CHAPTER 2 HYDROLOGY

2.1 Scope

This section sets forth the hydrologic parameters to be used in computations to determine volumes and peak rates of storm water runoff.

2.2 Computation Methods for Runoff

Runoff rates to be accommodated by each element of the proposed storm drainage system shall be calculated using the criteria of this section for land use runoff factors, rainfall, and system time.

Any nationally accepted computer modeling program using NRCS methodologies such as WinTR-55, HEC-HMS, Haestad Methods, InteliSOLVE or others as approved by the Director is acceptable.

The following methods of computations are allowed for the following drainage areas:

TABLE 2.2.1

<table>
<thead>
<tr>
<th>Computational Method</th>
<th>0-20 Acres</th>
<th>20-100 Acres</th>
<th>More than 100 Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rational *</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>NRCS Methodology *</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

* All Modeling requiring a hydrograph shall be done using NRCS Methodology.

2.2.1 Rational Method

The Rational Method may be used to calculate peak rates of runoff to elements of enclosed and open channel systems, including inlets, when the total upstream area tributary to the point of consideration is less than 100 acres. The Rational Method is defined as follows:

\[ Q = KCiA \]

where

\[ Q = \text{Peak rate of runoff to system in cfs} \]

\[ C = \text{Runoff coefficient as determined in accordance with Table 2.2.1.2} \]

\[ i = \text{Rainfall intensity in inches per hour as determined in accordance with Figure 2.2.1.1 in Appendix F.} \]
$K =$ Dimensionless coefficient to account for antecedent precipitation as follows, except the product of $C \cdot K$ shall not exceed 1.0.

**TABLE 2.2.1.1**

**ANTICEDENT PRECIPITATION COEFFICIENTS**

<table>
<thead>
<tr>
<th>Design Storm</th>
<th>$K$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% and more frequent</td>
<td>1.0</td>
</tr>
<tr>
<td>4%</td>
<td>1.1</td>
</tr>
<tr>
<td>2%</td>
<td>1.2</td>
</tr>
<tr>
<td>1%</td>
<td>1.25</td>
</tr>
</tbody>
</table>

**TABLE 2.2.1.2**

**RUNOFF COEFFICIENTS**

<table>
<thead>
<tr>
<th>LAND USE/ZONING</th>
<th>AVERAGE PERCENT IMPERVIOUS</th>
<th>AVERAGE PERCENT PERVIOUS</th>
<th>RATIONAL METHOD “C”</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Business</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Downtown Area</td>
<td>95</td>
<td>5</td>
<td>0.87</td>
</tr>
<tr>
<td>Neighborhood Areas</td>
<td>85</td>
<td>15</td>
<td>0.81</td>
</tr>
<tr>
<td>2. Residential</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-Family Areas</td>
<td>35</td>
<td>65</td>
<td>0.51</td>
</tr>
<tr>
<td>Multifamily Areas</td>
<td>60</td>
<td>40</td>
<td>0.66</td>
</tr>
<tr>
<td>Churches &amp; Schools</td>
<td>75</td>
<td>25</td>
<td>0.75</td>
</tr>
<tr>
<td>3. Industrial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light Areas</td>
<td>60</td>
<td>40</td>
<td>0.66</td>
</tr>
<tr>
<td>Heavy Areas</td>
<td>80</td>
<td>20</td>
<td>0.78</td>
</tr>
<tr>
<td>Parks, Cemeteries</td>
<td>10</td>
<td>90</td>
<td>0.36</td>
</tr>
<tr>
<td>Railroad Yard Areas</td>
<td>25</td>
<td>75</td>
<td>0.45</td>
</tr>
<tr>
<td>4. Undeveloped Areas</td>
<td>0</td>
<td>100</td>
<td>0.3</td>
</tr>
</tbody>
</table>
TABLE 2.2.1.2 Continued

<table>
<thead>
<tr>
<th>LAND USE/ZONING</th>
<th>AVERAGE PERCENT IMPERVIOUS</th>
<th>AVERAGE PERCENT PERVIOUS</th>
<th>RATIONAL METHOD “C”</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Surfaces</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impervious: asphalt</td>
<td>100</td>
<td>0</td>
<td>0.9</td>
</tr>
<tr>
<td>Concrete, roofs, etc.</td>
<td>0</td>
<td>100</td>
<td>0.3</td>
</tr>
<tr>
<td>Turfed Areas</td>
<td>100</td>
<td>0</td>
<td>0.9</td>
</tr>
<tr>
<td>Wet detention basins</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rational Method “C” for Non-Standard Land Use/Zoning Classifications

The “C” value can be calculated from any type of land use and known percent impervious surface from the following equation:

\[ C = 0.3 + 0.6 \times I \]  
where:
\[ I = \text{percent impervious divided by 100} \]

Unzoned But Master Planned Areas

Areas whose future land use is defined by an adopted land use plan shall be assigned runoff coefficients for the land use indicated on such plan.

3. Agricultural and Unplanned Areas

Proposed Conditions: Undeveloped areas designated as agricultural or those areas for which no specific land use is indicated shall be assigned a minimum of 35% impervious surface for purposes of the design of storm drainage systems (C=0.51).

4. Time of Concentration

Time of Concentration (\( T_C \)) is equal to the overland flow time to the most upstream inlet or other point of entry to the system, Inlet Time (\( T_I \)), plus the time for flow in the system to travel to the point under consideration, Travel Time (\( T_T \)).

\[ T_C = T_I + T_T \]
Inlet Time

$T_I$ shall be calculated by the following formula or determined graphically from Figure 2.2.1.2 in Appendix F, but shall not be less than 5.0 minutes nor greater than 15.0 minutes:

$$T_I = 1.8 \cdot \frac{(1.1 - C)D^{1/2}}{S^{1/3}}$$

where:

$T_I$ = Inlet Time in minutes

$C$ = Rational Method Runoff Coefficient as determined in accordance with this section

$D$ = Overland flow distance parallel to slope in feet

$S$ = Slope of tributary area surface perpendicular to contour in percent.

Travel Time

$T_T$ shall be calculated as the length of travel in the channelized system divided by the velocity of flow. Velocity shall be calculated by Manning's equation assuming all system elements are flowing full without surcharge. Travel time may be determined graphically from Figure 2.2.1.3 in Appendix F in lieu of calculation.

Modeling Unimproved Areas Upstream

When the upstream area is unimproved, use $T_I = 15$ minutes for the first 100’ from the most distant ridge line. Then use the following table to calculate $T_t$ to account for future development.

<table>
<thead>
<tr>
<th>AVERAGE CHANNEL SLOPE</th>
<th>VELOCITY IN FT/SEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>PERCENT</td>
<td></td>
</tr>
<tr>
<td>&lt; 2</td>
<td>7</td>
</tr>
<tr>
<td>2 to 5</td>
<td>10</td>
</tr>
<tr>
<td>&gt; 5</td>
<td>15</td>
</tr>
</tbody>
</table>
2.2.2 NRCS Unit Hydrograph Method

NRCS methodologies must be used for areas 100 acres or larger and for detention basin routing and may be used for areas less than 100 acres. The NRCS unit hydrograph method includes the use of the NRCS unit hydrograph, the Type II rainfall distribution, 24-hour storm duration and NRCS TR-55 or WinTR55 methodologies for calculating time of concentration and runoff coefficients with the following exception: overland flow length in the time of concentration calculation is limited to 100 feet (as established in the most current version of TR-55).

A. The rainfall depths for Boone County Missouri are:

<table>
<thead>
<tr>
<th>Recurrence Interval</th>
<th>% chance in given year</th>
<th>Depth (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>3.5</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>4.5</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>5.2</td>
</tr>
<tr>
<td>25</td>
<td>4</td>
<td>5.9</td>
</tr>
<tr>
<td>50</td>
<td>2</td>
<td>6.6</td>
</tr>
<tr>
<td>100</td>
<td>1</td>
<td>7.3</td>
</tr>
</tbody>
</table>

B. Runoff Coefficients:

**Standard Land Use/Zoning Classifications.** Runoff coefficients for various land use and zoning classifications by soil group may be found in Table 2.2.2.2 in Appendix F. This information is also available in TR-55 and WinTR-55, a free program available on the National Resource Conservations Service’s website.

**Composite Coefficients.** For areas not listed in Table 2.2.2.2 (office parks, shopping centers, trailer parks, etc.), a composite runoff coefficient based on the actual percentages of pervious and impervious surfaces shall be used.

**Curve Number Coefficients for disturbed soils.** All Curve Numbers for disturbed soils or soils to be disturbed shall be one letter greater than the Curve Number in the undisturbed condition.
Cur**ve Number Coefficients for water quality.** Areas with water quality practices shall have runoff curve numbers calculated according to Section 2.3 in this chapter.

**Unzoned But Master Planned Areas.** Areas whose future land use is defined by an adopted land use plan shall be assigned runoff coefficients for the land use indicated on such plan.

**Agricultural and Unplanned Areas.**

1. **Existing Conditions**

   For purposes of determination of development impact, undeveloped areas whose current land use is agriculture (crops, pasture, meadow) shall be assigned a maximum of 0% impervious surface or a maximum Curve Number of 78 (equivalent to good condition pasture, grassland or range on D soils).

2. **Proposed Conditions**

   Undeveloped areas designated as agricultural or those areas for which no specific land use is indicated shall be assigned a minimum of 35% impervious surface for purposes of the design of storm drainage systems (CN = 89).

3. **Redevelopment Areas**

   Areas in redevelopment shall be assigned a maximum Curve Number of 78 (equivalent to good condition pasture, grassland or range on D soils) for the pre-redevelopment condition.
C. Rainfall Mass

Two rainfall mass distributions are acceptable for modeling: the NRCS Type 2, twenty-four hour rainfall distribution, and the Huff distribution from Bulletin 71 – Rainfall Frequency Atlas of the Midwest. The distributions are given in Appendix F in Tables 2.2.2.3 and 2.2.2.4 respectively.

*NRCS Type 2

The NRCS Type 2 distribution is based upon Technical Paper 40, Rainfall Frequency Atlas of the United States published in 1961. The distribution is maximized so that shorter more intense rainfalls are built into the distribution. This allows peak flows for short times of concentration to be calculated using a 24-hour storm, but this distribution is not based upon observed rain events. The Type 2 distribution is built into most hydrology software and does not need to be input.

Huff Distribution

The Huff Distribution comes from Bulletin 71, Rainfall Frequency Atlas of the Midwest (Huff and Angel, 1992) published by NOAA and the Illinois State Water Survey. The “Huff Distribution” is actually a family of curves applicable to different sized watersheds and different types of storms. The distribution is expressed as cumulative percentages of total duration and total rainfall accumulation. The table given in Appendix F is for drainage areas less than 10 square miles. For larger areas, refer to Bulletin 71.

Four distributions are given in Table 2.2.2.4. Each distribution represents the quartile of a storm in which the majority of rain falls, and each is associated with a different storm duration. Storms with durations of 6 hours or less, 6 to 12 hours, 12 to 24 hours, and greater than 24 hours tend to be associated with the first, second, third, and fourth quartile respectively. The vast majority of modeling within the City will require use of the first quartile distribution.

D. Unit Hydrographs

The NRCS Dimensionless Unit Hydrograph (either curvilinear or triangular) shall be the basis for computation of runoff hydrographs.
E. Time of Concentration and Lag Time

Time of Concentration for NRCS methods shall be calculated using the method described in TR-55. Except that the maximum overland flow length shall be 100 feet.

Modeling Unimproved Areas Upstream

When the upstream area is unimproved, use \( T_i = 15 \) minutes for the first 100’ from the most distant ridge line. Then use the following table to calculate \( T_t \) to account for future development.

<table>
<thead>
<tr>
<th>AVERAGE CHANNEL SLOPE</th>
<th>VELOCITY IN FT/SEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>PERCENT</td>
<td></td>
</tr>
<tr>
<td>&lt; 2</td>
<td>7</td>
</tr>
<tr>
<td>2 to 5</td>
<td>10</td>
</tr>
<tr>
<td>&gt; 5</td>
<td>15</td>
</tr>
</tbody>
</table>

Lag Time

Lag Time \( (T_L) \) is the calculated time between the maximum rainfall intensity of a storm and the point of maximum discharge on the outlet hydrograph. Lag Time is used instead of time of concentration for unit hydrograph models. It shall be calculated as \( \frac{3}{5} \)th the time of concentration \( (T_c) \). The NRCS software, TR-55 and WinTR-55 calculate and apply lag time automatically. In other software the lag time may need to be calculated from \( T_c \) as indicated above and input into the program.

F. Hydrograph Routing

Routing of hydrographs through storage elements or reservoirs shall be by modified-Puls level pool routing. Routing through channels shall be by the Muskingum-Cunge method.

G. Calibration and Model Verification

All design discharge estimates should be calibrated to the extent possible using reliable gauge data, high water marks, or historical accounts. Model results should be evaluated to verify that they are reasonably conservative as compared to observed data and standard practice. Model calibration shall not be used to justify discharge estimates that are lower than those provided by the baseline unit.
hydrograph method, unless unusual site specific factors justify, where
the hydrologic impact of such factors must be thoroughly examined
and documented. Engineers shall recognize the significant uncertainty
associated with design discharge estimates and provide estimates that
are reasonably conservative and protective of the public interest. To
permit model verification, discharge rates (expressed as absolute
discharge or discharge per acre of tributary area) shall be plotted
relative to tributary area and compared to regression formula results,
gauge estimates, and/or known historical extremes.
2.3 WATER QUALITY HYDROLOGY METHODS

Sizing BMPs properly is critical to their success. Design detention and retention BMPs to capture and treat the Water Quality Volume (WQv). Design conveyance BMPs to handle peak discharge of the WQv. WQv is defined as the storage needed to capture and treat 90 percent of the average annual stormwater runoff volume. WQv is based on the Water Quality Storm and volumetric runoff coefficient and site area. The Water Quality Storm is defined as the storm event that produces less than or equal to 90 percent volume of all 24-hour storms on an annual basis. The Water Quality Storm rainfall for Columbia is 1.3 inches.

Two methods can be used to estimate the WQv for a proposed development—the Short-Cut Method and the Small-Storm Hydrology Method. Use the Short-Cut Method (Claytor and Schueler 1996) only for sites with one predominant type of cover and a drainage area less than 10 acres:

\[ WQv = P \times Rv \]

Where:

- \( WQv \) = Water Quality Volume (in watershed inches)
- \( P \) = Rainfall event in inches (the Water Quality Storm or other appropriate amount, with the approval of the city engineer)
- \( Rv \) = Volumetric runoff coefficient
  
  \[ 0.05 + 0.009(I) \]
- \( I \) = Percent site imperviousness

The Small Storm Hydrology Method (Claytor and Schueler 1996) is based on the volumetric runoff coefficient (\( Rv \)), which accounts for specific characteristics of the pervious and impervious surfaces of the drainage catchment. This method may be used for all drainage areas. \( Rv \)'s used to compute the volume of runoff are identified in Table 2.3.1. The Small Storm Hydrology Method is:

\[ WQv = P \times \text{Weighted } Rv \]

Where:

\[ \text{Weighted } Rv = \sum (Rv_i \times Ac_i) / \text{Total Acreage} \]

- \( Rv_i \) = Volumetric runoff coefficient for impervious cover type \( i \)
- \( Ac_i \) = Acreage of impervious cover type \( i \)
- Total Acreage = Total acreage of the drainage area

A reduction factor may be applied to the \( Rv \) values for drainage areas with disconnected impervious surfaces. The pervious surface flow path below an impervious area must be at least twice the length of the impervious flow path and some method must be used to spread the flow to a similar width as the impervious width. The reduction factors are provided in Table 2.3.2.
### TABLE 2.3.1

**VOLUMETRIC COEFFICIENTS FOR URBAN RUNOFF FOR DIRECTLY CONNECTED IMPERVIOUS AREAS**  
(CLAYTOR AND SCHUELER 1996)

<table>
<thead>
<tr>
<th>Rainfall (inches)</th>
<th>Flat roofs and large unpaved parking lots</th>
<th>Pitched roofs and large impervious areas (large parking lots)</th>
<th>Small impervious areas and narrow streets</th>
<th>Silty soils HSG-B</th>
<th>Clayey soils HSG-C and D</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75</td>
<td>0.82</td>
<td>0.97</td>
<td>0.66</td>
<td>0.11</td>
<td>0.20</td>
</tr>
<tr>
<td>1.00</td>
<td>0.84</td>
<td>0.97</td>
<td>0.70</td>
<td>0.11</td>
<td>0.21</td>
</tr>
<tr>
<td>1.25</td>
<td>0.86</td>
<td>0.98</td>
<td>0.74</td>
<td>0.13</td>
<td>0.22</td>
</tr>
<tr>
<td>1.30</td>
<td>0.86</td>
<td>0.98</td>
<td>0.74</td>
<td>0.13</td>
<td>0.22</td>
</tr>
<tr>
<td>1.50</td>
<td>0.88</td>
<td>0.99</td>
<td>0.77</td>
<td>0.15</td>
<td>0.24</td>
</tr>
</tbody>
</table>

### TABLE 2.3.2

**REDUCTION FACTORS TO VOLUMETRIC RUNOFF COEFFICIENTS FOR DISCONNECTED IMPERVIOUS SURFACES**  
(CLAYTOR AND SCHUELER 1996)

<table>
<thead>
<tr>
<th>Rainfall (inches)</th>
<th>Strip commercial and shopping center</th>
<th>Medium-to-high-density residential with paved alleys</th>
<th>Medium-to-high-density residential without alleys</th>
<th>Low-density residential</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75</td>
<td>0.99</td>
<td>0.27</td>
<td>0.21</td>
<td>0.20</td>
</tr>
<tr>
<td>1.00</td>
<td>0.99</td>
<td>0.38</td>
<td>0.22</td>
<td>0.21</td>
</tr>
<tr>
<td>1.25</td>
<td>0.99</td>
<td>0.48</td>
<td>0.22</td>
<td>0.22</td>
</tr>
<tr>
<td>1.30</td>
<td>0.99</td>
<td>0.50</td>
<td>0.22</td>
<td>0.22</td>
</tr>
<tr>
<td>1.50</td>
<td>0.99</td>
<td>0.59</td>
<td>0.24</td>
<td>0.24</td>
</tr>
</tbody>
</table>

To convert $WQ_v$ from watershed inches to volume in cubic feet:

$$WQ_v\text{ (in cubic feet)} = \frac{WQ_v\text{ (in watershed inches)}}{12}\times A$$

where: $A =$ Watershed area (in square feet)
To size a conveyance BMP correctly, calculate the peak discharge for the Water Quality Storm. Use the following procedure for estimating the peak discharge for the Water Quality Storm (Claytor and Schueler 1996):

1. Calculate a Curve Number (CN) based on the previously calculated WQv:

\[
CN = \frac{1000}{[10 + 5P + 10Q - 10(Q^2 + 1.25QP)^{1/2}]} 
\]

where

- \( P \) = Water Quality Storm rainfall (inches)
- \( Q \) = Runoff volume (inches)—equal to WQv (watershed inches)

2. Determine Time of Concentration (Tc):

\[
Tc = \left( \frac{L^{0.8} \left[(1000/CN)-9\right]^{0.7}}{1140 \times Y^{0.5}} \right)
\]

where

- \( Tc \) = Time of concentration (hours)
- \( L \) = Flow length (feet)
- \( CN \) = Runoff Curve Number
- \( Y \) = Average watershed slope (percent)

Use a minimum of 0.1 hours for Tc.

3. Use Table 2.3.3 or TR-55 to determine Initial Abstraction (Ia).
### TABLE 2.3.3

**Ia VALUES FOR VARIOUS CURVE NUMBERS**

<table>
<thead>
<tr>
<th>Curve Number</th>
<th>Ia (in.)</th>
<th>Curve Number</th>
<th>Ia (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>61</td>
<td>1.279</td>
<td>78</td>
<td>0.564</td>
</tr>
<tr>
<td>62</td>
<td>1.226</td>
<td>79</td>
<td>0.532</td>
</tr>
<tr>
<td>63</td>
<td>1.175</td>
<td>80</td>
<td>0.500</td>
</tr>
<tr>
<td>64</td>
<td>1.125</td>
<td>81</td>
<td>0.469</td>
</tr>
<tr>
<td>65</td>
<td>1.077</td>
<td>82</td>
<td>0.439</td>
</tr>
<tr>
<td>66</td>
<td>1.030</td>
<td>83</td>
<td>0.410</td>
</tr>
<tr>
<td>67</td>
<td>0.985</td>
<td>84</td>
<td>0.381</td>
</tr>
<tr>
<td>68</td>
<td>0.941</td>
<td>85</td>
<td>0.353</td>
</tr>
<tr>
<td>69</td>
<td>0.899</td>
<td>86</td>
<td>0.326</td>
</tr>
<tr>
<td>70</td>
<td>0.857</td>
<td>87</td>
<td>0.299</td>
</tr>
<tr>
<td>71</td>
<td>0.817</td>
<td>88</td>
<td>0.273</td>
</tr>
<tr>
<td>72</td>
<td>0.778</td>
<td>89</td>
<td>0.247</td>
</tr>
<tr>
<td>73</td>
<td>0.740</td>
<td>90</td>
<td>0.222</td>
</tr>
<tr>
<td>74</td>
<td>0.703</td>
<td>91</td>
<td>0.198</td>
</tr>
<tr>
<td>75</td>
<td>0.667</td>
<td>92</td>
<td>0.174</td>
</tr>
<tr>
<td>76</td>
<td>0.632</td>
<td>93</td>
<td>0.151</td>
</tr>
<tr>
<td>77</td>
<td>0.597</td>
<td>94</td>
<td>0.128</td>
</tr>
</tbody>
</table>

#### 4. Compute Ia/P and use Figure 2.3.1 in Appendix F or Exhibit 4-II in TR-55 to determine the unit peak discharge (qu) for the appropriate Tc.

If Ia/P is outside of the limiting values of Figure 2.3.1, the limiting value should be used.

**Convert this value from cfs/sm/in to cfs/ac/in, multiplying by (1 square mile/640 acre).**

#### 5. Calculate the peak discharge:

\[ Q_p = qu \times A \times WQv \]

where

- **Qp** = Peak discharge (cubic feet per second [cfs])
- **qu** = Unit peak discharge (cubic feet per second/acre/inch of runoff)
- **A** = Drainage area (acres)
WQv = Water Quality Volume (watershed inches)

For computing runoff volume and peak rate for storms larger than the Water Quality Storm, use the published CN’s from TR-55, and follow the prescribed procedures in TR-55 or other approved methods.

WATER QUALITY HYDROLOGY EXAMPLE CALCULATIONS

Example 1

3-acre office park, 70% Impervious, 30% Lawn and Landscaping

Flow length = 400 feet, average watershed slope = 4%

Calculate WQv in watershed inches:

Because this is a small site with one predominant type of cover, use the Short-Cut Method.

\[ P = 1.3 \text{ inches} \]
\[ Rv = 0.056 + 0.009 \times 70\% = 0.68 \]
\[ WQv = (1.3)(0.68) = 0.88 \text{ watershed inches} \]

Convert WQv to cubic feet:

\[
WQv = \frac{0.88 \text{ in}}{12 \text{ in/ft}} \times 3 \text{ acres} \times \frac{43560 \text{ ft}^2}{\text{acre}} = 9583.2 \text{ ft}^3
\]
Calculate peak discharge for the Water Quality Storm:

1. \[ CN = \frac{1000}{[10 + 5 \times 1.3 + 10 \times 0.88 - 10(0.88^2 + 1.25 \times 0.88 \times 1.3)^{1/2}]} \]
   \[ = 95.7 \]

2. \[ Tc = \frac{(400^{0.8} \times [\frac{1000}{95.7} - 9]^{0.7})}{(1140 \times 4^{0.5})} \]
   \[ = 0.07 \text{ hours} \]

*Use 0.10 hours (minimum Tc)

3. from Table 4-1 in TR-55

<table>
<thead>
<tr>
<th>CN</th>
<th>Ia</th>
</tr>
</thead>
<tbody>
<tr>
<td>95</td>
<td>0.105</td>
</tr>
<tr>
<td>96</td>
<td>0.083</td>
</tr>
</tbody>
</table>

Using linear interpolation, \( CN = 95.7, Ia = 0.090 \)

4. \[ Ia/P = \frac{0.090}{1.3} = 0.07 \]
   From Figure 2.3.1 in Appendix F, the limiting value for \( Ia/P = 0.10 \).
   Therefore using \( Ia/P = 0.10 \),
   \[ qu = \frac{1000 \text{ cfs / sm / in}}{640 \text{ acre}} \times \frac{1 \text{ sm}}{640 \text{ acre}} \]
   \[ = 1.56 \text{ cfs / ac / in} \]

5. \[ Qp = (1.56 \text{ cfs / ac / in})(3 \text{ ac})(0.88 \text{ in}) \]
   \[ = 4.12 \text{ cfs} \]
Example 2

12 – acre commercial development and park, 2 acres flat rooftops, 2.3 acres impervious parking, 0.7 acres narrow streets, 7 acres green space (hydrologic soils group C).

Flow length = 1000 feet, Average watershed slope = 2%

Calculate WQv in watershed inches:

Use Small Storm Hydrology Method.

\[
P = 1.3 \text{ inches}
\]

Weighted \( R_v \) = \[
\frac{(0.86)(2 \text{ ac}) + (0.98)(2.3 \text{ ac}) + (0.75)(0.7 \text{ ac}) + (0.22)(7 \text{ ac})}{12 \text{ ac}}
\]

= 0.50

\[
WQv = (1.3 \text{ in})(0.50)
\]

= 0.65 watershed inches

Convert WQv to cubic feet:

\[
WQv = \frac{0.65\text{in} * 12\text{ac} * 43560\text{ft}^2}{12\text{in} / \text{ft}}
\]

= 28314 ft³

Calculate peak discharge for the Water Quality Storm:

1. \[
CN = \frac{1000}{[10 + 5 * 1.3 + 10 * 0.65 - 10(0.65^2 + 1.25 * 0.65 * 1.3)^{1/2}]} = 92.3
\]

2. \[
Tc = \frac{(1000^{0.8} [ (1000 / 92.3) - 9]^{0.7})}{(1140 * 2^{0.5})}
\]

= 0.24 hours
3. From Table 2.3.3,
   \( CN = 92 \), \( I_a = 0.174 \)
   \( CN = 93 \), \( I_a = 0.151 \)

   Using linear interpolation, \( CN = 92.3 \), \( I_a = 0.167 \)

4. \( I_a/P = 0.13 \)
   From Figure 2.3.1 in Appendix F,
   \[
   qu = 750 \text{ cfs / sm / in} \times \frac{1 \text{ sm}}{640 \text{ acre}}
   \]

   \( qu = 1.17 \text{ cfs / ac / in} \)

5. \( Q_p = (1.17 \text{ cfs / ac / in})(12 \text{ ac})(0.65 \text{ in}) \)
   \[
   = 9.13 \text{ cfs}
   \]
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