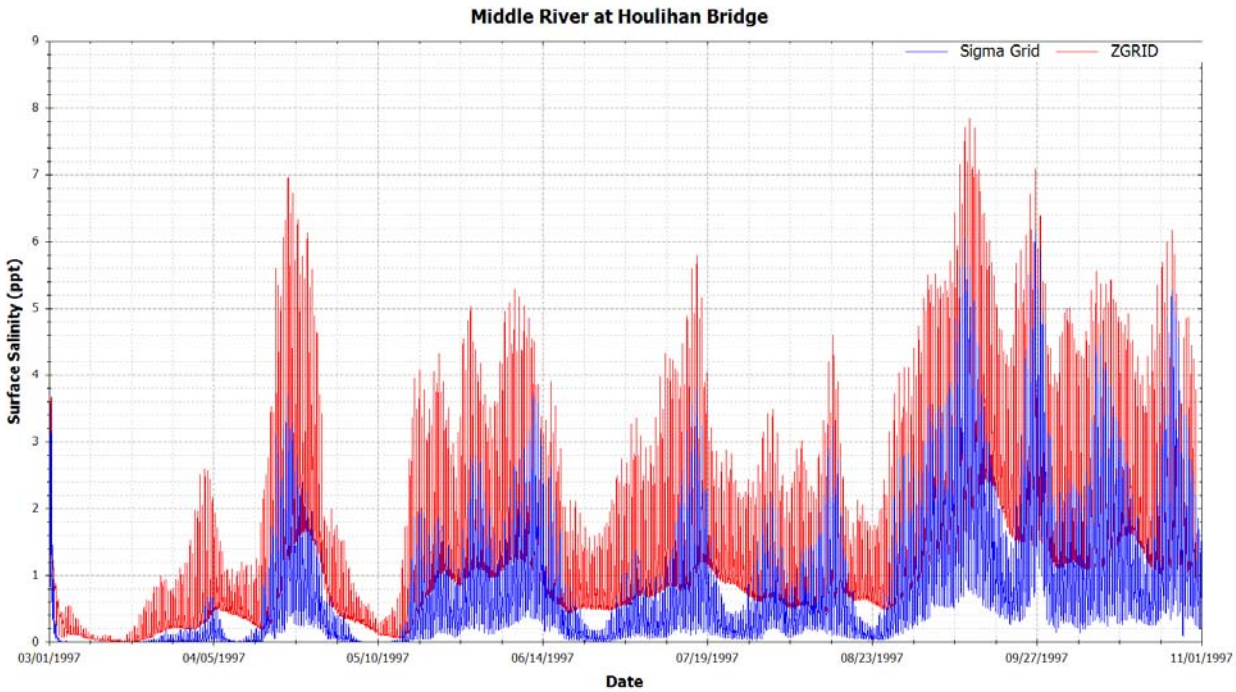

Figure 4-2 Middle River Salinity Comparisons

Table 4-3 Back River Salinity Comparisons

Back River Z-Grid - Sigma Grid 1997 Model Comparisons Salinity (ppt)			
Percentiles	10th	50th	90th
Sigma Grid	0.0	0.15	1.0
Z-Grid	0.02	0.33	1.79

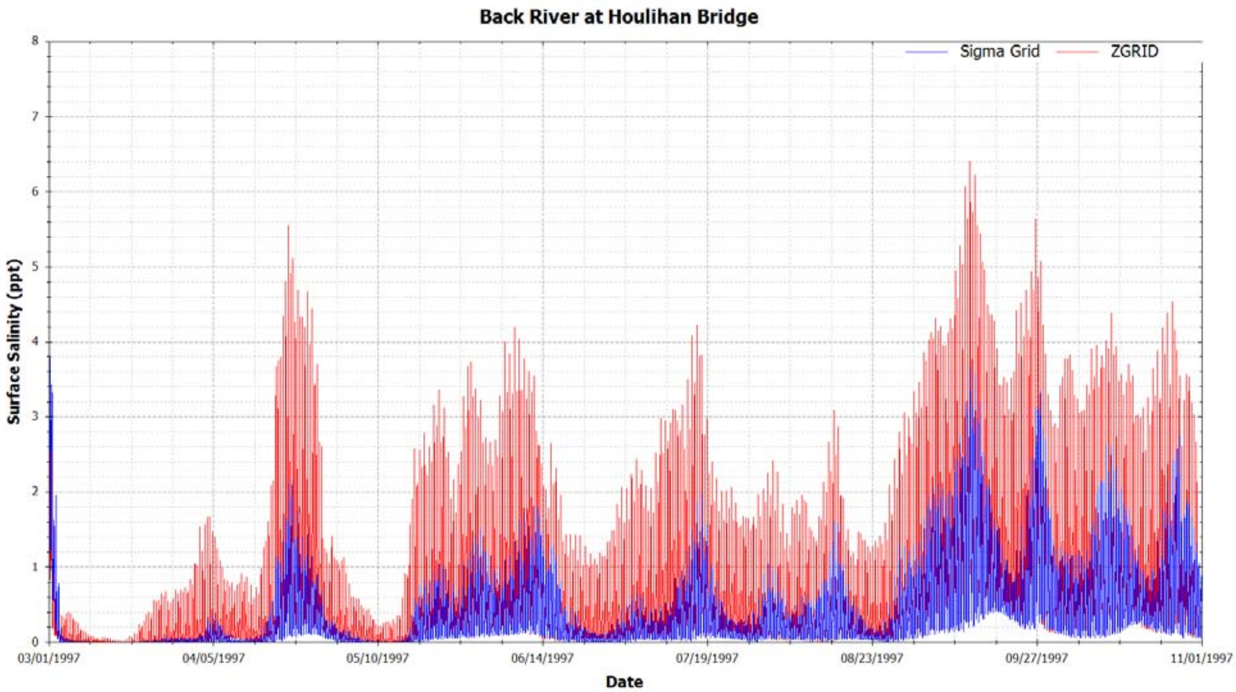

Figure 4-3 **Back River Salinity Comparisons**

4.2 Velocity Comparisons at Houlihan Bridge for Front, Middle and Back Rivers.

Houlihan Bridge crossings at Front, Middle and Back Rivers are used for Velocity Comparisons between the Sigma Grid and Z-Grid Models. Tables 4-4 to 4-6 and Figures 4-6 to 4-8 illustrate the differences in velocity for Front, Middle and Back Rivers. Overall the Z-Grid Model predicts higher surface velocities both in the upstream (+) and downstream (-) directions with an increase in the average surface velocity in the upstream direction. This corresponds with the increased salinity movement upstream.

Table 4-4 Front River Velocity Comparisons

Front River Z-Grid - Sigma Grid 1997 Model Comparisons Average Velocity (cm/sec)			
Percentiles	10th	50th	90th
Sigma Grid	-73	-28	+47
Z-Grid	-99	-40	+97

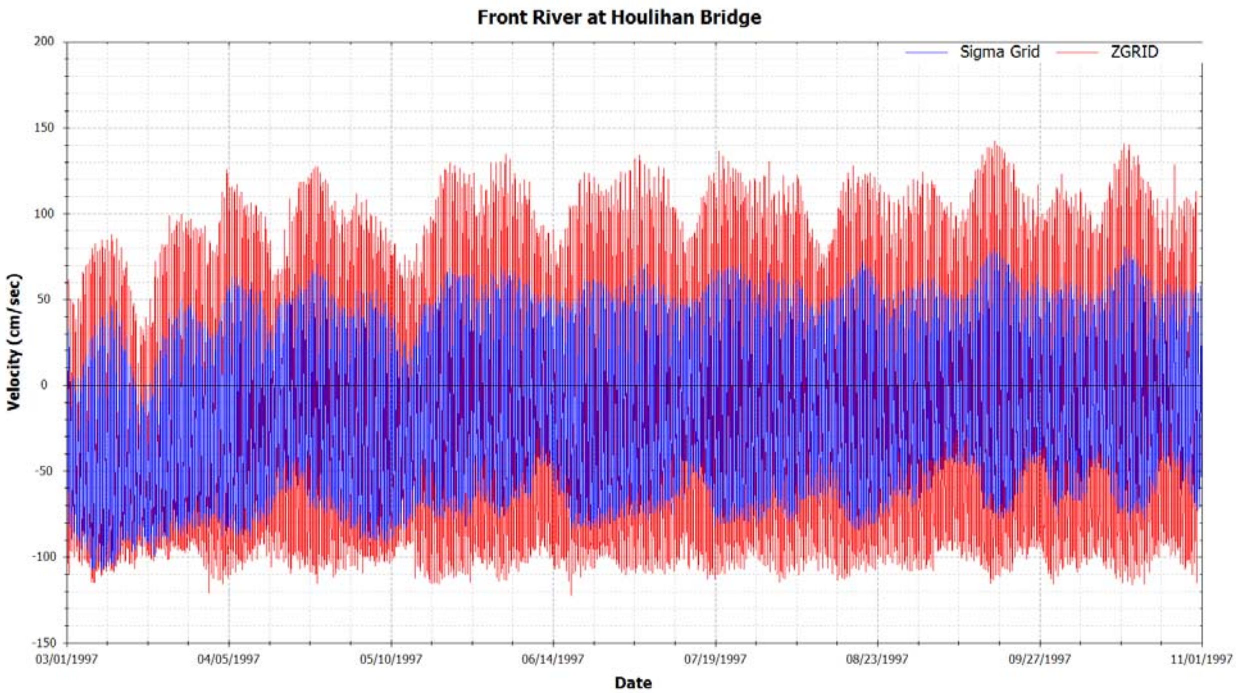

Figure 4-4 Front River Velocity Comparison

Table 4-5 Middle River Model Velocity Comparisons

Middle River Z-Grid - Sigma Grid 1997 Model Comparisons Velocity (cm/sec)			
Percentiles	10th	50th	90th
Sigma Grid	-34	-11	+27
Z-Grid	-48	-22	+46

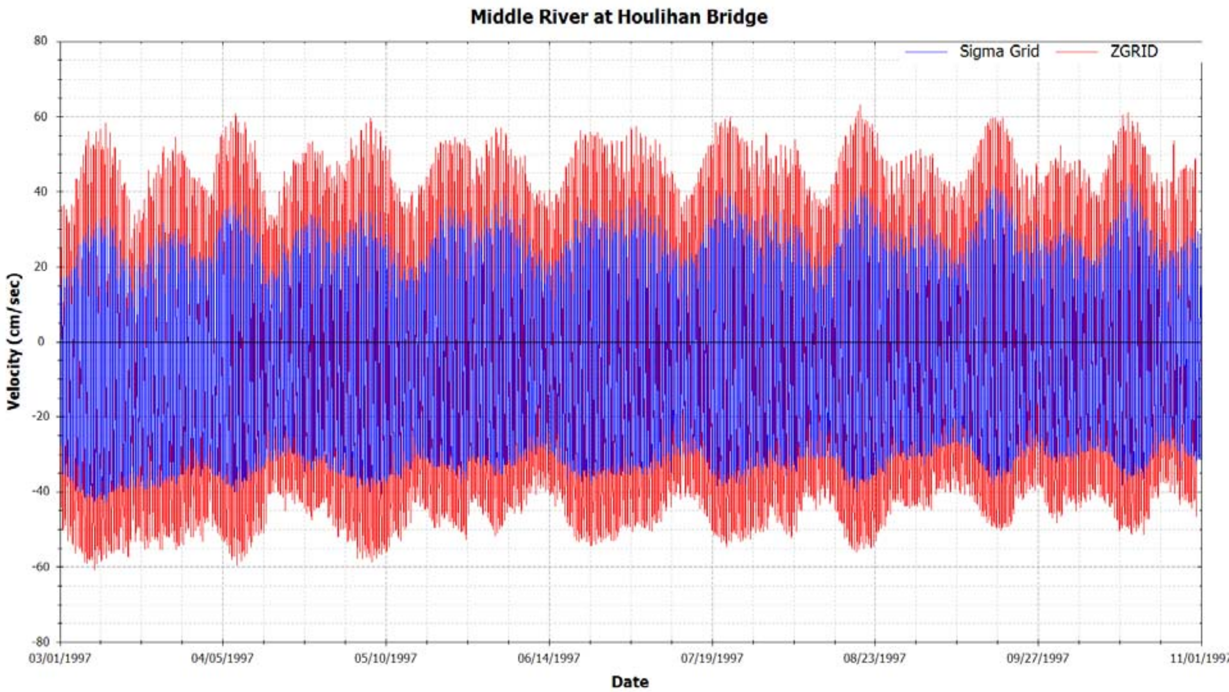

Figure 4-5 Middle River Velocity Comparison

Table 4-6 Back River Velocity Comparisons

Back River Z-Grid - Sigma Grid 1997 Model Comparisons Velocity (cm/sec)			
Percentiles	10th	50th	90th
Sigma Grid	-20	-14	+18
Z-Grid	-45	-23	+29

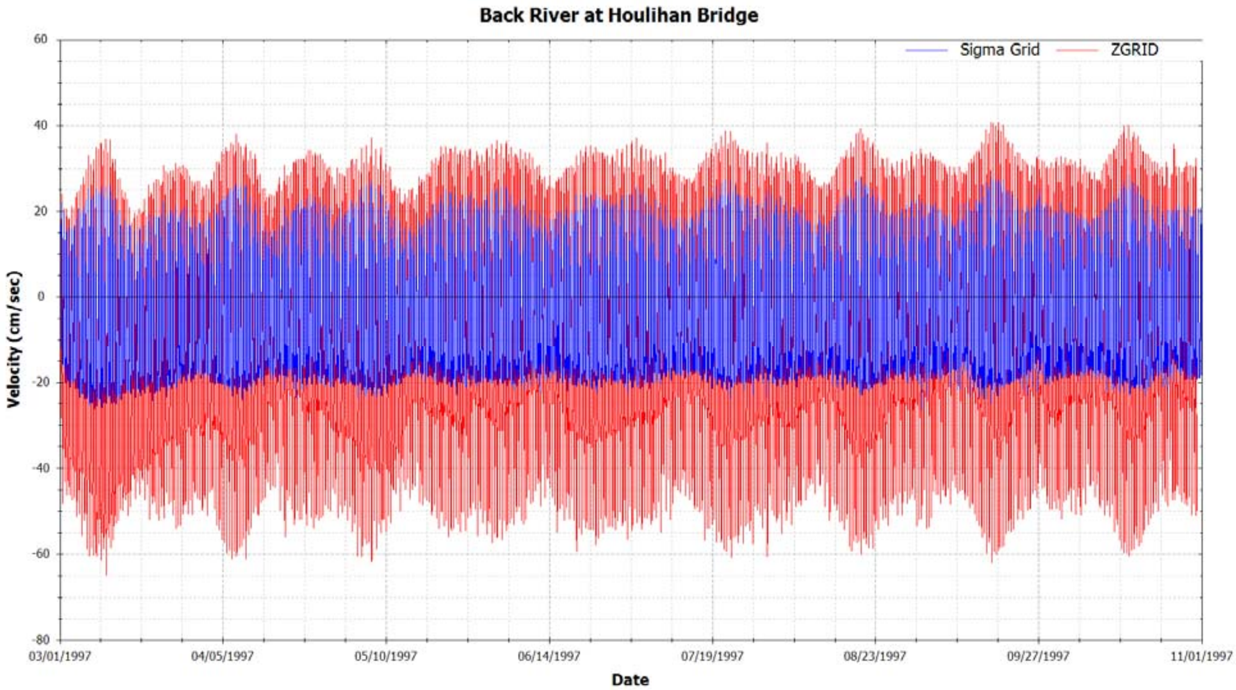

Figure 4-6 Back River Velocity Comparison

4.3 Salinity Comparisons for 48 ft Project Depth with Mitigation Plan 6A

For the Plan6A mitigation scenario, Tables 4-7 to 4-9 and Figures 4-7 to 4-9 show the differences in salinity predictions for Front, Middle and Back Rivers. For the Front and Middle Rivers the Z-Grid model predicts salinity moving upstream slightly farther than the Sigma Grid model, while for the Back River the Z-Grid model predicts salinity moving upstream slightly less than the Sigma Grid model. Also the Z-Grid model show much less tidal variation of salinity, this is due caused by fresh water moving farther down the Back River and the associated marsh areas, damping the impacts of the salinity movement.

Table 4-7 Front River Salinity Comparisons

Front River Z-Grid - Sigma Grid 1997 Model Comparisons Salinity (ppt)			
Percentiles	10th	50th	90th
Sigma Grid	0.0	0.65	3.9
Z-Grid	0.09	1.5	5.3

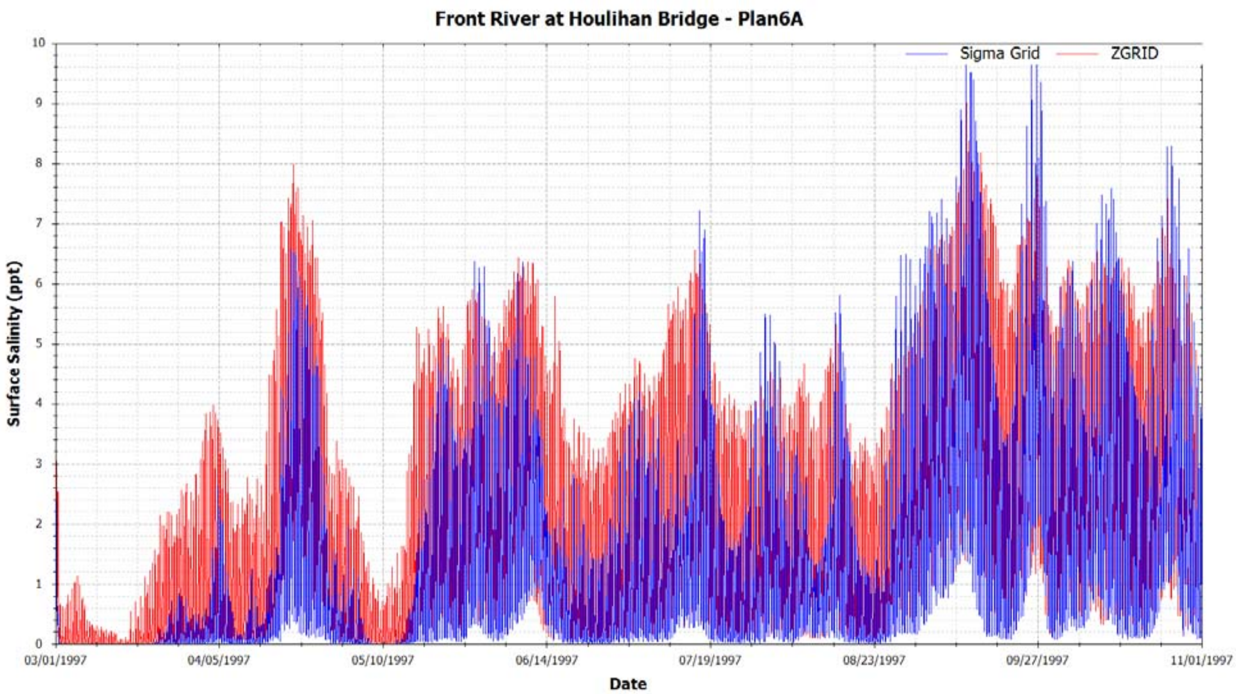

Figure 4-7 Front River Salinity Comparisons – Plan6A

Table 4-8 Middle River Salinity Comparisons

Middle River Z-Grid - Sigma Grid 1997 Model Comparisons Salinity (ppt)			
Percentiles	10th	50th	90th
Sigma Grid	0.0	0.04	0.36
Z-Grid	0.32	2.1	4.3

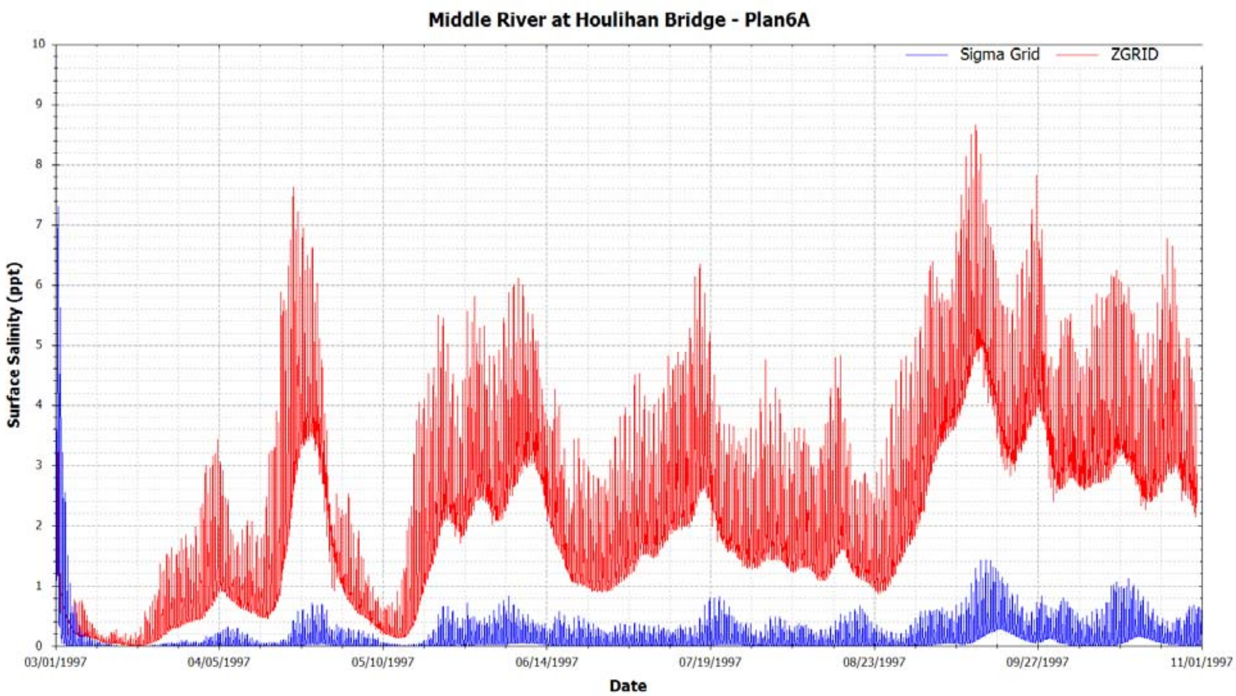

Figure 4-8 Middle River Salinity Comparisons – Plan6A

Table 4-9 Back River Salinity Comparisons

Back River Z-Grid - Sigma Grid 1997 Model Comparisons Salinity (ppt)			
Percentiles	10th	50th	90th
Sigma Grid	0.0	0.04	0.36
Z-Grid	0.0	0.03	0.17

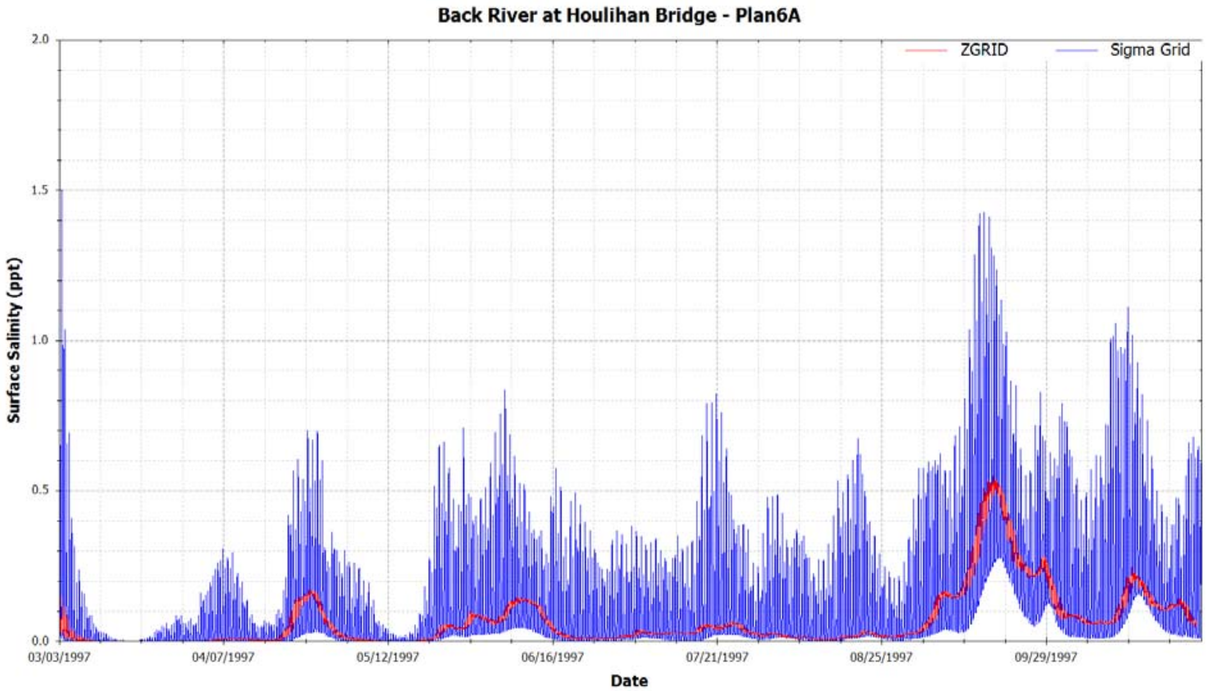

Figure 4-9 Back River Salinity Comparisons – Plan6A

4.2 Velocity Comparisons at Houlihan Bridge for Front, Middle and Back Rivers under Plan6A

Houlihan Bridge crossings at Front, Middle and Back Rivers are used for Velocity Comparisons between the Sigma Grid and Z-Grid Models. Tables 4-10 to 4-12 and Figures 4-10 to 4-12 illustrate the differences in velocity for Front, Middle and Back Rivers. Overall the Z-Grid Model predicts higher surface velocities both in the upstream (+) and downstream (-) directions with an increase in the average surface velocity in the upstream direction. This corresponds with the increased salinity movement upstream.

Table 4-10 Front River Velocity Comparisons

Front River Z-Grid - Sigma Grid 1997 Model Comparisons Average Velocity (cm/sec)			
Percentiles	10th	50th	90th
Sigma Grid	-70	-21	+48
Z-Grid	-101	-36	+85

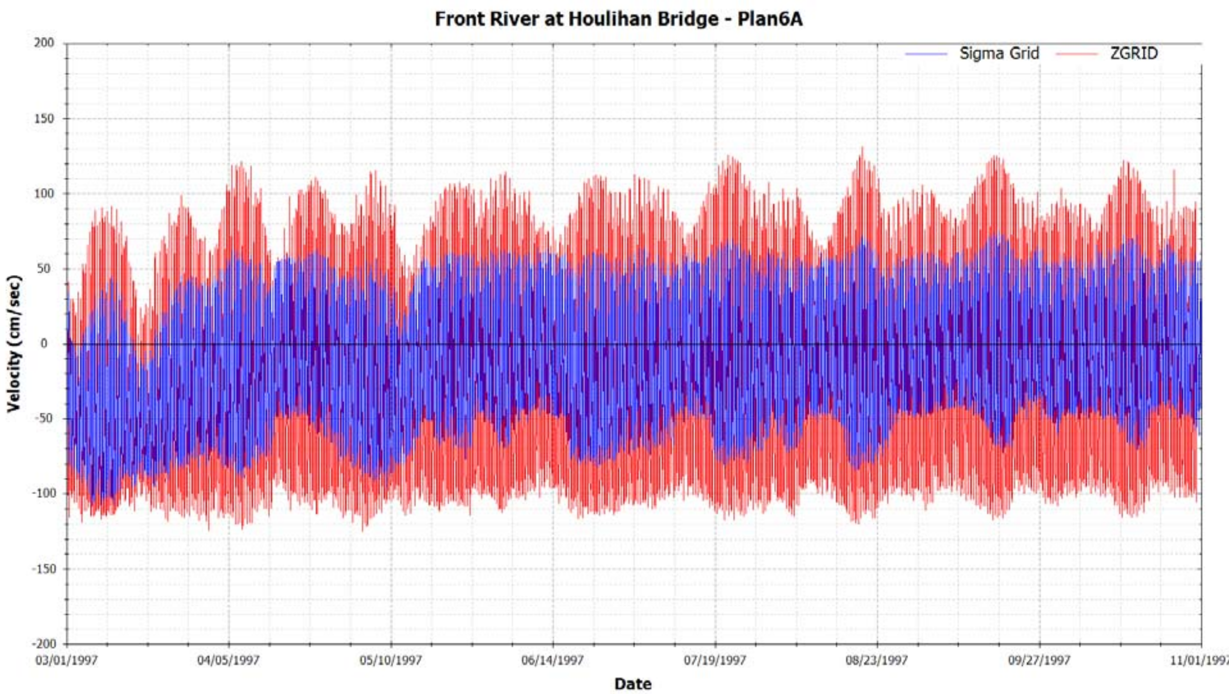

Figure 4-10 Front River Velocity Comparison

Table 4-11 Middle River Model Velocity Comparisons

Middle River Z-Grid - Sigma Grid 1997 Model Comparisons Velocity (cm/sec)			
Percentiles	10th	50th	90th
Sigma Grid	-31	-11	+19
Z-Grid	-41	-21	+37

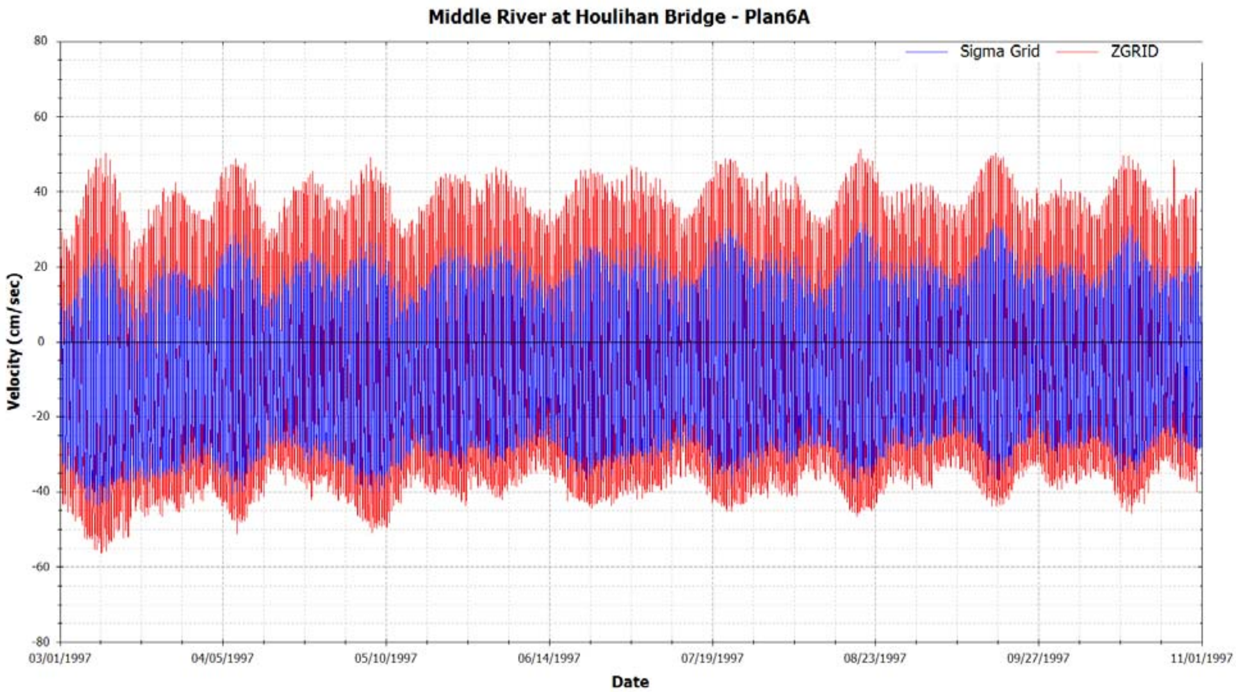

Figure 4-11 Middle River Velocity Comparison

Table 4-12 Back River Velocity Comparisons

Back River Z-Grid - Sigma Grid 1997 Model Comparisons Velocity (cm/sec)			
Percentiles	10th	50th	90th
Sigma Grid	-24	-15	+27
Z-Grid	-33	-21	+35

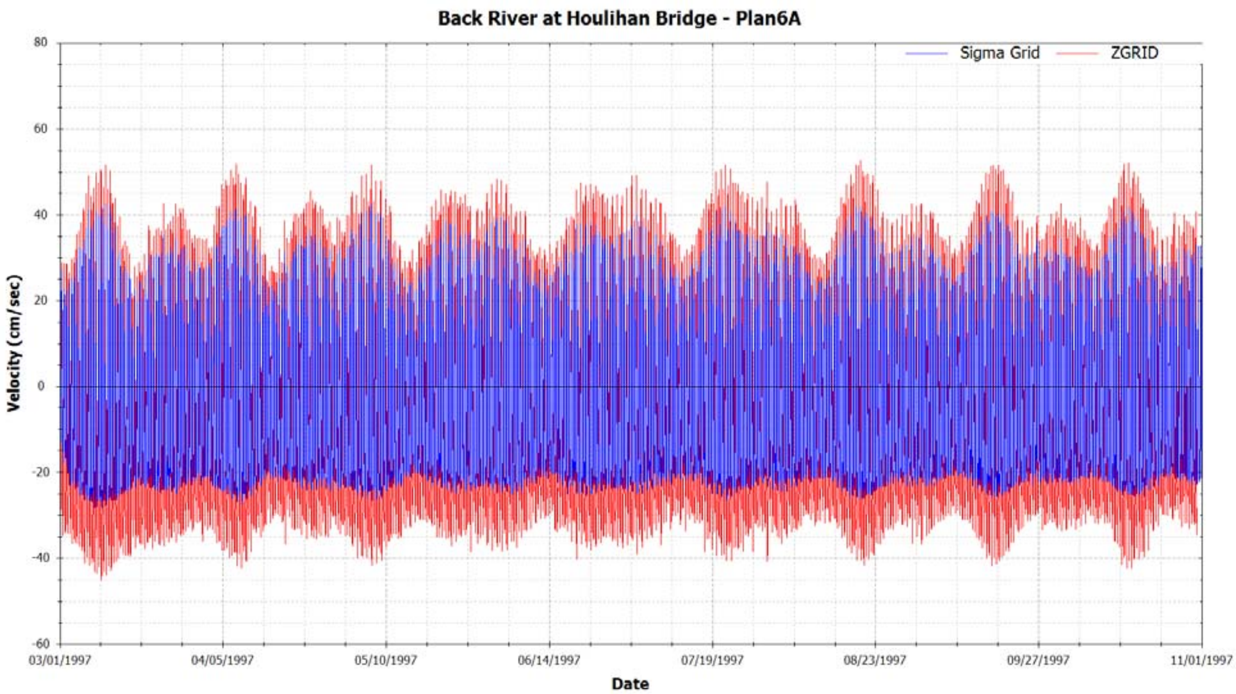

Figure 4-12 Back River Velocity Comparison

5.0 LOCATION OF THE 0.5 PPT SURFACE SALINITY AT THE 50% EXCEEDANCE VALUE

The amount of wetlands impacted was estimated by the Corps using a river salinity of 0.5 ppt at 50^{th} % exceedance value (EV) in the Front, Middle and Back Rivers. Figures 5-1 and 5-2 illustrate the location of the 0.5 ppt 50% EV for Front Middle and Back Rivers and potential wetlands impact using the Sigma Grid. The time period used to determine the 50% EV is March 1 to November 1, 1997 as specified by the Wetland Interagency Coordination Team.

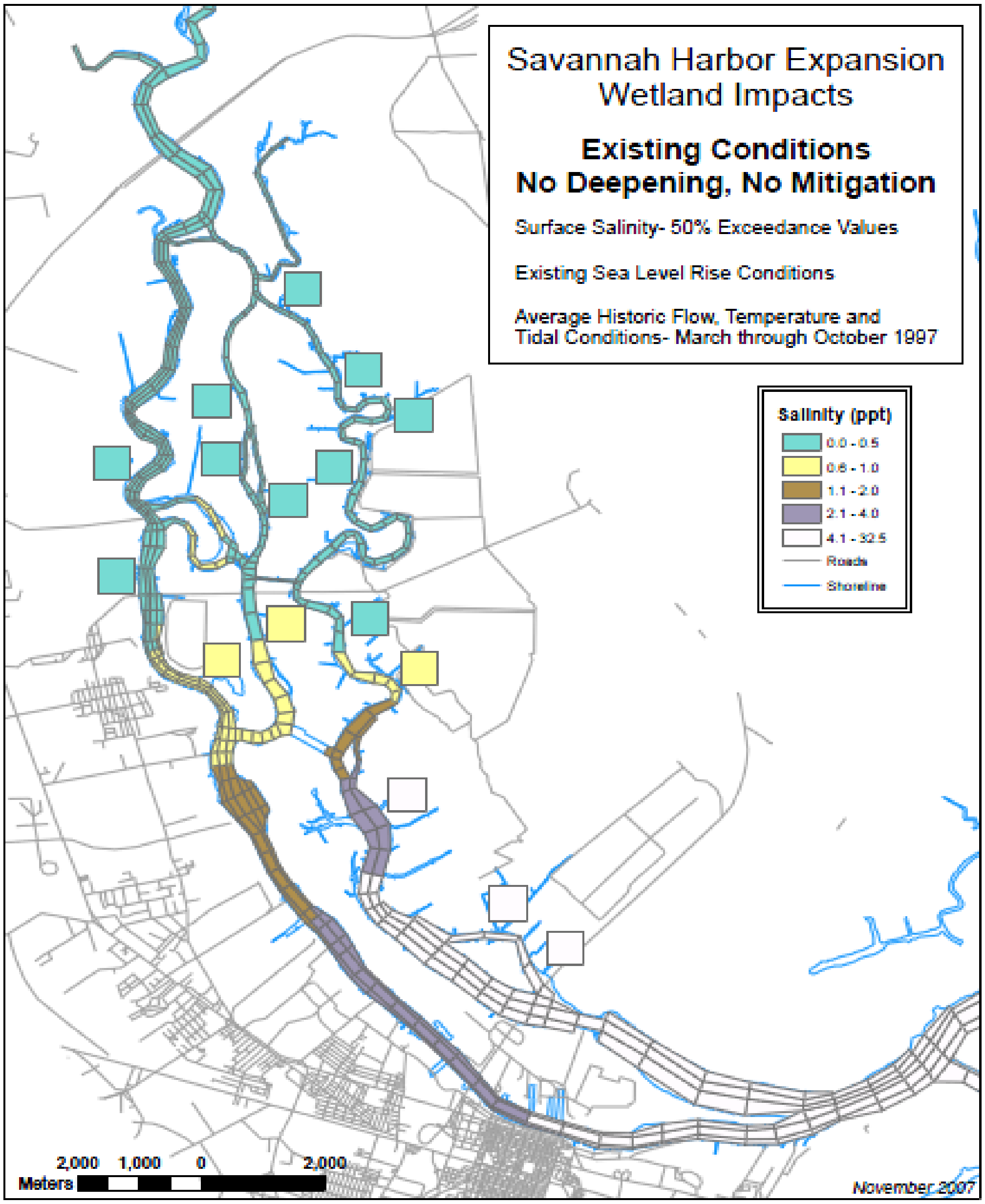

Figure 5-1 Locations of the Surface Salinity 0.5 ppt 50% EV under Existing Conditions
(Courtesy of the USACE Savannah District)

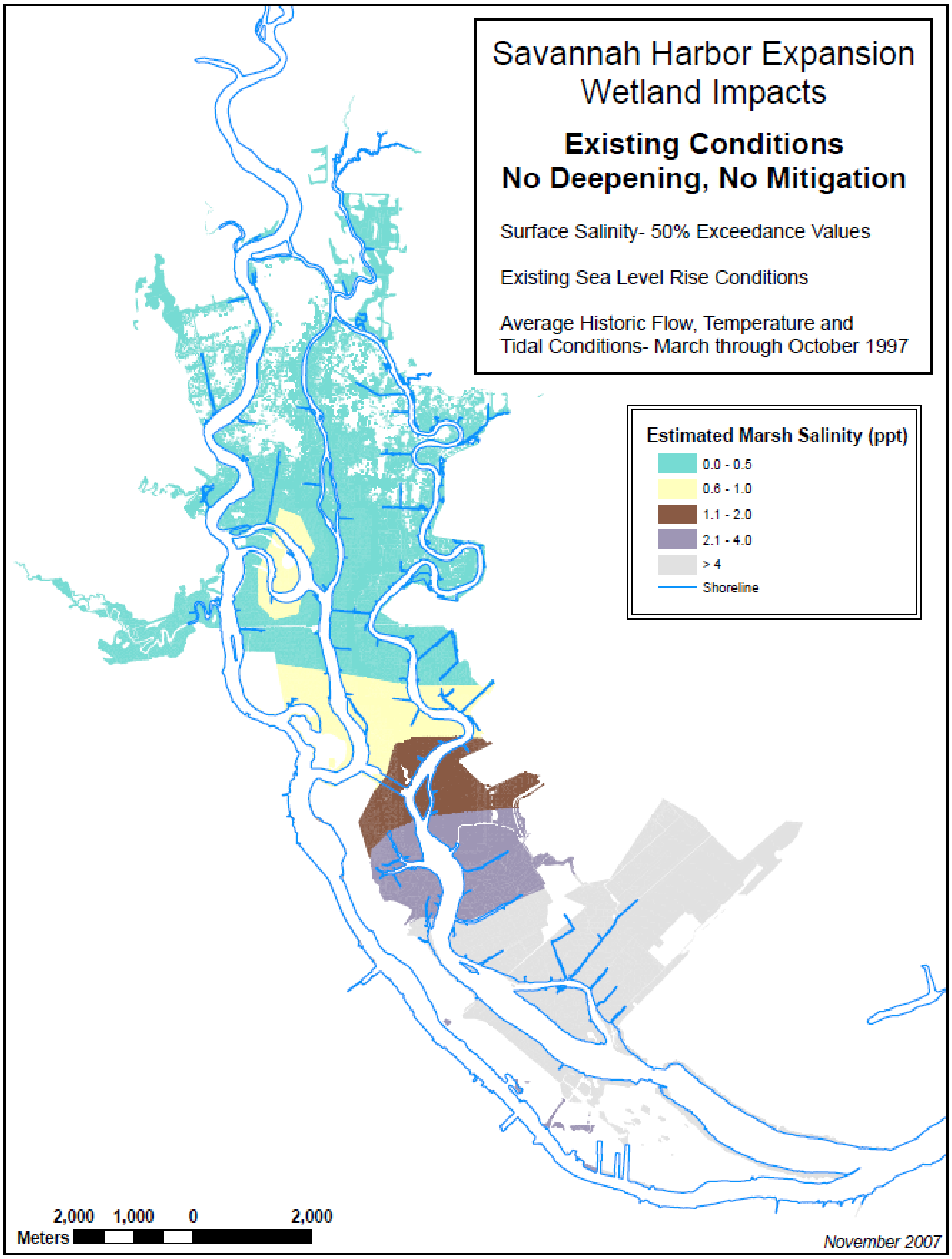

Figure 5-2 Wetland Predictions based on 0.5 ppt 50% EV under Existing Conditions
(Courtesy of the USACE Savannah District)

For the 48 foot proposed maximum channel depth, Figures 5-3 and 5-4 illustrate the location of the 0.5 ppt 50% EV for Front Middle and Back Rivers and potential wetlands impact using the Sigma grid.

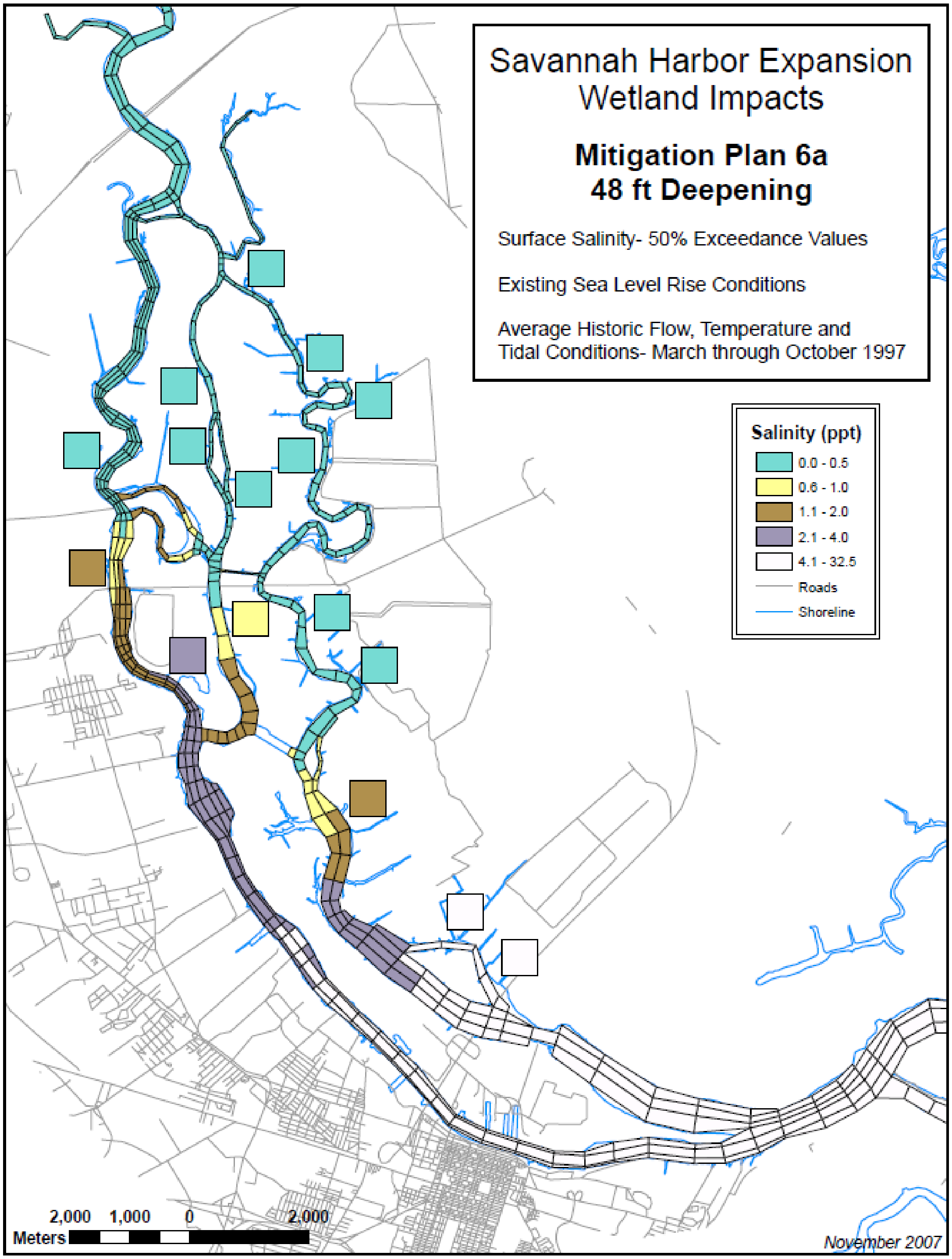

Figure 5-3 Locations of the Surface Salinity 0.5 ppt 50% EV under Deepening Conditions
(Courtesy of the USACE Savannah District)

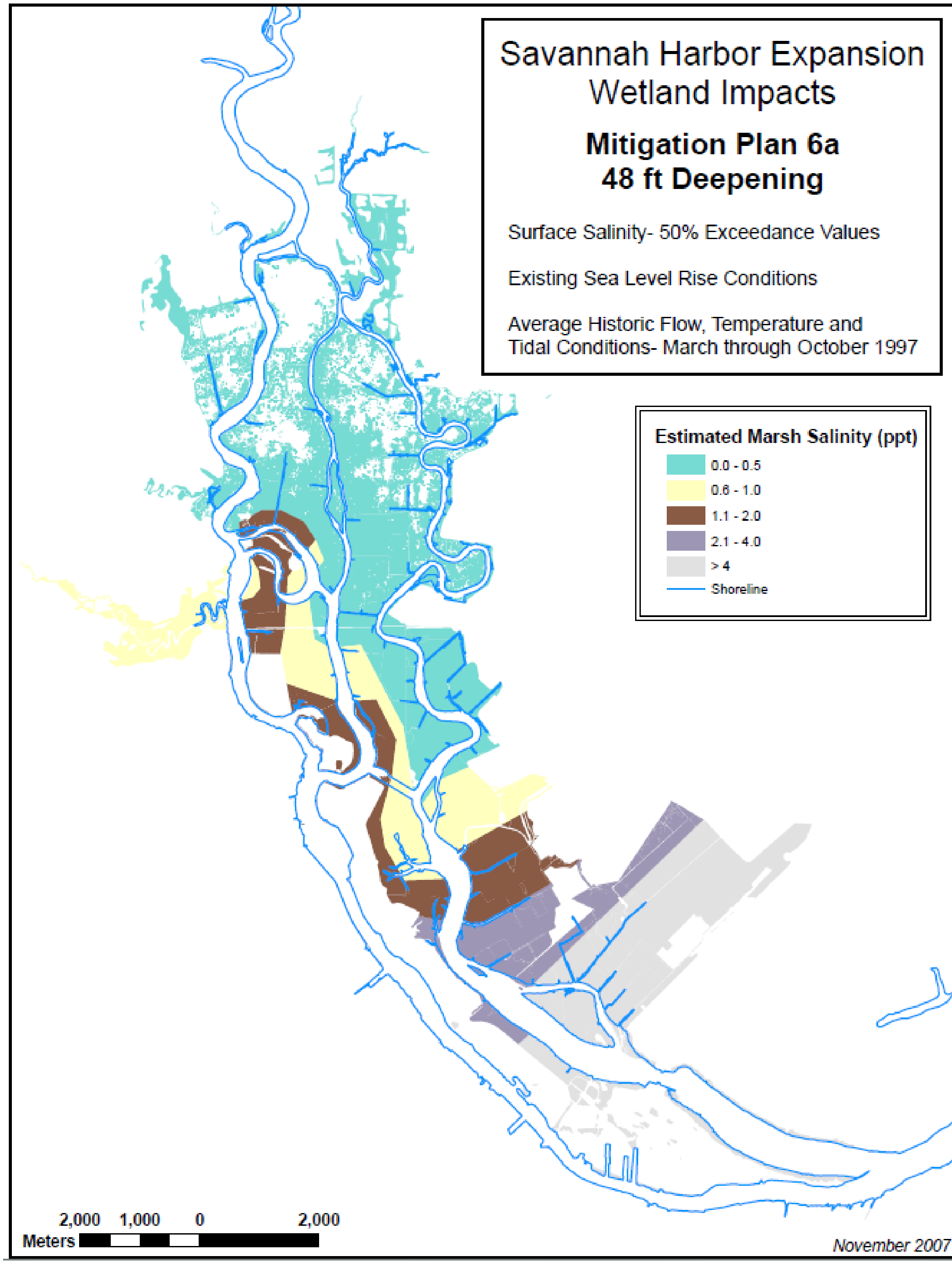

Figure 5-4 Wetland Predictions based on 0.5 ppt 50% EV under Plan6A
(Courtesy of the USACE Savannah District)

The following Sections compare the Zgrid and Sigma models predictions where the 0.5 ppt surface salinity at the 50% exceedance level occurs. The River Mile of each models cell that contains the surface salinity 0.5 ppt 50% was determined using the 1997 March 1 to November 1 predicted salinity data. The River Mile of where Houlihan Bridge crosses the rivers is used as a reference point. For the Front and Middle Rivers the Zgrid model predicts salinity moving slightly farther upstream, while on the Back

River the Zgrid salinity moves much farther downstream for the Plan6A predictions. Since the wetland impacts are based on the location of the 0.5 ppt surface salinity EV, the Zgrid model would move the fresh water wetlands boundary farther upstream for the wetlands in the vicinity of the Front and Middle Rivers and fresh water wetlands boundary downstream for those wetlands around the Back River.

5.1 Front River Surface Salinity 0.5 ppt 50% Exceedance Values

For existing conditions in the Front River, the Sigma Model predicts the 0.5 ppt 50% EV at River Mile 22.3, while the Z-Grid model predicts the 0.5 ppt 50% EV at River Mile 22.9. For reference Houlihan Bridge is at River mile 23.3.

For the 48 foot proposed maximum channel deepening scenario, the Sigma Model predicts the surface salinity 0.5 ppt 50% EV River Mile 23.1, while the Z-Grid model predicts the 0.5 ppt 50% EV River Mile 24.5.

In the Front River the Sigma Model extends the salinity impacts due to deepening 0.8 miles upstream while the Z-Grid extends the salinity impacts 1.6 miles upstream.

5.2 Middle River Surface Salinity 0.5 ppt 50% Exceedance Values

For existing conditions in the Middle River, the Sigma Model predicts the 0.5 ppt 50% EV at River Mile 1.9 while the Z-Grid model predicts the 0.5 ppt 50% EV at River Mile 3.5. For reference Houlihan Bridge is at River mile 2.1.

For the 48 foot proposed maximum channel deepening scenario, the Sigma Model predicts the surface salinity 0.5 ppt 50% EV River Mile 2.2, while the Z-Grid model predicts the 0.5 ppt 50% EV River Mile 3.9.

In the Middle River the Sigma Model extends the salinity impacts due to deepening 0.3 miles upstream while the Z-Grid extends the salinity impacts 0.4 miles upstream.

5.3 Back River Surface Salinity 0.5 ppt 50% Exceedance Values

For existing conditions in the Back River, the Sigma Model predicts the 0.5 ppt 50% EV at River Mile 6.3 while the Z-Grid model predicts the 0.5 ppt 50% EV at River Mile 6.1. For reference Houlihan Bridge is at River mile 7.3.

For the 48 foot proposed maximum channel deepening scenario, the Sigma Model predicts the surface salinity 0.5 ppt 50% EV River Mile 5.4, while the Z-Grid model predicts more upstream fresh water coming down the Back River on outgoing tide pushing the 0.5 ppt 50% EV to River Mile 2.6.

In the Back River the Sigma Model extends the salinity impacts due to deepening 0.9 miles downstream while the Z-Grid extends the salinity impacts 3.5 miles downstream.

6.0 DISSOLVED OXYGEN COMPARISON BETWEEN SIGMA GRID AND Z-GRID

The WASP water quality model had been updated between the Sigma grid WASP model and the Z-Grid WASP model. Some of the major updates were 1) the method of transferring the advection coefficient between EFDC and WASP in the hydrodynamic linkage file; 2) the method of calculating O'Connor-Dobbins reaeration rate using the top layer depth (Sigma WASP) and total depth (Z-Grid WASP) and 3) the different methods in handling the marsh loading. Due to these differences a meaningful side-by-side comparison of the predicted D.O. values was not practical. Each model was calibrated to predict the 1997 and 1999 measured D.O. values and therefore under existing conditions will behave similarly. However the following subjective conclusions can be made based on how each model transfers mass and salinity through out the harbor.

For point source dischargers, since the decay rates are very similar, the response of each models' D.O. predictions to BOD and ammonia loads will be similar.

For the Plan6A mitigation scenario, since the Z-Grid model extends the salinity farther upstream, the Z-Grid model will extend the low D.O range (D.O. less than 4 mg/l) a little farther upstream.

For the oxygen injection scenario the Z-Grid model will distribute the additional oxygen farther upstream in both the Front and Middle Rivers. Since the deepening impacts the D.O. in the upper areas of the Harbor (around River Miles 25 to 26) and the Z-Grid model moves oxygen farther upstream the Z-Grid model would predict less oxygen needed to mitigate the deepening D.O. impacts.

7.0 CONCLUSIONS

For the Front River, the Z-Grid model compared to the Sigma model shows higher surface salinity at Houlihan Bridge, by 0.5 ppt for the existing conditions and 0.9 ppt for the deepening scenario. The Z-Grid model compared to the Sigma model model moves the surface salinity 0.5 ppt 50% EV farther upstream 0.6 miles for the existing conditions and 1.4 miles upstream for the deepening scenario.

For the Middle River, the Z-Grid model compared to the Sigma model shows higher surface salinity at Houlihan Bridge, by 0.7 ppt for the existing conditions and 2.0 ppt for the deepening scenario. The Z-Grid model compared to the Sigma model moves the surface salinity 0.5 ppt 50% EV farther upstream 1.6 miles for the existing conditions and 1.7 miles upstream for the deepening scenario.

For the Back River, the Z-Grid model compared to the Sigma model shows higher surface salinity at Houlihan Bridge, by 0.2 ppt for the existing conditions and 0.0 ppt for the deepening scenario. The Z-Grid model compared to the Sigma model moves the surface salinity 0.5 ppt 50% EV farther downstream 0.2 miles for the existing conditions and 2.8 miles downstream for the deepening scenario.

The net impact on the wetlands due to the deepening, at the 0.5 ppt 50% EV, was estimated using Figures 5-2 and 5-4, The Sigma model predicted a net change of 337 acres of freshwater marsh conversion with the 48-foot depth alternative (Table 2 USACE November 2007 Evaluation of Marsh/Wetlands Impacts with Proposed Mitigation Plan). The Z-Grid model produces approximately 75 percent of the net change in the amount of wetlands as the Sigma model.

Since the Z-Grid model appears to include more tidal mixing, it should show that injected oxygen distributes farther upstream to critical D.O. impact areas. This should help (and not hinder) the performance of the proposed D.O. mitigation systems.

Overall, the Z-Grid model identifies less area of wetland impacts than the Sigma model, therefore using the Sigma model's mitigation estimates would adequately compensate for the deepening impacts.

Also, the Sigma model was peer reviewed by the Modeling Technical Review Group (MTRG) and its successor the Water Quality Interagency Coordination Team, with Agency Technical Review (ATR), and Independent Expert Peer Review (IEPR) in 2005 and 2006. The Sigma model was finalized in the modeling report (Tetra Tech 2006) with agency letters in March 2006 accepting the Sigma model as sufficient for analyzing harbor deepening.

Therefore, our recommendation is to continue to use the Sigma model for the impacts and mitigation analysis for harbor deepening. Since EPA has adopted the Z-Grid model for its TMDL analyses, the Corps could incorporate it if SHEP proceeds to construction.

8.0 REFERENCES

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