Practical assessment of the SWMM programme

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Abstract: The article describes the advantages and disadvantages of the SWMM programme user environment when working with it. The Storm Water Management Model (SWMM) is a programme developed by the U.S. EPA (United States Environmental Protection Agency). The SWMM programme is used worldwide to plan, analyse and design rainfall-runoff, combined and separate sanitary sewage systems and other drainage systems in urban areas [1]. The programme is freely available to download from the U.S. EPA website [2].

1. Introduction

Introduction: It is a dynamic rainfall-runoff simulation model used for a single rainfall event or for long-term simulation of runoff quantity and quality of water in predominantly urbanised areas. The model monitors the quantity and quality of runoff, flow-rate, water depth and quality in each sub-catchment area. The simulation time in individual channels and pipelines consists of multiple time steps. The results can be displayed as river basin maps, time series charts and tables and as statistical frequency analyses. The run-off process is based on sub-catchments with rainfalls with resulting surface runoff and its pollution. Furthermore, the runoff is conveyed into a system of conduits, manholes and stormwater tanks, pumping stations, and treatment controls can also be included. The SWMM monitors the quantity and quality of runoff within each area. It also monitors the flow-rate, depth, and water quality in the individual pipe and channel sections during the simulation which consists of several time steps [3].

2. Materials and Methods

It is programmed in C language and is only compatible with Windows operating systems (XP, Vista, 7, 8.1). Drawings covering the area of interest are not required; however, they streamline and accelerate working with the programme [4].

The SWMM programme work is based on the hydro-technical situation derived from the ideal roof method in AutoCAD. The SWMM programme can read only data in standard image formats (JPG, JPEG, BMP, etc.). PDF or DWG files are not supported in the workspace. The drawing format size is not important, the scale is not restricted. The best drawing format as the basis for the hydro-technical situation in SWMM is BMP. The format size is not important. The drawing can be easily zoomed in and out in the programme. The A1 format is also a suitable input data. The BMP image extension has proven to be the best in terms of readability in the SWMM programme. A minor disadvantage of this image format is its size. The input data in A1 format and resolution of 300-DPI has a size of 200MB.

2.1. Data import into the SWMM programme Soil reaction
Data imports into the SWMM programme may be primarily addressed in the form of an image with BMP extension; data can also be imported by entering coordinates of individual objects (e.g. manholes, outlets, CSOs). Rainfall data can also be entered as a text file, which must be entered into: Rain Gage → File Name and then the path to the text file containing data for the required simulation is entered. If no data is available (coordinates, map data in image format), the situation can be plotted directly into the SWMM programme because the visual form of the situation is irrelevant. All required lengths, areas, etc. are entered into tables of the respective objects and sections.

2.2. Data export from the SWMM programme

Data exports from SWMM can be addressed in two ways offered by the programme. All outputs are addressed via File → Export. The first export option is Map Export, where the programme offers three types of output extensions, the most useful being the DXF extension file, which can be opened in AutoCAD. AutoCAD plots individual manholes and sections between manholes. This gives the sewerage system in the relevant area. Another most common form of output is the Status and Summary Report, where the programme generates results of the entire simulation in an RPT text file that can be opened in Notepad.

2.3. Measured data/input data

The created project is a set of pre-defined objects where corresponding data needs to be filled in. The quantity and type of input data required by the programme depends on outputs required by the investor. If this only concerns assessment of the capacity of the sewerage system, the following data is required: geodetic survey of the sewerage system (manhole cover altitude and manhole depth), hydrological data of the area (total rainfall) and hydraulic data of the sewerage system and estimated roughness coefficient.

Units of the input and output (calculated) quantities can be entered in SI metric system or in US formats.

3. Results

The programme environment is well-organised and working in the programme is not demanding. Given its features, the environment is similar, for example, to EPANET 2.0 [3] and therefore designers working in similar programme should have no difficulties running this programme.

Each object is specified using data that is entered into the relevant object. Some of the data in the table must be filled in and are necessary to start the simulation. Other data serves to define the simulation results more accurately. In order for the required values to be filled in correctly, the table of the object also contains a note field, in which help is displayed, indicating data required to be entered in the respective box and unit.

3.1. Rain Gage

The design rainfall for a given location is determined using traditional methods. The input parameters are: Rain format can be entered as intensity [l/s ha], volume [mm]; Time interval [h:m]; The data source can be entered directly in the programme or a file and Time series can be attached.

The programme enables rain data input in formats provided by US meteorological institutions (NWS, NCDC) and in customised text files which must contain the following consecutive data: station ID, year, month, day, hours, minutes, rainfall values. This gives us the real rainfall. There are no rainfall databases or predefined diagrams here. However, the rainfall time behaviour can be entered with relevant intensities.

3.2. Subcatchment

This defines the area where surface runoff will be simulated. The runoff is discharged into manholes. The runoff coefficient in % must be entered for each catchment. The runoff coefficient value was determined on the basis of a sample unit hectare.
Input parameters: Rain Gage; Outlet; Area [ha]; Width [m]; % Imperv: runoff coefficient Ψ (if Ψ = 0.4, 40 is entered). To complete other data, a detailed land survey is needed. However, such data is not essential for preliminary simulation results.

3.3. Junction
Junctions in the SWMM are understood as manholes, the definition of which requires geodetic data only. Input parameters: Invert El. [m a.s.l.] and Max. Depth [m].

3.4. Conduit
The individual manholes are simply connected by conduits. Select the Conduit from the object menu and by clicking on the manhole sign enter the beginning of the section, and by clicking on the sign for the next manhole upstream draw the junction. Hydrological data of the network is required to define conduit sections.

Input parameters: Opening and Closing Manhole, Shape, Max. Depth [m], Length [m] and Roughness: Manning's roughness coefficient n must be entered.

When entering a section cross-section, use can be made of a predefined offer in the programme. There are 6 open (Rectangular, Trapezoidal, Triangular, Parabolic, Power, Irregular), and 17 commonly used closed cross-sections (Circular, Force Main, Filled Circular, Closed Rectangular, Horizontal Elliptical, Vertical Elliptical, Gothic, Catenary, Semi-Elliptical, Arch, Rectangular Triangular, Rectangular Round, Basket handle, Semi-Circular, Custom, Modified Basket handle, Egg, Horseshoe). If a cross-section other than those offered by the programme exists on the network, you can create your own cross-section by entering the coordinates X (height), Y (width). Dimensions (for circular), depth (for open) of the profiles are given in meters and are unlimited. Besides these basic parameters, which are necessary for the simulation, it is also possible to enter other ones so as to make the results more accurate. Extension of the entered parameters depends on the supporting data. These include: Inlet, Outlet offset: inlet height, outlet height over the respective manhole bottom; Initial flow; Energy loss: at the conduit inlet, conduit outlet, Seepage loss rate and check valve.

3.5. Outfall
The final junction on the network is determined by predefined boundary conditions. The outlet object is taken as the end junction of the entire network. During simulation, this junction is opened for the flow-rate from the sewer system and the conduit does not get filled which would be alerted by the programme as a calculation error. The outlet object is most often placed as the last manhole upstream the WWTP. Input parameters: Invert. [m a.s.l.] and Type.

3.6. Storage
Any size can be defined. Volume properties can be determined by the function or table (flood curve) where each water table in the reservoir determines the flooded area. Input parameters: bottom level [m a.s.l.], maximum depth [m], evaporation [mm/d] and infiltration [mm/h].

3.7. Pump
It is entered as a section between junctions. The pump is defined by a curve. There are 4 types of curves used to select the desired parameters. The input parameters are the curve and the on/off level [m]. Description of curves for setting up the pump:

- Off-line pump in a wet sump where the flow is increased gradually.
- In-line pump, the flow-rate increases gradually with the water table at the inlet junction.
- In-line pump, the flow-rate changes continuously with the difference between the levels of inlet and outlet junctions (centrifugal pump).
- In-line pump, the flow-rate changes continuously with the water table in the inlet manhole.
4. Discussion
Once all parts of the project are entered, the simulation can start. Wastewater runoff and water quality transport can be simulated. The outputs of the program are fully with the legislation of the Czech Republic [5,6].

4.1. Wastewater outflow
After the simulation, the programme can show the course of filling and emptying in the selected profile. Another option is to suspend the ongoing simulation at a certain time step to assess the condition at a given moment (time step). We recommend setting the duration of the simulation as at least 4 times longer than the rainfall event itself as the programme also considers the time of delay and the later rainwater runoff from the catchment area. The programme also offers a spreadsheet form of the output where the flow-rates in l/s, time, flow velocity, conduit filling percentage in terms of the flow-rate and water level are evaluated. This output enables comparison of the maximum values in the above parameters only.

4.2. Programme outputs
After the simulation, the outputs can be viewed. The outputs can be either in the form of text or graphics in the form of a longitudinal section profile or depending on the flow-rate over time. Simulation of outputs can be performed between individual manholes or selected sections.

5. Conclusion
The applicability of SWMM programme is suited for small and medium-sized municipalities with a not-too-branched sewer system. When working with larger sewer systems, the situation may become unclear and the method of calculating the surface runoff using the ideal roof method is less suitable for larger municipalities.

The advantages and disadvantages of the SWMM model are summarised in the following points:

Advantages of the SWMM programme:
- Freely available programme.
- Programme stability.
- Variability of inputs and outputs.
- Miscellaneous tools to facilitate work with the programme.
- Simulation of water quality behaviour and pollution transport (Pollutant Editor).

Disadvantages of the SWMM programme:
- Inability to enter data in dwg format.
- Does not work with GIS compared to competitive programmes.
- Cannot make calculations if the slope of the pipeline is in reverse slope.
- Absence of the "Return" button.

Acknowledgements
"The research report was drawn up in the framework of project No. LO1408 "AdMaS UP - Advanced Building Materials, Structures and Technologies" supported by the Ministry of Education, Youth and Sports in the framework of the purpose-oriented support of the "National Sustainability Programme I".

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