TIDE PREDICTIONS FOR THE WACCAMAW RIVER INCLUDING THE ATLANTIC INTRACOASTAL WATERWAY

Ryan Murray[1] and Dr. Scott C. Hagen[2]

AUTHORS: [1]Graduate Research Assistant, [2]Assistant Professor, University of Central Florida Dept. of Civil and Environmental Engineering, Orlando, FL 32816-2450.
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Abstract. Recent cooperative efforts between the University of Central Florida and the National Weather Service's Southeast River Forecast Center have resulted in the development of a finite element model for hydrodynamic calculations for the entire coast of South Carolina and a portion of North Carolina. The study area is located in the northern region of the South Atlantic Bight along the southeast coast of the United States. The studies have focused on the Waccamaw River for the purpose of improving river stage and flood forecasts for the National Weather Service's Southeast River Forecast Center. For the present effort, a sensitivity analysis is performed on selected parameters to produce the most accurate results with the model. The parameters optimized are the bottom friction and the eddy viscosity.

INTRODUCTION

The Waccamaw River drains the coastal areas of southern North Carolina and northern South Carolina. The river leaves Lake Waccamaw in North Carolina and flows southward through Conway, South Carolina. From there, it flows southward to a confluence with the Intracoastal Waterway near Enterprise Landing, South Carolina, through Winyah Bay, and into the Atlantic Ocean (Fig. 1). The study area encompasses over 18,000 square miles of open ocean and estuaries and extends more than 100 miles from shore. It includes all of the Waccamaw River and Atlantic Intracoastal Waterway estuarine system up to Conway, South Carolina.

The purpose of this effort is to determine the relative importance of including the Atlantic Intracoastal Waterway (AIW) in tidal calculations for the Waccamaw River. Previous studies (Bennett, 1999; Hagen and Bennett, 1999; Hagen *et al.*, 2002) have been performed with a domain that included only a small portion of the AIW and focused solely on capturing the flow dynamics at the coastline. This project expands on the previous analysis by incorporating freshwater inflows and by including the entire Waccamaw River and AIW up to Conway, South Carolina. As a result, the flow dynamics of the riverine and estuarine system, not just the coastline, can be captured.

This paper focuses on a sensitivity analysis of two parameters: bottom friction and eddy viscosity. In addition, three gradations of a finite element mesh are evaluated for effectiveness in capturing the riverine flow characteristics. Three freshwater inflow scenarios (low, medium and high) are incorporated to determine a range of the two parameters for each inflow. Ideally, the range of parameters would be applicable for any flow event in the riverine system. The values of each parameter are adjusted to determine what the optimal values are for the domain and selected flow scenario. This sensitivity analysis produces the best combination of mesh resolution, eddy viscosity and bottom friction.

In our previous studies, these parameters did not affect the accuracy of the results as much as the current simulations because the domain did not include the riverine system. This is due to the relatively deeper water and simpler geometry of the area when the Waccamaw River and AIW is not included. In the deep water, the friction factor does not influence the propagation of the flow as much as it does in shallow water. Also, in order for an eddy or eddies to form, not only must the eddy viscosity parameter be in the appropriate range, but the shoreline must be sufficiently irregular (thus the observed lack of significance of the eddy viscosity parameter in the previous studies). Since the entire riverine and estuarine system is included in this study and because of the meandering nature of the river, combined with the shallow bathymetry in the river, the bottom friction and eddy viscosity parameters become important.

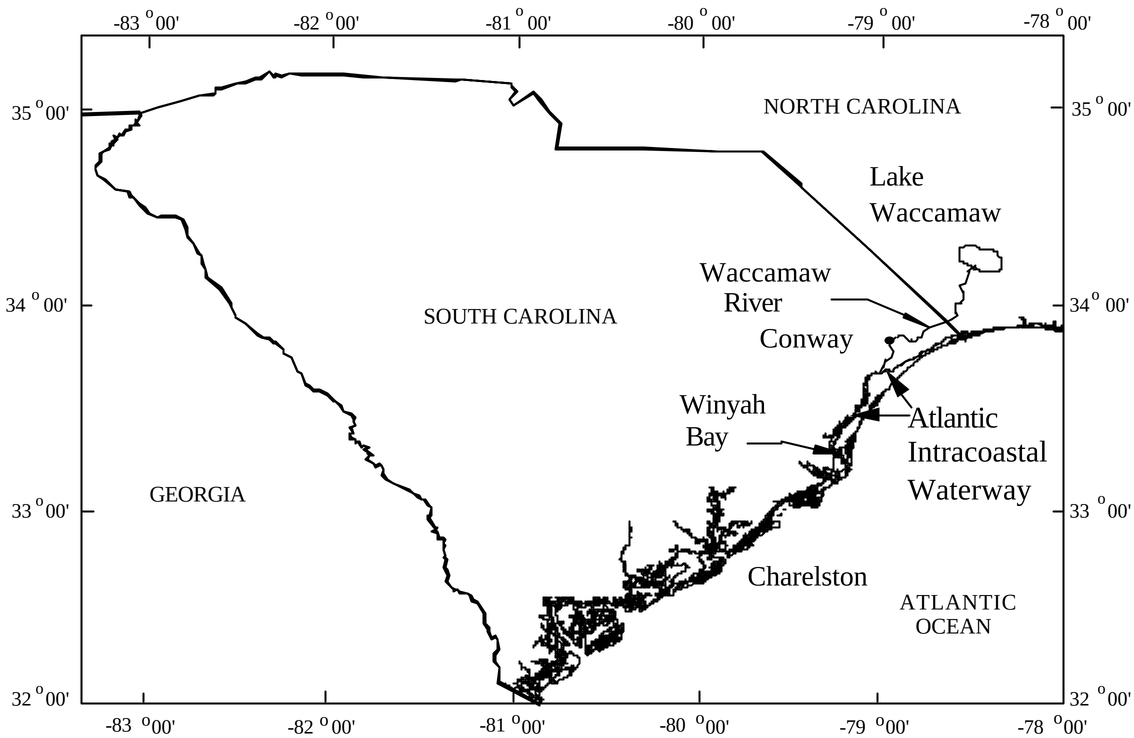

Figure 1. Study region.

MODEL DISCRETIZATION AND DESCRIPTION

A semi-circular arc is used to define the open ocean boundary, with endpoints at Savannah, Georgia and Cape Fear, North Carolina (Fig. 2). The bathymetric depth in the region ranges from greater than 600 meters out in the open ocean to less than 5 meters in the Waccamaw River and Atlantic Intracoastal Waterway.

The finite element mesh uses triangular elements to properly represent the irregularities of the study area boundary. Three different meshes were used in this study, each having a different resolution in the estuary system. The coarsest mesh has approximately 65,000 nodes, which comprise nearly 115,000 elements. The successive versions of the mesh have an increased number of nodes and elements in the Waccamaw River, north of the confluence of the Waccamaw and the AIW. Refinement is performed by splitting a single element into four elements by placing a node at the midpoint of each side of the triangle. This technique is performed two successive times, resulting in a grid that has element side lengths of approximately five meters. The coarsest of the finite element meshes that represents the study area is shown in Fig. 2.

Locations of freshwater inflow have been added to the mesh to better represent the local flow dynamics. An inflow is located at Conway, South Carolina, at the northern extreme of the domain (Fig. 2). It represents the freshwater inflow produced by the Waccamaw River north of Conway.

Simulations are performed with a two-dimensional, finite element code for coastal and ocean circulation. ADCIRC-2DDI (Advanced Circulation Model for Oceanic, Coastal, and Estuarine Waters—Two Dimensional Depth Integrated option; Westerink, Blain, Luettich, and Scheffner, 1992) is a system of computer programs that solve depth integrated, time dependent free surface circulation and transport problems. The program solves the depth-integrated continuity equation in the Generalized Wave-Continuity form in conjunction with the spherical momentum equations to obtain the water surface elevation and velocities in the latitudinal and longitudinal directions. Elevation boundary conditions are applied at the open ocean boundary in the form of tidal constituent forcings. The values for these tidal constituents are obtained from a larger Western North Atlantic tidal model.

It is desirable to run the model with a range of freshwater flow values. By using lateral inflows, the dynamics of the interaction of tidal flow and freshwater flow can be simulated. This aspect is very important to the National Weather Service's Southeast River Forecast Center for flood predictions. The Southeast River Forecast Center uses a one-dimensional generalized flood routing model, FLDWAV, to predict incorporating these flows into the ADCIRC model, certain areas show a dampening of the tidal wave but an overall increase in stage height due to an increase in total volume. High, medium and low flow events were incorporated into ADCIRC. By using a range of flow values, the ADCIRC model is calibrated and validated for almost any flow event the domain will encounter. These flow events are provided by the Southeast River Forecast Center. This will aid the Southeast River Forecast Center by providing correct tidal boundary conditions for their FLDWAV model.

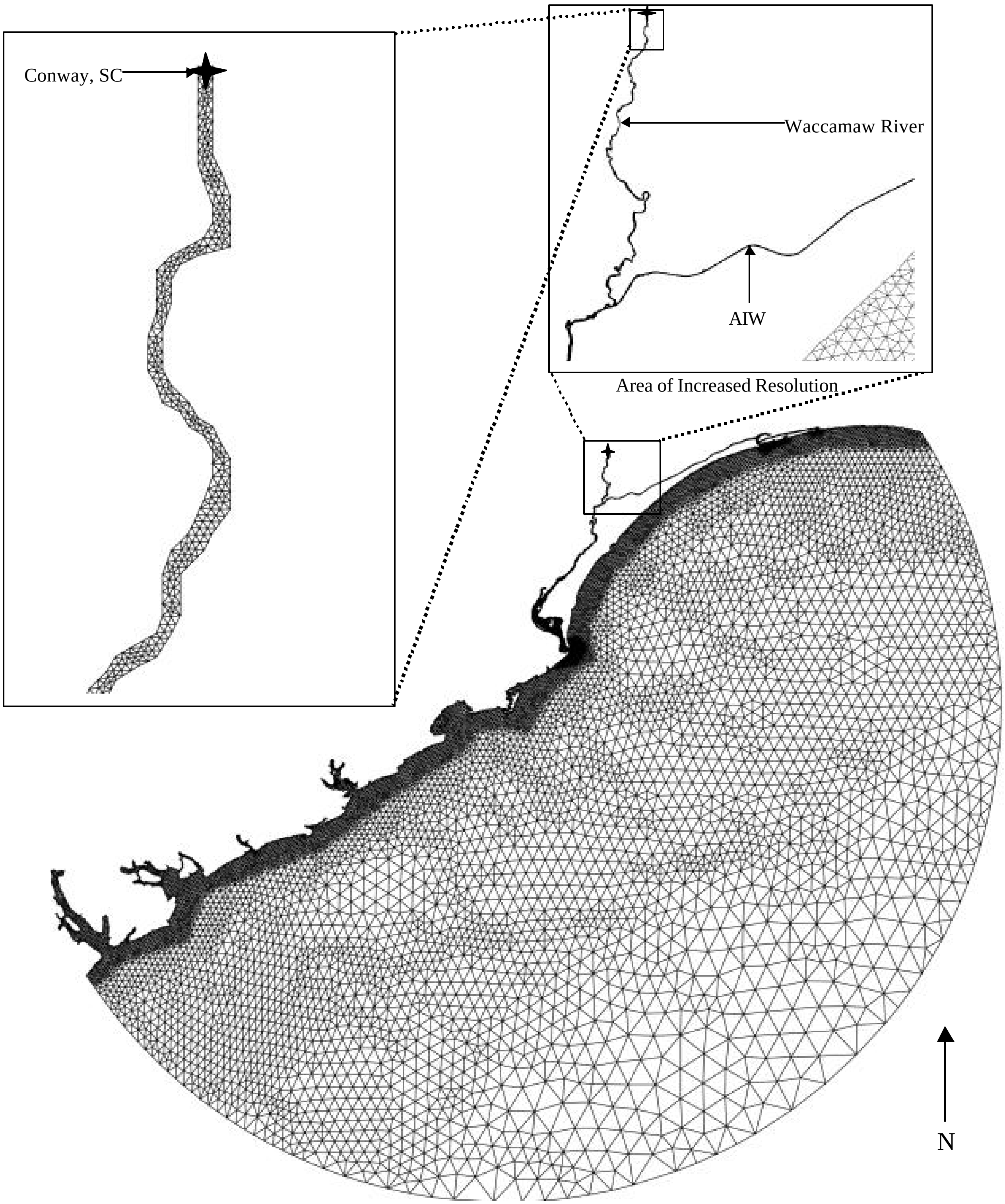

Figure 2. Finite element mesh of study region.

MODEL CALIBRATION AND RESULTS

The model is also calibrated by comparing simulation results with historical data. Simulation results are produced at several stations along the Waccamaw River and Atlantic Intracoastal Waterway. Initial comparisons between historical and simulated stage heights are made at known tidal gage locations along the coastline. The model is further verified by comparing the simulated stage heights with several USGS gage locations along the Waccamaw River and AIW.

The first sets of results produced were used to determine the optimal value for the friction factor. All initial runs were performed on the coarsest mesh. The optimization is isolated to only the friction factor parameter by using the same mesh and other parameters for the friction factor simulations.

The eddy viscosity parameter is analyzed by using the more resolved meshes to properly capture the formation of an eddy or eddies. In a coarse mesh, the size of the eddy could be smaller than the area of an element, therefore confining the eddy inside one element. With a resolved mesh, the area of an element is small enough to allow several elements to describe an eddy, and not confine the eddy to one element.

A range of values for the bottom friction parameter was determined for all flow scenarios (low, medium and high) with each mesh. Unfortunately, each flow event had a different range of bottom friction values. The eddy viscosity parameter effected the flow dynamics more with the resolved meshes than with the coarse one. With the finite element meshes, the most resolved mesh proved to be the most troublesome and arduous when it came to computing, but produced the best results.

FUTURE WORK

The results of this study coupled with previous efforts will provide a basis for real-time calculations of tide-stage for estuarine systems, which can be extended to the entire East Coast of the United States. Under full implementation, real-time simulations of tide-stage can be incorporated with hurricane and tropical storm surge predictions, which will enhance National Weather Service River Forecast System predictions. By utilizing the results from the ADCIRC model, the Southeast River Forecast Center will be able to increase the reliability of their FLDWAV model by allowing the implementation of tidal boundary conditions in the Waccamaw River. Other future work will include a hindcast of Hurricane Hugo in this region, along with extending the mesh out into the floodplain and applying wetting and drying of elements to determine the amount of inundation to surrounding areas due to a large flow event.

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