COASTAL WATERSHED IMPACTS: MODELING HYDRAULICS, HYDROLOGY, AND SEDIMENTS IN THE WEEKS BAY, ALABAMA

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ABSTRACT

Through the use of multiple models the goal is to present a clear defined approach for modeling an entire coastal watershed. Determination of holistic watershed impacts is critical in understanding the dynamics and interactions among the transitions (surface water, water infiltration, groundwater, brackish effects, soil erosion, and sediment transport) in the system. For examination of hydrology, hydrodynamics, and sediment, the demonstration site Weeks Bay, Alabama is selected. Weeks Bay Watershed is a diverse environment that contains rapid urban development, agricultural use, and natural habitat. Both urban and agriculture usage potentially increase runoff and change sedimentation behavior in the estuary, rivers, and watershed. Determination and interaction of the surface flow, groundwater flow, and sediment flux require a multi-model approach for analysis. In this study five models, GSSHA, HSPF, ADH, Hec-Ras, and SBT, are implemented and interconnected to quantify flows and sedimentation tendencies for the watershed-bay system. Multiple models are used such that solutions are targeted in a way that inter-model validation is achievable. Currently, completed work consists of: 1-D and data oriented sediment budget for the tidally influenced surface waters; 2-D shallow water ADH model setup with preliminary runs; HSPF model of the watershed, and GSSHA model set up for the Magnolia Watershed. Future work will consist of a 2-D shallow water ADH sediment model, and a 2-D surface water and groundwater GSSHA model. By implementing these models the modelers will help direct future work, both locally in the study site and globally by demonstrating model connections for work at other locations.

OBJECTIVE

The object of this study is to demonstrate the effective use of joining multiple models to model both the watershed and receiving waters in an attempt to understand watershed interactions as related to flow, sediment, and salinity. The work builds off of underway and completed work/projects.

Magnolia River 1 (upstream)

Donkey Farm near Noltie Creek

Irrigation land near Weeks Creek

Grassy land near Pensacola Branch

STUDY AREA

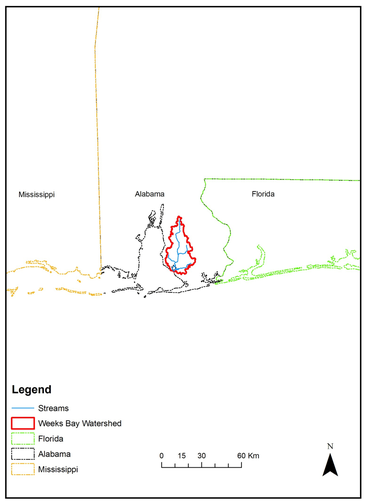


Figure 1. Study area

The study area, Weeks Bay, is an estuary located north of the Gulf of Mexico in Mobile Bay, Alabama. It covers approximately 3,000 acres with a watershed of 200 square miles (Figure 1). Weeks Bay Watershed is a diverse watershed that contains rapid urban development, agriculture, and natural habitat. Multiple site visits were conducted during which twenty seven channel cross-sections were surveyed and sediment samples where collected. In addition existing data was collected and compiled.

WATERSHED

HYDROLOGIC SIMULATION PROGRAM – FORTRAN (HSPF)

The HSPF software is a conceptual, continuous, lumped parameter watershed model that has been extensively used around the world since 1980. The Fish River USGS stream flow station (near Silver Hill, 02378500) was used in the hydrological calibration. The design period was set up from 1996 to 2007. The hydrological delineation and corresponding HSPF application are shown in figures 2 and 3. The basic HSPF model was generated from within BASINS but it was further improved manually. Hydrological calibration was performed using the Parameter Estimation Tool (PEST). The results and were subsequently improved manually. The calibration period was established at: 1998-2000. Figure 4 shows the results of the calibration. Determination coefficient (r^2) and Nash-Sutcliff (NS) coefficient values of 0.64 (correspondingly) were calculated.

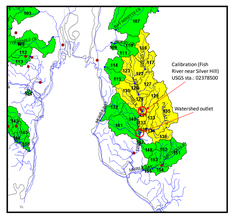


Figure 2. Watershed delineation

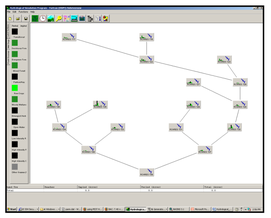


Figure 3. HSPF model application to the Fish River watershed.

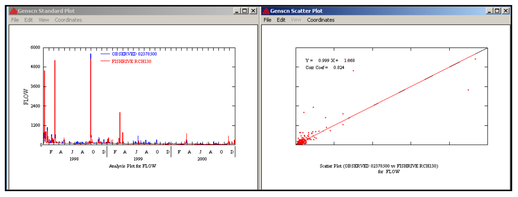


Figure 4 Calibration of the HSPF model application to the Fish River watershed.

GRIDDED SURFACE SUBSURFACE HYDROLOGIC ANALYSIS (GSSHA)

GSSHA is a physics based watershed model simulating 2D overland flow, 1D channel flow, surface water/groundwater interaction, and contaminant transformation & transport processes.The model was applied to simulate surface runoff in the Magnolia River watershed. The Magnolia River watershed is located in the right lower side of the Weeks Bay watershed. Model grid size was 100 m x 100 m yielding 4,472 grids (Figure 5). NEXRAD stage IV rainfall data were input from 01/01/2008 to 3/30/2008 (Figure 6). Preliminary results are shown in Figure 7. Further calibration is required.

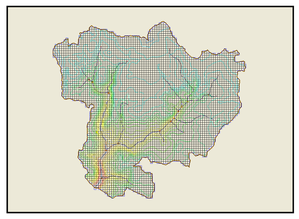


Figure 5. 100 x 100 m grid for the Magnolia River watershed

Figure 6. 4km x 4km radar rainfall

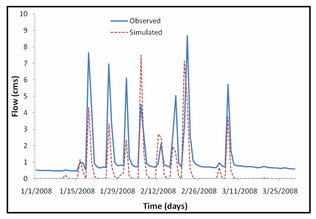
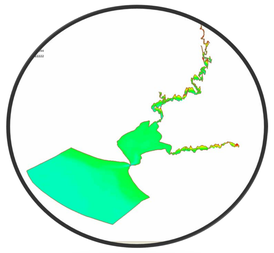


Figure 7. Result at the USGS 02378300 Magnolia River station

Wetlands on the banks of the Fish River

Fish River looking downstream at Bay



Tidally influenced area bathymetry for ADH that includes Weeks Bay, Fish and Magnolia Rivers as well as a portion of the Mobile Bay

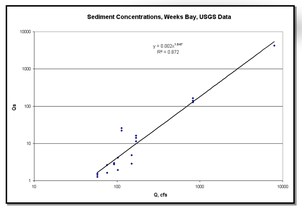


Figure 8. SBT sediment rating curve (Sharp 2009)

Table 1. SBT Results (Sharp 2009)

Comparison of Methods			
	Method, tons/year		
	Tier 1	Tier 2	Tier 3 (SIAM)
Upper	6,000	28,000	1,330,000
Lower	na	4,000	28,000
Average	6,000	15,000	525,000
Tidal Input	32,000	32,000	
Total	38,000	51,000	656,250
*Reported		22,500	
% Difference	69%	127%	2817%

RECEIVING WATERS

RIVER AND ESTUARY HYDRAULIC SIMULATION AND EVALUATION –(ADH & HEC-RAS)

HEC-RAS is a 1-D river model that is widely used to evaluate channel flows, velocity, water surface elevation, and basic sediment transport. Although not applicable for estuaries where energy is not conserved it is useful for a fundamental understanding the system. Currently, a HEC-RAS model of the Fish River was implemented in the sediment budget. Additional, modeling will include the 2-D model ADH. This a depth averaged model that uses the Shallow Water Equations on a finite element grid to solve for x and y velocity along with depth. ADH enable the simultaneous modeling of the entire system. Use of both models allows the modeler to make comparison and suggest future recommendations when only HEC-RAS is used.

USE OF THE SEDIMENT BUDGET TEMPLATE - (SBT)

Both urban and agriculture usage potentially increase sedimentation issues in the estuary and watershed. Determination of the annual sediment behavior in the system requires a sediment budget analysis. A Sediment Budget Template, SBT, developed by Sharp (2007) is implemented for additional process validation. The SBT analyzes the sources and the sinks through a multi-tiered approach to determine the annual sediment change (see Figure 8). Modifications were made to the SBT to accommodate the tidal exchange. Results indicate that estimated depositions range from 38,000 tons/year – 626,000 tons/year (see Table 1). Current approximations indicate a significant increase (70 - 2800%) in previously suggested deposition volumes (Sharp 2009). Sources are accounted for from both watershed contributions and a net positive influx from Mobile Bay.

FUTURE WORK

HSPF: extend model simulations for the entire weeks bay watershed and add the sediment module

GSSHA: extend model simulations at least one year and capture the entire weeks bay watershed; add the groundwater and sediment module

ADH: extend model runs to correspond with watershed simulations and evaluated the long term sediment process

Entire System: coupling watershed, stream and bay models

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Sharp, J. A. 2007. Sediment Budget Template for Aberdeen Pool. Master Thesis. Mississippi State University.

Sharp, J.A. 2009. Sediment Budget Template Applied to Weeks Bay, Alabama. Northern Gulf Institute Report. Mississippi State University.

NGI Northern Gulf Institute a NOAA cooperative institute

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