IMPROVEMENT OF STORM WATER DRAINAGE SYSTEM IN GREATER HYDERABAD MUNICIPAL CORPORATION

[1]C.Sarala, [2]G.SreeLakshmi,

[1]Associate Professor, [2]Research Scholar
Centre for Water Resources,
Institute of Science and Technology, JNTU Hyderabad.

ABTRACT

Greater Hyderabad Municipal Corporation is formed in April 2007 by merging erstwhile surrounding 12 municipalities with Municipal Corporation of Hyderabad. The geographical area of the corporation has therefore increased from 170 mt2 to 625 mt2. The average rainfall of Hyderabad is 1019millimeters. The city of Hyderabad had experienced highest rainfall in last 46 years during the year 2000, by continuous rainfall for 3days peaking 24 centimeters in 24 hours equivalent to one half of its annual rainfall. This act of nature combined with urban geography and social structure created waste local disaster for half a century. This heavy flooding has caused over flow of the existing major and minor nalas there by submerging low lying areas. Mostly slums were submerged under water for three to four days. This has necessitated for the modifications or improvement of the nalas and water bodies development. The existing nalas were mostly silted up, encroached and due to socio-economic situations of the rapidly urbanized Hyderabad city. This paper presents the methodology applied in improvement of storm water drainage and the analysis of the existing rainfall data for arriving at runoff for the design of the storm water drainage system to GHMC.

KEYWORDS: *Rainfall intensity, Runoff, inflow, Time of Concentration, infiltration, Unit Hydrographs,*

I. INTRODUCTION

Hyderabad city lies in the Deccan Plauteau and rises to an average height of 536m above mean sea level and is spread over an area of 260km2. The original city of Hyderabad was founded on the banks of river Musi. Hyderabad and Secenderabad called as twin cities as they are closely linked with each other. A man made tank Hussain Sagar separates twin cities. Hyderabad has a unique combination of a tropical wet and dry climate that borders on a hot semi-arid climate. Most of the rainfall is received during south- west monsoon (from June to September), as 40% of the annual rainfall of every year is mostly concentrated in monsoon months. The heaviest rainfall received in 24hours period is 241.5 millimeters on 24th August 2000.

The drainage system in Hyderabad comprises of a hierarchy of natural and manmade drains and water bodies that ultimately discharge surface runoff into River Musi and Hussainsagar, Numerous lakes and nalas constituting the major storm water drainage system for the city. The nalas are the major carriers of storm water finally disposing into the river and water bodies in the catchment. Currently the storm water drainage system of the city construction and maintenance are being dealt by Municipal Corporation and ULBs, there are 87 water bodies in the city. The most important are Hussainsager, Miralam tank, Saroornagar tank, Safilguda lake and Langaur House lake. All the major drains flowing in the city of Hyderabad fall under the catchment area of Musi River. Length all major and primary drains passing through the city of Hyderabad is around 139.33 km and carry the storm water finally draining into musi or other lakes located in the city. Teritiary storm water drains are roadside drains discharging storm water into primary drains and water bodies. The total length of tertiary drains in MCH area is about 1510 km.

During the study and observations, this was found that the prime flood prone areas in the twin cities are the low lying areas in the catchment area of Hussain Sagar, Saroornagar Tank, Errakunta, the bulkampet and kukatpally nalas. Hussain sagar surplus nalas covering Kavadiguda, Domalguda, languor houz. These areas have witnessed flooding in 2000 cautioning immediate intervention for effective controlling the flood. The key reasons for this situation are assessed as follows.

- Inadequate drainage system which was designed for the rainfall of 12mm/hr
- Excessive concentration of floods due to breaching of tanks.
- Disappearance of flood absorbing tanks.
- Dumping of debries and garbage into the open nalas.
- Illegal encroachment of natural water courses.
- Patta Lands in the natural water courses.
- Spring up of housing colonies in foreshores of the tanks.
- Sanctioning of layout with the reference to ground lands.
- Indiscriminate laying of service lines all along and across natural courses.
- Diversion of natural water courses to accommodate habitations.
- Increasing flooding due to increase in imperviousness.

In order to avoid inundation of the habitats and surrounding areas due to floods, the municipal corporation of Hyderabad has under taken a study to prepare a storm water drainage master plan by providing adequate measures and recommended improvement of nalas. The improvements on proposed includes deepening, widening provisions of retaining walls at critical sections, Modification of across drainage works and in addition suggested some safety measures such as prevention of dumping of waste into the nalas to prevent clogging.

The primary and secondary nalas are proposed for widening and remodeling duly constructing RCC retaining walls providing fencing to the nalas to avoid dumping of wastes. Wherever the road width is less, it is getting affected in widening of nalas, Box culverts are provided so that the road can be retained when the drains is crossing the busy road in order to avoid traffic problems tunneling process is prepared for remodeling of the nalas.

For the preparation of master plan for storm water drainage system, rainfall data for the last 30 years in obtained from IMD from 1978-2007. The data collected and analyzed using slip method and IDF curves are generated. Adopting a return period of 5 years and time of concentration as 30mmts, the average rainfall intensity of 45mm/hr is considered for preliminary hydraulic design of storm water drains.

The main problem in implementation /execution of the widening / Improvement of existing nalas is the encroachments all along the nalas on both banks, high raised buildings were also constructed on the banks of nalas. All the encroachments and unauthorized constructions are the hurdles in the implementation of the project.

Hence in order to avoid inundation of the habitats and surrounding areas Methodology and Prioritization has been considered in the improvement of storm water drains project in Hyderabad.

II. METHODOLOGY

METHODOLOGY includes list of activities to be organized and carried out at site, office and GHMC. The list of activities is listed herein:

- Reconnaissance and field investigation of project area.
- Data collection includes collection of data, drawings and maps from various authorities Viz.., GHMC, HUDA ,IMD, Municipal authorities etc..,
- Checking the collected data for its correction and modifications if any.
- Study of collected Maps and Drawings.
- Digitization of collected Drawings and Maps.
- Study and analysis of the collected data Viz.., Rainfall Data, Land use Data etc..,
- Analysis of Rainfall Data for arriving at the intensity of rainfall and development of IMD Curves.

- Drain inventory for each drainage zone survey in the project area.
- Preparation of alignment drawings for all major storm water duly incorporating the drain inventory data collected.
- Demarcation of catchment areas for each individual storm water drain in a drainage basin.
- Zoning and sub-zoning analysis.
- Analysis of catchment characterization from Land use plan.
- Demarcation of land use patterns like Residential area, Commercial area, Conservation zone, Manufacturing zone, Reserved Forest, Multi usage zone, Public and Semipublic areas ,Public utilities, Specially Reserved areas, transportable areas, Village settlements etc…,
- Analysis of coefficient of Run-off (C) for each drainage basin or zones duly incorporating the land use pattern.
- Preparation of comprehensive master plans slowly all the major and primary storm water drains.
- Preliminary design of major and primary storm water drains.
- Preparation of costing and BOQs
- Prioritization of storm water drains in the master plan.

2.1 Prioritisation of Storm Water Drains in Storm Zones

Prioritisation Categories: For the purpose of project the following categorization is developed.
FLOOD IMPACT: Flooding which causes structures to be encroached by flood water. The structural flooding project is identified through hydraulic and hydrologic analysis, study of topographic maps, field investigation and recorded historic problems. If structural flooding on a property occurs as a result of the grading and other changes made by the private entity or encroachments may choose not to consider structural flooding in its priority ranking.
Culvert Capacity: The amount of a structure can convey prior to over tapping. The over tapping frequency was identified through hydrologic and hydraulic analysis, study of topographic maps and field investigation.
Open Channels: This category includes the condition and capacity for the given open channel systems. The information regarding the conditions of the channel/drain was obtained from field visits and site investigation. This category is subdivided to address the severity of the erosion condition, threatening to the structures, road ways, other infrastructure or threatening to natural resources and properties. The capacity of the channel was identified through hydraulic and hydrological analysis. Miscellaneous factors include Health and Safety, critical locations, community departments, downstream impacts, complaints, under developed area, cost, legal issues and links to other improvements are considered in the prioritization systems.
Open System Prioritisation Ranking Worksheet: Prioritization ranking worksheet was used to prioritize each storm water drainage zone. Based on this prioritization Ranking worksheet GHMC area was divided in to 16 Drainage Zones.

2.2 Design Parameters:

Coefficient of run-off(C) in the drainage system mainly depends on imperviousness of the catchment area and shape of tributary apart from the duration of storm. Imperviousness varies according to the characteristics of the catchment Viz.., Type of soils, Types of developments (Commercial, residential, industrial) etc…,. The run-off coefficient (c) is a dimensionless decimal value that estimates the decimal portion of the rainfall that becomes run-off.
Imperviousness: The percentage of the drainage area can be obtained from the records of a particular drainage basin or district. In the absence of such data, standards prescribed by CPHEEO manual can be followed.

Table1. Imperviousness –CPHEEO Standards

TYPE OF AREA	PERCENTAGE OF IMPERVIOUSNESS
(a)Commercial and Industrial	70 - 90
(b)Residential area	
(i)High Density	60 - 75
(ii)Low Density	35 - 60
(c)Parks and Undeveloped	10 - 20

The weighted average imperviousness of drainage basin for the flow concentrating at a point may be estimated as***:***

$$I = \frac{A1I1 + A2I2 \dots \dots}{A1 + A2 \dots \dots .}$$

A_1, A_2= Drainage areas tributary to an under consideration.
I_1,I_2 = Impervious of respective areas.
I = Weighted average imperviousness of the total drainage basin.

Tributary Area: The drainage area for each storm water drain needs to be demarcated clearly on the map and measured. The boundaries of each tributary are dependent on topography, land use, nature of development and shape of drainage basin. The incremental area may be indicated separately on the compilation sheet and the total area is computed

Duration Of Storm: Continuous long light Rain saturates the soil and produces higher coefficient than that due to heavy but intermittent rain in the same area is significant in the same area because of the lesser saturation in the later case. Run-off from an area is significantly influenced by the saturation of surface nearest the point of concentration, rather than the flow from the distant area. The run-off coefficient of a larger area has to be adjusted by dividing into zones of concentration and by suitably decreasing the coefficient with the distance of the zones.

Intensity Of Rainfall (I): The intensity of rainfall or rain ration is the volume of rainfall for unit time; usually expressed in inches per hour or millimeters per hour. It is obtained by dividing the depth of the rainfall by the duration under consideration.

The intensity of rainfall decreases with duration of rainfall of the observed data in the intensity duration of rainfall of past records over a period of years in the area is necessary to arrive at fair estimates of the intensity-duration of a given frequency. The longer the record available, the more dependable is the forecast. In general for Indian conditions average intensity of rainfall is adopted in design is usually in the range of 12mm per hour to 20mm per hour as per the standards of CHPHEEO.

The relationship between intensity of rainfall and the duration is expressed by a suitable mathematical formula. The following two equations are commonly used as prescribed in CHPHEEO.

$i = a/t^n$…………………………………………(i)

$i = a/(t+b)$………………………………..(ii)

Where, I = intensity of rain fall in mm per hour , T = duration of storm in minutes and
a, b and n are constants.

The available data on I and t are plotted and the values of intensity (i) can be determined for any given time of concentration (t).

Time Of Concentration (t_c): Time of concentration is often defined as the time required for a storm water to flow from the hydro logically most remote point in the basin to the basin outlet. It is also defined as the time required for all parts of a basin to contribute to the discharge at outlet simultaneously. The maximum possible discharge under a constant rate of effective rainfall will be reached if the effective rain duration is equal to the time of concentration of the basin. t_c for a catchment is calculated using longest flow path with respect to the travel time with in catchment. The flow time need to be calculated along several possible paths before identifying the one resulting to the longest. t_c is the time required for the rain water to flow on the ground surface from the extreme point of the drainage basin and reach point under consideration.

t_c = inlet time (t) + time of flow in the sewer(t_f)

The inlet time dependent on the distance of the farthest point in the drainage basin to the inlet manhole, the shape, characteristics and topography of the basin and may generally vary from 5 to 30 minutes.

$$t_c = t + t_f$$

$$t_f = \frac{L}{V}$$ Time of flow in the sewer is calculated $t_f = 0$

Catchment Area: The drainage catchment (A) is one parameter which affects the design of the system. It is also termed as drainage basin or tributary area. A drainage basin or a catchment area is defined as topographic slopes that divert all the run-off to the same drainage outlet. Natural topography, layout of buildings, political boundaries, economic factors etc…, determine the tributary area. The physical boundary of the drainage basin is defined by the direction in which surface run of water will drain and follows the ridge line between horologic units on a topographic map. It appears as an irregular closed traverse that is everywhere, normal to the land contour. This boundary called as drainage divide or catchment boundary. Any precipitation falling on the drainage divide will either drain into the basin of interest because of the topographic slopes or will drain away from the drainage basin of interest. The catchment area includes all the points that lie above the elevation of the outlet and within the drainage divide that separates adjacent catchments.

2.4 Analysis Of Existing Data

Based on the prioritization and approach methodology briefed in the pre paragraphs the analysis of existing data is carried out.

The rainfall data for Hyderabad city is collected and analyzed for the years between 1978 and 2007 (30 years).The data furnished indicate heavy rainfall values in the range of 15 minutes duration. The data contains the rainfall details as Year, Month, Date and Time of commencement of storm, Intensity of storm (mm per hour), Heaviest fall in 15 minutes duration.

This type of data gives the realistic assessment of the variations in the intensities of rainfall during the period of storm. The maximum value of summation of the four consecutive rainfalls in 15 minutes duration is used for the analysis for a day with higher intensity storm. A storm with high intensity with shorter duration is usually has more impact compared to the once with lower intensity and longer durations. An analysis of rainfall intensities is carried out using the heaviest rainfall data in order to arrive at a reasonably realistic value for which affects the design of the system and ultimately the cost of the project.

The various types of rainfall data are available with the Indian Meteorological Department (IMD) for Hyderabad city with rain gauge station located near Begumpet Airport. The rainfall data is applicable for surrounding 40 sq.km areas as per the norms of IMD. The available types of data are: Daily rain fall data, hourly rain fall data and heavy rain fall data (from 1978-2007)

Based on the availability of the past rainfall data with IMD for the project location and the type of data available, the analysis is carried out to arrive at the intensity of rainfall. The analysis carried out infers salient concluding remarks as explained in pre-paragraphs.

2.5. Land Use Pattern and Run-Off Coefficient

Land use pattern is another factor in designing storm water drains. Land use pattern map was collected from the municipality and digitized to find out the area of different land use. Run-off coefficients were adopted for corresponding land use to arrive the run-off coefficients as per CPHEEO. The storm run-off which drains over the ground surface before reaching the storm sewers experiences the transmission losses, evaporation losses, infiltration losses depending upon the shape, topography or terrain and vegetative covers of the catchment area. The net run-off reaching the main drain will be less than the actual run-off. The factor influencing the run-off is termed as catchment coefficient or coefficient of run-off. Analysis of land use pattern has been carried out and suitable run-off coefficient selected from CPHEEO manual based on the type of surface and shape of tributary.

The intensity of rainfall is one of the major parameters which decide the design of storm water drainage system. It has a great impact on the technical and financial conditions of the project. It is understood that a thorough study is requested to establish suitable rainfall intensity values for the city. The quantum of rainfall occur during the particular duration is expressed as intensity of rainfall it is quantified in mm per hour and usually the intensity of rainfall decreases with duration. Analysis of the observed data on intensity and duration of the rainfall from the past records over a period of years in the area is necessary to arrive at a fair estimate of intensity duration for given frequencies. The longer the record available the more dependable is the forecast.

Table 2. Rainfall Intensities For Different Durations By CPHEEO Method

t(min)	Storm once in 2 Years	Storm once a year	Storm twice in a Year	Storm four times in a year
10	80.00	70.00	60.00	52.00
20	70.00	60.00	52.00	46.50
30	80.83	56.000	48.50	44.24
40	60.00	52.50	46.67	43.06
45	59.33	51.04	45.77	42.43
50	58.33	49.58	44.87	41.79
60	56.00	48.50	44.29	40.61

The higher values of intensities of rainfall produced from the analysis require a compromise between technical feasibility and economical viability. Those higher values of intensity produces higher design sections for which site conditions may not favor. The constraint is mainly land acquisition and uninterrupted execution of the system. CPHEEO manual suggests allowing flooding under such inevitable circumstances recommending suitable return period for different areas of importance.

For residential areas in peripheral areas frequency of flooding is taken as twice a year, for central and comparatively high priced areas taken as once a year. For commercial and high price areas it is once a year flooding is allowed. Based on the rainfall data obtained from IMD, the occurrence of the design storm for the period of 6 months, 1 year, 2 years and 5 years is selected from the above table. The intensity of duration curves on a log graph are drawn for various returns periods

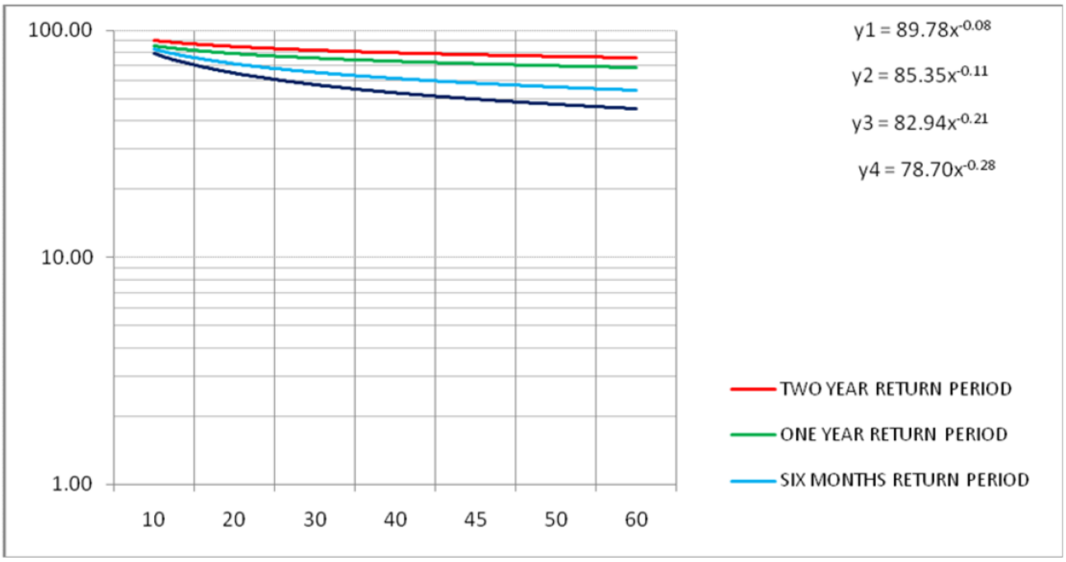

Figure 1. Intensity-Duration-Frequency Curves

Table 3. Rainfall Intensities For Shorter Durations FROM IDF Curves : For Various Return Periods

DURATION	TWO YEAR Y_1=89.78x-0.08	ONE YEAR Y_2=85.35x-0.11	SIX MONTHS Y3=82.94-0.21	THREE MONTHS Y_4=78.70x-0.28
60minutes	65.00	55.00	36.00	26.00
45minutes	67.00	57.00	38.00	28.00
30minutes	69.00	59.00	41.00	31.00

The data analyzed is for a period of 30 years (1978 – 2000). Intensity duration curve is plotted on a graph 3 months, 6 months, 1 year and 2 years frequencies. The study of the curve indicates that rainfall intensity for 2 years returns period can be adopted for commercial area purpose, Where as the project area is anticipated the sudden growth, hence very near future the area can be considered as high period area. The CPHEEO manual suggests one year return period for central and high priced areas.

For the purpose of design, it was meaningful and prudent to consider a one year return period.

The intensity of rainfall data for Hyderabad city from:

1) Intensity duration frequency analysis is carried out.
2) The available maximum 15mm rainfall recorded between 1978 and 2007 are considered and analyzed to establish the Design Rainfall Intensity for design of storm water drains.

Alternate -1 results the rainfall intensity as 45mm/hour with one year return period and whereas, Alternate-2 gives about t 59mm/hour for one year return period. As per CPHEEO sewerage manual, 15 mm rainfall is allowed on pavement. Therefore 45mm/hour rainfall intensity is considered for calculating Run-off calculation and line estimates.

The design of storm water drainage is done in general like sewage design. The area is divided into different zones (total 16 zones) depending upon profile based on contour of the area, population density spread with in GHMC limits and run off coefficients were adopted with high density low density, commercial and industrial areas. The run-off area is calculated based on different inlet points of drainage. Accordingly the size of the drain is arrived.

Table 4. Coefficients of Run off For Various Zones.

Zone Number	Run off Coefficient Value
1	0.537
2	0.502
3	0.542
4	0.546
5	0.542
6	0.550
7	0.537
8	0.572
9	0.489
10	0.541
11	0.546
12	0.550
13	0.567
14	0.549
15	0.563
16	0.584

III. DESIGN OF DRAINS

The design of drain system involves 1) Calculating the total discharge that the system will require to drain off and 2) Fixing the slope and dimensions of the drain to have adequate capacity to carry the discharge and for proper maintenance. Intensity using the following formulae given in IRC SS: SP - 13.

$$I = \frac{F \times (T+1)}{T \times (t+1)}$$

I = Intensity of rainfall within a shorter period of 't' hours within a storm.

F = Total rainfall in a storm in cm. falling in duration of 'T' hours.

t = Smaller time interval in hours within the storm duration of 't' hours.

Rational formulae of Run-off rates: Q = 10 CIA

IV. HYDRAULIC DESIGN OF DRAINS

Capacity is derived from Manning's formula

$$Q = (1/n)AR^{2/3}S^{1/2},\quad V = (1/n)R^{2/3}S^{1/2}$$

Where, Q = Discharge in cum/sec,V = Mean velocity in mts/sec
n = Manning's Rugosity Coefficient, R = Hydraulic mean radius (A/P)
A = Area of flow cross section in m^2,P = Wetted perimeter in mts
S = Gradient of drain bed.

Table 5. Maximum And Minimum Velocities

S.no	Description	Min(m/sec):	max(m/sec):
1	Internal drain (Brick Pitched or Plastered)	0.45	1.50
2	Intercepting and main drain (Brick Pitched or Plastered)	0.75	1.5
3	Pipe drain (Running Full)	0.75	1.8

Table 6. Minimum Free Board

S.No	BED WIDTH	FB(MM)
1	Beyond 300 mm Bed Width	100
2	Beyond 300mm and 900 mm Bed Width	150
3	Beyond 900mm and 1500mm Bed Width	300

Drain Shapes: The usual shapes are: Parabolic, Trapezoid, Rectangular, Triangular. The parabolic profile is considered to be the best for hydraulic flow but its actual construction and maintenance is difficult. The trapezoidal and rectangular sections are easy to construct and are considered most suitable. Triangular and V-shaped sections are not very popular as its de-silting is difficult.
Cunnets And Cross Slope In Bed: Cunett sections shall be provided in storm water drain centrally located to carry dry weather flow. A cross slope of 1 in 20 to 1 in 30 shall be provided in the bed towards the centre cunnet.
Tanks And Out Falls: The tanks and outfalls are the ultimate disposal points for the storm water drains. The storm water resulting from the rains will be collected to the drains and ultimately disposes into the outfalls or tanks the data such as capacity, full tank level, maximum water level, tank bottom level, catchment area maximum flood discharge, weir details pertaining to the tanks are collected from the government authorities. The data collected is analyzed. The data related to storm disposal drains like capacity of the drain , invert level of the drain width of the drain, depth of the drain etc…, are collected from the site and concerned authorities. This data is utilized in the design of new storm water drainage system for the project area under consideration.

V. PRELIMINARY COSTING

Preliminary costing is based on the typical geometric drain sections arrived for primary and major drains. This costing represents the block cost of the storm drains including the cross drainage works, protective works, operation and maintenance and other miscellaneous works.

VI. CONCLUSION

The intensity of rainfall data for Hyderabad city from rain fall duration frequency analysis is carried out. The available maximum 15mm rainfall recorded between 1978 -2007 are considered and analysed for design rainfall intensity for design of storm water drains.
Alternative I: Results the rainfall intensity as 45mm/he with one year return period.
Alternative II: Results about 59mm/ hr for one year return period. As per CPHEEO sewerage manual 15mm fall is allowed on pavements. Therefore 45mm/ hr rainfall is considered for calculating run off and discharge calculations.

AUTHORS

C.Sarala, Associate Professor, Centre for Water Resources, Institute of Science and Technology, Jawaharlal Nehru Technological University Hyderabad. Her research interest includes surface water resources analysis and environment related problems.

G. Sree Lakshmi, Research Scholar, Centre for Water Resources, Institute of Science and Technology, Jawaharlal Nehru Technological University, Hyderabad. Her research interest includes Hydraulics, Water supply Systems and Environmental related problems.