Manual

Road Drainage
Chapter 5: Hydrology

September 2019
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5 Hydrology

5.1 Introduction

Section 6.1 of the Austroads Guide to Road Design – Part 5 is accepted for this section.

5.2 Rainfall

Section 6.3 of the Austroads Guide to Road Design – Part 5 is accepted for this section. Sections 6.3.1 and 6.3.2 in the Austroads Guide to Road Design – Part 5 of Rainfall Intensity, Frequency and Duration and the corresponding tables are addressed in Section 5.8 of this manual.

5.3 Rainfall – runoff relationship

Section 6.2 of the Austroads Guide to Road Design – Part 5 is accepted for this section.

5.4 Methods available for runoff calculation

There are several techniques available for flood estimation in various-sized catchments and these procedures are described, in detail, in the latest release of Australian Rainfall and Runoff (ARR), A Guide to Flood Estimation, 2019.

Methods and techniques for determining flood discharges or runoff estimation in larger catchments, usually associated with major structures, such as bridges and floodways, are not described in this manual.

While there are many methods for flood estimation, the standard method of routine runoff calculation used by the department for small rural and urban catchments is the Rational Method.

The Rational Method is a simple, statistical method used to calculate peak discharge from a catchment for a given Annual Exceedance Probability (AEP).

5.5 Rational method

Sections 6.6.1 (for rural catchments) and 6.7.1 (for urban catchments) of the Austroads Guide to Road Design – Part 5 are accepted for this section. The method should be applied with consideration to the background and applicability statements contained within Sections 6.4.1 and 6.4.2 of the Austroads Guide to Road Design – Part 5, subject to the amendments stated in Sections 1.2.4, 5.7 and 5.9 of this RDM.

Regarding the use and applicability of the Rational Method for Departmental projects, the Rational Method as a primary flow estimation method is only supported for longitudinal drainage design or for small catchments with catchment areas of less than 100 ha and/or corresponding times of concentration of less than 30 minutes. Use of the Rational Method as a validation of a flow estimation is only supported for longitudinal drainage design or for small rural catchments with catchment areas of less than 25km² and/or corresponding times of concentration of less than 2 hours.

5.6 Catchment area

Sections 6.4.2 and 6.5.1 of the Austroads Guide to Road Design – Part 5 are accepted for this section.

5.7 Time of concentration

5.7.1 General

Sections 4.6.1 and 4.6.11 (for rural catchments) and 4.6.1 to 4.6.10 (for urban catchments) of Queensland Urban Drainage Manual (QUDM), 4th Edition 2016 are accepted for this section.
5.7.2 Rural catchments

Sections 4.6.1 and 4.6.11 (for rural catchments) and 4.6.1 to 4.6.10 (for urban catchments) of QUDE are accepted for this section, subject to the following amendments:

Addition(s):

1. Use of Method (a) Bransby-Williams Method within Section 4.6.11 of QUDE is not to be used for Department of Transports and Main Roads (TMR) projects.

5.7.3 Urban catchments

Section 4.6 of QUDE is accepted for this section subject to the following amendments:

Addition(s):

1. Use of Method (a) Bransby-Williams Method within Section 4.6.11 of QUDE is not to be used for TMR projects.

2. Channel flow

Note: The slope of the energy line is often difficult to determine, therefore use a representative slope of the channel (So) in the vicinity of the site to estimate the slope of the energy line – that is, So ≈ S.

5.8 Rainfall intensity – frequency – duration

Sections 6.3.1 and 6.3.2 of the Austroads Guide to Road Design – Part 5 are accepted for this section, subject to the following amendments.

Addition(s)

Design rainfall IFD should be derived using the online tool on the Bureau of Meteorology website.

5.9 Runoff coefficient

The runoff coefficient, ‘C’, is a statistical composite of several aspects, including the effects of rainfall intensity, catchment characteristics, infiltration (and other losses) and channel storage. It should not be confused with the volumetric runoff coefficient which is the ratio of total runoff to total rainfall.

5.9.1 Rural catchments

Section 4.5 of QUDE is accepted for this section.

5.9.2 Urban catchments

Section 4.5 of QUDE is accepted for this section subject to the following amendments.

Addition(s)

1. The runoff coefficient must account for the future development of the catchment as depicted in the planning scheme or zoning maps for the relevant local government, but should not be less than the value determined for the catchment under existing conditions.

5.9.3 Adjustment factors

Section 4.5 of QUDE is accepted for this section.
5.10  **Partial area effects**

Section 6.6.4 of the Austroads *Guide to Road Design* – Part 5 is accepted for this section, subject to the following amendments.

**Addition(s)**

1. Two generally accepted procedures for use with the Rational Method for the calculation of peak flow rates from partial areas are presented in the following sections. One method is for rural catchments and the other for urban catchments. It is recommended that the hydrologic assessment of catchments with unusual or widely varying surface features should be undertaken by the Hydraulics and Flooding Section, Engineering and Technology Branch or a suitably prequalified consultant using an appropriate numerical runoff-routing model.

2. Rational Method parameters including time of concentration methods shall comply with Sections 5.7.2 and 5.9 of this RDM.

5.10.1  **Rural catchments**

Section 6.6.4 of the Austroads *Guide to Road Design* – Part 5 is accepted for this section.

5.10.2  **Urban catchments**

Section 6.7.4 of the Austroads *Guide to Road Design* – Part 5 is accepted for this section.

5.11  **Progressive catchments**

Section 6.6.5 of the Austroads *Guide to Road Design* – Part 5 is accepted for this section subject to the following amendments.

**Addition(s)**

1. Should the situation occur in an urban environment where one stream crosses a road several times, then specialist assistance is required from either the Hydraulics and Flooding Section, Engineering and Technology Branch or a suitably prequalified consultant.

2. Rational Method parameters including time of concentration methods shall comply with Sections 5.7.2 and 5.9 of this RDM.

5.12  **Worked example (rural): rural runoff**

Refer Worked example 5A of this RDM.

5.13  **Worked example (urban): urban runoff**

Refer Worked example 5B of this RDM.
5A Work Example (Rural): Rural Run-off

This example describes the process used to determine the stormwater run-off from a simple rural catchment.

**Catchment characteristics:**

- Catchment Latitude -21.133 (S) and Longitude 148.563 (E)
- Catchment area = 40ha
- Catchment slope = 2.25% - (This is a measure of the average slope of the full drainage catchment, not the stream bed, thus, it is not the same as stream slope or 'equal area slope', please refer to section 4.6.11, part c of QUDM)
- Stream length = 1200m
- Figure 5A-1 summarizes the characteristic of the site which includes:
  - Country type = Rolling Country
  - Land description = Medium Density bush or good grass cover with Medium Soil permeability.

Figure 5A-1 defines the locality of the subject site.

*Figure 5A-1 – Catchment area*
The task for this example is to estimate the peak flow draining from the catchment for all design event AEPs (1%, 2%, 5%, 10%, 18%, 39% and 63%).

The Rational Method as prescribed in section 4.6 of QUDM will be used to assess peak flows for the different AEP flood events using Equation 4.2 as prescribed below (QUDM):

\[ Q = \left( \frac{C_y \cdot t \cdot I_y \cdot A}{360} \right) \]

Where:

- \( Q_y \) = Peak flow rate (m³/s) for Annual Exceedance Probability (AEP)
- \( C_y \) = Coefficient of discharge (Dimensionless)
- \( A \) = Area of Catchment (ha)
- \( t \cdot I_y \) = Average rainfall intensity (mm/h) for a design duration of 't' hours
- \( t \) = nominal design storm duration as defined by the time of concentration (\( t_c \))

**Step 1: Determine the Time of Concentration (\( t_c \)) as per section 4.6 of QUDM.**

The subject catchment has a slope of 2.25%, therefore using Table 4.6.6 of QUDM a stream velocity of 0.7m/s is adopted.

\[ t_c = \left( \frac{1.2 \cdot k \cdot 1000}{0.7 \cdot \frac{m}{s}} \right) \div 60 = 29 \text{ mins} \]

Note: Table 4.6.6 of QUDM is acceptable for catchment areas less than 5km².

**Step 2: Determine the coefficient of discharge (\( C_y \)) for all AEP events as per section 4.5 of QUDM.**

The recommended steps for determining coefficient of discharge (\( C_y \)) include:

1. Determine the fraction of impervious (\( f_i \)) for the catchment from Table 4.5.1 (QUDM)

   Fraction of impervious (\( f_i \)) = 0 (Open Space)

2. Determine the 1-hour rainfall intensity (\( I_{10} \)) for the 10-year ARI (10% AEP)

   **Table 5A-1 – Adopted IFD data (mm/h)**

<table>
<thead>
<tr>
<th>Duration</th>
<th>Duration in (mins)</th>
<th>63%</th>
<th>39%</th>
<th>18%</th>
<th>10%</th>
<th>5%</th>
<th>2%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 min</td>
<td>45</td>
<td>47.0</td>
<td>52.7</td>
<td>69.6</td>
<td>80.4</td>
<td>90.4</td>
<td>103</td>
<td>112</td>
</tr>
<tr>
<td>1 hour</td>
<td>60</td>
<td>39.7</td>
<td>44.6</td>
<td>59.5</td>
<td>69.1</td>
<td>78.0</td>
<td>89.3</td>
<td>97.6</td>
</tr>
<tr>
<td>1.5 hour</td>
<td>90</td>
<td>30.9</td>
<td>35.1</td>
<td>47.6</td>
<td>55.7</td>
<td>63.3</td>
<td>73.1</td>
<td>80.3</td>
</tr>
<tr>
<td>2 hour</td>
<td>120</td>
<td>25.8</td>
<td>29.4</td>
<td>40.5</td>
<td>47.8</td>
<td>54.7</td>
<td>63.6</td>
<td>70.2</td>
</tr>
</tbody>
</table>

   Rainfall Intensity (\( I_{10} \)) = 69.1mm/hr

3. Determine the 10-year discharge coefficient (\( C_{10} \)) from table 4.5.4 of QUDM.
   - Rainfall intensity (\( I_{10} \)) was previously calculated as 69.1mm/hr
   - It can be seen from Table 4.5.4 (QUDM) that intensity of 69.1mm/hr falls between standard duration of 65 – 70mm/hr. Thus, based on this, and the assumed site characteristics, the calculated discharge coefficient (\( C_{10} \)) is:

   \[ C_{10} = 0.66 \]
Step 3: Determine design rainfall intensity for each of the AEP design events.

For a time of concentration (tc) of 29 mins, the following rainfall intensity is applicable.

**Table 5A-2 – Rainfall intensity (mm/hr)**

<table>
<thead>
<tr>
<th>Duration in (mins)</th>
<th>63%</th>
<th>39%</th>
<th>18%</th>
<th>10%</th>
<th>5%</th>
<th>2%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>64.5</td>
<td>71.9</td>
<td>94.1</td>
<td>108.0</td>
<td>121.0</td>
<td>138.0</td>
<td>149.0</td>
</tr>
<tr>
<td>29</td>
<td>59.8</td>
<td>66.7</td>
<td>87.4</td>
<td>101.0</td>
<td>113.0</td>
<td>128.0</td>
<td>139.0</td>
</tr>
<tr>
<td>30</td>
<td>58.7</td>
<td>65.6</td>
<td>86.0</td>
<td>98.9</td>
<td>111.0</td>
<td>126.0</td>
<td>137.0</td>
</tr>
</tbody>
</table>

Step 4: Determine the design discharge for all AEP events.

Peak design discharge is calculated using equation 4.2 as prescribed in section 4.3 of QUDM.

**Table 5A-3 – Peak design discharge**

| AEP (%) | Frequency Factor 
| Factor ($f_i$) | Runoff Coefficients ($C_r$) | Intensity Frequency Duration (mm/hr) | Area (ha) | Discharge (m³/s) |
|---------|-----------------|----------------------------|-------------------------------------|----------|-----------------|
| 63%     | 0.80            | 0.53                       | 59.8                                | 40       | 3.5             |
| 39%     | 0.85            | 0.56                       | 66.7                                |          | 4.2             |
| 18%     | 0.95            | 0.63                       | 87.4                                |          | 6.1             |
| 10%     | 1.00            | 0.66                       | 101.0                               |          | 7.4             |
| 5%      | 1.05            | 0.69                       | 113.0                               |          | 8.7             |
| 2%      | 1.15            | 0.76                       | 128.0                               |          | 10.8            |
| 1%      | 1.20            | 0.79                       | 139.0                               |          | 12.2            |
5B Work Example (Road Drainage): Road Drainage Run-off

This example describes the process used to determine the stormwater run-off from a simple road drainage catchment.

Catchment Characteristics:

- Catchment Latitude -27.452 (S) and Longitude 152.988 (E)
- Catchment area = 0.2ha
- Catchment slope = 6% - (This is a measure of the average slope of the full drainage catchment, not the stream bed, thus, it is not the same as stream slope or 'equal area slope', please refer to section 4.6.11, part c of QUDM).
- Stream length = 190m

Figure 5B-1 defines the locality of the subject site.

Figure 5B-1 – Catchment area
The task for this example is to estimate the peak flow draining from the catchment for all design event AEPs (1%, 2%, 5%, 10%, 18%, 39% and 63%).

The Rational Method as prescribed in section 4.6 of QUDM will be used to assess peak flows for the different AEP flood events using Equation 4.2 as prescribed below (QUDM):

\[ Q = \frac{(C_y \cdot t \cdot I_y \cdot A)}{360} \]

Where:

- \( Q_y \) = Peak flow rate (m³/s) for Annual Exceedance Probability (AEP)
- \( C_y \) = Coefficient of discharge (Dimensionless)
- \( A \) = Area of Catchment (ha)
- \( t \cdot I_y \) = Average rainfall intensity (mm/h) for a design duration of 't' hours
- \( t \) = nominal design storm duration as defined by the time of concentration (t_c)

**Step 1: Determine the Time of Concentration (t_c) as per section 4.6 of QUDM.**

*Main Stream - Kerb flow travel time*

Using section 4.6.8 of QUDM calculated the time of flow in the kerb and channel for the main stream.

The length of the channel is calculated as 190m with a slope of 6.0%. Thus, using figure 4.6 of QUDM a travel time of 2mins was determined. Notwithstanding this, a minimum \( t_c \) of 5mins was adopted.

**Step 2: Determine the coefficient of discharge (C_{10}) for all AEP events as per section 4.5 of QUDM.**

The recommended steps for determining coefficient of discharge (C_y) include:

1. Determine the fraction of impervious (fi) for the catchment from Table 4.5.1
   
   Fraction of impervious (fi) = 1.0 (Road and Kerb and Channel)

2. Determine the 1-hour rainfall intensity (\(^{1}I_{10}\)) for the 10-year ARI (10%AEP)

**Table 5B-1 – Adopted IFD data (mm/h)**

<table>
<thead>
<tr>
<th>Duration</th>
<th>Duration in (mins)</th>
<th>63%</th>
<th>39%</th>
<th>18%</th>
<th>10%</th>
<th>5%</th>
<th>2%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 min</td>
<td>30</td>
<td>53.8</td>
<td>61.0</td>
<td>83.1</td>
<td>98.0</td>
<td>112.0</td>
<td>131.0</td>
<td>146.0</td>
</tr>
<tr>
<td>45 min</td>
<td>45</td>
<td>41.8</td>
<td>47.3</td>
<td>64.7</td>
<td>76.4</td>
<td>88.0</td>
<td>103.0</td>
<td>115.0</td>
</tr>
<tr>
<td>1 hour</td>
<td>60</td>
<td>34.5</td>
<td>39.0</td>
<td>53.4</td>
<td>63.3</td>
<td>73.0</td>
<td>86.0</td>
<td>96.0</td>
</tr>
<tr>
<td>1.5 hour</td>
<td>90</td>
<td>26.0</td>
<td>29.4</td>
<td>40.4</td>
<td>48.1</td>
<td>55.6</td>
<td>65.9</td>
<td>73.8</td>
</tr>
</tbody>
</table>

Rainfall Intensity (\(^{1}I_{10}\)) = 63.3 mm/hr

3. Determine the 10-year discharge coefficient (C_{10}) from table 4.5.3 of QUDM.
   - Rainfall intensity (\(^{1}I_{10}\)) was calculated as 63.3 mm/hr
   - It can be seen from table 4.5.3 that intensity of 63.3 mm/hr falls between standard duration of 60 – 64 mm/hr. Thus, based on this, and the assumed site characteristics, the calculated coefficient (C_{10}) is:

\[ C_{10} = 0.9 \]
Step 3: Determine design rainfall Intensity for each of the AEP design events.

For a time of concentration ($t_c$) of 5mins, the following rainfall intensity is applicable.

**Table 5B-2 – Rainfall Intensity (mm/hr)**

<table>
<thead>
<tr>
<th>Duration in (mins)</th>
<th>63%</th>
<th>39%</th>
<th>18%</th>
<th>10%</th>
<th>5%</th>
<th>2%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>116.0</td>
<td>131.0</td>
<td>179.0</td>
<td>212.0</td>
<td>243.0</td>
<td>286.0</td>
<td>317.0</td>
</tr>
<tr>
<td>5</td>
<td>111.0</td>
<td>126.0</td>
<td>171.0</td>
<td>202.0</td>
<td>232.0</td>
<td>272.0</td>
<td>302.0</td>
</tr>
<tr>
<td>10</td>
<td>91.5</td>
<td>104.0</td>
<td>141.0</td>
<td>166.0</td>
<td>190.0</td>
<td>221.0</td>
<td>244.0</td>
</tr>
</tbody>
</table>

Step 4: Determine the design discharge for all AEP events.

Peak design discharge is calculated using equation 4.2 as prescribed in section 4.3 of QUDM.

**Table 5B-3 – Peak design discharge**

<table>
<thead>
<tr>
<th>AEP (%)</th>
<th>Frequency Factor ($f_y$)</th>
<th>Runoff Coefficients ($C_r$)</th>
<th>Intensity Frequency Duration (mm/hr)</th>
<th>Area (ha)</th>
<th>Discharge (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>63%</td>
<td>0.80</td>
<td>0.72</td>
<td>111</td>
<td>0.20</td>
<td>0.04</td>
</tr>
<tr>
<td>39%</td>
<td>0.85</td>
<td>0.77</td>
<td>126</td>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td>18%</td>
<td>0.95</td>
<td>0.86</td>
<td>171</td>
<td></td>
<td>0.08</td>
</tr>
<tr>
<td>10%</td>
<td>1.00</td>
<td>0.90</td>
<td>202</td>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td>5%</td>
<td>1.05</td>
<td>0.95</td>
<td>232</td>
<td></td>
<td>0.12</td>
</tr>
<tr>
<td>2%</td>
<td>1.15</td>
<td>1.00</td>
<td>272</td>
<td></td>
<td>0.16</td>
</tr>
<tr>
<td>1%</td>
<td>1.20</td>
<td>1.00</td>
<td>302</td>
<td></td>
<td>0.18</td>
</tr>
</tbody>
</table>