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ISSN 0974-5904, Volume 08, No. 02

International Journal of Earth Sciences and Engineering

April 2015, P.P.507-511

Storm Water Drainage Design (Case Study Vijayawada)

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Abstract: A scientific drainage system to catch the storm water is a long term need of the society, particularly in cities. Urbanization along with its impermeable structures is one of the major causes of flooding in urban areas. The rainfall intensity and characteristics of catchment area are the major factors for designing urban storm water drainage facilities. These facilitates have a paramount advantage to safely dispose the generated floods to receiving system. Many cities lack in providing proper drainage system. The present model utilizes the rainfall in design storm water drainage system. Historical record of 20 years rainfall data has been taken for study. Different methods were reported in literature for runoff estimation. In the present study, rational method has been used for estimation of storm water runoff which is widely reported in literature. The present study is to estimate runoff of a drainage basin and also to design as a case study for Vijayawada City in Andhra Pradesh, India where the excess runoff is a major problem to the environment due to dense population.

Keywords: *Rational method, Drainage, Runoff, Storm water, Environment and Flooding*.

1. Introduction

Storm water drainage is the process of draining excess water from streets, sidewalks, roofs, buildings and other areas. The system used to drain storm water are often referred to as storm drains and are also called storm sewers and drainage wells (Harshil. H. Gajjar, 2006). Storm water can be any precipitation, such as rain, snow and sleet that falls on the surface of the earth. Structural measures to control storm water include storage reservoirs, flood embankments, drainage channels, anti-erosion works, channel improvement works, detention basins and non-structural measures include flood forecasting, flood plain zoning, flood proofing, disaster preparedness etc.(Dieter H. Lindner,2013). In areas with natural, unaltered ground water, about 10% of the precipitation becomes runoff and about 50% infiltrates into the soil to form or replenish ground water and flows into streams. Evaporation and uptake by plants accounts to the remaining 40%.When natural conditions change due to development, land use and other activities, this water cycle becomes altered .As the land becomes more covered with impervious surfaces, more precipitation converts as runoff. This runoff carries the dust, other loads, and pollutants. When the development is more as much as 55% may become runoff (JNNURM Project, 2006).

Technologies for storm water infiltration, such as infiltration basins and trenches, soak away pits, bioretention systems (rain gardens) and porous pavements are well developed (Mikkelsen PS ,1996), (Pagotto C, 2000). Rain gardens use vegetated soil media to improve storm water quality (Bratières k, 2008), attenuate flow rates (Hunt WF, 2009) and, depending on the design, promote infiltration and evapotranspiration (Hamel P, 2011). Where infiltration is not possible, they can be built with an under drain which discharges treated water directly to the storm water system (and thus the receiving water), at a rate controlled to match the pre-development low-flow regime (Hunt, 2009).

Storm sewers (also storm drains) are large pipes or open channels that transport storm water runoff from streets to natural bodies of water, to avoid street flooding. Storm drains vary in design from small residential dry wells to large municipal systems. Many storm drainage systems are designed to drain the storm water, untreated, into rivers or streams. A combined sewer is a type of sewer system that collects sanitary sewage and storm water runoff in a single system. Combined sewers can cause serious water pollution problems due to combined sewer overflows, which are caused by large variations in flow between dry and wet weather. Any storm drain in the area may be discharging different quantity of water and also the type of pollutants it contributes. Since the cities becoming densely populated, the per-household volumes of waste water exceed the infiltration capacity of local soils and hence require greater drainage capacity and the introduction of sewer systems.

Vijayawada city is Andhra Pradesh in India population is increasing day by day due to its increased population and commercial activities are also increasing. The Vijayawada drainage system is not completely underground sewerage. All domestic wastewater generated in the basin is discharged through open channels in to the nallas. This open surface drain system has got many problems such as very easy for foreign matter to have entry in the open drains which hampers. The flow creates stagnation of the sewage, creates odour nuisance, and creates mosquito and files problems and also causing deterioration to river water quality. Several methods are available at the moment for managing this problem and one such method is the storm water drain design.

1.1. Sewage outfalls and Discharge into Canal

1.1.1. Bandar canal

The canal is traversing for a distance of 7.5 km on the southern side of the city. The canal has 10 bridges for easy movement of traffic. The five sewages out falls in the area discharge around 15 MLD of sewage into the canal.

1.1.2. Ryves canal

The canal flows for a distance of 7.6 km on the northeastern side of the city. There are 8 bridges across it. There are 8 sewage out falls discharges around 25 MLD of sewage into the canal.

1.1.3. Eluru canal

The canal flows for a distance of 65km in Krishna and Godavari districts. There are 6 bridges, 2 railway bridges and 2 foot-over bridges across this canal. Total of 18 sewage out falls discharges around 22 MLD of sewage into this canal.

2. Objectives

- To study the existing condition of road and urban storm water drainage.
- Design of underground sewage collection system.
- To identify the extent of impact of urban storm water drainage on roads.

3. Study Area

The geographic location of the Vijayawada city is located in Krishna district of Andhra Pradesh state and lies between latitude 16.5083N and longitude 80.6417E. The geographical area of Vijayawada is 62 Sq. Km. The months of April to June are the summer months with the temperature ranging from a minimum of 27 ^{0}c to 45 ^{0}c. The temperature during winter months ranges from 28^{0}c to 17^{0}c. (VGTM UDA).The annual rainfall in the region is about 965 mm and is contributed by the southwest monsoon. Vijayawada city is located on banks of Krishna river, bounded by the Indrakiladri hills on west and Budemeru River on north. In the midst of Andhra Pradesh and largest city in the state. Vijayawada is considered as the agriculture and commercial capital of Andhra Pradesh. It is the major railway junction connecting north and south India (VGTM UDA).

The Andhra Pradesh was bifurcated and formed a new state called “Andhra Pradesh”. The Government also announced recently the capital of Andhra Pradesh would come near to Vijayawada city. In view of the recent announcement by the Government, city has got importance and many Government establishments will be coming to Vijayawada shortly. In future, city will be developed in big way and demands will be more for infrastructure facilities. The study area and municipal divisions are given in figures 1 and 2 respectively.

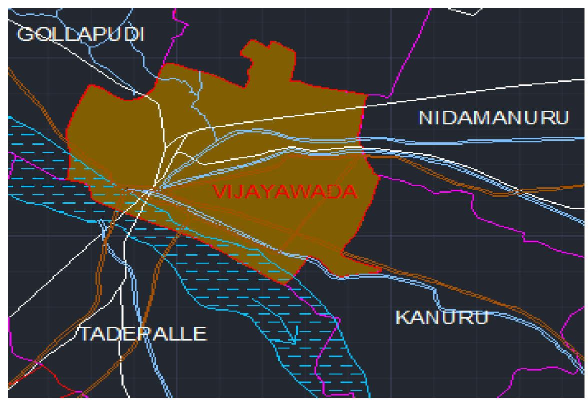

Figure 1: *Study area*

4. Methodology

The field data required for the design of the sewerage system such as details of exiting water supply, the ward wise population as per census, development plan etc. were collected from the Vijayawada Municipal council. In the present study, rational method is used to estimate discharge for the Vijayawada. Discharge is a major input for the storm water design and also the Geographical Information of the city is essential to find out the general slope of the ground which helps in finalizing the alignments and directions of the sewers.

4.1. Methods of Population Forecasting

There are many methods for the population forecasting suitable for the city. From that some of the methods are given below:

4.1.1. Arithmetical Increase Method

In this method, the average increase of population per decade is calculated from the past records and added to the present population to find out population in the next decades. This method gives low value and is suitable for well settled and established communities. Formulae of this method as below:

$$P_n = P_1 + n*X \quad (1)$$

Where

P_n is Population in the n_{th} Decades
P_1 is Population in the latest Decades
n is No. of Decades
X is Avg. Arithmetical Increase

4.1.2. Incremental Increase Method

In this method the increment in arithmetical increase is determined from the past decades and the average of that increment is added to the average increase. This method increases the figures obtained by the arithmetical increase method. Formulae of this method as below:

$$P_n = P_1 + n*X + n*(n+1)*(Y/2) \quad (2)$$

Where,

P_n is Population in the n_{th} Decades
P_1 is Population in the latest Decades
n is No. of Decades
X is Avg. Arithmetical Increase
Y is Avg. Incremental Increase

4.1.3. Geometric Progression Method

In this method the percentage increase is assumed to be the rate of growth and the average of the percentage increase is used to find out future increment in population. This extension has to be done carefully and it requires vast experience and good judgment. This method gives much higher value and mostly applicable for growing towns and cities having vast scope for expansion. Formulae of this method as below:

$$P_n = P_1 * (1 + Z)^n \quad (3)$$

Where,

P_n is Population in the n_{th} Decades
P_1 is Population in the latest Decades
n is No. of Decades
Z is Geometric Mean

Table 1: *Population prediction of Vijayawada city*

Year	Geometric Method	Athematic Method	Incremental Method
2001	845217	845217	845217
2005	1011400	933200	932930
2011	1177577	1021203	1020641
2021	1640630	1197190	1195504
2031	2285767	1373176	1369804
2041	5476698	1549162	1545228.3
2051	13122167	1725149	1720090

4.2. Rational Method for Estimation of Storm water Runoff

The rational method is a simple technique for estimating a design discharge from a small watershed. It was developed by Kuichling for small drainage basins in urban areas.

The rational method is the basis for design of many small structures.

$$Q=CiA \quad (4)$$

Where

Q is run off in m^3/sec
i is Intensity of rain fall (mm/hr)
A is Area in hec
C is Coefficient of runoff.

4.2.1. Coefficient of runoff

Considering the topography, slope and nature of soil in the study area the value of 'C' was assessed and found to be in between 0.7 to 0.9.

4.3. Hydraulic Design Equation

Normally, The Manning's equation is used most commonly for the design of sanitary sewers because it is efficient, popular and fully satisfied the experimental results (Bansal V. K, 2011) and same is used for this design.

The Manning's Equation is as below,

$$V = (1/n) * R^{2/3} * S^{1/2} \quad (5)$$

Where,

V is Velocity in metre/sec
n is Friction Factor
0.011 (For Plastic smooth pipe)
0.013 (For Cement-concrete pipe)
R is Hydraulic Radius in metre
(C/s area of flow in sq. metre)
Wetted perimeter in metre
S is Slope of Energy Grade Line
Wastewater = 80 % of water supply per person

5. Results and Discussions

The discharge is calculated for the rainfall data for the Vijayawada were collected for storm events occurring from January 1994 to 2014. All the required information for the application of the storm water drainage design such as friction factor n is 0.017, slope of energy gradient s is 0.002, coefficient of runoff C is 0.85, intensity of rainfall (mm/hr) 'I' is 20 mm/hour and area of the Vijayawada were extracted with the help of GIS database. Comparison of observed and estimated values has been carried out and is reported in table: 2.The good coefficient of determination value (0.871) indicates that good relation exists between observed and estimated values as shown in fig.2. Velocity and area of storm drain were determined using computed discharge. The area and diameter of the sewer line were calculated. The calculated values division wise diameters are tabulated below in table 3.

Table 2: *Comparison of Observed and estimated discharge*

Divisional. No	Area (hectares)	Observed m^3/sec	Estimated m^3/sec
1	420	7.151	9.44
2	236	4.032	5.56
3	137	2.350	2.87
4	44	0.817	0.82
5	23	0.487	0.45
6	24	0.481	0.38
7	37	0.683	0.62
8	55	0.968	0.82
9	17	0.428	0.32
10	14	0.344	0.21
11	15	0.410	0.32
12	24	0.524	0.38
13	82	1.419	1.49
14	25	0.528	0.38
15	43	0.775	0.72
16	69	1.198	1.19
17	18	0.347	0.21
18	80	1.376	1.33
19	80	1.386	1.33
20	97	1.673	1.83
21	63	1.110	1.06
22	364	6.195	9.44
23	308	5.244	8.00
24	541	9.203	9.44
25	291	4.961	7.56
26	216	3.689	5.21
27	42	0.762	0.62
28	33	0.623	0.45
29	53	0.956	0.82
30	47	0.853	0.82
31	38	0.684	0.62
32	64	1.115	1.06
33	50	0.901	0.82
34	33	0.619	0.45
35	153	2.617	3.12
36	759	12.907	9.44
37	147	2.519	3.12
38	76	1.334	1.33
39	93	1.610	1.65
40	65	1.138	1.06
41	115	1.982	2.42
42	335	5.705	8.94
43	182	3.111	3.93
44	71	1.241	1.19
45	64	1.129	1.06
46	121	2.096	2.42
47	38	0.802	0.82
48	53	0.985	0.93
49	91	1.593	1.65
50	142	2.440	2.87

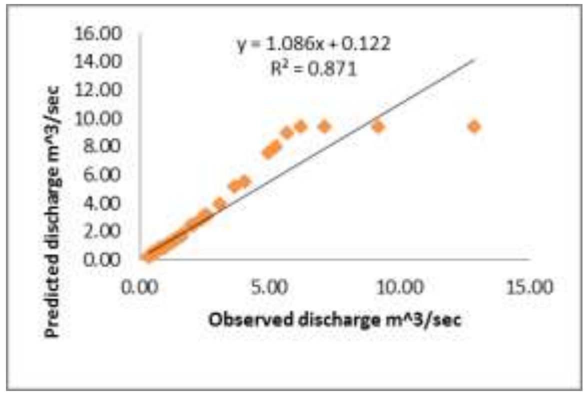

Figure 2: *graph showing observed and calculated discharge*

Table 3: *Divisional wise discharge and sewer diameter*

Divisional No	Area (Ha)	Population	Discharge Q(m^3/sec)	Sewer diameter (mts)
1	420	7293	5.21	1.91
2	236	12612	2.42	1.43
3	137	13199	1.06	1.09
4	44	43123	0.32	0.65
5	23	59809	0.13	0.50
6	24	45292	0.13	0.50
7	37	33357	0.26	0.59
8	55	20522	0.45	0.70
9	17	86341	0.13	0.47
10	14	65571	0.10	0.42
11	15	95920	0.13	0.46
12	24	71592	0.14	0.52
13	82	15828	0.82	0.85
14	25	63916	0.26	0.52
15	43	27293	0.26	0.63
16	69	15987	0.45	0.78
17	18	25617	0.13	0.42
18	80	10106	0.62	0.84
19	80	16659	0.62	0.84
20	97	15101	0.82	0.92
21	63	24329	0.45	0.75
22	364	4604	3.93	1.78
23	308	5255	3.38	1.63
24	541	4154	7.13	2.17
25	291	8988	3.12	1.59
26	216	10583	2.42	1.37
27	42	29948	0.82	0.62

28	33	38642	0.26	0.56
29	53	34043	0.45	0.70
30	47	33477	0.45	0.66
31	38	23703	0.26	0.59
32	64	17252	0.45	0.75
33	50	31560	0.32	0.68
34	33	35848	0.26	0.56
35	153	10360	1.49	1.15
36	759	2866	11.02	2.56
37	147	12912	1.83	1.13
38	76	26262	0.82	0.82
39	93	18292	0.82	0.91
40	65	20785	0.62	0.76
41	115	17070	1.19	1.01
42	335	6607	4.54	1.71
43	182	10921	2.01	1.26
44	71	21338	0.62	0.80
45	64	25306	0.62	0.76
46	121	24192	1.19	1.03
47	38	96405	0.32	0.64
48	53	52425	0.45	0.71
49	91	28534	0.82	0.90
50	142	16062	1.49	1.12

Figure 3: *Vijayawada municipality divisions*

6. Conclusions

Rational method has been successfully used for the estimation of storm wise discharge in Vijayawada city with good coefficient of determination 0.871. Diligent efforts are required to estimate these parameters in order to reach the value of runoff coefficient. In the present study care has been taken to determine the value of runoff coefficient 'C'. It was noted that the existing sections are not sufficient in most of the places to accommodate the runoff. The inundation of the study area is also may be the blockage of the drains in various points. Hence periodical maintenance of existing drains is essential.

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