Statement of Need		
Submitter: **Mashriqui, Hassan**	**Organization or Field Office:**	**Date Submitted:** *7/29/2008*
Number: *SON-2008 007*	**HOSIP Date:** 7/29/08	

1 Title

Two Dimensional (2D) Modeling of River-Estuary-Ocean (REO) Interactions to Enhance Operational River Forecasting

2 Description

For several decades, National Weather Service (NWS) River Forecast Centers (RFCs) have used one-dimensional (1D) river hydraulic models to forecast stages on major rivers and analyze dam break scenarios. RFCs use either the Dynamic Wave Operational Model (DWOPER) or the Flood Wave Dynamic Model (FLDWAV) for operational forecasting. A Hydrologic Operations and Service Improvement Process (HOSIP) project is underway to transition DWOPER and FLDWAV models into Hydrologic Engineering Center - River Analysis System (HEC-RAS) models. Another HOSIP project is underway to develop specifications for including wind modeling capabilities in HEC-RAS. However, these projects do not address the inherent limitations of 1D models and the ability to obtain accurate estuary and ocean boundary conditions using 1D models.

In coastal zones where rivers widen and flow into estuaries, 1D modeling assumptions break down. Water levels near river mouths and in estuaries will vary in two dimensions depending on tides, winds, freshwater inflows, and atmospheric pressure (Gong et al. 2007; Walker 2001; Wang 1979). Observed and simulated data show that coastal waters are controlled by various meteorological phenomena such as thunderstorms, sea breeze, coastal fronts, tropical storms and hurricanes (Figure 1). These meteorological forcings work at scales ranging from 1 km for a single thunderstorm to over 100 km wide for hurricane rotational winds (USACE, 2002). Operational modeling of such a complex system requires a physically-based, 2D, or 3D model with the scientific basis to simulate responses to key forcing parameters. Although other NOAA offices run them for estuaries and oceans, these are not always routine, operational runs and linkages between these models and RFC river forecast models are limited. The difficulty in linking to river and estuary models is one reason why the farthest downstream forecast points modeled by RFCs may be hundreds of miles away from the coastal areas (Figure 2). Figures 2-4 show that large, heavily populated, coastal areas remain outside the domain of NWS routine river forecasts (Crossett et al., 2004).

Lower Mississippi River Forecast Center (LMRFC), Northeast River Forecast Center (NERFC) and Southeast River Forecast Center (SERFC) have indicated that current 1D model capabilities do not meet all of their forecasting requirements in coastal zones. Specifically, SERFC and LMRFC have attempted to use 1D models in coastal zones and have not been satisfied with the accuracy of their water level forecasts. A logical next step in improving the availability and accuracy of forecasts in coastal areas is to develop the capability to robustly couple 1D and 2D operational models. In doing so, 2D ocean and estuary models would receive freshwater inflows

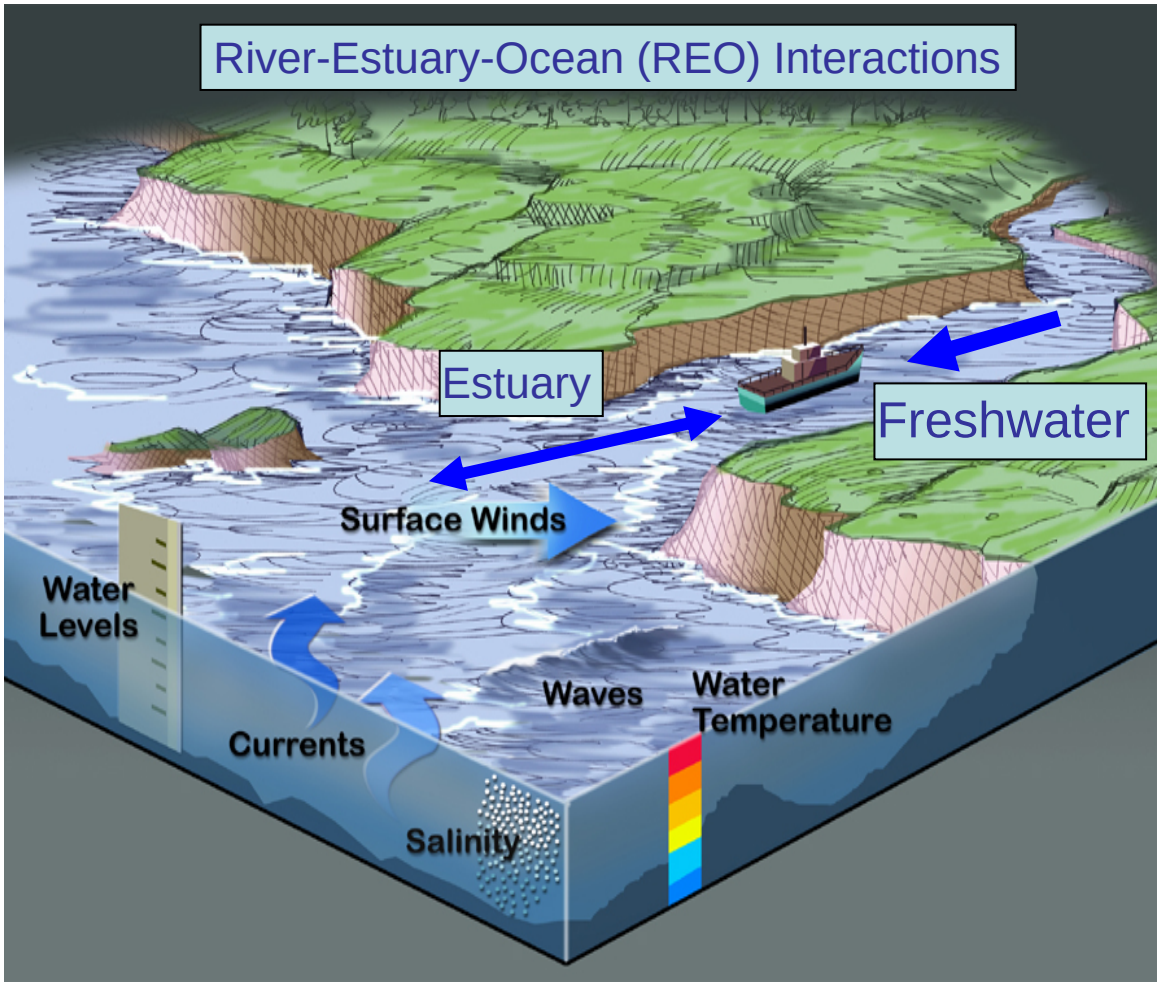

Figure 1. Schematic diagram showing complex bathymetry and topography and a few of the physical processes governing coastal water interaction of a typical River-Estuary-Ocean (REO) system. The technology exists to routinely simulate US coastal waters using 2D models for NWS daily operational needs (Modified from Dr. Frank Aikman's presentation).

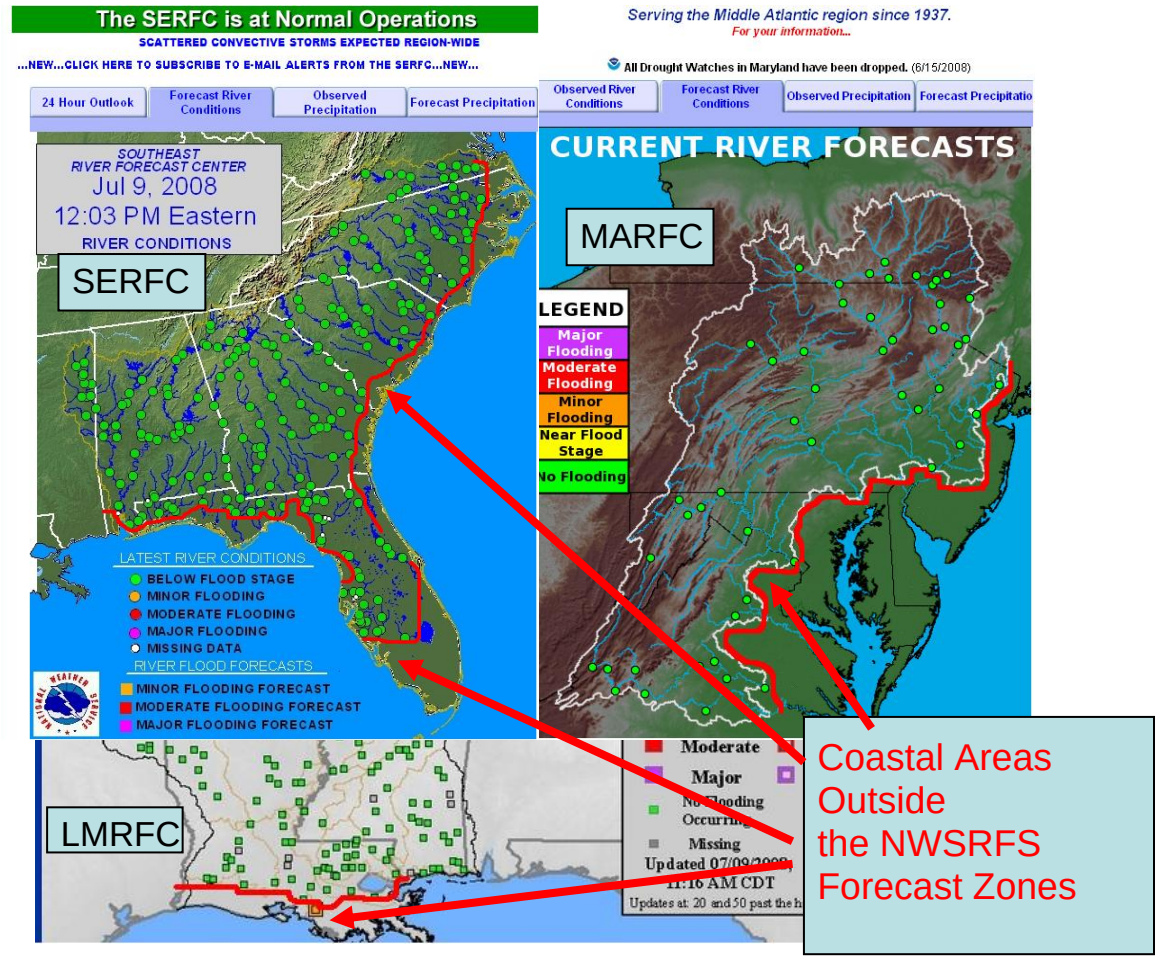

Figure 2. Coastal boundaries of the daily routine forecast points for some selected RFCs. Red lines show the approximate extent of the forecast points compared to the US coast lines. As seen from the above diagram, large parts of the coast, often heavily populated communities are outside the forecast zones. These communities are vulnerable to riverine and coastal water hazards. Note that the farthest downstream MARFC forecast location is just outside the Washington DC area. Therefore, in the event of a tropical storm, MARFC will not be able to provide river stage or storm surge forecasting to the citizens of the greater Washington DC area.

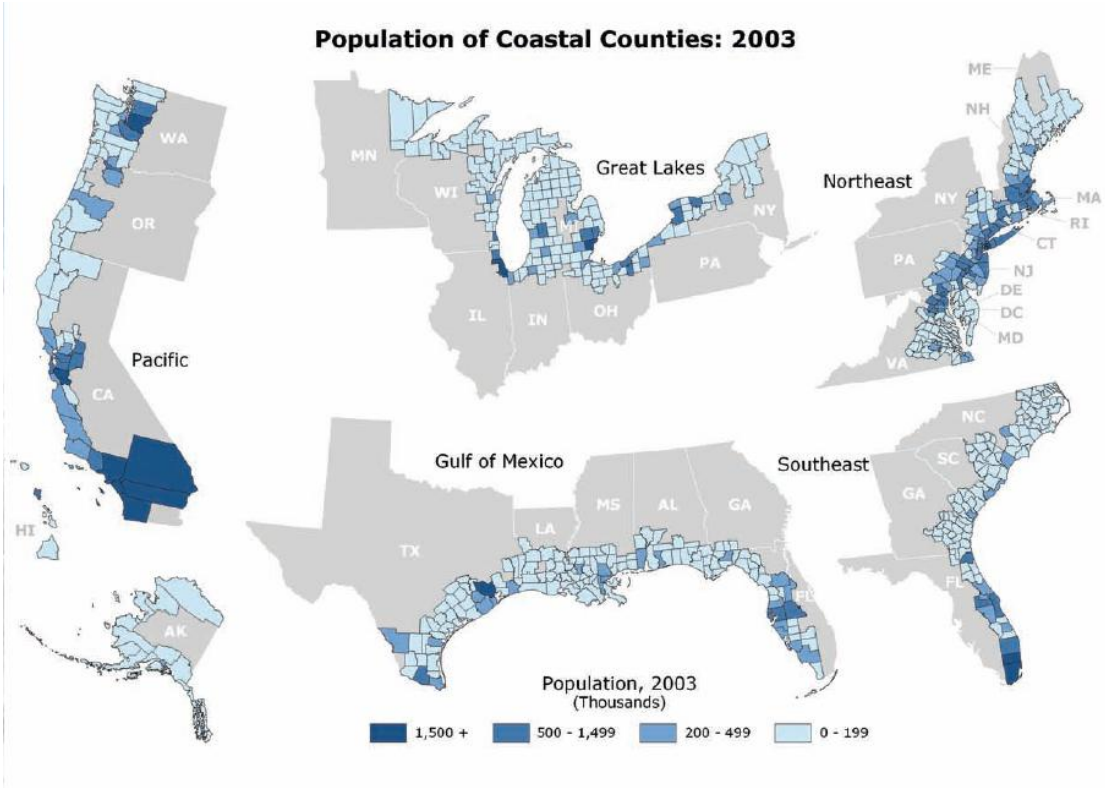

Figure 3. Coastal county population in 2003. As shown in Figure 2, large parts of these coastal populations are out side the RFCs routine river forecast zones. Source: (Crossett et al.; 2004; U.S. Census Bureau and W&PE, Inc.)

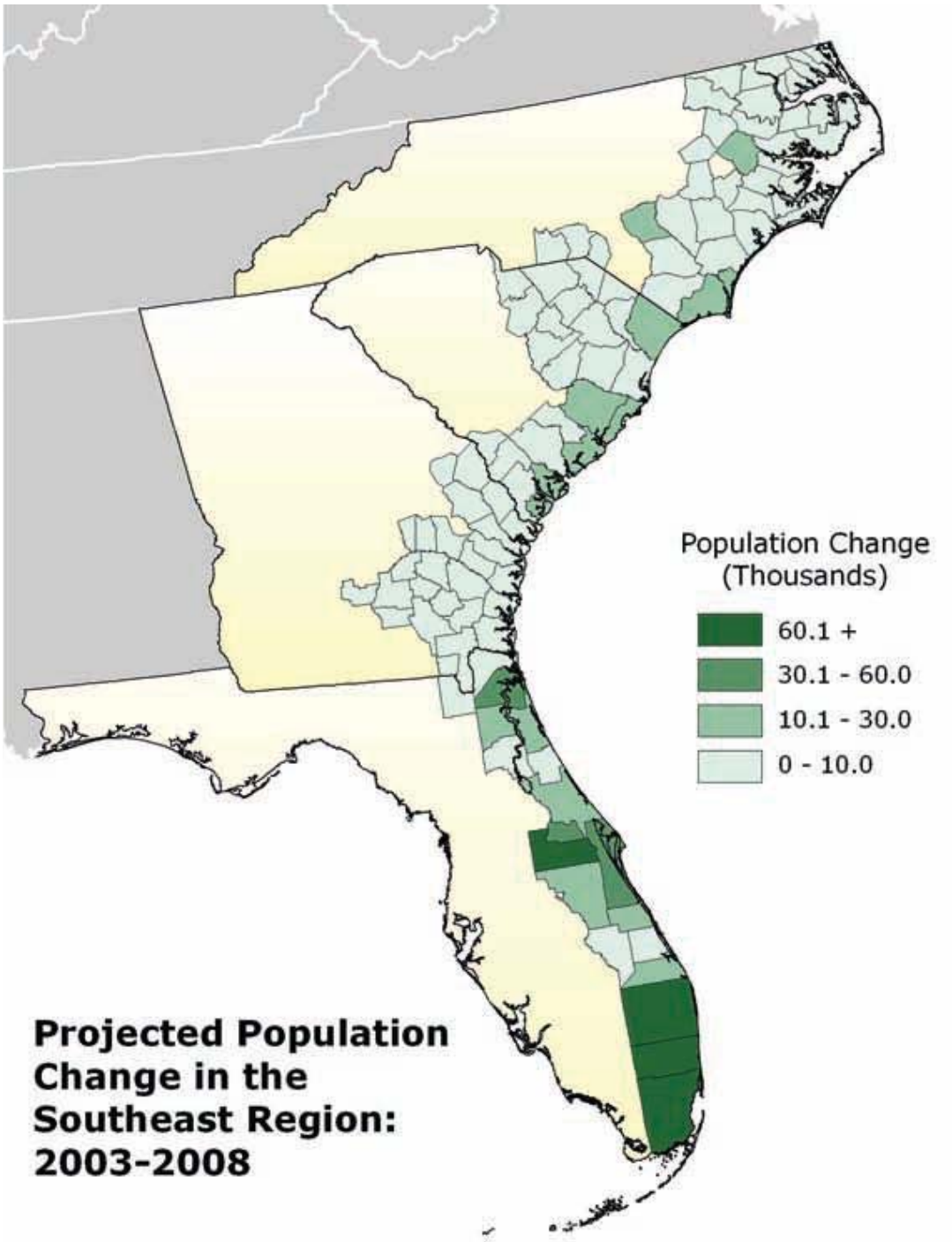

Figure 4. Projected population change in the Southeast Region: 2003-2008. (Source: Crossett et al., 2004; U.S. Census Bureau and W&PE, Inc.)

from 1D models, and 1D river models would receive stage boundary conditions from the 2D models (Figure 5). One of the challenges in doing this efficiently is to define where a 1D model should end and where a 2D model should begin.

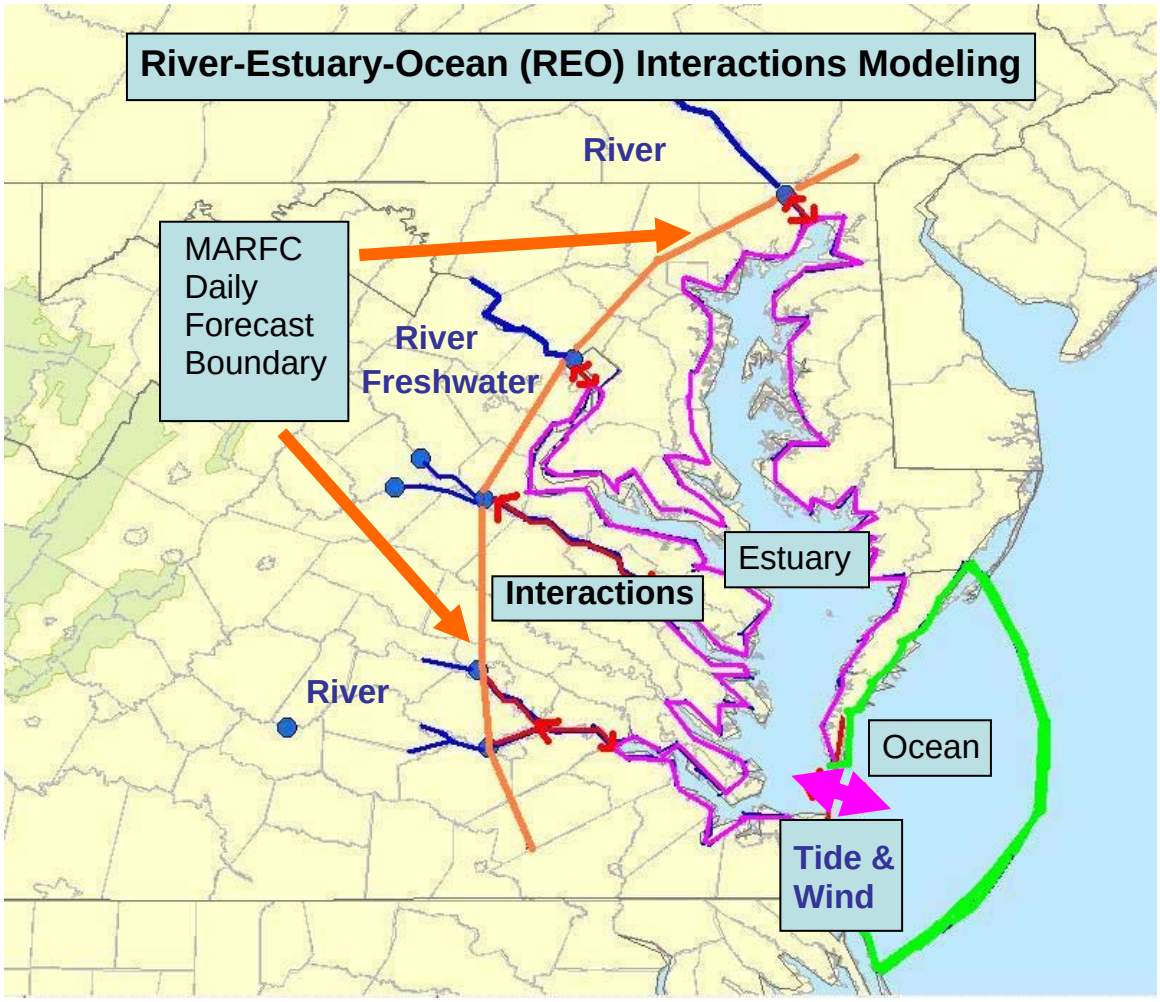

Figure 5. A Conceptual model diagram showing three major components, river inflow, estuary circulation and ocean forcing of a two dimensional (2D) River-Estuary-Ocean (REO) forecast system to support daily forecasts for the Chesapeake Bay basin. The REO modeling will link freshwater input from river models to the ocean forcing for a coastal basin resulting in accurate exchange of model states among river estuary and ocean models. The REO modeling capability can be used to improve forecast accuracy at existing locations and expand forecast services to new locations, improving the information available to the citizens of coastal communities.

This SON initiates a Hydrologic Science and Modeling Branch (HSMB) research project to evaluate "state-of-the art" two dimensional (2D) hydrodynamic models for possible use in a river-estuary-ocean (REO) forecast system. The evaluation will be done through a pilot study in which several models are implemented and validated over the same domain. Criteria considered in the evaluation will include:

- model accuracy
- ease-of-use
- computational requirements
- compatibility with NWS operational systems
- licensing costs
- availability of training and support

The study will define the costs and benefits of the REO model in sufficient detail to aid decision makers on implementation related decisions. The study will not directly make recommendations on policy issues such as whether REO components should be run at RFCs, at an NWS national center, or within NOS, etc.; however, it will provide detailed information to aid in these types of decisions. The project deliverable will be a document that describes the methodology, results, and conclusions from the study.

Candidate models for the evaluation include: 1) the NWS Sea, Lake and Overland Surges from Hurricanes (SLOSH) model; 2) the Advanced Circulation Model (ADCIRC) model 3) MIKE 21 software products developed by the Danish Hydraulic Institute; and 4) the SOBEK model developed by the WL¦Delft Hydraulics in the Netherlands. Researchers in the academia have developed several forecast models that may also be evaluated.

3 Justification

3.1 Linkages

The REO modeling capability will enable NWS forecasters to produce reliable forecasts for events that cannot be accurately forecasted using the current 1D river models. By utilizing a "state-of-the-art" coastal model, the NWS will be able to produce more accurate forecasts at more points; consequently aiding in protecting life and property and carrying on the major objective of the National Oceanic and Atmospheric Administration (NOAA) "to Serve Society's need for Weather and Water Information".

Capabilities to model tide and wind-driven river-estuary-ocean interactions are consistent with and fulfill the primary, high-priority Office of Hydrologic Development (OHD) core goal to "1. Improve the quality of physical inputs and forcings, e.g. Quantitative Precipitation Estimation (QPE), Quantitative Precipitation Forecast (QPF), temperature, snow, evapotranspiration, soil conditions, burn data, etc." This project will also move us closer to providing an integrated "One NOAA" approach for coastal modeling and inundation mapping in flood prone areas.

3.2 Need Originator, Sponsor & Stakeholders

Originator: Hassan Mashriqui, Ph.D, PE, Hydraulic Engineer, HSMB/OHD/NWS

Sponsors: Edward J Capone, Senior Hydrologist, NERFC, Taunton, MA
David Reed, Supervisory Hydrologist, LMRFC, Slidell, LA
Peter Ahnert, Hydrologist-in-Charge, MARFC, State College, PA

Stakeholders: All RFC's & WFO's
OHD Scientists and Software Engineers
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4 Existing Capabilities and Limitations Related To The Need

RFCs are currently limited to 1D hydraulic river models in the Advanced Weather Interactive Processing System (AWIPS) baseline. As described in Section 2, this limits the applicability and accuracy of these models in coastal areas.

Within NOAA, several offices are using 2D models for coastal water simulations or forecasts. They are the NWS Extratropical Water Level Forecast, National Ocean Service (NOS) and Center for Operational Oceanographic Products and Services (CO-OPS), and the National Centers for Environmental Prediction (NCEP) Atlantic Ocean basin-scale forecast system. However, these models are not effectively linked to RFC forecast models. Without freshwater input from the NWS, these coastal models often lack critical river input resulting in inaccurate forecasts. For example, modeling done by Pietrafesa et al. (2001) worked well for hurricane Dennis (1999) but failed to perform as well when hurricane Floyd hit because antecedent conditions (including fresh water runoff from the streams/river systems) could not be accounted for. In addition, some of these models do not have the capabilities to simulate wetting and drying during flooding.

Several programs within NOAA and academia provide bathymetric and topographic data or historical and forecast oceanographic and meteorological data for all or some selected coastal locations. For example, the Coastal and Inland Flood Observation and Warning (CI-FLOW) program is focused primarily to the Tar-Pamlico River basin in North Carolina. This REO project will not duplicate any basin scale research effort rather; it will consider global operational river and estuary modeling needs from the NWS and RFC perspective. Technologies developed by such basin scale efforts can be leveraged by the NWS to create improved REO forecasts in coastal zones.

5 Benefits and Performance Impact

This project will move us closer to operational REO modeling. REO modeling provides both new capabilities and more accurate boundary conditions for existing NWS river models. A large portion of the US population will receive new and/or improved water related forecasts. Thus, an REO system will have the capability to protect lives and properties of the citizens of the United States. Coordination between the NWS and the other entities within NOAA will also be enhanced. In addition, by evaluating and using external hydraulic models, the NWS will be able to capitalize on advancements in hydraulic development tools and expertise from other entities such as the Federal Emergency Management Administration's (FEMA) Flood Insurance Studies (FIS) and the US Army Corps of engineers (USACE).

6 Constraints

None.

7 References

Crossett, K.M., Culliton, T.J., Wiley, P.C., Goodspeed, T.R. (2004). Population Trends Along the Coastal United States: 1980-2008, National Oceanic and Atmospheric Administration, NOAA's National Ocean Service, Management and Budget Office, Special Projects, September 2004.

Gong, W., Shen, J., Reay, W.G. (2007). The hydrodynamic response of the York River estuary to Tropical Cyclone Isabel, 2003. Estuarine, Coastal and Shelf Science 73 (2007)

Pietrafesa,L.J., Dickey, D. and Xie, L. 2001. Flooding Due to Hurricanes Dennis and Floyd, Chapter 2 in Environmental and Socio-Economic Impacts of Hurricane Floyd, Carolina Coastal Press.

U.S. Army Corps of Engineers. 2002. Coastal Engineering Manual. Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes).

Walker, N.D. (2001). Tropical Storm and Hurricane Wind Effects on Water Level, Salinity, and Sediment Transport in the River-Influenced Atchafalaya-Vermilion Bay System, Louisiana, USA, Estuaries, Vol. 24, No. 4, (Aug., 2001), pp. 498-508.

Wang, D. P.1979. Wind-driven circulation in the Chesapeake Bay, winter 1975. J. Phys. Oceanogr., 9, 564–572.

8 Attachments

None

9 Resource Proposal for Stage 2

Hassan Mashriqui will be the project leader and main analyst. Seann Reed will assist with project planning and review. Both Hassan and Seann are FTEs so their time will be paid through OHD base funds. The results of Stage 2 analysis will determine whether any additional resources will be required for Stage 3.

Stage 2 analysis will yield information required to properly scope and estimate the resources for Stage 3 of the project. The following activities are proposed for Stage 2:

Stage 2 – Research and Analysis	Start & End Dates
Literature review	07/2008 – 08/2008
Identify existing sources of coastal wind, tide and other forcing parameters	
Review existing River, Estuary and Ocean models (including NOAA NOS, NWS models, ADCIRC, Mike11, and SOBEK).	
Based on literature review and software availability, identify one or more models to use in the project.	07/2008 – 08/2008
Identify one or more study areas of interest to RFCs, and define modeling experiments to validate that the selected model(s) will solve RFC problems.	08/2008 – 09/2008
Write HOSIP Stage 3 Project Plan describing the experiments in more detail.	08/2008 – 09/2008

10 Appendix A - Acronym List

AHPS	Advanced Hydrologic Prediction Service
AWIPS	Advanced Weather Interactive Processing System
CHPS	Community Hydrologic Prediction System
FLDWAV	Flood Wave Dynamic Model
FY	Fiscal Year
GPRA	Government Performance and Results Act
HEC	Hydrologic Engineering Center
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HSEB	Hydrology Software and Engineering Branch
HOSIP	Hydrologic Operations and Service Improvement Process
MIKE 11	A Dynamic Flow model Developed by the Danish Hyd. Inst.
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
NWSRFS	National Weather Service River Forecast System
OCWWS	Office of Climate, Water, and Weather Service
OHD	Office of Hydrologic Development
QPE	Quantitative Precipitation Estimation
QPF	Quantitative Precipitation Forecast
RFC	River Forecast Center
SOBEK	A Dynamic Flow model Developed by the Delft Hydraulics
USACE	US Army Corps of Engineers
WFO	Weather Forecast Office

11 Approval Section

Proposed Core Goals >>>> Select from list of 21 Hydrology Core Goal (s) defined. Required for all Projects. ***Primary Core Goal is listed first.	***Primary***	Improve the quality of physical inputs and forcings, e.g. QPE, QPF, temperature, snow, evapotranspiration, soil conditions, burn data, etc
	Other	
	Other	
	Other	

Project Leader:	Hassan Mashriqui	**HOSIP Admin Analyst:**	Deb Atkins

Gate 1 Approval				**Date:**	
Office Name	**Group Leader**	**Project Area Lead**	**Branch Chief**	**OHD Architecture**	**OCWWS**
HSMB	Seann Reed		Geoff Bonnin		

Dependencies:			
Funding Secured for Stage 2:	Yes		
Are project resources available to begin work on Stage 2 activities?	Yes		
Stage 2 Expected Start Date:	July 29 2008	**Stage 2 Expected End Date:**	Sept 30, 2008

Gate 1 Review and Analysis Statement: *This section will be completed by the Gate 1 Review Committee and will define the disposition of the SON. Possible definitions could be that the SON is approved and a project initiated, the SON is approved but no project is initiated at this time, and the SON is rejected. In addition, if approved, the OHD Hydrology Laboratory Chief may designate the project as an End-to-End (E2E) Project.*