Appendix I

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Appendix II

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Appendix III

__TYPE OF SURFACE__	__RUNOFF COEFFICIENT__

Non-Urban Areas

Bare Earth	0.55
Steep Grassed Areas (slope 2:1)	0.60
Turf Meadows	0.25
Forested Areas	0.20
Cultivated Fields	0.30

Urban Areas

All Watertight Roof Surfaces	0.90
Pavement (concrete, asphalt)	0.85
Gravel	0.85
Impervious Soils (Heavy)	0.55
Impervious Soils (with turf)	0.45
Slightly Pervious Soil	0.25
Slightly Pervious Soil (with turf)	0.20
Moderately Pervious Soil	0.15
Moderately Pervious Soil (with turf)	0.10
Business, Commercial & Industrial	0.85
Apartments & Townhouses	0.70
Schools & Churches	0.55
Single Family Lots $< 10,000$ ft^2	0.45
Lots $< 12,000$ ft^2	0.45
Lots $< 17,000$ ft^2	0.40
Lots $> \frac{1}{2}$ Acre	0.35
Park, Cemetery or Unimproved Area	0.30

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Table 3.1.1 (TR-55 Table 3-1) : Runoff Coefficient's for use in the Rational Method calculations for Pipe, Channel and Detention Design

Worksheet 3: Time of Concentration (T$_c$) or travel time (T$_t$)

Project		By		Date
Location		Checked		Date

Check one: ☐ Present ☐ Developed

Check one: ☐ T$_c$ ☐ T$_t$ through subarea

Notes: Space for as many as two segments per flow type can be used for each worksheet.
Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to Tc only)

	Segment ID		
1. Surface description (table 3-1)			
2. Manning's roughness coefficient, n (table 3-1)			
3. Flow length, L (total L † 300 ft) .... ft			
4. Two-year 24-hour rainfall, P$_2$ .... in			
5. Land slope, s .... ft/ft			
6. $T_t = \dfrac{0.007\ (nL)^{0.8}}{P_2^{\ 0.5}\ s^{0.4}}$ Compute T$_t$ .... hr		+	=

Shallow concentrated flow

	Segment ID		
7. Surface description (paved or unpaved)			
8. Flow length, L ....ft			
9. Watercourse slope, s .... ft/ft			
10. Average velocity, V (figure 3-1) .... ft/s			
11. $T_t = \dfrac{L}{3600\ V}$ Compute T$_t$ .... hr		+	=

Channel flow

	Segment ID		
12. Cross sectional flow area, a .... ft^2			
13. Wetted perimeter, p$_w$ .... ft			
14. Hydraulic radius, $r = \dfrac{a}{p_w}$ Compute r .... ft			
15 Channel slope, s .... ft/ft			
16. Manning's roughness coefficient, n			
17. $V = \dfrac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V ....ft/s			
18. Flow length, L .... ft			
19. $T_t = \dfrac{L}{3600\ V}$ Compute T$_t$ .... hr		+	=
20. Watershed or subarea T$_c$ or T$_t$ (add T$_t$ in steps 6, 11, and 19) .... Hr			

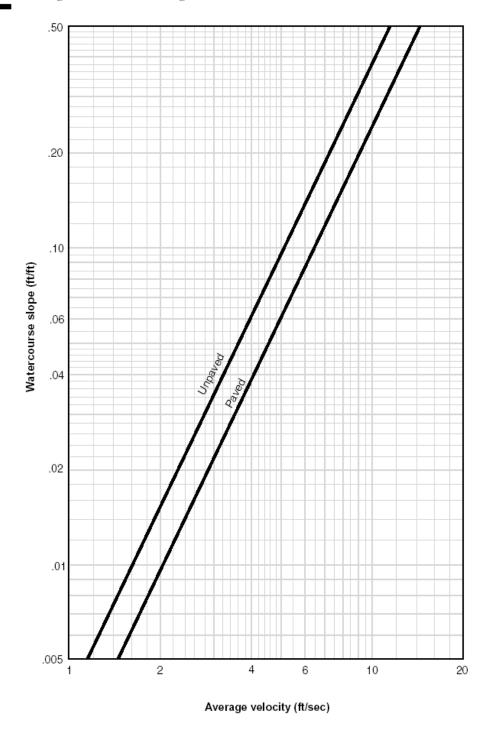(210-VI-TR-55, Second Ed., June 1986)   D–3

Worksheet 3.2.1: Time of Concentration or Travel Time Worksheet

SURFACE DESCRIPTION	n
Smooth Surfaces (concrete, asphalt, gravel, bare soil)	0.011
Fallow (no residue)	0.05
Cultivated Soils:	
Residue cover </= 20%	0.06
Residue cover > 20%	0.17
Grass:	
Short Grass Praire	0.15
Dense Grass	0.24
Bermuda Grass	0.41
Range (natural)	0.13
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80

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Table 3.2.2 (TR-55 Table 3-1): Roughness coefficient's (Manning's n) for sheet flow to be used in Time-of-Concentration calculations

(210-VI-TR-55, Second Ed., June 1986)

Figure 3.2.3 (TR-55 Figure 3-1): Average Velocities for Estimating Travel Time for Shallow Concentrated Flow.

Worksheet 2: Runoff curve number

Project		By	Date
Location		Checked	Date

Check one: ☐ Present ☐ Developed

1. Runoff curve number

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN [1]			Area ☐ acres ☐ mi² ☐ %	Product of CN x area
		Table 22				
.						

[1] Use only one CN source per line

Totals ➡

$$CN \text{ (weighted)} = \frac{\text{total product}}{\text{total area}} = \underline{\hspace{3cm}} = \underline{\hspace{1.5cm}} \quad ; \quad \text{Use CN} ➡$$

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Worksheet 3.3.1 (TR-55 Worksheet 2): Runoff Curve Number Worksheet

Table 2-2a   Runoff curve numbers for urban areas [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area [2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3]:					
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 storm sewers (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
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
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
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1] Average runoff condition, and $I_a = 0.2S$.

[2] 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 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 figure 2-3 or 2-4.

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

[4] Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

[5] Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 3.3.2 (TR-55 Table 2-2a): Runoff Curve Numbers for Urban Areas

Table 2-2b   Runoff curve numbers for cultivated agricultural lands [1]

Cover description			Curve numbers for hydrologic soil group			
Cover type	Treatment [2]	Hydrologic condition [3]	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T+ CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T+ CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

[1] Average runoff condition, and I_a=0.2S

[2] Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.

[3] Hydraulic condition is based on combination factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue cover on the land surface (good ≥ 20%), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table 3.3.3 (TR-55 Table 2-2b): Runoff Curve Numbers for Cultivated Agricultural Lands

Table 2-2c   Runoff curve numbers for other agricultural lands [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. [2]	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. [3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 [4]	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 [4]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

[1]   Average runoff condition, and $I_a = 0.2S$.
[2]   *Poor:*   <50%) ground cover or heavily grazed with no mulch.
      Fair: 50 to 75% ground cover and not heavily grazed.
      Good: > 75% ground cover and lightly or only occasionally grazed.
[3]   *Poor:*   <50% ground cover.
      Fair: 50 to 75% ground cover.
      Good: >75% ground cover.
[4]   Actual curve number is less than 30; use CN = 30 for runoff computations.
[5]   CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
[6]   *Poor:*   Forest litter, small trees, and 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, and litter and brush adequately cover the soil.

Table 3.3.4 (TR-55 Table 2-2c): Runoff Curve Numbers for Other Agricultural Lands

Return Period	a	b	N	R^2
2	32.852	7	0.7780	0.99966
5	46.060	8	0.7859	0.99958
10	56.974	9	0.7953	0.99952
25	72.739	10	0.8115	0.99942
50	84.475	11	0.8147	0.99940
100	92.718	11	0.8145	0.99942

Table 3.4.1.1: IDF EQUATION VALUES

		Return Period – Rainfall Intensity (in/hr)					
Hours	**Minutes**	**2**	**5**	**10**	**25**	**50**	**100**
0.08	5	4.75	6.14	6.99	8.08	8.83	9.69
0.17	10	3.63	4.75	5.48	6.40	7.07	7.77
0.25	15	2.97	3.92	4.55	5.34	5.94	6.53
0.5	30	1.98	2.64	3.09	3.65	4.10	4.50
1	60	1.25	1.67	1.96	2.31	2.62	2.88
2	120	0.76	1.02	1.20	1.40	1.59	1.75
3	180	0.56	0.75	0.88	1.03	1.17	1.29
6	360	0.33	0.44	0.52	0.60	0.68	0.75
12	720	0.20	0.26	0.30	0.35	0.39	0.43
24	1440	0.11	0.15	0.17	0.20	0.22	0.25

Table 3.4.1.2: IDF Table

		Return Period – Rainfall Depth (in)					
Hours	**Minutes**	**2**	**5**	**10**	**25**	**50**	**100**
0.08	5	0.40	0.51	0.58	0.67	0.74	0.81
0.17	10	0.61	0.79	0.91	1.07	1.18	1.30
0.25	15	0.74	0.98	1.14	1.34	1.49	1.63
0.5	30	0.99	1.32	1.55	1.83	2.05	2.25
1	60	1.25	1.67	1.96	2.31	2.62	2.88
2	120	1.52	2.04	2.40	2.80	3.18	3.50
3	180	1.68	2.25	2.64	3.09	3.51	3.87
6	360	1.98	2.64	3.12	3.60	4.08	4.50
12	720	2.40	3.12	3.60	4.20	4.68	5.16
24	1440	2.64	3.60	4.08	4.80	5.28	6.00

Table 3.4.2.1: IDD Table

Cumulative Storm Time (Percent)	Cumulative Storm Rainfall (percent) for Given Storm Type			
	First Quartile	Second Quartile	Third Quartile	Fourth Quartile
5	16	3	3	2
10	33	8	6	5
15	43	12	9	8
20	52	16	12	10
25	60	22	15	13
30	66	29	19	16
35	71	39	23	19
40	75	51	27	22
45	79	62	32	25
50	82	70	38	28
55	84	76	45	32
60	86	81	57	35
65	88	85	70	39
70	90	88	79	45
75	92	91	85	51
80	94	93	89	59
85	96	95	92	72
90	97	97	95	84
95	98	98	97	92

(SOURCE: Rainfall Frequency Atlas of the Midwest by Huff and Angel)

Table 3.4.3.1: Median Time Distributions of Heavy Storm Rainfall at a Point

Appendix IV

Pipe Material	**Manning's n**
Concrete Pipe	0.012
Concrete Boxes	0.012
Corrugated Metal Pipe or Pipe Arch	
2 2/3" x ½" Helical Corrugation	0.022
2 2/3" x ½" Annular Corrugation	0.022
15" to 36"	0.025
42" to 96"	0.024
3" x 1" Corrugation	0.027
5" x 1" Corrugation	0.025
Structural Plate Pipe or Pipe Arch	
6" x 2" Corrugation	0.033
9" x 2½" Corrugation	0.035
Spiral Ribbed Corrugated Metal Pipe	0.013
Smooth High Density Polyethylene (HDPE)	0.012
Smooth Lined Interior Polyvinyl Chloride (PVC)	0.012
Smooth Interior Corrugated HDPE	0.012
Ductile Iron Pipe	0.012

Table 4.2.1.1: Manning's "n" Values for Pipes

Storm Drain Computation Sheet

Station		Length (ft)	Drainage Area (acres)		Runoff Coefficient	C	A x C		Flow Time (min)		Rainfall Intensity (in/hr)	Total Runoff Q (cfs)	Diameter of Pipe (in)	Slope of Pipe (ft/ft)	Flowing Full Velocity	Upstream Invert Elevation	Downstream Invert Elevation	Manhole Invert Drop	Depth of Cover
From	To		Increment	Total			Increment	Total	To Upper End	In Section									

Worksheet 4.2.1.2 (INDOT Figure 36-12F): Storm Drain Computation Sheet

Hydraulic Grade Line Computation Sheet

Station	TW	D_O	Q_O	L_O	V_O	$V_o^2/2g$	H_O	Sf_O	H_f	K_O	C_D	C_d	C_Q	C_P	C_B	K	$K(V_o^2/2g)$	EGL_O 2+7	EGL 10+18+19	HGL EGL-7	TOC ELEV
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)

Worksheet 4.2.1.3 (INDOT Figure 36-13D): Hydraulic Grade line Computation Sheet

INLET COMPUTATION SHEET

Location		Gutter Discharge (Design Frequency _____)					Gutter Discharge (Allowable Spread _____)								Inlet Discharge			Remarks
Inlet No.	Stat.	Drain Area "A" (acre)	Runoff Coefficient "C"	Time of Concentration "T$_c$" (min.)	Rainfall Intensity "i" (in/hr)	Flow "Q" (cfs)	Grade "S$_o$" (ft/ft)	Cross Slope "S$_x$" (ft/ft)	Prev. Runby (cfs)	Total Gutter Flow (cfs)	Depth "d" (ft)	Gutter Width "W" (ft)	Spread "T" (ft)	W/T	Inlet Type	Intercept "Q$_i$" (cfs)	Runby "Q$_r$" (cfs)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

Worksheet 4.3.2.1 (INDOT Figure 36-10K): Inlet Spacing and Gutter Spread Computation Sheet

Type of Gutter or Pavement	Manning's "n"
Concrete	0.012
Asphalt Pavement:	
Smooth Texture	0.013
Rough Texture	0.016
Concrete Gutter – Asphalt Pavement:	
Smooth	0.013
Rough	0.015
Concrete Pavement:	
Float Finish	0.014
Broom Finish	0.016
For Gutters with small slope, where sediment may Accumulate, increase the "n" values above by:	0.002

USDOT, FHWA, HDS-3 (1961)

Table 4.3.2.2: Roughness coefficient's (Manning's n) for Street and Pavement Gutters

Open Channel Surface Material		**n**
Concrete		0.012
Gravel Bottom with sides	- Concrete	0.020
	- Mortared Stone	0.023
	- Rip-Rap	0.033
Natural Stream Channels:		
Clean, Straight Stream		0.030
Clean, Winding Stream		0.040
Winding with weeds and pools		0.050
With Heavy Brush and Timbers		0.100
Flood Plains:		
Pasture		0.035
Field Crops		0.040
Light Brush and Weeds		0.050
Dense Brush		0.070
Dense Trees		0.100

Chow, 1959

Table 4.4.1.1: Roughness coefficient's (Manning's n) for Open Channel Surfaces

Typical Maximum Velocities for Open Channel Linings

Open Channel Lining Material	Desirable Maximum Velocity (ft/s)
Concrete, Trowel Finish	15
Concrete, Broom or Float Finish	15
Rip-Rap	10
Gabions	10
New Earth (Uniform, Sodded, Clay)	3-5
Existing Earth (Fairly Uniform, With Some Weeds	3-5
Dense Weeds	3-5
Swale with Grass	3-5

Table 4.4.2.1: Desirable Maximum Velocities for Open Channel Linings

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Appendix VI

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Appendix VII

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Appendix XII

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