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Evaluating the Capacity of Existing Stormwater Drainage System in Kapan, Kathmandu via SWMM Model

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ABSTRACT – Overflowing drainage systems in the Nepalese cities are the most significant issue due to unplanned urban expansion and inadequate drainage networks. As the city's drainage networks are not designed to handle the extra runoff from catastrophic flooding incidents, flash floods typically occur during short-duration, and high-intensity rainstorm storms frequently. In the vicinity of Kapan, Kathmandu, and many other Nepalese cities, particularly during the rainy season, roads are seen changing into the streams. This study employs a hydrological analysis model to examine the storm water drainage system existing currently in the Kapan area. Being the EPA Storm Water Management Model (SWMM) physically based, deterministic type that simulates the inflows, outflows, and storages of water within a sub-catchment efficiently, it is chosen here mainly to model the catchments specifically. Though it has not been employed frequently in the context of Nepal, despite its popularity in the industrialized countries such as United States of America for the proper management of the storm water, the SWMM is particularly employed here to model the catchments due to its publicly available, easy to obtain, simple data input parameters, and simple processing steps in compared to other relatively more expensive yet sophisticated models. The catchment's overall area of 360.57 hectares was at first separated into the 86 sub catchments using the SWMM based on its surface elevation and existing drainage network, and the attributes of each sub-catchment were then assigned accordingly. After the proper identification of the sub-catchments, the runoff from the relevant sub-catchments was routed to the respective nodes, and finally to the outlet via conduits. In the current study, the drain system (Combined Sewer line) is given along the center of the road network. The storm network are represented by junctions, conduits, and outfalls. The longitudinal and velocity profiles of the drain were obtained. The critical runoff and capacity of existing drains were determined, as well as their validation with discharge derived using the rational technique. With the runoff generated during peak rainfall 45.08 mm/hr., the Kapan area's existing drainage system was found to be insufficient. This study suggests that the SWMM would be the most effective model to be employed for predicting the sudden surface runoff and for prior managing of the storm water, particularly in Kathmandu and other vulnerable parts of main cities in Nepal, where overflow has caused serious problems during rainfall.

KEYWORDS – ***Hydrological Analysis, Flooding, Overflow, Storm Water Drainage System (Combined Sewer Line), Imperviousness***

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1. INTRODUCTION

Water is essential for life, yet excessive amounts can have a negative impact on how long living things can survive. Earlier, when the majority of the area was agriculturally productive land, it could use the rains on its own and did not need a drainage system. The current trend of haphazard migration and rapid, unplanned urbanization affects natural drainage, which ultimately increases the pressure on roadside drains. Due to the construction of buildings, paving, and concrete structures, the impervious area is growing (K. Basnet, 2020). During storm events, urban drainage systems are generally designed to drain surface runoff from urban areas (e.g., paved roadways, parking lots, walkways, and roofs). Excess storm water, on the other hand, can produce urban flooding, as well as traffic disruption, economic loss, and pollution and health hazards. Increased impermeable land cover results in increased surface runoff, quicker runoff concentration, and greater peak flow rate. As a result, there is a growing need to improve drainage capacity in quickly urbanizing areas in order to minimize flooding (H. Qin, 2013).

In June 30, 2021, there was a heavy rainfall for about 2 hours in the Kapan area of the Kathmandu city which instantly turned the Kapan-Tarkari Bazzar-Sat Tale road section into river flooding and water logging area. Because of which many shops and business spots were forced to close for hours and vegetables, utensils were flooded away. The rainwater was about three feet above the road (The Kathmandu Post, 2021). Figure 1 shows the Kapan area of Kathmandu where the roads are overflowed with rivers water during heavy rainfall. Immediately after this, the local Governments and its components were mobilized into the affected areas intensely. They made some recognizable effort for mitigating the problems of this type urban flooding, however, the proper implementations with long term solutions and vision were strongly lacked. This specific urban flooding problem in the Kapan area ultimately raised several negative impact in the society such as damaging road and building infrastructures, spreading water borne diseases, contaminating of rivers, lakes, and other bodies of water, impact on the ecosystem, loss of life and financial damage and soon (A. Kadaverugu, 2021). The more adverse effect of this flooding was turned into the human loss: an 8 year old boy was flooded in the Kapan area on the northern outskrits of Kathmandu. This is not the last and first incident in the same specific area; even after the year 2021; the people residing over the same area have been facing the similar type of problems every year (Online Khabar, 2021).

Besides those direct hazardous effects of the floods, unmanaged drainages, and water logging problems, the water that remains on the road surface over time degrades the pavement, reducing its bearing ability and load dispersion capacity, and creating potholes and ruts. Loss of subgrade causes the road pavement to break down under the weight of traffic. Floods could harm the infrastructure of the water supply and foul up sources of water used in homes (A. Kadaverugu, 2021).

Among the wide range methods responsible to evaluate the discharge and runoff, the Rational method is the simplest method to determine peak discharge (Q) from drainage basin runoff and frequently used for sizing sewer systems. It is presented from the perspective of each of the rational method's three independent variables which are runoff coefficient (C), catchment or drainage basin area (A) and rainfall intensity (I) (T. Mulvaney, 1851). The return period is a function of the design point. The average return period for the design storm is known as the design interval. Design return periods are typically claimed to be between 2 and 15 years, with 10 years being the most usual for storm sewers in residential regions and between 10 and 100 years for storm sewers in commercial and high-value sectors, depending on the economic justification. (ASCE, 2006).

Based on the technical designation, Nepal Road Standard, NRS 2013, has provided an instruction for which return period for different classes of roads should be used to calculate drainage discharge that must be accounted for. The process for determining such design outflow from catchment or drainage basin, however, has not been adequately covered. (DOR, 2013).

To determine the design discharge, various watershed modeling techniques are used. In countries with good infrastructure, it is relatively usual to use well-established drainage design guidelines and modeling techniques. In the context of Nepal, engineering institutes such as Institute of Engineering have begun modeling procedures for various watersheds. (K. Basnet, M. Neupane, 2018).

For modelling storm water, here we used storm water management model (SWMM) software which is organized by Environment Protection Agency of United States of America (EPA). SWMM is an open source software application that can be used for single event of long term simulations of runoff quality and quantity. Though developed counties like USA, China and India used SWMM for modeling of storm water drain, frequent usage of the SWMM was not reported in the context of Nepal. However there was one study lately conducted in Lakeside, Pokhara by Sanjay Khadka and Kashav Basnet in the year 2019 was mainly focused to design the drainage network system just to prevent overflow at present situations considering

Figure 1. Overflow on a road of the study area (Kapan) during heavy rainfall.

rainfall data of single year with current Land Use Land Cover (LULC) while in this study the existing drainage network was modeled using SWMM considering 10 years return period rainfall data. SWMM model has the benefit of being user-friendly and beginner-friendly in terms of functionalizing its multistep serially, making its source codes and simple learning exercises available on YouTube, availability of EPA SWMM user's guide, designing the drain size with ease, etc. Due to its direct access, simple data-input parameters, and straight forward processing processes in comparison to other costly and challenging mathematical models, it would be a more relevant model in the context of Nepal for drainage, flooding, and water-blockage.

With the selection of this model, this research work that was mainly aimed at evaluating the capacity of existing storm water drainage system in Kapan, Kathmandu is structured as follows: In section 2, Materials and Methods are described concisely; in section 3, Results and Discussions are presented; and in section 4, Conclusion is given quantitatively.

2. MATERIALS AND METHODS

The flow chart of the present study is shortly summarized in Figure 2 followed by the details about the study area, and its selection specifically.

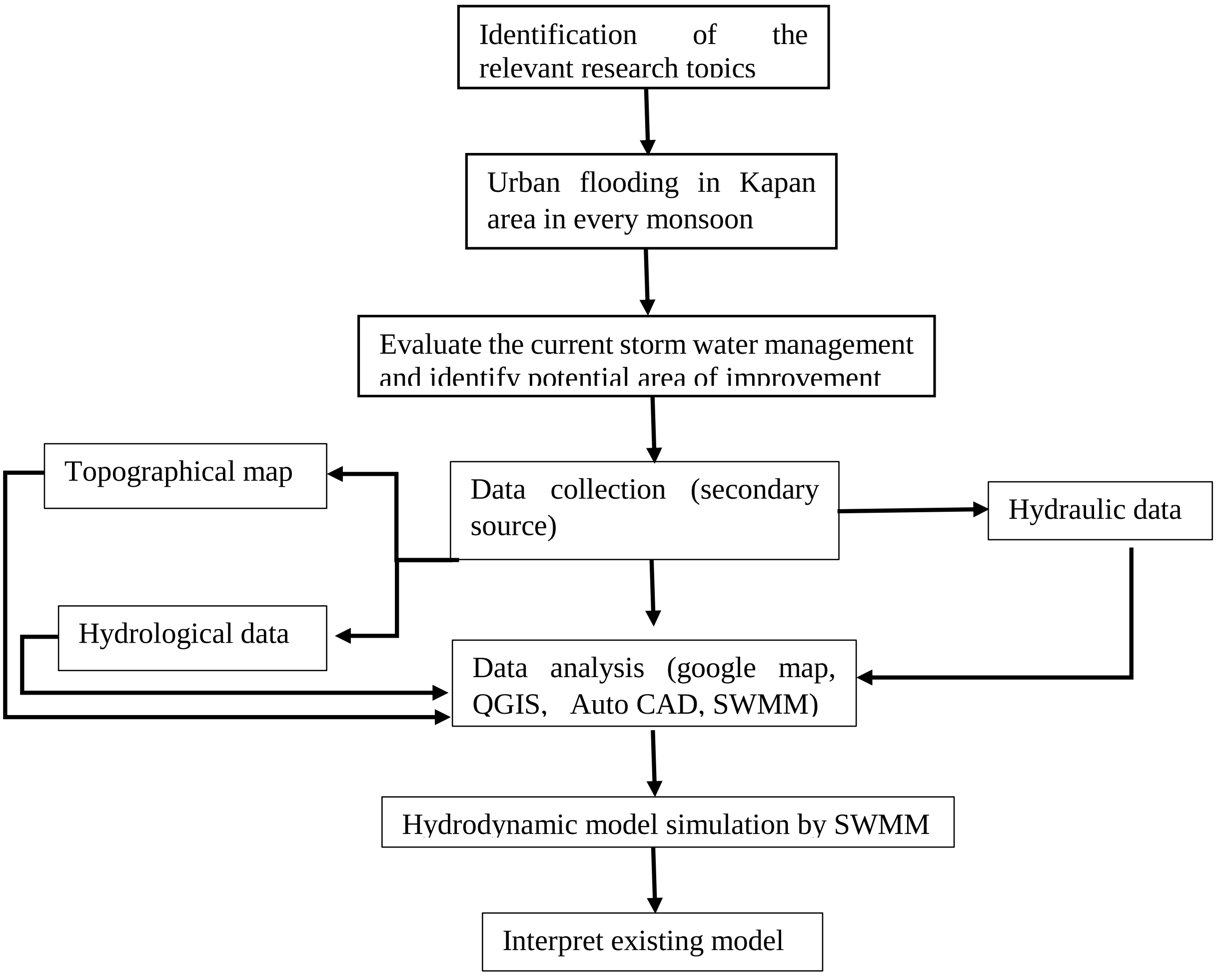

Figure 2. The overall diagram of the study

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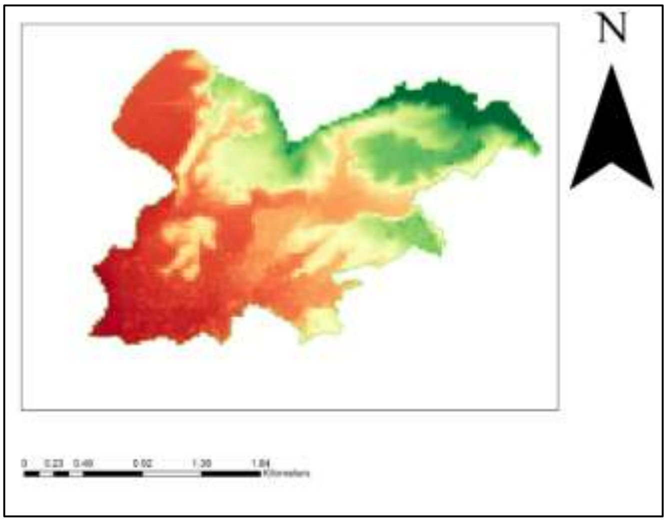

Figure 3. Study Area located at Kapan, Kathmandu, Nepal with digital elevation map

Firstly, the area to be studied (Figure 3) was identified. The study area lies in the Budhanilkantha municipality which is located in Kathmandu district, Bagmati Province of Nepal. The geographic position of the municipality is located at 85°20'09" to 85°23'28" east latitude and 27°43'19" to 27°48'50" north longitude. The study area for a project on storm drainage assessment within the municipality would specifically focus on the area within the municipality's boundaries of wards 10, 11 and 12. The total coverage area of proposed study area is 360.57 hectares.

The map of the study area was loaded into the SWMM as a backdrop image. The total area was divided into number of catchments based on elevation and existing drainage system. The study area is characterized by a mix of residential, commercial, and industrial land use. The area is densely populated and has a well-developed road network. This project would include an examination of the existing storm drainage infrastructure, such as catch basins, inlets, and channels, as well as an assessment of the effectiveness of the infrastructure in managing and conveying storm water. The study would include a review of the existing storm water management framework, as well as identify any gaps or weaknesses that need to be addressed. It would also examine the percentage of impervious surfaces like pavements and buildings, and the extent of open areas like parks and green spaces. The study will involve collecting data on the current state of storm drainage systems, including their design, construction, and maintenance. This information will be used to evaluate the capacity and efficiency of the systems, identify areas where improvements are needed.

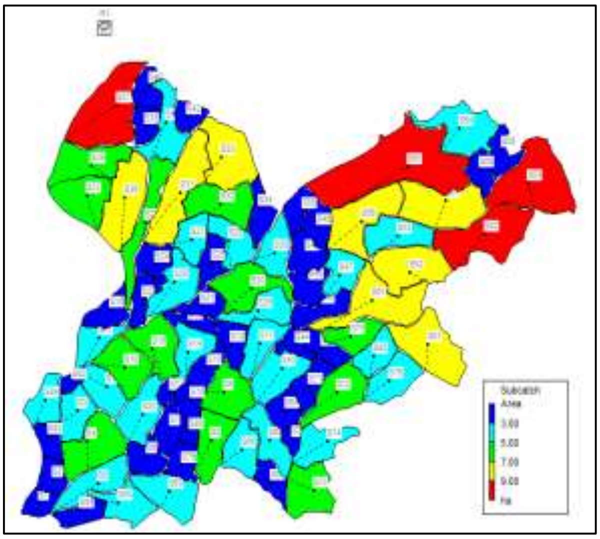

Figure 4. Sub catchment of Study Area located at Kapan, Kathmandu, Nepal in SWMM

2.1 Computation of Sub-Catchment Area and Imperviousness

Sub catchment area is a measure of the area of land that contribute runoff to a particular point such as stream, rivers or drainage basin. The total catchment area is calculated as 360.57 hectares using AutoCAD. The whole catchment is divided into 86 sub catchments based on existing drainage system and slope analysis using Google Earth Map. The overall percentage of imperviousness of catchment is 73.50%. The percentage of imperviousness of each sub catchment is calculated by computing rooftop area, pavement area, forest area and open space area using land use map of Kapan area for the year 2020 A.D. The sub catchment are shown in Figure 4 and the sub catchment area along with percentage of imperviousness are in Table 2.

2.2 Assigning Nodes, Conduits and Outfall

The input parameters for conduits, nodes, and junctions were entered once the road network. On the basis of existing drainage network system, outfall and conduits were modelled on SWMM which is shown in Figure 5.

2.3 Time Series Rainfall Data

Time series rainfall data is a record of the amount of rainfall that occurs over a period of time, typically at regular intervals such as daily, hourly, or even minutely. Rainfall data was obtained from DHM. The

Figure 5. Existing Drainage Network System with assigned Nodes and Conduits as Sub catchment Modelled in SWMM

sub catchments regions were defined. Elevation and maximum depth were the input parameters for nodes; drainage network dimension (length and diameter) and Manning's roughness coefficient were those for conduits; and invert elevation and maximum depth of drains were those for outfalls. The values for the elevation were derived from QGIS. In this study drainage system was provided along the center of

following Figure 6 shows the graphical representation of 24h accumulated precipitation obtained from manual station measured at Tribhuvan International Airport, Kathmandu for the period from January 1, 1993 to July 17, 2021. Storm sewers typically have a design return period of 10 years (ASCE). Gumbel's distribution approach was utilized to calculate the return period of ten years. After analyzing daily rainfall data, rainfall intensity was derived using PC Jha method which is shown in Table 1. The hourly rainfall data of 45.08 mm on May 22, 2023, and the rainfall intensity of 43.68 mm/hr calculated using the PC Jha method over a 10-year return period are almost similar. So, hourly rainfall data of 45.08 mm at interval of 15 minutes for 24 hours of most rainy day of May 22, 2023 was entered in SWMM as shown in Figure 7.

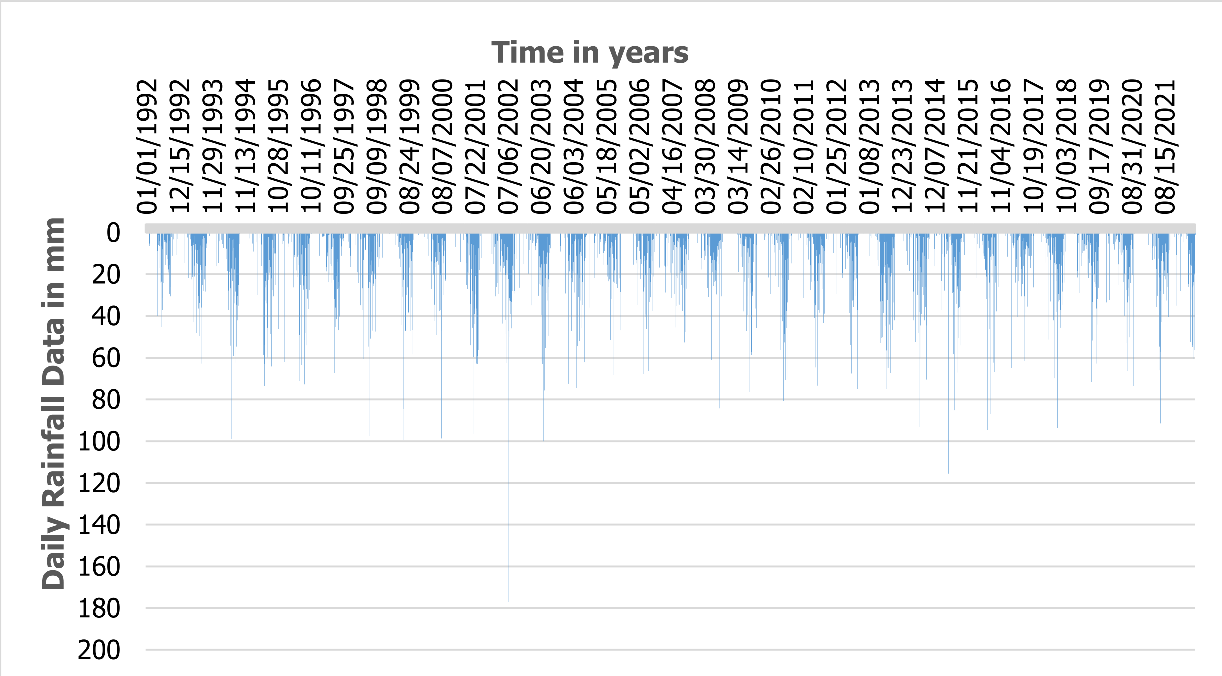

Figure 6. Graphical representation of 24h accumulated precipitation from manual station measured at Tribhuvan International Airport, Kathmandu in the period from January 1, 1993 to July 17, 2021

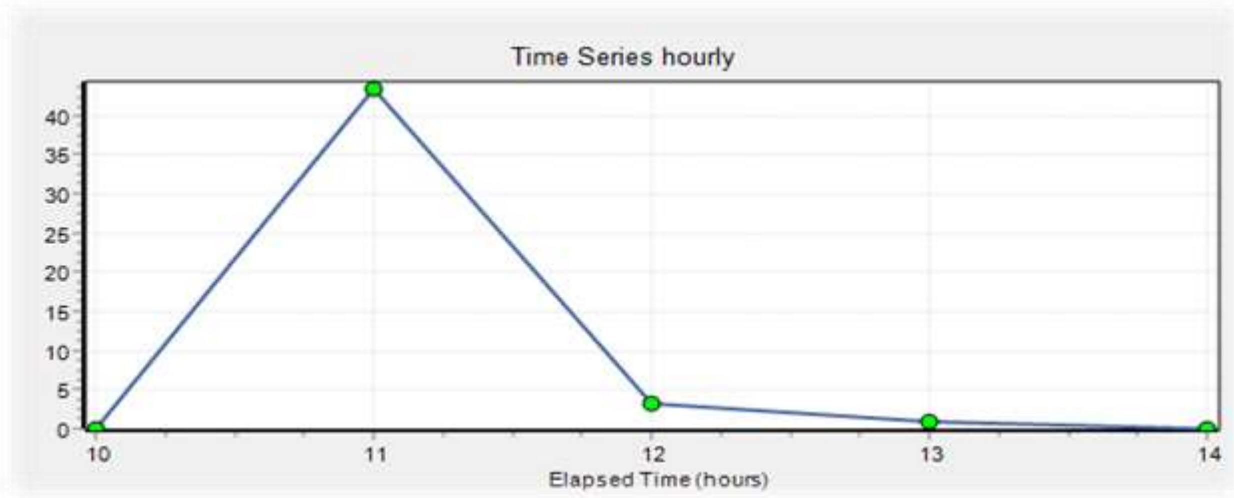

Figure 7. Time series of rainfall data of most rainy day of May 22, 2023 in hourly interval entered in SWMM

Table 1: Intensity in mm/hr and mm/15 min for different return period using Empirical Formula Based on PC Jha method

Return Period	Y_t	K	Depth (mm/day)	Intensity (mm/hr) based on Empirical Formula	Intensity (mm/15 min)
2	-0.3665	-0.1643	82.523	31.359	7.840
5	-1.4999	0.7195	104.249	39.615	9.904
10	-2.2504	1.3046	118.634	45.081	11.270
20	-2.9702	1.8658	132.432	50.324	12.581
50	-3.9019	2.5923	150.293	57.111	14.278
100	-4.6001	3.1367	163.677	62.197	15.549

2.4 Runoff in Sub Catchment

Runoff is the water that flows over the surface of the land and is not absorbed into the ground. The catchment runoff was calculated using the precipitation data entered however the result differed because of the different terrain characteristics and other properties. As paved surfaces and buildings occupied the majority of the land area, a high runoff coefficient value was achieved. Due to the constant increase in concrete construction projects, the natural drainage is in diminishing order. The impervious surface in Kapan is in increasing order as a result runoff is higher.

2.5 Map Analysis

The Land Use Land Cover (LULC) Map of Kapan, Kathmandu, Nepal was

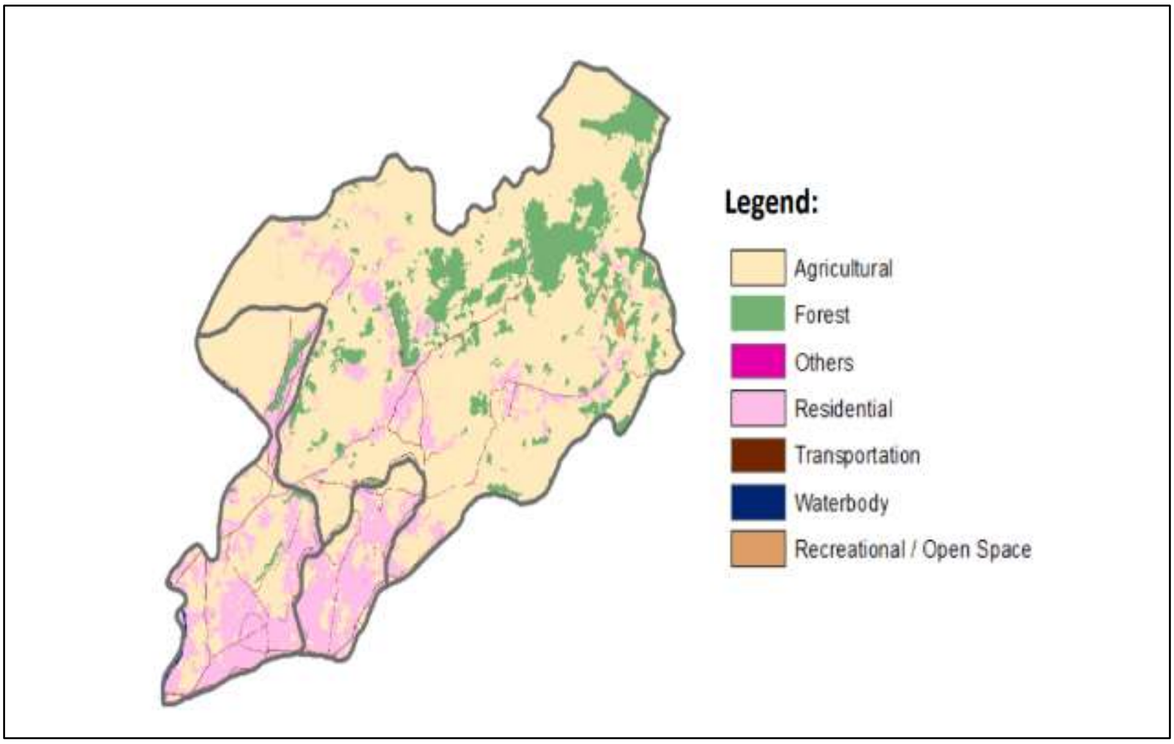

Figure 8. Land Use Map of Kapan Area for the year 2000 AD

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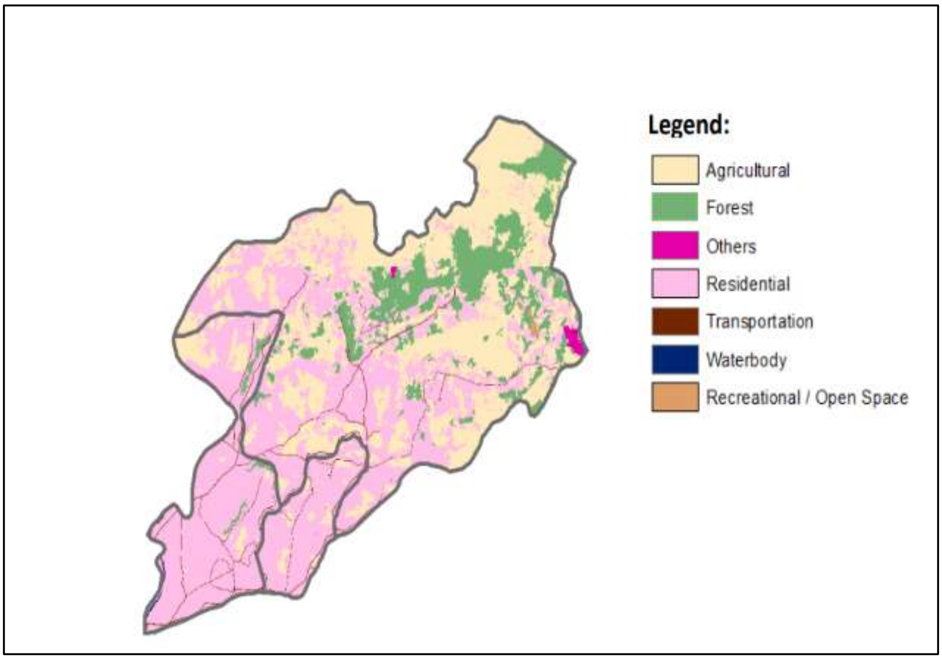

Figure 9. Land Use Map of Kapan Area for the year 2010 AD

studied from 2000 to 2020 AD. The changing trend of the land pattern of the study area were analyzed on every 10 year interval. The LULC map were obtained from the Budhanilkantha Municipality. The LULC for the years 2000, 2010 and 2020 were shown in Figure 8, 9 and 10 respectively. Due to the dynamic nature of land usage, it is always shifting from one type to another. The roof top area or built-up, paved surface and transportation were observed to be increasing along with the trend of lowering agricultural land, open space and forest area which were represented by pie chart of each year in Figure 11, 12 and 13 respectively.

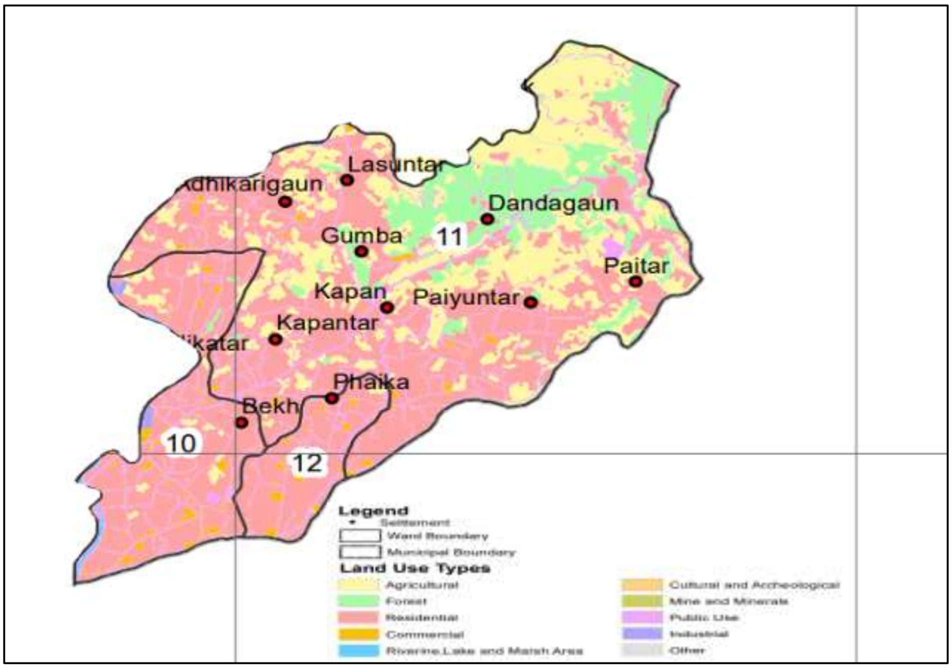

Figure 10. Land Use Map of Kapan Area for the year 2020 AD (Budhanilkantha Municipality)

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Increasing trend of conversion of agricultural land to built-up area, forest area to agricultural land and built-up area, construction of pavement road networks and soon decreases the perviousness of the land and as a result during rainy season flooding is obvious. So the solution of the overflow problem and storm water management techniques is necessary.

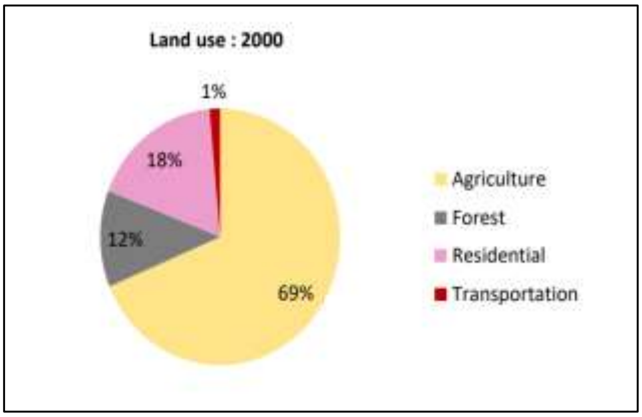

Figure 11. Graphs showing percentage of land use for the year 2000

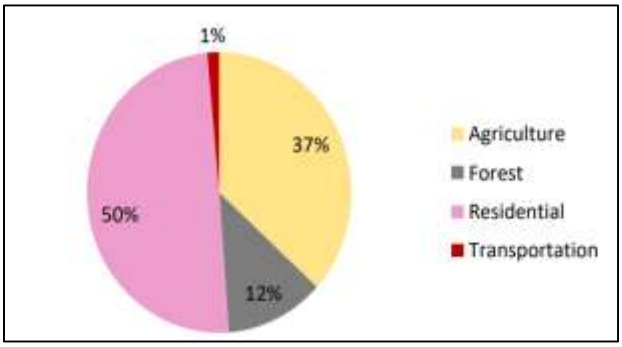

Figure 12. Graphs showing percentage of land use for the year 2010

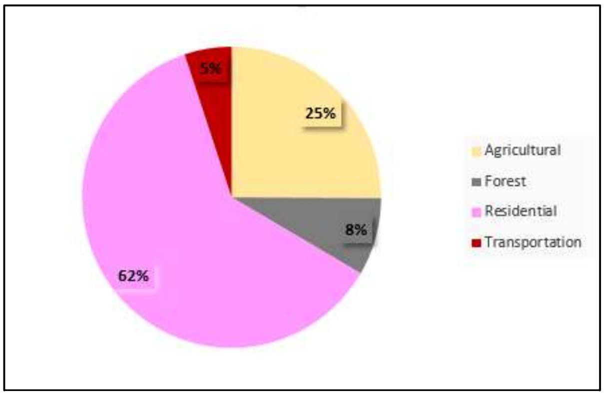

Figure 13. Graphs showing percentage of land use for the year 2020

Much of the land use was found to be in populated regions between 2010 and 2020. From 2000 to 2020, there was no significant change in transportation or forest, built-up areas. This demonstrates the urbanization of the area.

The graph above depicts the changes in agricultural land. In 2000, the 69% of agricultural land was turned into 37% in 2010 and 25% in 2020. The rise in built-up areas from 18% in 2000 to 50% in 2010 and 62% in 2020. This demonstrates that infrastructural development results in the depletion of agricultural land and a rise in settlement areas.

2.5 Comparison of Runoff

We modeled the system in SWMM using appropriate manning's N, % impervious, slope, widths & area of each sub-catchment, and we also attempted to compute runoff using the rational method Q=CIA/360. We anticipated that both strategies would produce comparable peak flows for a given return period of rainfall events through the system. However, SWMM consistently produces larger peak flows than the rational method.

The Width parameter in SWMM is used to determine the Time of Concentration and to vary the discharge estimate. SWMM determines runoff in sub-catchments using a variety of parameters and a dynamic flow routing technique. While the rational method is a simple equation involving simply the runoff coefficient (C), intensity (I), and area (A). The selection of the design storm shape, which affects the discharge rate, is another possible variation in runoff using SWMM and rational procedure.

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Table 2. Comparison of SWMM modeled peak runoff with the discharge by Rational Method along with imperviousness of each sub catchment

S.N	Sub catchments	% of impervious area	Rational method				Peak Runoff (*CMS*) using SWMM model
			Area (*ha*)	runoff coefficient, *C*	Rainfall Intensity (*mm/hr*)	Discharge (*CMS*)	
1	SC#1	95.74	1.84	0.79	45.08	0.18	0.22
2	SC#2	92.82	2.24	0.78	45.08	0.21	0.27
3	SC#3	92.26	3.49	0.77	45.08	0.33	0.42
4	SC#4	95.27	6.47	0.78	45.08	0.61	0.78
5	SC#5	97.59	4.73	0.79	45.08	0.45	0.57
6	SC#6	99.00	2.94	0.80	45.08	0.28	0.35
7	SC#7	99.00	2.76	0.80	45.08	0.27	0.33
8	SC#8	99.04	4.18	0.80	45.08	0.40	0.60
9	SC#9	88.83	5.05	0.75	45.08	0.46	0.61
10	SC#10	95.01	2.48	0.78	45.08	0.24	0.30
11	SC#11	94.64	3.73	0.78	45.08	0.35	0.45
12	SC#12	85.65	2.67	0.74	45.08	0.24	0.32
13	SC#13	97.78	1.64	0.80	45.08	0.16	0.20
14	SC#14	88.34	3.46	0.75	45.08	0.31	0.42
15	SC#15	99.00	3.09	0.80	45.08	0.30	0.37
16	SC#16	99.00	2.83	0.80	45.08	0.27	0.34
17	SC#17	91.81	3.61	0.77	45.08	0.33	0.43
18	SC#18	71.18	5.20	0.67	45.08	0.42	0.62
19	SC#19	82.59	5.17	0.72	45.08	0.45	0.62
20	SC#20	81.04	4.91	0.72	45.08	0.43	0.59
21	SC#21	69.00	2.44	0.66	45.08	0.19	0.29
22	SC#22	89.66	2.24	0.75	45.08	0.21	0.27
23	SC#23	65.17	5.18	0.64	45.08	0.40	0.62
24	SC#24	70.85	2.94	0.67	45.08	0.24	0.35
25	SC#25	91.66	4.93	0.77	45.08	0.46	0.59
26	SC#26	78.46	2.60	0.70	45.08	0.22	0.31
27	SC#27	72.41	3.16	0.67	45.08	0.26	0.38
28	SC#28	75.42	3.72	0.69	45.08	0.31	0.45
29	SC#29	81.53	3.81	0.72	45.08	0.33	0.46
30	SC#30	71.22	5.81	0.67	45.08	0.47	0.70
31	SC#31	59.29	7.44	0.61	45.08	0.55	0.89
32	SC#32	57.06	5.36	0.60	45.08	0.39	0.64
33	SC#33	40.83	7.78	0.53	45.08	0.49	0.93
34	SC#34	57.50	2.77	0.60	45.08	0.20	0.33
35	SC#35	75.66	3.92	0.69	45.08	0.33	0.47
36	SC#36	89.77	7.68	0.76	45.08	0.70	0.92

S.N	Sub catchments	% of impervious area	Rational method				Peak Runoff (*CMS*) using SWMM model
			Area (*ha*)	runoff coefficient, *C*	Rainfall Intensity (*mm/hr*)	Discharge (*CMS*)	
37	SC#37	82.93	5.86	0.73	45.08	0.51	0.70
38	SC#38	77.49	5.85	0.70	45.08	0.50	0.70
39	SC#39	77.47	2.22	0.70	45.08	0.19	0.27
40	SC#40	75.36	2.32	0.69	45.08	0.19	0.28
41	SC#41	64.21	4.94	0.64	45.08	0.38	0.59
42	SC#42	61.63	2.04	0.62	45.08	0.15	0.24
43	SC#43	82.45	4.99	0.72	45.08	0.44	0.60
44	SC#44	85.00	2.12	0.73	45.08	0.19	0.25
45	SC#45	74.45	2.87	0.68	45.08	0.24	0.35
46	SC#46	65.88	2.78	0.65	45.08	0.22	0.33
47	SC#47	74.59	3.43	0.69	45.08	0.28	0.41
48	SC#48	58.17	2.89	0.61	45.08	0.21	0.35
49	SC#49	68.18	2.34	0.66	45.08	0.19	0.28
50	SC#50	47.56	2.03	0.56	45.08	0.14	0.24
51	SC#51	74.45	8.44	0.69	45.08	0.70	0.98
52	SC#52	66.36	7.31	0.64	45.08	0.57	0.88
53	SC#53	70.29	4.79	0.66	45.08	0.39	0.57
54	SC#54	99.00	2.41	0.81	45.08	0.24	0.29
55	SC#55	97.00	3.80	0.80	45.08	0.37	0.46
56	SC#56	43.55	7.47	0.52	45.08	0.47	0.89
57	SC#57	84.87	10.14	0.73	45.08	0.90	1.22
58	SC#58	14.25	2.08	0.40	45.08	0.10	0.25
59	SC#59	52.61	1.98	0.58	45.08	0.14	0.24
60	SC#60	97.00	4.99	0.81	45.08	0.49	0.60
61	SC#61	40.14	7.33	0.52	45.08	0.46	0.88
62	SC#62	57.79	9.02	0.56	45.08	0.61	1.08
63	SC#63	36.32	9.93	0.48	45.08	0.58	1.19
64	SC#64	17.49	4.73	0.38	45.08	0.22	0.56
65	SC#65	25.49	17.53	0.44	45.08	0.93	2.09
66	SC#66	95.00	3.96	0.78	45.08	0.38	0.48
67	SC#67	95.00	2.24	0.78	45.08	0.21	0.27
68	SC#68	88.00	3.79	0.75	45.08	0.34	0.45
69	SC#69	70.00	2.52	0.66	45.08	0.20	0.30
70	SC#70	98.00	1.04	0.80	45.08	0.10	0.13
71	SC#71	96.00	2.93	0.79	45.08	0.28	0.35
72	SC#72	85.00	5.28	0.74	45.08	0.48	0.63
73	SC#73	90.00	5.32	0.76	45.08	0.49	0.64
74	SC#74	83.00	4.01	0.73	45.08	0.35	0.48

S.N	Sub catchments	% of impervious area	Rational method				Peak Runoff (*CMS*) using SWMM model
			Area (*ha*)	runoff coefficient, *C*	Rainfall Intensity (*mm/hr*)	Discharge (*CMS*)	
75	SC#75	60.00	6.79	0.63	45.08	0.52	0.81
76	SC#76	75.00	4.66	0.69	45.08	0.39	0.56
77	SC#77	99.50	0.92	0.80	45.08	0.09	0.11
78	SC#78	99.00	1.65	0.80	45.08	0.16	0.20
79	SC#79	99.00	2.19	0.80	45.08	0.21	0.26
80	SC#80	97.00	0.91	0.79	45.08	0.09	0.11
81	SC#81	97.50	8.19	0.79	45.08	0.79	0.99
82	SC#82	97.50	0.81	0.79	45.08	0.08	0.10
83	SC#83	95.00	2.00	0.78	45.08	0.19	0.24
84	SC#84	93.00	3.37	0.77	45.08	0.31	0.41
85	SC#85	95.00	3.07	0.78	45.08	0.29	0.37
86	SC#86	92.20	2.03	0.77	45.08	0.19	0.24
	Total	73.50	360.57				

3. RESULTS AND DISCUSSIONS

The relevant results and the concerned discussions are presented in the following subsections concisely. The exact quantitative values are mentioned wherever necessary.

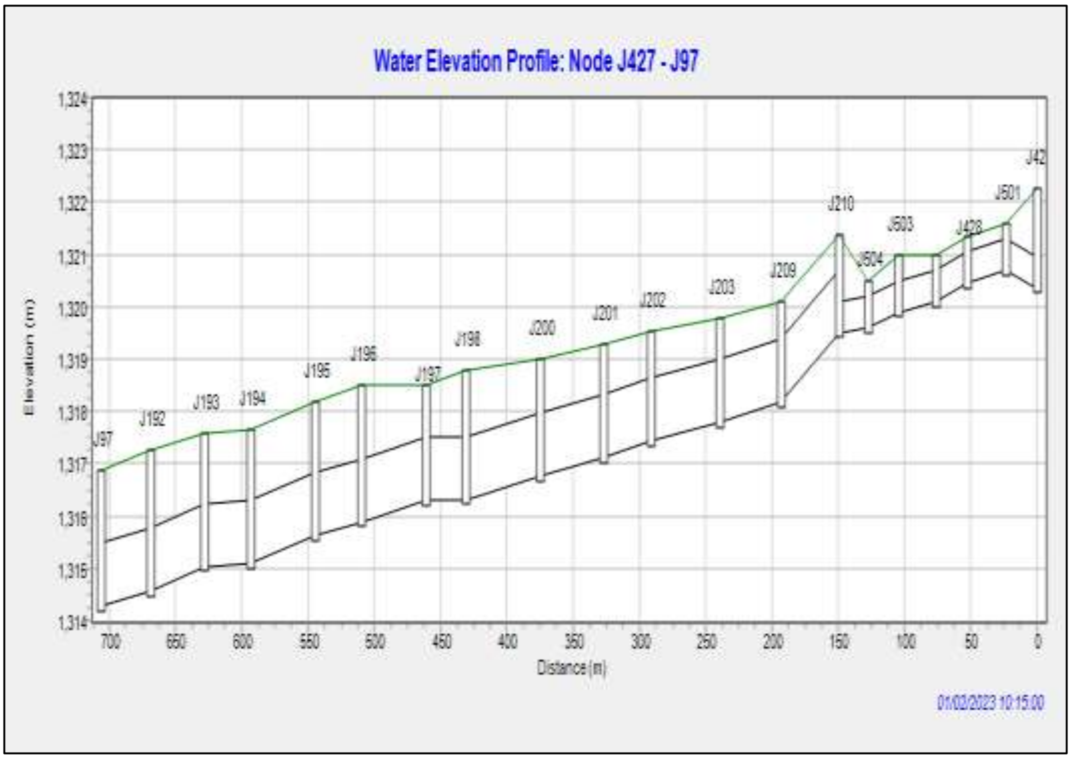

Figure 14. Water Elevation Profile of Drainage before Flooding

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3.1 Analyzing Longitudinal Profile

Here, the input parameters required to run simulation are entered and the required elevation for nodes and outfall are obtained from QGIS. After running simulation, the longitudinal profile of drain path is obtained. Here Aqua color indicate the

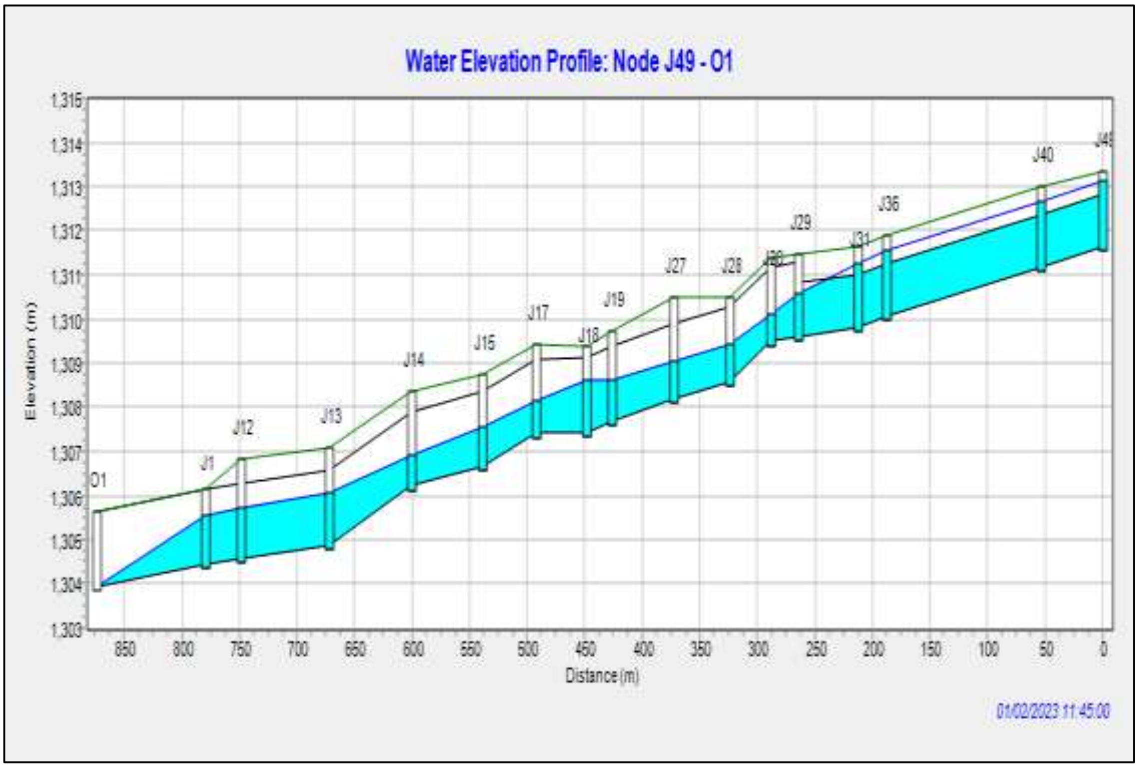

Figure 15. Water Elevation Profile at Sewer Line Joining Node J427 and J97

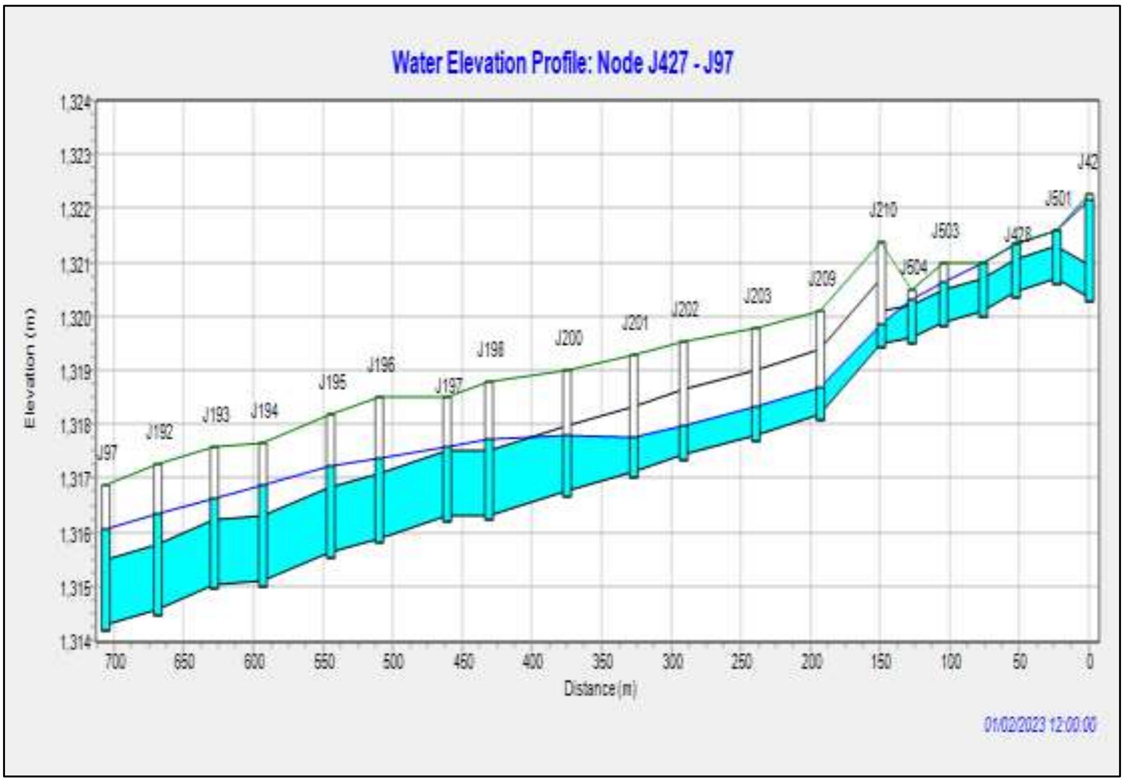

Figure 16. Water Elevation Profile at Sewer Line Joining Node J49 and Outfall O1

water depth in conduit and nodes during runoff at 12:00:00 time, green line joining the crown of node indicates the ground elevation and HGL line is shown using blue line.

Node Flooding refers to all water that overflows a node, whether it ponds or not. in the extraneous continuity statement. Nodal flooding happens once the Aqua color reaches the top level of the node or the HGL line just touches the ground surface. The water elevation profile for different main sewer line (longest path) is given in Figure 14, 15 and 16.

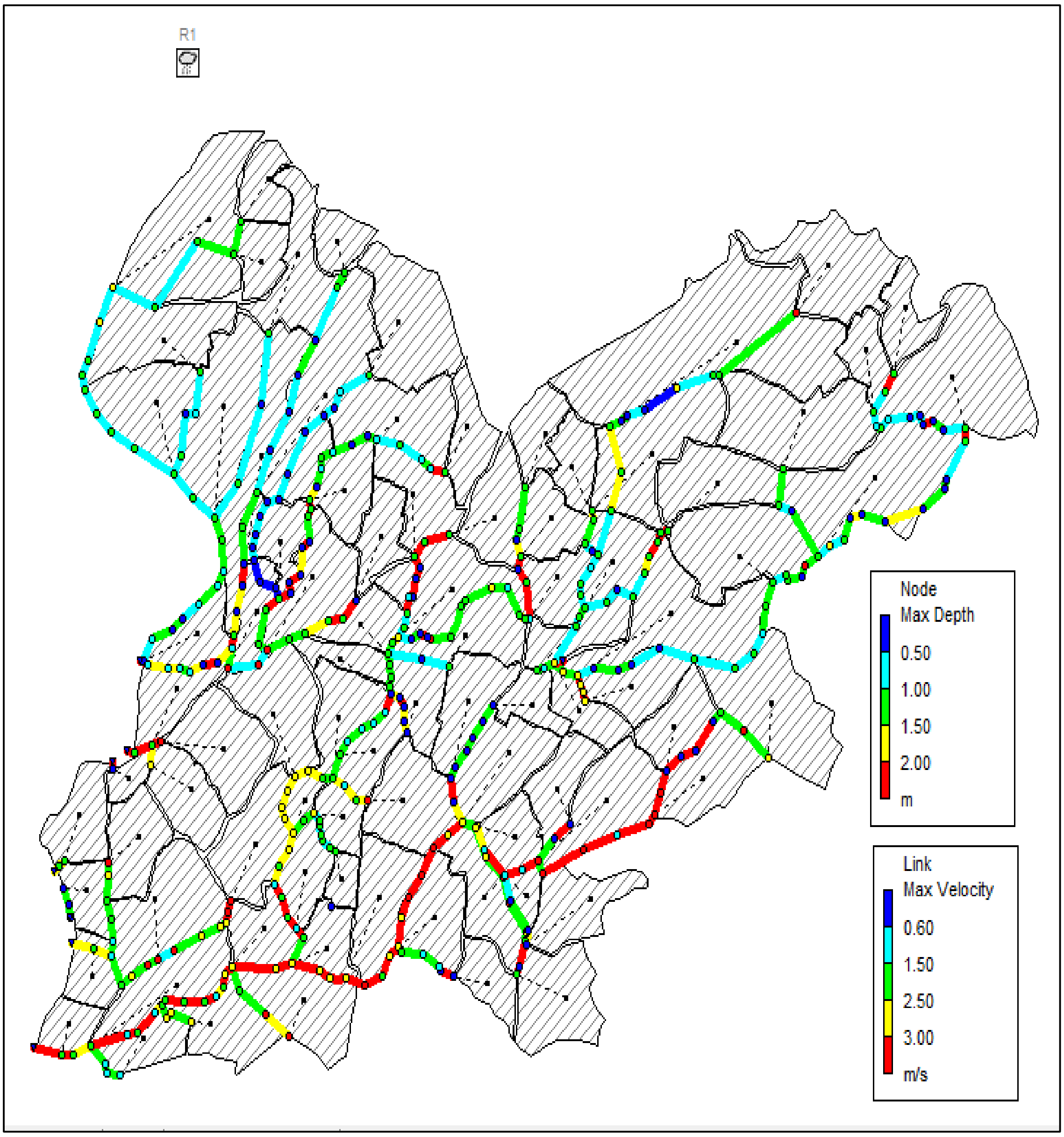

Figure 17. Catchment Area with Sub catchment, Nodes and Link Based on Depth and Velocity

In most cases, the flooding message denotes that the node's water surface standing is at ground level. Any water that is immobile downstream leaks out of the top of the manhole and is taken into account

3.2 Velocity Profile Drain during Runoff

As the flow rises, so does the water's velocity in the drain, and vice versa. The slope is a crucial parameter for rise in

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addition to the flow speed. Each node and links are colored with different color shade based on maximum node depth and maximum velocity respectively. The Red color indicates maximum node depth greater than 2m and maximum velocity greater than 3 m/s. The Yellow color indicates node depth between 1.5m to 2m and velocity 2.5 m/s to 3 m/s. The Green color indicates node depth between 1.0m to 1.5m and velocity 1.5 m/s to 2.5 m/s. The Aqua color indicates node depth between 0.5m to 1m and velocity 0.6 m/s to 1.5 m/s. The blue color indicates node depth less than 0.5m and velocity less than 0.6 m/s. The velocity profile drain during peak flow is shown in Figure 17.

It is well recognized that increasing impermeable portions in a catchment increases flood risk. The removal of pervious surfaces diminishes soil penetration, while artificial drainage replaces natural channels. This combination has a significant impact on a catchment's hydrological response to rainfall, such as faster reaction, greater quantity of water flow, increased occurrence of minor floods, and decreased groundwater recharge.

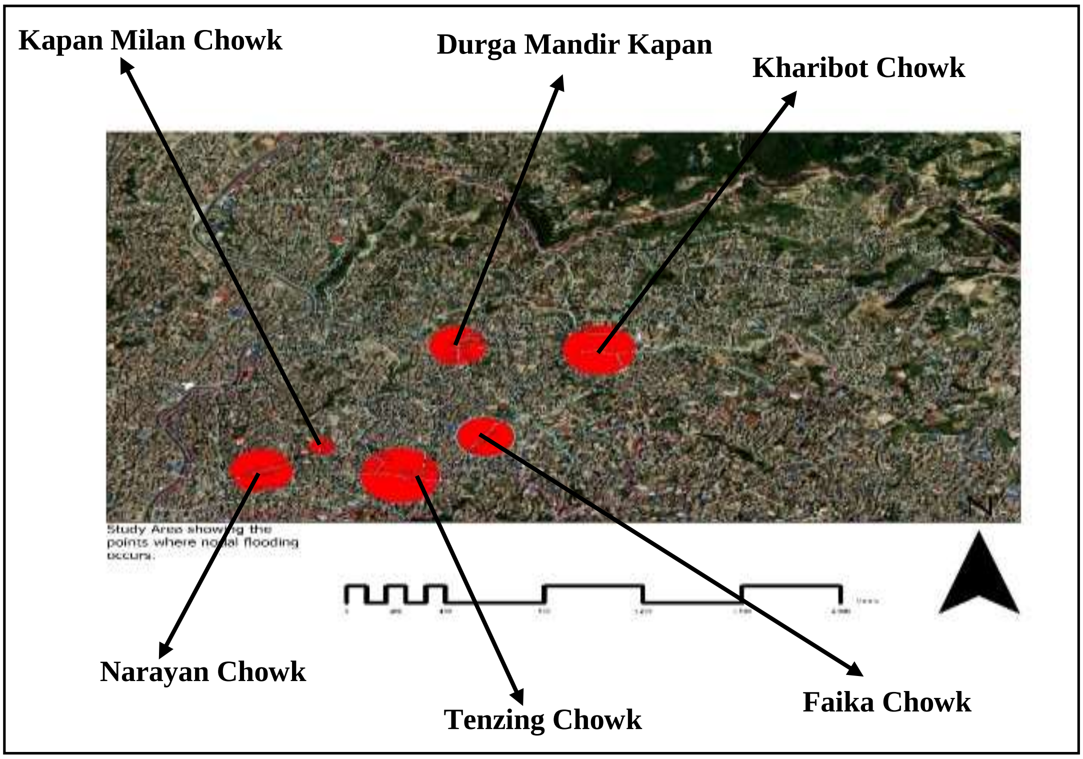

Figure 18: Red areas in the figure denotes the region where nodal flooding occurs.

3.3 Nodal Flooding Area

When we run the model in SWMM, we found that the major flooded areas of Kapan during monsoon season are: Kapan Tarkari Bazzar, Sat Tale to Gumba road sections, Milan Chowk, Durga Mandir Chowk, kharibot Chowk, Faika Chowk soon which are shown by red spots in Figure 18. Flooding has occurred in regions where imperviousness percentage exceeds 80% in our research area. This demonstrates urbanization has increased impervious area and results in flooding problem during heavy rainfall events.

4. CONCLUSION

Storm water Management is one of the major problems in urban areas of Nepal.

The roads turning into streams are one of the readily observed drainage incidents in the Kathmandu and many other urban areas of Nepal especially during rainy seasons. Unplanned growth of residential areas, building constructions, pavement construction and other concrete structures decreases the natural drainage. In this study, we specifically elected Kapan, Kathmandu as a study area due to its existing runoff and drainage problems. The catchment was modeled with Storm Water Management Model (SWMM). The existing drainage network data were collected from Kathmandu UPATYAKA KHANEPANI, Limited (KUKL). The rainfall data of 10 year return period obtained from Gumbels extreme value analysis for Kathmandu Airport was taken for modeling. Drainage discharge, Outfall loading, elevation Profile on SWMM was found to be satisfactory. Further the Sub catchment discharge using SWMM was compared by using Rational Method. Some nodes were differed to that of the rational method.

The assessment of storm water drainage network of Kapan, Kathmandu, revealed that the existing system is inadequate and unable to handle the volume of runoff during heavy rainfall events, leading to localized flooding after analyzing the longitudinal profile of drain generated from SWMM. In this study's slope analysis, it was determined that the steep topography caused the concentration time shorter, which increased junction overloading and led to overland flow. Many drains appear to be clogged with garbage and waste. So, drain clogging can also be concluded another reason for flooding. Urbanization or infrastructure development results in the depletion of agricultural land, open space, and forest area, and an increase in settlement areas results in increased imperviousness, which reduces soil infiltration, decreases ground water level, increases water flow on roads, and soon. Many concrete or bituminous pavements have been built in the last ten years in the name of development, and open areas have been paved and converted into parking lots, business areas, and soon. These factors reduce the soil's capacity to absorb water, raising the risk of flooding. The findings of the study showed that there is a need for regular maintenance of the system, including the removal of debris and sediment, and the installation of new pipes and inlets where necessary. Additionally, the assessment indicated a lack of proper maintenance and regular monitoring of the system. To lower the risk of flooding in the studied regions, attention must be paid in improving the permeability of the surfaces.

In conclusion, the storm water drainage assessment of Kapan, Kathmandu provides a comprehensive overview of the current state of the drainage system and highlights the need for improvement. It can be concluded that with the use of SWMM as a potential tool, the effectiveness to model and design for storm water management in vulnerable areas of Kathmandu and other major cities of Nepal with key issue of overflow was observed.

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6. REFERENCES

1. American Society of Civil Engineers (ASCE). (1982). *Gravity Sanitary Sewer Design and Construction, Manuals Practice No. 60*. New York.

2. American Society of Civil Engineers (ASCE). (1992). Design and Construction of Urban Storm water Management Systems, *ASCE Manuals and Reports of Engineering Practice No. 77*, New York.

3. American Society of Civil Engineers (ASCE). (2006). *Standard Guidelines for the Design of Urban Storm water Systems ASCE/EWRI 45–05*, New York.

4. Ashok Kadaverugu, Kashi Viswanadh Gorthi, & Nageshwar Rao Chintala. (2021). Impacts of Urban Floods on Road Connectivity-A *Review and Systematic Bibliometric Analysis. Current World Environment, Vol. 2, pp. 16.*

5. Basnet, K. and Neupane, M. (2018). Storm water drainage design based on hydrologic analysis: A case study on Lamachaur catchment area, Pokhara, *Nepal. Oodbodhan: A journal of TUTA*

6. Basnet, A. *et. al*. (2020). Sustainable Urban Storm Water Drainage Design using SWMM: a Case Study of Lamachaur, Pokhara, Nepal. *International Journal of Engineering and Science, Vol. 10, No. 08, pp. 01-12.*

7. Department of Road, DOR. (2013). Nepal Road Standard, Planning and Design Branch, Department of Road, Babarmahal, Kathmandu, Nepal.

8. Hua-peng Qin, Zhuo-xi Li, Guangtao Fu. (2013). The effects of low impact development on urban flooding under different rainfall characteristics. *Journal of Environmental Management, Vol. 129, No. 0301-4797, pp. 577-585.*

9. Khadka, S. and Basnet, K. (2019). Storm Water Management of Barahi Chowk Area, Lakeside, Pokhara, Nepal using SWMM. *Proceedings of 2nd International Conference on Engineering & Technology, KEC Conference, Vol. 2, No.1, pp. 320-325.*

10. Mulvany, T. (1851). On the use of self-registering rain and flood gauges in making observations of the relation of rainfall and flood discharges in given catchment. *Trans. Inst. cio, Engrs. Ire, Vol. 4, pp. 18-33.*

11. Online Khabar. (2021). Frequent floods in Kathmandu suburbs expose community leader's shortsightedness inefficiency. Daily Newspaper.

12. PC. Jha. (2006). Estimation of hourly rainfall design intensity from 24 hours maximum rainfall: the context of Nepal. *Journal of Hydrology and Meteorology, SOHAM-Nepal, Vol. 3. pp 86-94.*

13. Rossman, L.A. (2015). Storm Water Management Model User's Manual Version 5.1. National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, USA.

14. Saksena, S. (2022). Plotting Flood Frequency Curve Using Gumbels Distribution. Available: *https://serc.carleton.edu/hydromodules/steps/166250.html*

15. The Kathmandu Post. (2021). Encroachment of River of Kathmandu Valleys River and Poor Drainage Worsen Inundation. Daily Newspaper.