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Application of an enhanced spill management information system to inland waterways

Janey S. Camp[1], Eugene J. LeBoeuf*, Mark D. Abkowitz[2]

Department of Civil and Environmental Engineering, Vanderbilt University, VU Station B 351831, 2301 Vanderbilt Place, Nashville, TN 37235-1831, USA

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ABSTRACT

Spill response managers on inland waterways have indicated the need for an improved decision-support system, one that provides advanced modeling technology within a visual framework. Efforts to address these considerations led the authors to develop an enhanced version of the Spill Management Information System (SMIS 2.0). SMIS 2.0 represents a state-of-the-art 3D hydrodynamic and chemical spill modeling system tool that provides for improved predictive spill fate and transport capability, combined with a geographic information systems (GIS) spatial environment in which to communicate propagation risks and locate response resources. This paper focuses on the application of SMIS 2.0 in a case study of several spill scenarios involving the release of diesel fuel and trichloroethylene (TCE) that were simulated on the Kentucky Lake portion of the Tennessee River, each analyzed at low, average, and high flow conditions. A discussion of the decision-support implications of the model results is also included, as are suggestions for future enhancements to this evolving platform.

1. Introduction

Spill response managers have indicated the need for a decision-support system that provides advanced modeling technology within a visual framework [1]. Currently available models for spill response assistance include 1D and 2D modeling systems such as RiverSpill and ICWater [2], GNOME [3], and SMIS 1.0 [4]. While some of these models provide rough estimates of spill plume locations, often in a geographic information system (GIS) environment, the representation of plume location is presented as leading edge [2] or in bulk river segments [4]. Efforts to overcome these limitations led the authors to develop an enhanced version of the Spill Management Information System (SMIS 2.0).

SMIS 2.0 represents a user-friendly, state-of-the-art 3D hydrodynamic and chemical spill modeling system tool that provides for improved predictive spill fate and transport capability, combined with a geographic information systems (GIS) spatial environment in which to better inform and assist decision support for planning and response activities. Within SMIS 2.0, the 3D Generalized, Longitudinal-Lateral-Vertical Hydrodynamic and Transport (GLLVHT) model is employed to provide hydrodynamic information for contaminant transport modeling through the Chemical/Oil Spill Impact Model (COSIM) [5]. Utilizing a graphical user interface within ESRI's ArcMap, SMIS 2.0 enables users to edit the COSIM control file, execute the spill model, and load and format the output for viewing within GIS. Employment of SMIS 2.0 requires only experience with use of basic GIS tools, thus aiding in timely and effective spill response. Once the spill model results are placed in ArcMap, simple spatial queries can lead to identification of: (i) local emergency response personnel such as hospitals, fire departments, and police within a specified distance of the spill event location; (ii) schools or other sensitive populations (e.g., nursing homes) that may need to be evacuated; (iii) sensitive species that may be impacted within or along the waterway; and (iv) spill response resources such as location of spill response contractors, and materials. In addition, using a pre-set template, maps can be produced for printing or display through other means such as screen projection within a spill response operations center, or distributed to spill response personnel in the field through email and/or website postings. SMIS 2.0 can also be used for training and planning of response strategies through development of plausible scenarios. Spill scenario output files can be saved in a common directory and added to ArcMap at any future time.

Abbreviations: BTEX, benzene, toluene, ethylbenzene, and xylenes; COSIM, Chemical and Oil Spill Impact Model; ERM, Environmental Resources Management, Inc.; ESRI, Environmental Systems Research Institute, Inc.; GLLVHT, Generalized, Longitudinal-Lateral-Vertical Hydrodynamic and Transport; GEMSS, Generalized Environmental Modeling System for Surface Waters; GIS, geographic information systems; RM, River Mile; SMIS, Spill Management Information System; TCE, trichloroethylene; TVA, Tennessee Valley Authority; USACE, U.S. Army Corps of Engineers.

* Corresponding author. Tel.: +1 615 343 7070; fax: +1 615 322 3365.
E-mail addresses: janey.v.smith@vanderbilt.edu (J.S. Camp), eugene.j.leboeuf@vanderbilt.edu (E.J. LeBoeuf), mark.d.abkowitz@vanderbilt.edu (M.D. Abkowitz).
[1] Tel.: +1 615 322 2739; fax: +1 615 322 3365.
[2] Tel.: +1 615 322 3436; fax: +1 615 322 3365.

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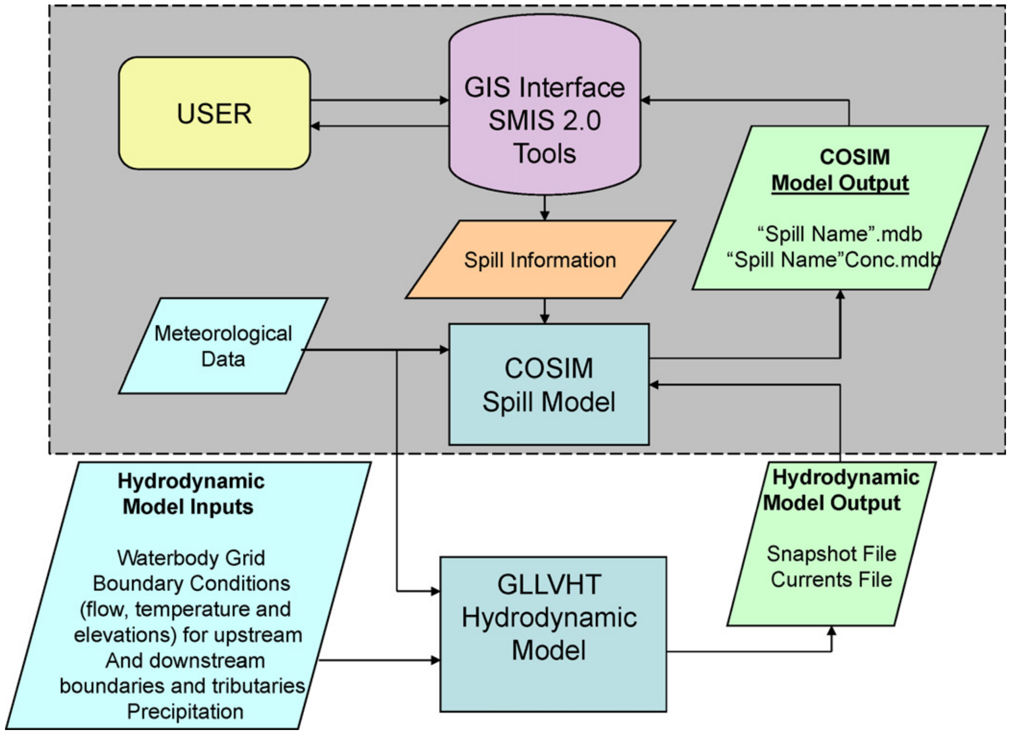

Fig. 1. System diagram. The items contained in the gray box are components of the SMIS 2.0 system. Those outside of the box are considered background information that is set up prior to a spill occurrence.

This paper focuses on the application of SMIS 2.0 as a decision-support tool in a case study of possible spill scenarios occurring near the Johnsonville, Tennessee fossil fuel electrical generating facility on Kentucky Lake. Three different spill scenarios are considered: (i) an average probable spill, (ii) a maximum probable spill, and (iii) a worst case spill, as defined by the Tennessee Valley Authority (TVA), under varying flow conditions [6]. SMIS 2.0 is used in creation of the scenarios and manipulation of the output for viewing in ArcMap. Presentation and comparison among simulation results for each scenario is provided, including a demonstration of querying capabilities within ArcMap to locate nearby schools. Placement of booms on the waterbody to assist with chemical spill recovery and protection measures is also evaluated. Boom interactions are of interest for: (i) developing pre-planned boom placement locations, (ii) evaluating containment and exclusion strategies, and (iii) determining resource needs for typical spill situations.

1.1. SMIS 2.0

As outlined in Camp et al. [1], SMIS 2.0 combines ArcMap 9.2 with Generalized Environmental Modeling System for Surface Waters (GEMSS) and COSIM modeling for enhanced spill response support. GEMSS contains multiple hydrodynamic models that can be used to provide water velocity information for COSIM spill modeling. The 3D GLLVHT model was selected for use in SMIS 2.0 to enable advanced (3D) hydrodynamic modeling for more accurate representation of flow characteristics in a waterbody that may impact spill plume migration. A diagram of the components involved with the flow of information identified and the corresponding SMIS 2.0 toolbar are shown in Figs. 1 and 2, respectively.

COSIM is capable of modeling numerous chemical constituents, including benzene, toluene, ethylbenzene, and xylenes (BTEX) hydrocarbons and their chemical sub-components [5,7]. In this application, a diesel fuel spill is simulated. In addition, COSIM can represent many physical and chemical interactions between the spilled chemical and the environment, including advection, dispersion, biodegradation, and evaporation. Volatilization, mixing, and degradation processes are also considered in the COSIM model. Additional information on the model's capabilities for simulating the physical and chemical processes associated with specific chemicals can be obtained from the developers [7]. Wind effects in the *x*- and *y*-directions on the water body hydrodynamics and plume migration are considered to be either all on or all off. Wind direction and speed are provided in the meteorological data input file.

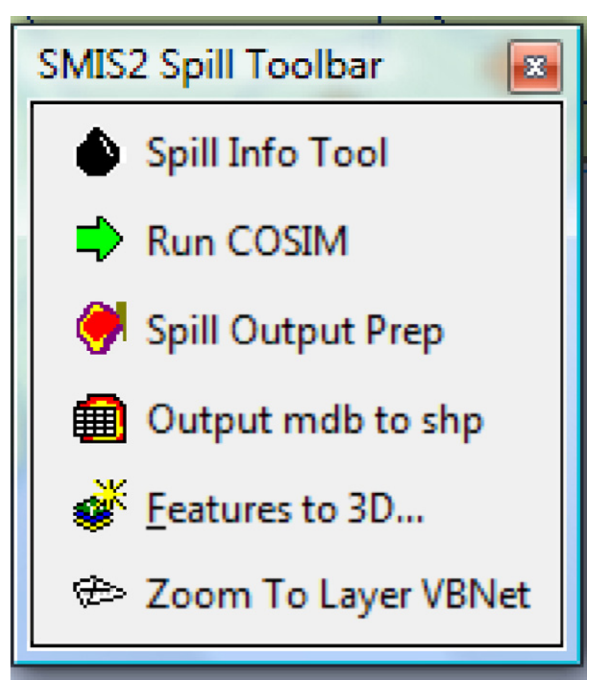

Fig. 2. SMIS 2.0 system toolbar.