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IMPACT OF URBANIZATION AND DEVELOPMENT ON PEAK FLOWS IN CHANDIGARH, INDIA

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Abstract: *Chandigarh is one of the planned cities in post independent era. Due to increase in population, development in the bordering areas of Chandigarh and increase in migrant population the urbanized land use has increased and consequently land use pattern has been modified in recent years. The modifications associated with urban development leads to removal of vegetation and soil and grading of the land surface. Consequently, it results in increase of peak discharge, volume, and frequency of local flooding due to insufficiency of stormwater control practices. This study focuses on the increase in impervious cover within Chandigarh due to new and existing residential, industrial and commercial buildings, new parking lots, construction of new pavements, and construction of new bypass roads as per revised rules by the UT administration. It has been concluded from this study that the percent increase of paved area at each sub watershed gets accumulated at the level of entire watershed of Chandigarh and has flooding problems and lots of inconvenience to the residents of Chandigarh.*

The present study has undertaken watershed modeling to understand the urgent need of onsite control of stormwater runoff and the important role of residents of Chandigarh in assisting the UT administration in dealing with flooding issues. The study has also discussed the impact on stormwater runoff from pervious to impervious condition of the land use with or without stormwater control practices and hence no or additional loading on downstream stormwater control practices within Chandigarh.

The study has discussed many approaches for reducing peak flows in an urbanized watershed which includes techniques that promote infiltration and storage of water in the soil column, such as infiltration trenches, permeable pavements, and reducing impermeable surfaces.

Keywords: *Urbanization, Land Use, Impervious area, Rational Method, Hydrological Model, HydroCAD*

"1. Introduction:"

Urbanization has been defined as the concentration of people in urban settlements and the process of modification in land use into residential, commercial and industrial communities. The land surface modifications due to urbanization produce changes in the magnitude of runoff volume mainly due to increase in impervious areas which reduces infiltration and reduces catchment response times, all leading to flood peaks and volumes. The urbanized flooding considerably differ from rural flooding as urbanization leads to developed catchments which increases the flood peaks from 1.8 to 8 times and flood volumes by up to 6 times [1]. Figure 1 summarizes the effects of urbanization on the hydrological processes [2].

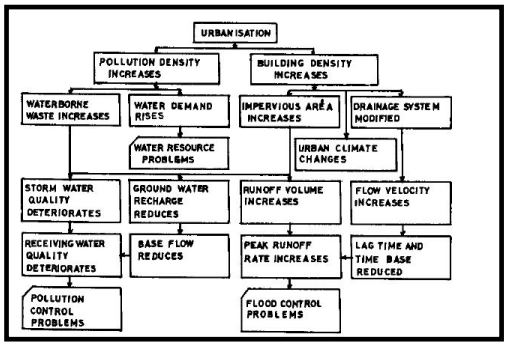

Figure 1: Urbanization and hydrological processes

"2. Distribution of land uses:"

The focus of this study is on areas within Chandigarh which is a Union Territory (U.T.) and is the joint capital of both Punjab and Haryana. Geographically, it falls in Survey of India topo-sheet no. 53B/14. With a gently sloping terrain, it has a total land area of 28170 acres. The area includes Phase I, Phase II and Phase III sectors besides the area under the periphery. The term 'sector' or the neighboring unit can be considered as synonym for traditional Indian term "mohalla". The details of area falling under different phases of development are shown in Table 1.

Table 1: Phases of development and their areas [3]

Category	Sectors	Area in (acres)
Phase I	1 to 30	9398.83
Phase II	31 to 47	5158.76
Phase III	48 to 56 (part)	1870.54
Remaining area of periphery		11741.88
Total		**28170.00**

The existing land use of Chandigarh is primarily urban and has been classified into residential, commercial, transport, industrial, public, recreational, agricultural, infrastructure and vacant land for Phase I, II and III. In the periphery area of Chandigarh there are other existing land uses which are classified as defense area, railway, forest, and vacant land. The detailed distribution of land uses and the area occupied by each land use is classified as pre-development condition of the catchment. Land comprises the physical environment, including weather, soils, hydrology and vegetation, to the extent that these influence potential for land use. The types of land use considered for a land depends on being relevant under general physical, economic and social conditions prevailing in an area. The different land uses in Chandigarh are shown in Figure 2.

It has been proposed in the Draft Chandigarh Master Plan- 2031 for planned development in the vacant land (3082.67 acres) of the periphery area of Chandigarh. Consequently the percentage of each land use within the periphery of Chandigarh has been increased as shown in Table 2.

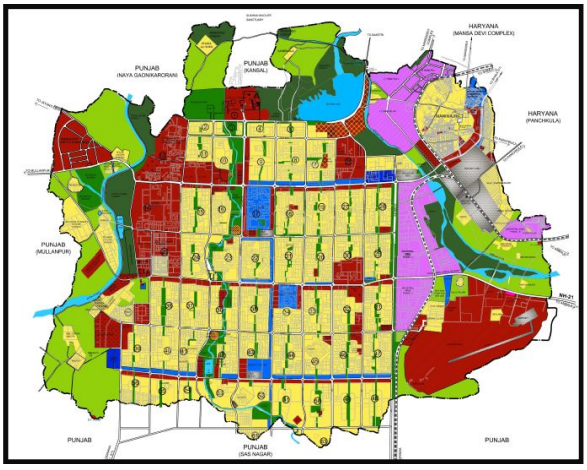

Figure 2: Existing Land Use [3]

Table 2: Existing and proposed land use [3]

Percentage (%) of land use		
Category	**Existing Land Use %**	**Proposed land Use %**
	Phase I, II, III and Remaining area of periphery	Phase I, II, III and Remaining area of periphery
Residential	37.88	38.64
Commercial	4.76	5.07
Transport	7.26	7.44
Industrial	4.71	5.72
Public	10.54	13.82
Recreational	8.62	10.00
Agriculture	-	2.95
Public Utilities	1.07	1.21
Railway Land	1.12	1.12
Defense	4.52	4.52
Forest	7.50	8.89
Reserved	-	1.05
Vacant Land	10.94	-

"3. Study Area:"

Within each land use there are different surface conditions which contribute to the volume and peak flows within an urbanized watershed. The surface conditions of each land use can be classified into impervious and pervious areas or developed and undeveloped areas such as asphalt or concrete-pavement, brick paving, roofs of buildings, grass yards of most of the houses have been paved and

covered soils in poor, good or fair condition etc.
In Chandigarh, the areas within sectoral grid (i.e. Phase, I, II and III) and outside sectoral grid are being modified in lieu of development and hence yielding higher runoff and consequently increase load on stormwater control systems and cause flooding. The selected areas are studied as post development condition of the catchment and evaluates the increase in runoff due to impervious areas recently constructed or has been proposed under various categories as shown in Table 3.

Table 3: Selected areas for this study

Category	Location
Recently laid and Proposed Cycle Tracks	1. Recently laid on both sides of roads V2 and V3. 2. Proposed through sectors.
Revised Zoning of Various Marla Houses	1. Recently implemented for all sectors, from 5 Marla upto 14 Marla houses.
Recently constructed junctions/ slip roads at road intersections	1. On all intersections of V2 and V3 roads.
Selected industrial/ commercial new constructions	1. Judicial Academy, Sector 43 2. Existing Phase I and II and Proposed Phase III of IT park

"4. Characterization of Post Development Impervious Cover in Study Area:"

The cycle tracks, classified as type V8 road, are exclusively for the convenience of pedestrians and cyclists. The cycle tracks run along both sides of city's vertical roads (V3 roads, The Paths) and the horizontal roads (V2 roads, The Margs) as shown in Figure 3. From hydrologic engineer point of view, the cycle tracks are impervious areas from where the contributing of stromwater runoff was not accounted in the original design of stormwater control systems. The increase in impervious area due to cycle tracks is as listed in Table 4.

The revised zoning of various Marla houses (5 Marla to 14 Marla) has provided additional covered area and the green area in the front yard and backyard of almost every Marla house has vanished. The front unauthorized constructions have come up in lieu of urbanization and need for more space. In this study the sector 20 of Chandigarh was analyzed and increase in impervious area was as observed in Table 4. Urbanization is a necessity in today world's to accommodate the growing population which is projected as 25lacs in year 2026 as against 14lacs in year 2011 by census of India for Chandigarh but the infrastructure needs to be upgraded at the pace of development in the region.

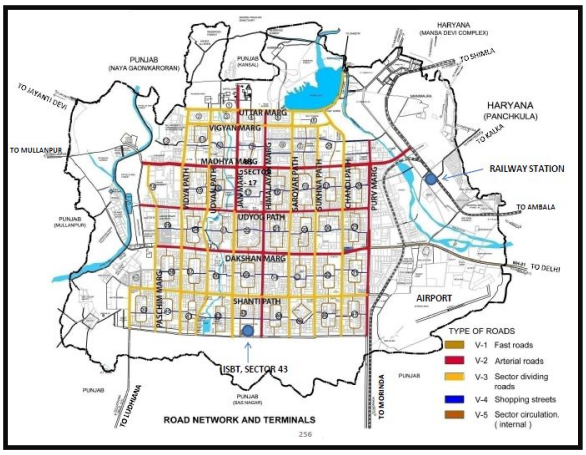

Figure 3: Map of Road Network of Chandigarh [3]

Table 4: List of Impervious surfaces

Category	Description	Impervious Area (ac)
Cycle Tracks		66.42
Revised Zoning Plans / Need for urbanization	Front yard paved	1.73
	Back yard paved	
	pervious spaces removed/	1.43
Junctions at intersections		10
New Constructions	Judicial Academy Sector 43/ ISBT 43/ Hospital 43	95
	IT Park	620
Total impervious study area		794.58

"4. Methodology:"

The rainfall and runoff data developed in this study is prepared for use in the HydroCAD program (Version 10.00) by HydroCAD Software Solutions Inc. HydroCAD is a Computer Aided Design system for modeling the hydrology and hydraulics of stormwater runoff.

In this study, the rational method is used to determine peak flows from each study area. The Rational method predicts the peak runoff according to the formula: Q=CIA, where 'C' is a runoff coefficient, 'I' is the rainfall intensity, and A is the sub-catchment area. In order to generate a complete runoff hydrograph, it is assumed that the runoff begins at the start of the storm and increases linearly to the peak value. The peak runoff is sustained until the event duration has elapsed, and then decreases linearly to zero. The rate at which the hydrograph rises and falls is based on the Time of Concentration (Tc) which is calculated using Kirpich Equation for direct entry in the HydroCAD program.

"4.1. Rainfall and Runoff Methodology:"

In this study, for manual calculations by Rational method the rainfall intensity has been taken as 25mm/hr as used by Chandigarh Administration for design of new and proposed stormwater drainage system. The Phase I and Phase II of Chandigarh has stormwater drainage system predominantly laid out from design for the rainfall intensity of 12 mm/hour. The volume of runoff has been calculated by assuming the duration of storm as 5 hours as no particular rainfall event has been selected for calculation of results.

The peak flow and volume of runoff has been also calculated using the HydroCAD model. The data for Intensity Duration Frequency (IDF) curve has been calculated to insert in the model using values of constants (K,a,x,n), particularly for Chandigarh, given by Central Soil and Water Conservation Research and Training Institute, Dehradun. The intensity (i) of storm is expressed in cm/h as follows:

$i = KT^x/(D+a)^n$

Where T is the return period and D is the duration of the storm. The IDF curve plot is shown in Figure 4.

The emphasis is to notice the significant difference between the runoff volumes from pre to post developed catchment.

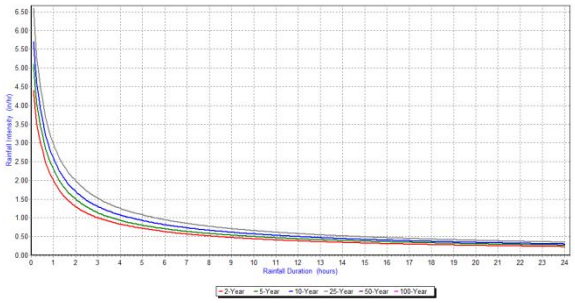

Figure 4: Intensity Duration Frequency Curve [1]

"6. Results:"

The manual calculations of the pre-development and post development runoff have been performed as shown in Table 5. The difference in volume of runoff from pre to post development of the catchment in Table 5 is significant which is 261900 cu.m.

Table 5: Peak runoff and volume calculations using Rational method

Category	Rational Method			
	Post development runoff		Pre-development runoff	
	Q m^3/s	V m^3	Q m^3/s	V m^3
Cycle Tracks	1.77	31860	0.56	10080
Revised	0.05	900	0.01	180
Zoning Plans	0.04	720	0.01	180
Junctions	0.27	4860	0.08	1440
New	2.53	45540	0.80	14400
Const.	16.55	297900	5.2	93600
Total		381780		119890

V= Volume of runoff; Q= Peak Runoff

In the model the intensity for various return periods is quite different from the assumed rainfall intensity of 25mm/hr for manual calculations. The model if run for duration of 5 hrs and return period of 10 yr then based on IDF curve the intensity is 23.7mm/hr, which is almost equivalent intensity used for manual calculations.

As shown in Table 6 the model and the manual calculations provide similar results. There is noticeable increase in peak runoff and volume of runoff and hence the stormwater systems in the city

are overwhelmed.

Table 6: Peak runoff and volume calculations using model

Category	HydroCAD			
	Pre-development runoff		Post-development runoff	
	Q m^3/s	V m^3	Q m^3/s	V m^3
Revised Zoning Plans	0.014	249	0.044	787
	0.011	213	0.037	673
Junctions	0.08	1435	0.25	4544

The results discussed above are based on initial stages of research and more data is being generated such as identification of land uses being modified in other sectors of Chandigarh, data for specific rainfall events, usage of other methodologies to calculate runoff, identification of rainfall intensity and return period which suits the climate of the city and can be used for design of stormwater drainage systems.

"8. Acknowledgements:"

This research is guided by respected Dr.A.M.Kalra, Professor, Department of Civil Engineering, PEC University of Technology, Chandigarh.

"9. References:"

Reports

[1] National Disaster Management Authority, 2010. *National Disaster Management Guidelines-Management of Urban Flooding.* A publication of the National Disaster Management Authority, Government of India.
ISBN: 978-93-80440-09-5, September 2010, New Delhi.

[2] National Institute of Hydrology, 1998-99. *Present Status of Urban Hydrology*. Prepared by National Institute of Hydrology Roorkee, UK, India.

[3] Chandigarh Administration, 2013. *Draft Chandigarh Master Plan-2031*. Prepared by Chandigarh Administration.