CITY UTILITIES
DESIGN STANDARDS MANUAL

Book 2
Stormwater (SW)
SW5 Hydrology

June 2015

SW5.01 Purpose

This Chapter provides design policies which shall be used during a hydrologic analysis performed within the City of Fort Wayne's stormwater jurisdiction.

SW5.02 Rainfall

The probability that a storm event of a certain magnitude will occur in any given year is expressed in terms of event frequency and return period. The frequency, or exceedance probability, is a measure of how often a specific rainfall event will be equaled or exceeded. For specific storm durations, a rainfall intensity exists that corresponds to a given frequency. The intensity-duration-frequency (IDF) curve provided in Figure SW5.1 illustrates the average rainfall intensities corresponding to a particular storm frequency for various storm durations. Figures SW5.2 and SW5.3 contain frequency and duration of events based on rainfall intensity and rainfall depth, respectively. The most recent precipitation data can be found at http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=in. Select station FORT WAYNE WSO AP (12-3037).

Figure SW5.1 Intensity-Duration-Frequency Curves for the City of Fort Wayne
Source: NOAA Atlas 14, Volume 2, Version 3, 2004

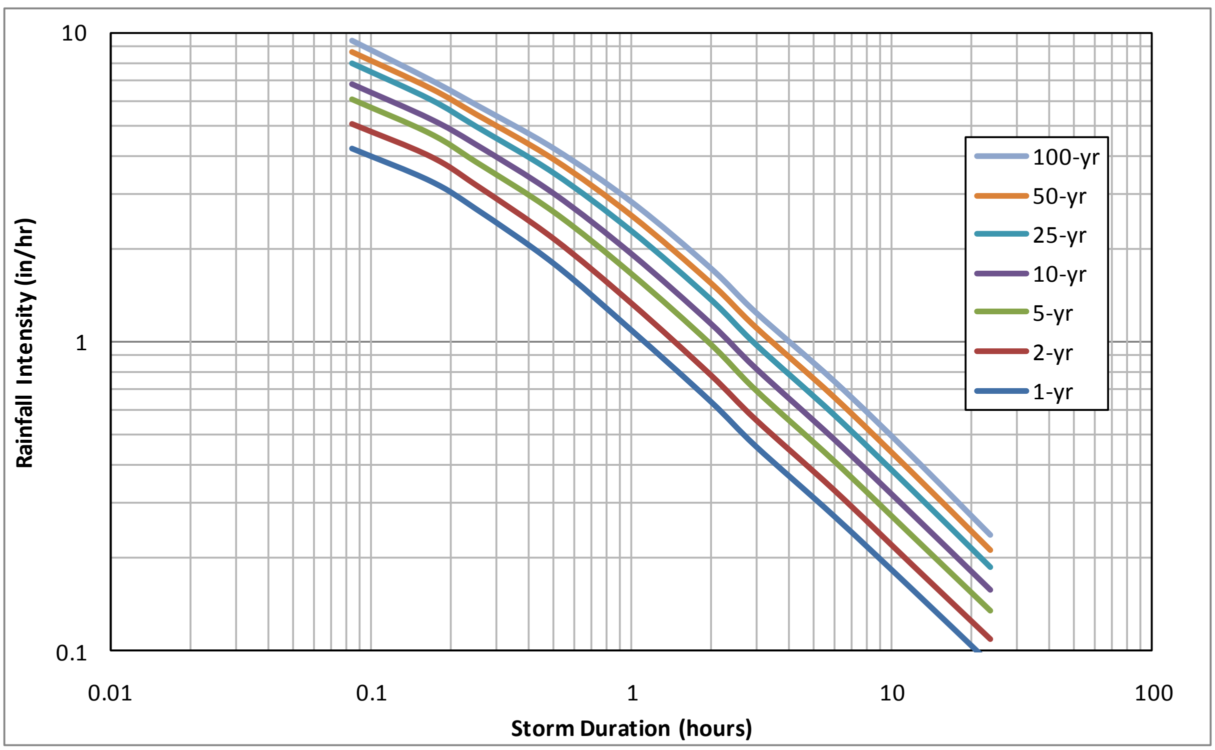

Figure SW5.2 Intensity-Duration-Frequency

Hours	Minutes	Return Frequency - Rainfall Intensity (in/hr)						
		1-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
0.08	5 *	4.20	5.04	6.12	6.84	7.92	8.64	9.48
0.17	10	3.30	3.96	4.74	5.28	6.06	6.60	7.08
0.25	15	2.68	3.20	3.84	4.36	4.96	5.44	5.88
0.50	30	1.78	2.14	2.64	3.02	3.50	3.88	4.24
1	60	1.08	1.32	1.66	1.92	2.27	2.55	2.84
2	120	0.64	0.78	0.99	1.15	1.38	1.56	1.75
3	180	0.46	0.56	0.70	0.82	0.98	1.11	1.25
6	360	0.27	0.33	0.41	0.48	0.58	0.66	0.75
12	720	0.16	0.19	0.24	0.28	0.33	0.38	0.43
24	1440	0.09	0.11	0.14	0.16	0.19	0.21	0.24

*Minimum time of concentration (T_c)

Figure SW5.3 Depth-Duration-Frequency

Hours	Minutes	Return Frequency - Rainfall Depth (in)						
		1-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
0.08	5 *	0.35	0.42	0.51	0.57	0.66	0.72	0.79
0.17	10	0.55	0.66	0.79	0.88	1.01	1.1	1.18
0.25	15	0.67	0.8	0.96	1.09	1.24	1.36	1.47
0.50	30	0.89	1.07	1.32	1.51	1.75	1.94	2.12
1	60	1.08	1.32	1.66	1.92	2.27	2.55	2.84
2	120	1.28	1.56	1.98	2.3	2.75	3.11	3.49
3	180	1.37	1.67	2.1	2.46	2.94	3.34	3.75
6	360	1.63	1.98	2.48	2.9	3.49	3.98	4.5
12	720	1.89	2.27	2.84	3.32	3.99	4.54	5.14
24	1440	2.17	2.61	3.25	3.77	4.5	5.1	5.72

*Minimum time of concentration (T_c)

1. Rainfall Distributions

The Huff rainfall distribution most accurately reflects rainfall conditions in Fort Wayne. To use the Huff distribution, the Engineer specifies the total depth of rainfall, the duration, and the proper quartile. The distribution for each of the quartiles is provided in Figure SW5.4. Storm distributions for hydrograph computation are determined by applying the appropriate Huff Distribution for the following conditions:

Storm Duration	Distribution
≤ 6 hours Duration	Huff 1st Quartile
6 hours < Duration ≤ 12 hours	Huff 2nd Quartile
12 hours < Duration ≤ 24 hours	Huff 3rd Quartile
> 24 hours Duration	Huff 4th Quartile

Figure SW5.4. Huff Rainfall Distribution

	Cumulative storm rainfall (%) for given storm type			
Cumulative storm time (%)	**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: Bulletin 71, “Rainfall Frequency Atlas of the Midwest”, 1992

2. Design Storm Frequencies

The design storm frequency is the basis for all hydrologic computations. Selection of the design storm shall conform to the criteria set forth within the appropriate section dedicated to each drainage system type provided in this manual. The Engineer shall run the appropriate return frequency storm(s) for the full range of durations (5 minute through 24 hours).Refer to Figure SW5.5 for a summary of the design storm frequency requirements.

Figure SW5.5 Acceptable Runoff Generation Methods

Stormwater Facility Type	Design Requirements
Storm Sewers (SW6)	Minor (10 year) and Major (100 year)[1].
Inlets (SW7)	10 year[2] – 100year[2]
Culverts(SW8)	Public Culverts – 100 year event
	Public Culverts within Right-of-Way – 50 year
	Private Culverts[3] – 50 year event provisions made to contain 100 year event.[4]
Open Channels (SW9)	100-year with 2’ of freeboard to the top of channel bank
	Chanel Lining and stability – 10 year event

***Notes**: 1 – Major event is used if specific conditions, listed in Chapter SW6, are met.*
2 – Refer to SW7 for ponding depth limits.
3 – Privately owned culverts located outside right-of-way and serving areas, which do not require detention.
4 – Lesser capacities may be considered, refer to Chapter SW8 for additional information.

SW5.03 Runoff

Proper calculation of runoff is critical to proper planning and sizing of storm drainage facilities. This section identifies the methodology to be used for determining the storm runoff design peaks and hydrograph generation for preparation of storm drainage studies, plans, and facility designs.

1. Time of Concentration Calculation

Time of Concentration (T_c) is the amount of time it takes for the most hydraulically distant point in the watershed to contribute flow. T_c influences the shape of the runoff hydrograph and has two components:

- The time for overland flow to occur from a point on the perimeter to a natural or artificial drainage conduit or channel.
- The travel time in the conduit or channel to the outflow point of the catchment.

The minimum time of concentration for all computations shall be 5 minutes. Technical Release 55 (TR-55, June 1986) Chapter 3 provides the procedure for calculating T_c. Refer to Exhibit SW5-1 for the T_c worksheet.

2. Peak Flow Calculations

Peak flow calculations represent the first level of runoff analysis. This analysis is used to determine the maximum flow rate at a given point resulting from a storm event. Peak flow analysis is sufficient to design storm sewers and culverts whose purpose is only to convey runoff. As indicated in Figure SW5.6, the Rational and Graphical Peak Discharge

Methods are approved peak flow calculation methods for use in Fort Wayne.

A. Rational Method

The Rational Method can be used to compute peak flows for watershed areas less than twenty (20) acres. This method assumes that all rainfall abstractions are represented by a single runoff coefficient, C. Where distinctive land use features are known, use of an area weighted C factor is required. The Rational Method equation is:

$$Q = CiA$$

Where:

Q = Runoff (cfs)

i = Rainfall intensity (in/hr, see Figure SW5.2)

A = Drainage area (acres)

C = Runoff coefficient (see Exhibit SW5-2)

Using the Rational Method assumes:

- The rainfall intensity is uniform over the entire watershed during the entire storm duration.
- The storm duration is equal to Tc.
- The Tc is the time required for the runoff from the most remote part of the watershed to reach the point under design.

B. Graphical Peak Discharge Method - (TR-55)

The Graphical Peak Discharge Method uses the runoff curve number (CN), where CN > 40. This number is a function of soil type and land use. For details on using the NRCS (SCS) procedure refer to TR-55, June 1986. This method is implemented by first applying the following equations to calculate the runoff depth:

$$Q = (P-0.2*S)^2/(P+0.8*S) \text{ and } S=(1000/CN)-10$$

Where:

Q = Runoff depth (in)

P = Rainfall depth (in, see Figure SW5.3)

S = Retention (in)

CN = Curve number (see Exhibit SW5-3 & Exhibit SW5-4)

Peak discharge is estimated as:

$q_p = q_u * A * Q * F_p$

Where:

q_p =Peak flow rate (cfs)

q_u = Unit peak flow rate (cfs/mi^2 per inch of runoff, refer to TR-55)

A =Drainage area (mi^2)

Q = Runoff depth calculated from previous equation (in)

F_p = Pond and swamp adjustment factor
= 1 if there are no ponds or swamps

3. Hydrograph Generation Methods

A hydrograph represents runoff flow as it varies over time at a particular location. The area under the hydrograph represents the total volume of runoff. As opposed to peak rate of runoff, the hydrograph accounts for the variation in volume and flow rate over the duration of the of the storm event. Hydrographs are necessary to assess the effects of stormwater detention/retention facilities. Hydrographs are also necessary for assessing the effects of combining runoff from two or more subcatchments discharging to a common location in complex drainage areas with multiple subcatchments.

Hydrologic modeling software or the Tabular Hydrograph Method listed in Figure SW5.5 are approved methods for hydrograph generation. Engineers are responsible for understanding the limitations and correct application of modeling software used for hydrograph generation. For details on the Tabular Hydrograph Method refer to TR-55, June 1986. In some cases detailed hydrologic studies may have been completed for the area of interest, and can be used with approval from City Utilities.

Figure SW5.6 Acceptable Runoff Generation Methods

Peak Flow Calculation Methods	**Application Criteria**
Rational Method	Drainage Areas < 20 acres
Graphical Peak Discharge Method	1. Applicable to drainage areas of all sizes 2. Drainage area must be hydrologically homogeneous (i.e. describable by one CN) 3. CN > 40 4. 0.1 hrs. < T_c < 10 hrs. 5. Drainage area can have only one main stream, or if more, the branches must have nearly equal T_c's. 6. For use with 24 hour storm rainfall depths
Hydrograph Generation Method	**Application Criteria**
Tabular Hydrograph Method	1. Applicable to drainage areas of all sizes 2. Divide drainage area in subbasins that have a reasonably homogeneous CN and one main channel 3. For use with 24 hour storm rainfall depths 4. T_c < 2 hrs.
TR-20 (*preferred*)	Used to generate and route runoff hydrographs. Output consists of peaks and/or hydrographs. TR-20 develops hydrographs from rainfall using the dimensionless unit hydrograph, drainage area, time of concentration, and SCS curve number.
HEC-HMS (HEC-1) (*preferred*)	Provides a variety of options for simulating precipitation-runoff process.
WinTR-55	Uses the TR-20 model for hydrograph generation and routing. Provides a variety of options for defining precipitation, land use, and dimensionless unit hydrograph. Not as comprehensive as TR-20.
Unit Hydrograph	For gauged watershed – rainfall and runoff records can be used to generate a site-specific unit hydrograph. For ungauged watersheds – synthetic unit hydrographs may be used, such as NRCS, Clark, and Snyder.
EPA SWMM	Used to route and combine hydrographs for sub-catchments. Appropriate for use in more complex basins.
Published Hydrologic Information	May be used where Fort Wayne and/or State have developed detailed hydrologic studies appropriate for use in the study area.

SW5.04 Offsite Hydrologic Analysis

The design of stormwater facilities shall consider and accommodate the storm runoff from watersheds upstream to the drainage area(s) being analyzed as indicated in Figure SW5.7. Investigation of facilities downstream of the boundaries of the project area is a required part of the design process.

Figure SW5.7 Assumptions for Onsite and Offsite Storm Flow Analysis

Analysis Type	Requirements for Use in Fort Wayne
Onsite Analysis	The proposed fully developed land use plan shall be used to determine runoff coefficients. Changes in flow patterns (from undeveloped site conditions) caused by the proposed development shall be considered. The proposed lot grading shall be used to calculate the time of concentration or the runoff calculation parameters.
Offsite Analysis	Upstream drainage areas shall be considered developed for analysis of onsite stormwater facilities. Where the offsite area is fully or partially undeveloped, the runoff shall be calculated assuming the basin is fully developed. Fully developed land use parameters (i.e. C and CN) shall be based on current zoning. Downstream analysis of the impacts of drainage improvements shall be completed to a point in the receiving watercourse where an increase in the stage of the receiving stream during the design storm is less than or equal to 0.14 feet (0.14’).