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CE 5338

Hydrologic Engineering,

Professor Martin Pierson

HW 3, Sep. 14, 2022

In [3]:

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from wand.image import Image as WImage
img = WImage(filename='5338+HW+3+Rational+Method.pdf')
img
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Out[3]:

CE 5338

Pierson **HYDROLOGIC ENGINEERING**

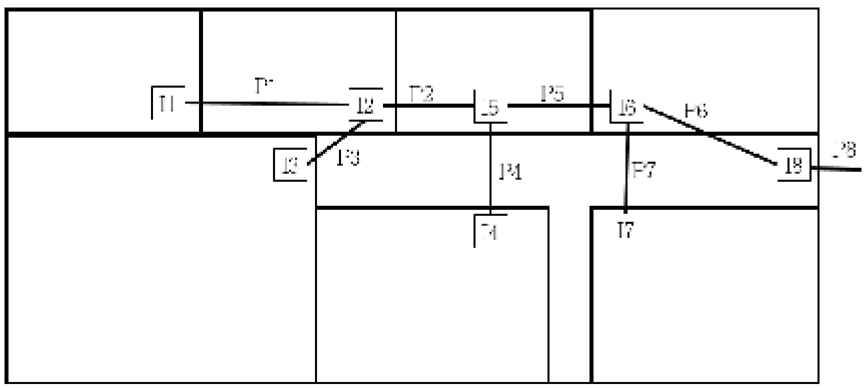
Assignment #3

Pipe Sizing for Storm Drainage by the Rational Method

Due Sept. 14th (10 points)

The sketch below shows a proposed layout for a storm drainage system for a subdivision in Springfield. The table below shows the land use, drainage area, length of overland flow, length of each pipe, and percentage of impervious area for each sub-basin. Use the City of Springfield Design guide; rational method to compute the **design discharge** for each inlet and each pipe. Submit a table that summarizes your calculations.

The city requires that the system be designed for a 10 year recurrence interval. Determine the **size of pipes** needed.



ID #	Land Use	Average Lot Size, acre	Drainage area, acres	Impervious area, %	Land Average Slope, %	Length of Overland Flow, (ft)
I1	Residential	1/4	3	-	8.3	200
I2	1/2 ImPervious 1/2 Lawn		3	-	7.7	170
I3	Residential	1/2	5	-	5	300
I4	Residential	1	3	-	5	300
I5	Woods	n/a	3.5	15	2.2	450
I6	Residential	1/4	2.5	-	2.2	250
I7	Residential	1/2	2.5	-	1.5	200
I8	Road Way	n/a	2.5		1.5	300

PipeID #	Average Slope of Pipe, %	Length of Pipe , (ft)
P1	1.4	170
P2	0.5	160
P3	0.5	125
P4	0.5	140
P5	0.3	160

PipeID #	Average Slope of Pipe, %	Length of Pipe , (ft)
P6	0.3	300
P7	0.2	125
P8	0.1	200

Solution

Chapter 5 Calculation of Runoff

Table 13. USGS Regression Equations for Estimation of Peak Flows in Urban Areas (Southard 2010)

Recurrence Interval	USGS Regression Equation (Q = estimated peak flow rate [cfs], A = drainage area [mi2], I = impervious area in percent)
2-year	$Q_2 = 188DRNAREA^{0.599}10^{0.014IMPLNLCD01}$
5-year	$Q_5 = 352DRNAREA^{0.592}10^{0.011IMPLNLCD01}$
10-year	$Q_{10} = 484DRNAREA^{0.594}10^{0.010IMPLNLCD01}$
25-year	$Q_{25} = 671DRNAREA^{0.599}10^{0.008IMPLNLCD01}$
50-year	$Q_{50} = 826DRNAREA^{0.604}10^{0.008IMPLNLCD01}$
100-year	$Q_{100} = 991DRNAREA^{0.608}10^{0.007IMPLNLCD01}$
500-year	$Q_{500} = 1420DRNAREA^{0.619}10^{0.006IMPLNLCD01}$

Table 2. Rainfall Intensity-Duration-Frequency Relationships from NOAA Atlas 14 Volume 8 Version 2, Precipitation-Frequency Atlas of the United States, Midwestern States.

Duration	Intensity of Precipitation (in/hr)						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year
5 min	4.56	5.16	6.36	7.32	8.64	9.72	10.80
10 min	3.30	3.78	4.62	5.34	6.30	7.08	7.86
15 min	2.68	3.08	3.76	4.32	5.12	5.76	6.40
30 min	1.96	2.28	2.78	3.20	3.78	4.24	4.68
1 hr	1.29	1.50	1.84	2.14	2.55	2.88	3.21
2 hr	0.80	0.93	1.15	1.34	1.61	1.82	2.04
3 hr	0.60	0.69	0.86	1.00	1.21	1.38	1.56
6 hr	0.37	0.42	0.52	0.60	0.73	0.83	0.94
12 hr	0.22	0.25	0.30	0.35	0.42	0.48	0.54
24 hr	0.13	0.15	0.18	0.21	0.25	0.28	0.32
48 hr	0.08	0.09	0.11	0.13	0.15	0.17	0.19
72 hr	0.06	0.06	0.08	0.09	0.11	0.12	0.13

Table 5. Values of Nk for the Kerby-Hathaway Equation

Surface Type	Nk
Smooth impervious surface	0.05
Smooth bare packed soil, free of stones	0.10
Poor grass, cultivated row crops, or moderately-rough bare surfaces	0.20
Pasture or average grass cover	0.40
Deciduous timberland	0.60
Conifer timberland, deciduous timberland with deep forest litter, or dense grass cover	0.80

Table 6. Runoff Coefficients Based on Surface Type for Rational Equation

By Surface Type—Use as Basis for Computation of Composite Runoff Coefficients			
Surface Type	**Runoff Coefficients**		
Asphalt, concrete pavement, roofs	0.95-1.0		
Gravel surfaces, compacted	0.85-0.95		
Gravel surfaces, not compacted	0.50-0.70		
Parks, golf courses, farms	0.10-0.20		
Lawns, pastures, hayfields			
Flat (<2% slopes)	0.10-0.15		
Average (2-7% slopes)	0.15-0.20		
Steep (>7% slopes)	0.20-0.30		
Woods	0.05-0.15		
Composite Coefficients for Single Family Residential Areas			
	Flat (<2% slopes)	Average (2-7% slopes)	Steep (>7% slopes)
Average lot size, 1/4 acre	0.35-0.45	0.40-0.50	0.45-0.55
Average lot size, 1/3 acre	0.30-0.40	0.33-0.43	0.40-0.50
Average lot size, 1/2 acre	0.25-0.35	0.30-0.40	0.36-0.46
Average lot size, 1 acre	0.20-0.25	0.25-0.30	0.30-0.38
Average lot size, 3 acres	0.10-0.20	0.16-0.24	0.25-0.33

Note: The ranges of C values presented in this table are typical for return periods of 2- to 10-years and assume average antecedent moisture conditions. Higher values are appropriate for larger design storms.

Table 1. Typical Manning's Roughness Coefficient (n) Values for Open Channels.

Channel Lining	Minimum	Average	Maximum
Earthen	0.020	0.025	0.030
Mowed grass	0.025	0.030	0.035
Grass-not mowed	0.030	0.035	0.040
Grass with brush/trees	0.040	0.050	0.060
Cobble bottom, grass/root side	0.030	0.040	0.050
Concrete-smooth	0.012	0.013	0.015
Concrete-rough	0.015	0.017	0.020
Riprap d_{50} 6 inches	0.032	0.035	0.038
Riprap d_{50} 9 inches	0.035	0.038	0.040
Riprap d_{50} 12 inches	0.038	0.040	0.042
Riprap d_{50} 18 inches	0.040	0.042	0.044
Riprap d_{50} 24 inches	0.042	0.044	0.047
Grouted boulders	0.025	0.032	0.040

Design Peak for 10 year storm: Q_{10}

Section	Land use	Acre	Avg lot size (Acre)	Overland length (ft)	Impervious area, %	Land average, slope %	Pipe slope average	Pipe length	c (coefficient)	N_k	i (intensity, in/hr) = t_inf	Q (cfs- cubic foot per sec.)
I_1	Residential	3	1/4	200		8.3	1.4	170	0.5	0.4	0.5239	0.7859
I_2	1/2 impervious 1/2 Lawn	3		170	**50**	7.7	0.5	160	0.3	0.4	0.5147	0.4632
I_3	Residential	5	1/2	300		5	0.5	125	0.35	0.4	0.5026	0.8795
I_4	Residential	3	1/1	300		5	0.5	140	0.275	0.4	0.5484	0.4524
I_5	Wood	3.5	n/a	450	15	2.2	0.3	160	0.1	0.6	1.1392	0.3987
I_6	Residential	2.5	1/4	250		2.2	0.3	300	0.5	0.4	1.3528	1.6910
I_7	Residential	2.5	1/2	200		1.5	0.2	125	0.35	0.4	0.7989	0.6991
I_8	Roadway	2.5	n/a	300		1.5	0.1	200	0.975	0.05	0.2314	0.5640

Q (cfs) =	**CiA**
Q_max =	1.6910
t_overland=	**.0078(N_k* L/[S^0.5])^0.77**
L_undev <=	500 ft.
L_dev <=	300 ft.
t_undev=	**0.83(L/[S^0.5])^0.77**
t_grass=	**2 * t_undev**
t_overland=	**0.4 * t_undev**
t_concrete=	**0.2 * t_undev**
Darcy (ft)	(2.16*Q*n/√S)^.375
Manning (ft)	(0.811*f*Q/(*g* *S))^0.2

Section	Pipe length	Pipe slope average	Darcy (ft)	n	Manning	f_concrete (graph)	Pipe Diameter (in)	Pipe Design (in.)
I_1	170	1.4	**0.749**	0.15	**0.553**	0.017	8.988	9
I_2	160	0.5	**0.909**	0.15	**0.679**	0.017	10.905	11
I_3	125	0.5	**0.909**	0.15	**0.687**	0.018	10.905	11
I_4	140	0.5	**0.909**	0.15	**0.687**	0.018	10.905	11
I_5	160	0.3	**1.000**	0.15	**0.753**	0.017	12.001	12
I_6	300	0.3	**1.000**	0.15	**0.734**	0.015	12.001	12
I_7	125	0.2	**1.079**	0.15	**0.825**	0.018	12.949	13
I_8	200	0.1	**1.229**	0.15	**0.926**	0.016	14.746	13

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