



AUTOMATION OF SWMM SUBCATCHMENT GENERATION

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Abstract

In EPA Storm Water Management Model (SWMM) the runoff load based on subcatchments has determining role in the whole model. The manual delineation and parameter setting of subcatchments are time consuming and also may result errors. The automation of these tasks can be done by various tools. The open source and public domain code of SWMM makes the program modifications and extensions possible. Some new programmed features embedded into SWMM like subdivision of subcatchments and calculation of width are introduced here. The easily readable-writable database format of SWMM allows to communicate with external programs. Open source or commercial GIS programs can solve the emerged tasks in case of available data. In case of ground surface data with sufficient precision the subcatchment delineation can be done. In case of enough detailed land cover data their main runoff parameters produced by geometric GIS functions are also introduced.

Key Words: SWMM; subcatchment; GIS; delineation; runoff; watershed

1. INTRODUCTION

EPA SWMM [8] is one of the most popular hydrodynamic simulation software for urban storm water networks. Its computational engine programmed in C language is fast, stable, well-tested. The user interface programmed in Delphi is working reliable, but provides only the core functionality. The whole software is open source and public domain, therefore any new program function is possible to build in. An introduced GeneralStorm program [3] is based on the original computational engine and completely replaced the user interface containing some new subcatchment functions.

Data processing is meaning a significant part of model building. The building of the surface runoff model means the delineation of the subcatchments, then filling up all the subcatchment parameters with data e.g. manning roughness for pervious and impervious areas.

There have been already born specific results from application of geo-informatics supporting SWMM model building including subcatchment delineation and parameterization [6], [10]. We present a general and up-to-date method applicable for different local conditions.

SWMM runoff model is working as a lumped model, i.e. the subcatchment parameters like slope, perviousness etc. are homogenous for each subcatchment. Distributed models are

preferred in case of large drainage basins. Other applications are using a combination of distributed and lumped models. All these applications are producing homogenous SWMM subcatchments based on land use. Some of them [5] are applying high resolution land use and DTM data increasing the subcatchment division up to the land cover raster resolution producing small and rather homogenous subcatchments. In case of urban storm sewer network the runoff water is reaching the sewers at discrete points, at the inlets. In our SWMM modelling approach the subcatchment division is determined and limited by the distribution of the inlets. The subcatchments belonging to inlets are not homogenous in real, therefore we produce area weighted average for subcatchment parameters (slope, perviousness, n-manning etc.).

The development of remote sensing imagery and GIS programs e.g.[14] has already been serving almost all the necessary functions to perform the common data processing subtasks. Choosing the right GIS tool in right order remarkable facilitates the model building process.

2. MATERIALS AND METHODS

Two different urban datasets were selected to demonstrate the possible methods for preparing subcatchments into SWMM. The first study area is part of a Hungarian large city Szeged [11]. It has relatively plain ground surface with surface elevation difference of a few meters. The second selected area is a part of a Hungarian city Biatorbagy [9]. It is hilly with elevation difference of about 50 meters. Their areas are approximatively equal, about 300ha. In case of the hilly study area we could produce the digital terrain model (DTM) based on the available detailed survey data, about 25000 points (Figure 1).

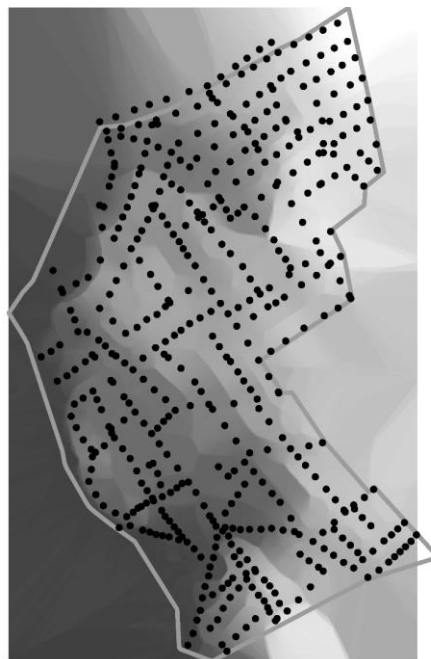


Figure 1: Hilly study area with DTM raster and manholes

For the European cities with more than 100,000 inhabitants the free Urban Atlas [1] providing land cover and land use data, we could use it free in case of Szeged (Figure 2).

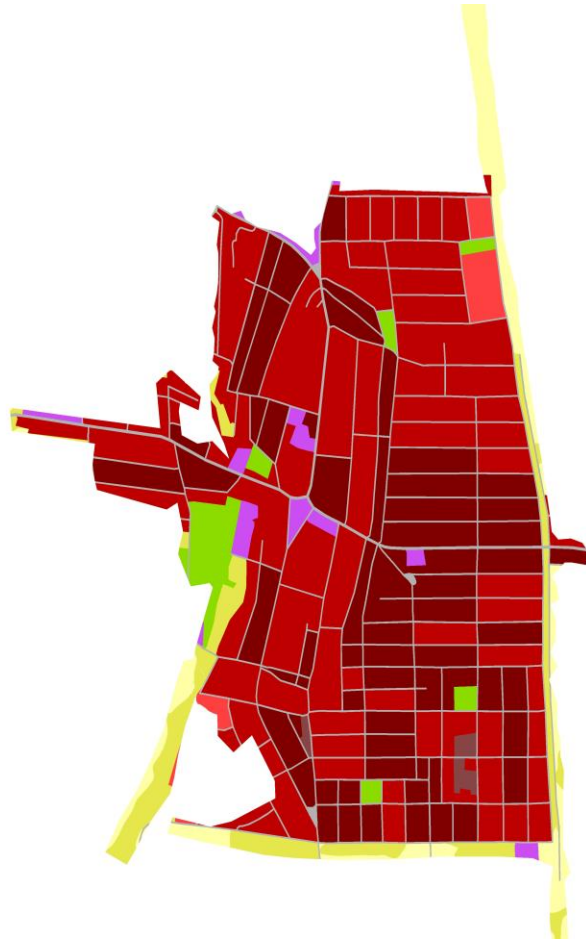


Figure 2: Plain study area with land cover polygons and with manholes

Some functions of own SWMM based development (GeneralStorm) is introduced which is providing subdivision of subcatchments and calculating the geometric shape parameter.

Subcatchment delineation and parameter filling methods are introduced in GIS programs. QGIS [7] is free and open source, while ArcGIS [2] is a commercial software.

3. RESULTS

Solutions with internal, programmed in SWMM and external GIS tools are introduced.

3.1 Programming SWMM

In case of available coarse, relatively large subcatchment delineation, a new function called “explode” can divide it into smaller parts (Figure 3). The division is controlled by the count of the aimed new subcatchments. This feature is used for eliminating the peak of loads from large subcatchments, thus improving also the pipe flows calculations.

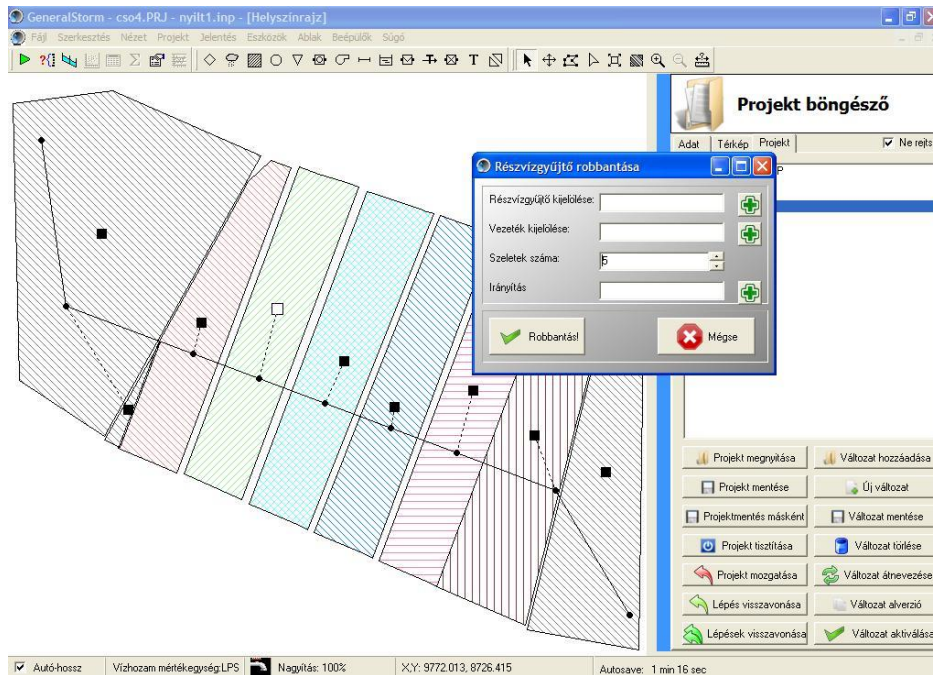


Figure 3: Subcatchment subdivision in GeneralStorm

The geometric shape parameter of the subcatchments in SWMM is described with the “Width” parameter. The “Width” should be given manually in SWMM as a number. In our development it is a calculated from the ratio of the area and the runoff length. In case of irregular shapes the manual data fill would be quite long and would mean possible source of errors.

3.2 External tools

In case of plain surface Voronoi (Thiessen) polygons produced from the manholes of the storm water network can be a good approximation of the subcatchment areas (Figure 4). The slope of each subcatchment can be estimated as an average slope estimated for the whole study area.

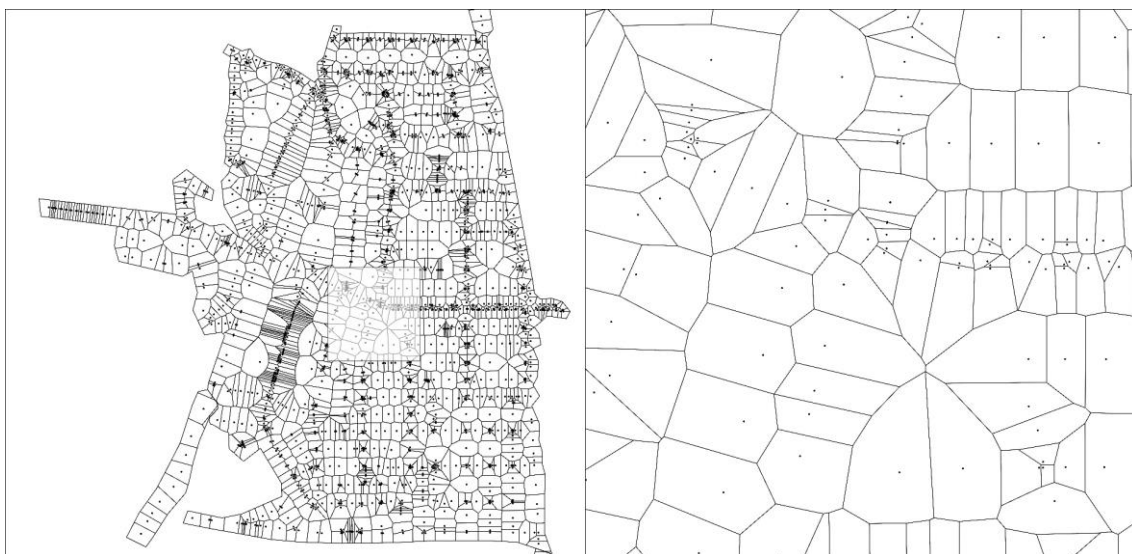


Figure 4: Subcatchment delineation by Voronoi-polygons, whole plain and zoomed study area

In case of hilly surface and sufficient number of surface elevation point raster interpolation tool in QGIS can easy produce surface raster (Figure 1). ArcGIS Spatial Analyst Hydrology tools can be used for delineation of subcatchments as raster in the following steps:

- filling the smaller sinking surface errors
- flow directions calculation
- flow accumulation calculation
- making snap pour points to find manholes placed not exactly at deep points
- watershed calculation

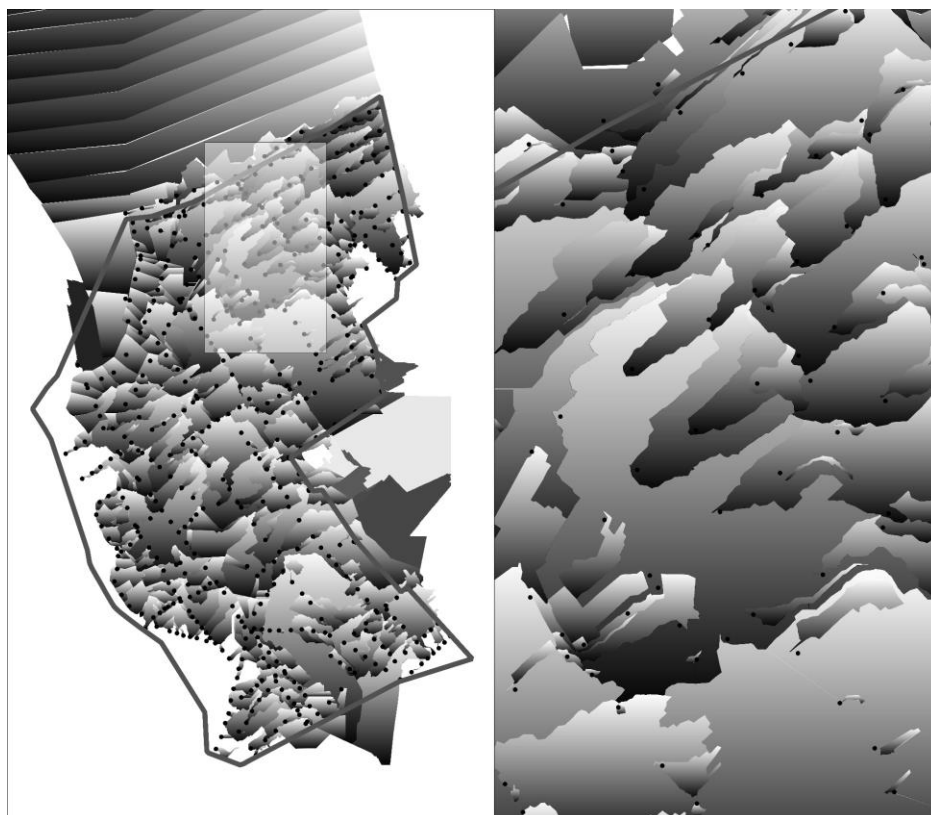


Figure 5: Watershed delineation with GIS tools, whole hilly study area and zoomed area

Watershed polygons can be created from watershed raster by raster to polygon conversion tool. Slope for each watershed polygon can be produced by statistical raster calculations (Figure 6).



Figure 6: Watershed slopes with GIS tools, hilly study area

In case of designing a new storm water network, the missing manhole surface elevations can be derived from the raster DTM.

In case of available data for land cover, further runoff parameters can be filled automatically for the SWMM subcatchments. The following steps can be applied in order to generate impervious-pervious ratio and area weighted n-manning values for each subcatchments:

- intersect the watershed polygons layer with land cover polygons layer
- setting impervious-pervious ratio (n_{imp}), n-Manning for impervious (n_{imp}), n-Manning for pervious areas (n_{perv}) in case of each land covers in a table
- joining previous table with intersected polygon's attribute table
- creating new calculated fields in the attribute table with the area of intersected polygons (area):
 - $area_{imperv_perv_ratio} = area * imp,$
 - $area_n_{imp} = area * n_{imp},$
 - $area_n_{perv} = area * n_{perv}$
- dissolving intersected polygons by watershed ID, summing the values in the new fields created in previous step
- creating new calculated fields:
 - $newarea = \text{area of dissolved polygons},$
 - $imperv_perv_ratio = (area_{imperv_perv_ratio}) / newarea,$
 - $n_{imp} = (area_n_{imp}) / newarea,$
 - $n_{perv} = (area_n_{perv}) / newarea,$
- creating simple polygons by multipart to singlepart function

Watershed and manhole data can be converted into SWMM using Python language in GIS. The “Width” of the subcatchment can be calculated as the ratio of the area and the flow route using Python. The watersheds and their attributes (imperv_perv_ratio, n_imp, n_perv) can be used as SWMM subcatchments and its runoff parameters i.e. Percent of impervious area, Manning N for impervious area, Manning N for pervious area (Figure 7). Depending on the formats of the available data some conversion steps can be convenient to execute in CAD programs, eventually using the VBA program language.

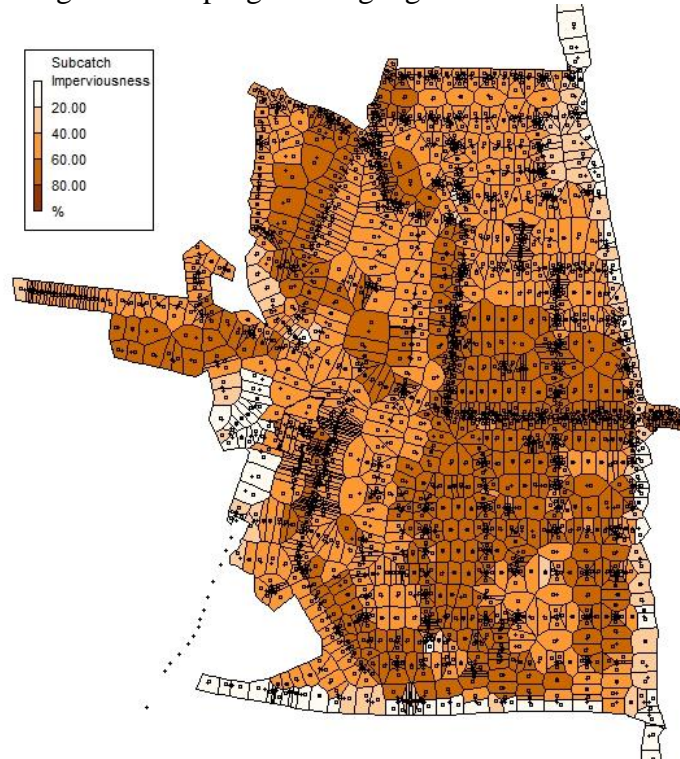


Figure 7: Impervious-pervious ratio with manholes in SWMM

4. DISCUSSION

The introduced methods can be used for preparation of an SWMM runoff model. The selected tasks are depending on the local surface conditions, available data and software. The selected tools can shorten the model building process and the final model is more reliable than it would be by manual edition.

ACKNOWLEDGEMENTS

Thank you for our colleagues at TUB working together in the hydrodynamic projects [9], [11].

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Author Profile



Dr. Marcell Knolmar was graduated at the Budapest University of Technology as civil engineer and has been working for the same university at the Department of Sanitary and Environmental Engineering as researcher and teacher. He has significant results on the fields of computer aided sewer design, geographical information system of sewer networks and designing of rain monitor device. He certificated his PhD degree in the field of the computer aided sewer design. His current research scope is the hydraulic modelling of sewer networks, specially the sediment transport of sewer networks.



Dr. Roland Fulop was graduated at the Budapest University of Technology as civil engineer and has been working for the same university at the Department of Sanitary and Environmental Engineering as researcher and teacher. He has significant results on the fields of drinking water networks. He certificated his PhD degree in the field of the reconstruction. His current research scope is modelling and reconstruction of drinking water networks.