The CMS Model

and Its Application to the St. Augustine Inlet Area

Sponsored by
Florida Department of Environmental Protection,
Bureau of Beaches and Coastal Systems

Submitted by
Beaches and Shores Resource Center
Institute of Science and Public Affairs
Florida State University

June 2011

I. Overview of The Coastal Modeling System (CMS)

The CMS has been a research and development area of The Coastal Inlets Research Program (CIRP) at the United States Army Corps of Engineers - Engineering Research and Development Center (USACE-ERDC), Coastal and Hydraulics Laboratory (CHL) since 2006 (Buttolph et al. 2006). The system is a coordinated system of major multidimensional numerical models integrated to simulate waves, currents, water level, sediment transport, and morphology change in the coastal zone. Emphasis is on navigation channel performance and sediment exchanges between the inlet and adjacent beaches in the coastal zone. The CMS has been verified with field and laboratory data.

CMS-Flow is a component of the CMS. CMS-Flow is a finite-volume, depth-averaged numerical model which can compute hydrodynamics (water levels and current flow velocity), sediment transport, and morphology change (Camenen and Larson 2007).

CMS-Wave is another component of the CMS. The model is a 2-D wave spectral transformation (phase-averaged), which calculates spectral wave propagation including refraction, diffraction, reflection, shoaling and breaking (Lin et al. 2008).

For the current study, the CMS Model was utilized to simulate the hydrological impacts on the St. Augustine inlet area by a historical storm. The Thanksgiving Storm of 1984 was selected for this task due to its track and landfalling location and a long 3 days duration affecting the St. Augustine Inlet area.

II. CMS Model Set-up for the St. Augustine Inlet Area

<u>Bathymetry</u>

The study area covers an alongshore distance of 28.2 km and an across shore distance of 23.8 km in St. Johns County. The bathymetry for river, inlet, nearshore, offshore and beach areas from multiple data sources were compiled as shown in Table 1.

Table 1: Various data and its sources used in study area

Area	Resource	Date	Datum	Projection
Inlet	FDEP Sounding	10/2009	NAVD88-ft.	NAD83 State Plan East
R70-R128	FDEP Profile Survey	04/2008	NAVD88-ft.	NAD83 State Plan East
Borrow Area	USACE via Taylor Engineering	08/2008	MLLW-ft.	NAD83 State Plan East
		12/2007	NAVD88-ft.	NAD83 State Plan East
Land, Jetties	USGS LIDAR	2007	NAVD88-m.	NAD83 Geographic
Offshore, Rivers	NOAA Navigation Charts	1983	MLW-ft.	NAD83 Geographic

Before these bathymetry datasets were used to build a CMS grid, the horizontal plane was set to UTM Zone 17, NAD83 in meters and the vertical datum was converted to mean sea level in meters. Figures 1 and 2 show a result of bathymetry applied in the study area.

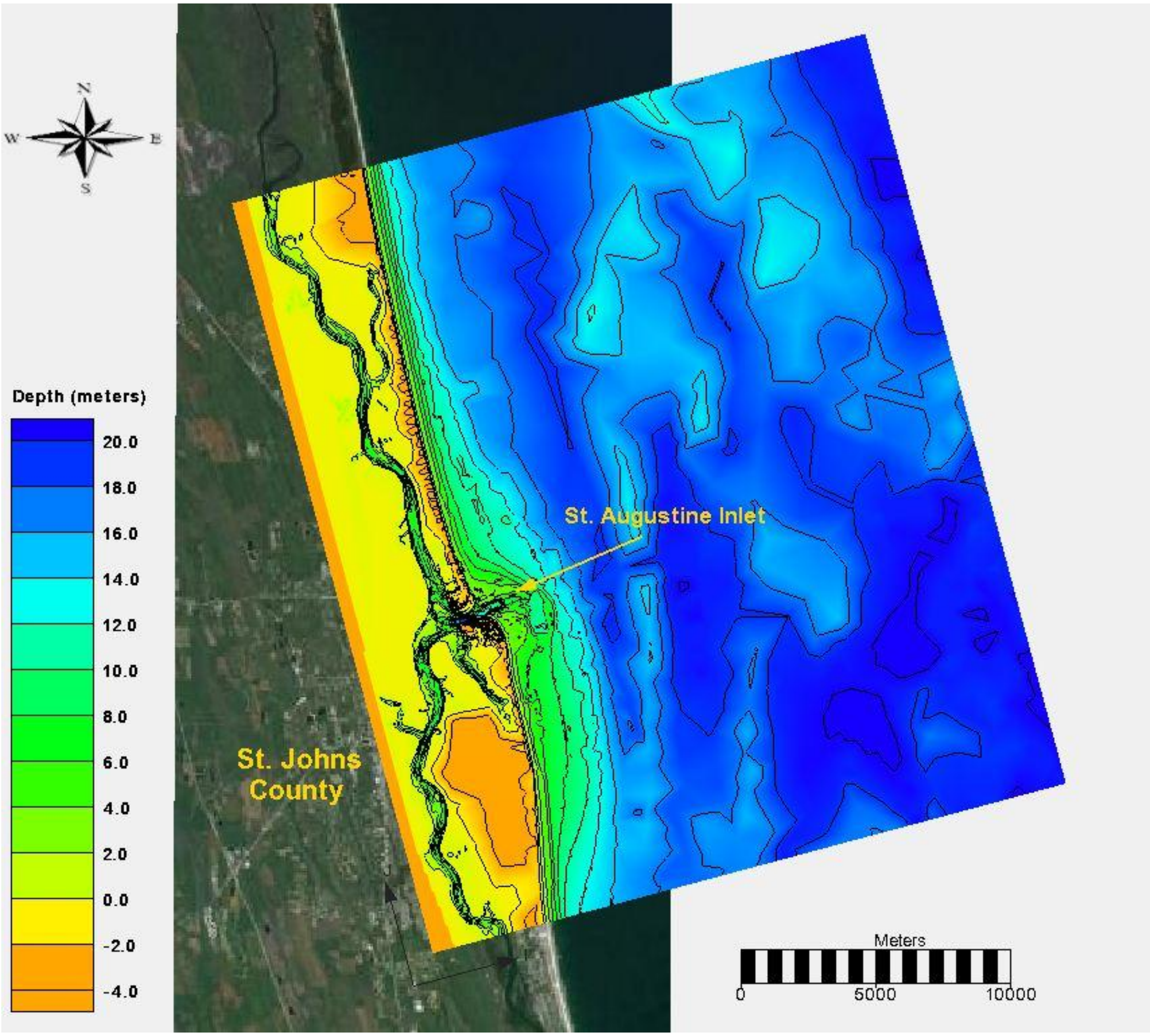

Figure 1: General view of bathymetry in the project area.

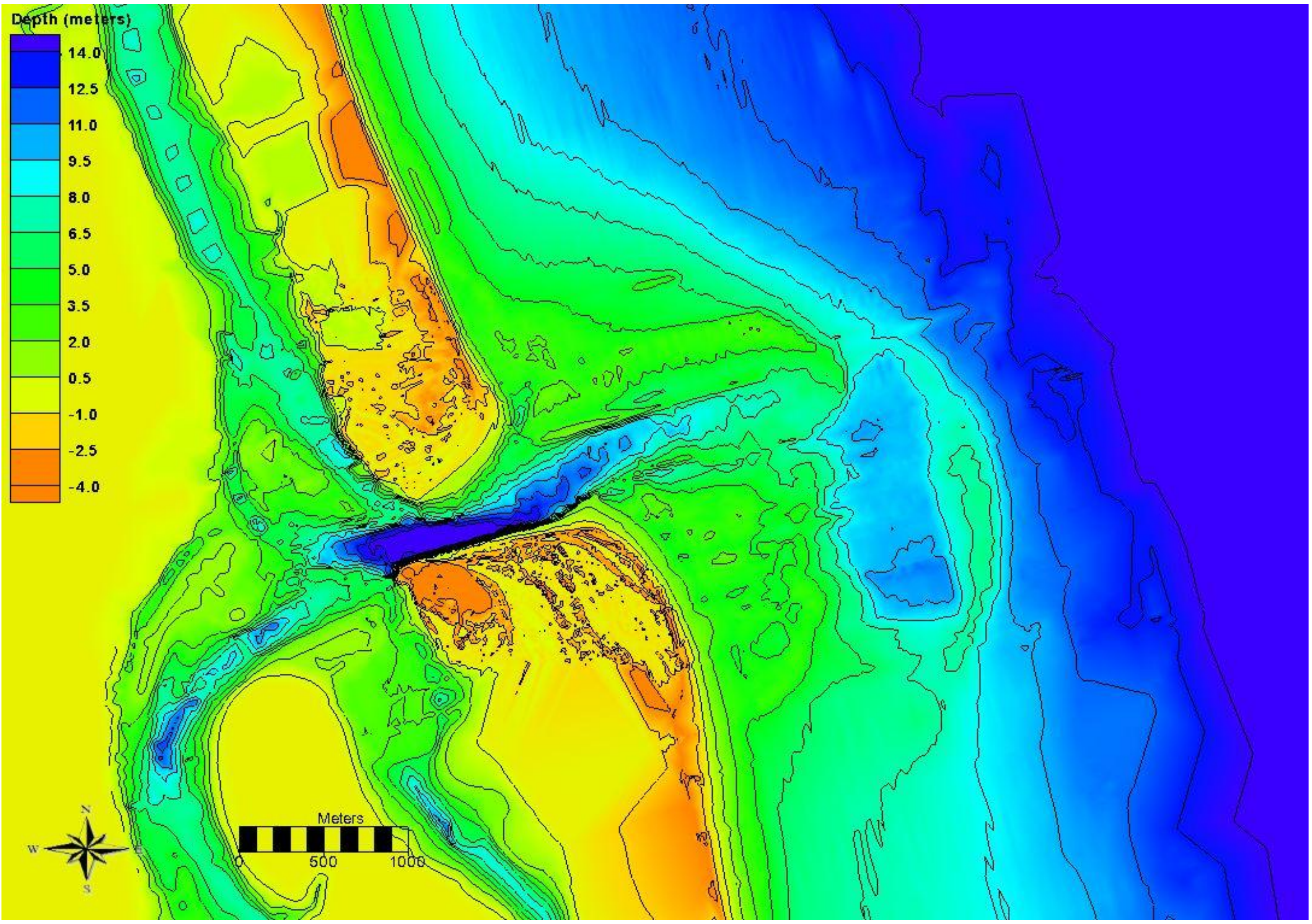

Figure 2: A close-up view of bathymetry for the inlet area.

CMS Model Grids

The CMS model grid for the flow and sediment transport was generated first and the same grid was transformed 180 degrees in the cell orientation for the waves. The main inlet, borrow area and the shoreline were the primary areas of focus, where the cell sizes were refined to 10 m by 5 m. The largest cell size at the offshore boundary is 80 m by 120 m. A total of 490,958 cells cover the grid distances, 28.2 km in alongshore and 23.8 km in across shore directions (Figure 3). Figure 4 shows a detailed view of the inlet area.

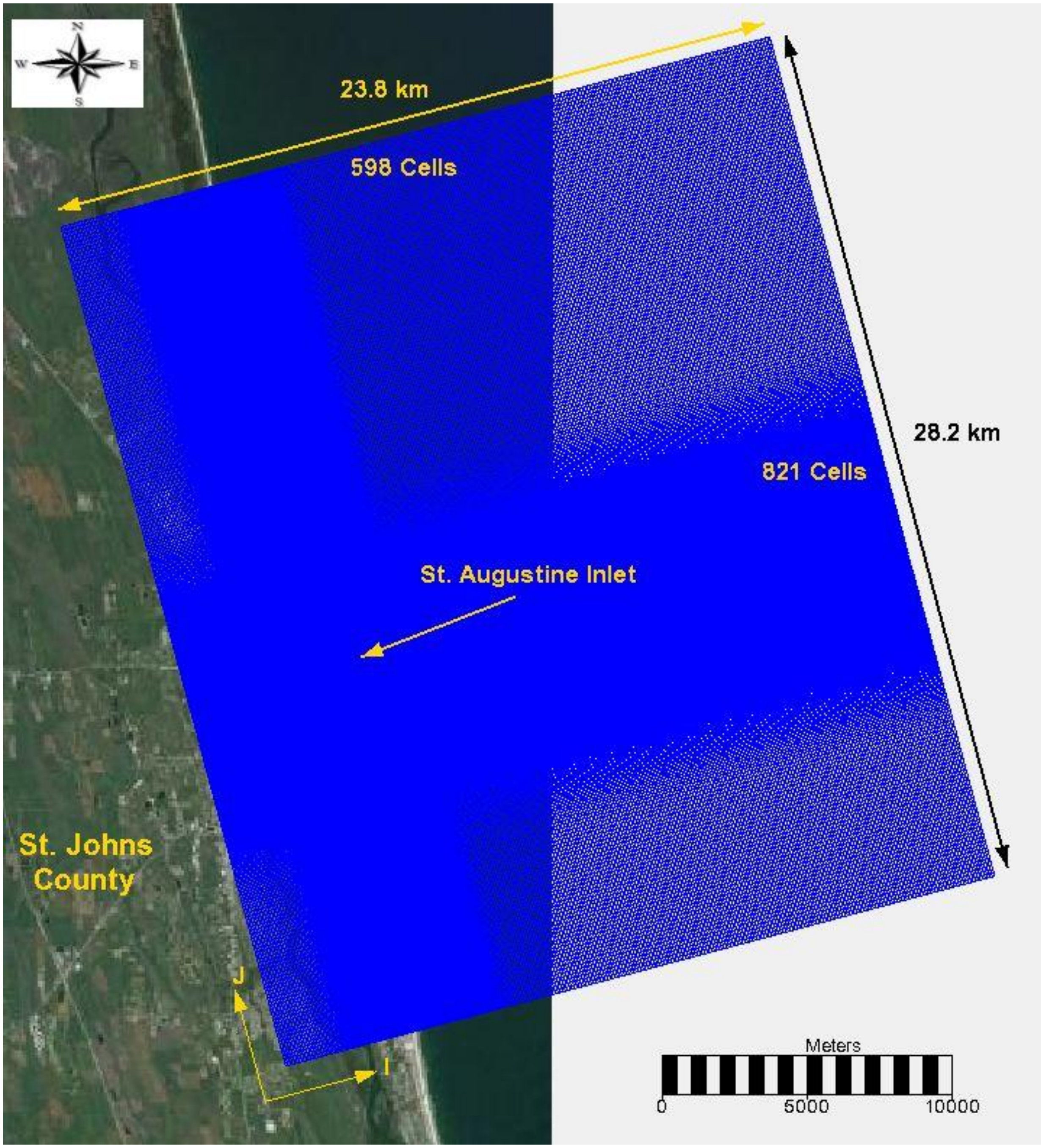

Figure 3: A general view of the grid set-up.

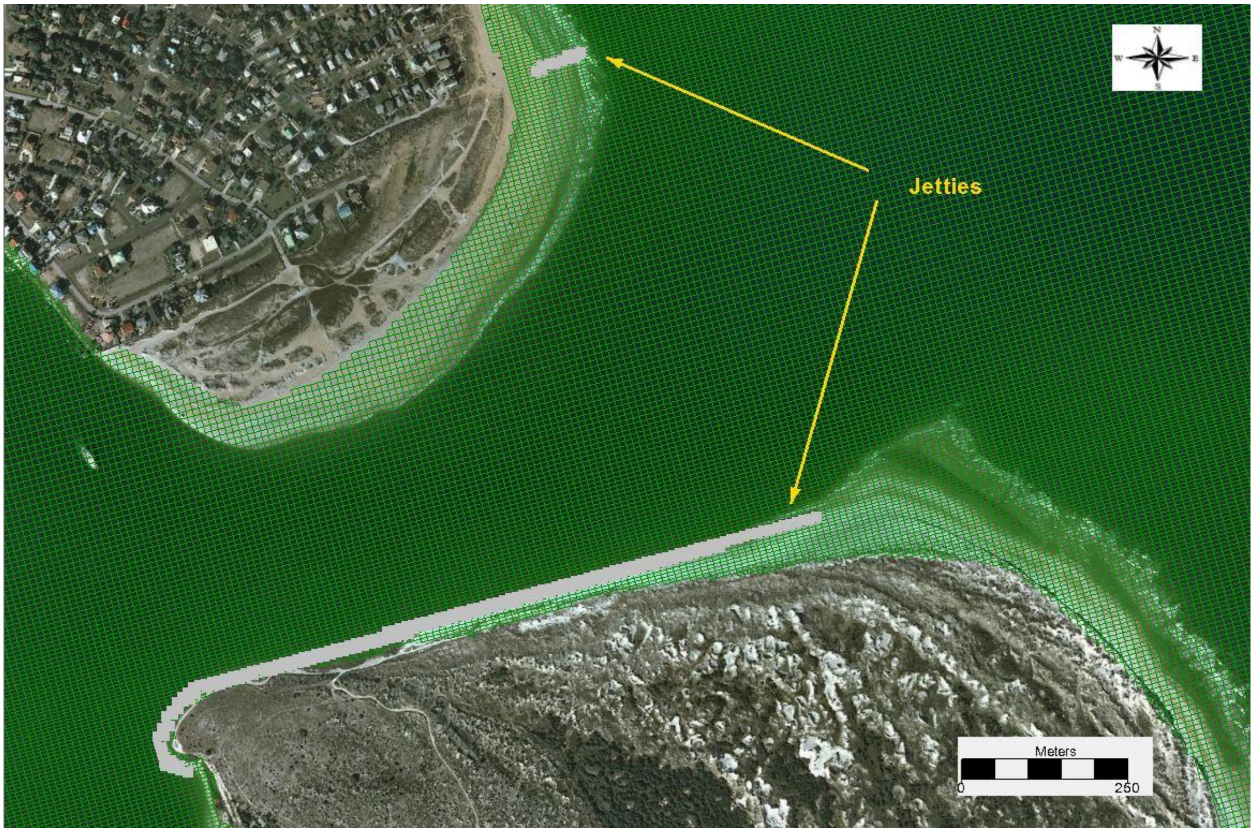

Figure 4: A detailed view of the small cells, 10 m by 5 m, in the inlet area.

CMS-Flow Model Controls

The boundary conditions for CMS-Flow were assigned with the ocean cell strings. The ocean boundary condition was set to the calculated storm surge levels of St. Johns County during the Thanksgiving Storm in 1984 (Dean, et al 1993) and is shown in Figure 5.

The CMS-Flow and CMS-Wave models are able to incorporate wind data to refine the hydrodynamic and wave propagation calculations. The wind speed and direction for the Thanksgiving Storm of 1984 were imported from WIS Station 63417 as input and are shown in Figures 6 and 7.

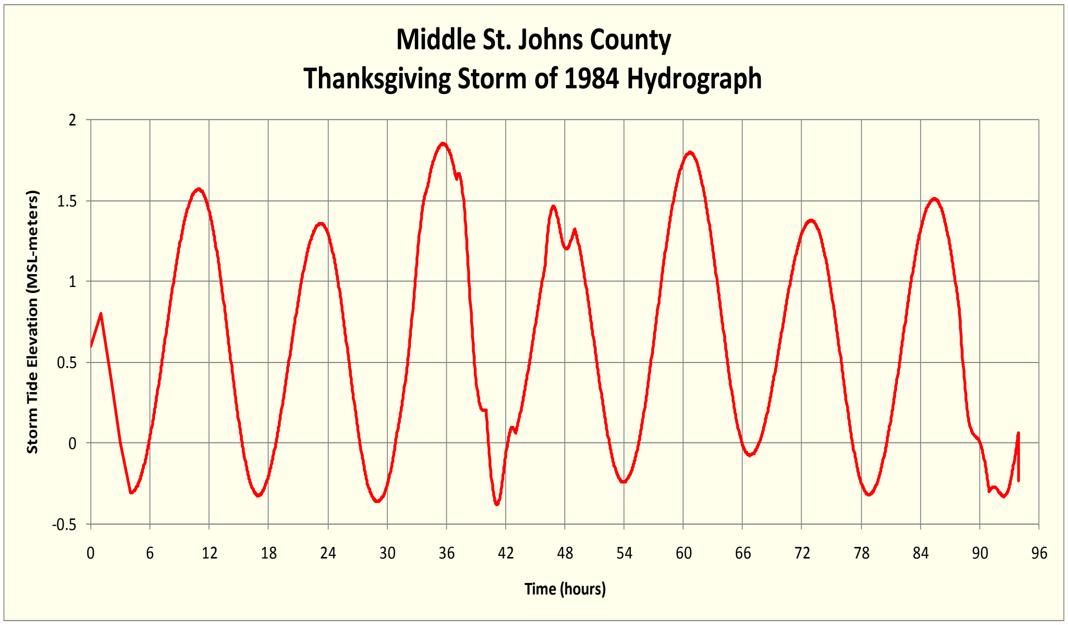

Figure 5: Calculated hydrograph of Thanksgiving Storm of 1984 in the middle St. Johns County.

As a user-specified option, CMS-Flow calculates sediment transport rates and resultant changes in water depth through gradients in the transport rates. Three transport rate formulations are available in CMS-Flow Version 8.5h:

a. The Lund-CIRP (Camensen and Larson 2007) formula computes both bed load and suspended load transport rates and combine both to obtain a total load transport rate.

b. The Watanabe (1987) formula produces a total transport rate, estimating the contributions of combined suspended sediment load and total load in a “calculation-at-a-point” formulation.

c. The van Rijn (2007a,b) transport formula uses separate equations for suspended and bed loads.

The Non-equilibrium Transport (NET) model with the Lund-CIRP formula were selected to calculate transport rate for combined waves and current. Table 2 lists all the parameters in CMS-Flow model used in the current study. Sediment density, water density, water temperature, bed load scaling factor, suspended load scaling factor, sediment porosity, bed load coefficient, and morphologic acceleration factor were set to their respective default values.

Table 2: CMS-Flow Model Input Parameters

Model Parameter		Transport		Wind
Start Date	11/21/1984	Transport Rate Time Step	0.6 sec.	Imported from WIS Station 63417, as shown in Figures 6 and 7.
Start Time	12 a.m.	Morphologic Time Step	3 sec.	
Simulation Duration	94 hr.	Hard Bottom	Jetties	
Ramp Duration	3 hr.	D50	0.15mm	
Hydrodynamic Time Step	0.3 sec.			
Others	Default Values	Others	Default Values	

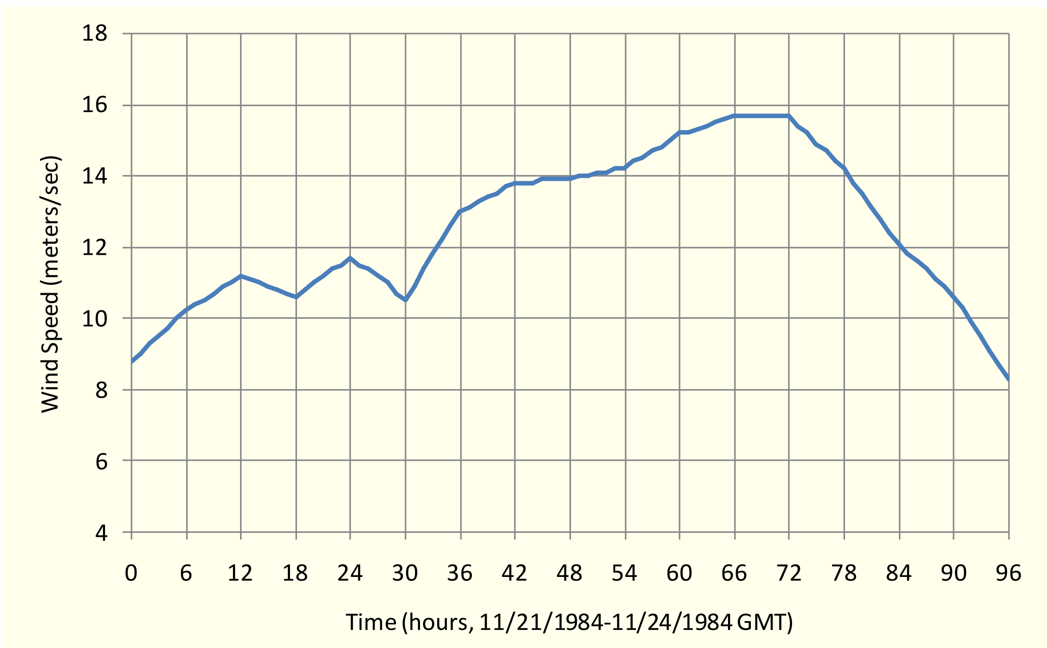

Figure 6: Wind speeds for Thanksgiving Storm of 1984.

Figure 7: Wind directions for Thanksgiving Storm of 1984.

CMS-Wave Model Controls

Full directional hourly spectra was imported into the SMS for the CMS-Wave Model from WIS Station 63417. Figure 8 shows the spectra for hour 64. A spatially constant friction coefficient, cf, of 0.0175, which was recommended by Dally (2009) for St. Johns County between deep and shallow water, was applied in this study .

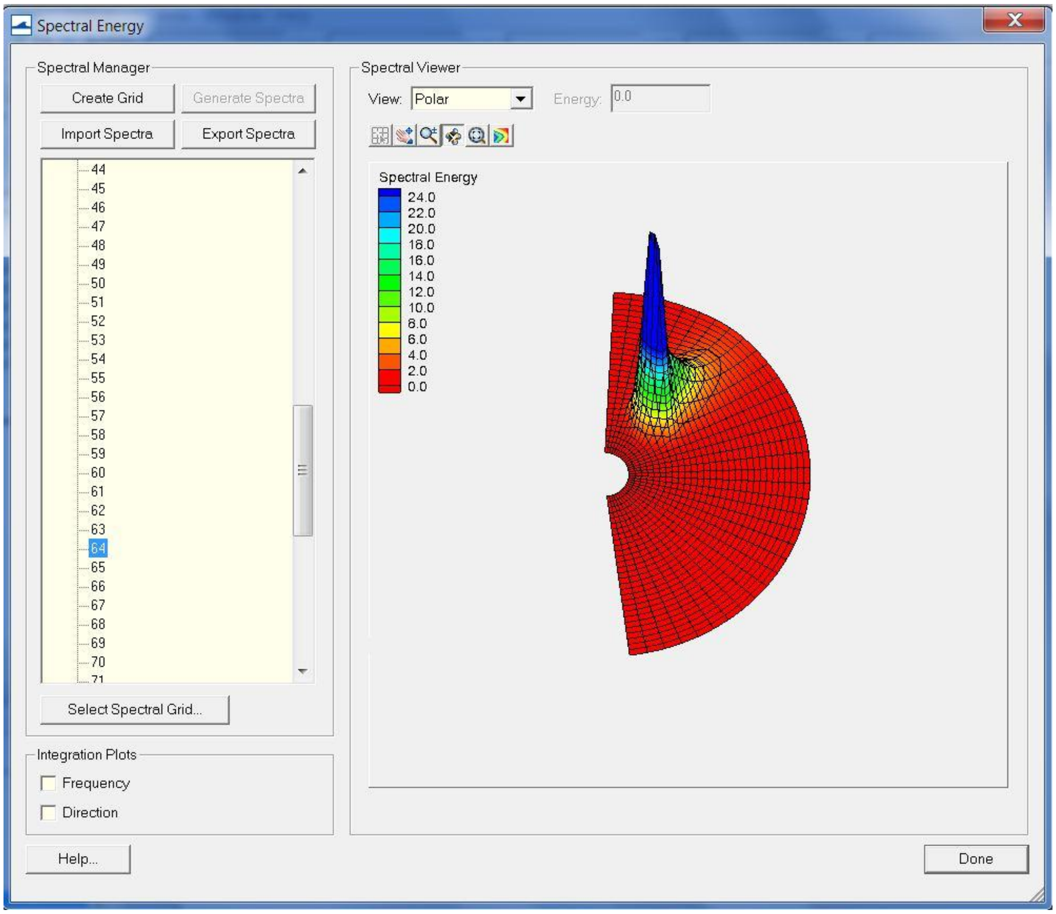

Figure 8: Wave spectrum data for Thanksgiving Storm of 1984.

The CMS-Flow and CMS-Wave models were tested separately to make sure there were no problems with their grids, or input parameters. Once the CMS-Flow and CMS-Wave models had been setup properly and loaded in SMS, the process of coupling (steering) the CMS-Flow and CMS-Wave models was initiated. First the wave model was run twice at time zero to the first steering interval. The wave information was then interpolated on to the flow grid and the flow model was run from time zero to the first steering interval. The flow information is then interpolated on the wave grid and the wave model was run for the second steering interval and the process was repeated until the simulation was complete. The steering interval was set to one hour and the simulation duration was 94 hours.

III. Output Results

Results from the 94 hours simulation runs were set to output every hour for morphologic changes, bathymetries, water levels, flow directions, wave heights, wave directions through out the entire grid system. Some plots for selected time step are presented in Figures 9 to 12. Video clips to show the history of those above mentioned outputs are attached with the report.

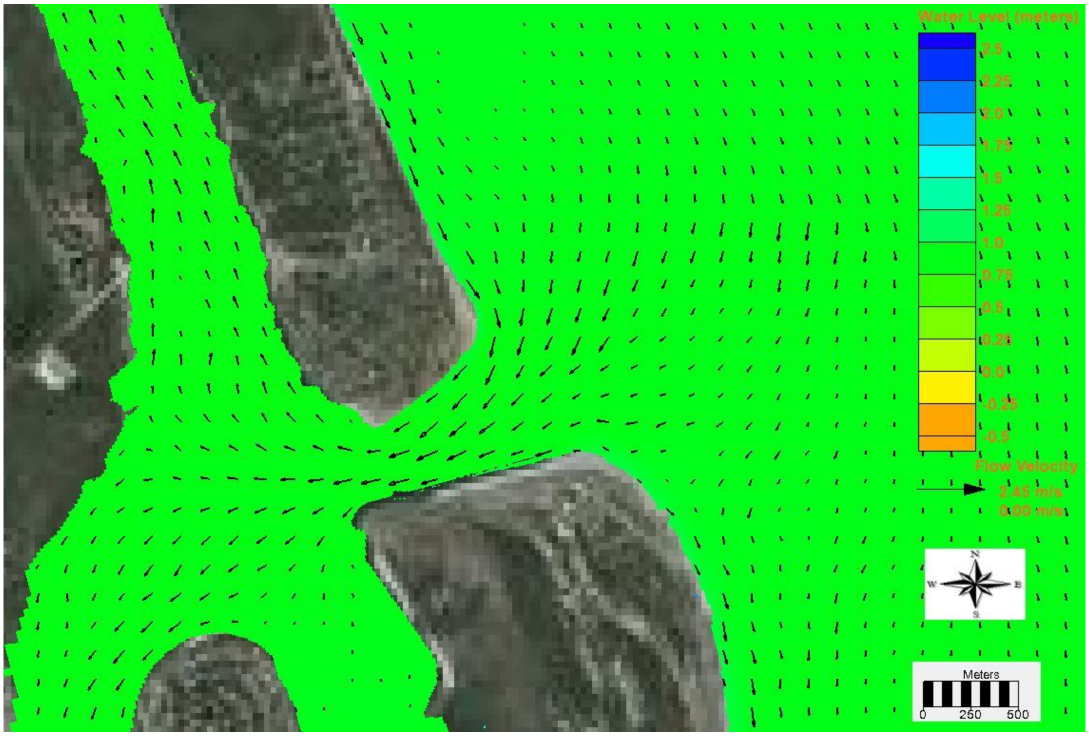

Figure 9: Water level and flow velocity at 65th hour run.

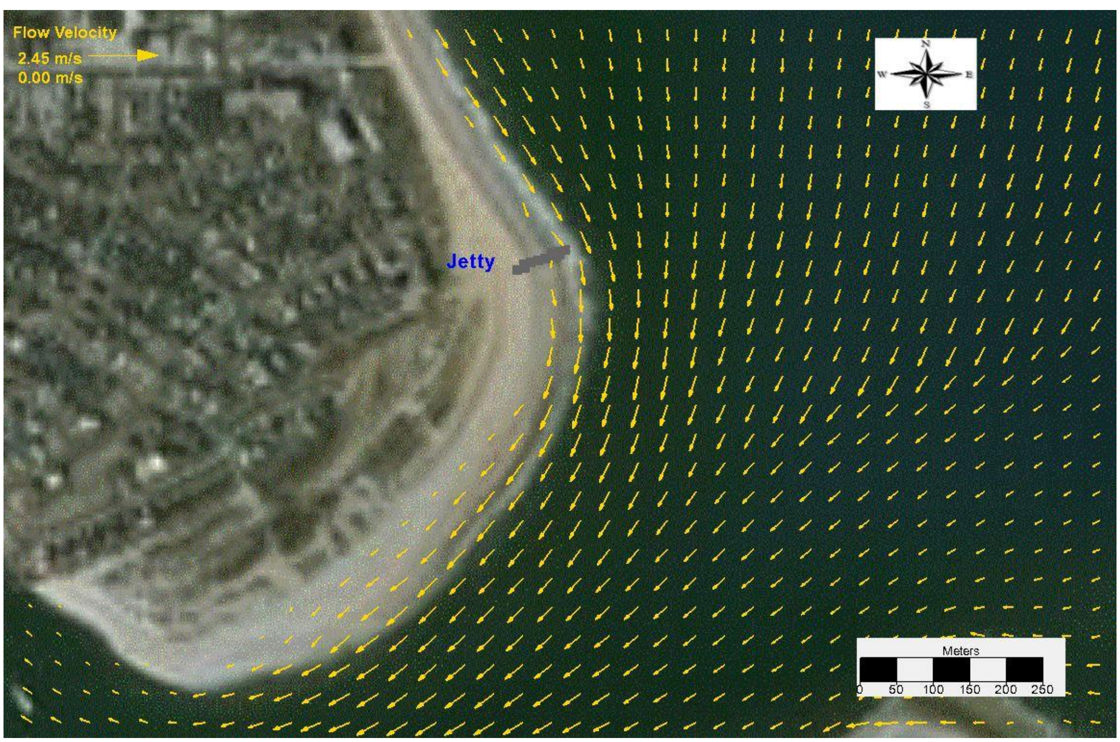

Figure 10: Close-up view of flow pattern around jetty area.

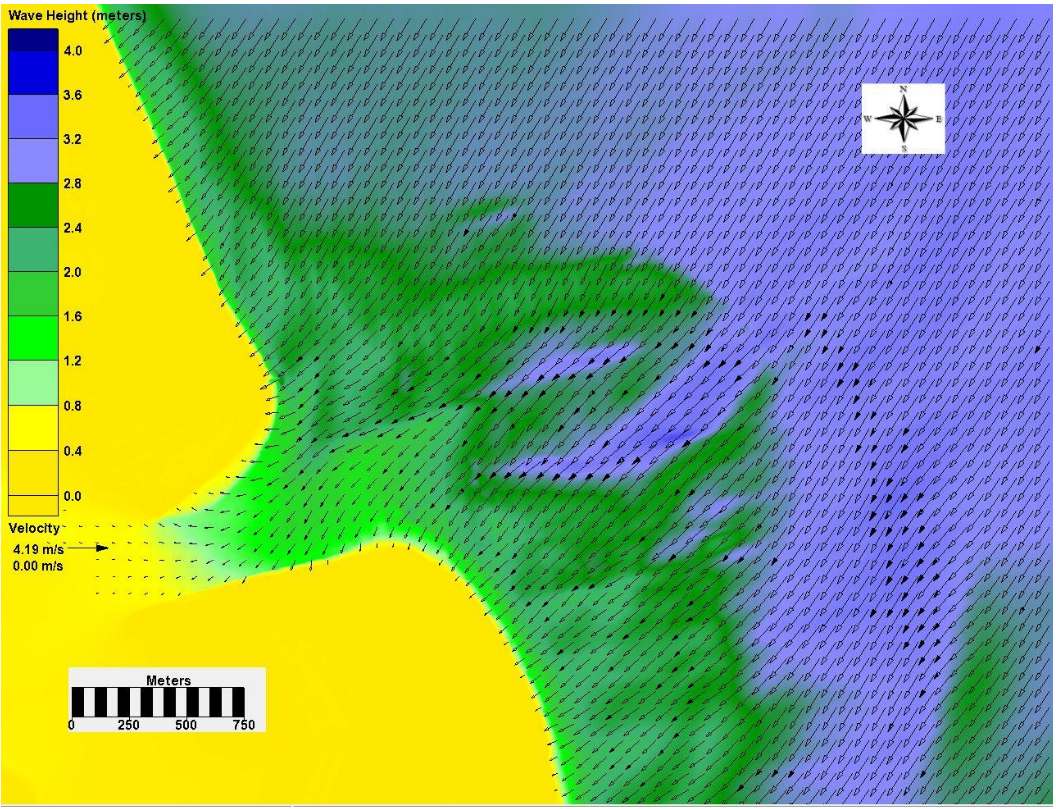

Figure 11: Wave velocities and wave heights at 66th hour run.

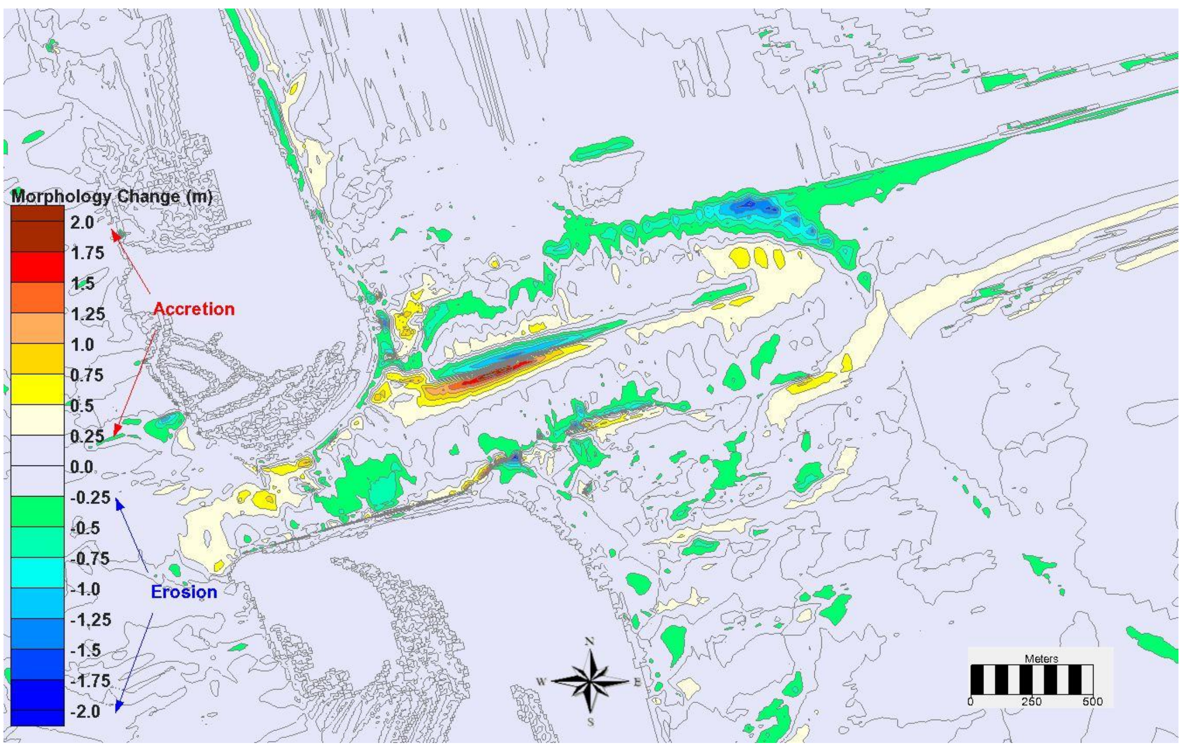

Figure 12: Morphologic Changes at the end of simulation run.

IV. Conclusions and Recommendations

1. Results from the simulation runs for the Thanksgiving Storm of 1984 in the St. Augustine inlet area were reasonably calculated by the CMS models as shown in the previous section. For example, erosion along the shoreline north of inlet and slight erosion inside channel were presented. And persistent NE wind/wave direction caused shoal migration southward was as expected. There was no field surveyed data before and after the storm available to verify the accuracy of these model calculations. The study, therefore, had used the most updated bathymetry data and had followed the best recommendations from the model developers (Reed and Lin 2011) to set up the model controls.

2. The field surveys play an important role in the inlet study. It will be very beneficial for future studies if more detailed bathymetry surveys are available. For example, the models need at least ground survey every 500 ft. for the beach and upland areas and sounding arrays every 100 ft. for the nearshore area. Ebb and flood shoals need to be identified and measured if possible. LIDAR data is useful for low land area and can be used to fill the gap between beach ground surveys and to present shoreline and jetties.

3. The CMS models have the capability to generate variable cells within a grid domain. The smallest cells were set as 10 m by 5 m to represent inlet area and jetties in great detail. The offset in using small size and a great number of cells for a project is an increase of model run time. The 94 hours simulation of the Thanksgiving Storm in this study took about 130 hours for a PC with 4 processors to run for wave, flow and sediment transport.

For the long term cases like monthly, seasonal, and yearly prediction of sediment transports and flows, it is necessary to increase the cell sizes and/or reduce the grid domain to control the model run time within a reasonable range. Increasing the PC multiprocessor number is a viable solution to speed up the calculations.

4. The CMS models are in the process to include onshore, offshore, roller, and undertow sediment movements in the current alongshore sediment transport processes. The next version of SMS, due later in 2011, will include the telescoping function to make grid generation easier and more versatile. Therefore, it is important to keep up with the model advances and revisions, so the model results from a study are accurate and refined to the present standard.

V. References

1. Buttolph, A. M., C. W. Reed, N. C. Kraus, N. Ono, M. Larson, B. Camenen, H. Hanson, T. Wamsley, and A. K. Zundel, “Two-Dimensional Depth-Averaged Circulation Model CMS-M2D: Version 3.0, Report 2, Sediment Transport and Morphology Change”, Coastal and Hydraulics Laboratory Technical Report ERDC/CHL-TR-06-7. Army Engineer Research and Development Center , Vicksburg, MS, 2006.

2. Camenen, B., and Larson, M., “A unified sediment transport formulation for coastal inlet application”, *Technical report ERDC/CHL CR-07-1*, US Army Engineer Research and Development Center, Vicksburg, MS, 2007.

3. Dally, W.R., “Development of a Nearshore Synthetic Wave Record for St. Johns County, Florida”, Melbourne beach, Florida, March 2009.

4. Dean, R. G., Chiu, T. Y. and Wang, S. Y. “High Frequency Storm Hydrograph Development and Erosion Model Calibration”, Dept. of Coastal and Oceanographic Engineering, U. of Florida, and Beaches and Shores Resource Center, Florida State U., March 1993.

5. Lin, L., Z. Demirbilek, H. Mase, J. Zheng, and F. Yamada, “CMS-Wave: a nearshore spectral wave processes model for coastal inlets and navigation projects”, Coastal Inlets Research Program, Coastal and Hydraulics Laboratory Technical Report ERDC/CHL TR-08-13. Army Engineer Research and Development Center, Vicksburg, MS, 2008.

6. Reed, C. and Lin, L., Personal Communications, 2011.

7. van Rijn, L.C., "Unified View of Sediment Transport by Currents and Waves. I: Initiation of Motion, Bed Roughness, and Bed-load Transport", Journal of Hydraulic Engineering, 133(6), 649-667, 2007a.

8 van Rijn, L.C., "Unified View of Sediment Transport by Currents and Waves. II: Suspended Transport", Journal of Hydraulic Engineering, 133(6), 668-689, 2007b.

9. Watanabe, A. "3-dimensional numerical model of beach evolution," Proceedings Coastal Sediments '87, ASCE, 802-817, 1987.