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An assessment of the rational method's limitations for calculating runoff in Islamabad's urban areas: A Case Study EMAAR Housing Society

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Abstract – Peak discharge estimate is often done using the rational method. Because ground properties and precipitation rates vary, many writers have identified differences in catchment areas that limit the application of the rational technique in different regions. The researchers generally said that this strategy might yield findings that are acceptable within 200-acre limits. Nevertheless, in order to verify the applicability and catchment constraints for the future design of storm drainage systems, it is necessary to assess the applicability of rational approaches with regard to catchment area for the Islamabad region. Various places of interest were established, each with drainage areas measuring 663.8 acres, 805.4 acres, 1056.9 acres, and 1529.0 acres. All sites of interest have their corresponding discharge values determined using the rational technique. The outcomes were then contrasted with the same catchments using the soil conservation service (SCS) curve number approach. Comparing the data, it was evident that the Rational Method technique would be more appropriate for developed regions, or bigger areas with different terrain and area types. Upon completion of this research project, readers will possess the capacity to assess the suitability of the rational method.

Keywords – Soil Conservation Service, Storm Drainage, Rational Technique, Rational Method. Discharge.

I. INTRODUCTION

In the same way that several manuals and books are available that discuss catchment area constraints in relation to the research area and topographical features of the region, different writers have produced papers in which different catchment area limitations are stated. This system was first presented in 1889, and most engineering offices in the US still use it now. Nothing else has developed to such a degree of widespread acceptance by the practicing engineer as this practical drainage design technique, despite the fact that it has often been criticized by scholars for being overly simplistic. for used with appropriate understanding and application, the Rational Method may yield good results for designing urban storm drains and sizing storm drains and street inlets. According to [1] the rational technique may be applied to watersheds in the US state of Albama that have drainage areas of less than 200 acres since it is a straightforward process and cannot be applied to complicated watersheds with larger drainage areas. [2] looked at a 483 km2 region for study, however their findings were unacceptable, and they concluded that the rational method approach was inappropriate for such a large area. The Atlanta Regional Commission, [3] stated in the Georgia Stormwater Management Manual that the maximum drainage area that should be used with the Rational Method is 25 acres, and that the rational method should not be used for storage design or any other application that requires a more detailed routing procedure. [4] conducted study on the Indus and Jhelum River basins in Pakistan and found that the rational technique is applied for catchments of 40 acres or less. According to the New Jersey Department of Environmental Protection in the United [5], the rational technique is confined to drainage regions less than 20 acres since it cannot estimate total runoff amounts. The method can be considered the most reliable approach to estimating the design storm peak runoff, according to a study conducted by Fauzi Bin [6] on the rainfall-runoff characteristics of the urban catchment of Sungai Kerayong, Malaysia. However, experience has shown that the method only yields satisfactory results on small catchments up to 80 hectares (197.684 acres), as larger catchments require the hydrograph method due to the significant effects of storage and timing. According to Planning & Development Department Infrastructure Division, South Carolina, [7] storm drains and individual culverts that are not a part of a pipe network or system and do not have a contributing drainage area more than 20 acres may be sized using the rational technique. The logical approach may be used to watersheds ranging in size from 5 to 160 acres, according to a [8] publication by the Board of County Commissioners, Arapahoe, State of Colorado, America. According to Urban Drainage and Flood Control District, Colorado USA [9], it is appropriate to use the rational technique for the analysis of design storm runoff in urban catchments that are not complicated and typically span 160 acres or less. It was also mentioned that the logical method's biggest flaw is that it often yields a single point on the runoff hydrograph. The logical approach has a tendency to overestimate the actual flow in complicated locations and at the intersection of sub-catchments, leading to the oversizing of drainage infrastructure. In order to route hydrographs through the drainage facilities, the rational technique does not offer the necessary direct information. The rational technique is restricted to small regions in part because hydro-graphs for bigger catchments must be routed according to best design practices in order to provide an economically sound design.

The history given above makes it evident that various values are indicated in literature with regard to the catchment area constraints of the rational technique in relation to various study sites. The reasonable approach, according to the researchers, may be used in many locations based on the properties of the ground and variations in precipitation rate.

The catchment area constraints for this approach, which range from a minimum of 5 acres to a maximum of 6177.63 acres, are up for debate among researchers. Therefore, in order for this technique to be used for design purposes, it is imperative that the assumptions found in the literature for this particular metropolitan region of Pakistan be verified.

II. MATERIALS AND METHOD

There are several stages to the work. First, information on the site's topography and drainage is gathered directly from the location itself. after which the gathered data is analyzed, and relevant data is extracted from the accessible data. Furthermore, data on catchments and streams is produced using Global Mapper and DEM for surface modeling of terrain. Following site selection, information on every stream is gathered, including information on the stream's characteristics, drainage area, slope, and other factors. Additionally, using Google Earth, Global Mapper, and AutoCAD, several locations of interest were established, and the related drainage area was computed.

The region is then divided into developed and undeveloped zones to determine the C-weighted. As per CDA requirements, the highest intensity of rainfall is recorded. Next, runoff is computed using the rational method. The correctness of the rational technique is then verified by comparing the results with the SCS Curve Number technique.

A. *Site Selection and Data Collection*

A location in Islamabad known as "EMAAR Housing Society," next to the Islamabad Expressway and DHA Phase-II Extension Islamabad, has been chosen with a minimum elevation of 487.00 and a maximum elevation of 537.00 in order to assess the validity of the rational technique by addressing assumptions found in the literature.

The location was chosen because it had both developed and undeveloped areas, and it was simple to get information on the contour plan and road network plan. Next, important information is gathered from the site for the study project, such as the contour plan, master plan, grading points that show the elevation of every place, etc.

Figure 1: Location Map of EMAAR Islamabad

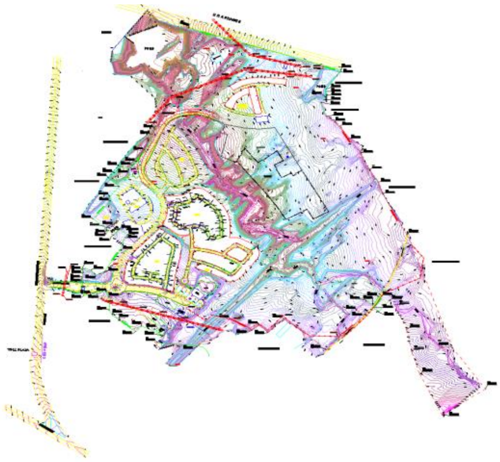

Figure 2: Contour plan of Selected Site Islamabad

B. *Rational Method*

Equation 1 of the Rational Method is frequently used to calculate the design flow rate, or surface runoff, in storm sewer design. In hydraulic storm sewer design, the Rational Equation and the estimate of its parameters to compute Q are essential components.

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$$\mathbf{Q = CIA} \qquad (1)$$

Where,
Q = Maximum rate of runoff (ft3/sec or m3/sec)
C = Runoff coefficient
i = Average rainfall intensity (in. / hr. or mm/hr.)
A = Drainage area (ac or ha)

Stormwater runoff peak flows may be estimated using the Rational Method for small-ditch, culvert, storm drainpipe, gutter, and drainage inlet design. Mulvaney, 1850; Kuichling, 1889) describe the rational technique as a tool for predicting peak (maximum) discharge from relatively limited drainage basins. Therefore, in order for hydraulic design engineers to implement this approach appropriately, it is necessary to assess the method's limits.

It was observed that several writers indicated various geographic restrictions on the use of the rational approach, but none of them offered an explanation for these restrictions.

Therefore, it is necessary to confirm that the assertion about the rational method's restriction for the Islamabad region is accurate.

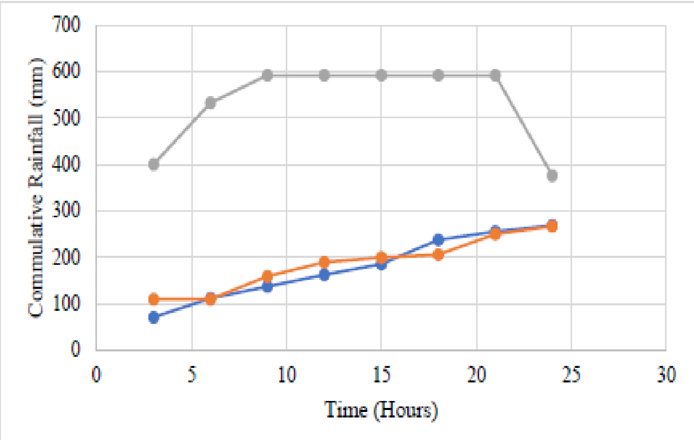

Figure 3: Rainfall record at Islamabad Airport.Islamabad

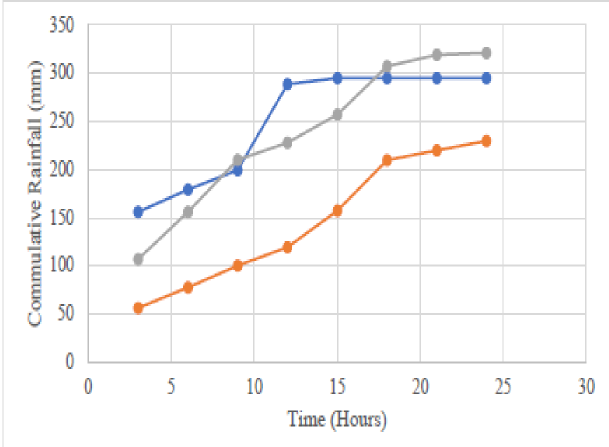

Figure 4: Rainfall record at PMD office, H-8.Islamabad

III. AVERAGE RAINFALL FOR SELECTED SITE (USING SAMSAM MODEL)

Because the logical approach is only useful in regions where the characteristics of the rainfall are consistent across the board. Because of this, five distinct locations are chosen within the chosen area, and the average precipitation at each place is predicted using the SamSam Model.

Figure 5: Selected locations for checking rainfall characteristics

IV. RESULTS

Google Earth is used to compute the total built area for each stream. Developed regions are designated based on real conditions, and a value is computed for each. Each stream's developed area is indicated in Figure 6, and values are computed and tabulated before being presented in tables in the next section.

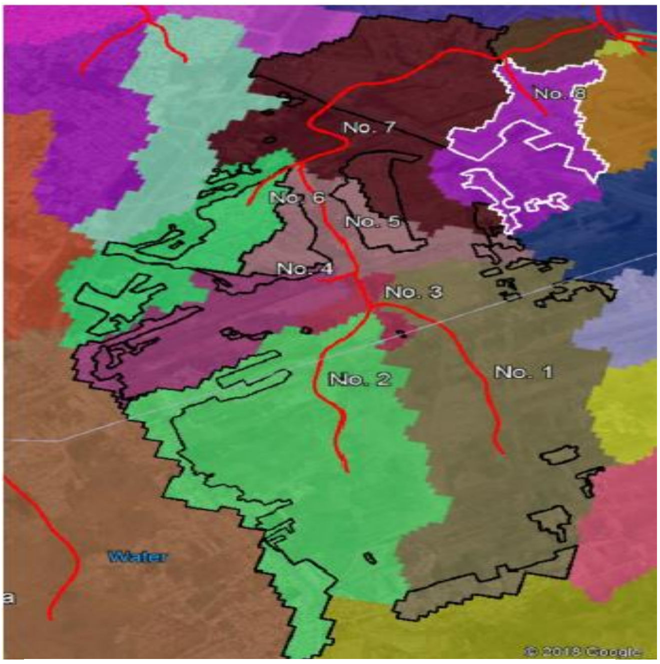

Figure 6: Developed area marked using Google Earth Tool.

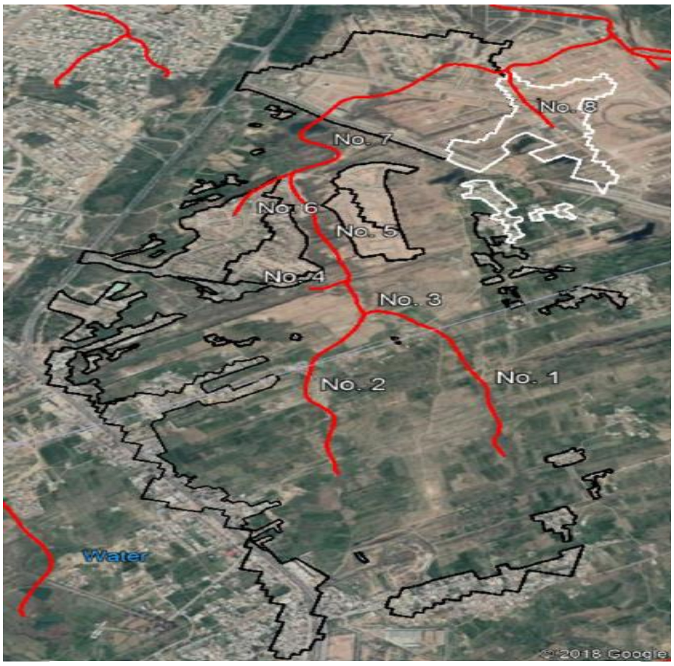

Figure 7: Another view for developed area marked using Google Earth

The discharge summary determined using a logical approach is listed in the table below. To verify the validity of the rational method approach, the findings from this technique will be compared with those from another way, the NCRS CN method, in the next section.

Table 1: Rainfall record at Islamabad Airport.Islamabad

Sr.#	Description	Drainage Area (acres)	Discharge by Rational Method (Cfs)
1	1st Point of Interest	663.79	1418.38
2	2nd Point of Interest	805.39	1721.95
3	3rd Point of Interest	1056.97	2292.51
4	4th Point of Interest	1528.99	3352.74

Table 2: Discharge for 1st Point of Interest using CN Method.

Point of Interest No. 1									
Sr. No.	**Streams contributing in Drainage / Discharge**	**CN for Hydrologic SoilGroup**	**Rainfall(in)**	**Runoff "Q" (in)**	**Corresponding Drainage Area**		**"Q" Individual Discharge**	**"Q" Stream Discharge**	**"Q" Comm. Discharge**
1	**Stream No. 1 (Developed)**	90	3.58	2.52	0.14	33.96	85.65	555.92	
2	**Stream No. 1 (Un Developed)**	77	3.58	1.49	1.28	316.47	470.27		1091.50
3	**Stream No. 2 (Developed)**	90	3.58	2.52	0.27	67.50	170.23	535.58	
4	**Stream No. 2 (Un Developed)**	77	3.58	1.49	0.99	245.86	365.35		

Table 3: Discharge for 2nd Point of Interest using CN Method.

Point of Interest No. 1									
Sr. No.	**Streams contributing to Drainage / Discharge**	**CN for Hydrologic SoilGroup**	**Rainfall (in)**	**Runoff 'Q' (in)**	**Corresponding Drainage Area**		**"Q" Individual Discharge**	**"Q" Stream Discharge**	**"Q" Comm. Discharge**
1	Stream No. 3 (Developed)	90	3.58	2.52	0.00180	0.44	1.12	1127.58	
2	Stream No. 3 (Un Developed)	77	3.58	1.49	0.095	23.53	34.96		1328.59
3	Stream No. 4 (Developed)	90	3.58	2.52	0.10	25.30	63.80	201.01	
4	Stream No. 4 (Un Developed)	77	3.58	1.49	0.37	92.34	137.21		

Table 4: Discharge for 2nd Point of Interest using CN Method.

<table>
<tr><th colspan="10">Point of Interest No. 3</th></tr>
<tr><th>Sr. No.</th><th>Streams contributing in Drainage / Discharge</th><th>CN for Hydrologic Soil Group</th><th>Rainfall (in)</th><th>Runoff ”Q” (in)</th><th colspan="2">Corresponding Drainage Area</th><th>“Q” Individual Discharge</th><th>“Q” Stream Discharge</th><th>“Q” Comm. Discharge</th></tr>
<tr><td>1</td><td>Stream No. 5 (Developed)</td><td>90</td><td>3.58</td><td>2.52</td><td>0.198</td><td>48.89</td><td>123.31</td><td rowspan="2">1543.04</td><td rowspan="4">1821.71</td></tr>
<tr><td>2</td><td>Stream No. 5 (Un Developed)</td><td>77</td><td>3.58</td><td>1.49</td><td>0.248</td><td>61.33</td><td>91.13</td></tr>
<tr><td>3</td><td>Stream No. 6 (Developed)</td><td>90</td><td>3.58</td><td>2.52</td><td>0.268</td><td>66.23</td><td>167.04</td><td rowspan="2">278.68</td></tr>
<tr><td>4</td><td>Stream No. 6 (Un Developed)</td><td>77</td><td>3.58</td><td>1.49</td><td>0.304</td><td>75.12</td><td>111.64</td></tr>
</table>

Table 5: Discharge for 2nd Point of Interest using CN Method.

<table>
<tr><th colspan="10">Point of Interest No. 4</th></tr>
<tr><th>Sr. No.</th><th>Streams contributing to Drainage / Discharge</th><th>CN for Hydrologic Soil Group</th><th>Rainfall (in)</th><th>Runoff “Q” (in)</th><th colspan="2">Corresponding Drainage Area</th><th>“Q” Individual Discharge</th><th>“Q” Stream Discharge</th><th>“Q” Comm. Discharge</th></tr>
<tr><td>1</td><td>Stream No. 7 (Developed)</td><td>90</td><td>3.58</td><td>2.52</td><td>0.836</td><td>206.57</td><td>520.98</td><td rowspan="2">2592.35</td><td rowspan="4">2947.24</td></tr>
<tr><td>2</td><td>Stream No. 7 (Un Developed)</td><td>86</td><td>3.58</td><td>2.17</td><td>0.465</td><td>114.94</td><td>249.65</td></tr>
<tr><td>3</td><td>Stream No. 8 (Developed)</td><td>90</td><td>3.58</td><td>2.52</td><td>0.324</td><td>80.01</td><td>201.79</td><td rowspan="2">354.89</td></tr>
<tr><td>4</td><td>Stream No. 8 (Un Developed)</td><td>86</td><td>3.58</td><td>2.17</td><td>0.285</td><td>70.49</td><td>153.11</td></tr>
</table>

V. DISCUSSION

Various studies have identified varying catchment area limitations for the usage of the radial approach; yet the calculations show that findings look increasingly dependable as the area rises. To address this proportion of developed and undeveloped land, it is necessary to clarify that the findings of the rational technique must apply to greater areas for all types of areas. This calculation is done for all locations of interest.

It has been noted that the presence of a more developed region increases the acceptability of the outcomes of the rational technique. Table 6 contains a tabulation of the computation details.

Various writers have said in the literature that the rational technique is not appropriate for catchment areas with greater values. However, a comparison of the data revealed that results become more acceptable as the area value increases. It implies that depending on the sort of catchment region, it may be relevant to wide areas. As a result, not all places can use the assumptions found in the literature.

Figure 6: Developed Area Percentage Related with Results.

Percentage Difference w.r.t Area Distribution						
Description	**Developed Area**	**Total Catchment Area**	**Percentage of Developed Area**	**Discharge from Rational Method**	**Discharge from CN Method**	**Percentage by which 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

VI. CONCLUSION

Due to variations in precipitation rate and ground properties, several authors have specified different catchment area constraints for the application of the rational technique for different places.

Therefore, depending on the ground features and area type (built or undeveloped), the constraints for using the rational technique for every catchment area will need to be verified first.

Even with a greater region, the rational technique may be applied if the chosen catchment is fully developed. Since Islamabad's urban regions comprise the majority of its developed areas, storm drainage system design may be done rationally. With this straightforward procedure, the discharge value for any catchment area may be easily determined.

REFERENCES

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

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

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

[4] 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.

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

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

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

[8] 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.

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