Modeling radionuclide transport in overland flow: An urban case study

Supplemental Material

S1. Building Layer Data Processing

Buildings in the case study model area represent a separate type of catchment, collecting all the rainwater and directing it to curb gutters or pervious areas. Building footprints were available from the SEMCOG GIS data warehouse. Separate files for Metropolitan Detroit, Wayne County, and Macomb County were obtained, clipped to the study area, and then merged together using ArcGIS. The number of buildings was very large, and there are many small buildings that have little impact on the direct discharge of rainfall to the sewer system. Using all the buildings in the case study model as obstructions negatively affected the run time for 2D node generation. (Taking between 8 hours to more than 24 hours for the computers used in this study, depending on the CPU structure and computing speed, operating system, and RAM configuration of the computer used). Two options were evaluated:

- Remove small obstructions (buildings)
- Focus the 2D mesh on the area where decontamination would be most critical

Both options greatly reduced the required computing time. Buildings smaller than 200 square feet represent less than 1 percent of the buildings present, and buildings smaller than 300 square feet represent about 2 percent of the buildings (Figure S1). By comparison, about 2 percent of the 2D cells were smaller than about 1,000 square feet. Removing obstructions smaller than 200 square feet greatly reduced the computing time; less than 1 hour was required to create the 2D nodes and cells for the more powerful computers (e.g. quad core 2.7 GHz CPUs running 64-bit operating systems). Figure S1 illustrates a method for evaluating the obstruction size in comparison of the subcatchment size. Thus, obstructions smaller than 200 square feet can be removed without sacrificing detail in the model. In addition, by focusing only on the area nearby the detonation for the 2D nodes, the cells could be generated in under hour. Subcatchment names and other attributes needed to incorporate the buildings as subcatchments or to associate each building with the GDRSS or GIS subcatchment that contained it were added using tools available in ArcGIS. The building sublayer with the calculated or imported data was exported as a new feature class. The outlets for building subcatchments were auto assigned to junctions using PCSWMM’s set outlet tool.
S2. Meteorological Data and Analysis

Review of Detroit area National Oceanic and Atmospheric Administration (NOAA) data indicated that records for the Detroit Metropolitan Airport were the most robust and internally consistent, and included hourly and sub-hourly observations, daily summary data, and short-duration precipitation summaries. Data for the years 1981 to 2017 obtained using the Local Climatological Dataset tool (https://www.ncdc.noaa.gov/cdo-web/datatools/lcd) were loaded into the relational database for processing and analysis. Hourly accumulation precipitation data were converted to incremental hourly data with the following adjustments:

- Trace amounts were not included.
- Data flagged as suspect were reviewed for viability and either accepted as the reported value or rejected.
- Wind data flagged as suspect were accepted at the reported value.

Wind rose diagrams for peak hourly daily and sustained winds indicate prevailing wind direction for the area is from the southwest, with sustained winds in the range of 15 to 30 miles per hour (Figure S2).
Figure S2. Wind rose diagrams for A) sustained winds and B) daily peak winds from the Detroit Metropolitan Airport from 1981 to 2017.

Storm Frequency analysis was conducted to establish the return frequency of storm peak intensities for both 1-hour and 24-hour peak rainfall events. The method uses ranked annual maximum rainfall intensity values to compute the annual exceedance probability for a similar rainfall event occurring each year (Kirby 1981; Tasker 1978). Peak annual hourly and daily rainfall data were extracted from the database using data query tools available in Microsoft® Access™. Figure S3 shows the data plotted on log-log scale with the best-fit least squares regression curve. The $R^2$ value for both curves is better than 0.90, indicating a good fit to the data. The peak values estimated for the 1-hour 2-year return frequency rainfall are within the ranges given for NOAA Atlas 14 precipitation frequency estimates for the Detroit City Airport and Detroit Metropolitan Airport. However, the estimate for the 24 hour 2-year return rainfall predicted in this analysis is below the ranges for the 24 hour 2-year return event (Table S1).

| Event   | Location | Min   | Peak | Max   |
|---------|----------|-------|------|-------|
| 1-hour  | DET      | 0.962 | 1.05 | 1.36  |
|         | DWT      | 0.996 |      | 1.35  |
| 24-Hour | DET      | 2.08  | 1.89 | 2.67  |
|         | DWT      | 2.02  |      | 2.7   |

DET – Detroit City Airport
DWT – Detroit Metropolitan Airport
Source for Min and Max: https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=mi

Table S1. Range in Estimated Rainfall Depth for 2-Year Return Events.
S3. Washoff Parameter Analysis

To establish the relative effects of using different values in the exponential loss equation a simple cumulative loss model was developed in Microsoft Excel using a constant runoff depth and a range of coefficients representative of the land use types of the area being modeled. Table 4 and Figure 7 illustrate the washoff behavior for the range of values obtained from the EPA SWMM Water Quality Manual (U. S. Environmental Protection Agency 2016) and Maharjan, Pachel, and Loigu (2017). Buildings and roads are modeled as specific land use types. Urban land use subcatchments are areas that do not include buildings or roads and are a combination of open and paved areas.

Cumulative washoff is listed as a percentage of the initial subcatchment inventory. Runoff depth is the median value for the peak runoff depth of all subcatchments from the modeled runoff for the July 27, 2014 2-year return 1-hour peak intensity storm. This simple washoff model can be used to assess the cumulative washoff over a range of values applicable to the land use types used in the simulations. The ranges for all coefficients and exponents from Maharjan, Pachel, and Loigu (2017) exhibit considerable overlap, but using the maximum, mean, and minimum values in the simple cumulative washoff model illustrated that there is a variability in response within this range, from about 3-50 percent washoff for the peak 1-hour rainfall event (Table S2 and Figure S4). Values were assigned to the land use types to reflect the range of values in Table S2 (based on this qualitative assessment) for use in the case study model.
Table S2. Simple Washoff Assessment

| Simulation Duration (hour) | EPA TSS | Max TSS | Mean TSS | Min TSS |
|---------------------------|---------|---------|----------|---------|
| 0.012                     | 0.9     | 0.6     | 0.1      | 0.0     |
| 0.04                      | 2.7     | 1.9     | 0.3      | 0.1     |
| 0.11                      | 7.9     | 5.7     | 1.0      | 0.3     |
| 0.33                      | 22.1    | 16.3    | 3.1      | 0.8     |
| 1.00                      | 53.3    | 41.8    | 9.2      | 2.4     |
| 4.00                      | 95.3    | 88.6    | 32.2     | 9.2     |
| 12.00                     | 100.0   | 99.9    | 68.9     | 25.2    |
| 24.00                     | 100.0   | 100.0   | 90.3     | 44.1    |

TSS – Total suspended solids.

Figure S4. Cumulative washoff assessment.
References

Kirby, WH. 1981. "Annual flood frequency analysis using US Water Resources Council guidelines (program J407)." US Geological Survey Open-File Report:79-1336.

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