ArcGIS and SWMM Integration

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GIS integration saves time and money in hydrologic and hydraulic (H&H) modeling projects. To increase cost-effectiveness of H&H models, an innovative software called AGSWMM was developed. AGSWMM links Storm Water Management Model's (SWMM) latest release SWMM5 with the latest release of the world's leading GIS software, ArcGIS™. The linkage was made possible because of the open data structures of the two programs. The chapter explains the urgency and importance of developing the new linkage. It also describes the steps for developing an interface between SWMM5 and ArcGIS. The methodology is demonstrated with various examples and a case study. Considering the fact that both ArcGIS and SWMM5 are new software products, this chapter should be valuable to many readers.

15.1 SWMM4

Numerous H&H models were created in United States during the 70s including the U.S. EPA's legacy computer program SWMM. SWMM is a comprehensive computer model for analysis of quantity and quality problems associated with urban runoff. SWMM is one of the most successful models produced by EPA for the water environment. SWMM was developed in 1969-71 as a mainframe computer program and has been continually maintained and updated. Versions 2, 3, and 4 of SWMM were distributed in 1975, 1981, and 1988, respectively (Huber and Dickinson, 1988; Roesner et al., 1988). The last version 4.3 was released by EPA in May 1994 for the 16-bit MS-DOS operating system. Professor Wayne Huber of Oregon State University, one of the authors of SWMM, has developed several updated versions of

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SWMM4. His latest version 4.4H was updated in March 2002. SWMM versions 4.0 to 4.4 are commonly referred to as SWMM4. All of these and previous SWMM versions were written in the FORTRAN programming language. None of them had a user interface or graphics display capability. Users must provide ASCII text input and rely on ASCII text output.

15.2 SWMM5

After years of planning, EPA released an updated (beta test) version 5 of SWMM in 2003 referred to as SWMM5. The official version of SWMM5 is scheduled for release in the first quarter of 2004. Written in C++ programming language, SWMM5 incorporates modern software engineering methods as well as updated computational techniques. The modular, object-oriented computer code of SWMM5 is designed to simplify its maintenance and updating as new and improved process sub-models are developed. The new code also makes it easier for third parties to add graphical user interfaces (GUI) and other enhancements onto the SWMM engine. This approach resembles the approach used by the highly successful EPANET model from EPA, which analyzes hydraulic and water quality behavior in drinking water distribution systems (Rossman, 2000). Figure 15.1 shows a screenshot of SWMM5's interface.

15.3 Comparison of SWMM4 and SWMM5

Table 15.1 provides a side by side comparison of SWMM4 and SWMM5. The decades-old FORTRAN code used in SWMM4 and older version engines has been replaced with object-based C++ code in SWMM5. This makes the code easier to read, maintain and extend, and help make SWMM more accessible to a new generation of H&H modelers. The most notable change is the addition of a GUI for running SWMM, although the option to use a command line version of the program will remain. Users will also notice that the block nature of the program (Rainfall, Runoff, Transport, Extran, Storage/Treatment, etc.) has been replaced with a more integrated view of the rainfall-runoff-routing process. For example, one will no longer have to use three different descriptions of the same pipe, depending on whether it was included in the Runoff, Transport, or Extran blocks. The input data file, whether created internally by the GUI or externally by the user, will have a more intuitive structure and be easier to work with.

Additional SWMM5 information is available at EPA's SWMM5 Web site (<http://www.epa.gov/ednnrmrl/swmm/>).

Figure 15.1 SWMM5 Interface.

Table 15.1 Comparison of SWMM4 and SWMM5

Feature	SWMM4	SWMM5
Operating system	DOS	WINDOWS
Programming Language	FORTRAN	C
Graphic User Interface (GUI)	No	Yes
Network map	No	Yes
Input	Text line data structure (like HEC-1)	Tabular data structure (like EPANET)
Output	Text	Tabular

There are no plans at this time to provide a direct linkage between SWMM and CAD or GIS packages. Third-party developers are encouraged to explore such opportunities. There is some interest in incorporating SWMM into the EPA's Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) package, which is a modeling support information system that works with ESRI's ArcView GIS (EPA, 2004).

15.4 ArcView 3.x

Through the 1990s, professional GIS packages like ArcInfo and MGE designed for GIS data conversion work were not user-friendly to casual GIS users. They were complex software systems that required substantial training and technical skills. Casual GIS users, such as civil and environmental engineers, generally do not have the technical expertise to develop, run, and maintain a complex GIS. ArcView, on the other hand, was a user-friendly desktop mapping and GIS software that could be learned without extensive training or GIS experience. ArcView was a sophisticated desktop mapping and GIS package that brought the power of GIS to the average PC user. ArcView versions 3.0 to 3.3 are commonly referred to as the ArcView 3.x. ArcView 3.3 is the last release of ArcView 3.x and no new releases of the product are anticipated. ArcView 3.x used “Avenue,” a scripting language for creating custom applications and user interfaces. Avenue provided a full-function, object-oriented, application-development environment designed specifically for GIS. Because Avenue was a vendor (ESRI) specific programming language, it was difficult to find and hire Avenue programmers. Many employers had to have their existing programmers trained by ESRI to use Avenue. With more than 500,000 users, ArcView 3.x might be considered the most popular desktop GIS package until the advent of ArcView 8.1.

15.5 ArcView 8.x

ArcView 8.1 was released after version 3.2. The jump from version 3 to 8 signified a major revision to the software as well as alignment with ESRI’s new software suite called ArcGIS 8.1. ArcView and ArcGIS versions 8.0 to 8.3 are referred to as the ArcView 8.x and ArcGIS 8.x, respectively. Though the ArcView 8.x product suite is functionally equivalent to ArcView 3.x, it adds several new capabilities and notable improvements. For example, while the software features of the two versions are similar, the interfaces to access those features are substantially different. So, at a minimum migrating from ArcView 3.x to 8.x requires learning the new interface. ArcView 3.x has a limited support life and will be eventually phased out. Thus, in order to avoid learning both the versions, the new users should start with ArcView 8.x.

With release 8.1, ArcView is now a subset of ArcInfo and uses the same interface and satellite applications (e.g., ArcCatalog). ArcView 8.x is the entry point into the ArcGIS product suite and is, therefore, often considered synonymous to ArcGIS. It is based on Microsoft Component Object Model (COM) technology for Windows and runs on Microsoft Windows 9X/NT/XP/2000 platforms. This version permits the direct reading of more

than 40 data formats and uses a new ArcCatalog application for browsing and managing data. GIS customization and application development uses built-in Visual Basic for Applications (VBA), which means that Avenue has become obsolete with this release. ESRI's abandonment of Avenue as the preferred programming language for customization and application development is perhaps the most significant change in ArcView 8.x (Jenkins, 2002). However, this change is good in the sense that it eliminates the need to learn a new vendor-specific programming language. In fact, development of new ArcView applications has never been easier thanks to the new generation of college graduates that are already familiar with VBA. ESRI has, nonetheless, provided technical white papers on Avenue-to-VBA migration and examples for converting existing Avenue scripts to VBA programs. Table 15.2 provides a side by side comparison of ArcView 3.x and ArcView 8.x.

Table 15.2 Comparison of ArcView 3.x and ArcView 8.x

Feature	ArcView 3.x	ArcView/ArcGIS 8.x
Release date (3.0)	1996	2001
Type	Standalone	Modular (Part of ArcGIS)
Interface	Different from ArcInfo	Similar to ArcInfo
Customization	Avenue	VBA
Data model	Features	Features & objects
Database	DBF and INFO	Microsoft Access (for personal geodatabase)
Extensions	Will not run on 8.x	Will not run on 3.x
Price	\$1200	\$1500

15.6 ArcGIS 8.x

Between 1997 and 2000, ESRI worked vigorously to rewrite its key software platform using Information Technology (IT) standards. This effort resulted in reengineered ArcInfo 8.x and ArcIMS based on a new object-component architecture using a host of industry and government standards, such as Structure Query Language (SQL), Common Object Request Broker Architecture (CORBA), COM, TCP/IP, HTTP, XML, JAVA, and C++. These developments produced ArcGIS 8.x, which represents ESRI's new software architecture rather than a new software product (Shamsi, 2002).

Although the work presented in this chapter is based on ArcView and ArcGIS version 8, AGSWMM has been verified to be compatible with ESRI's new versions of ArcView and ArcGIS software released in July 2004.

15.7 GIS and Modeling Linkage Methods

Shamsi (1998, 1999, 2002) provides a taxonomy to define the different ways a GIS can be linked to H&H models. The three GIS linkage methods defined by Shamsi are:

1. Interchange method,
2. Interface method, and
3. Integration method.

The interchange method employs a batch process approach to interchange (transfer) data between a GIS and an H&H model. The interface method provides a direct link to transfer information between the GIS and the model. The interface method consists of at least the following two components: (1) a pre-processor, which analyzes and exports the GIS data to model input files; and (2) a post-processor, which imports the model output and displays it as a GIS layer. GIS integration, conversely, is a combination of a model and a GIS such that the combined program offers both the GIS and the modeling functions. This method represents the closest relationship between GIS and model. At the present time, the interface method is the most commonly used method and was used to develop a linkage between SWMM5 and ArcGIS described in this chapter.

Notable examples of previous work linking SWMM and GIS are SWMMDUET (SWMM 4.2 and ARC/INFO 6.0 integration), PCSWMM (SWMM 4.4 and ArcView Shapefile Interchange), SWMMTools (SWMM 4.4 and ArcView 3.2 interface), and AVSAND (SWMM 4.4 [TRANSPORT Block only] and ArcView 3.2 integration) (Shamsi, 2004)

15.8 SWMM4 and ArcView 3.x

During the 1990s, several interfaces were developed to link SWMM4 and ArcView 3.x. For example, Shamsi (1998) developed the first SWMM4 interface (for the Runoff and Extran blocks) called AVSWMM. This interface was presented in Computational Hydraulics Int.'s (CHI) 1997 Stormwater Modeling Conference held in Toronto, Ontario in February. Heinemann (2001) developed a SWMM4 interface called SWMMTools Extension. This interface was presented in CHI's 2000 Stormwater Modeling Conference.

Existing SWMM4-ArcView3 interfaces will continue to work with SWMM4 and ArcView 3.x. Unfortunately for the following reasons these interfaces cannot work with SWMM5 or ArcView 8.x:

1. SWMM4 and SWMM5 input file format is different.
2. SWMM4 and SWMM5 output file format is different.

3. SWMM4 and SWMM5 have a different data structure (e.g., three different representations of the same pipe are not required in Runoff, Transport, and Extran blocks).
4. ArcView 3.x interfaces are written in Avenue, which are not compatible with with ArcView 8.x.

15.9 SWMM5 and ArcView 8.x

It is obvious from the above discussion that the existing SWMM4-ArcView3 interfaces cannot work with the new versions of ArcView (Version 8.x) and SWMM (Version 5). Thus, to benefit from the new features of the new software versions, new interfaces should be developed. A sample SWMM5-ArcView8 interface developed recently by ATS-Chester Engineers (Pittsburgh, Pennsylvania, www.atschester.com) is described below.

15.9.1 AGSWMM

Main features of AGSWMM are listed below.

1. links SWMM5 (Beta test version E) with ArcGIS 8.3.
2. developed using VBA.
3. installs a Dynamic Link Library (DLL) file.
4. adds a new “AGSWMM” toolbar in ArcGIS.
5. allows creation of SWMM5 input file from GIS layers.
6. allows creation of SWMM5 backdrop map (emf file) in ArcGIS.
7. allows on-screen editing of input parameters in ArcGIS.
8. allows thematic mapping of SWMM5 output in ArcGIS.

Figure 15.2 shows the AGSWMM toolbar. The toolbar consists of two tools: SWMM Input and SWMM Results View. SWMM Input tool opens the input form shown in Figure 15.2. It allows users to create the SWMM5 input file. Left side of the form is used for creating input data for nodes (e.g., manholes). Right side of the form is used for creating input data for links (or conduits, e.g., pipes). The users can assign the appropriate GIS layer attributes to SWMM5 input parameters using the dropdown pick lists. The users can either create a new SWMM5 input file using the “Make SWMM Input File” button at the bottom of the input form, or they can update the input parameters in an existing SWMM5 input file by selecting the “Synchronize SWMM File” button. The synchronization capability allows the users to edit the input file attributes in ArcGIS (e.g., change a sewer pipe diameter) and automatically reflect the changes in SWMM5 input file. This features allows keeping the SWMM5 input files current. “Make Backdrop File” button creates a backdrop map file for SWMM5 in the required “emf” file format. This button

automatically updates the SWMM5 input file with appropriate scaling factor and offset distance so that it will properly align with nodes and links in the SWMM5 map window. Figure 15.3 shows a SWMM5 map screenshot without a backdrop file. Figure 15.4 shows the same map with a backdrop file created by AGSWMM. The difference between the two maps is remarkable. The backdrop map can facilitate panning and zooming to desired locations for editing, adding, or deleting nodes, links, or other SWMM5 objects.

Figure 15.2 AGSWMM Toolbar and Input Form.

Figure 15.5 shows the View SWMM Results form that is opened by clicking the “SWMM Results View” tool from the AGSWMM toolbar. This form allows users to select SWMM5 output parameters for nodes (on left side) and links (or conduits on right side) for creating thematic maps.

15.9.2 AGSWMM Case Study

To demonstrate the AGSWMM application and check its output accuracy, “Example 1 of Extran Manual” example packaged with SWMM5 was selected (Roesner et al., 1988). AGSWMM successfully replicated the output results included in the EXTRAN manual. This example reproduces Example 1 of the 1988 Extran Users Manual. It is a simple, two branch pipe network with a free outfall (Node 10208) subject to inflows at three locations (Nodes 80408, 82309, and 81009).

Figure 15.3 SWMM5 Map Window Without a Backdrop File.

These inflows cause several pipes to surcharge and several nodes to flood. Figure 15.6 shows a screenshot of Example 1 network in SWMM5. Figure 15.7 shows the same network in ArcGIS. Note the layers for roads and streams added to create the backdrop map. Figure 15.8 shows the SWMM5 screenshot after synchronizing the ArcGIS data and adding the backdrop map.

Figure 15.4 SWMM5 Map Window With a Backdrop File.

Figure 15.5 AGSWMM View Results Form.

Figure 15.6 Case Study Network in SWMM5.

Figure 15.7 Case Study Network in ArcGIS.

Figure 15.7 shows two thematic maps for sewer pipes and manholes. The sewers have been classified by the “ratio of maximum to design flow” SWMM5 output parameter. Pipes where this ratio is greater than 1.0 carry more flow than pipe’s design (full pipe) flow and are therefore considered surcharged. The legend for the sewers layer indicates that Pipe 1602 is surcharged. The manholes have been classified by the “total minutes flooded” SWMM5 output parameter. Manholes where this ratio is greater than zero are

flooded (or overflowing from the top). The legend for the manholes layer indicates that Manhole 80408 overflows for 1 minute but Manhole 80608 overflows for 144 minutes. These overflows are the result of downstream hydraulic bottleneck in surcharged Pipe 1602. Such thematic maps can be a very powerful model output presentation tool for large systems containing thousands of nodes and links.

Figure 15.8 Case Study Network in SWMM5 With Backdrop Map.

Linking SWMM with GIS is not without some disadvantages. The simplistic modeling approach and user-friendly tools, provided by GIS-based models like AGSWMM, may encourage inexperienced users to become instant modelers which could be counter productive. The user-friendly interface of an integrated package may incorrectly make a complex model to appear quite simple, which may lead to misapplication of the model by inexperienced users. Modeling should not be made easy at the expense of good science. Another potential downside of integrating SWMM with ArcGIS is that all the SWMM options, especially those available through command line only, are not be available in it.

15.10 Conclusions

Due to new software releases, many existing ArcView3.x and SWMM4 interface applications have become obsolete. The developers must, therefore, develop new interface applications that are compatible with new versions of

ArcView, ArcGIS, and SWMM. This chapter presented a sample software called AGSWMM that provides an interface for linking SWMM5 and ArcView/ArcGIS 8.x. AGSWMM allows creation of SWMM5 input data from within ArcGIS, allows mapping of SWMM5 output as thematic maps, and creates backdrop map files for SWMM5. AGSWMM satisfies EPA's objective of allowing third parties to add graphical user interfaces and other enhancements to SWMM5.

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