Application of ArcGIS Model Builder and Python Scripting for urban Flood Modeling

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Abstract

Accurate projection of flood extents in urban catchments has become a challenging task. Accurate data on inundation is useful for identifying flood risk areas and developing flood management strategies to mitigate the negative consequences. Owing to high costs of sophisticated flood simulation modeling software, currently, the required flood data for different studies and projects in Sri Lanka is collected through gauging stations, GPS devices and participatory based mapping approaches. However, these methods are highly time consuming and limited in accuracy. Hence, this paper presents an integrated model that simulates flood prone areas, flood levels and flood water accumulation time in urban areas using ArcGIS model builder and Python scripting. The model was calibrated and validated considering part of the urbanized area beside Kelani River. The results indicated that there is a high level of consistency between the observed and simulated results. Accordingly, the model presented in this paper can be used to simulate the flood inundation information in urban areas in a relatively fast, inexpensive and accurate manner.

Key words: *Flood Model, Arc-GIS, Python Scripting, Simulation*

1.0 Background

A flood is defined as the inundation of an area by an unexpected rise of water because of extreme rainfalls or dam failure (Disaster Management Center). As shown in Figure 1, it is the most frequent climate exacerbated disaster in Sri Lanka.

In Sri Lanka, most of the flood management approaches are based on hydrological measurements. However hydrology based flood management approaches are most suitable for large scale flood prone areas. Since most of our urban flood prone areas are small in scale, hydrology based flood assessment is inadequate to get a reliable result on flooding conditions of that area. Hence it is vital to consider about the other integrated factors which influence for flood, when assessing the flood condition in small scale urbanized areas. Hence, the objective of this research is to develop an integrated flood model considering the factors such as land cover, rainfall, abstraction levels, elevation, soil types and impervious areas.

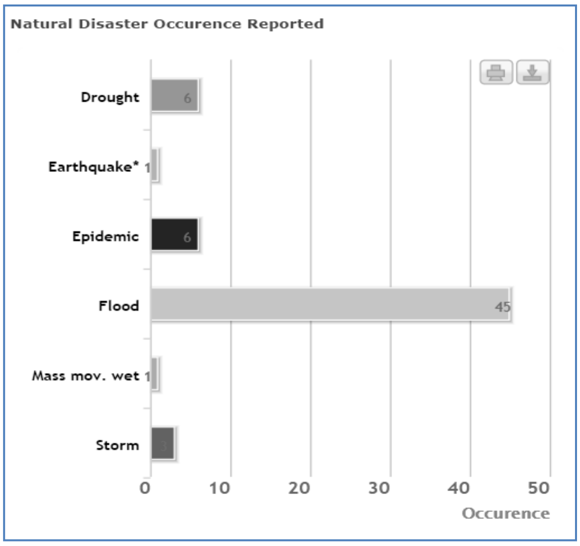


Figure 13: Natural disaster occurrence during the past decade
Source: Disaster Management Center, 2005

2.0 Research Problem

Information about flood estimation is the prime data which needs for developing any flood related plan, project, strategy or research Before developing flood risk management strategies for any flood prone area, a vulnerability and disaster risk assessment will be conducted for that area. Such assessment is important for identifying hazard areas and elements at risk. The relevant strategies and action projects are decided for the flood prone area based on those results. Thus, preparation of vulnerability and disaster risk assessment requires accurate flood estimations of the flood prone area to identify the areas with high, moderate and low risk.

However, due to the high cost of sophisticated software used in flood simulation, flood estimation data in Sri Lanka is currently obtained through gauging stations, GPS devices and participatory based mapping approaches. In Sri Lanka, gauging stations are available only for several main water bodies. Hence, flood estimations collected via gauging stations are frequently inadequate to estimate the floods levels of the entire flood prone area. GPS based flood estimations always require ample coordinates and flood levels of the inundation locations. Most of the time, the relevant records are collected from the community of the area. Hence, that method is less accurate. The third method of participatory based mapping approaches always relies on people's perceptions. Hence, that method also has varying accuracy levels.

In addition to that, there are various commercially developed software for flood simulation. Most of the time they are high in cost and need vast amounts of input data to get a relatively accurate result. In some cases, the results produced by them are not represent the real ground context of our country.

Therefore it is essential to have a proper method to simulate flood inundation information in a relatively fast, inexpensive and accurate manner for urban catchment areas of Sri Lanka.

3.0 Objectives

The main objective of this research is to develop an integrated model using Arc-GIS Model Builder and Python Scripting to simulate flood inundation information in urban catchments. The sub-objectives of the research are,

- To simulate inundation areas
- To simulate inundation depth (flood level)
- To simulate the flood water accumulation time

4.0 Flood Estimation Methods

Flood estimation methods can be mainly classified as direct methods and indirect methods.

4.1 Direct Methods

Under direct methods, flood estimations are collected through measurements

4.1.1 Measurements based on current meter

A current meter is oceanographic device which measures the volume of water discharge in a unit time.

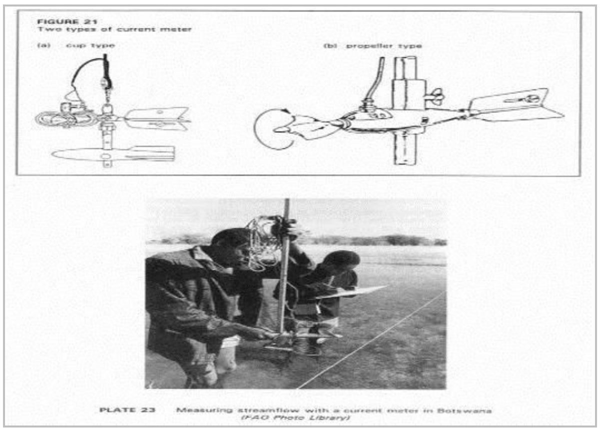


Figure 14: Measurements based on Current Meter

4.1.2 Measurements based on gauging heights

A Gauge Height is a measuring device used to determine the height of water in streams. In Sri Lanka, the Irrigation Department has established 35, 10 and 24 Gauge Heights to measure the water levels of streams in Wet Zone, Intermediate Zone and Dry Zone respectively. However information provided by them are inadequate to estimate the overall flood levels spatially for the entire flood prone area.

Figure 15: Measurements based on Gauging Stations

4.1.3 Measurements based on GPS devices

Another, recently developed direct method of measuring flood levels is use of GPS (Global Positioning System). Using the GPS devices, coordinates of the inundation locations and the flood levels are recorded. These data are usually obtain from the community of the area. Then the data are exported to GIS software to estimate the flood levels of the entire area. However this method is highly time consuming and needs large number of GPS points to accurately estimate the flood levels of the entire area.

Figure 16: Measurements based on GPS Devices

4.1.4 Measurements based on participatory mapping

Under this method, the community of the area is asked to mark the flood prone areas on the paper maps. The information in the maps are digitized so that it can be analyzed and visualized using GIS. However, the flood levels and areas drawn in the maps can be considered qualitative data, since they are based on people's knowledge, opinions and perceptions. Most of the time, the locations and boundaries of the areas that people draw on the community maps have varying accuracy levels. This is the main drawback of this method.

Figure 17: Measurements based on participatory mapping approaches

4.2 Indirect Methods

Under indirect methods, flood estimations are collected through equations and modeling.

4.2.1 Rational Method

The Rational Method is the most commonly used method of determining peak discharge from small drainage areas. Peak discharge is the greatest amount of runoff coming out of the watershed at any time. The Rational Method is expressed in Equation 1.

Equation 1

$$Q = CIA$$

Where;

Q = Peak discharge (m^3/s)
C = Rational method runoff coefficient
I = Rainfall intensity, mm/hour
A = Catchment area (ha)

The rainfall intensity is the height of the water layer covering the ground in a period of time. The runoff coefficient (C) is a dimensionless coefficient relating the amount of runoff to the amount of precipitation received. It is a larger value for areas with low infiltration and high runoff (pavements, steep gradients), and a lower one for permeable, well vegetated areas (forest, flat land). Table 1 shows the values of the runoff coefficient for different land uses.

Table 8: Values of Runoff Coefficient (C) for Rational Formula

Land Use	C	Land Use	C
Business		**Lawns**	
Downtown areas	0.70 – 0.95	Sandy soil, flat, 2%	0.05 – 0.10
Neighborhood area	0.50 – 0.70	Sandy soil, avg., 2-7%	0.10 – 0.15
		Sandy soil, steep, 7%	0.15 – 0.20
		Heavy soil, flat, 2%	0.13 – 0.17
		Heavy soil, avg., 2-7%	0.18 – 0.22
		Heavy soil, steep, 7%	0.25 – 0.35
Residential		**Agricultural land**	
Single family areas	0.30 – 0.50	Bare packed soil	
Multi units, detached	0.40 – 0.60	▪ Smooth	0.30 – 0.60
Multi units, attached	0.60 – 0.75	▪ Rough	0.20 – 0.50
Suburban	0.25 – 0.40	Cultivated rows	
		▪ Heavy soil, no crop	0.30 – 0.60
		▪ Heavy soil, with crop	0.20 – 0.50
		▪ Sandy soil, no crop	0.20 – 0.40
		▪ Sandy soil, with crop	0.10 – 0.25
		Pasture	
		▪ Heavy soil	0.15 – 0.45
		▪ Sandy soil	0.05 – 0.25
		Woodlands	0.05 – 0.25
Industrial		**Streets**	
Light areas	0.50 – 0.80	Asphaltic	0.70 – 0.95
Heavy areas	0.60 – 0.90	Concrete	0.80 – 0.95
		Brick	0.70 – 0.85
Parks, cemeteries	0.10 – 0.25	Unimproved areas	0.10 – 0.30
Playgrounds	0.20 – 0.35	Drives and walks	0.75 – 0.85
Railroad yard areas	0.20 – 0.40	Roofs	0.75 – 0.95

4.2.2 TR-55 Runoff Equation

Technical Release 55 (TR-55) presents simplified procedures for estimating runoff and peak discharges in small watersheds. These procedures are applicable to small watersheds, especially urbanizing watersheds. The TR-55 equation is as follows:

Equation 2

$$Q = \frac{(P - I_a)^2}{P - I_a + s}$$

Where;

Q = Depth of runoff (in)

P = Rainfall (mm)

I_a = Initial abstraction (in)

S = Potential maximum retention after runoff begins (in)

Initial abstraction (I_a) is all losses before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, evaporation, and infiltration. I_a is highly variable but generally correlates with soil and land cover parameters. Through studies of many small agricultural watersheds, I_a was found to be approximated by the following empirical equation:

Equation 3

$$I_a = 0.2S$$

By removing I_a as an independent parameter, this approximation allows use of a combination of S and P to produce a unique runoff amount. Substituting equation 3 into equation 2 gives:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}$$

S is related to the soil and cover conditions of the watershed through the CN (Curve Number). Mass rainfall is converted to mass runoff by using a runoff curve number (Figure 6).

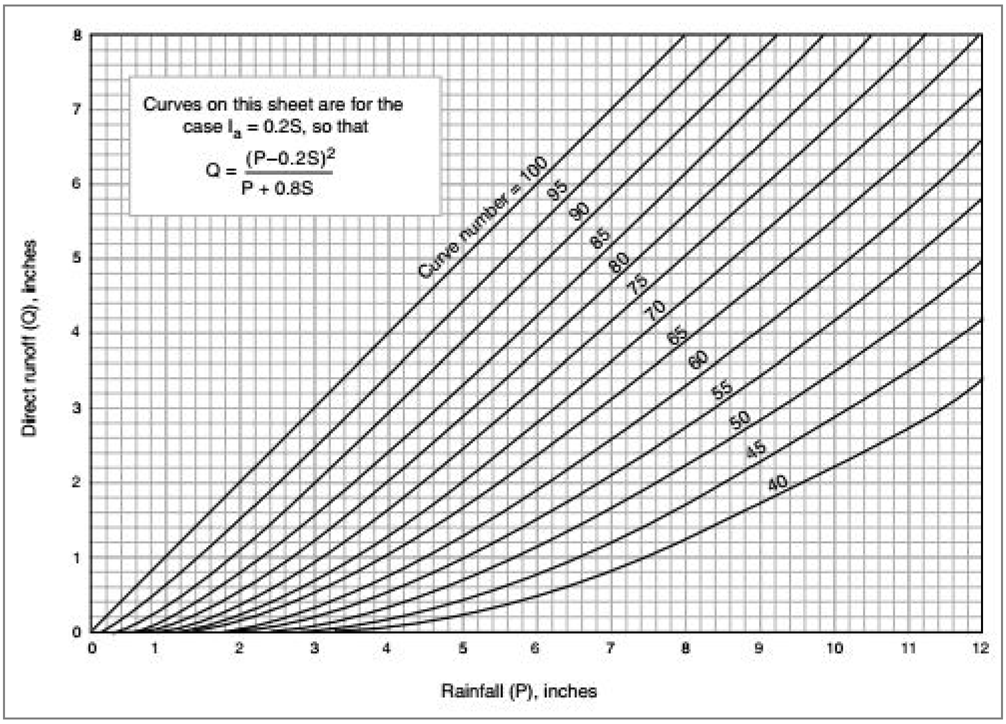


Figure 18: Runoff Curve Numbers (CNs)

S is related to CN by:

Equation 4

$$S = \frac{1000}{CN} - 10$$

CN is based on soils, plant cover, amount of impervious areas, interception, and surface storage. Accordingly, Table 2 shows the computed CNs for different land cover types based on the soil categories.

Table 9: Curve Numbers for urban areas

Land cover type	**Curve Numbers for soil types**			
	A	**B**	**C**	**D**
Open space (lawns, parks, golf courses, cemeteries, etc.)				
▪ Poor condition (grass cover < 50%)	68	79	86	89
▪ Fair condition (grass cover 50% to 75%)	49	69	79	84
▪ Good condition (grass cover > 75%)	39	61	74	80
Impervious areas				
▪ Paved parking lots, roofs, driveways, etc. (excluding right of way)	98	98	98	98

▪ Streets and roads				
○ Paved; curbs and storm sewers (including right of way)	98	98	98	98
○ Paved; open ditches (including right of way)	83	89	92	93
○ Gravel (including right of way)	76	85	89	91
○ Dirt (including right of way)	72	82	87	89
Urban districts				
▪ Commercial and business	89	92	94	95
▪ Industrial	81	88	91	93
Residential districts by average lot size				
▪ 1/8 acre or less	77	85	90	92
▪ 1/4 acre	61	75	83	87
▪ 1/3 acre	57	72	81	86
▪ 1/2 acre	54	70	80	85
▪ 1 acre	51	68	79	84
▪ 2 acres	46	65	77	82

A – Sand, loamy sand, or sandy loam
B - Silt loam or loam
C – Sandy clay loam
D – Clay loam, silty clay loam, sandy clay, silty clay or clay

4.2.3 Terminal Velocity Formula

The Terminal Velocity formula can be used to measure the velocity of the flood water.

Equation 5

$$V_t = \sqrt{\frac{2mg}{pAC_d}}$$

Where;

V_t –Terminal Velocity
m – Mass of the considered fluid section
g - force of the moving direction
C_d - Drag coefficient
ρ - Density of fluid
A – projected area

4.2.4 Flood Modeling

A model is a simplified version of a real world process, system, phenomenon, or entity. Flood modeling helps to predict flood routing patterns using software. Flood modeling is very important to identify flood prone areas, flood levels, velocity of flood flow and flood accumulation time.

An integrated model is a model where various factors or aspects are combined, rather than considering them in a fragmented way. There are several factors that influence urban flooding. They are,

- Rain fall
    - This is the main factor that influence flooding
    - Flood is a common incidence in Sri Lanka, especially in the monsoonal periods. Out of two monsoon periods; South Western monsoon and North Eastern monsoon, South Western monsoon brings the heavy flood for Western Province.

- Terrain/Slope
  - This factor deals with flood routing which is also known as pattern of floods.
  - If a stream has a steep slope, it will have a faster velocity. When the water can't maintain its high velocity in the areas which have gentle slope, there is a probability of flood occurrence at thefringe areas of mountainous zones and intermediate plain zones during the rainy seasons.

- Hydrology
  - This factor also deals with flood routing.
  - When rivers have several bends, velocity of water is decreased. Otherwise river will overflow and create floods. This is the reason for floods in Rathnapura area.
  - Human intervention on hydrological patterns such as land filling and rerouting rivers can also trigger floods.
  - In urbanized areas, because of land paving, infiltration level of land is decreased and creates flood.

- Soil Type
  - Different soil types have different saturation levels.
  - The Wet Zone of Sri Lanka is mainly covered by Red Yellow Podizolic soil which has low saturation level. This character is one of the reasons for high runoff in Western Province.

- Land cover/Land Use
  - Different land cover types have different infiltration capacities. For an example grassland and forest covers have high water infiltration levels while asphalt surfaces have low infiltration level.
  - High surface water runoff can be seen in land covers with low infiltration level.

- Drainage system/Existing storm water discharge system
  - Drainage systems are also an important factor to mitigate floods.
  - Areas with proper drainage systems can manage storm water run-off even at higher level of rainfall.
  - For better flood management, the drainage systems must be well maintained and they should be designed according to the surface water runoff volume

- Human Behavior
  - To certain extent, human behavior also influences flooding. Lack of maintenance of canals, unauthorized land filling and filling of low lands are some of activities which lead for generating floods.
  - In addition to that, the community of the area should aware about hydrological cycles to respond in any flood events.

5.0 Arc-GIS Model Builder and Python Scripting

Arc-GIS is a Geographic Information System (GIS) which facilitates working with maps and geographic information produced by a company called Esri. The Model Builder is an application in the Arc-GIS software to create, edit and manage models. Model Builder can also be thought of as a visual programming language for building workflows. Most importantly, it provides a graphical interface for making models and visually understanding how GIS modeling works.

Python is a free, cross-platform, open-source programming language that is both powerful and easy to learn. Its design philosophy emphasizes code readability, and its syntax allows programmers to express concepts in fewer lines of code than would be possible in languages such as C++ or Java.

Python was introduced to the ArcGIS community at version 9.0. Since then, it has been accepted as the scripting language of choice for geoprocessing. The language is widely used to perform advanced level calculations and raster analysis.

6.0 Case Study

In Sri Lanka, Kalu, Kelani, Gin, Nilwala and Mahaweli are the main river basins vulnerable to floods. Among them, urban floods are more predominant in the Kalu and Kelani river basins. Floods are a frequent disaster in the following areas of those basins:

- Ragamaarea -Gampaha District
- Miriswaththa-Balummahara area -Gampaha District
- Gampaha town -Gampaha District
- Sri Jayawardhanapura Kotte –Colombo District
- Katukurunda Area –Kaluthara District
- Kaluthara town –Kaluthara District
- Waththala, Hekiththa, Wanawasala and Dalugama- Gampaha District

Source: Disaster Management Center/Irrigation Department

The Waththala, Hekiththa, Wanawasala and Dalugama areas which belong to the Kelani River basin were selected as the case study area to develop the urban flood model (Figure 7). In Waththala, Wanawasala and Hekiththa areas, most of the houses which locate at low lying areas are affected during the South Western monsoon due to blocking of canal systems and low level of infiltration due to land filling.

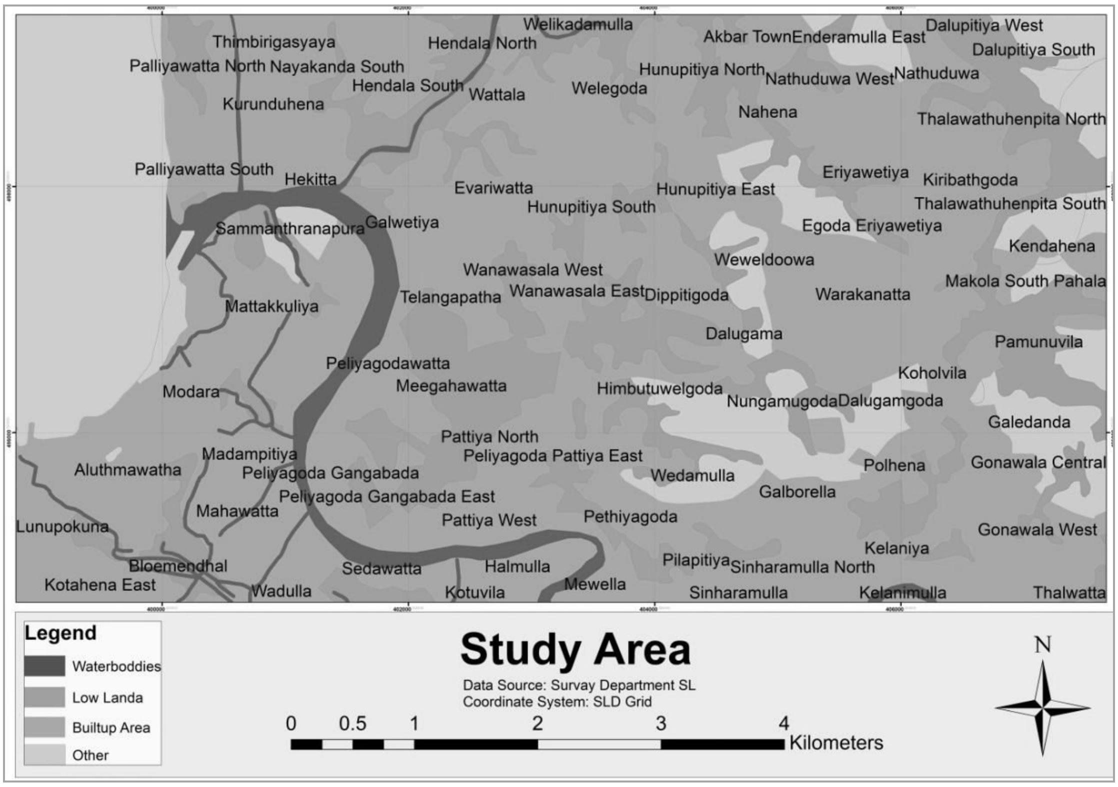


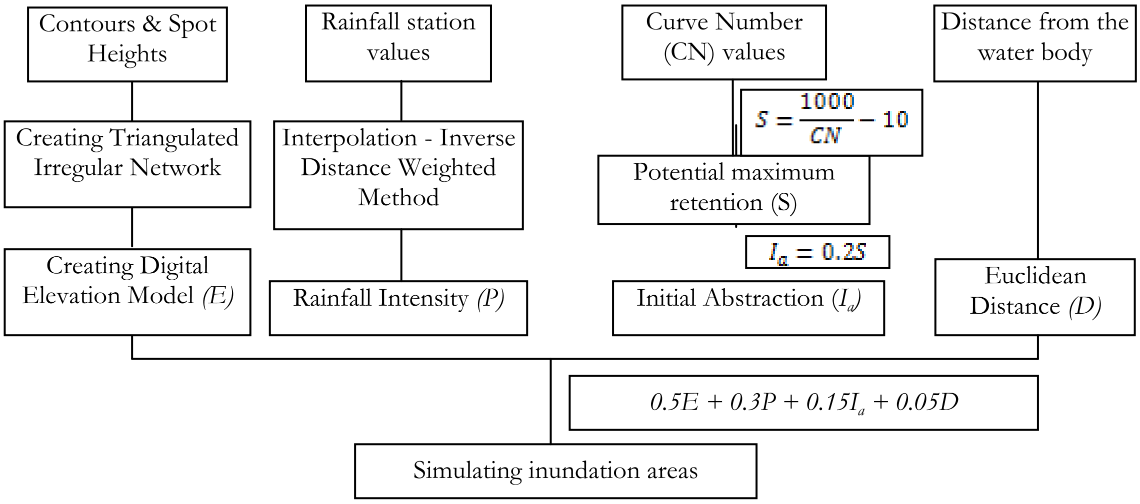
Figure 19: Case Study Area

Sources: Survey Department & Google Earth 2014 Astrim Image

7.0 Methodology& Results

Three models were prepared using Arc-GIS Model Builder and Python scripting to achieve the three objectives of this research.

7.1 Model 1 - Simulating the inundation areas



Assumptions:

1. The coefficient values of the formula were obtained from the research done by *R.Suthakaran, K.Perera and N.Wikramanayake* on "Rainfall intensity-duration-frequency relationship for Colombo region in Sri Lanka"

2. 10m×10m pixel size was considered for the analysis

Table 10: Input Data of Model 1

Input Data	Source
Contours & Spot Heights	Sri Lanka Land Reclamation & Development Corporation
Rainfall station values	Meteorological Department
Soil layer	Survey Department, 2010
Land cover layer	Survey Department, 2010
Curve Number (CN) values	Curve Numbers for urban areas(Table 2)
Water body layer	Survey Department, 2010

Figure 8: Digital Elevation Model
Source: Compiled by the Authors

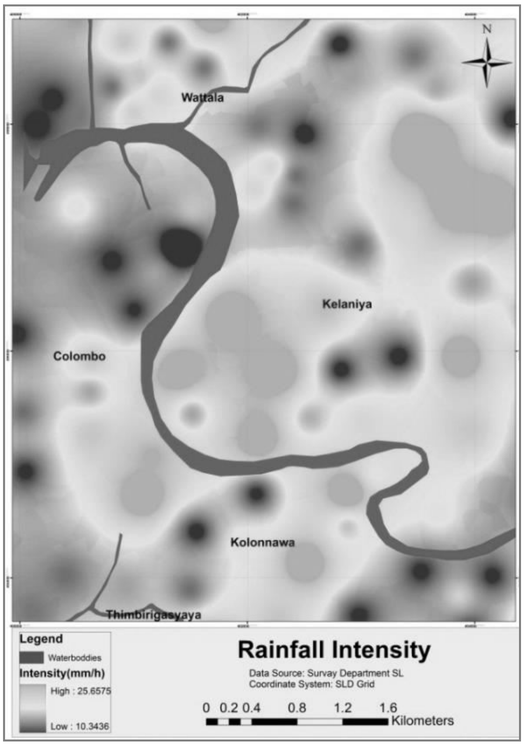


Figure 9: Rainfall Intensity
Source: Compiled by the Authors

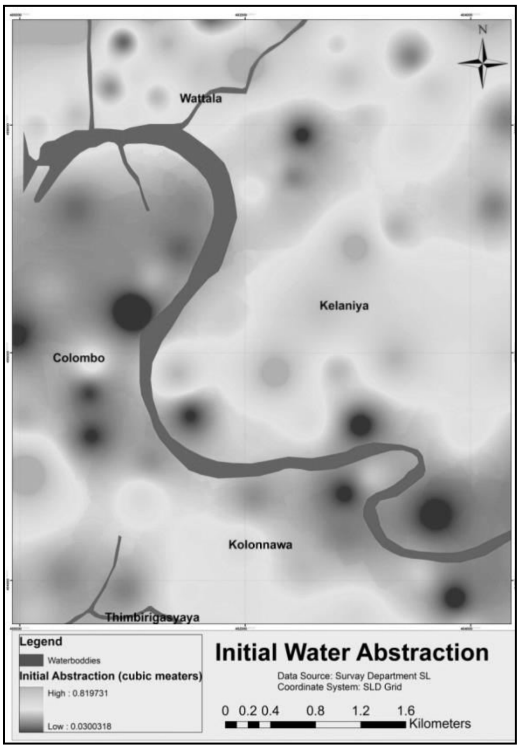


Figure 10: Initial Abstraction Level
Source: Compiled by the Authors

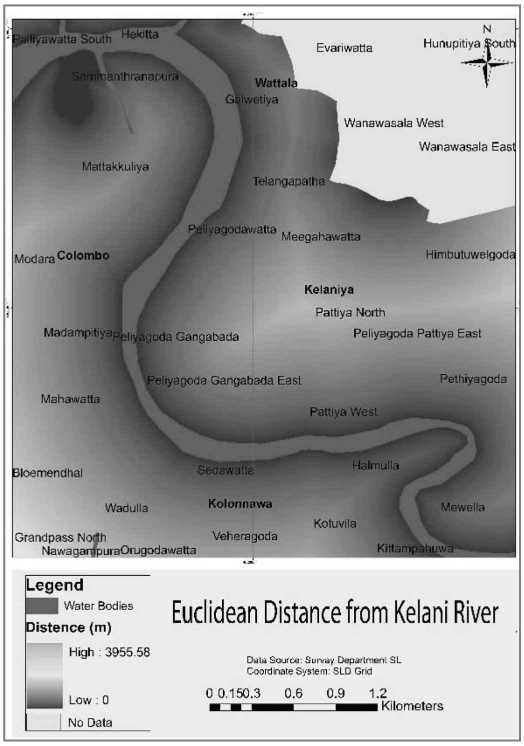


Figure 11: Euclidean Distance from Kelani River
Source: Compiled by the Authors

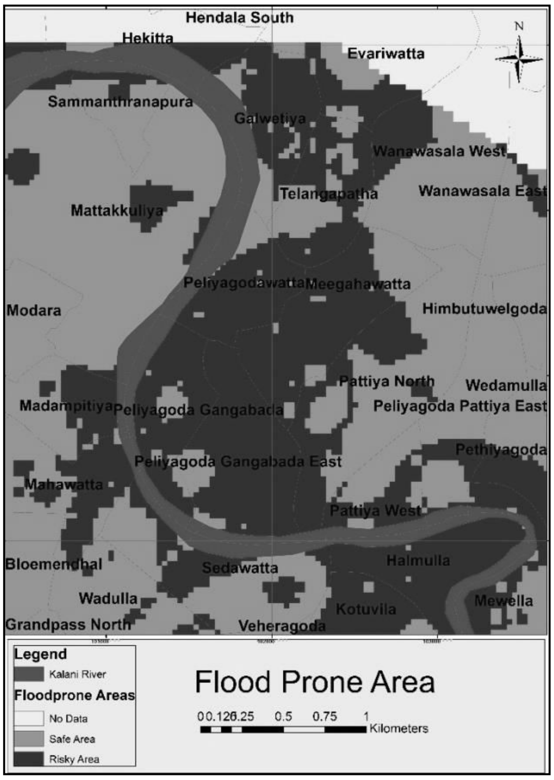


Figure 12: Simulated Inundation Area
Source: Compiled by the Authors

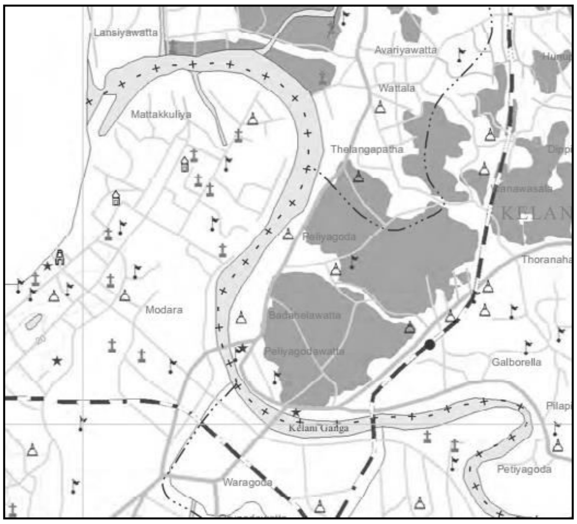


Figure 13: Flood Prone Area map produced by DMC & Irrigation Department
Source: Compiled by the Authors

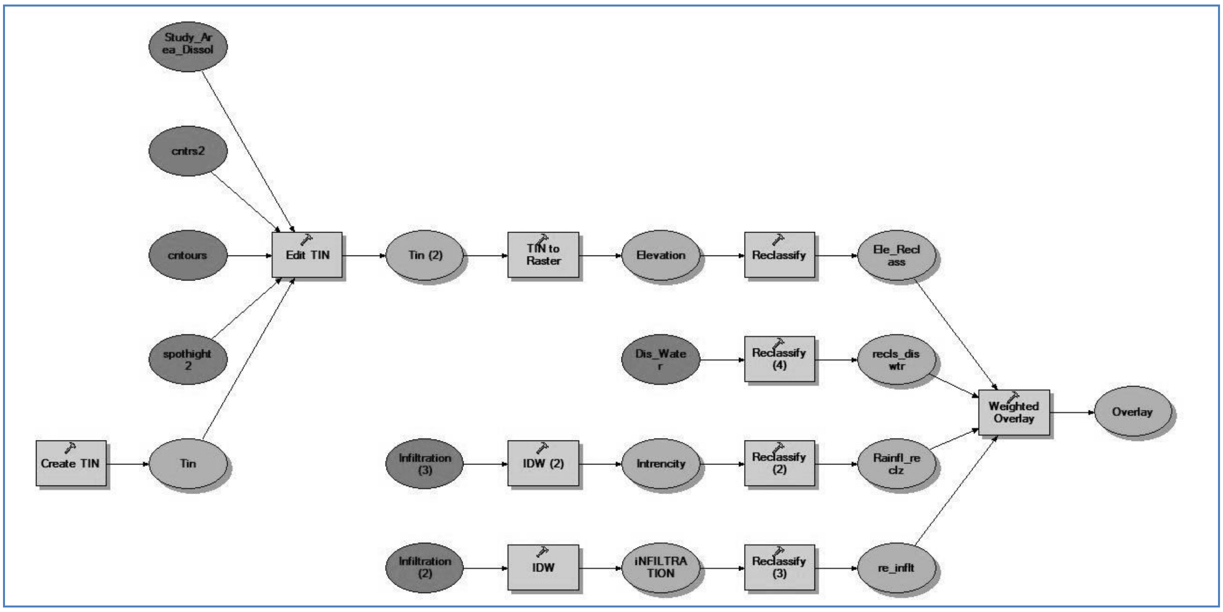
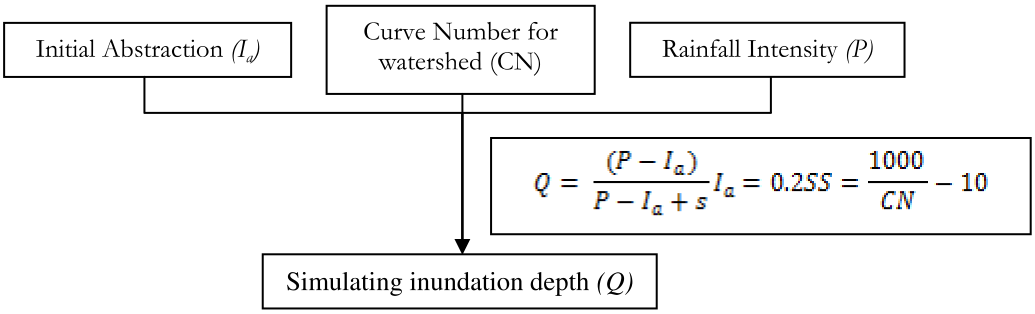


Figure 14: Arc-GIS Model Builder for simulating the inundation areas

Figure 12 shows the inundation areas produced from model 1. Accordingly, the brown colored areas represent the inundation area beside the Kelani River. As depicted in the map Grama Niladhari areas like Sedawaththa and Veheragoda are safe from flooding as they are located closer to the southern bank bund. The results obtained from the model were further validated with the flood map produced by the Disaster Management Center (DMC) and Irrigation Department (Figure 13). Therefore, it seems that the inundation areas shown in the two maps are closely related to each other. Figure 14 shows the screenshot of the Model Builder window of Arc-GIS software which was used to simulate the inundation areas.

7.2 Model 2 - Simulating the inundation depths (flood levels)



Assumption:

1. 10m×10m pixel size was considered for the analysis

Table 11: Input Data of Model 2

Input Data	Source
Initial Abstraction	Obtained from results of Model 1
Curve number for watershed	Curve Numbers for urban area (Table 2)
Rainfall Intensity	Obtained from results of Model 1

Initial Abstraction and Rainfall intensity values were obtained for each pixel based on the results of Model 1. The curve number for the watershed area was obtained from Table 2.

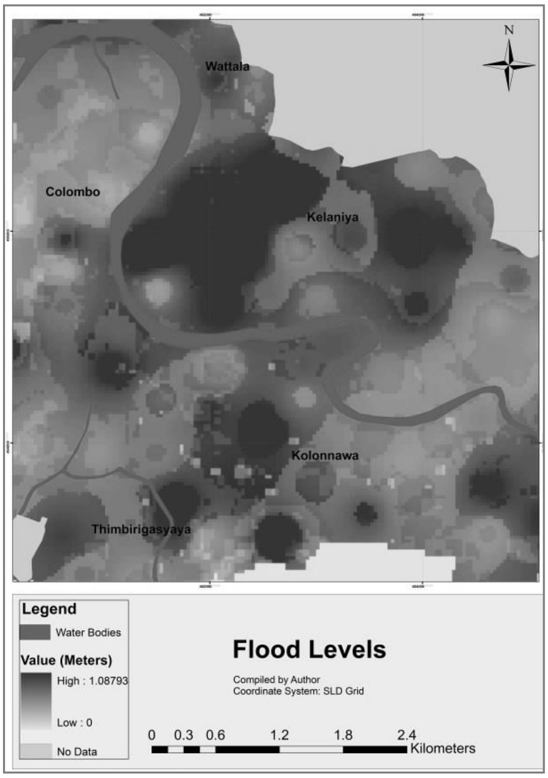
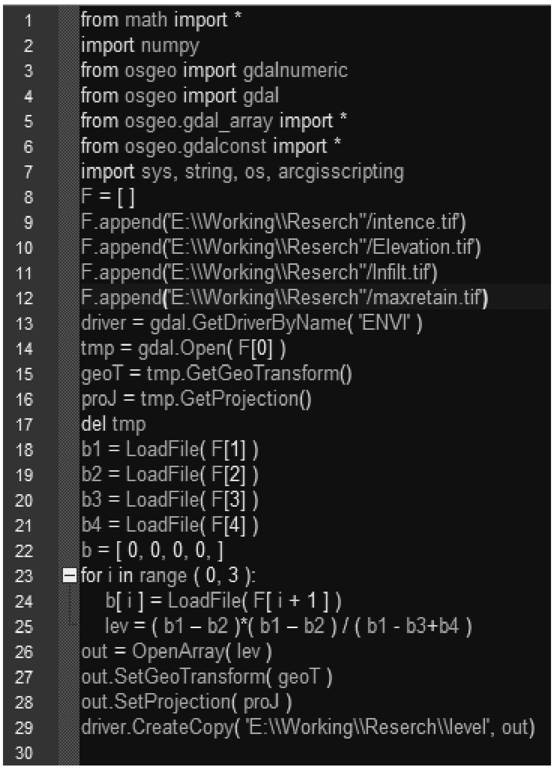


Figure 15: Simulated Inundation Depths
Source: Compiled by the Authors



```
from math import *
import numpy
from osgeo import gdalnumeric
from osgeo import gdal
from osgeo.gdal_array import *
from osgeo.gdalconst import *
import sys, string, os, arcgisscripting
F = [ ]
F.append('E:\\Working\\Reserch"/intence.tif')
F.append('E:\\Working\\Reserch"/Elevation.tif')
F.append('E:\\Working\\Reserch"/Infilt.tif')
F.append('E:\\Working\\Reserch"/maxretain.tif')
driver = gdal.GetDriverByName( 'ENVI' )
tmp = gdal.Open( F[0] )
geoT = tmp.GetGeoTransform()
proJ = tmp.GetProjection()
del tmp
b1 = LoadFile( F[1] )
b2 = LoadFile( F[2] )
b3 = LoadFile( F[3] )
b4 = LoadFile( F[4] )
b = [ 0, 0, 0, 0, ]
for i in range ( 0, 3 ):
    b[ i ] = LoadFile( F[ i + 1 ] )
    lev = ( b1 – b2 )*( b1 – b2 ) / ( b1 - b3+b4 )
out = OpenArray( lev )
out.SetGeoTransform( geoT )
out.SetProjection( proJ )
driver.CreateCopy( 'E:\\Working\\Reserch\\level', out)
```

Figure 16: Simulation of inundation depth using Python Scripting
Source: Compiled by the Authors

Figure 15 shows the inundation depths simulated from model 2. The highest simulated flood level of 1.2 m is obtained for Wanawasala, Peliyagoda, Hekiththa & Waththala areas. When validating those results through field observations, the residents of that area also stated that they received 4-5 feet flood level. Figure 16 shows the screeshot of the Python script which was written to caculate the inundation depth.

The accuracy of the simulated flood levels of the entire inundation area was checked using the "Accuracy Assessment" method. For that several points were randomly selected in the inundation area and the simulated flood levels were crosschecked with the actual flood levels on the ground. Figure 17 shows the randomly selected locations for the validation.

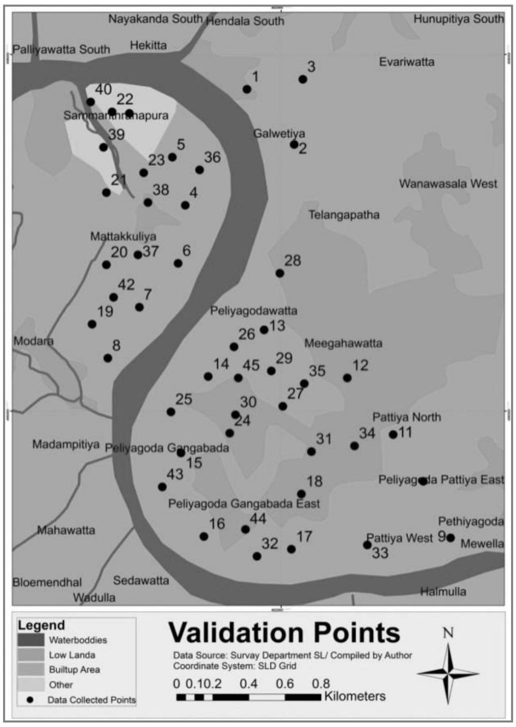


Figure 17: Locations of validation points
Source: Compiled by the Authors

The accuracy assessment method uses the "Kappa coefficient" to test the consistency of the actual values and simulated values.

$$Kappa\ coefficient = \frac{n\sum n_{kk} - \sum n_{k+}n_{+k}}{n^2 - \sum n_{k+}n_{+k}}$$

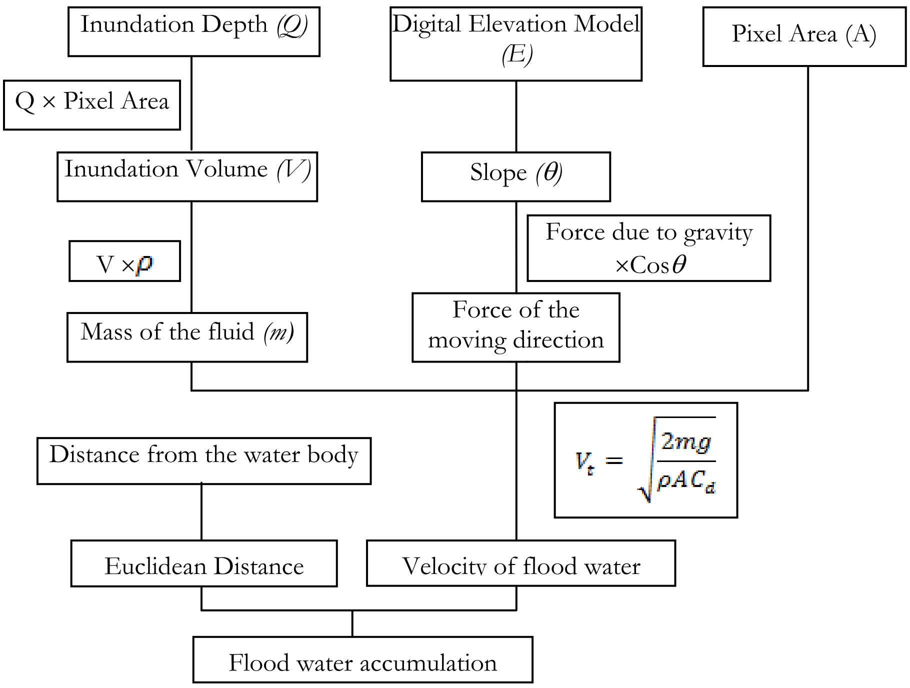
Where;
n = number of validation points
n_{kk} = difference between actual value and predicted kth value
$n_{k+}n_{+k}$ = difference between sum of actual values and sum of predicted values

Definitions of Kappa Coefficient Values:

Poor agreement - less than 0.2
Faire agreement - 0.2-0.4
Moderate agreement - 0.4-0.6
Good Agreement - 0.6-0.8
Very good agreement - 0.8-1.0

In this validation process the Kappa coefficient was received as 0.7544. Accordingly it can be concluded that there is a "Good Agreement" between the actual values and simulated results.

7.3 Model 3- Simulating the flood water accumulation time



Assumptions:

1. Density of flood water was considered as equal to density of water (ρ)- 1000 km/m^3
2. Force due to gravity was considered as 9.8 N/kg
3. Drag Coefficient (C_d) was considered as equal to entire area - 0.44
4. 10m×10m pixel size was considered for the analysis

Table 12: Input Data of Model 3

Input Data	Source
Inundation Depth (Flood level)	Obtained from results of Model 2
Digital Elevation Model	Obtained from results of Model 1
Pixel Area	Considered as 100m^2 (10m×10m)
Distance from the water body	Obtained from results of Model 1

Calculation of flood accumulation time is very essential for studies about floods. However it is rarely used in majority of the studies on flood modeling. Flood Accumulation time is important to execute flood mitigation actions such as activating pumping houses, evacuation planning and opening water outlets.

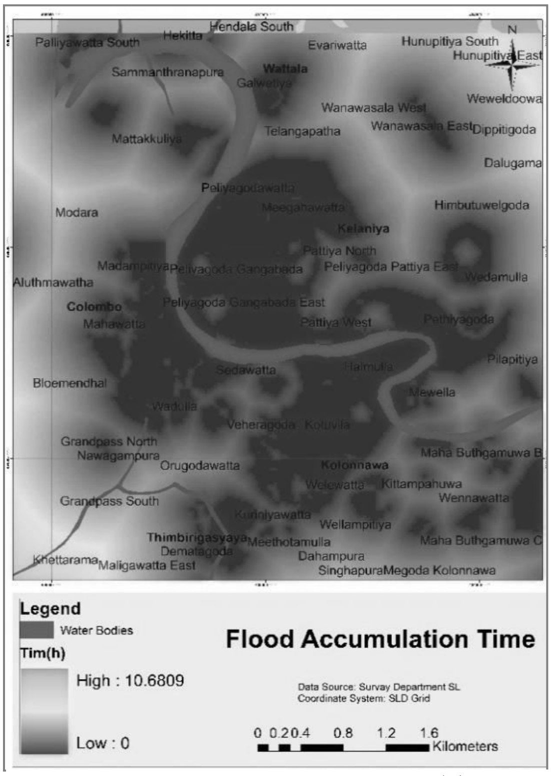


Figure 18: Flood Accumulation Time

Source: Compiled by the Authors

```
from math import *
import numpy
from osgeo import gdalnumeric
from osgeo import gdal
from osgeo.gdal_array import *
from osgeo.gdalconst import *
import sys, string, os, arcgisscripting
F = [ ]
F.append('E:\\Working\\Reserch"/dis.tif')
F.append('E:\\Working\\Reserch"/Elevation.tif')
F.append('E:\\Working\\Reserch"/Infilt.tif')
F.append('E:\\Working\\Reserch"/maxretain.tif')
F.append('E:\\Working\\Reserch"/slope.tif')
F.append('E:\\Working\\Reserch\\level')
driver = gdal.GetDriverByName( 'ENVI' )
tmp = gdal.Open( F[0] )
geoT = tmp.GetGeoTransform()
proJ = tmp.GetProjection()
b1 = LoadFile( F[1] )
b2 = LoadFile( F[2] )
b3 = LoadFile( F[3] )
b4 = LoadFile( F[4] )
b5 = LoadFile( F[5] )
b = [ 0, 0, 0, 0,0 ]
for i in range ( 0, 4 ):
    b[ i ] = LoadFile( F[ i + 1 ] )
    m = ( b5 – b2 )*10000
    f= m*10*cos(b4)
    a=f/m
    r=a*m/sin(b4)
    t= (a-r)/sin(b4)
    v=at
    t1= b1/v
out = OpenArray( t1 )
out.SetGeoTransform( geoT )
out.SetProjection( proJ )
driver.CreateCopy( 'E:\\Working\\Reserch\\time', out)
```

Figure 19: Calculation of Flood Accumulation Time using Python Scripting

Figure 18 shows the simulated flood accumulation time of the area beside Kelani River. According to the above map Paliyagoda, Wanawasala, and Waththla has lower flood accumulation time about 1-2 hours. Figure 19 shows the screenshot of the Python script which was written to calculate the flood accumulation time.

The result of this model is also useful to get an idea about the direction of flood with respect to time. For an example Peliyagoda is located in close proximity to Kelani River and Meegahawaththa is located 1.5km away from KelaniRiver. As flood water accumulation time is proportional to the distance from the Kelani River, Meegahawaththa area should has high accumulation time compared to Peliyagoda. However according to the above figure, Meegahawaththa has less accumulation time compared to Peliyagoda. That result indicates Meegahawaththa area is suffering from floods which come from Northern side. Therefore the above result is also useful in getting an idea about travelling direction of flood water.

8.0 Conclusion

In this study, three models have been developed using Arc-GIS software and Python scripting to simulate the inundation areas, inundation depths and flood water accumulation times in part of the area in the Kelani River basin. The simulated results, validated through field observations and secondary information indicated that there is a high level of consistency between the observed and simulated results. Hence, the flood modeling approach presented in this research can be considered as an indirect flood estimation method to simulate the flood information of small scale urban catchment areas in an accurate manner. However, the accuracy of the model outputs are solely based on the accuracy and reliability of the input data used in the model. For example, the model needs large scale contour data and cluster of rainfall station values to simulate an accurate result. Pixel size is also a major determinant of deciding the accuracy of simulated outputs. The greater the pixel size, the lesser the accuracy of spatial outputs. On the other hand, low pixel sizes require more detailed information. In this study 10m × 10m pixel size was taken for developing the flood model.

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