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Development of a GIS-based Spill Management Information System

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Abstract

Spill Management Information System (SMIS) is a geographic information system (GIS)-based decision support system designed to effectively manage the risks associated with accidental or intentional releases of a hazardous material into an inland waterway. SMIS provides critical planning and impact information to emergency responders in anticipation of, or following such an incident. SMIS couples GIS and database management systems (DBMS) with the 2-D surface water model CE-QUAL-W2 Version 3.1 and the air contaminant model Computer-Aided Management of Emergency Operations (CAMEO) while retaining full GIS risk analysis and interpretive capabilities. Live ‘real-time’ data links are established within the spill management software to utilize current meteorological information and flowrates within the waterway. Capabilities include rapid modification of modeling conditions to allow for immediate scenario analysis and evaluation of ‘what-if’ scenarios. The functionality of the model is illustrated through a case study of the Cheatham Reach of the Cumberland River near Nashville, TN.

Keywords: GIS; Spill Management Information System; CE-QUAL-W2; CAMEO

1. Introduction

In order to more effectively manage risks associated with accidental or intentional chemical releases into the environment, the Nashville District of the U.S. Army Corps of Engineers (USACE) engaged Vanderbilt University’s Department of Civil and Environmental Engineering to develop a decision support system (DSS) to aid responders in identifying, responding to, and mitigating the effects of chemical release incidents. The project goal was to develop a Spill Management Information System (SMIS), coupling geographic information systems (GIS) with advanced water quality and air dispersion models to provide real-time information to emergency responders following an incident involving hazardous materials [1]. For this application, hazardous materials were defined as any commodity, including petroleum products that, if released, would pose considerable danger to human health and the environment. Additionally, the SMIS application was designed for short-term impact mitigation activities, as opposed to the evaluation of long-term chronic impacts of a contaminant spill.

SMIS was designed to overcome many of the communications and coordination challenges generated following a spill incident by providing responders with access to uniform information comprised of real-time incident information and maps, contaminant transport models, chemical response data, areal displays of contaminant procession, and locations of sensitive receptors. Proper utilization of this tool greatly reduces the time required to acquire and decipher pertinent chemical data, establish jurisdiction of responder responsibility, locate available waterbody access points, identify proximity of emergency response units (i.e., fire, police, U.S. Coast Guard (USCG)), and generate local contacts for community notification to protect against toxic vapor exposure.

Two types of information systems underpin SMIS: GIS and a database management system (DBMS). GIS is an information technology utilized to maintain and analyze geographic data capable of organizing data into layers and relating sets by geography. Certain relationships and operational trends are more easily conveyed in a geographic context than in a traditional tabular format [1]. GIS functionality may also be delivered through a standard Internet browser, a valuable feature enabling the distribution of uniform and current data [2]. GIS has been broadly adopted for use with predictive models providing functions for data storage, calculation of required parameters, data manipula-

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tion, and output processing [3]. GIS capabilities have also been employed to provide spatial decision support systems (SDSS) with output display, spatial data management, and interface functions [4–6]. The relatively weak user interface but strong computational capabilities of most water quality models [5] underscore the benefits garnered from employing GIS as the front-end application for SMIS. The review work of Martin et al. [7] elucidates the benefits realized by employing GIS with water resources predictive models, techniques of interface, and current trends in development.

DBMS refers to software that collects, manipulates, queries, and retrieves tabular data. Efficient database construction and combination of project-relevant datasets into a single application reduces instances of data redundancy, error, and computational lag time. Dobbins and Abkowitz [8] chronicle the development of a centralized response database for several modes of hazardous materials transport. This project was accomplished by identifying the most commonly used emergency response databases for all modes of transportation, developing relationships between the data, and building intuitive interfaces allowing for rapid information retrieval. Resultantly, facility and vessel operators benefit from having access to a comprehensive chemical database, rapidly accessible in the event of a release or human contact with the material [8]. Dobbins and Abkowitz [2] further explore the effectiveness of this approach through the development of a prototype decision support system (DSS) employing global positioning system (GPS), GIS, and the Internet for inland waterway barge accidents. In the event of an incident, this system enables en-route responders to view incident details via an Internet GIS map service.

This manuscript serves to provide a proof-of-principle demonstration of SMIS within a case study environment. Daniel et al. [9] detail the architectural requirements for SMIS and advancements in developing a decision support system (DSS) within the model. This paper begins with an overview of system components comprising SMIS, including the interfacing of surface water quality and air quality models. Data input and other pre-processing functions are then described, followed by methods of SMIS execution, data output, and results interpretation. A case study, highlighting the Cheatham Reach of the Cumberland River located in Nashville, TN is used to illustrate SMIS capabilities. The paper concludes with a summary of SMIS competencies, limitations, and plans for future phases of work.

2. System components

The impact of a waterway injection of a hazardous material is modeled for GIS display through two pathways: surface water and air. Although spill effects propagate through other pathways, the most acute and immediately dangerous short-term effects advance through these mediums [2]. The major components of SMIS include Environmental Systems Research Institute (ESRI, Redlands, CA) ArcView Version 8.2 GIS, the two-dimensional (2-D) surface water quality and hydrodynamic model CE-QUAL-W2 Version 3.1 developed by USACE, the atmospheric dispersion modeling suite Computer-Aided Management of Emergency Operations (CAMEO) developed by the U.S. Environmental Protection Agency (USEPA) and the National Oceanic and Atmospheric Administration (NOAA), and customized Visual Basic (VB) functions for data input, model execution, and results presentation (Fig. 1).

VB coding is a well-defined mechanism allowing user-developed routines to be called within the normal user in-

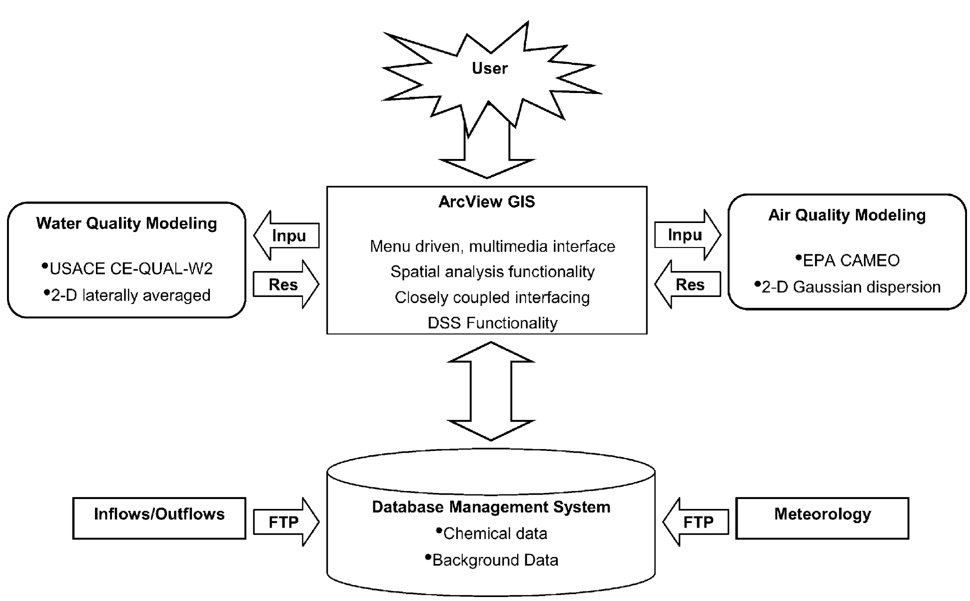

Fig. 1. Spill Management Information System (SMIS) architecture.