Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Simulation of the urban drainage system of Itanagar township using the Storm Water Management Model 5.2 (SWMM 5.2)

Kaveri Tajo
North Eastern Regional Institute of Science and Technology
Mudang Tamer
mudangtamer@gmail.com
NERIST: North Eastern Regional Institute of Science and Technology https://orcid.org/0009-0000-5709-1984
Ram Kailash Prasad
North Eastern Regional Institute of Science and Technology

Research Article

Keywords: Intensity–duration–frequency curve, Low impact development, Storm Water Management Model, Urban drainage, Urban flooding, Itanagar

Posted Date: November 6th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10910411/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Abstract

The existing drainage network of C Sector, Itanagar (Arunachal Pradesh, India), was analysed using the Storm Water Management Model version 5.2 (SWMM 5.2), a dynamic rainfall–runoff simulation model developed by the United States Environmental Protection Agency for the analysis, design and management of urban stormwater drainage systems. Daily rainfall data for the period 1986–2022 were obtained from the India Meteorological Department, Pune, and intensity–duration–frequency (IDF) curves were developed by Gumbel's method for return periods of 5, 10, 30, 50 and 100 years. The model simulates the hydrological and hydraulic processes within the urban catchment, including surface runoff generation and flow routing through the drainage network. The results show that the number of flooding nodes increases with increasing rainfall intensity: no node floods for the 5-year return period, whereas 2, 3, 6 and 7 nodes flood for the 10-, 30-, 50- and 100-year return periods respectively, with the total flood volume rising from 2.278×10^6 to 15.683×10^6 L. Two low impact development (LID) measures, namely rain barrels and permeable pavements, and their combination were then implemented to quantify their effect on runoff and flooding. Rain barrels reduced the total flood volume by up to 67.38% and permeable pavements by up to 32.84%, while the combined LID eliminated node flooding entirely for the 5- and 10-year return periods. The effectiveness of LID decreased as the return period increased. The study is useful for assessing future floods and for reducing the likelihood of urban flooding in hilly townships of the Eastern Himalaya.

1 Introduction

In India, the summer monsoon season, which runs from June to September, contributes between 70 and 75% of the annual rainfall of the country. The areas that receive the maximum rainfall are the west coast, the north-eastern states, West Bengal and coastal Odisha. In some parts of the country, heavy rainfall occurs during this season. Urban flooding is primarily caused by such heavy rainfall, and it differs greatly from rural flooding because urbanisation increases flood peaks by 1.8 to 8 times and flood volumes by almost six times (NDMA 2025). Additionally, urbanisation increases the impervious area, such as roads, roofs and pavements, which in turn increases runoff. Natural hydrological phenomena indicate that rainstorms react quickly to an increased impervious area, resulting in higher peak flows in drainage channels. Climate projections suggest that winter rainfall may rise by 20 to 30% by the 2080s (Rafiq et al. 2016), and the threat of flooding could rise significantly as a result of such an increase. The effect of urban flooding can be decreased to some extent by preserving the drainage channels that are already in place, providing alternative drainage routes, preventing solid waste from entering the drainage system and installing pervious pavements that allow rainwater to infiltrate.

Over the past few years, the number of large habitations in Itanagar has increased, and some of the houses have been observed to be built above the drains. In the low-lying part of the city, encroachment in the upper catchment of the steep urban region also results in significant flooding. Owing to inadequate sewerage systems, the majority of the homes release their waste into the existing stormwater channels. In the past, stormwater drainage systems were designed to withstand rainfall with an intensity of 12–20

mm/h (NDMA 2025). Whenever rainfall has been more intense, these drainage capacities have been readily overloaded. In addition, extensive encroachment on the natural drains has reduced their cross-section and caused flooding. The capacity of the sewers is also greatly reduced by improper solid waste disposal and by the dumping of construction debris into them.

Urban flooding is difficult to predict and control, since it occurs suddenly and affects places that are not obviously vulnerable to floods. It is therefore crucial to remove excess water quickly and efficiently. Appropriate drainage system design, maintenance and conservation are among the strategies used to reduce its severity. Although such occurrences cannot be prevented, their impact can be reduced by simulating floods and by creating action plans and alert systems (Rangari et al. 2018).

Urban flood scenarios in a watershed can be effectively modelled using open-source tools such as the Hydrologic Engineering Center's River Analysis System (HEC-RAS) (Rangari et al. 2019), the Storm Water Management Model (SWMM) and MIKE URBAN (Bisht et al. 2016). Geographic information system software, including QGIS and ArcGIS, significantly streamlines the extraction and processing of the spatial data required as direct inputs for the development of SWMM simulations (Patel et al. 2024).

SWMM was developed by the United States Environmental Protection Agency (USEPA) in 1971. It is a dynamic rainfall–runoff simulation model that simulates runoff quantity and quality, mostly from urban regions. Eight generic types of LID control, namely bioretention cells, green roofs, infiltration trenches, permeable pavements, rain barrels, rain gardens, roof disconnection and vegetative swales, can be explicitly modelled in SWMM. Urban drainage systems such as sanitary sewers, combined sewers and stormwater networks can be planned, analysed and designed using SWMM. The model can simulate stormwater runoff, evaporation, infiltration and groundwater interaction for roof, road and grass areas, as well as for pits and pipes. The sub-catchments that receive rainfall and generate runoff and pollutant loads are the primary concern of the SWMM runoff module (Rossman and Simon 2022).

In this study, the drainage network of C Sector, Itanagar, Arunachal Pradesh, is analysed using SWMM 5.2. Two LID controls, namely rain barrels and permeable pavements (Abduljaleel and Demissie 2021), are also implemented to estimate their effect on runoff and flooding events. At many locations, the drainage networks are encroached upon by the inhabitants, obstructing the runoff flow path. There is therefore a need to examine the drainage network of the area in order to manage the runoff flowing through the drains. The city has a dense population with a large built-up area, and open spaces are slowly being converted into paved surfaces. In addition, there is heavy migration of people from rural areas to Itanagar. Hence, a situation of urban flooding is likely to arise in Itanagar in the near future. The study of the drainage network for managing runoff water can therefore be of great importance for developing sustainable living conditions in the township.

2 Study area and data

The area chosen for this study is C Sector of Itanagar township. The geographic location of the study area is 27°05'48.18" N latitude and 93°37'14.85" E longitude, with an average elevation of 320 m. The

location map of C Sector, Itanagar, is shown in Fig. 1, and a satellite image of the area is shown in Fig. 2. The digital elevation model (DEM) was obtained from Bhuvan (Indian Geo-Platform of ISRO), and the satellite images were obtained from Google Earth Pro. Daily rainfall data for Itanagar for the period 1986–2022 were obtained from the India Meteorological Department (IMD), Pune.

3 Methodology

The methodology adopted in this study comprises the development of intensity–duration–frequency (IDF) curves for the available rainfall data using Gumbel's method, the development of the stormwater management model, and a capacity analysis of the present drainage system using SWMM for the design storm intensity obtained from the IDF curves. Low impact development is then implemented to reduce the increased discharge of stormwater.

3.1 Generation of intensity–duration–frequency curves

The daily maximum rainfall data of Itanagar for the period 1986–2022 obtained from IMD, Pune, were used for the development of the IDF curves. Gumbel's distribution was used for the return periods of 5, 10, 30, 50 and 100 years, and the resulting frequency values were used to develop the IDF curves shown in Fig. 3. An IDF curve gives the expected rainfall intensity of a storm of a given duration having the desired frequency of occurrence for Itanagar township. The peak runoff of each sub-catchment was estimated using the design storm intensity calculated for the various return periods.

3.2 Development of the SWMM 5.2 model

To develop the SWMM model, the study area was divided into twenty-seven sub-catchments on the basis of the built-up roads and settlements, the drainage lines and the parks. The total number of outfall nodes was five, with forty conduits and thirty-eight junctions connecting them to the outfalls. A sub-catchment is a smaller area of a water catchment in which all the rain falling within the area flows to the same waterway at the same point. Conduits are the channels that convey the runoff collected from the sub-catchments to the junctions and finally to the outfalls. The area of each sub-catchment is provided as input in SWMM to simulate the runoff from that sub-catchment. The layout of the SWMM model of the study area is shown in Fig. 4, and the model superimposed on the Google Earth image is shown in Fig. 5.

In order to quantify the peak runoff and identify the areas of flooding, the model requires a number of input factors, such as the sub-catchment characteristics and the physical characteristics of the drainage network. These input parameters were obtained through a combination of field measurements, software defaults, values derived in QGIS 3.28 and literature sources. The physical characteristics of each sub-catchment, including area, length, slope and contour, were extracted from DEM data of 30 m resolution using QGIS 3.28. The width of the overland flow path, which is an important parameter, was calculated as W = A/L (Bisht et al. 2016), where A is the sub-catchment area and L is the length of the overland flow

path. The percentage imperviousness of each sub-catchment was assigned from the range provided for the corresponding type of area (CPHEEO 2019).

Other sub-catchment parameters, such as N-Perv (which relates to the permeability of the soil), D-store impervious (the depth of impervious storage), N-Imperv (Manning's roughness coefficient for impervious surfaces) and the conduit roughness (i.e. how smooth or rough the inside of the conduit is), are described in Table 1. Simulations were carried out for the runoff generated by the different rainfall intensities corresponding to the 5-, 10-, 30-, 50- and 100-year return periods, and the flooding junctions were thereafter identified.

Table 1
Input parameters required for the SWMM model simulation

Parameter	**Description**
Deterministic parameters	
Impervious	Impermeability of the sub-catchment
Conduit length	Channel length
Area	Sub-catchment area
Width	Overflow width
Slope	Slope of sub-catchment
Uncertain parameters	
N-Perv	Manning's coefficient in permeable area
D-store impervious	Depth of storage in impervious area
D-store pervious	Depth of storage in pervious area
N-Imperv	Manning's coefficient in impervious zone
Conduit roughness	Manning's coefficient of channel
Maximum rate	Maximum infiltration rate
Source: Rossman and Simon (2022)	

3.3 Low impact development scenarios

Two scenarios were used in this study to examine the differences in stormwater runoff with and without the incorporation of low impact development practices. In scenario 1 (SC 1), stormwater is simulated without the incorporation of LID in the study area. In scenario 2, LID measures, namely rain barrels, permeable pavements and a combination of both, were implemented to reduce the increased stormwater runoff. Three sub-scenarios were developed under scenario 2, namely scenario 2a (SC 2a) for rain barrels, scenario 2b (SC 2b) for permeable pavements and scenario 2c (SC 2c) for the combined

LID. The capacity and height of the barrel were taken as 2000 L and 1.5 m respectively. The effective area of the barrel is calculated as the ratio of the volume to the height, giving an area of 1.3 m² for each unit. The size of the paver block was taken as six inches by twelve inches. The input parameters for the LID scenarios are given in Table 2. The percentage reductions in the total volume at the outfalls and in the flood volume were calculated using the developed SWMM model under scenarios 1 and 2.

Table 2
Input parameter values for the LID scenarios in SWMM 5.2

LID control	Parameter	Value
Rain barrel	Storage — barrel height (mm)	1500
	Drain — drain delay (h)	48
Permeable pavement	Surface — roughness (Manning's n)	0.013
	Surface — slope (%)	1
	Pavement — thickness (mm)	100
	Pavement — void ratio	0.15
	Soil — porosity	0.45
	Soil — conductivity (mm/h)	10.92
	Soil — suction head (mm)	109.98
Source: Rossman and Simon (2022)		

4 Results and discussion

4.1 Runoff and flooding in the existing drainage network

The results of the runoff simulations, expressed as surface runoff discharges at all the outfall nodes, are given in Table 3. The maximum flow occurs at outfall node O1, and the next highest outflow discharge occurs at outfall node O3. Both the total volume and the maximum flow increase with increasing rainfall intensity. Seven flooding nodes were identified in total, and a comparison of the flood volume at each node is presented in Table 4. There is no flooding node in the first condition, that is, for the 5-year return period, which indicates that the present drainage system has sufficient carrying capacity for short-return-period events. In the second condition there are two flooding nodes, and there are three, six and seven flooding nodes in the third, fourth and fifth conditions respectively. The total flood volume increased from 2.278×10^6 to 15.683×10^6 L, as shown in Table 5. Variation in rainfall results in an increase in the number of flooded junctions, as a consequence of which flooding increases downstream. Identifying the flooding junctions or locations in an area or town on the basis of IDF relationships can therefore also be used to manage flooding events.

Table 3
Surface runoff generated at all the outfall nodes (m^3/s) and total flow volume (10^6 L)

Outfall node	Parameter	5 yr	10 yr	30 yr	50 yr	100 yr
O1	Average flow	2.321	2.709	3.162	3.334	3.557
	Maximum flow	6.058	6.294	6.285	6.344	6.339
	Total volume	84.735	99.641	120.873	128.227	138.812
O2	Average flow	0.770	0.926	1.112	1.209	1.327
	Maximum flow	1.829	2.209	2.776	3.033	3.387
	Total volume	28.257	34.010	42.591	46.493	51.866
O3	Average flow	1.093	1.314	1.582	1.718	1.885
	Maximum flow	2.582	3.124	3.932	4.429	4.802
	Total volume	40.112	48.293	60.496	66.045	73.685
O4	Average flow	0.964	1.159	1.394	1.514	1.662
	Maximum flow	2.230	2.693	3.385	3.702	4.138
	Total volume	35.393	42.599	53.348	58.235	65.965
O5	Average flow	0.225	0.270	0.322	0.349	0.383
	Maximum flow	0.539	0.646	0.805	0.878	0.978
	Total volume	8.219	9.872	12.336	13.455	14.995

Table 4
Flood volume at the flooding nodes (10^6 L)

Flooding node	5 yr	10 yr	30 yr	50 yr	100 yr
J6	–	–	2.981	3.879	5.223
J7	–	–	–	0.116	0.764
J8	–	2.060	3.071	4.106	5.668
J10	–	0.218	0.340	0.349	0.351
J17	–	–	–	–	0.571
J18	–	–	–	0.487	0.354
J31	–	–	–	1.565	2.752

Table 5
Overall flow volume to the outfalls and flood volume (10^6 L)

Condition	Volume at outfall	Flood volume in nodes	Number of flooded junctions
5 yr	196.72	–	–
10 yr	234.41	2.278	2
30 yr	289.65	6.401	3
50 yr	312.47	10.502	6
100 yr	344.34	15.683	7

4.2 Effect of low impact development

The simulation results for scenarios 1 and 2 are given in Tables 6 and 7 for the 5-, 10-, 30-, 50- and 100-year return periods. For the 5-year return period, the combined LID reduced the total volume of the system by 5.61%, and no node floods under this condition. For the 10-year return period, the total volume is reduced by 3.84% and the flood volume by 67.38%. For the 30-year return period, the total volume at the outfalls and the flood volume are reduced by 2.66% and 64.46% respectively. For the 50-year return period, LID reduced the total volume and the flood volume by 1.99% and 47.20% respectively, and for the 100-year return period the total volume is reduced by 1.69% and the flood volume by 33.56%.

Table 6
Simulation results for the LID scenarios

Scenario	Return period (yr)	Total flow volume to outfall (10^6 L)	Total flood volume (10^6 L)	Flooded nodes
SC 1	5	196.72	–	–
	10	234.41	2.278	J8, J10
	30	289.65	6.401	J6, J8, J10
	50	312.47	10.502	J6, J7, J8, J10, J18, J31
	100	344.34	15.683	J6, J7, J8, J10, J17, J18, J31
SC 2a	5	189.06	–	–
	10	228.04	0.743	J8
	30	284.23	3.775	J6, J8
	50	307.84	7.101	J6, J7, J8, J18, J31
	100	340.19	11.783	J6, J7, J8, J17, J18, J31
SC 2b	5	193.14	–	–
	10	231.59	1.530	J8, J10
	30	286.66	5.710	J6, J8, J10
	50	309.89	9.560	J6, J7, J8, J10, J18, J31
	100	341.79	14.730	J6, J7, J8, J10, J17, J18, J31
SC 2c	5	185.68	–	–
	10	225.42	–	–
	30	281.94	2.725	J6, J8
	50	306.26	5.545	J6, J7, J8, J10, J18, J31
	100	338.52	10.420	J6, J7, J8, J10, J17, J18, J31

Table 7
Percentage reduction in the total flow volume to the outfalls and in the total flood volume (10^6 L)

Return period (yr)	Item	SC 1	SC 2a	% reduction	SC 2b	% reduction	SC 2c	% reduction
5	Total volume to outfall	196.72	189.06	3.89	193.14	1.82	185.68	5.61
	Total flood volume	–	–	–	–	–	–	–
10	Total volume to outfall	234.41	228.04	2.72	231.59	1.20	225.42	3.84
	Total flood volume	2.278	0.743	67.38	1.530	32.84	–	100.00
30	Total volume to outfall	289.65	284.23	1.87	286.66	1.03	281.94	2.66
	Total flood volume	6.401	3.775	41.02	5.710	10.80	2.725	64.46
50	Total volume to outfall	312.47	307.84	1.48	309.89	0.83	306.26	1.99
	Total flood volume	10.502	7.101	32.38	9.560	8.97	5.545	47.20
100	Total volume to outfall	344.34	340.19	1.21	341.79	0.74	338.52	1.69
	Total flood volume	15.683	11.783	24.87	14.730	6.08	10.420	33.56

Compared with scenario 1, the number of flooding nodes decreases with the implementation of rain barrels and of the combined LID. A decrease in the number of flooded nodes implies a reduction in flood volume. The simulation of the combined LID shows no node flooding for the 5- and 10-year return periods. There is no decrease in the number of flooding nodes for the permeable pavement measure,

although a reduction of up to 1.82% in the total volume of the system and of 32.84% in the total flood volume is still observed. The percentage reduction in the total volume reaching the outfalls and in the total flood volume decreases with increasing return period, showing that low impact development practices are less effective for larger rainfall events.

Jemberie and Melesse (2021) examined the effect of various low impact developments on rainfall of 10-min, 30-min and 1-h duration and showed that such developments significantly reduce runoff for the shortest rainfall duration, with rain barrels alone decreasing peak runoff by up to 35%. Zhu and Chen (2017) reported that integrated approaches can reduce a higher percentage of the flooding flow in densely populated sub-catchments, and that low impact development approaches are more successful in flood reduction for lower intensity–duration–frequency relationships. Furthermore, there is a good likelihood that the flooding volume will decrease if all forms of low impact development measure are implemented under the various scenarios (CPHEEO 2019). In the present study, high runoff is expected under both scenarios for the longer-return-period events, that is, the 30- to 100-year return periods, and this will cause flooding downstream of the town. The results show that the implemented low impact development measures can minimise the flooding problems in the low-lying or downstream part of C Sector, Itanagar township. With rain barrels, the overall flooding volume of the junctions is decreased by 67.38%, and with permeable pavements it is decreased by 32.84%. The simulation results for the 10-, 30-, 50- and 100-year design storms show that node J8 (the Legi Complex area, Itanagar) is commonly affected by flooding.

4.3 Comparison with earlier studies

Bibi (2022) evaluated LID measures in the town of Dodola, Ethiopia, using SWMM 5.1 and reported that permeable pavement can reduce the peak runoff by up to 35.2% and bioretention by 21.2%, while the total flooding volume of the junctions is reduced by up to 34% and 46% for bioretention and permeable pavement respectively. In Rattanakosin Village, Thailand, a single 3.2 m^3 rain barrel reduced the combined sewer overflow volume by 5%, and a combination of rain barrel and bioretention decreased the combined sewer overflow volume by 17% for a 2-year return period rainfall event with a peak intensity of 113.2 mm/h (James 2013). In comparison, LID implementation in C Sector of Itanagar township reduced the total flood volume by up to 67.38% for rain barrels and 32.84% for permeable pavements, while the total volume of the catchment is reduced by up to 3.89% for rain barrels and 1.82% for permeable pavements.

5 Conclusions

In this study, the existing drainage network of C Sector, Itanagar, has been analysed using the SWMM model. The data required for the model were obtained from the India Meteorological Department, Pune, Bhuvan, Google Earth imagery, QGIS and the default values in SWMM 5.2. Simulations were carried out for five different rainfall intensity conditions corresponding to the 5-, 10-, 30-, 50- and 100-year return periods. The simulation results give a detailed depiction of the surface runoff pattern during various

storm events and show that both the total outflow volume and the total flood volume increase with increasing storm intensity.

The results further show that the present drainage system is adequate for the 5-year return period, that is, it can accommodate the corresponding surface runoff. The number of nodes that flood increases as the rainfall intensity increases, the numbers of flooded nodes for the 10-, 30-, 50- and 100-year design storms being 2, 3, 6 and 7 respectively. The simulation results for the 10-, 30-, 50- and 100-year design storms show that node J8 (the Legi Complex area, Itanagar) is commonly affected by flooding. Flooding at the nodes can be minimised by increasing the dimensions of the channels in the drainage system.

Incorporating LID into the existing stormwater drainage system helps to reduce the increased flooding downstream of the town. The LID measures applied are rain barrels, permeable pavements and a combination of both. Low impact development practice reduces the flood volume by up to 67.38% in scenario 2a and 32.84% in scenario 2b. These findings indicate that the incorporation of rain barrels and permeable pavements is effective in mitigating urban flooding by substantially reducing the flood volume within the study area. In the combined LID simulation, no flooding occurs for the two design storm events of 5 and 10 years. Comparing the different rainfall intensity conditions, it is further found that the control ability of LID approaches is more effective in reducing flooding for short-return-period rainfall events, whereas for longer-return-period events the flood reduction decreases.

The study shows that decision makers and municipal authorities can gain valuable insight into the hydrological behaviour of stormwater management and can thereby identify the critical areas or locations that require attention. The simulations successfully identify the junctions that are highly susceptible to flooding, along with the locations where runoff is manageable for a particular design storm. Such information may be vital for planning effective stormwater management strategies, such as implementing green infrastructure or enhancing existing drainage systems, for the sustainable development of cities in developing countries.

References

1. Abduljaleel Y, Demissie Y (2021) Evaluation and optimization of low impact development designs for sustainable stormwater management in a changing climate. Water 13(20):2889. https://doi.org/10.3390/w13202889
2. Bibi TS (2022) Modeling urban stormwater management in the town of Dodola based on landuse and climate change using SWMM 5.1. J Hydrol Reg Stud 44:101267. https://doi.org/10.1016/j.ejrh.2022.101267
3. Bisht DS, Chatterjee C, Kalakoti S, Upadhyay P, Sahoo M, Panda A (2016) Modeling urban floods and drainage using SWMM and MIKE URBAN: a case study. Nat Hazards 84(2):749–776. https://doi.org/10.1007/s11069-016-2455-1
4. CPHEEO (2019) Manual on storm water drainage systems, 1st edn. Central Public Health and Environmental Engineering Organisation, Ministry of Housing and Urban Affairs, Government of

India, New Delhi
5. James W (2013) Pragmatic modeling of urban water systems. CHI, Guelph
6. Jemberie MA, Melesse AM (2021) Urban flood management through urban land use optimization using LID techniques, city of Addis Ababa, Ethiopia. Water 13(13):1721. https://doi.org/10.3390/w13131721
7. NDMA (2025) Urban floods. National Disaster Management Authority, Ministry of Home Affairs, Government of India. https://ndma.gov.in/urban-floods. Accessed 13 Dec 2025
8. Patel RS, Taneja S, Singh J, Sharma SN (2024) Modelling of surface run-off using SWMM and GIS for efficient stormwater management. Curr Sci 126(4)
9. Rafiq F, Ahmed S, Ahmad S, Ali Khan A (2016) Urban floods in India. Int J Sci Eng Res 7(1)
10. Rangari VA, Prashanth SS, Umamahesh NV, Patel AK (2018) Simulation of urban drainage system using a storm water management model (SWMM). Asian J Eng Appl Technol 7:S1
11. Rangari VA, Umamahesh NV, Bhatt CM (2019) Assessment of inundation risk in urban floods using HEC-RAS 2D. Model Earth Syst Environ 5(4):1839–1851. https://doi.org/10.1007/s40808-019-00641-8
12. Rossman LA, Simon MA (2022) Storm water management model user's manual version 5.2. EPA/600/R-22/030. United States Environmental Protection Agency, Cincinnati
13. Zhu Z, Chen X (2017) Evaluating the effects of low impact development practices on urban flooding under different rainfall intensities. Water 9(7):548. https://doi.org/10.3390/w9070548

Figures

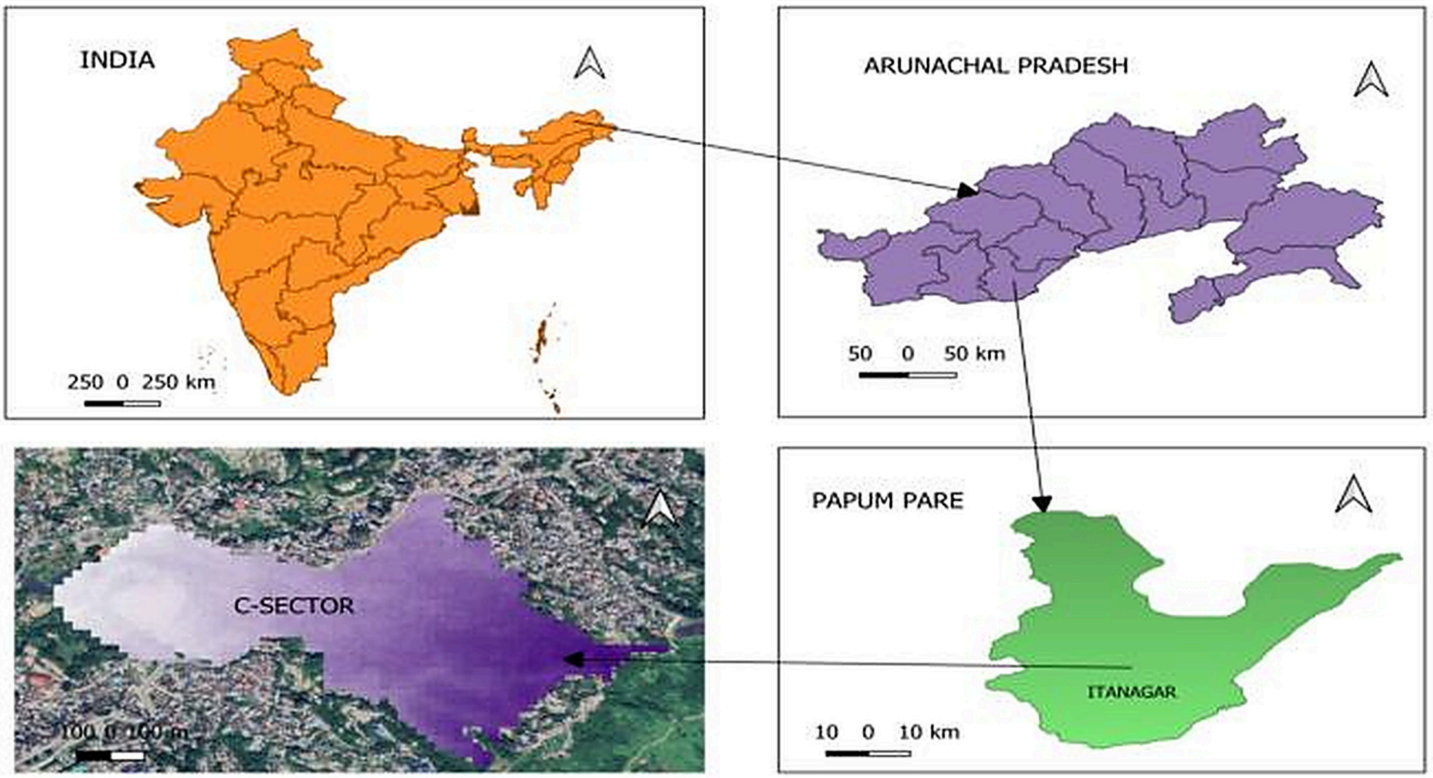


Figure 1

Location map of C Sector, Itanagar



Figure 2

Satellite image of C Sector, Itanagar (source: Google Earth Pro)

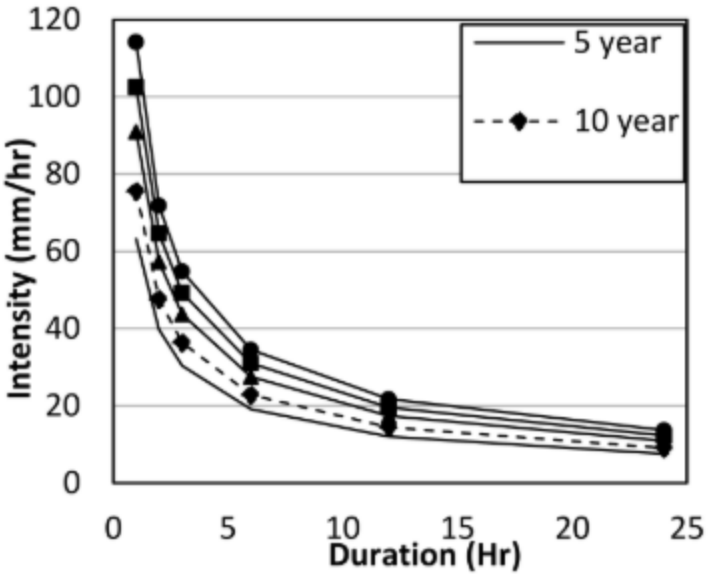


Figure 3

Intensity–duration–frequency curves for Itanagar township for the period 1986–2022



Figure 4

SWMM model layout of the study area showing sub-catchments, junctions, conduits and outfalls

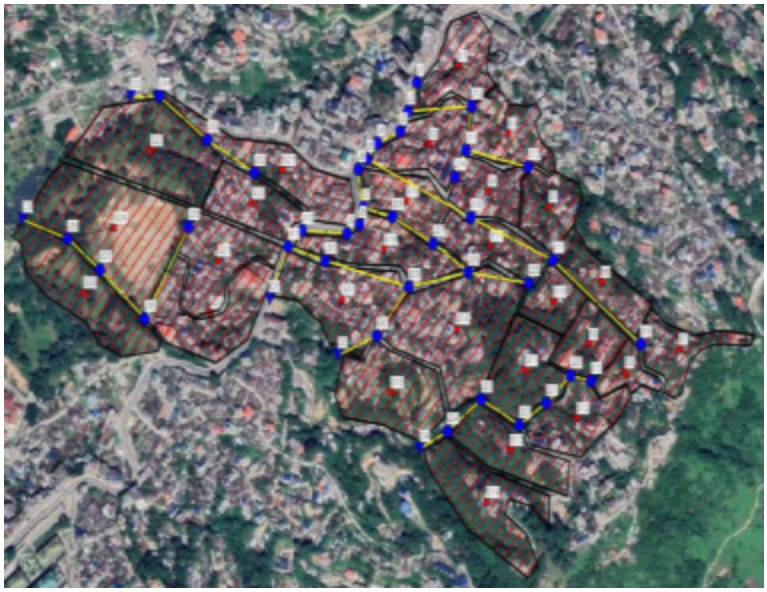


Figure 5

SWMM model of the study area with the Google Earth image as backdrop