Storm Water Management of Barahi Chowk Area, Lakeside, Pokhara, Nepal using SWMM

Sanjay Khadka
Department of Civil and Geomatics Engineering
Infrastructure Engineering and Management Programme,
Paschimancal Campus, Institute of Engineering,Tribhuvan University
Pokhara, Nepal
Coolsanjay516@gmail.com

Keshav Basnet, Ph.D
Department of Civil and Geomatics Engineering
Infrastucture Engineering and Management Programme,
Paschimanchal Campus, Institute of Engineering, Tribhuvan University
Pokhara, Nepal
basnet.keshav@wrc.edu.np

***Abstract*— Overflow of water from existing drainage is emerging issues in many cities of Nepal. Unplanned growth of urban areas is affecting the natural drainage surface. The drainage networks in the city do not have sufficient capacity to carry excess runoff due to extreme flooding events and hence flash floods occur almost in events of short duration rainfall with high intensity. The roads turning into streams can be easily observed in Barahi Chowk area of Lakeside, Pokhara and many other urban areas of Nepal especially during rainy seasons. This study is mainly focused on storm water drainage design based on hydrological analysis and comparison with existing drainage system for the Barahi Chowk area. The catchment is modeled with Storm water Management Model (SWMM). The EPA SWMM is a physically based, deterministic model, which simulates water inflows, outflows and storages within a sub-catchment. However it is not in used before in the case of Nepal though it is famous in the developed countries like USA for managing storm water. Total area of the catchment 40.57 hectares using SWMM was divided into eight sub catchments based on its surface elevation and existing drainage network. Then the properties of each sub-catchment were assigned accordingly. After the sub-catchments were defined, the runoff from the corresponding sub catchments were distributed to the respective nodes and finally to the outlet through a conduits. In the present research, the drain system with single side of the road had been provided. The storm network had been represented by conduits, junctions and outfall. The complete storm network was drawn as line diagram in SWMM. The longitudinal profile of drain was obtained. Hit and trial on SWMM was done in SWMM simulation for obtaining suitable drain size to prevent overflow. Once the required depth and breadth obtained to hold peak runoff, simulation was conducted to another drain network. Critical runoff and capacity of existing drains along with validation with discharge obtained from rational method was performed and found to be similar. The existing drainage system of Lakeside (Barahi Chowk) was found to be inadequate with the runoff generated during the peak rainfall. In conclusion, SWMM found to be a potential tool that can be used for storm water management in vulnerable areas of Pokhara and other major cities of Nepal where overflow is a major problem.**

Keywords—Storm water drainage design Hydrological analysis, Flooding, Overflow, Road side Drain

I. Introduction

Water is a prime requirement for the existence of life however uncontrollable amounts of water can adversely affect the survival of living beings. Earlier, Most of the area was agricultural cultivable land used the rainfall to itself; the drainage system was not required. Due to haphazardly migration to days, rapid and unplanned urbanization; natural drainage gets affected which finally raised the load to road side drains. The impervious area is in increasing phase due to the construction of buildings, Pavements and concrete structure. The overflow of water from existing drain during peak rainfall and the roads turning into streams can be observed in Lakeside (Barahi Chowk) area as shown in fig. 1. Due to the overflow problem probability of road accidences increases, Difficult to pedestrian and vehicles in travelling, affects in tourism sectors, trade sectors nearby area could be observed in Lakeside area. About the problem news was published on Annapurna Post Newspaper on 2076-02-07. The study Lakeside area lies in northwestern corner of the Pokhara City. The study area extends from 28°20’82.05” latitude 83°96’05.60” longitude and 28°20’75.99” latitude 83°95’95.79” longitude. The Lakeside catchment includes northern part of Ward Karyalaya chowk to Nareshwor Chowk extending up to Mira Galli, Barahi Chowk, Durbar Chowk of Pokhara Metropolitan City, Ward No. 6 (fig. 2). The study and analysis determines the capacity and adequacy of existing drainage network system to incorporate run off from the catchment during rainy days using SWMM and hence effectively manage storm water through an appropriate design of drainage that could hold the peak runoff during the rainy days.

Pokhara city receives the maximum rainfall among all parts of the country. Lakeside, lying to the northwestern of the main city just at the base of high hills has an unpredictable rainfall pattern. Thus storm water management stands a high challenge there. It is a high necessity to manage overflows from drains. Analysis of storm water and drainage system assists in proper modeling of urban drainage system consequently benefitting urban planners, Metropolitan city and concerned institutions in urban planning and infrastructure management. As described in the Storm Water Management Rules, the NJDEP (New Jersey Department of Environmental Protection) has specified that one of two general runoff computation methods be used to compute runoff rates and volumes. These are the NRCS methodology, which consists of several components, and the Rational Method (and the associated Modified Rational Method), which are generally limited to drainage area. The NRCS runoff equation was developed to estimate total storm runoff from total storm rainfall. That is, the relationship excludes time as a variable. Rainfall intensity is ignored. An early version of the relationship was described by Mockus (1949). The rational method is a simple technique for estimating a design discharge from a small watershed. It was developed by Kuichling (1889) for small drainage basins in urban areas. With the intent of using the rational method for hydraulic structures involving volume control, the modified rational method was developed by Poertner (1974). Based on the technical classification; Nepal Road Standard (NRS) 2013 has made a provision for which the return period for various classes of road for calculating drainage discharge should be accounted. But it has not properly mentioned the methodology for Estimation of such design discharge from catchment. Different watershed modeling techniques can be used to determine the design discharge in our Nepal. In developed country like USA well developed drainage design guideline and modeling practice is very common. In India the modeling practice is started in educational institutions like IIT, NIT. Adequacy of existing drain was checked at (National Institute Technology), Warangal. In our country Nepal the modeling practice is started in engineering universities. The main objective of this study is to determine the capacity and adequacy of existing drainage network system to incorporate run off from the catchment during rainy days using SWMM and hence effectively manage storm water through an appropriate design of drainage that could hold the peak runoff during the rainy days.

Fig. 1. Overflow on a road of Lakeside (Barahi chowk) catchment during heavy rainfall

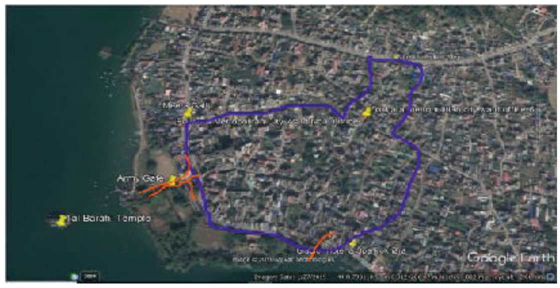

Fig. 2. Study area of Lakeside catchment

II. MATERIALS AND METHODS

A. Calculation of sub catchments area

The total catchment area was calculated as 40.57 hectares using Google Earth. The elevation of the catchment is 819 m and 800 m at the top and bottom levels of the catchment respectively. The length between top level and bottom level of the catchment is 934.40 m. The whole catchment is divided into eight sub-catchments based on elevation and existing drainage networks. The sub-catchments are presented in Fig. 3 and the calculated area for those sub-catchments is shown in Table 1**Error! Reference source not found.**.

Table 1 Area calculation of sub-catchments

S.N.	Sub- catchment	Area (Hectares)
1	Sub-catchment 1	2.78
2	Sub-catchment 2	4.98
3	Sub-catchment 3	7.64
4	Sub-catchment 4	5.33
5	Sub-catchment 5	3.27
6	Sub-catchment 6	3.30
7	Sub-catchment 7	6.63
8	Sub-catchment 8	6.67
	Sum	40.57

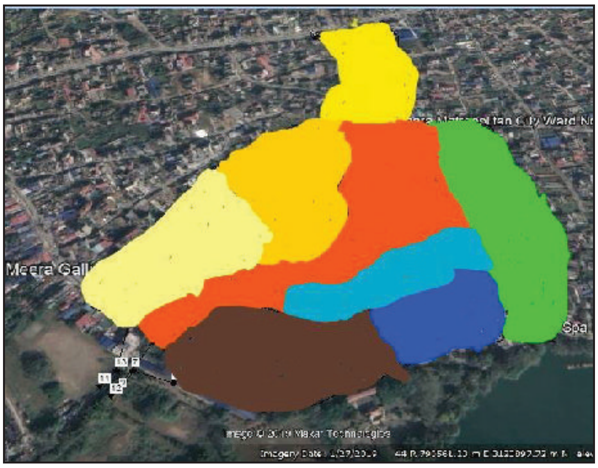

Fig. 3. Catchment area divided into eight sub-catchments

B. Assigning nodes, conduits and outfall

After the sub catchments are defined, the input parameters for conduits, node and junctions are entered as shown in fig. 4. The input parameters for junction are elevation and maximum depth, for conduits is drainage network shape and size, outfalls are Invert elevation and maximum depth. The runoff from the corresponding sub catchments are distributed to the respective nodes and finally to the outlet through a conduits. In this project, the drain systems single sides of the road have been provided. On the basis of field Drainage Network the nodes, conduits and outlets are modeled on SWMM.

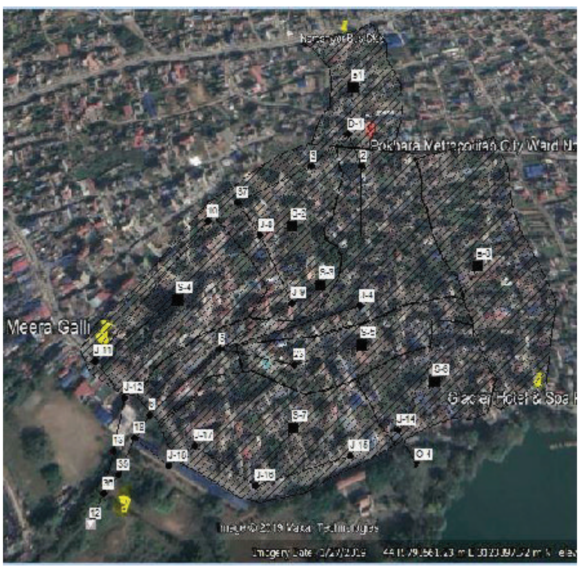

Fig. 4. Nodes and conduits from sub catchments connecting to outlets after SWMM simulation

C. Time Series Rainfall Data

Rainfall data obtained from the Tipping Bucket located at Pashchimanchal Campus for the period 2018-01-01 to 2018-12-30 was analyzed first. The time series rainfall data at interval of five minutes for one hour of most rainy day of 2018 September 11 is entered. As shown in graph of Fig. 5 the rainfall for first 30 to 45 minutes is in increasing trend then it's decreasing for the next 15 minutes. This is assigned to rain gage and connected to the sub catchments that contribute to runoff. Maximum rainfall value that is 8.20 mm is obtained at 45 minute interval. This is the reason of originating this study such that it can contribute to the society of Lakeside area by solving the overflow problem in roads.

D. Runoff in Sub- Catchment

From the precipitation data entered, the runoff from the catchment was computed which varied from each other due to varying land features and other properties. As most of the land area is covered with buildings and paved surface, the runoff coefficient value is almost high. The natural Drainage is in decreasing order due to the increase in concrete construction works. The impervious surface is in increasing order. As higher the value of imperviousness of surface, higher will be the runoff. The summarized data for sub catchment obtained from SWMM is illustrated in Table 2.

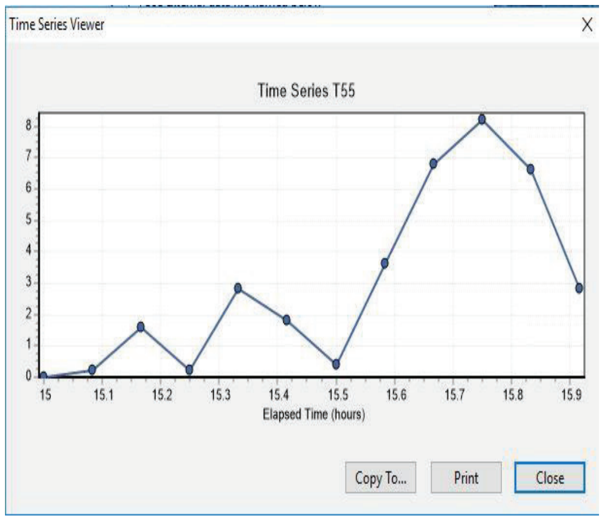

Fig. 5. Time history of maximum rainfall observed from data of the station

Table 2 Data for Sub catchment obtained from SWMM

Summary Results

Subcatchment Runoff — Click a column header to sort the column.

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coeff
s1	35.00	0.00	0.00	2.38	32.98	0.92	0.69	0.942
S-4	35.00	0.00	0.00	1.43	33.78	1.80	1.29	0.965
S-2	35.00	0.00	0.00	3.74	31.47	1.57	1.14	0.899
S-3	35.00	0.00	0.00	2.50	32.58	2.49	1.70	0.931
S-6	35.00	0.00	0.00	1.66	33.66	1.11	0.83	0.962
S-7	35.00	0.00	0.00	2.00	33.14	2.20	1.53	0.947
S-5	35.00	0.00	0.00	2.38	32.95	1.08	0.81	0.941
s-8	35.00	0.00	0.00	3.00	32.13	2.14	1.49	0.918

III. RESULT AND DISCUSSION

A. Analyzing Longitudinal Profile

The inputs parameters required are entered to the model based on the Field measurement of existing drainage network. The required elevation is obtained from Google Earth Pro. With the entered parameters the longitudinal profile of drain is obtained after SWMM simulation. Sky blue color indicates the maximum flow level during rainfall. Water Elevation Profile D1 to J6 of sub catchments 3 is shown in Fig. 6 and Fig 7**.**

B. Velocity Profile Drain During Runoff

The velocity of water in Drain increases as the discharge increase and vice versa. Along with the discharge the slope is also important parameter for rise in velocity. The velocity profile during peak flow is shown in fig. 8. The conduits 11, 13 connecting to outlet 2 and conduits 21, 22 connecting to outlet 1 are colored with red color indicating the maximum velocity greater than 2m/s. The yellow color indicates the velocity in 1 m/s to 2 m/s. The green color indicates the velocity in range 0.10 m/s to 1 m/s.

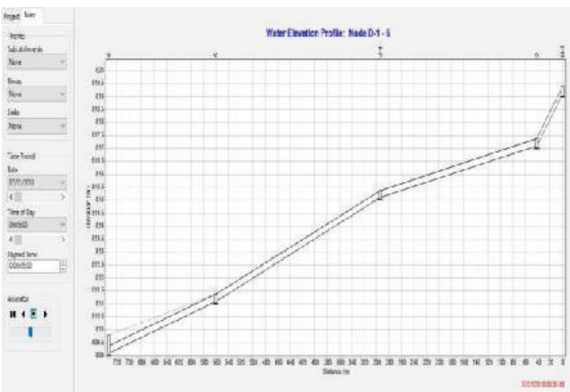

Fig. 6. Water Elevation Profile at 5 minutes interval of rainfall Sub catchment -3

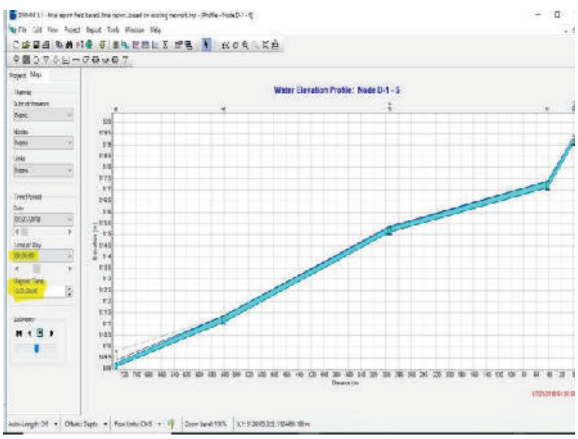

Fig. 7. Water Elevation Profile at 55 minutes interval of rainfall in Sub catchment - 3

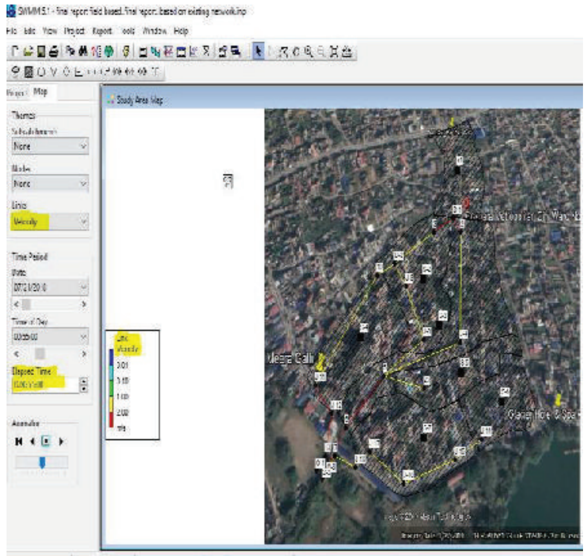

Fig. 8. Velocity profile of existing drain during peak rainfall at 55 minutes interval

C. Design of Storm Water Drainage

Sizes of existing drains in all of eight sub-catchments were measured in the field. The measured width of the existing drain in sub-catchments was used in SWMM simulations. The longitudinal profile is analyzed. The peak flow at 55 minutes is observed to exceed existing drain Level. The water gets overflow from drain during the peak rainfall period. Simulation is done and the longitudinal profile of the drain of all sub catchments is analyzed similarly. After simulation on SWMM, it is observed that the water gets overflowed during peak run off. The existing drain is found not sufficient to hold the peak runoff during the rainy days. To prevent the overflow of water from drain, necessity of increasing the drain shape is observed. The size of drain is increased with hit and trail method in SWMM. At certain depth and breadth the longitudinal profile of drain seems to be safe. Similarly, all drainage networks are analyzed after SWMM simulation. The input drain size based on site measurement and modeled drain size is illustrated in Table 3. In general, results of this study suggest that the depth of the existing drains need to be increased. Another solution for avoiding the overflow problems on the roads of Lakeside area is reducing the discharge load on the existing drains and this is possible by providing cross drains from the existing drainage system. The safe drain dimension is suggested for construction of drain in site. This suggest that the proper storm water management is important for avoiding the overflow problems on the road for which design of minimum required drainage size is critical that is based on hydrological analysis.

Table 3 Cross section of conduits of existing drain and modeled drain size after SWMM simulation

Link	Existing Drainage (meter)		Modeled Drainage (meter)	
	Breadth	Depth	Breadth	Depth
2	0.40	0.25	0..40	0.50
3	0.40	0.25	0.40	0.50
4	0.40	0.25	0.40	0.50
5	0.40	0.40	0.40	0.50
6	0.50	0.50	0.50	1.00
7	0.35	0.28	0.28	0.35
8	0.40	0.28	0.28	0.40
9	0.40	0.28	0.50	0.60
10	0.40	0.28	0.50	1.00
12	0.57	0.50	0.50	1.00
13	0.35	0.28	0.28	0.35
14	0.35	0.28	0.28	0.35
15	0.35	0.28	0.28	0.35
16	0.35	0.28	0.40	0.50
17	0.35	0.28	0.40	0.50
18	0.35	0.28	0.50	1.00
19	0.35	0.28	0.50	0.50
20	0.70	0.25	0.60	0.50
21	0.70	0.25	0.85	1.0
22	0.70	0.25	0.85	1.0
23	0.70	0.25	0.85	1.0
C-4	0.57	0.57	1.10	1.10

D. Validation with Application of manning's Formula for Designing Drain

Needhidasan and Manoj (2013) used Manning's equation to design the drains size Palayam area of Calicut City in Kerala, India where the excess runoff is really a threat to the environment due to dense population. Basnet and Neupane (2018) performed hydrologic analysis and design storm water drainage in the area of Lamachaur, Pokhara, Nepal using Manning's equation and found the existing drainage system of Lamachaur area is inadequate to safely discharge the surface water. Manning's equation is a semi-empirical equation and is the most commonly used equation for uniform steady state flow of water in open channels. The application of this equation is restricted to small areas only. Therefore, it only serves as a benchmark for designing side drains especially for the conditions when modeling of storm water (e.g., using SWMM) is not possible. Manning's equation was used in this study for the calculation of storm water drainage size required in the Lakeside area of Pokhara and compared with the drainage size modeled with SWMM. From the manning's formula the drain size at conduits from Army camp Gate to outlet was designed 1.10m *1.35m and from SWMM we get the drain size 1.10m*1.10m.The dimension was found relatively similar..

Manning's equation is given as,

$$Q = (1/n) * A * R^{2/3} * S^{1/2} \quad \textbf{(1)}$$

Where,

Q = volumetric water flow rate passing through the stretch of channel, (m^3/s)

A = cross-sectional area of flow perpendicular to the flow direction, (m^2)

S = bottom slope of c-hannel, (m/m)

R= hydraulic mean depth, (m)

IV. CONCLUSION

Street flooding is one of the major problems in urban areas of Nepal. The roads turning into streams can be easily observed in Barahi Chowk area of Lakeside, Pokhara and many other urban areas of Nepal especially during rainy seasons. Unplanned growth of areas, building constructions, Pavement Construction and other concrete structures decreases the natural drainage. The catchment is modeled with Storm water Management Model (SWMM) which is freely available potential model for storm water management in urban areas of Nepal. The complete storm network of Lakeside (Barahi Chowk) was drawn as line diagram in SWMM. The rainfall data that is obtained from rain gauge station (tipping bucket) was converted to the precipitation for 5 mm interval. The existing Drainage system was found to be inadequate with the runoff generated during the peak rainfall after analyzing the longitudinal profile of drain generated from SWMM. At many places drain seems to be logged with debris and wastages. The newly planned drainage networks with manhole have been provided to solve the overflows problems. The discharge to Durbar Chowk from ward office needs to be crossed to Lake using Hume pipe. For the validation of SWMM, the drain was designed using Manning's formula and found comparable with modeling results. Analysis of storm water and drainage system assists in proper modeling of urban drainage system consequently solves problem of people, benefits urban planners and concerned institutions in urban planning and infrastructure management. Proper design of drainage and regular repair and maintenance plays important role to prevent overflow of drain problems. In conclusion, SWMM found to be a potential tool that can be used for storm water management in vulnerable areas of Pokhara and other major cities of Nepal where overflow is a major problem.

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