Storm Water Drainage System Design – A Case Study

Shuchi Mishra[1], Gaurav Tanwer[2]

[1]Engineer, WAPCOS Limited, Govt. of India undertaking under Ministry of Jal Shakti,
[2]Engineer, WAPCOS Limited, Govt. of India undertaking under Ministry of Jal Shakti

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Abstract *— Storm Water is a network of structures, channels and underground pipes that carry stormwater to ponds, lakes, streams and rivers. Detailed Project Report for Storm Water Drainage Scheme is prepared to facilitate an implementable plan for the area. This paper presents a novel design of stormwater drainage system for a city. The objectives of preparing scheme are to identify all flood-prone areas in the catchment of draining areas, assessment of water flooding in the area affecting the stakeholders and details of all feasible stormwater systems to address the issues.*

1. Introduction

A storm drain system is designed to drain excess runoff and ground water from paved streets, parking lots, sidewalks and roofs. Storm drains vary in design from small roadside drain to large municipal systems. They are fed by street gutters on most motorways, freeways and other busy roads, as well as towns in areas which experience heavy rainfall and flooding. Stormwater remains logged giving rise to unsanitary conditions in densely populated areas and slums which in turn results in an increase in morbidity primarily due to pathogens, parasitic infections and infestations in all segment of the population, particularly with the urban slum dwellers.

1.1 Topography

Dewas is situated on the Malwa plateau in the west-central part of Madhya Pradesh. The city of Dewas is located to the North-East of Indore, South-East of Ujjain, and South-West of Shajapur. Dewas is situated on the level plains of the Malwa Plateau, and the land rises gently merging into the Vindhya Range. Chambal & Kali Sindh Rivers arise from the Vindhya Range which flows through the district. Kshipra also is known as holy river is the main river flowing in Dewas district.

1.2 Existing Drainage System

Dewas Municipal Corporation gets the water from the Kshipra barrage from Narmada, Rajanal Talab, tube wells and other river sources. The per capita demand as per the CPHEEEO manual, i.e. 135 lpcd with 15% losses, the total water required is 43 MLD whereas Dewas is getting only 10 MLD of water from various sources. The stormwater drainage system in Dewas city consists of tertiary drains. The tertiary drains are the roadside drains either pucca or kutcha. The network of tertiary drains in the town covers a length of around 157 km of open drains and 46 km of covered drains. This coverage is about 68% of the present road network in the town. As against the desired level of coverage of 100% of the road network, the current coverage is deficient. As the town lacks a proper drainage system, the rainwater finds its way through streets into kutcha nalla/natural drains. These natural drains are close to the residential area causing unhygienic conditions.

1.3 Key Issues

The major issues identified for stormwater drainage that needs to be addressed are listed below:

- The city is vulnerable to floods during monsoons due to lack of drainage facilities.
- The existing Drainage system needs a significant revamping as it is dilapidated and has been encroached at many places. All the existing Kuccha open drains have to be upgraded to both Pucca Open and Closed Drains.
- Efforts shall be concentrated towards the development of a new adequately planned drainage system.
- All the natural drains shall be periodically cleaned to prevent flooding of the city during monsoon and other occasional rains.
- Encroachments of the open drains are also a major cause of concern, and immediate attention requires clearing them free from the wastewater.
- Awareness programs have to be conducted to local citizens to avoid dumping waste in the open drains.

2. Design Formulae Adopted

2.1 Runoff Estimation

The rational method has been used for estimation of storm water runoff using formula

$$Q = \frac{C \times I \times A}{3600 \times 1000}$$

Where,

Q = Discharge in m^3/sec.
A = Drainage area in sq. m.
C = Runoff coefficient
I = Design rainfall intensity in mm/hr corresponding to time of concentration T_C.

2.2 Time of concentration (T_C)

Time of concentration for an area may be defined as the time required by the water to reach the concerned point from the most remote point of the drainage area. i.e. the period after which the entire area shall start contributing to the runoff is called the concentration time. Time of concentration consists of two parts:

Inlet Time (T_i)

$$T_i = \left(\frac{0.885 \times L \times L \times L}{H}\right)^{0.385}$$

T_i = Inlet time in hours
L = Length of overland flow in kilometers from the critical point to the mouth of drain.
H = Elevation difference in meters between the two points.

Channel Flow Time (T_f)

$$T_f = \frac{LengthofDrain}{VelocityofFlow}$$

The total time of concentration at a given point in the drain for working out the discharge at that point can be obtained by:

$$T_c = T_i + T_f$$

2.3 Sizing of storm water drains

Sizing of storm water drains shall be based on Manning's formula.

$$V = \frac{1}{N} \times R^{2/3} \times S^{1/2}$$

Where,
V = Velocity of flow (m/sec)
N = Manning's rugosity coefficient
R = Hydraulic radius = Area of Cross Section of Channel / Wetted Perimeter
S = Slope of the drain

2.4 Selection of outfall

An essential requirement of plot drainage is that the outfall point of storm drain should be above the HFL of the river body into which it discharges. This is considered such that even under simultaneous maximum discharge condition, there is no backing up of water and waterlogging of the area.

2.5 Development of IDF Curves

Following two types of equations are commonly used.

$$i = \frac{a}{t^n}$$

$$i = \frac{a}{t + b}$$

Where,
i: Intensity of rainfall in mm/hr
t: Duration of storm in minutes
a, b, n: Constants

3. Design Results

3.1 Rainfall Analysis

The rainfall intensity data for a period of 47 years were collected and analyzed. IDF curves are prepared for intensity once in a year and twice in a year. Frequency of storms is given in Table 1, and prepared IDF curves are given in Figure 1.

Table 1: Frequency of storms

Frequency of Storms												
Intensity	>=5	>=10	>=15	>=20	>=25	>=30	>=35	>=40	>=45	>=50	>=55	>=60
Duration	No. of storms of intensity for 47 years											
0 - 60	868	481	278	169	109	84	58	42	30	22	12	8
60 - 120	617	271	135	82	47	28	15	7	5	1	0	0
120 - 180	498	192	89	47	25	10	5	1	0	0	0	0
180 - 240	376	124	55	25	8	2	0	0	0	0	0	0
240 - 300	319	94	39	12	5	0	0	0	0	0	0	0
300 - 360	266	71	26	6	1	0	0	0	0	0	0	0
360 - 420	216	58	17	5	0	0	0	0	0	0	0	0
420 - 480	182	45	10	1	0	0	0	0	0	0	0	0
480 - 540	153	36	6	0	0	0	0	0	0	0	0	0
540 - 600	135	28	5	0	0	0	0	0	0	0	0	0
600 - 660	113	22	2	0	0	0	0	0	0	0	0	0
660 - 720	104	17	1	0	0	0	0	0	0	0	0	0
720 - 780	94	11	0	0	0	0	0	0	0	0	0	0
780 - 840	86	8	0	0	0	0	0	0	0	0	0	0
840 - 900	76	7	0	0	0	0	0	0	0	0	0	0
900 - 960	67	6	0	0	0	0	0	0	0	0	0	0
960 - 1020	**63**	**5**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1020 - 1080	58	5	0	0	0	0	0	0	0	0	0	0
1080 - 1140	53	2	0	0	0	0	0	0	0	0	0	0
1140 - 1200	49	2	0	0	0	0	0	0	0	0	0	0
1200 - 1260	45	1	0	0	0	0	0	0	0	0	0	0
1260 - 1320	42	1	0	0	0	0	0	0	0	0	0	0
1320 - 1380	41	0	0	0	0	0	0	0	0	0	0	0
1380 - 1440	38	0	0	0	0	0	0	0	0	0	0	0
									Twice in a Year (dotted line)			
									Once in a Year (solid line)			

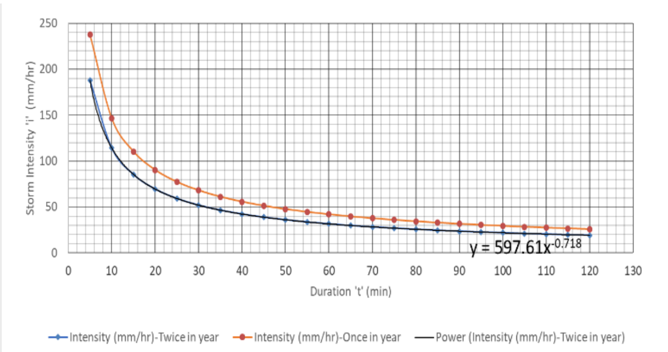

Figure 1: Intensity Duration Frequency curve

3.2 Demarcation of Catchment Area

The catchment area is demarcated based on the topography of the area on GIS. The total drainage area has been divided into three major drainage zones.

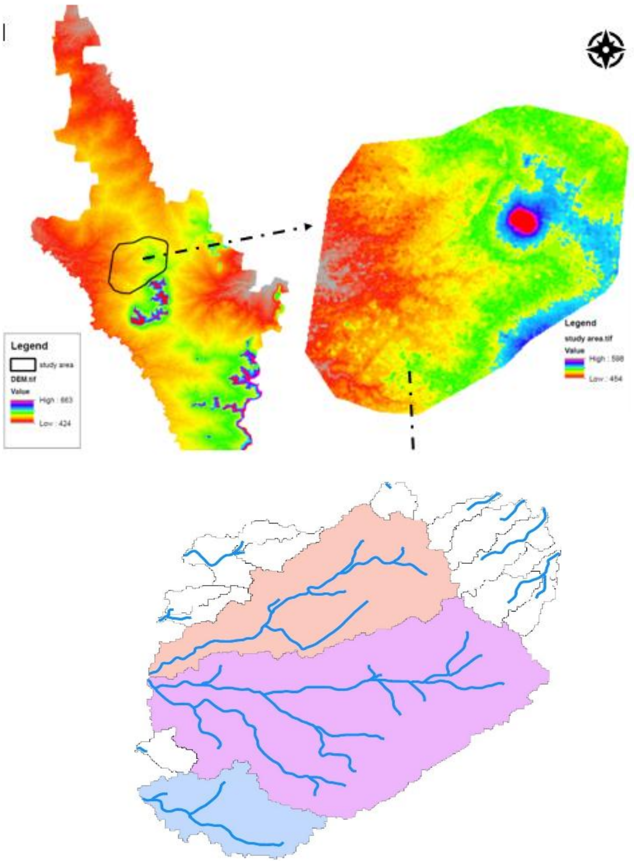

Figure 2: DEM of Study Area

3.3 Design of Drains

Drains are designed to successfully convey runoff to the point of disposal. Stormwater drains are designed as given in Table 2:

Table 2: Design Elements of Storm water drains

S.No.	Catchment Discharge (cumec)	Width (m)	Depth (m)	Length (m)	Slope (1 in)	Velocity (m/s)
1	2.56	1.5	1.50	40	300	1.72
2	2.56	1.5	1.50	100	300	1.72
3	2.56	1.5	1.50	100	300	1.72
4	5.12	2.0	2.00	100	350	1.96
5	5.12	2.0	2.00	100	350	1.96
6	5.12	2.0	2.00	100	350	1.96
7	5.12	2.0	2.00	100	350	1.96
8	9.60	2.5	2.50	100	450	2.03
9	9.60	2.5	2.50	100	450	2.03
10	9.60	2.5	2.50	100	450	2.03
11	9.60	2.5	2.50	100	450	2.03
12	9.60	2.5	2.50	100	450	2.03
13	9.60	2.5	2.50	100	450	2.03
14	12.80	3.0	2.50	100	500	2.07
15	12.80	3.0	2.50	100	500	2.07

Accordingly, drains are designed for the entire area. Secondary, tertiary drains are joined with existing natural drains. Sections of drain and Existing Bed level & Ground level and proposed bed level for one drain is given in Figure 3 and Figure 4.

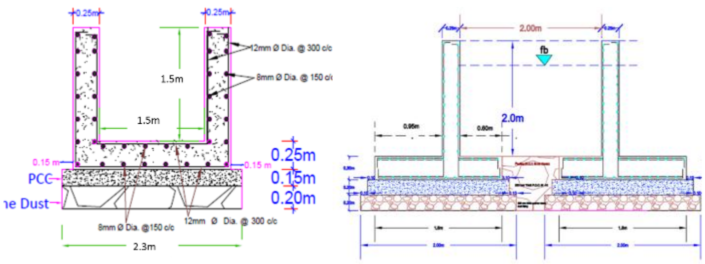

Figure 3: Sections of Drains

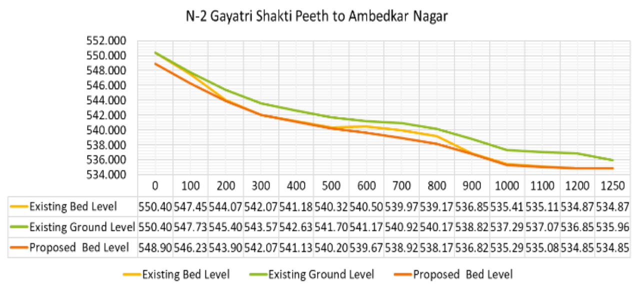

Figure 4: Existing Bed level & Ground level and proposed bed level for a drain from Gayatri Shakti Peeth to Ambedkar Nagar

3.4 Innovative Practices

With growing depletion of water resources, it has now become a necessity to view stormwater as a resource but rather as a nuisance that must be removed quickly. Drainage systems should not only be designed to dispose of stormwater but also should be environmentally beneficial, causing minimal or no long-term detrimental damage.

Source reduction technique should be adopted before designing stormwater drains for carrying stormwater. The main type of source control components that can be adopted at household and community level are Green roofs, Rainwater harvesting, Permeable paving, swales, infiltration basins, detention, retention ponds, wetland, soakway etc. Source controls maximizes permeability within site to promote attenuation, treatment and infiltration, reducing the need for offsite conveyance. These techniques will not only reduce the runoff but also recharge groundwater aquifers.

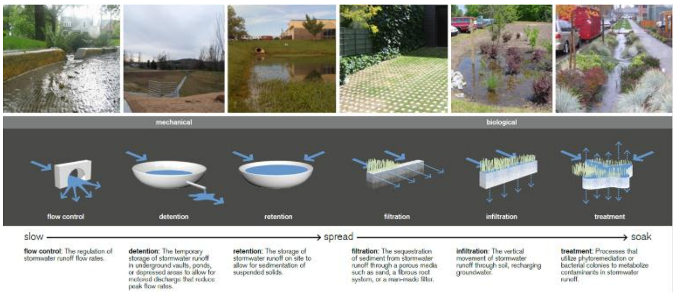

Figure 5: Low Impact Development Methodology

Source: Low Impact Development, design manual for urban areas, University of Arkansas Community Design Center, Fayetteville, North Carolina, United States.

These structures can be made at a household level, in parking, along sidewalks, streets and in open spaces, flood plains, green infrastructure and infiltration area etc.

- Rainwater from roofs can be stored in a tank for non-potable usage.
- Permeable surfaces can be constructed in our houses that rains through voids between solid parts of the pavement to infiltrate rainwater from pavements residential areas
- Roof gardens can be created in houses to manage runoff from roofs
- Infiltration trench and Soakways can be constructed to infiltrate rainwater
- Retention, detention ponds and Wetlands can be created for storing water which will ultimately recharge groundwater.

A few examples of innovative approaches in residential area, parking, streets and open spaces is given in Figure 6 below:

Roof top RWH

Permeable Pavement

Roof Garden

Infiltration Trench

Soakway

Swale

Infiltration Basin

Wetland

Retention Pond

Bioretention

Figure 6: Innovative Approaches

4. CONCLUSIONS

Incidences of flooding are rising in India. During every monsoon, one city or the other gets flooded. It is necessary to have a sustainable and economic stormwater drainage system for preventing our cities from suffering from loss of lives and property. Climate change is also causing extreme impacts in India from trends of no rain for long periods and then a sudden bout of excessive rainfall. Therefore, for a sustainable drainage system, innovative practices should also be adopted for the reduction of runoff at the source. In addition to a robust drainage system, regular operation & maintenance of the system is a must for a functional drainage system.

5. REFERENCES

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