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Title: Regional-Scale Morphology Model

Topic Area: Modeling and Assessment, B2.2: Regional Morphology Model

Objective: To provide analytical techniques and a numerical model for simulating macro to micro-level sediment transport and geomorphic processes in river basins.

Problem: Numerical methods for simulating hydrologic, hydraulic, and sediment transport processes in watersheds, streams, and estuaries are useful management tools for planning and assessment. Typically, these tools are applied at the project level over a relatively short time span to provide the necessary information for predicting impacts due to changing hydraulic and sediment transport conditions. For example, an investigation of changing land use practices may dictate that a hydrologic / sediment transport study be performed to evaluate the impact of increasing runoff on local streams and tributaries. The study is typically confined to a single watershed and local streams. Although this type of study is useful on the local level, it is increasingly important to understand how changing conditions on an individual watershed contribute to the overall balance of water and sediment transported throughout the interconnected hydrologic region. Unstable channels and banks will result in increased sediment transport through tributaries resulting in localized changes in channel morphology as streams strive to achieve an equilibrium condition. This in turn may affect the stability of larger connected streams and rivers due to the change in sediment load coming from the watershed. Conversely, best land use management practices implemented at the watershed level to reduce erosion such as reservoirs, bank stabilization, and grade control will act to reduce sediment loads in tributaries and streams. These practices may stabilize the local watershed, but can potentially induce instability in larger connected streams and rivers due to the change in sediment transport. In watersheds and channels with highly erosive soils and sediments, changes in sediment transport and channel morphology can take place over a relatively short time frame, whereas areas with more resistant soils the changes may be much more gradual.

This cause and effect relationship may not be significant for a single small watershed in a river basin, but when changes in flow and sediment transport are considered within entire sediment regions, the impacts can be significant for navigation, flood control, and environmental quality. Increased sediment loads entering waterways potentially result in diminished project performance, high channel maintenance costs, reduction in aquatic habitat diversity, and water quality degradation.

Benefits: The benefits of such a regional sediment model are considerable. Planning studies can be conducted on a local watershed basis to evaluate the best land management practices to reduce erosion as well as maintain channel stability within the watershed. These studies can then be expanded to other watershed evaluations within the same sub region or to the entire river basin. Land use scenarios can be simulated to estimate impacts of increasing or decreasing sediment loads on local or main river channels. The effect of a single project feature on local processes and on the region can be evaluated. On a macro scale, estimated regional sediment loads can be routed through the main river channel for evaluation of channel response. This approach will provide the capability for evaluating either short-term response problems or long-term (decades) evaluations of watershed and channel response.

This effort addresses field needs as listed in the appendix: (1) regional scale hydrologic and sediment models for treating RSM scale problems; (2) engineering and geological time-scales across temporal and spatial scales merging non-linear dynamic modeling; (6) universal models that can provided reliable information on a regional basis; (15) combined model for short term event and long term erosion; (28) system and local effects of stabilization structures and (71) long-range (more than 3 months) sediment forecasting.

This work produces new tools and methods for the USACE and nation. It is an integral part of the Regional Sediment Management Research Program, and thus contributes primarily to support of the USACE's navigation, flood/storm damage reduction, and environmental protection and quality missions. It supports all 8 Civil Works strategic goals and 7 of 9 Listening Session objectives identified by HQUSACE as R&D priorities. With companion work units, it employs active technology transfer and insertion.

Work Description: This effort will develop Cascade-I, which will incorporate an interactive suite of numerical models providing the capability to simulate hydrologic, hydrodynamic, and sediment transport phenomena from local to sub-regional to regional scales. The modeling system will be designed to not only perform detailed one, two, or three-dimensional simulations, but also perform generalized first generation cause and effect studies on channel morphology using closed form regime-type equations. Artificial neural network (ANN) computations will provide a systematic methodology for reducing simulation time, improving simulation reliability, and increasing the simulation accuracy for each level of sediment transport analysis. The approach is to develop an alternative methodology (neuro-numerical) for combining the advantages of the numerical sediment model (physical basis and spatial estimation) and ANN's modeling approach (rapid and high accuracy) in developing effective and quick response management tools. Three scales of analysis capability are described below, with the smaller scale calculations embedded within the larger scale, and cascading up or down in scale as needed.

Local Scale. At the local scale, overland and channel sediment and flow routing will be accomplished using multi-dimensional hydrology/hydraulics/sediment transport models. At this level, rainfall/runoff relationships will be simulated, including impacts of land management practices, retention ponds or reservoirs, and channel stabilization measures / structures. Flows and transport in channels and overflows into adjacent land will be calculated using the best available physics-based algorithms, including those supplied by work units in the Processes Task Area. The GSSHA model, being improved under the "Watershed-Scale Sediment TMDL Model" work unit and the ADH model, being developed under the Multi-Dimensional Sediment Processes" work unit will form these components within Cascade-I.

Sub-regional Scale. At the sub-regional scale, flow and sediment are transported through a system of channels common to multiple watersheds in the basin. Capability will be developed for evaluating sediment transport and channel response using one- to multi-dimensional sediment transport models. Where appropriate, the one-dimensional model will be used to evaluate basic channel response such as aggradation and degradation, meandering, and bifurcation. This modeling will be accomplished using one or more of several candidate models (e.g.,a future version of HEC-RAS, WASH123, and a future version of ADH) as a base module coupled with ANN computations and the regional scale modeling

Regional Scale. Regional scale analysis consists of the entire river basin watershed and associated channels. At this scale, simulations include sediment and water routing and channel response through the entire sediment region. Analysis capabilities include channel stability and geomorphic response for all watershed channels, distributaries, the main channel, and receiving waters, including reservoirs and estuaries. The interactive models will provide the capability to conduct both broad (macro level) and detailed (micro level) studies with feedback mechanisms. The calculations will embody morphologic processes as defined by work units in the Processes Task Area. At the macro level, sediment transport and geomorphic response will be evaluated with the simplest computational model(s) to identify specific areas where significant geomorphic and channel response changes occur (channel geometry changes due to degradation, aggradation, and/or meandering). The regional scale model may employ ANN neuro-numerical tools.

This effort will include developing new analytical techniques to support the models, enhancing existing models to include capability for simulating sediment transport and geomorphic processes, and developing a system architecture that will accommodate the multiple interactive modeling systems. This work unit will be closely coordinated with the coastal Cascade work unit and the Processes task area for developing quantitative and qualitative analytical relationships for use in the numerical models. It will use the same interface as Cascade-C as developed in the "Graphical User Environment" work unit. In summary, Cascade-I will allow total flexibility for performing general or detailed sediment transport studies of any portion of a river basin.

Products and Schedule:

The primary product of this work will be the regional morphology model for inland and estuarine areas, Cascade-I.

Product	Scheduled
1. TN: Evaluation and selection of sediment transport and geomorphic response algorithms	Q3/02
2. TN: Modeling geomorphic changes in alluvial channels	Q4/02
3. TN: Case study – Test and evaluation of modeling Capabilities	Q3/03
4. TN – Case study results - Development of interactive modeling capabilities	Q4/03
5. Beta Version: Cascade-I Version 1	Q2/04
6. User Guide: Cascade-I	Q2/04
7. TR – Basin wide approach to modeling hydrologic hydraulic, sediment transport, and geomorphic processes	Q4/04