Appendix D: Stormwater Facility Sizing Methods

There are two methods for sizing stormwater facilities: 1) the Simple Method and 2) the Engineered Method.

Simple Method

The Simple Method uses pre-defined sizing factors to size stormwater facilities based on the amount of new or replaced impervious area which will be added. Background and instructions for using this method are contained in **section 2, "Stormwater Facility Sizing and Submittals."**

The sizing factors in the Simple Sizing Form were calculated using a spreadsheet based on the Santa Barbara Urban Hydrograph following the SCS Type 1A 24-hour storm event using a 10-year event (3.6"/24-hours; see **Table D-1**) where that storm event was stored without overflow from a facility when using the assumed infiltration rates for type A, B, C, and D soils listed in **Table D-2**. Note that in order to meet the requirements outlined in the SWMM, a facility meeting the Simple Method may still need an overflow if the facility cannot retain the 100-year event.

For any project where the sizing factor on the Simple Sizing Form would require facilities larger than those listed in the stormwater management options (**section 1.2.4**), an on-site stormwater facility meeting the sizing requirements for Type A soils may be installed (assumed to treat the water quality event), and then the Engineered Method must be used to design a downstream centralized facility to detain and provide flow control to meet the requirements in **section 1.0**.

Projects in Type C and D soils that use the Simple Sizing Form to size lot-level facilities for water quality only (use Type A soil sizing factor) must then use the Engineered Method to size a downstream facility to provide detention and flow control. **Downstream facilities designed in this manner can assume a 50% reduction in impervious area draining from water quality treated areas for hydrological calculations.**

Engineered Method

The Engineered Method uses hydraulic and hydrologic engineering calculations to size stormwater facilities. This appendix provides requirements for the various hydrologic and hydraulic calculations necessary to determine runoff, flow, volume, storage, conveyance capacity, etc.

Impervious area utilized in calculations may be reduced per the guidelines in **Section 3.1** "Impervious Area Reduction." Hydrologic analysis requirements can be found in **Section 2.3.2** "Engineered Method." The information provided in this appendix is intended to provide guidance for making consistent hydrologic calculations that will be submitted to the City for review.

D.1. Engineered Method Requirements

To meet Design Standard requirements according to the Engineered Method, stormwater facility design flows and volumes shall be determined using the methods, assumptions and inputs specified in this appendix.

For every project, the impervious area shall include the total proposed impervious area, including all streets, driveways, redeveloped areas, and tentative building footprints based on the allowed building coverage and setbacks per the zoning code.

A. Drainage Areas

All hydrologic analyses must include the drainage area of the site being evaluated and all of the upstream contributing basin area, including those areas outside the proposed development site. Drainage calculations for flow control analysis shall include both the pre-developed and the post-developed drainage conditions within the proposed development site.

B. Acceptable Analytical Methods

Facilities may be sized by routing a hydrograph through the facility (rate-based facilities with a storage volume component) using a continuous simulation program (using a minimum of 20 years of Gresham rainfall data) or a single-storm hydrograph-based analysis method. The preferred single-storm hydrograph method for calculating stormwater runoff for stormwater treatment and flow control is the Santa Barbara Urban Hydrograph (SBUH) Method. The Soil Conservation Service Type 1-A, 24-hour rainfall distribution, shall be used in all single storm hydrograph methods.

C. Hydrograph Methods

The following conditions shall be met when evaluating the basin area characteristics using a hydrograph method.

1. Pre-development Conditions

Develop a runoff hydrograph based on the pre-development site conditions including the contributing pervious and impervious areas along with their associated runoff curve numbers. The curve numbers (CN) that should be used are available in **Table D-3.**

2. Post-development Conditions

A runoff hydrograph shall be created from an accurate characterization of the post-development site conditions. The runoff hydrograph shall include the contributing pervious and impervious areas along with their associated runoff CN values (see **Table D-3**). Sub-basins shall be delineated and routed together when appropriate. A separate analysis of just the impervious area shall also be performed. The larger of the two hydrographs shall be used for design.

D. Rational Method

The Rational Method may only be used to determine the peak flow for sizing conveyance systems with contributing drainage areas less than ten acres. Since conveyance systems are designed for post-development conditions, **the time of concentration shall be a maximum of ten minutes and a minimum of five minutes.**

D.2. Stormwater Treatment and Flow Control Design Storm Events

As specified in Section 1 "Requirements", where stormwater treatment facilities are required, they must be designed to treat 80 percent of the average annual rainfall – this water quality event is equal to 1.2 inches in a 24-hour period.

For sites where full retention/infiltration is not feasible, the methods described in this appendix shall be used to demonstrate that the post-development runoff volumes and flow rates are controlled so that:

- The 2-year, 24-hour post-development peak flow rate is restricted to at least one-half of the 2-year, 24-hour pre-development design storm peak flow; and
- Post-development flows from the 10-, and 25-year, 24-hour design storm peak flows are equal to or less than the predevelopment 10-, and 25-year design storm at 24-hour levels.

D.3. Hydrograph Methods

A hydrograph method, such as the Santa Barbara Urban Hydrograph (SBUH) method, shall be used to determine the design flows and volumes for all stormwater facilities when using the Engineered Method. Hydrograph methods use the physical characteristics of the site and a design storm to determine the magnitude, volume, and duration of the runoff hydrograph if a software package is utilized. Documentation of the software used shall be submitted with the results, along with all assumptions and input values.

The typical input information needed for hydrograph methods are:

1. Basin area characteristics – pervious and impervious land areas
2. 24-hour type 1A rainfall distribution
3. Total 24-hour rainfall amount
4. Runoff Curve Numbers (CN) applicable to site
5. Time of Concentration

D.3.1 Basin Area Characteristics

For the highest degree of accuracy in hydrograph analysis, proper selection of homogeneous basin areas is needed. Significant differences in land use within a given basin must be addressed by dividing the basin area into sub-basins with similar land use and/or runoff characteristics. Hydrographs should be computed for each sub-basin area and superimposed to form the total runoff hydrograph for the basin.

All pervious and impervious areas within a given basin or sub-basin shall be analyzed separately. By analyzing pervious and impervious areas separately, the cumulative errors associated with averaging these areas are avoided, resulting in a more accurate runoff hydrograph.

D.3.2 Rainfall Distribution and Depth

The rainfall distribution to use within the City is the design storm for a 24-hour duration based on the standard NRCS Type 1A rainfall distribution. This distribution is contained in **Table D-5**.

Table D-1 contains the 24-hour rainfall totals that shall be used in determining the runoff hydrograph for various sized storm events.

Table D-1. 24-hour rainfall depths for Gresham, OR

Recurrence Interval (Years)	WQ	2	10	25	50	100
24-hour Rainfall (inches)	1.2	2.8	3.6	4.0	4.4	4.9

D.3.3 Runoff Curve Number (CN)

Runoff curve numbers were developed by the Natural Resources Conservation Service (NRCS) after studying the runoff characteristics of various types of land. Curve numbers (CN) were developed to consolidate diverse characteristics such as soil type, land usage, and vegetation into a single variable for computing runoff.

Runoff CNs to be used in the hydrograph methods are included in **Table D-3**. The CN values are based on the hydrologic soil groups described in **Tables D-2a** and **D-2b**. For developments doing stormwater quality treatment at the localized scale and treating 50% of the impervious surface as pervious, the CN value for "lawn/landscaped areas with amended soils" shall be used for that modeled impervious surface.

The CN values in **Table D-3** are for wet antecedent moisture conditions. Wet conditions assume previous rainstorms have reduced the capacity of soil to absorb water. Given the frequency of rainstorms in the Gresham area, wet conditions are most likely, and give conservative hydrographic values.

Table D-2a. Gresham soil types from the Natural Resource Conservation Service's (NRCS) Soil Survey of Multnomah County (1983, Table 24). The NRCS soil maps can be found on-line at https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm.

Soil Survey Map ID#	Soil Group	Hydrologic Soil Group
1	Aloha silt loam	C
2	Aloha-Urban land complex	C
7	Cascade silt loam	C
10	Cornelius silt loam	C
25	Latourell loam	B
26	Latourell-Urban land complex	B
29	Multnomah silt loam	B
30	Multnomah-Urban land complex	B
34	Powell silt loam	D
36	Quafeno loam	C
37	Quatama loam	C

Soil Survey Map ID#	Soil Group	Hydrologic Soil Group
38	Quatama-Urban land complex	C
40	Rafton silt loam	C/D
45	Sauvie silt loam	C/D
46	Sauvie silty clay loam	C/D
51	Urban land-Latourell complex	B
54	Urban land- Quatama complex	C
55	Wapato silt loam	D
57	Wollent silt loam	D

Table D-2b. Hydrologic soil group descriptions from NRCS. The assumed infiltration rates in this table are the values used in developing the Simple Sizing Form and are listed for reference. These should not be used for the Engineered Method, as those projects require infiltration testing following guidance in **Appendix E**.

NRCS Hydrologic Soil Group	Assumed Infiltration Rate	Description
Group A	4"/hour	Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist chiefly of deep, well drained to excessively drained sands or gravels. These soils have a high rate of water transmission.
Group B	2"/hour	Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.
Group C	0.5"/hour	Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils that have a layer that impedes the downward movement of water or soils that have a moderately fine texture or fine texture. These soils have a slow rate of water transmission.
Group D	0.1"/hour	Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clay soils that have a high shrink-swell potential, soils that have a permanent high water table, soils that have a fragipan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

Source: USDA/NRCS National Engineering Handbook, Chapter 7 "Hydrologic Soil Groups" (2007)

Table D-3. Runoff Curve Number (CN) values for NRCS Hydrologic Soil Groups

Cover Description	A	B	C	D
Pervious Surfaces				
Compacted lawn.	68	79	86	89

Cover Description	A	B	C	D
Un-amended soil				
Pasture or grass/lawn with **amended soil**	39	61	74	80
Grass/Woods combination	32	58	72	79
Forest/Woods	30	55	70	77
Impervious Surfaces				
Paved roads, parking lots, roofs, driveways	98	98	98	98
Gravel roads and parking areas	76	85	89	91
Compacted Dirt	72	82	87	89
Green Practices				
Pervious Pavement	76	85	89	91
Trees	36	60	73	79
Green Roof	61	61	61	61
Infiltration and Filtration Stormwater Planter	30	48	65	73

Sources: Pervious and impervious values are from National Engineering Handbook (2004). Values for green practices come from Portland's Stormwater Management Manual

D.3.4 Time of Concentration (T_c)

Time of concentration, T_c, is the time for a theoretical drop of water to travel from the furthest point in the drainage basin to the facility being designed.

T_c is derived by calculating the overland flow time of concentration and the channelized flow time of concentration. T_c depends on several factors, including ground slope, ground roughness, and distance of flow.

Total time of concentration should be a minimum of 10 minutes for pre-developed conditions and a minimum of 5 and maximum of 10 minutes for post-developed conditions. However, if the portion of the contributing area within 300' upstream of the developed site will remain in an undeveloped condition and is 50% or more of the total contributing area, the post-developed Tc shall be calculated and documented by the engineer of record and may exceed 10 minutes.

Calculations for total T_c should be divided into three segments: sheet flow, shallow concentrated flow, and channel/pipe flow. The total time of concentration (T_c) is calculated as:

$$T_c = T_{osf} + T_{scf} + T_{ocf}$$

Time of concentration for overland sheet flow (T_{osf}). For the first 300 feet of overland flow, the sheet flow time of concentration can be calculated with the kinematic wave equation:

$$Sheet\ flow\ T_{osf} = \frac{0.42(nL)^{0.8}}{P^{0.5} * s^{0.4}}$$

T_{osf}	=	Flow time for overland sheet flow (minutes)
L	=	Overland Flow Length (feet)
n	=	Manning's Roughness Coefficient (See **Table D-4**)
P	=	Rainfall event (inches/24 hours)
s	=	Average Slope of Overland Area (foot/foot)

Time of concentration for shallow concentrated flow (T_{scf}). For overland flow distances greater than 300 feet, sheet flow typically becomes shallow concentrated flow. The average velocity for this flow can be determined from **Figure D-2**, where the average velocity is a function of watercourse slope and surface type.

$$Shallow\ concentrated\ flow, T_{scf} = \frac{L}{60(V)(s)^{0.5}}$$

Tscf	=	Flow time for shallow concentrated flow (minutes)
L	=	Flow Length (feet)
V	=	Velocity Factor Coefficient
s	=	Slope of Land Segment (feet/feet)

Time of concentration for open channel flow (T_{ocf}). For open channels, Manning's equation should be used to estimate average flow velocity.

$$Open\ channel\ flow, T_{ocf} = \frac{L}{60(V)(s)^{0.5}}$$

T_{ocf}	=	Flow Time for open channel flow (minutes)
L	=	Flow Length (feet)
V	=	Flow Velocity (feet/second) (See **Figure D-2**)
s	=	Slope of Land Segment (feet/feet)

Table D-4. Manning's Roughness Coefficients for Overland Sheet Flow

Surface Types:	**n**
Impervious Areas	0.014
Gravel Pavement	0.02
Developed: Landscape Areas (Except Lawns)	0.08
Undeveloped: Meadow, Pasture, or Farm	0.15
Developed: Lawns	0.24
Pre-developed: Mixed	0.30
Pre-developed: Woodland and Forest	0.40
Development Types:	**n**
Commercial Development	0.015
Industrial Development, Heavy	0.04
Industrial Development, Light	0.05
Dense Residential (over 6 units/acre)	0.08
Normal Residential (3 to 6 units/acre)	0.20
Light Residential (1 to 3 units/acre)	0.30
Parks	0.40

D.4. Santa Barbara Urban Hydrograph (SBUH) Equations

Abstract Runoff Value $$S = \left(\frac{1000}{CN}\right) - 10$$

Runoff Depth $$D(t) = \frac{(Pt-0.2(S))^2}{(Pt+0.8(S))}$$

Total Runoff $$R(t) = D(t) - D(t-1)$$

Instantaneous Hydrograph $$I(t) = \frac{60.5\big(R(t)\big)A}{dt}$$

Design Flow Rate $$Q(t+1) = Q(t) + w(I(t) + I(t+1) - 2Q(t))$$

Where:

CN = Curve Number

D(t) = Depth of Runoff at Time (t)

Pt = Precipitation for the Time Increment

A = Basin Area in acres

Dt = Time Interval in Ten Minute Increments

w = $dt/(2T_c + dt)$

T_c = Time of Concentration for the Drainage Basin

Storage Determination

Inflow–Outflow=Change in Storage $$[(I_1 + I_2)/2] – [(O_1 + O_2)/2] = S_1 – S_2$$

Where:

I	=	Inflow at Time 1 and Time 2
O	=	Outflow at Time 1 and Time 2
S	=	Storage at Time 1 and Time 2

The time interval, Δt, must be consistent with the time interval used in developing the inflow hydrograph. The time interval used for a 24-hour storm is ten minutes. The terms I_1, I_2, O_1, and S_1 are known from the inflow hydrograph and from the storage and outflow values of the previous time step. The unknowns O_2 and S_2 can be solved iteratively from the given stage-storage and stage-discharge curves.

Figure D-1. Average velocity of shallow concentrated flow. From Figure III-2 in *Soil Conservation Service Handbook (1972).*

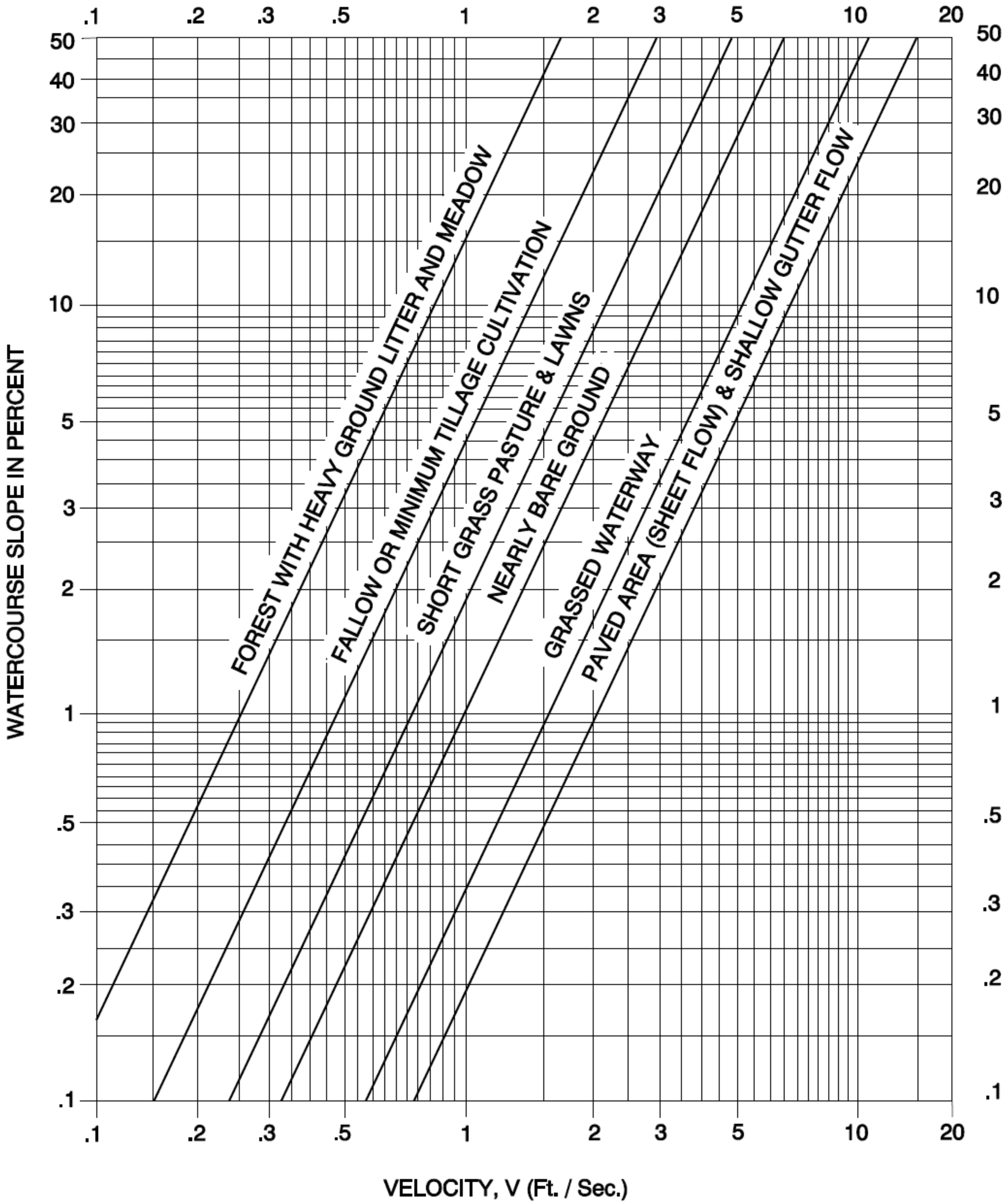


Table D-5. NRCS 24-Hour Type IA Rainfall Distribution

Time from Start of Storm (Minutes)	% Rainfall	Cumulative % Rainfall	**Time from Start of Storm (Minutes)**	% Rainfall	Cumulative % Rainfall	**Time from Start of Storm (Minutes)**	% Rainfall	Cumulative % Rainfall	**Time from Start of Storm (Minutes)**	% Rainfall	Cumulative % Rainfall
10	0.40	0.40	**370**	0.95	22.57	**730**	0.72	67.40	**1090**	0.40	86.00
20	0.40	0.80	**380**	0.95	23.52	**740**	0.72	68.12	**1100**	0.40	86.40
30	0.40	1.20	**390**	0.95	24.47	**750**	0.72	68.84	**1110**	0.40	86.80
40	0.40	1.60	**400**	0.95	25.42	**760**	0.72	69.56	**1120**	0.40	87.20
50	0.40	2.00	**410**	1.34	26.76	**770**	0.57	70.13	**1130**	0.40	87.60
60	0.40	2.40	**420**	1.34	28.10	**780**	0.57	70.70	**1140**	0.40	88.00
70	0.40	2.80	**430**	1.34	29.44	**790**	0.57	71.27	**1150**	0.40	88.40
80	0.40	3.20	**440**	1.80	31.24	**800**	0.57	71.84	**1160**	0.40	88.80
90	0.40	3.60	**450**	1.80	33.04	**810**	0.57	72.41	**1170**	0.40	89.20
100	0.40	4.00	**460**	3.40	36.44	**820**	0.57	72.98	**1180**	0.40	89.60
110	0.50	4.50	**470**	5.40	41.84	**830**	0.57	73.55	**1190**	0.40	90.00
120	0.50	5.00	**480**	2.70	44.54	**840**	0.57	74.12	**1200**	0.40	90.40
130	0.50	5.50	**490**	1.80	46.34	**850**	0.57	74.69	**1210**	0.40	90.80
140	0.50	6.00	**500**	1.34	47.68	**860**	0.57	75.26	**1220**	0.40	91.20
150	0.50	6.50	**510**	1.34	49.02	**870**	0.57	75.83	**1230**	0.40	91.60
160	0.50	7.00	**520**	1.34	50.36	**880**	0.57	76.40	**1240**	0.40	92.00
170	0.60	7.60	**530**	0.88	51.24	**890**	0.50	76.90	**1250**	0.40	92.40
180	0.60	8.20	**540**	0.88	52.12	**900**	0.50	77.40	**1260**	0.40	92.80
190	0.60	8.80	**550**	0.88	53.00	**910**	0.50	77.90	**1270**	0.40	93.20
200	0.60	9.40	**560**	0.88	53.88	**920**	0.50	78.40	**1280**	0.40	93.60
210	0.60	10.00	**570**	0.88	54.76	**930**	0.50	78.90	**1290**	0.40	94.00
220	0.60	10.60	**580**	0.88	55.64	**940**	0.50	79.40	**1300**	0.40	94.40
230	0.70	11.30	**590**	0.88	56.52	**950**	0.50	79.90	**1310**	0.40	94.80
240	0.70	12.00	**600**	0.88	57.40	**960**	0.50	80.40	**1320**	0.40	95.20
250	0.70	12.70	**610**	0.88	58.28	**970**	0.50	80.90	**1330**	0.40	95.60
260	0.70	13.40	**620**	0.88	59.16	**980**	0.50	81.40	**1340**	0.40	96.00
270	0.70	14.10	**630**	0.88	60.04	**990**	0.50	81.90	**1350**	0.40	96.40
280	0.70	14.80	**640**	0.88	60.92	**1000**	0.50	82.40	**1360**	0.40	96.80
290	0.82	15.62	**650**	0.72	61.64	**1010**	0.40	82.80	**1370**	0.40	97.20
300	0.82	16.44	**660**	0.72	62.36	**1020**	0.40	83.20	**1380**	0.40	97.60
310	0.82	17.26	**670**	0.72	63.08	**1030**	0.40	83.60	**1390**	0.40	98.00
320	0.82	18.08	**680**	0.72	36.80	**1040**	0.40	84.00	**1400**	0.40	98.40
330	0.82	18.90	**690**	0.72	64.52	**1050**	0.40	84.40	**1410**	0.40	98.80
340	0.82	19.72	**700**	0.72	65.24	**1060**	0.40	84.80	**1420**	0.40	99.20
350	0.95	20.67	**710**	0.72	65.96	**1070**	0.40	85.20	**1430**	0.40	99.60
360	0.95	21.62	**720**	0.72	66.68	**1080**	0.40	85.60	**1440**	0.40	100.0

D.5. Rational Method

The rational method may be used for analyzing conveyance from small drainage basins, ten acres or less in size, with the following restrictions:

1. May only be used for determining the peak flow for determining the required capacity of conveyance elements.

2. The time of concentration shall be a maximum of ten minutes and a minimum of five minutes.

3. For areas larger than ten acres in size, one of the hydrograph methods listed in the next section shall be used to determine the peak flow conditions.

Rational Method Equation

The rational method calculation shall be made as follows: $Q = C_y \times C \times I \times A$

Q	=	Peak flow (cubic feet/second)
C_y	=	Runoff Coefficient adjustment factor (see **Table D-7** for Runoff Coefficient Adjustment Factors)
C	=	Runoff Coefficient
I	=	Rainfall Intensity (inches/hour)
A	=	Drainage Area (acres)

Runoff Coefficient "C"

The runoff coefficient is difficult to estimate because it represents the interaction of many complex factors including surface ponding, infiltration, antecedent moisture, ground cover conditions, ground slopes, and soil type. The actual runoff coefficient for a given drainage basin can best be approximated by calculating a weighted average of all distinct surface types:

$$C_{av} = \frac{\sum C_x A_x}{A_{total}}$$

Table D-6. Runoff Coefficients (C)

Developed Surface Types	Flat 0% to 2%	Rolling 2% to 10%	Hilly Over 10%
Impervious Areas	0.9	0.9	0.9
Gravel Pavement	0.5	0.55	0.6
Landscape Areas (Except Lawns)	0.3	0.35	0.4
Lawns	0.17	0.22	0.35
Pre-developed Surface Types			
Meadow, Pasture, or Farm	0.25	0.3	0.35
Mixed	0.15	0.2	0.25
Woodland and Forest	0.1	0.15	0.2
Development Types			
Commercial Development	0.8	0.85	0.9
Industrial Development, Heavy	0.7	0.8	0.9
Dense Residential (over 6 units/acre)	0.7	0.75	0.8
Industrial Development, Light	0.6	0.7	0.8
Normal Residential (3 to 6 units/acre)	0.5	0.55	0.6
Light Residential (1 to 3 units/acre)	0.35	0.4	0.45
Parks	0.15	0.2	0.25

Runoff Coefficient Adjustment Factor

The runoff coefficients listed in **Table D-6**, above, are applicable for a storm with a recurrence interval of ten years or less. Less frequent, higher intensity storms require adjusted runoff coefficients because infiltration and other losses have a proportionally smaller effect on runoff. Runoff coefficient adjustment factors (C_y) for storms of different recurrence intervals are listed in **Table D-7**.

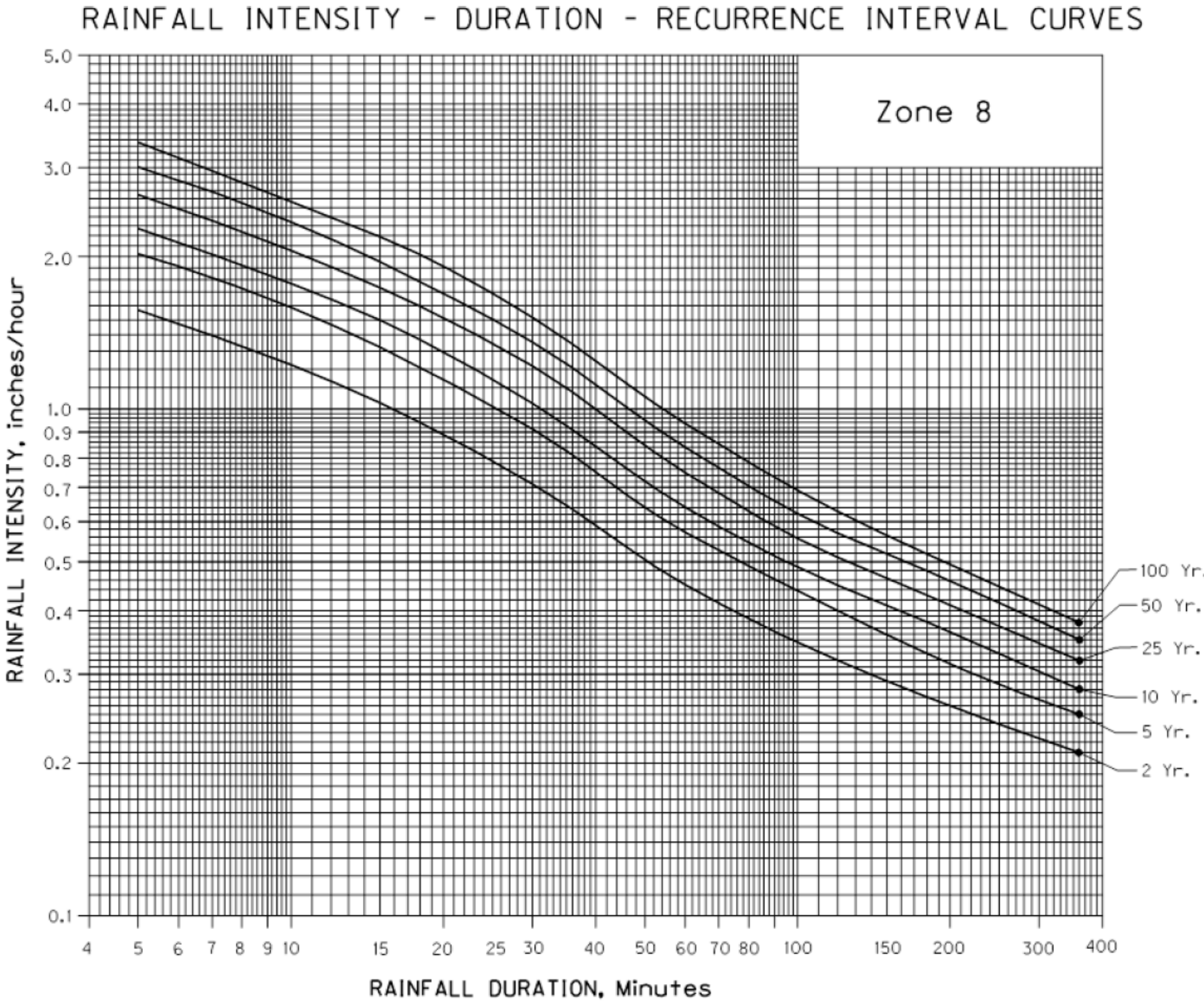
Table D-7. Runoff Coefficient Adjustment Factors

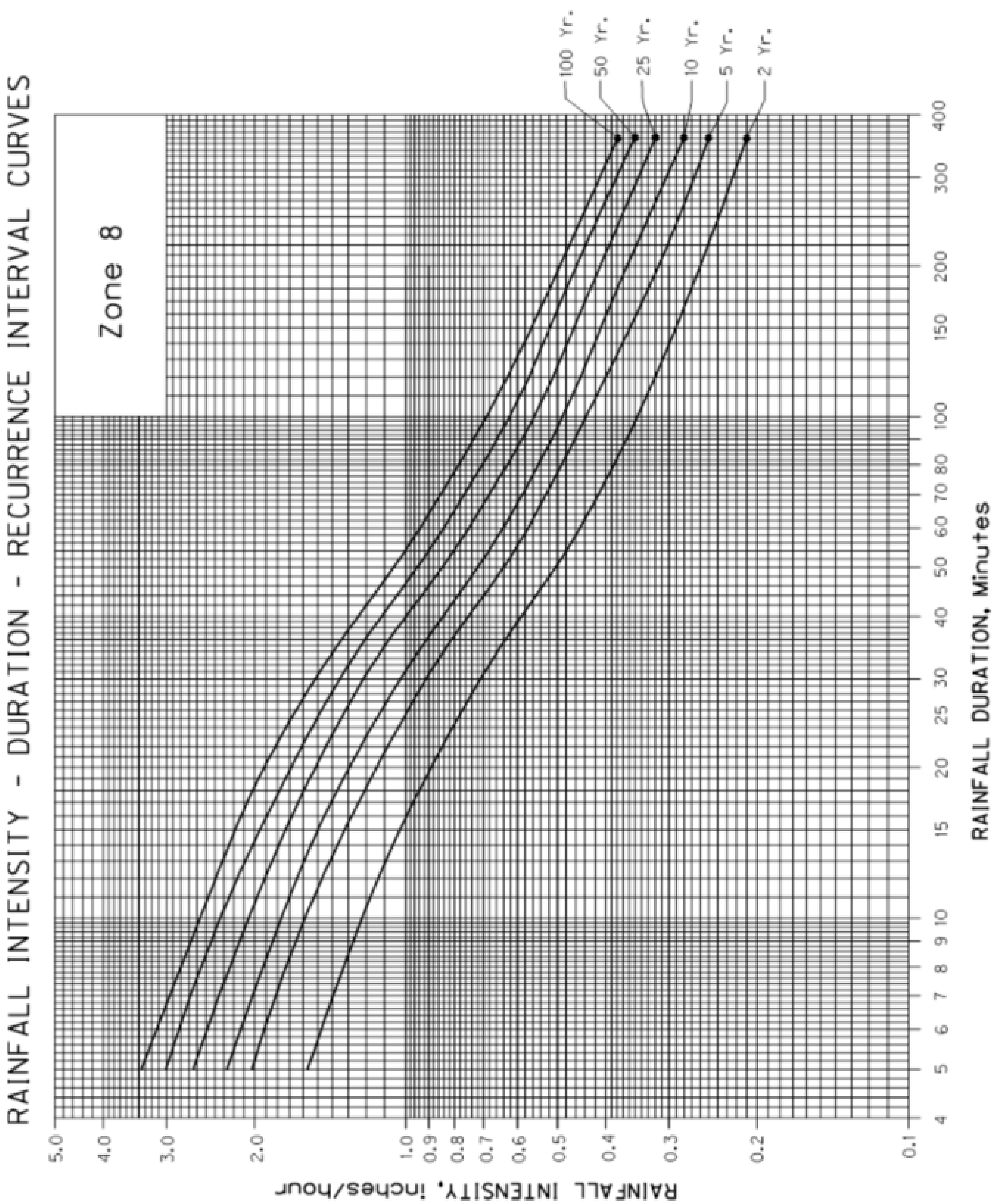
Recurrence Interval	Runoff Coefficient Adjustment Factor (C_y)
10 years or less	1.0
25 years	1.1
50 years	1.2
100 years	1.25

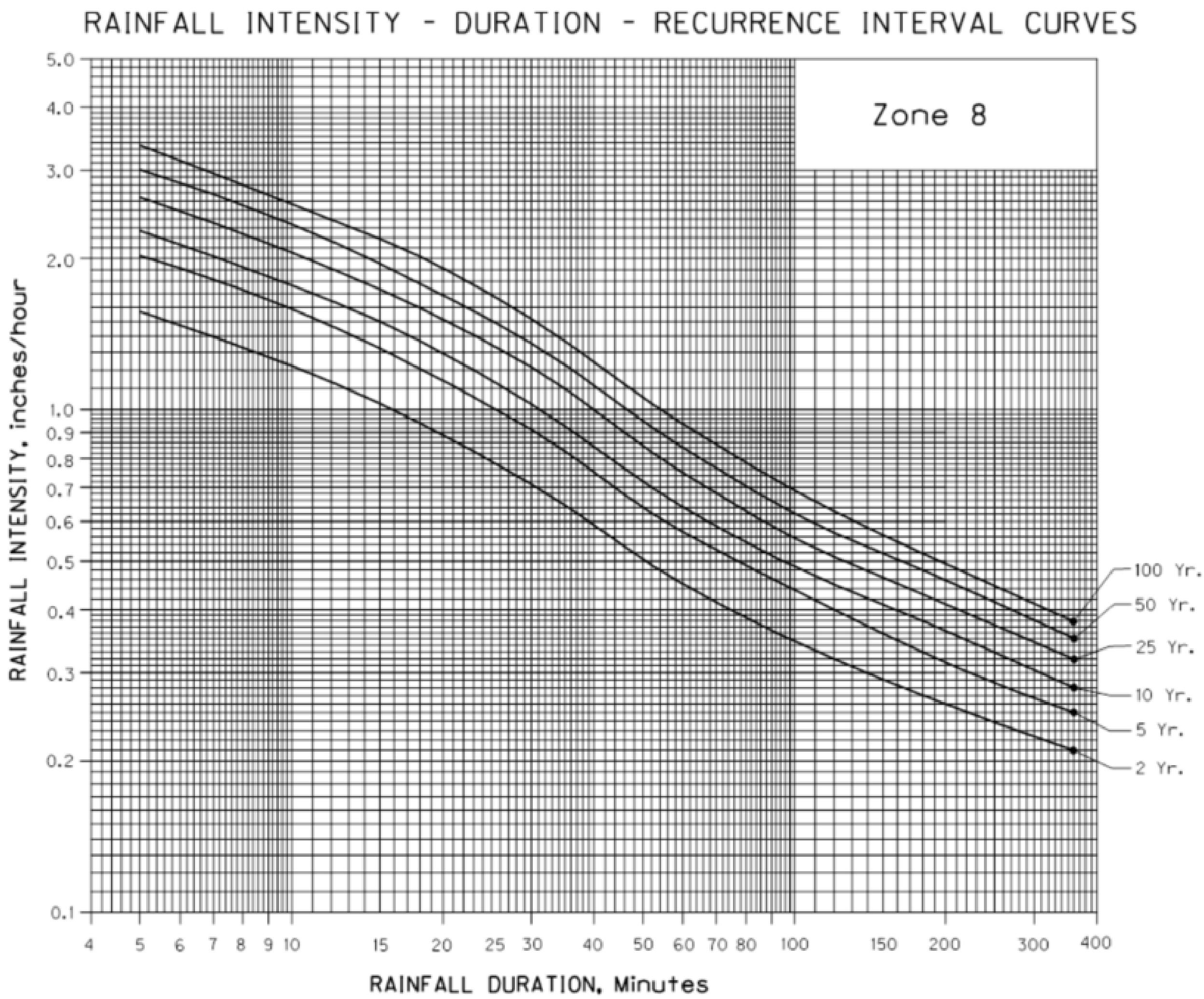
Rainfall Intensity "I"

The cumulative rainfall intensity shall be derived from the Rainfall Intensity-Duration-Frequency curve (Gresham is in Zone 8, see **Figure D-2**). The design storm interval is typically based on the longest time of concentration for the drainage area.

Figure D-2. Rainfall Intensity-Duration-Frequency curve




RAINFALL INTENSITY - DURATION - RECURRENCE INTERVAL CURVES
Zone 8
100 Yr.
50 Yr.
25 Yr.
10 Yr.
5 Yr.
2 Yr.
RAINFALL DURATION, Minutes
4
5
6
7
8
9
10
15
20
25
30
40
50
60
70
80
100
150
200
300
400
RAINFALL INTENSITY, inches/hour
5.0
4.0
3.0
2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


RAINFALL INTENSITY - DURATION - RECURRENCE INTERVAL CURVES
Zone 8
RAINFALL INTENSITY, inches/hour
5.0
4.0
3.0
2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
4
5
6
7
8
9
10
15
20
25
30
40
50
60
70
80
100
150
200
300
400
RAINFALL DURATION, Minutes
100 Yr.
50 Yr.
25 Yr.
10 Yr.
5 Yr.
2 Yr.