Mobile Basin Regional Sediment Management – Sulis Application

The purpose of this Technical Note is to document an application of the Sulis Informatics Services toolkit for regional sediment management in the Mobile Basin.

Mobile Basin

The Mobile Bay watershed covers two thirds of the state of Alabama and portions of Mississippi, Georgia, and Tennessee (Figure 1). It is the fourth largest watershed in the United States in terms of flow volume and is the sixth largest river system in the U.S. in terms of area. Lower Mobile Bay is a designated national estuary under the EPA's National Estuary Program. Mobile Bay and the rivers draining into it support major uses with national implications which include the Tennessee-Tombigbee Waterway, the Port of Alabama, commercial fisheries, large industry, tourism and recreation, and abundant development.

Water from the upper-most reaches of the watershed makes its way to the Gulf of Mexico through Mobile Bay. Throughout this process sediments and nutrients are transported and deposited along the way. Understanding the mechanisms and processes of how sediments move through the entire watershed enable informed management decisions relating to sedimentation, water quality, environmental resources, habitat management, and human uses, including dredged material management.

The Mobile Bay Basin has been
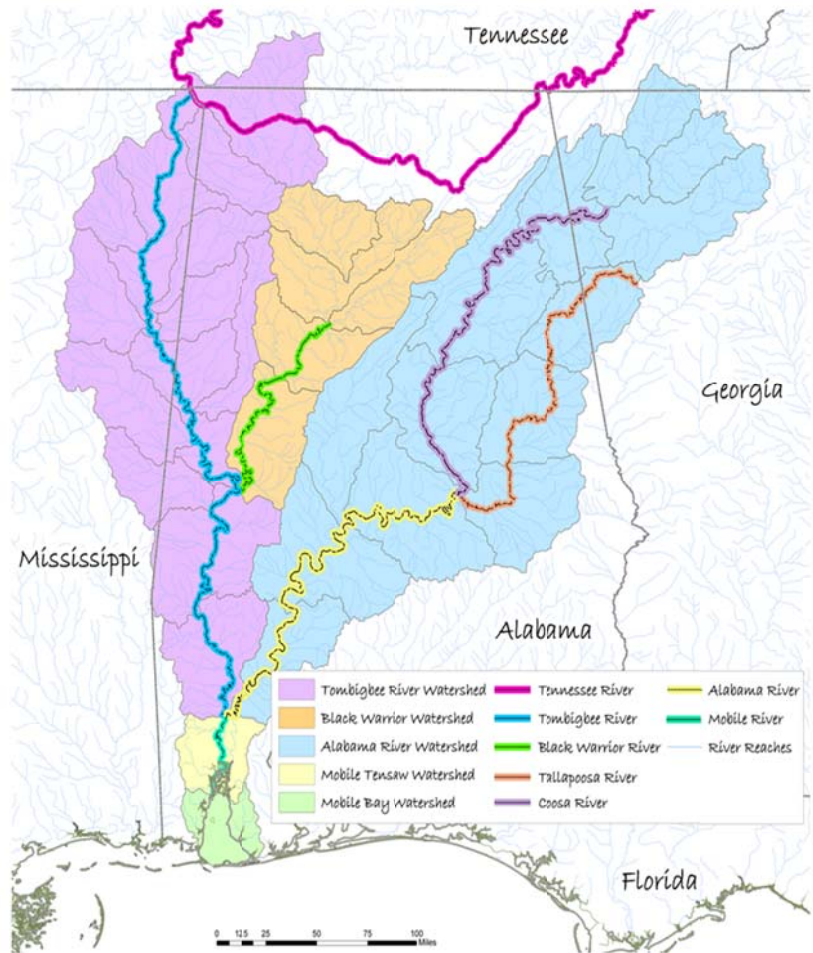
the subject of numerous studies and projects by various agencies including EPA, NASA, USACE SAM and ERDC, NRCS, NOAA, Mississippi State University, and others. To a large extent, these efforts are complementary, albeit separate, initiatives.

One of the primary tasks of the Mobile Basin Regional Sediment Management project is to develop a Regional (Watershed) Sediment Management Implementation Plan to provide the necessary elements for the management of sediment resources while considering environmental restoration, conservation, and preservation. The plan is intended to also maximize interagency collaboration to assess current management practices towards improving water quality and optimize beneficial use of sediment resources. Such a management plan will reduce Operations and Management (O&M) costs through:

- An understanding of regional sediment dynamics including sources, movement, sinks, related watershed and coastal processes, and influences of structures and actions that affect sediment movement, deposition, and loss (essential to identify cost-saving solutions).
- More effective management of watershed sediment, including reduced dredging and disposal costs and beneficial uses of dredged material
- Cooperation among stakeholders to make informed cooperative management decisions and develop regional strategies across jurisdictional boundaries.

Sulis

Healthy Watersheds, Healthy Oceans, Healthy Ecosystems is the underlying goal of Sulis[1], a computer-based, resource management system[2] developed by the Northern Gulf Institute[3] with advice and assistance from the Corps of Engineers (NGI 2009). Sulis Informatics Services (SIS) provide users ready access to environmental and natural resources information in a useful form to better understand aquascapes and their processes, to evaluate the probable consequences of management decisions and natural change, and to make informed decisions with a holistic perspective. The key words in the description include:

- "users" are those who manage water, land, and ecosystem resources at the Federal, state, and local level; stakeholders who want to understand the effects of natural and anthropogenic changes and be able to influence policy and implementation; and those who advise both groups.

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[1] Sulis is the Celtic mythological goddess of wisdom, usually associated with the hot springs at Bath, England.

[2] Informatics is a general term which in this context means the use of information science, mathematics, visual science, computer science and engineering to manage and understand complex information. An informatics service is a software module that performs a specific piece of information processing in support of management or understanding.

[3] NGI is a NOAA Cooperative Institute comprised of Dauphin Island Sea Lab, AL, Florida State University, Louisiana State University, Mississippi State University, and University of Southern Mississippi. Web page: http://www.northerngulfinstitute.org/

- "ready access" which implies that a variety of users from technophiles to the technologically limited can operate the system at a simple level, at least, without having a computer specialist at their side.
- "natural resources information" which includes a variety of information types (e.g., water quantity and quality, land use, biotic health) and formats (spreadsheets, GIS shape files, etc.) suitable for the intended use.
- "useful form" indicates that displays are informative and understandable, including graphics.
- "aquascape" is used to indicate that the perspective is that of the complete hydrologic footprint, including that of a watershed – an area of the earth's surface from which water flows downhill to a single outflow point – plus the water-spread – the coastal and ocean area over which the watershed's flow spreads and ocean forcing affects coastal and upstream waters.
- "holistic" is used to denote the fundamental interconnectedness of the water cycle, the physical environment, ecosystems, and human systems.

Sulis provides a systematic approach to holistic water, land, and ecosystem resources management by providing information service modules organized and adapted for a specific aquascape.

Sulis Integration with USACE Systems

Sulis SIS has been designed to integrate with Corps of Engineers systems and to fill a niche not occupied by other Corps' tools. In terms of complexity, it fits between powerful modeling informatics systems (such as the Surface Water Modeling System (SMS) and HEC-GeoRAS) and simple tools (such as spreadsheets). In terms of data handling, it fits between powerful GIS systems (Such as eCoastal and CorpsMap) and simple viewers (such as Google Earth). It terms of integration, it is designed to connect with all the above Corps tools.

Sulis RSM shares some characteristics, such as simple tools, with existing Corps systems such as ACES and eCoastal, and can even share tools with those systems, but does not duplicate any tools available elsewhere in the Corps. In turn, a proposed future development will create a Sulis Toolbar that can be added to other Corps' GIS applications in order to provide seamless access to SIS capabilities.

Sulis use relies heavily on results from numerical models, such as the Corps' AdH, ADCIRC, and ICM. SIS scripts specifically formulated to read standard output files from those numerical models have been, and continue to be, created under separate funding.

Integration of Sulis with Corps of Engineers systems has been a keystone concept of its design, reducing development costs and reducing future data translation costs. Data that have been processed for incorporation into eCoastal are completely compatible with Sulis (and vice-versa). Data produced by Corps models can be ported into Sulis- and Federal-standard formats automatically, without requiring modelers to change their models.

Sulis SIS Framework

The Sulis Informatics Services framework consists of a graphical user interface (Figure 2 shows the Mobile RSM home page) and an architecture (Figure 3) designed to provide resource managers with the information and visualization tools they need to make informed management decisions and to visualize the effects of those decisions. It is designed for decision makers who have a basic familiarity with computers, but who need not be computer experts. It complements GIS databases such as the USACE eCoastal and eBasin systems. It can offer access to multiple mapping databases, such as the Digital Coast and the Multi-purpose Marine Cadastre; observation databases, such as NOAA's Ecosystem Data Assembly Center; and model-derived databases from the user's selected numerical models. It will also soon include an inference engine that will, among other capabilities, leverage a few model simulations into dozens or hundreds of management scenarios. All of these results are displayed by visualization tools, including standard maps and 2-dimensional GIS displays plus advanced 3-dimensional displays.
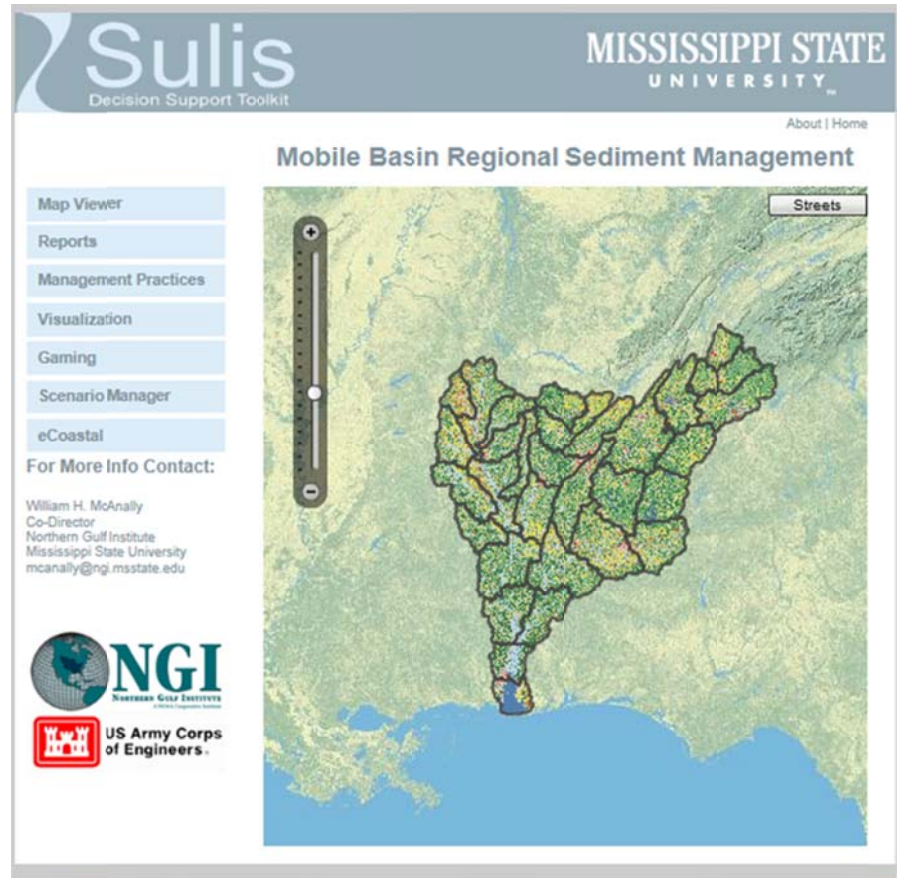
Regional Sediment Management, Integrated Ecosystem Assessment, and Coastal and Marine Spatial Planning (CMSP) are among the management functions that can be facilitated with Sulis. It consists of five major components:

- User interface – a graphical set of screen displays to enable user input and to display results. (Figures 2 and 4-15)
- Observed data – field observations from institutional databases such as the Corps' eCoastal, eBasin, and Corps Map, USGS real-time and historical gauge data, EPA's Storet, and NOAA's NESDIS and EDAC, or locally compiled and quality assured data. Institutional databases may be accessed through hyperlinks and downloads, not by recreating those databases, unless the user has a specific need to store all data locally.

- Models – Sulis employs the results of various numerical models, including those of the Corps of Engineers and NGI Earth Ecosystem Models, which include quantitative prediction capabilities for physical, biological, and human processes so that the effects of management actions on resources can be evaluated (NGI 2011, Haines and Soball 2007).
- Model Results Database – a local repository of specific model predictions which can be extracted and displayed and/or analyzed by the Inference Engine.
- Inference Engine – a program that evaluates user requests, fetches data, performs analyses, and generates results for the user employing "services". It is under development.
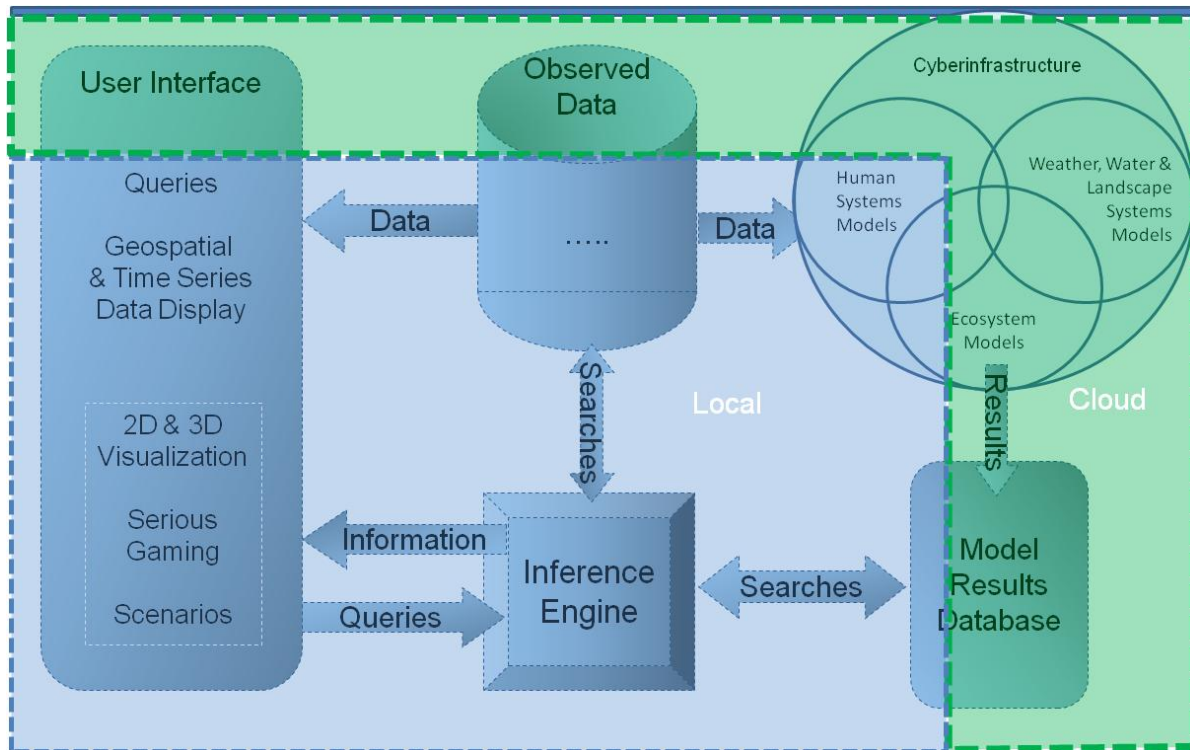
Figure 3. Sulis Architecture. Numerical models used for the system information include AdH. A portion of the system can reside on a local machine while the bulk of the data resides on remote servers (the cloud).

Sulis includes standard software components, used in every application, and custom components, specific to the aquascape of interest. The user interface and inference engine have a standard design. Models and data from models and observations are custom components for the aquascape and the application. For example, Sulis for Regional Sediment Management in the Mobile Basin and CMSP for the Gulf of Mexico may share the same basic toolset in the user interface and inference engine, but each will have its own models, databases, and services unique to their application.

The User Interface is designed for simplicity and ease of use through user-centered requirements definition and prototyping. It is based on public domain, web-based GIS software, including ESRI ArcGIS Explorer and Flexviewer, Google Earth, and others.

Some data are stored locally, such as information collected by the Sulis user and data from public databases that are used so frequently that they are downloaded once and retained. Much data will remain on servers for downloading only when needed. Large server-housed databases accessible by Sulis include:

- eBasin/eCoastal
- U.S. Geological Survey surface and ground water data
- National Ecological Observatory Network (NEON)
- EPA Better Assessment Science Integrating Point and Nonpoint Sources (BASINS)
- National Coastal Data Development Center (NCDDC) databases

Mobile RSM Sulis

The Sulis implementation for Mobile Regional Sediment Management presently includes the information listed in Tables 1 and 2 in its databases. Figure 4 shows the base Viewer page for Mobile RSM, with buttons to launch the pre-configured Maps Viewer, Brookley Hole beneficial uses of dredged material Scenario Viewer, and Custom Map Creator. Figures 4-15 in this document are screenshots of the web interface, which can be accessed at the URL: http://www.ngi.msstate.edu/sulis/applications/RSM/.

Clicking on the Map Viewer brings up the screen shown in Figure 5, in this case with dredged material placement areas depicted in purple. To the right top is a "More" button that permits adding additional layers to the map (see the Example - Mile 366) and a choice between a blank Canvas, Aerial photo, or Topographic background to the map. To the top left is a slider bar (for zooming in and out) and a list of pre-configured map topics for display. In the left bottom is a distance scale bar and an indicator showing the latitude and longitude of the cursor. In the background is a map of the region with state boundaries and major waterbodies.
Pre-configured maps installed for the demonstration include:

- Watershed Demographics
- Sediment Impaired Waters
- Dredging Events
- Sediment Placement Areas
- Sediment Budgets
- Numerical Models
- Freight Transport
- Watershed Non-Governmental Organizations
- Land Use/Land Cover
- Terrain Characteristics

The above list can be accessed one at a time from the pick list at the left of the screen or in multiples from the More button on the right.

At the scale of Figure 5, the sediment placement areas tend to blur together, but if the slider bar is used to zoom in to Mobile Bay, the distinct placement areas can be clearly seen as in Figure 6. Further information about individual placement sites can be displayed by clicking on the site, as shown in Figure 6. In this demonstration, only the Mobile District's site number, type, and project are displayed. Adding site capacity (total and remaining), sediment characteristics, and disposal restrictions will greatly enhance its usefulness as a management tool, including identifying potential beneficial uses.

Selecting Dredging Events from the left pick-list replaces the disposal sites map with one showing dredged channels, as shown in Figure 7. (For this demonstration, only the main bay channel data were available for use in Sulis. The other channels can be added.) Clicking the

channel produces a history of dredging events, with Net and Gross dredged volumes listed by Year, as shown.
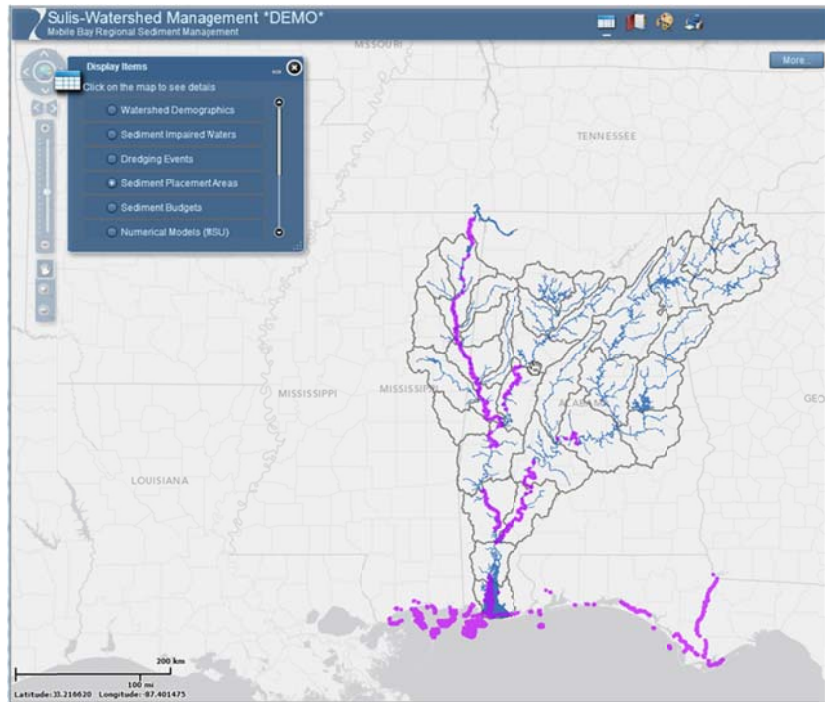

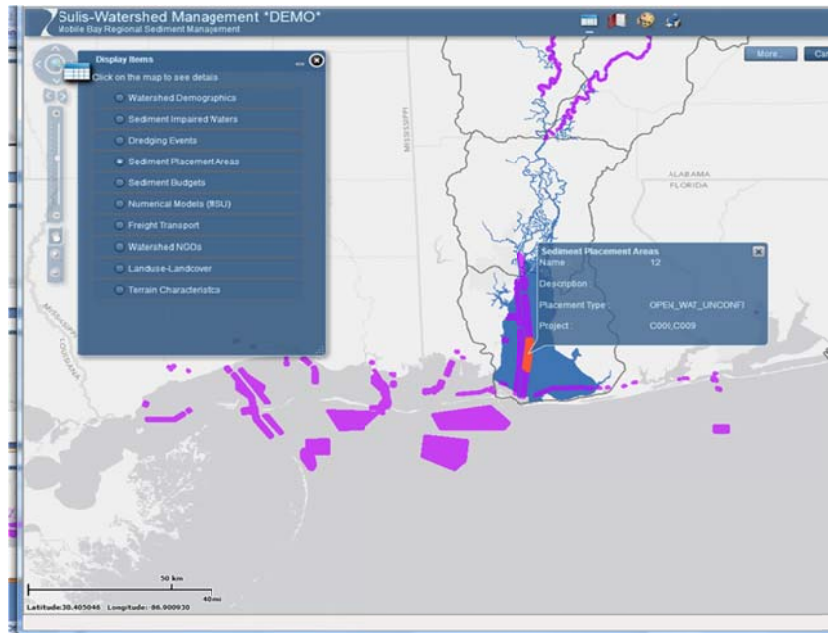**Figure 5. Sulis Map Viewer with Sediment Placement Areas**

Figure 6. Placement Areas Zoomed with Site Table

In addition to the pre-configured maps discussed above, a custom map maker can be accessed by clicking one of the options at the bottom of the Base screen (Figure 4). Figure 8 illustrates the capability with a map combining Impaired Waters, Dredged Material Placement Areas, and Navigation Routes from various sources. Hundreds of other layers can be added from a searchable list.

This demonstration represents only a fraction of available Sulis capabilities. Sulis RSM is ready to accept additional RSM information consisting of:
- Numerical models used by USACE and others
- Numerical model results showing hydrodynamic, salinity, sedimentation and ecosystem effects of:
  – Dredging events
  – Dredged Material Beneficial Uses
  – Structural solutions to sedimentation problems
  – Non-structural solutions to sedimentation problems
  – Effects of extreme events (hurricanes, droughts) on projects
- Shoreline and bankline erosion
- Sediment Budgets on additional sections of the system as they are completed.
- Habitat types, including oyster reefs

Tool services presently include the SWES Surface Erosion Estimator. Addition of the NGI Tiered Sediment Budget Tool is underway and it, as well as other tools added to Sulis by other projects, will simultaneously become available for Mobile RSM application.
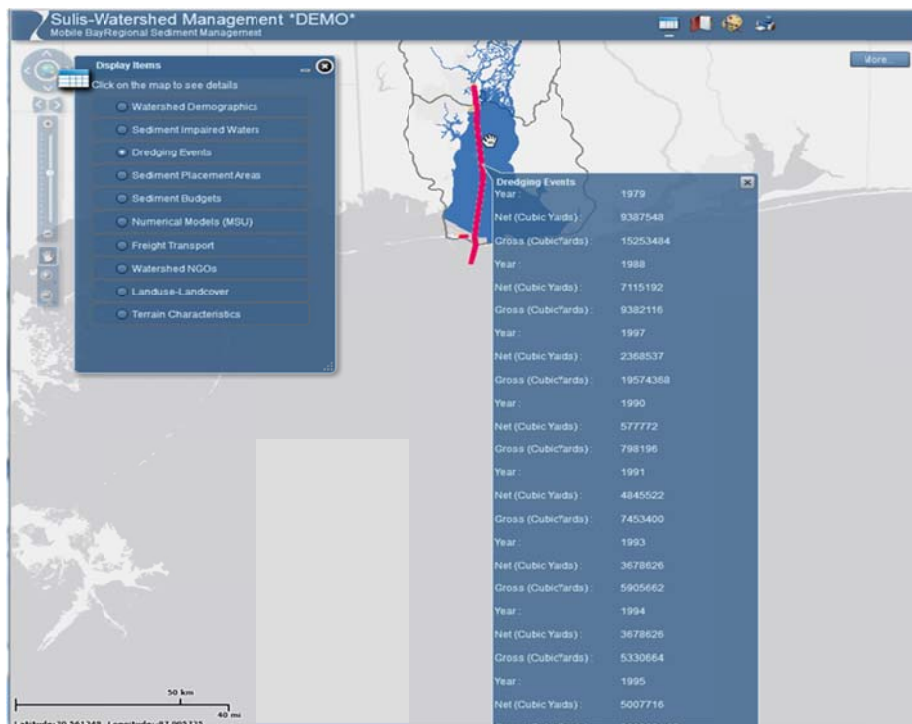

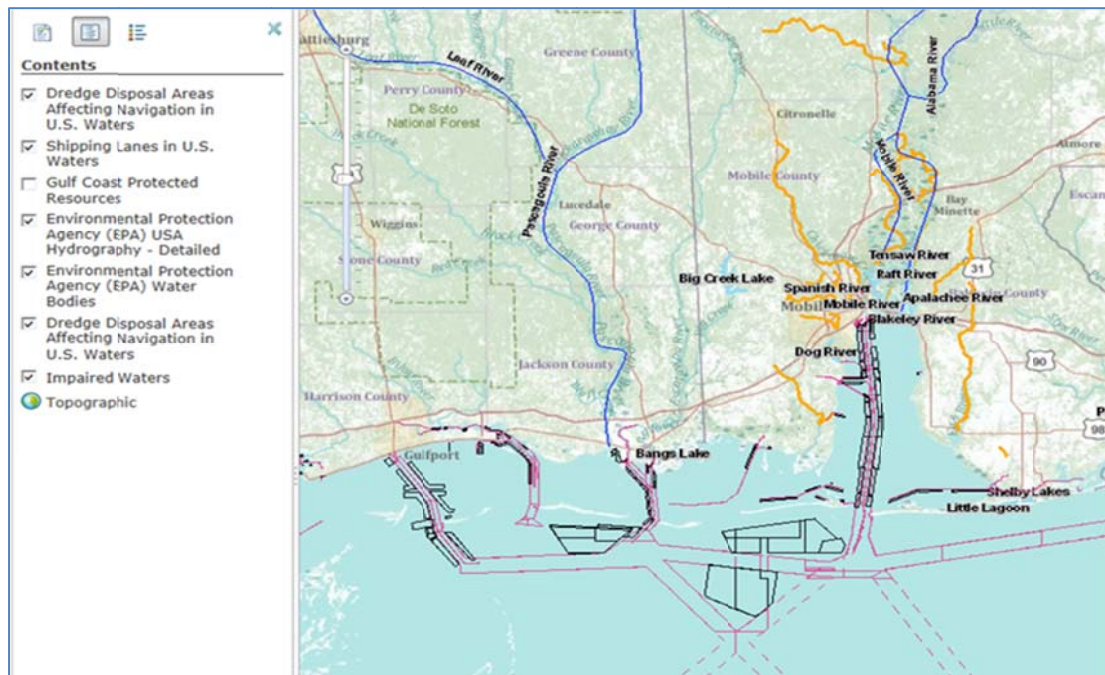**Figure 7. Dredging Events Display with Table**

Figure 8. Composite View from Custom Map Maker

Example – Brookley Hole Beneficial Use

To demonstrate Sulis application to Mobile RSM, the Brookley Hole beneficial use site is displayed in Figures 9 – 13. Figure 9 shows a three-dimensional rendering of the hole that contrasts its depth with that of the surrounding waters, reducing its habitat value. Figure 10 is a screen capture from the Sulis window following a click on "Launch Brookley Hole Scenario Viewer" in Figure 4. It shows three versions of a beneficial uses of dredged material plan selected by USACE in consultation with stakeholders – filling the Brookley hole with dredged material to various depths. Figure 11 shows the same display, but with the map zoomed to three different levels so as to see the surrounding landmarks.

Evaluation of filling Brookley Hole will involve multiple aspects, including the cost/benefits of placing sediment there rather than the usual disposal areas and environmental effects, such as:

- Modeling movement of any sediment plume from the site during placement
- Modeling alterations to water surface elevations, flow velocities, and circulation
- Modeling ecosystem responses
- Expert evaluation of the implications

Results from an AdH model (developed and run by the USACE Engineer Research and Development Center's Coastal and Hydraulics Lab) of Mobile Bay for the existing conditions have been imported into Sulis for display. Figure 12 shows ebb phase current speeds throughout the Bay for the existing conditions, and Figure 13 shows a Sulis display zoom into the area of interest. Were this an application rather than a demonstration, all three scenarios would have

been modeled and the results imported to Sulis to display changes in important parameters as a result of the filling. Technical evaluation of all plans will be best evaluated using model results and model data viewers, such as SMS for USACE models and EFDC_Explorer for EFDC. Model results can then be imported to the Sulis database for customized viewing by USACE staff and stakeholders.
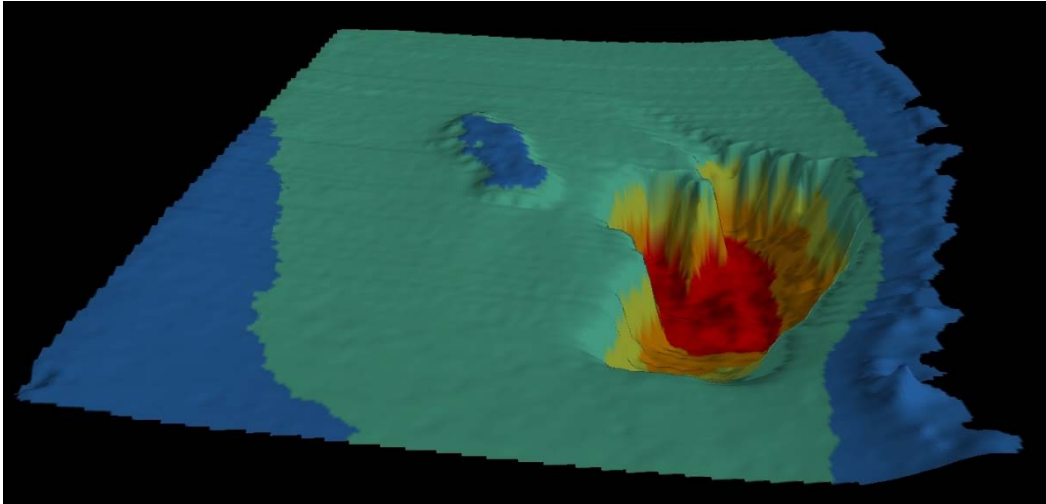

Figure 9. Sulis Viewer Depiction of the Brookley Hole Area with Colored-Coded Depths.
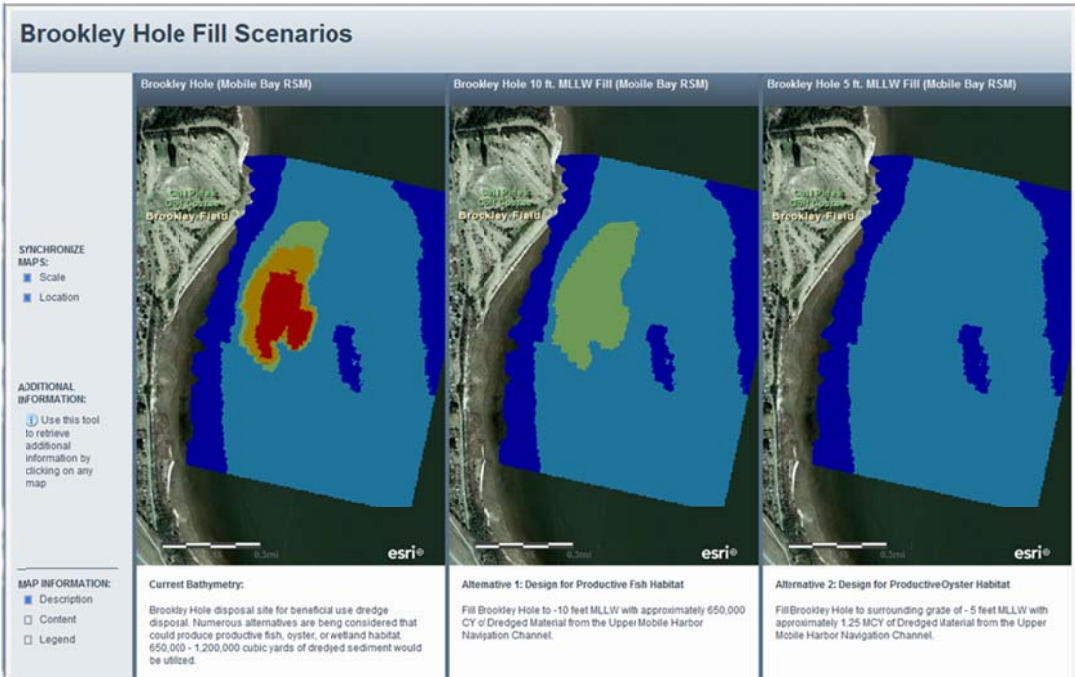

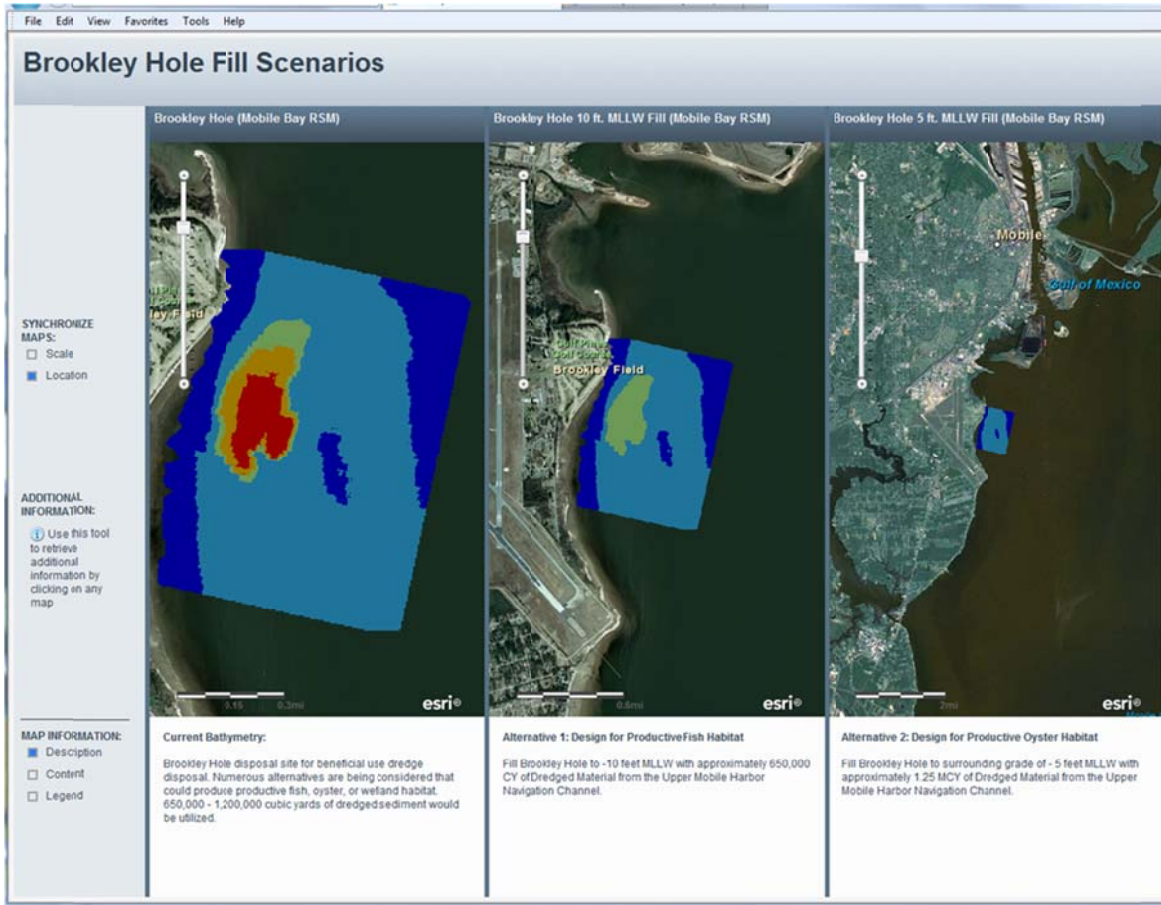**Figure 10. Scenario Viewer with Brooklet Hole As-Is and with Two Filling Options**

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Figure 11. Scenarios Viewer Zoomed to 3 Levels for Brookley Hole Site

Example – Mile 366

Near mile 366 on the Tenn-Tom Waterway in Aberdeen Pool has been a chronic sedimentation location since the waterway opened in 1984. Figure 14 shows a profile of the Waterway with a 16-year summation of dredging depicted, clearly showing the spike of about 180,000 cu yd per year at mile 366. A solution to this sedimentation problem will provide significant cost savings to the USACE. Solving it in the context of a regional sediment management plan would be ideal.

Figure 15 shows the Sulis Map Viewer display with several layers turned on – Land Use/Cover (multi-colors), Freight Transport (green), Impaired Waters (gold), and Aberdeen Pool (red). Results of a Sediment Budget analysis, showing deposition of 568,000 to 838,000 cu yd per year in a pop-up table, are consistent with the channel dredging experience and confirm the common belief that the dredging there is a consequence of sediment supply from the local watershed.
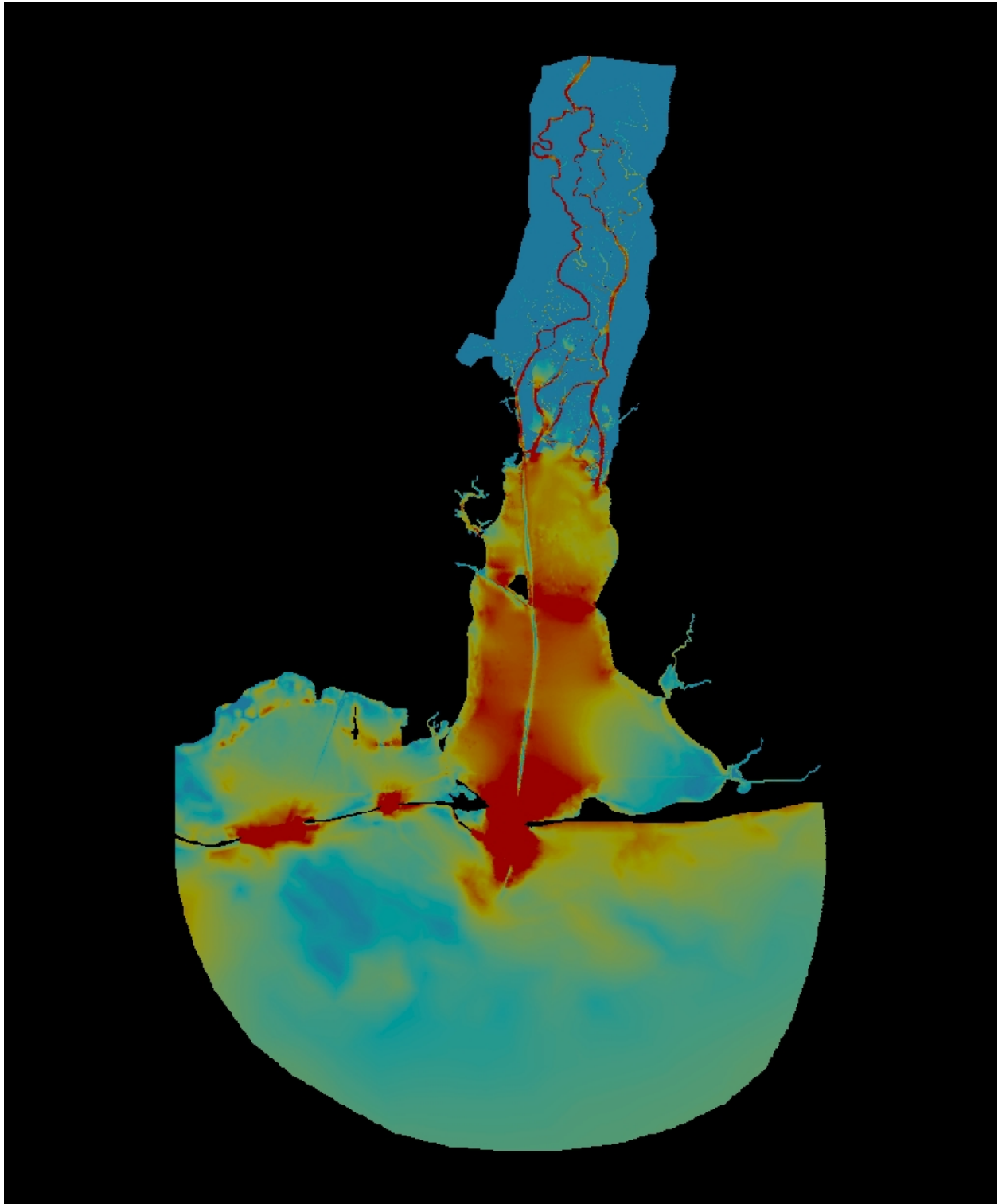
Figure 12. Ebb Phase Current Speeds from AdH Model (Provided byEngineer Research and Development Center)
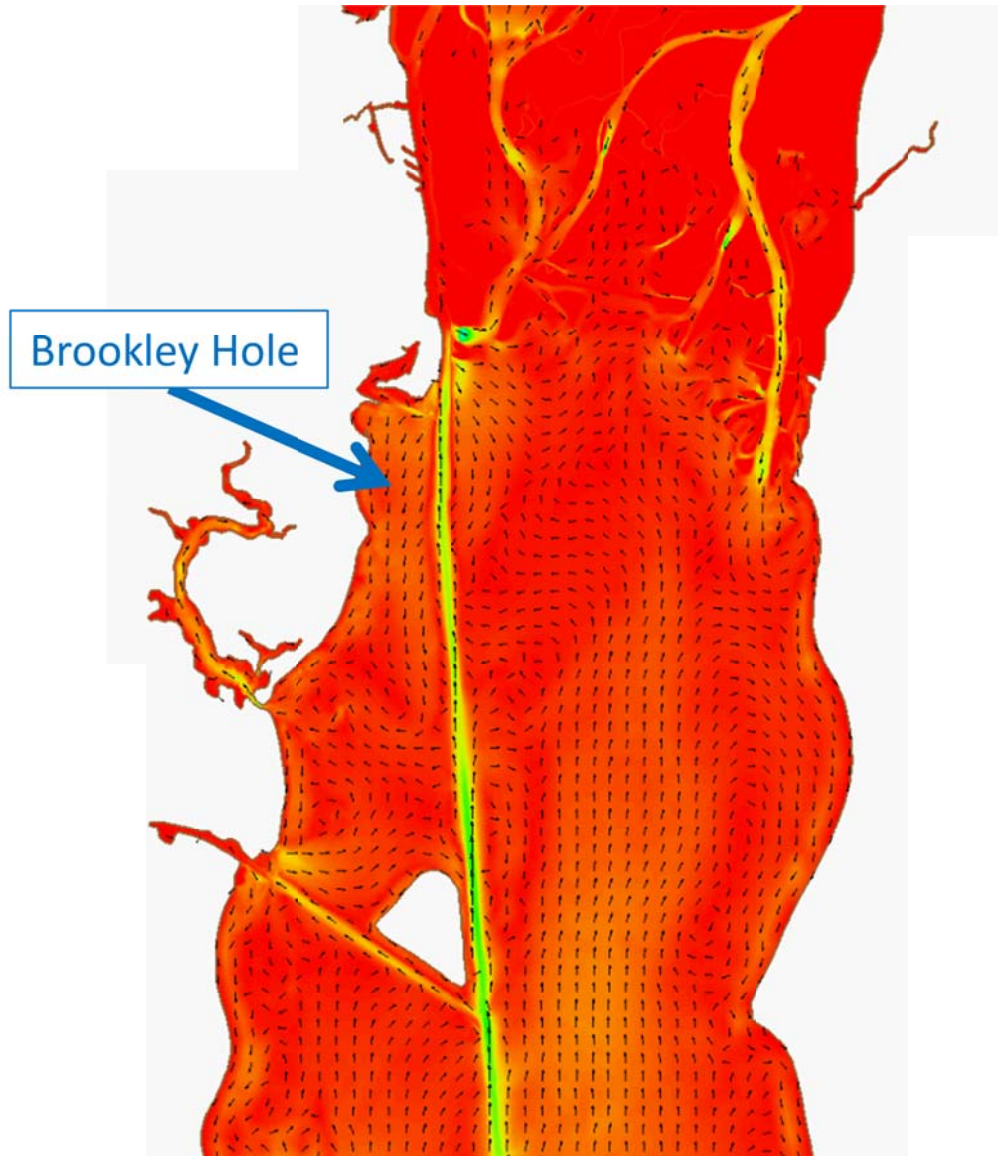
Figure 13. Flood Phase Currents Zoomed to Brookley Hole Area Showing Current Directions (AdH model results provided by Engineer Research and Development Center)

Figure 15 shows that Tupelo, MS, a rapidly-growing urban area, lies in the sub-watershed draining to Aberdeen Pool. Careful examination shows that much of the area is agricultural, including pastures, row crops, and silviculture – all land uses that may cause land erosion if best management practices are not rigorously applied. If a Bankline Erosion layer were present, it would show extensive bank caving from Tupelo to the Pool, another source of sediment.
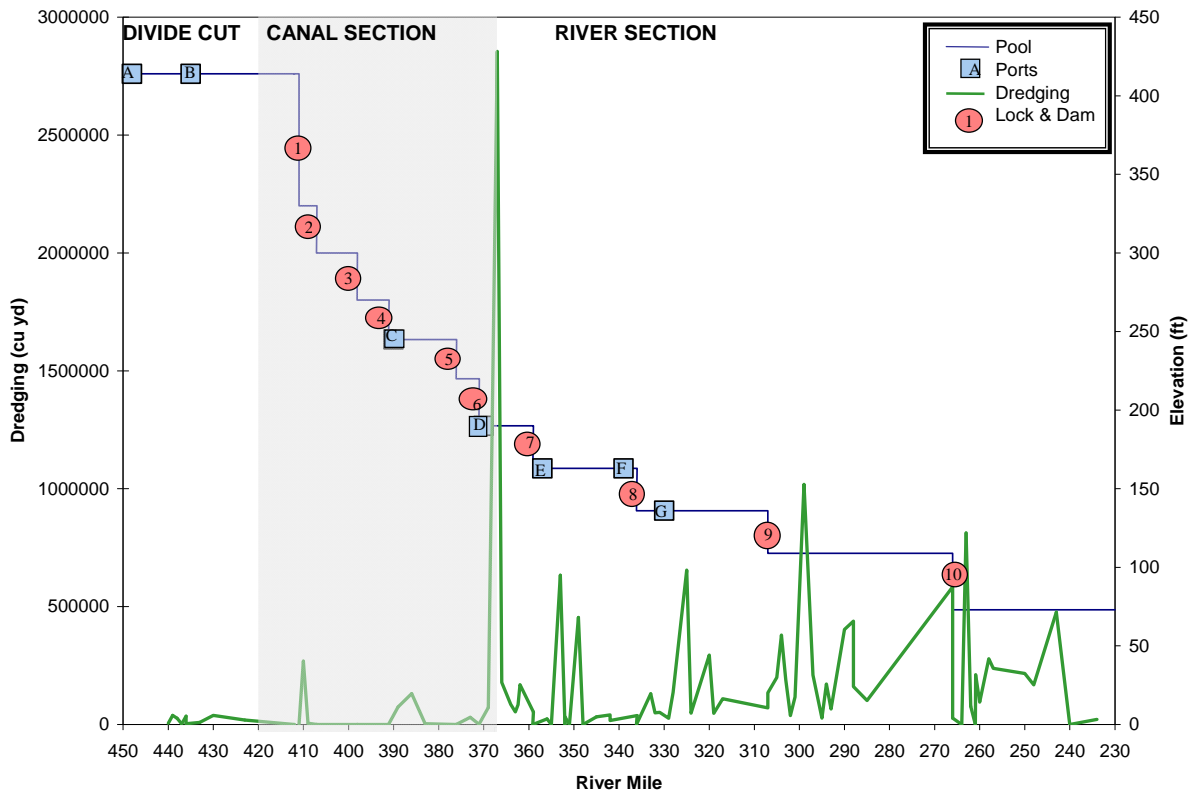
Figure 14. Tenn-Tom Waterway with 16-Year Dredged Quantities (Source: McAnally et al. 2004)

How can Sulis be used to manage the situation at mile 366? First, the data layers should be expanded to include:

- Bankline Erosion
- Channel Grain-Size Distributions
- Numerical Model Results
- Hydrographic Contours
- Capacities of Confined Disposal Areas

From these displays USACE engineers could identify the proximate sources of sediment depositing in the channel, paths through which it moves, and locations for possible remedies, such as:

- Best Management Practices to reduce land and bank erosion
- Structures to flatten local stream slopes
- Sediment traps to prevent material from reaching the channel
- Pool structures to redirect the sediment plume
- Land reclamation sites to receive dredged material (beneficial use)

Some of the above could be performed as USACE restoration projects or accomplished by leveraging investments by the National Resources Conservation Service or The Nature Conservancy, etc. Using the RSM fundamental approach of stakeholder engagement, other ideas will be generated and the best combination of local, state, and federal efforts can be identified and implemented, using Sulis as a display tool for engagement.
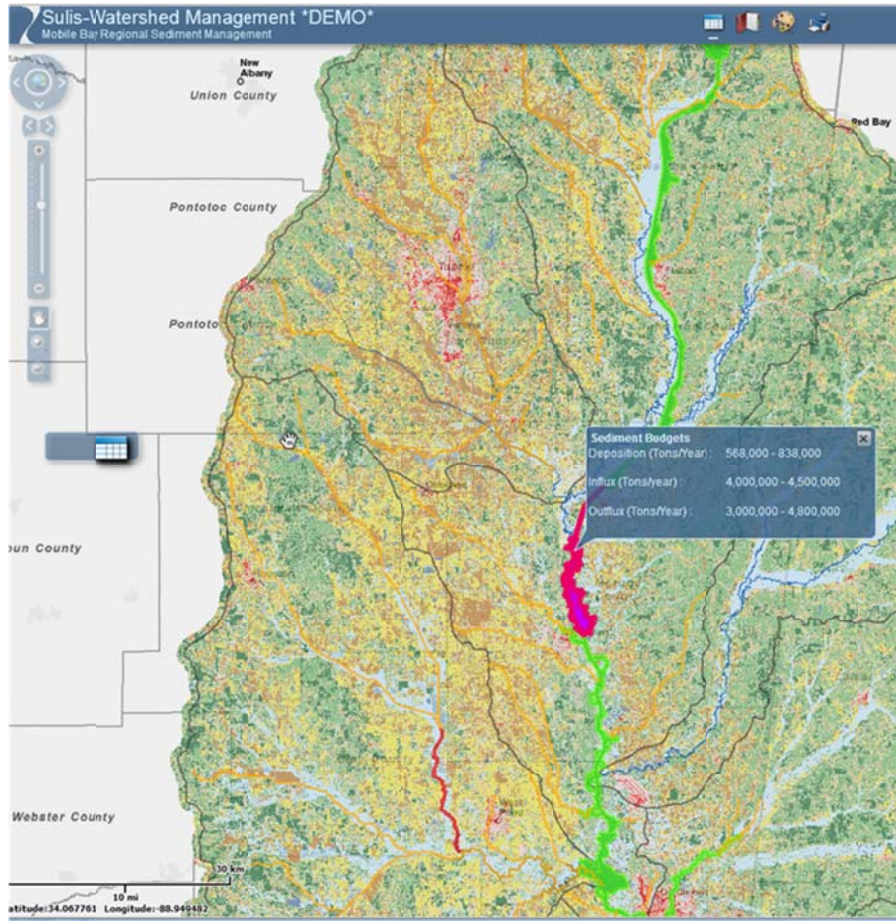

Figure 15. Sulis Composite Map of Aberdeen Pool Area of Tenn-Tom.

Additional Information

Additional information about Sulis and RSM for Mobile Basin can be obtained from:

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Additional information about the USACE RSM Research Program can be found at:
http://chl.erdc.usace.army.mil/rsm.

References

Hains, J., and D. Soballe. 2007. *The ecosystem concept and linking models of physical-chemical processes to ecological responses: Introduction and annotated bibliography.* SWWRP Technical Notes Collection (ERDC TN-SWWRP-07-3). U.S. Army Engineer Research and Development Center. Vicksburg, MS.

McAnally, W. H., Haydel, J. F. and Savant, G. 2004. Port Sedimentation Solutions for the Tennessee-Tombigbee Waterway in Mississippi, Mississippi State University, Mississippi State, MS.

NGI 2009. Sulis: A Framework for Healthy Watersheds – Healthy Oceans – Healthy Ecosystems, Northern Gulf Institute H30 Team, Stennis Space Center, MS. 20 September

NGI 2011. Earth Ecosystem Modeling Framework. Northern Gulf Institute Ecosystem Team, Stennis Space Center, MS.

Table 1: Application Arc Server Map Services for RSM

Sediment Impairments	
Title:	MobileBayImpairments
Layers:	303(d) Impaired Waters Watersheds (Summary)
Tables:	N/A
Sources:	USGS, EPA
URL:	http://geodataserv.hpc.msstate.edu/ArcGIS/rest/services/MobileBayRSM/MobileBayImpairments/MapServer

Dredged Material Placement Areas	
Title:	MobileBaySedimentPlacementAreas
Layers:	Sediment Placement Areas
Tables:	N/A
Sources:	USACE
URL:	http://geodataserv.hpc.msstate.edu/ArcGIS/rest/services/MobileBayRSM/MobileBaySedimentPlacementAreas/MapServer

Freight Transport	
Title:	MobileBayFreight
Layers:	Freight (Ton Miles) MB_NHD_Poly_V1
Tables:	N/A
Sources:	USGS, USACE
URL:	http://geodataserv.hpc.msstate.edu/ArcGIS/rest/services/MobileBayRSM/MobileBayFreight/MapServer

Dredging Events	
Title:	MobileBayDredgeEventsYear
Layers:	Yearly Dredging Events (1979-199)
Tables:	N/A
Sources:	USACE
URL:	http://geodataserv.hpc.msstate.edu/ArcGIS/rest/services/MobileBay303dImpairments/MapServer

Watershed NGOs	
Title:	MobileBayNGO
Layers:	Non-Governmental Organizations
Tables:	N/A
Sources:	USGS
URL:	http://geodataserv.hpc.msstate.edu/ArcGIS/rest/services/MobileBayRSM/MobileBayNGO/MapServer

Landuse-Landcover	
Title:	MobileBayNLCD
Layers:	Watersheds (Summary) NLCD 2000 NLCD 1990
Tables:	N/A
Sources:	USGS
URL:	http://geodataserv.hpc.msstate.edu/ArcGIS/rest/services/MobileBayRSM/MobileBayNLCD/MapServer

Table 1. (continued)

Terrain Characteristics	
Title:	MobileBayNED
Layers:	Watersheds (Summary) NED Terrain Data • Hillshade • Elevation • Slope
Tables:	N/A
Sources:	USGS
URL:	http://geodataserv.hpc.msstate.edu/ArcGIS/rest/services/MobileBayRSM/MobileBayNED/MapServer

Watershed Demographics	
Title:	MobileBayPopulation
Layers:	Watershed Demographics
Tables:	year_1990 year_1980 year_1970
Sources:	USGS, NOAA
URL:	http://geodataserv.hpc.msstate.edu/ArcGIS/rest/services/MobileBayRSM/MobileBayPopulation/MapServer

Base Layers	
Title:	MobileBayBasin
Layers:	Basin Outline Hydrology • Primary Streams (NOAA) • Secondary Streams (NOAA) • Flowlines (NHD) • Lakes (NOAA) NOAA Coastal Assessment Framework (CAF) • Mobile Bay Fluvial Drainage Area (FDA) • Mobile Bay Estuarine Drainage Area (EDA) • Mobile Bay CAF USGS Catchments (8-Digit HUCs) NLCD Land Cover and Products • NLCD 1992 Land Cover • NLCD 2000 Land Cover • NLCD 2000 Canopy • NLCD 2000 Impervious USGS National Elevation Data and Products • NED Terrain Hillshade • NED Terrain Elevation • NED Terrain Slope • NED Terrain Ruggedness
Tables:	N/A
Sources:	USGS, NOAA
URL:	http://geodataserv.hpc.msstate.edu/ArcGIS/rest/services/MobileBayRSM/MobileBayBasin/MapServer

Table 2. Base Map Arc Server Map Services (ESRI)

Streets	
Title:	World_Street_Map
Layers:	World Street Map
Tables:	N/A
Sources:	ESRI, DeLorme, AND, Tele Atlas, First American, ESRI Japan, UNEP-WCMC, USGS, METI, ESRI Hong Kong, ESRI Thailand, Procalculo Prosis
URL:	http://server.arcgisonline.com/ArcGIS/rest/services/World_Street_Map/MapServer

Topo	
Title:	World_Topo_Map
Layers:	Topographic Info • Elevation (m) • Elevation (ft) • Slope • Aspect Places Info • Place Names (Country Level) • Place Names (State Level) • Place Names (County Level) • Place Names (City Level) Scale Descriptions • Level 0-15
Tables:	N/A
Sources:	USGS, FAO, NPS, EPA, ESRI, DeLorme, TANA, other suppliers\
URL:	http://server.arcgisonline.com/ArcGIS/rest/services/World_Topo_Map/MapServer

Aerial	
Title:	World_Imagery
Layers:	World Imagery Low-Resolution (15m) Imagery
Tables:	N/A
Sources:	ESRI, i-cubed, USDA FSA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGP
URL:	http://server.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer

Boundaries and Places	
Title:	World_Boundaries_and_Places_Alternate
Layers:	World Boundaries and Places
Tables:	N/A
Sources:	© 2009 ESRI, AND, TANA
URL:	http://server.arcgisonline.com/ArcGIS/rest/services/Reference/World_Boundaries_and_Places_Alternate/MapServer