Analysis of Storm Water Drainage System at Park Road in Colombo Using Storm Water Management Model (SWMM)

A.B.D.T. Nandharathne[1] and T.M.N. Wijayaratna[2]
Department of Civil Engineering, University of Moratuwa, Sri Lanka

ABSTRACT: Colombo city is the main commercial and administrative hub of Sri Lanka. The city is frequently subjected to flooding during rainy seasons which disturb day to day routines. The existing drainage system is not sufficient for the current storm water demand. In this study, the existing storm water drainage system in Park road area in Colombo 5 is analyzed using Storm Water Management Model (SWMM). Apart from simulating the existing storm water drainage system in the area, the present study identifies the possible reasons for the flooding and introduces remedial measures using the Storm Water Management Model (SWMM).

1 INTRODUCTION

The capital city of Colombo is the economical and administrative hub of the country. Even though Colombo is such an important place, during rainy days some parts of the city become inaccessible. In the last few decades there is an increasing trend of floods which completely disturbs the daily routines of the people. The drainage system of the Colombo city was mainly built in the early parts of the 20th century, with certain modifications been carried out during last decades to improve the drainage. However, the existing drainage system is still not adequate due to the ever increasing storm water volumes due to rapid urbanization. The percentage of impervious areas is on an increasing trend resulting in less infiltration and high surface runoff. This study was conducted to analyze the present situation of a part of Colombo drainage system using Storm Water Management Model (SWMM) developed by the United States Environmental Protection Agency (USEPA).

USEPA's Storm Water Management Model (SWMM) is an open source software which can be used to simulate a storm water drainage system with open drains and closed conduits (Arthur, 2010, Suhyung et al., 2007, Zhang et al. 2013). Rainfall-runoff, free surface flow, pressured flow and water quality simulations can be done with the SWMM. Latest version of USEPA SWMM (version 5.0) is used in this study.

The study area considered in this study is the Park Road Catchment in Kirulapone, Colombo 5 (See Fig. 1(a)). This area consists of residential areas, commercial facilities, hospitals and some administrative offices in addition to a dense road network. It is a highly populated area with thousands of residents and visitors. Flooding is experienced whenever there is heavy rainfall. Park road catchment has several spots where heavy flooding takes place. The storm water collected in this area is discharged to the nearby Kirulapone canal and high water levels in the canal are also a reason for floods.

The Park road hydro catchment is divided into fifty four (54) sub catchments based on the drainage pattern. The drainage system of the Park road area consists of seventy nine manholes operating as intakes for underground pipe system and a network of open drains draining into the Kirulapone canal. All underground pipes are made of concrete and have rectangular or circular cross sections. Open drains are concrete lined with rectangular cross sections.

2 OBJECTIVES

Main objectives of this study are,

1. Identify the critical points of the drainage system which are vulnerable to flooding during the design storm.
2. Identify the possible reasons for flooding at above points.
3. Propose solutions to overcome the flooding issue and test them using the SWMM.

3 METHODOLOGY

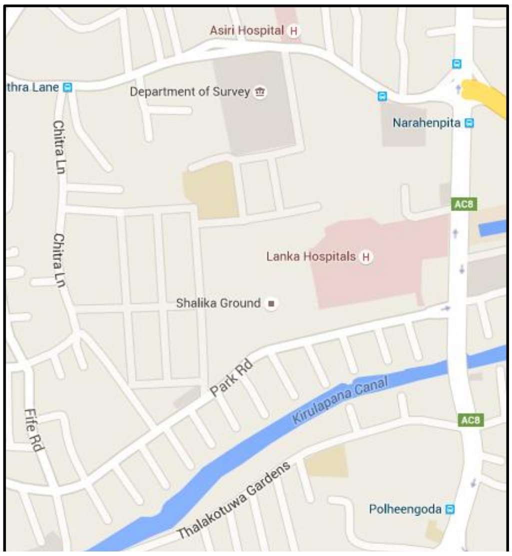
Data collection from the Drainage Division of Colombo Municipal Council and through field visits, developing the SWMM model, interpreting the model results to explain the flooding issue and testing alternative arrangements in the model to ease the flood highlight the methodology.

---

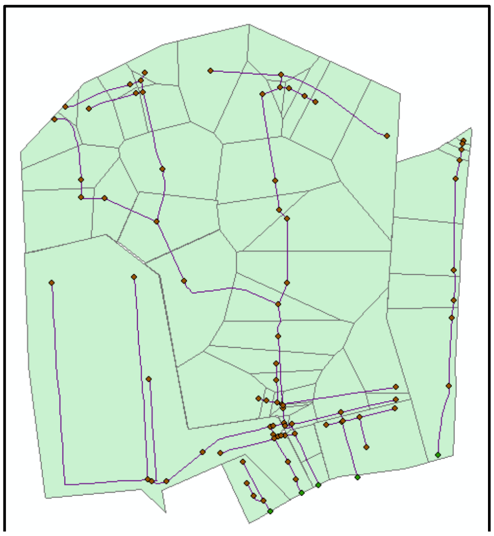
1 Former Student 2 Senior Lecturer e-mail : nimalw@uom.lk

3.1 *Modelling of the existing drainage system*

Several field visits were carried out to understand the existing drainage system and flooding issues of the study area. The basic details of existing drainage network of Park road sub-catchment and the available hydraulic parameters were collected from the Drainage Division of Colombo Municipal Council (CMC). Data related to the dimensions and levels of drainage network and characteristics of the catchment were in GIS format. Ersi ArcGIS software was used to analyze and prepare the data for SWMM. The ArcGIS shape files of the Park Road catchment was imported to the SWMM by converting them to the ‘inp’ file format.



(a) Study Area



(b) ArcGIS Map

Fig. 1 Study area and the ArcGIS map of the study area

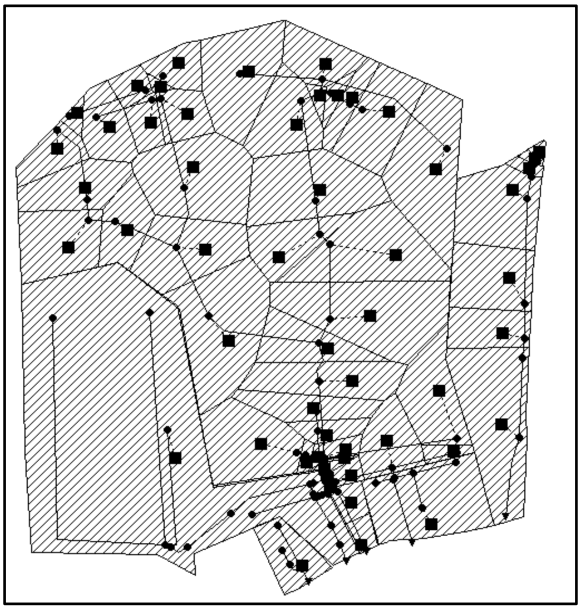


Fig. 2 Study area modelled in SWMM

Then the hydraulic and other required physical parameters were assigned to the drainage network. Manholes in the drainage network are referred as junctions in SWMM. There are 79 junctions in the Park road catchment SWMM model (see Fig. 2). Maximum depth of the manhole, initial depth (elevation of the manhole opening) and the invert elevation are the main parameters to be defined. At each junction (manhole) the maximum depth was calculated as follows;

Maximum depth=Initial depth-Invert elevation

Initial depth and invert elevation of each junction is given in the GIS shape file in junction properties which are collected from the CMC.
Conduits and canals of the drainage system are referred as links in SWMM. Links are the most difficult component to be modeled in SWMM. Link network cannot be imported directly into the SWMM database from ArcGIS. Each link has to be drawn manually in SWMM. Thereafter main properties of the links have to be defined. MUID (link identification given in the data base) of each link in GIS properties has to be assigned to the name of the link in SWMM. The property called “Length C” in GIS was defined as the length of the link in SWMM. All the connections regardless of whether they are conduits or canals, defined as conduits in SWMM. For circular shape conduits the maximum depth is defined in SWMM properties (See Fig. 3). However, for rectangular cross sections, close rectangular shape in SWMM has to be selected and both maximum depth (height) and width have to be given.

Conduit 66_13_13B_3871D_66_13_13B_4652

Property	Value
Name	66_13_13B_3871D_66_13_13B_4652
Inlet Node	66_13_13B_3871D
Outlet Node	66_13_13B_4652
Description	
Tag	
Shape	CIRCULAR
Max. Depth	0.15
Length	386.013461
Roughness	0.01
Inlet Offset	0
Outlet Offset	0
Initial Flow	0
Maximum Flow	0
Entry Loss Coeff.	0
Exit Loss Coeff.	0
Avg. Loss Coeff.	0
Seepage Loss Rate	0
Flap Gate	NO
Culvert Code	

Fig. 3 Property table of a conduit in SWMM

As mentioned in a previous section, the Park road catchment is divided into 54 sub catchments based on their drainage points and hydraulic characteristics. Under sub catchments in SWMM, an outflow has to be assigned for each sub catchment. Closest junction was named as the outflow of each sub catchment.

Then the most important part for a proper simulation of storm water drainage model is to define a rainfall event. The design rainfall used in the MIKE URBAN flood models developed in Metro Colombo Urban Development Project was used in the present study as well. Table 1 shows the design rainfall event which has a return period of 10 years. Designing urban drainage system for a storm event with 10 years is an accepted norm in Sri Lanka and many other countries.

Table 1. Time series of design rain event used for model simulation (Adopted from Metro Colombo Urban Development Project/ Rainfall value given in mm).

Time (H:M)	Value
00:00	0
01:00	1
02:00	2
03:00	4
04:00	10
05:00	100
06:00	10
07:00	4
08:00	2
09:00	1
10:00	0

It was decided to use some of the hydrologic parameters used in the MIKE URBAN flood model of Metro Colombo Urban Development Project as those parameters are found to be representing the Colombo drainage system adequately (Drainage Division, CMC, 2013 and 2014).

- Percentage of impervious area = 65%
- Manning's roughness value for impervious area = 0.02
- Manning's roughness value for pervious area = 0.05

Prior to run the SWMM simulation, time limits should be set according to the date. Simulation time was extended to cover the time taken for the whole system to drain completely.

4 RESULTS

SWMM outputs are the data related to sub catchment runoff, water depth of the manholes, inflow at manholes, surcharge at both manholes and outflows, flooding at both manholes and outflows and flow in conduits. SWMM outputs are available in the tabular and graphical forms. Some graphical outputs such as water profile plots for selected drainage lines are very useful as they can be used to identify the bottle necks in the drainage lines.

Results of the analysis of existing drainage system show that there are thirty two (32) manholes out of a total of 79 manholes in the Park road catchment which have got flooded due to the design rain event. The flooding details for the 13 manholes where the total flood volume is greater than 1000m^3 are shown in Table 2 to show the format of the SWMM outputs.

Table 2. Flood results of most vulnerable manholes

Summary Results

Node Flooding — Click a column header to sort the column.

Node	Hours Flooded	Maximum Rate CMS	Day of Maximum Flooding	Hour of Maximum Flooding	**Total Flood Volume 10^6 ltr**
66_13_8D_4081T	1.02	0.316	0	05:41	1.091
66_13_13B_6996	1.05	0.310	0	06:00	1.105
66_13_13B_6653	1.39	0.259	0	06:13	1.113
66_13_14A_8881T	2.77	0.321	0	05:30	1.169
66_13_13B_7683T	8.50	0.276	0	05:12	1.248
66_13_8D_5171D	8.88	0.268	0	06:00	1.273
66_13_13B_4996	1.06	0.367	0	05:40	1.315
66_13_13B_6896	1.08	0.384	0	06:00	1.378
66_13_8D_7071D	5.17	0.324	0	06:00	1.393
66_13_13B_5871D	1.10	0.404	0	06:00	1.463
66_13_13B_6654	6.77	0.309	0	06:25	3.001
66_13_13B_4653	1.13	1.453	0	06:00	4.727
66_13_13B_6683T	7.47	1.369	0	05:18	8.853

Reasons for flooding can be identified by using the water elevation profiles given by the SWMM for any selected drainage path.

5 CONCLUSION

Each drainage line was analyzed separately by using the water height profile. Fig. 4 shows the drainage path from 66-13-13B-3871D manhole to 66-13-13B-6597O outflow. Water depth is shown by the solid colored area inside the pipeline.

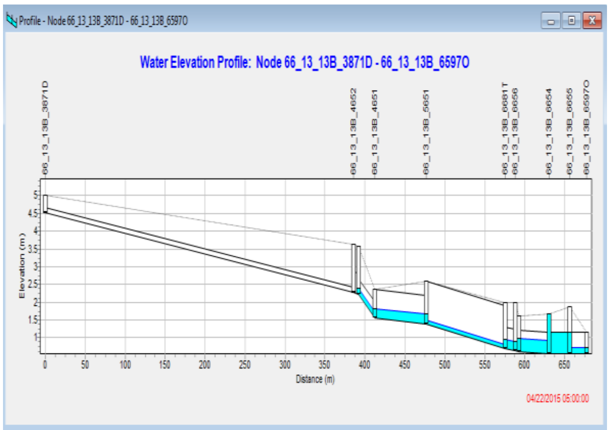


Fig. 4 Water profile of a drainage path in existing system

According to the results given through the SWMM two main reasons for flooding in the studied catchment have been identified. They are,

- Bed slope of conduit is not sufficient.
- Conduit size is not sufficient.

When analyzing the above mentioned drainage path it can be identified that the 66-13-13B-6654 manhole is flooded due to insufficient size of the downstream conduits and insufficient slope of the adjacent downstream conduit.

The simulation was carried out for the drainage system, remodeled by applying the proposed solution. The water profile diagram obtained is shown in Fig. 5.

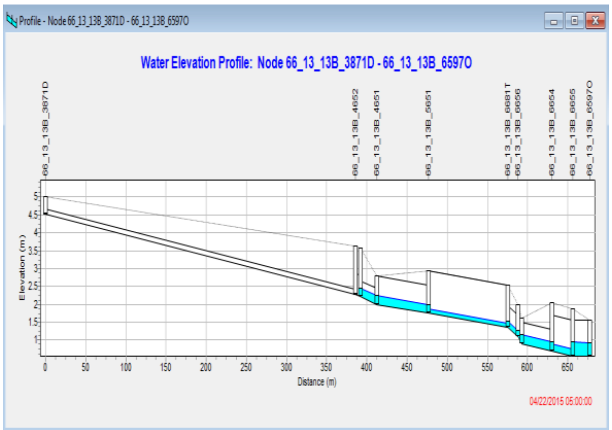


Fig. 5 Water profile after the proposed solution

As shown, solutions for flooding at each branch of the drainage network are proposed and evaluated by using SWMM.

The present study shows that USEPA Storm Water Management Model (SWMM) can be used for the analysis of local drainage systems. Even though the SWMM is not very user friendly, it is a public domain software which is a major advantage.

ACKNOWLEDGMENTS

Our sincere thanks go to Colombo Municipal Council and the staff in CMC who provided me with the required data and other necessary information regarding to the study. Special gratitude to Eng. P.A. Chandrapala and Eng. Preethika of the Drainage division of Colombo Municipal Council for their support and guidance provided throughout the study.

We would like to thank, all the academic staff at the Department of Civil Engineering, University of Moratuwa and my friends for the support they extended in many ways.

REFERENCES

Arthur, R.S., 2010. Stormwater Runoff Simulation Using SWMM: Evaluating Stormwater Management on the University of Virginia Grounds.

Suhyung, J., Minock, C., Yoon, J., Yoon, Y., Kim, S., Kim, G., Kim, L., Aksoy, H., 2007. Using SWMM as a tool for hydrologic impact assessment.

Zhang, W., Zhang, X. and Liu, Y., 2013. Analysis and Simulation of Drainage Capacity of Urban Pipe Network.

Drainage Division, Colombo Municipal Council (CMC), 2014 and 2013. MIKE URBAN Flood Modeling Reports, Metro Colombo Urban Development Project (Unpublished documents).