SECTION 2 – DETERMINATION OF STORM RUNOFF

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2.1.0 GENERAL

If continuous records of the amounts of runoff from urban areas were as readily available as records of precipitation, they would provide the best source of data on which to base the design of storm drainage and flood protection systems. Unfortunately, such records are available in very few areas in sufficient quantity to permit an accurate prediction of the stormwater runoff. The accepted practice, therefore, is to relate runoff to rainfall, thereby providing a means for predicting the amount of runoff to be expected from urban watersheds at given recurrence intervals.

Numerous methods of rainfall runoff computations are available on which the design of storm drainage systems may be based. The method chosen is dependent upon the Engineer's technical familiarity and the size of the area to be analyzed. For the method chosen the Engineer will be responsible for making reasonable assumptions as to the development characteristics of the study area.

2.1.1 RAINFALL APPLICATION INSTRUCTIONS FOR HYDROLOGIC ANALYSES AND DESIGNS

The City of Round Rock has developed and adopted guidelines for hydrologic analyses and designs for application of rainfall estimates data and for implementation of runoff determination methods associated with hydrologic analyses and designs. These guidelines are entitled Rainfall Application Instructions for Hydrologic Analyses and Designs (hereinafter referred to as “the RAIn”) and are attached to this Section 2 as Appendix A.

2.2.0 EFFECTS OF URBANIZATION

It has long been recognized that urban development has a pronounced effect on the rate of runoff from a given rainfall event. The hydraulic efficiency of a drainage area is generally increased as a byproduct of urbanization which in effect reduces the storage capacity of a watershed. This reduction of a watershed's storage capacity is a direct result of the elimination of pervious surfaces, small ponds, and holding areas. This comes about by the grading and paving of building sites, streets, drives, parking lots, and sidewalks and by construction of buildings and other facilities characteristic of urban development. The result of the improved hydraulic efficiency is illustrated graphically in Figure 2-1 in Appendix B of this Manual, which is a plot of the runoff rate versus time for the same storm with two different stages of watershed development.

2.2.1 Design Assumptions for Stormflow Analysis

A. When analyzing an area for channel design purposes, urbanization of the full watershed without detention ponds shall be assumed (except as noted in paragraph E. below). Zoning maps, future land use maps, and master plans should be used as aids in establishing the anticipated surface character of the ultimate development.

The selection of design runoff coefficients and/or percent impervious cover factors are explained in the following discussions of runoff calculation.

B. An exception to paragraph A. above may be granted if the channel is immediately downstream of a regional detention pond and written approval is obtained from the Director of the Utilities and Environmental Services Department (hereinafter, the “UES Director”).

C. In designing a storm sewer system within a residential subdivision, full development of adjoining and interior tracts without detention must be assumed.

D. In designing a storm sewer system within a commercial or multifamily subdivision, stormflows can, at the Engineer's discretion, reflect the flow reduction anticipated by future detention ponds. This applies exclusively to the flows generated by those properties contained within the subdivision. Provisions for conveyance of the 1% annual chance (100-year) undetained flows within the right-of-way or drainage easements still apply (See Section 1.2.2C.).

E. In the event the Engineer desires to incorporate the flow reduction benefits of existing upstream detention ponds, the following field investigations and hydrologic analysis <u>will be required</u>: (Please note that under no circumstances will the previously approved construction plans of the upstream ponds suffice as an adequate analysis. While the responsibility of the individual site or subdivision plans rests with the Engineer of record, any subsequent engineering analysis must assure that all the incorporated ponds work collectively.)

1. A field survey of the existing physical characteristics of both the outlet structure and ponding volume. Any departure from the original Engineer's design must be accounted for. If a dual use for the detention pond exists, (e.g., storage of equipment) then this too should be accounted for.
2. A comprehensive hydrologic analysis which simulates the attenuation of the contributing area ponds. This should not be limited to a linear additive analysis but rather a network of hydrographs which considers incremental timing of discharge and potential coincidence of outlet peaks.

F. For new developments on undeveloped properties that are included within a preliminary plat approved by the City prior to October 1, 2020 for which drainage infrastructure has been comprehensively designed and constructed for the approved preliminary plat area, the Engineer of Record will be required to use the RAIn for on-site runoff conveyance design. For these cases, where the existing system(s) may not completely accommodate the proposed design runoff to the City drainage standards when calculated by the RAIn, the City may still administratively approve the design as long as adverse flooding is not caused for the subject site or other landowners. Adverse flooding in this context will refer to flooding that causes identifiable damage to buildings or vehicles, or that harms people.

2.3.0 METHOD OF ANALYSIS

Numerous methods of rainfall-runoff computation are available on which the design of storm drainage and flood control systems may be based. The Rational Method is acceptable as adequate for drainage areas totaling 100 acres or less; however, its use may be more problematic for the Engineer when Times of Concentration exceed 15 minutes and/or when complex hydrologic routing is required. For larger drainage areas, the Natural

Resource Conservation Service (NRCS) hydrologic method should be used. Alternate methods of analysis may be used, provided any such alternate method has been generally accepted within the engineering community, is properly justified, and is approved by the UES Director. The method of analysis must remain consistent when drainage areas are combined and the method which applies to the largest combined drainage area should be used.

2.4.0 RATIONAL METHOD

The Rational Method is based on the direct relationship between rainfall and runoff, and is expressed by the following equation:

$$Q_p = CiA \qquad \text{(Eq. 2-1)}$$

Where:

Q_p is defined as the peak runoff in cubic feet per second. Actually, Q_p is in units of inches per hour per acre. Since this rate of in/hr/ac differs from cubic feet per second by less than one (1) percent (1 in/hr/ac = 1.008 cfs), the more common units of cfs are used.

C is the coefficient of runoff representing the ratio of peak runoff rate "Q_p" to average rainfall intensity rate "i" for a specified area "A".

i is the average intensity of rainfall in inches per hour for a period of time equal to the time of concentration (t_c) for the drainage area to the point under consideration.

A is the area in acres contributing runoff to the point of design.

The following basic assumptions are associated with the Rational Method:

A. The storm duration is equal to the time of concentration.

B. The computed peak rate of runoff at the design point is a function of the average rainfall rate during the time of concentration at that point.

C. The return period or frequency of the computed peak flow is the same as that for the design storm.

D. The necessary basin characteristics can be identified and the runoff coefficient does not vary during a storm.

E. Rainfall intensity is constant during the storm duration and spatially uniform for the area under analysis.

2.4.1 Runoff Coefficient (C)

The proportion of the total rainfall that will reach the drainage system depends on the imperviousness of the surface and the slope and ponding characteristics of the area. Impervious surfaces, such as asphalt pavements and roofs of buildings, will be subject to approximately one hundred (100) percent runoff (regardless of the slope). On-site inspections and aerial photographs may prove valuable in estimating the nature of the surfaces within the drainage area.

The runoff coefficient "C" in the Rational Formula is also dependent on the character of the soil. The type and condition of the soil determines its ability to absorb precipitation. The rate at which a soil absorbs precipitation generally decreases as the rainfall continues for an extended period of time. The soil infiltration rate is influenced by the presence of soil moisture (antecedent precipitation), the rainfall intensity, the proximity of the ground water table, the degree of soil compaction, the porosity of the subsoil, and ground slopes.

It should be noted that the runoff coefficient "C" is the variable of the Rational Method which is least susceptible to precise determination. A reasonable coefficient must be chosen to represent the integrated effects of infiltration, detention storage, evaporation, retention, flow routing and interception, all of which affect the time distribution and peak rate of runoff.

Table 2- 1 presents recommended ranges for "C" values based on specific land use types.

TABLE 2- 1
RATIONAL METHOD RUNOFF COEFFICIENTS FOR COMPOSITE ANALYSIS
Runoff Coefficient (C)

Character of Surface	Return Period						
	2 Years	5 Years	10 Years	25 Years	50 Years	100 Years	500 Years
DEVELOPED							
Asphaltic	0.73	0.77	0.81	0.86	0.90	0.95	1.00
Concrete	0.75	0.80	0.83	0.88	0.92	0.97	1.00
Grass Areas (Lawns, Parks, etc.)							
*Poor Condition**							
Flat, 0-2%	0.32	0.34	0.37	0.40	0.44	0.47	0.58
Average, 2-7%	0.37	0.40	0.43	0.46	0.49	0.53	0.61
Steep, over 7%	0.40	0.43	0.45	0.49	0.52	0.55	0.62
*Fair Condition***							
Flat, 0-2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2-7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
*Good Condition****							
Flat, 0-2%	0.21	0.23	0.25	0.29	0.32	0.36	0.49
Average, 2-7%	0.29	0.32	0.35	0.39	0.42	0.46	0.56
Steep, over 7%	0.34	0.37	0.40	0.44	0.47	0.51	0.58
UNDEVELOPED							
Cultivated							
Flat, 0-2%	0.31	0.34	0.36	0.40	0.43	0.47	0.57
Average, 2-7%	0.35	0.38	0.41	0.44	0.48	0.51	0.60
Steep, over 7%	0.39	0.42	0.44	0.48	0.51	0.54	0.61

TABLE 2- 1 (Continued)
RATIONAL METHOD RUNOFF COEFFICIENTS FOR COMPOSITE ANALYSIS
Runoff Coefficient (C)

Character of Surface	Return Period						
	2 Years	5 Years	10 Years	25 Years	50 Years	100 Years	500 Years
Pasture/Range							
Flat, 0-2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2-7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Forest/Woodlands							
Flat, 0-7%	0.22	0.25	0.28	0.31	0.35	0.39	0.48
Average, 2-7%	0.31	0.34	0.36	0.40	0.43	0.47	0.56
Steep, over 7%	0.35	0.39	0.41	0.45	0.48	0.52	0.58

Assumptions:

1. Composite “C” value for developed conditions (C_{DEV}) = $IC_1 + (1\text{-}I)C_2$ where:
   I = Impervious cover percentage (decimal value)
   C_1 = “C” value for impervious cover
   C_2 = “C” value for pervious cover
2. Maximum allowable impervious cover values may be limited by land use type; refer to applicable City of Round Rock Zoning and/or Development Ordinances

Notes

* Grass cover less than 50 percent of the area.
** Grass cover on 50 to 75 percent of the area.
*** Grass cover greater than 75 percent of the area.

Source: 1. Rossmiller, R.L. “The Rational Formula Revisited.”

2.4.2 Time of Concentration

The time of concentration is the time for surface runoff to flow from the most remote point in the watershed to the point of interest. This applies to the most remote point in time, not necessarily the most remote point in distance. Runoff from a drainage area usually reaches a peak at the time when the entire area is contributing. However, runoff may reach a peak prior to the time the entire drainage area is contributing if the area is irregularly shaped or if the land use characteristics differ significantly within the area. Sound engineering judgment should be used to determine a flow path representative of the drainage area and in the subsequent calculation of the time of concentration. The time of concentration at any point in a storm drainage system is a combination of the sheet flow (overland), the shallow concentrated flow and the channel flow, which may include storm drains. The minimum time of concentration for any drainage area shall be five (5) minutes. Additionally, the minimum slope used for calculation of sheet and shallow flow travel time components should be 0.005 feet per foot (0.5%). The preferred procedure for estimating time of concentration is the NRCS method as described in NRCS's Technical Release 55 (TR-55). This method is outlined below. The overall time of concentration is calculated as the sum of the sheet, shallow concentrated and channel flow travel times; note that there may be multiple shallow concentrated and/or channel segments depending on the nature of the flow path.

$$T_c = T_{t\ (sheet)} + T_{t\ (shallow\ concentrated)} + T_{t\ (channel)} \qquad \text{(Eq. 2-2)}$$

A. **Sheet Flow.** Sheet flow is shallow flow over land surfaces, which usually occurs in the headwaters of streams. The Engineer should realize that sheet flow occurs for only relatively short distances, especially in urbanized conditions. For undeveloped conditions, sheet flow distances shall not exceed 300 feet; and sheet flow distances in excess of 150 feet may be relatively rare. Sheet Flow travel time for undeveloped conditions shall be calculated based on the surface characteristics prior to development, including any pre-existing impervious cover. Sheet flow distances for developed/urbanized conditions shall not exceed 150 feet, and typically should not exceed 100 feet except where adequate justification has been provided by the Engineer. Sheet Flow travel time for developed conditions shall be calculated based on the anticipated surface characteristics of the contemplated development, and the expected and/or existing surface characteristics of any contributing areas outside of the contemplated development. In some heavily urbanized drainage areas, sheet flow may essentially be non-existent in the headwater area. The NRCS TR-55 method employs Equation 2-3, which is a modified form kinematic wave equation, for the calculation of the Sheet Flow travel time.

$$T_{t(sheet)} = 0.42(nL)^{0.8}/\{(P_2)^{0.5}(s)^{0.4}\} \qquad \text{(Eq. 2-3)}$$

where,

$T_{t(sheet)}$ = Sheet Flow travel time in minutes L = Length of the reach in ft.
n = Manning's n (see Table 2-2)
P_2 = 2-year, 24-hour rainfall in inches (from the RAIn as discussed in Section 2.4.3)
s = Slope of the ground in ft/ft

B. **Shallow Concentrated Flow.** After a maximum length as discussed in A above, sheet flow collects in swales, small rills, and gullies and develops into shallow concentrated flow. Typically, shallow concentrated flow is not within well-defined channels and will have depths of 0.1 to 0.5 feet. The portion of the total time of concentration due to shallow concentrated flow can be computed from Equations 2-4 and 2-5. These two equations are based on the solution of Manning's Equation with different assumptions for n (Manning's roughness coefficient) and r (hydraulic radius, ft.). For unpaved areas, n is 0.05 and r is 0.4; for paved areas, n is 0.025 and r is 0.2.

Unpaved $T_{t(\text{shallow concentrated})} = L/\{(60)(16.1345)(s)^{0.5}\}$ (Eq. 2-4)

Paved $T_{t(\text{shallow concentrated})} = L/\{(60)(20.3282)(s)^{0.5}\}$ (Eq. 2-5)

where,

$T_{t(\text{shallow concentrated})}$ = Shallow Concentrated Flow travel time in minutes

L = Length of the reach in ft.

s = Slope of the Shallow Concentrated Flow path in ft/ft

C. **Channel or Storm Sewer Flow.** The velocity in an open channel or a storm drain not flowing full can be determined by using Manning's Equation. Channel velocities can also be determined by using backwater profiles. For open channel flow, average flow velocity is usually determined by assuming a bank-full condition. Note that the channel flow component of the time of concentration may need to be divided into multiple segments in order to represent significant changes in channel characteristics. The details of using Manning's equation and selecting Manning's "n" values for channels can be obtained from Section 6 of this Manual.

For storm drain flow under pressure conditions (hydraulic grade line is higher than the lowest crown of a storm drain) the following equation should be applied:

$V = Q/A$ (Eq. 2-6)

where:

V = Average velocity, ft/s
Q = Design discharge, cfs
A = Cross-sectional area, ft^2

TABLE 2- 2 MANNING'S "n" FOR SHEET (OVERLAND) FLOW	
Manning's "n"[1]	**Surface Description**
0.015	Concrete (rough or smoothed finish)
0.016	Asphalt
0.05	Fallow (no residue)
Cultivated Soils:	
0.06	Residue Cover ≤ 20%
0.17	Residue Cover > 20%
Grass:	
0.15	Short-grass prairie 100% vegetated ground cover with areas of heavy vegetation (parks, green- belts, riparian areas etc.) dense under- growth
0.24	Dense grasses[2]
0.41	Bermudagrass
0.13	Range (natural)
Woods:[3]	
0.40	Light underbrush
0.80	Dense underbrush
Notes	
[1] The Manning's n values are a composite from information compiled by Engman (1986).	
[2] Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.	
[3] When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.	
Source: City of Austin, Watershed Engineering Division	

2.4.3 Rainfall Intensity (i)

Rainfall intensity (i) is the average rainfall rate in inches per hour and is selected on the basis of design rainfall duration and design frequency of occurrence. The design duration is equal to the time of concentration for the drainage area under consideration. The design frequency of occurrence is a statistical variable which is established by design standards or chosen by the Engineer as a design parameter.

The selection of the frequency criteria is necessary before applying any hydrologic method. Storm drainage improvements in Round Rock must be designed to intercept and carry the runoff from a 4% Annual Chance {twenty-five (25) year} frequency storm, with an auxiliary or overflow system capable of carrying a 1% Annual Chance {one hundred (100) year} frequency storm.

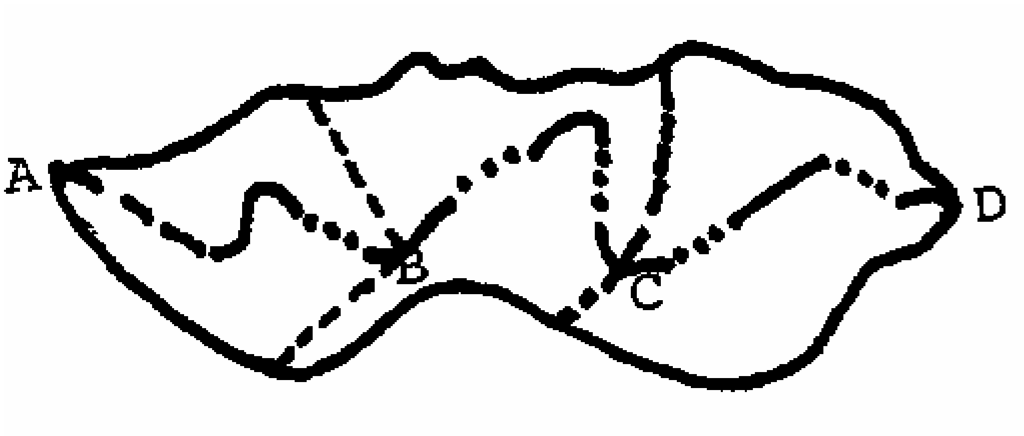
The rainfall intensity used in the Rational Method shall be based on the design frequency selected, and design duration determined, by the Engineer, subject to the approval of the UES Director, and shall be determined from the RAIn for hydrologic designs and analyses.

2.4.4 Drainage Area (A)

The size (acres) of the watershed needs to be determined for application of the Rational Method. The area may be determined through the use of topographic maps, supplemented by field surveys where topographic data has changed or where the contour interval is too great to distinguish the direction of flow. The drainage divide lines are determined based on existing topography, but could be altered by proposed street layout, lot grading, structure configuration and orientation, and many other features that result from the urbanization process.

<u>Example 2-1</u>

An urbanized watershed is shown in the following figure. Three types of flow conditions exist between the most distant point in the watershed and the outlet. The calculation of time of concentration and travel time in each reach is as follows:



Reach	Description of Flow	Slope (%)	Length (Ft.)	Drainage Area No. and Acreage	"n" Value/ Surface Type
A to B	Sheet flow (lawn)	1.8	50	DA-1 (3 acres)	0.3 (dense/Bermuda grasses)
B to C	Shallow concentrated flow (gutter)	2.0	840	DA-2 (20 acres)	Paved
C to D	Channel Flow (Storm drain with inlets; Dia.= 3 feet)	1.5	1,200	DA-3 (30 acres)	0.015

For reaches A-B and B-C, the travel time can be calculated from Equations 2- 3 and 2- 5.

$$T_{t(A-B)} = 0.42(0.3 \times 50)^{0.8}/(P_2)^{0.5}(0.018)^{0.4}$$

$$= 18.282/(P_2)^{0.5} \text{ min.}$$

$$T_{t(B-C)} = 840/(60)(20.3282)(0.02)^{0.5}$$

$$= 4.87 \text{ min.}$$

The flow velocity in reach C-D needs to be calculated from Manning's Equation, using the assumption of full pipe flow, as follows:

$$V_{C-D} = (1.49/n)\, R^{0.67} s^{0.5}$$

$$= (1.49/n)\, (D/4)^{0.67}\, s^{0.5}$$

$$= (1.49/0.015)\, (3/4)^{0.67}\, (0.015)^{0.5}$$

$$= 10.04 \text{ ft/s}$$

The channel flow travel time is calculated by dividing the length by the velocity and dividing by 60 to convert to minutes:

$$T_{t(C-D)} = 1200/(10.04)(60)$$

$$= 1.99 \text{ min.}$$

The total time of concentration is calculated by adding all of the calculated sheet flow, shallow concentrated flow, and channel flow components:

$$T_c = T_{t(sheet)} + T_{t(shallow\ concentrated)} + T_{t(channel)}$$
$$= T_{t(A\text{-}B)} + T_{t(B\text{-}C)} + T_{t(C\text{-}D)}$$
$$= 18.282/(P_2)^{0.5} + 4.87 + 1.99$$
$$= [18.282/(P_2)^{0.5} + 6.86] \text{ (minutes)}$$

Time of concentration in decimal minutes may be used but rounding to the nearest whole number of minutes (greater than or equal to 5) is generally acceptable.

For this example, Drainage Area DA-1 (traversed by reach A-B) is a grassed lawn area in fair condition, Drainage Area DA-2 (traversed by reach B-C) is commercial development composed of 76% impervious (concrete paved) area and 24% pervious grassed (good condition, average slope) area, and Drainage Area DA-3 (traversed by reach C-D) is an industrial development composed of 68% impervious (concrete paved) area and 32% pervious grassed (good condition, average slope) area.

The composite runoff coefficients (C) for Drainage Areas DA-2 and DA-3 are calculated as follows:

$$C_{DA\text{-}2} = (0.76)(0.97) + (1-0.76)(0.46)$$
$$= (0.76)(0.97) + (0.24)(0.46)$$
$$= 0.8476$$

Use 0.85

$$C_{DA\text{-}3} = (0.68)(0.97) + (1-0.68)(0.46)$$
$$= (0.68)(0.97) + (0.32)(0.46)$$
$$= 0.8068$$

Use 0.81

The runoff coefficients (C) for the three (3) areas are given as follows for the 1% Annual Chance (100-year) event.

DRAINAGE AREA (Reach)	Reach Length (ft.)	Velocity (fps)	t_c (min)	C	Area (acres)
DA-1 (A-B)	50	--	$18.282/(P_2)^{0.5}$	0.41	3
DA-2 (B-C)	840	--	4.87	0.85	20
DA-3 (C-D)	1200	10.0	1.99	0.81	30
			TOTAL $18.282/(P_2)^{0.5}+7$	WEIGHTED AVERAGE 0.80	TOTAL 53

The intensity (i) of the 1% Annual Chance (100-year) rainfall event is obtained from the RAIn as discussed in Section 2.4.3.

The weighted average runoff coefficient (C) = (0.41 X 3 + 0.85 X 20 + 0.81 X 30)/53= 0.80

Thus the peak flow Q_p = C x i x A = 0.80 X i (in/hr) X 53 acre = Q_p cfs

2.5.0 NATURAL RESOURCES CONSERVATION SERVICE METHOD

The Natural Resources Conservation Service (NRCS) hydrologic method is widely used by engineers and hydrologists for analyses of small urban watersheds. This method is based on extensive analytical work using a wide range of statistical data concerning storm patterns, rainfall-runoff characteristics and many hydrologic observations in the United States.

The NRCS method can be applied to urban drainage areas of any size. The primary parameters required to calculate a runoff hydrograph with the method include the rainfall depth, rainfall distribution, runoff curve numbers, time of concentration, and drainage area. For detailed information regarding the NRCS method, the user is referred to the following NRCS publications. These can be obtained from the Natural Resources Conservation Service at http://www.wcc.nrcs.usda.gov/. They are:

NEH-4: "Hydrology," Section 4, National Engineering Handbook
TR-55: Urban Hydrology for Small Watersheds
TP-149: A Method for Estimating Volume and Rate of Runoff in Small Watersheds

The Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS) computer programs include the ability to apply the NRCS method and may be downloaded from the US Army Corps of Engineers website at http://www.hec.usace.army.mil/.

2.5.1 Rainfall Distribution

The 24-hour frequency storm for use with the NRCS method is hereby adopted by the City. Rainfall depth-duration-frequency values, meteorological parameters, guidance on time-step selection, and other direction regarding application of rainfall for the NRCS method/use of HEC-HMS shall be determined from the RAIn for hydrologic designs and analyses.

2.5.2 Natural Resources Conservation Service Runoff Curve Number

The NRCS has developed an index, the runoff curve number (CN), to represent the combined hydrologic effect of soil type, land use, agricultural land treatment class, hydrologic condition, and antecedent soil moisture. These watershed factors have the most significant impact in estimating the volume of runoff, and can be assessed from soil surveys, site investigations and land use maps.

The CN is an indication of the potential runoff for a given antecedent soil moisture condition, and it ranges in value from zero (0) to one hundred (100). The NRCS runoff CN's are grouped into three (3) antecedent soil moisture conditions -- Antecedent Runoff Condition (ARC) I, ARC II and ARC III. Values of runoff curve numbers for all three (3) conditions may be computed following guidelines in Part 630, Chapter 10, of the National Engineering Handbook. ARC I is the dry soil condition and ARC III is the wet soil condition. ARC II is normally considered to be the average condition. The Antecedent Runoff Condition (ARC) was previously referred to as the Antecedent Moisture Condition (AMC) in older NRCS publications.

However, studies of hydrologic data indicate that ARC II is not necessarily representative of the average condition throughout Texas. Instead, investigations have shown that the average condition ranges from ARC I in west Texas to between ARC II and ARC III in east Texas. The NRCS curve number values given in Table 2- 3 are for an ARC II. If it is desired to change to an ARC I or III, the adjustments given in Part 630, Chapter 10 of the National Engineering Handbook should be used. Justification must be provided for the selection of an ARC other than ARC II.

The NRCS has classified more than four thousand (4,000) soils into four (4) hydrologic groups, identified by the letters A, B, C, and D, to represent watershed characteristics.

Group A: (Low runoff potential). Soils having a high infiltration rate even when thoroughly wetted and consisting chiefly of deep, well-drained to excessively drained sands or gravels.

Group B: Soils having a moderate infiltration rate when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well-drained soils with moderately fine to moderately coarse texture.

Group C: Soils having a slow infiltration rate when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water or soil with moderately fine to fine texture.

Group D: (High runoff potential). Soils having a very slow infiltration rate when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.

Table 2-3 lists the CN's for the four (4) soil groups under various land uses, land treatment and hydrologic conditions. Any CN climatic adjustment factor(s) allowed within the City of Round Rock shall be as specified in the RAIn for hydrologic designs and analyses. CN's for future (fully developed) conditions should be based on estimated maximum future impervious cover and/or any maximum allowable impervious cover for land uses as prescribed in City of Round Rock Zoning and/or Development Ordinances, if applicable. When calculating future (fully developed) peak runoff rates it is recommended that the undeveloped CN and the maximum impervious cover be used as input parameters. In order to determine the soil classifications in the Round Rock area, the NRCS Soil Survey of Williamson or Travis County, Texas should be used. Digital versions of these soil datasets are available online at https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/survey/.

Table 2- 3 NRCS Runoff Curve Numbers (CN's) for Urban Areas and Agricultural Lands (assuming ARC II condition)					
Cover Description		**CN for Hydrologic Soil Group**			
Cover type and Hydrologic Condition	**Average % Impervious Area1**	**A**	**B**	**C**	**D**
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[2]					
Poor condition (grass cover <50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas					
Paved parking lots, roofs, driveways, etc. (excluding right of way)		98	98	98	98
Streets and Roads					
Paved; curbs and storms drains (excluding right of way)		98	98	98	98
Paved open ditches (including right of way)		83	89	92	93
Gravel (including right of way)		76	85	89	91
Dirt (including right of way)		72	82	87	89
Urban districts					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)		77	86	91	94

Table 2- 3 (Continued) NRCS Runoff Curve Numbers (CN's) for Urban Areas and Agricultural Lands (assuming ARC II condition)					
Cover Description		**CN for Hydrologic Soil Group**			
Cover type and Hydrologic Condition	**Average % Impervious Area**[1]	**A**	**B**	**C**	**D**
Residential districts by average lot size					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Agricultural lands					
Pasture, grassland, or range- continuous forage for grazing[3]					
Poor		68	79	86	89
Fair		49	69	79	84
Good		39	61	74	80
Meadow-continuous grass, protected from grazing and generally mowed for hay		30	58	71	78
Brush - brush-weed-grass mixture with brush the major element[4]					
Poor		48	67	77	83
Fair		35	56	70	77
Good		30[7]	48	65	73
Woods - grass combination (orchard or tree farm)[5]					
Poor		57	73	82	86
Fair		43	65	76	82
Good		32	58	72	79
Woods[6]					
Poor		45	66	77	83
Fair		36	60	73	79
Good		30[7]	55	70	77

Table 2- 3 (Continued) NRCS Runoff Curve Numbers (CN's) for Urban Areas and Agricultural Lands (assuming ARC II condition)					
Cover Description		**CN for Hydrologic Soil Group**			
Cover type and Hydrologic Condition	**Average % Impervious Area[1]**	**A**	**B**	**C**	**D**
Farmsteads - buildings, lanes, driveways and surrounding lots		59	74	82	86

Notes

1 The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system; impervious areas have a CN of ninety-eight (98) and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using methods in NRCS TR-55 Urban Hydrology for Small Watersheds.

2 CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

3 Poor: less than 50 percent ground cover or heavily grazed with no mulch.
Fair: 50 to 75 percent ground cover and not heavily grazed.
Good: greater than 75 percent ground cover and lightly or only occasionally grazed.

4 Poor: less than 50 percent ground cover.
Fair: 50 to 75 percent ground cover.
Good: greater than 75 percent ground cover.

5 CN's shown were computed for areas with 50 percent woods and 50 percent grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

6 Poor: Forest litter, small trees & brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, & litter and brush adequately cover the soil.

7 Actual CN is less than 30; use CN = 30 for runoff computations.

Source: NRCS TR-55: Urban Hydrology for Small Watersheds

2.5.3 Time of Concentration

The procedures for estimating time of concentration for the NRCS method are described in the NRCS Technical Release 55 (TR-55) and in Section 2.4.2 of this manual. Three (3) types of flow (sheet flow, shallow concentrated flow and channel flow) are considered. Table 2-2 shall be used for determination of sheet flow Manning's roughness coefficients rather than the table in TR-55.

In hydrograph analysis, the time of concentration can be defined as the time from the end of excess rainfall to the point of inflection on the falling limb of the hydrograph. The time of concentration determines the shape of the runoff hydrograph. Times of concentration are required for the existing and developed conditions to adequately model the impact of the development on stormwater runoff. The methodology presented in TR-55 provides a reasonable approach for the estimation of time of concentration. The lag time, defined as the time between the center of mass of excess rainfall to the runoff peak, is typically used in the HEC-HMS implementation of the NRCS methodology. The lag time can be estimated with Equation 2-8:

$$T_{lag} = (0.6)(T_c) \qquad \text{(Eq. 2-8)}$$

In general, times of concentration for the developed condition should be calculated based on conservative assumptions that consider the expected increased hydraulic efficiency. Times of concentration should be representative of the overall drainage area, not simply based on the longest flow path. Sheet flow lengths should be carefully examined and properly justified. Additionally, the minimum slope used for calculation of sheet and shallow concentrated flow travel time components should be 0.005 feet per foot (0.5%).

(Eq. S-4)