Evaluation of Limitations of Rational method for Runoff Calculation for Urban Areas of Islamabad

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Abstract: **Rational Method is generally used for estimation of peak discharges. Different authors mentioned different catchment area limitations for use of rational method, for different locations due to variation in precipitation rate and variation of ground characteristics. Mostly, the researchers stated that the results from this method could be acceptable upto area limitations of 200 acres. However, there is need to evaluate the applicability of rational method with respect to catchment area for Islamabad region to check the application and catchment limitations for the design of storm drainage system in the future. Digital Elevation Modeling (DEM) along with Global Mapper, Sam-Sam water harvesting have been used to estimate runoff by rational method. Different points of interest developed with drainage areas of 663.8 acres, 805.4 acres, 1056.9 acres and 1529.0 acres respectively. Corresponding value of discharge from rational method was estimated for all points of interest. Then the results were compared with Soil Conservation Service (SCS) Curve Number method applied to same catchments. The results obtained from comparison showed that Rational Method approach could be applicable for larger areas with respect to characteristics of the ground and type of the area i.e. for developed areas. Readers will be able to evaluate the applicability of Rational Method approach after going through this research work.**

Keywords: **Catchment, Digital Elevation Modeling, Global Mapper, Sam-Sam water harvesting, Curve Number.**

I. INTRODUCTION

The Rational Method is extensively used for estimating design flow rate in storm sewer design using equation illustrated below. The Rational Equationplays a key role in hydraulic design of storm sewers.

$$Q = C\ i\ A \qquad \text{Eq. (1)}$$

The Rational Method can be used to estimate stormwater runoff peak flows for the design of gutter flows, drainage inlets, storm drain pipe, culverts and small ditches. It is most applicable to small, highly impervious areas. The rational method is a tool for estimating peak (maximum) discharge from relatively small drainage areas (Mulvaney, 1850; Kuichling, 1889). So there is need to evaluate the limitations of the method so that it can be used as a guide for hydraulic design engineers to apply this method accordingly. The TxDOT provides guideline of 200 acres for application of the rational method. In the literature review, Thompson (2004) reports that other researchers applied the rational method to watersheds with drainage areas exceeding 200 acres; but gave no upper limit. It is noted that different authors mentioned different area limitation for the use of rational method but no one provided the justification behind that limitation. So it is required to verify the correct statement regarding the limitation of the rational method for Pakistan region.

II. METHODOLOGY

To evaluate the validity of rational method by addressing assumptions available in the literature a site has been selected in Islamabad known as "EMAAR Housing Society" near Islamabad Expressway, DHA Phase-II Extension, Islamabad. The work is carried out in different phases. Firstly the necessary data is collected from actual site regarding drainage of the area and topography of the site. Then catchments & streams data is generated by using Global Mapper. After selection of location, data of

Fig.1: Location Map of EMAAR Islamabad

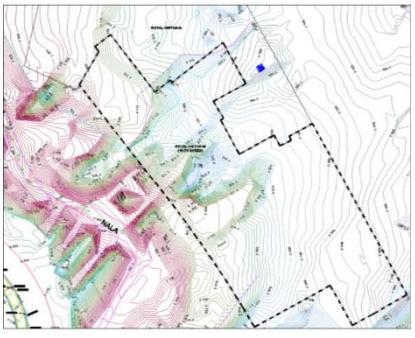


Fig. 1: Enlarged Contour Plan of Drainage Network

all streams is compiled which shows stream details, corresponding drainage area, slope of the stream etc. Moreover, different points of interest developed and corresponding drainage area is calculated using Google Earth, Global Mapper and AutoCAD. Runoff is then calculated by using Rational Method. Results obtained from rational method are then compared with the SCS Curve Number Method to verify the applicability of rational method.

A. Selection of Drainage Area, A

Different catchment areas corresponding to points of interest are developed using Global Mapper, Google Earth. The developed area as well as undeveloped area is considered for each catchment area.

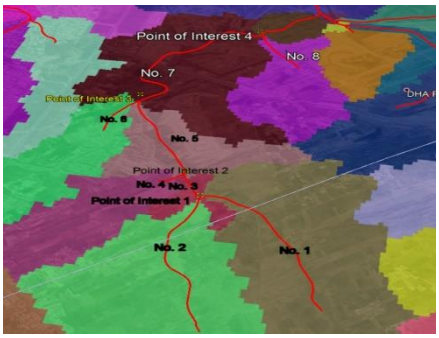


Fig. 2: Development of Interest Points–Using Global Mapper

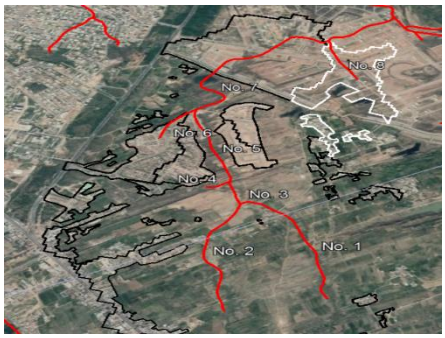


Fig. 3: Catchment Area, Streams Development - Using Google Earth

B. Estimation of Time of Concentration, Tc

Time of concentration is the time required for runoff from most distant point to reach at the tip of any catchment. It is calculated for both types of flow i.e. for channel flow and for overland flow. Izzard method is used for overland flow whereas Kirpich method is used for calculation of channel flow.

C. Calculate C-weighted ,C

C is the runoff coefficient calculated for all categories of catchment area i.e. houses, parks, roads etc. There are different types of areas i.e. developed areas, partial developed areas, near future developing areas and completely undeveloped areas.

D. Rainfall Intensity,i

The intensity of rainfall (i) is the meanprecipitation rate in in. /hr. or in mm/hr. for definite rainfall period and a nominated frequency. For applicability of rational method the duration of the rainfall should be greater than the Tc for any area i.e. Tc > d.Detail of rainfall characteristics for all selected points of interest is also obtained from SamSam Model. SamSam Model showed that rainfall is uniform for all selected points. It means that rainfall characteristics for all points are same throughout the year. Hence, rational method approach is valid for this selected area as there is no change in yearly rainfall amount at all remote points within the selected area.

E. Estimation of runoff and verification of its validity,Q

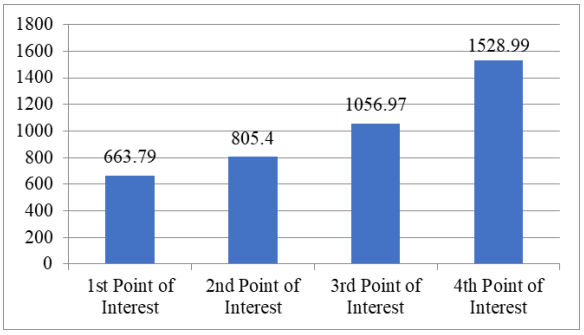
After calculating above mentioned factors, runoff is estimated from rational method by using Eq. (1). Then the results are compared with SCS Curve Number method to check the validity of method and to compare the results.

III. RESULTS

Discharge is calculated from both methods corresponding to each point of interest. Rational method and SCS CN method both are applied to same catchment area to visualize the results and to check the validity of rational method.
It is observed from calculations that Rational Method approach estimate high value of discharge as compared to CN method.

Table 1: Comparison of Discharge from both Methods

Description	Developed Area	Total Catchment Area	Percentage of Developed Area	Discharge from Rational Method	Discharge from CN Method	Rational Method value higher from CN approach
	(acres)	(acres)	(%)	(Cfs)	(Cfs)	(%)
1st Point of Interest	101.46	663.79	15.28	1418.38	1091.50	29.95
2nd Point of Interest	127.20	805.40	15.79	1721.95	1328.60	29.61
3rd Point of Interest	242.33	1056.97	22.93	2292.51	1821.71	25.84
4th Point of Interest	528.91	1528.99	34.59	3352.74	2947.24	13.76



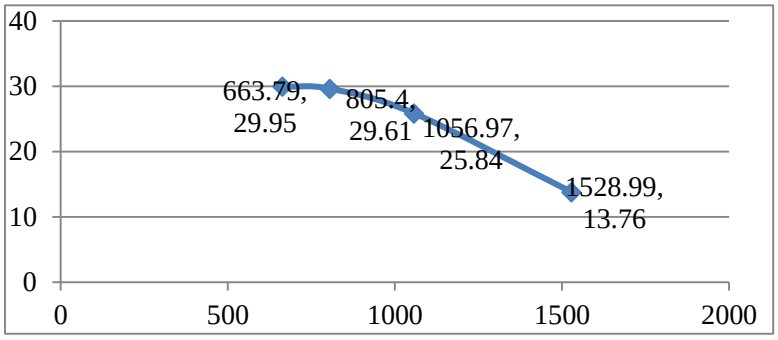


Figure 4: Catchment Area corresponding to each Point of Interest

Figure 5: Percentage Difference of Rational Method with respect to Catchment Area

It is observed from above shown graph that results from Rational Method become more acceptable when area is larger irrespective of limitations available in literature.

IV. CONCLUSSIONS

Different researchers mentioned different catchment area limitation for use of rational method, but from the calculations it is observed that as area increases results seems more reliable. But there is need to clear that either for all type of areas results of rational method be applicable to larger areas, for addressing this percentage of developed and undeveloped area is calculated for all points of interest.

It is observed that results of rational method will be more acceptable if more developed area is present. In literature, different authors mentioned that rational method is not applicable to catchment area of larger value but the comparison showed that as the area value goes on higher side, results are more acceptable. It means that it can be applicable to large areas depends upon type of catchment area. So assumptions available in the literature are not valid for all locations.

V. RECOMMENDATIONS

As different authors mentioned different catchment area limitations for use of rational method, for different locations due to variation in precipitation rate and variation of ground characteristics. So, the limitations for use of rational method for any catchment area will be needed to verify first depending upon the ground characteristics and type of the area i.e. developed or undeveloped.

If there is all developed area in the selected catchment then rational method can be applicable even if there is larger area. Urban areas of Islamabad included mostly the developed areas so rational method can be adopted for design of storm drainage system. This is a simple method which can be easy to find out discharge value for any catchment area.

Correct application of either method needs another study including hydrograph method or any other technique.

REFERENCES

[1]. A. Bradley, L. L. Wehmeyer, L.-C. Chen, "Evaluation of design flood frequency methods for IOWA streams," 2009.

[2]. Arapahoe county storm water management manual. Arapahoe Board of County Commissioners, 2011.

[3]. B.T. David, "The rational method," Civil Engineering Department, Texas Technical University, 2006.

[4]. Debo and Associates, Georgia storm water management manual. Jordan Jones and Goulding Atlanta Regional Commission, 2001.

[5]. Urban storm water management manual for Malaysia. Department of Irrigation and Drainage Malaysia, 2006.

[6]. F. B. Baharudin, "A study on rainfall-runoff characteristics of urban catchment of Sungai Kerayong," 2007.

[7]. H. Ahsan, G. Nabi, M. W. Boota and T. Abbas, "Development of envelope curve for Indus and Jhelum River basin in Pakistan and estimation of upper bound using envelope curve," Journal of Himalayan Earth Sciences, 2016.

[8]. New Jersey storm water best management practices manual, Chapter 5, Computing Storm Water Runoff Rates and Volumes, 2004.

[9]. N. Dhakal, X. Fang, T. G. Cleveland and D. B. Thompson, "Revisiting modified rational method," World Environmental and Water Resources Congress, 2011.

[10]. NCDENR storm water BMPmanual. North Carolina Department of Environment and Natural Resources, 2007.

[11]. Storm water management & erosion control design manual. Planning & Development Department Infrastructure Division, 2010.

[12]. Hydraulic design manual. Texas Department of Transportation, 2016.

[13]. T. G. Cleveland, D. B. Thompson and X. Fang, "Use of the rational and modified rational methods for TxDOT hydraulic design," Texas Tech Center for Multidisciplinary Research in Transportation, 2011.

[14]. Drainage criteria manual (Vol. 1). Urban Drainage and Flood Control District, 2007.

[15]. Urban storm drainage criteria manual. Urban Drainage and Flood Control District (UDFCD), Denver, 2017.

[16]. W. M. D. Wijesinghe and N. T. S. Wijesekera, "Comparison of rational formula alternatives for stream flow generation for small ungauged catchments," Journal of the Institutions of Engineers, Srilanka, 2011.