CITY UTILITIES DESIGN STANDARDS MANUAL

Book 2
Stormwater (SW)
SW6 Storm Sewers

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SW6.01 Purpose

The purpose of this Chapter is to establish the minimum standards and technical design criteria for all storm sewers in regard to hydrology, size, and alignment within the City of Fort Wayne. The primary function of storm sewer systems is to collect excess stormwater from street gutters, convey the excess stormwater through storm sewers and along the street right-of-way, and discharge it into a detention basin, water quality best management practice (BMP) or the nearest receiving water body (FHWA 1996). The design of storm sewers presented in this section relies on fundamental hydrologic and hydraulic design concepts. Designers should refer to Chapter SW5 - Hydrology, Chapter SW7 - Inlets, Chapter SW8 – Culverts, and Chapter SW9 - Open Channels for additional design methodology.

SW6.02 Design Storms

Two design storms shall be considered for sizing storm sewers: the minor (10-year) storm and the major (100-year) storm. Refer to Chapter SW5 - Hydrology for appropriate hydrologic design methods. In each case, storm sewers shall be sized to carry the portion of the runoff that cannot be conveyed on the surface, as dictated by the available capacity in streets and swales during these two events. Designers shall ensure that storms in excess of pipe design flows can be safely conveyed through a development without damaging structures or flooding major roadways.

Inlets shall be spaced in street gutter line to prevent flow from entering public road intersections and to allow one lane (based on lane width of the road) of traffic to remain open for local streets. Arterial and collector streets must have one travel lane in each direction open to traffic.

The hydraulic grade line (HGL) shall not exceed the crown of the pipe by more than five percent (5%) of the diameter of the pipe for the design storm.

1. Minor Event Design Storm

   At a minimum, all storm sewers shall be designed to convey the peak flow for the minor storm (10 year storm event).

2. Major Event Design Storm

   The storm sewer system shall be sized to convey the major storm (100 year storm event) if any of the following conditions are met:

   a) The street capacity for the major storm is exceeded; especially where the grade slopes down behind the curb and the major storm capacity is limited to the height of the curb.

   b) The major storm flows split off in an undesired direction (e.g. flow splits at intersections).

   c) The storm sewer system is accepting flow from an upstream storm sewer system or branch that is designed for the major storm.

   d) Regional storm sewers are designed for the major storm.

e) The storm sewers must convey un-detained flows to a regional detention basin if an over-land flow path to the basin is not available.

SW6.03 Alignment Criteria

All storm sewers shall be constructed with a straight alignment between manholes. Sound engineering judgment shall be utilized when determining locations for stormwater systems. Existing easements and rights-of-way shall be utilized if possible. Service needs of both the present service area and future service areas should be thoroughly evaluated. Figure SW6.1 provides the minimum horizontal and vertical alignment criteria.

Figure SW6.1 Horizontal and Vertical Alignment Criteria

Alignment of Storm Sewer Relative to:	Alignment		Comment
	Minimum Vertical Clearance	Minimum Horizontal Clearance	
Water Main	18 inches	10 feet	The distance shall be measured edge to edge. Approval from City Utilities will be required for lesser clearances.
Building Structure or Foundation	-	10 feet (@ depth of less than 10 feet) 15 feet (@ depth of greater than 10 feet)	
Cover	3 feet	-	Minimum cover depends upon the pipe size type and class, and the soil bedding condition. The storm sewer grade shall be such that a minimum cover is maintained to withstand AASHTO HS-20 loading on the pipe.

1. Placement in Existing Rights-of-Way and Easements

   For storm sewers located within existing or proposed street right–of-way, the preferred placement should be as shown on Exhibit SA5-1.

   In areas of concrete pavement, consideration shall be given to placing the storm sewer in a location such that when saw-cut, an edge of the pavement to be removed would coincide with an existing construction joint resulting in the need to only saw-cut one side of the pavement. Manhole structures shall be either completely outside the pavement or completely inside the pavement. The existence of curbs or proposals of future curb and gutter shall be taken into account when evaluating the benefit of reducing the number of manholes in curved streets.

2. Minimum Distance from Water Lines

   Storm sewers shall be laid at least the vertical and horizontal distance listed in Figure SW6.1. The distance shall be measured from outside edge of pipe to outside edge of pipe.

   In instances where it is not possible to maintain the minimum horizontal alignment, City Utilities may allow deviation on a case-by-case basis. This deviation may allow installation of the storm sewer closer to the water main, provided that the water main is in a separate trench or on an undisturbed earth shelf located on one side of the sewer and at an elevation so the bottom of the water main is at least 18" above the top of the storm sewer.

   When proper separation as described above is not possible, both the water main and storm sewer must be constructed of slip-on mechanical joint pipe from structure to structure, complying with the water supply standards outlined in Chapter MA5 – Stormwater Materials and Testing Requirements and Chapter MA7 – Water Materials and Testing Requirements of this Standards and be pressure tested to 150 psi to assure watertight joints before backfilling. In all instances when separation cannot be maintained, City Utilities shall be consulted for guidance and approval.

3. Minimum Distance from Additional Utilities

   All plans shall show the location of both underground and overhead utilities (existing and proposed). The location of the utilities shall be derived from the best information available. Each utility company shall receive a set of plans prior to final submittal on which they may note changes or additions to utility information. The adequacy of the separation of the storm sewer and other utilities shall be determined by both the appropriate utility company and the design engineer. Any necessary relocation shall be closely coordinated with the respective utility company.

SW6.04 Hydraulic Design

Storm sewers are designed to have capacity that meets or exceeds the design discharge (peak flow rate) as determined using the Rational Method (Chapter SW5-Hydrology). Hydraulic computations are then performed to determine the capacity of storm sewer systems. Refer to Urban Drainage Design Manual Hydraulic Engineering Circular 22, 3rd Edition Chapter 7 for more technical detail on design methodology for storm sewer hydraulic design. As site conditions allow, the rate at which water flows through the storm sewer system and MS4 conveyances shall be regulated to reduce outfall scouring and stream bank erosion.

1. Flow Equations and Storm Sewer Sizing

   Storm sewer flow is usually unsteady and non-uniform, but for design purposes it is assumed to be steady and uniform at the peak flow rate. Manning's equation is utilized, which can be stated as:

   $$Q= 1.49/n\ AR_h^{2/3}S_f^{1/2}$$

   Where:

   Q = flow rate (cfs)

   n = Manning's Roughness Coefficient, Exhibit SW6-1

   A = flow area (ft^2)

   R_h = hydraulic radius (ft), defined as flow area, A, in square feet divided by wetted perimeter, (P_w) in feet

   S_f = friction slope (equal to storm sewer slope for uniform flow) (ft/ft)

   Initially storm sewers can be sized to flow just full (i.e., as open channels using nearly the full capacity of the pipe). For circular pipes,

   $$D_r = (2.16*nQ_p/\sqrt{S_o})^{3/8}$$

   In which D_r is the minimum size pipe required to convey the peak design flow and Q_p is the peak design flow.

   The typical process for sizing storm sewers proceeds as follows:

   a) Use the Rational equation to calculate peak flow rate for design storm event.

   b) Size storm sewer using Manning's equation assuming uniform, steady flow at the peak.

   c) Check proposed storm sewer sizes using the energy equation by accounting for head losses.

   d) If surcharging occurs at manholes or inlets, increase storm sewer size and repeat process.

2. Hydraulic Grade Line

   The hydraulic grade line (HGL) in newly constructed storm sewers shall not exceed the crown of the pipe by more than five percent (5%) of the diameter of the pipe for the minor storm (or the major storm if the storm sewer is designed to convey that flow). If an exception is requested, the HGL shall be determined by starting at the downstream end of the proposed drainage system using the maximum water surface elevation experienced for the design period. Tailwater shall be included in the analysis. For these exceptions, design calculations shall be provided where the HGL exceeds the crown of the pipe.

   Sound engineering judgment shall be used to account for the HGL in storm sewers affected by storm events exceeding the design storm event.

3. Headlosses

Energy losses in pipes, structures, and appurtenances shall be taken into account in all designs, including:

a. Pipe Friction Losses

The headloss due to friction in a pipe is computed as follows:

$$H_f = [V^2 n^2 L]/[(2.21)(R_h)^{4/3}]$$

Where:

H_f = Friction loss, ft
V = Velocity, ft/s
n = Manning's Roughness Coefficient (See Exhibit SW6-1)
L = Length of pipe, ft
R_h = Hydraulic radius of pipe, ft

b. Structure and Appurtenance Losses

Local losses in structures and appurtenances shall be computed as follows:

$$H_L = K(V^2/2g)$$

Where:

H_L = Headloss in structure, ft
K = Headloss coefficient
V = Velocity, ft/s
g = Acceleration of gravity, 32.2 ft/s^2

Values for K may be obtained using the following Figure:

Figure SW6.2

Structure Type	K
90 degree bend	0.4
45 degree bend	0.32
Straight Through	0.05

Values for other bends may be derived through linear interpolation.

c. Exit Losses

For sudden expansion at storm drain outlet, the exit loss is:

$$H_o = 1.0\ [(V_o^2/2g) - (V_d^2/2g)]$$

Where:

V_o = Average outlet velocity
V_d = Channel velocity downstream of outlet in the direction of the pipe flow
g = Acceleration due to gravity (32.2 ft/s^2)

4. Velocity

The velocity in newly designed storm sewer systems shall not be less than 2.5 ft/s. This velocity shall be based on full flow, gravity conditions.

5. Slopes

   The minimum slope for storm sewers less than 48” in diameter shall be such that minimum velocities can be achieved. The minimum slope for storm drains with diameters of 48” or greater shall be 0.001 ft/ft.

SW6.05 Construction Materials

Construction materials must be in accordance with Chapter MA5-Stormwater Materials and Testing Requirements.

SW6.06 Pipe Size

The minimum pipe diameter for storm sewers, with the exception of perforated underdrains shall be 12”. Perforated underdrains for use in poorly drained and flat drainage areas shall have a minimum diameter of 4”.

SW6.07 Manholes

1. Manholes shall be located at the following locations:

   - Where dictated by spacing requirements
   - Storm sewer junctions
   - Transitions in alignment
   - Transitions in grade
   - Transitions in pipe diameter
   - Transitions in material

2. Spacing

   Manholes shall be placed at the intervals provided in Figure SW6.3.

Figure SW6.3 Maximum Manhole Spacing Intervals

Pipe Diameter	Maximum Distance
12" - 15"	400'
18" - 30"	500'
33" and greater	600'

3. Manhole Diameter

   Figure SW6.4 provides criteria for the maximum pipe size that can connect to a specific diameter manhole structure. The designer shall use this Figure as a guideline. More detailed information is provided in Exhibit SW6-2.

Figure SW6.4 Manhole Maximum Allowable Pipe Diameter

Minimum Manhole Diameter	Maximum Pipe Size Straight Through and up to 45° angle			Maximum Pipe Size 45° to 90° angle		
	RCP	HDPE	PVC	RCP	HDPE	PVC
48”	18”	18”	24”	18”	18”	24”
60”	36”	36”	36”	24”	24”	27”
72”	42”	42”	48”	36”	36”	42”
84”	54”	54”	60”	42”	42”	48”
96”	60”	60”	66”	48”	48”	54”

Additional Manhole requirements based on diameter include:

- For flexible pipe in sizes less than 36 inches (36”) or rigid pipe less than thirty inches (30”) in diameter, a compression connector or resilient connector per ASTM C923 shall be installed.
- For all materials, pipe sizes 36 inches (36”) and larger, seep ring and non-shrink grout shall be installed.

All manholes must have sufficient wall between pipe openings to meet the following criteria:

- For circular structures, the minimum distance allowed between precast holes shall be six inches (6”).
- For rectangular structures such as junction chambers, where pipe is to be installed in adjacent walls, a minimum of six inches (6”) of wall as measured from the interior corner is required on each side of the pipe beyond the precast opening for the pipe. This rule is not applicable for structures which have pipe installed in opposite walls or where one outlet pipe is utilized.

4. Transitions in Alignment

Changes in direction of flow (internal angles between pipes) at manhole junctions of less than 90 degrees (90°) are not recommended due to hydraulic losses.

5. Transitions in Grade

For all manhole and junction chamber structures with equal diameter influent and effluent pipes, a minimum 0.10 foot (0.1 ‘) drop between the inverts of the influent and effluent pipes shall be maintained to offset losses experienced at manhole structures. The flow channel through a manhole shall be made to conform in shape, and slope to that of connecting sewers.

6. Transitions in Pipe Diameter

Storm sewer pipe size changes are only allowed at manhole and junction chamber structures. Drop between the influent and effluent pipes of different diameters shall be sufficient to maintain the energy gradient. The influent and effluent pipes with different diameters shall be connected to manholes and junction chamber structures according to the criteria in Figure SW6.5.

Figure SW6.5 Diameter Change Criteria

Diameter	Criteria
24 inch (24”) or less	1. When increasing pipe diameter by six inches (6”) or less, crown elevations at the centerline of manhole shall match. 2. When increasing pipe diameter by more than six inches (6”), the springlines of the pipes at the centerline of the manhole shall match.
27 inch (27”) or greater	1. Begin design by matching crowns at centerline of manhole and evaluate energy grade line (EGL) of upstream and downstream segments. EGL shall not increase in downstream segment. 2. If EGL of downstream segment lies below EGL of upstream segment, the downstream sewer may be raised by two-thirds the difference between the upstream and downstream EGLs.

7. Bench

   A bench shall be provided on each side of any manhole channel when the pipe diameter(s) are less than the manhole diameter. The bench shall be sloped no less than ½ inch per foot (4%). No manhole pipe shall discharge onto the surface of the bench.

8. Adjustment Rings

   In general, acceptable adjustment ring sizes are 3, 4, and 6-inches tall. A 6” adjustment ring shall be used when lowering of a manhole rim is not anticipated.

SW6.08 Outlets

Storm sewer outlets shall be designed to allow expansion of flow and reduction of velocity, to prevent erosion downstream, and to allow for proper construction and maintenance of cut or embankment slopes at the outlet.

A headwall or flared end section shall be provided at all pipe outlets. Flared end sections and headwalls shall have a toe wall extending a minimum of 18" below grade at their downstream end to prevent undercutting.

1. Erosion Protection at Outlets

   Adequate erosion protection shall be provided at all storm sewers. Outlet protection design shall take into account:

   - Velocity of discharge
   - Invert elevation of outlet
   - Tailwater elevations
   - Energy dissipation and erosion protection
   - Orientation of outlet

Typical outlet protection includes riprap lined aprons and basins. Refer to HEC 14 Hydraulic Design of Energy Dissipaters for Culverts and Channels 3rd Edition, Chapter 10: Riprap Basins and Aprons for riprap basin and apron design procedures. Outlet protection structures shall be designed to accommodate the design flow used for sizing the drainage structure discharging to the outlet protection.

The invert of the storm sewer outlet shall be equal to or higher than the invert of the receiving drainage path at the outfall. When practical, outlets shall be oriented to discharge runoff in the downstream direction. If the outlet cannot be positioned in a downstream direction, potential for scour must be considered. A lining of riprap or other suitable material shall be installed on opposite channel bank if erosion potential exists.

Outlet protection shall include details on dimensions, D_{50} of riprap, depth of riprap layer and depth of gravel filter layer.

SW6.09 Non-Gravity Flow Stormwater Systems

Stormwater facilities are to be gravity flow. Facilities designed to include pumps or mechanized equipment such as gates will be allowed only through the variance process described in General Requirements, Chapter GR3 - Variances.

SW6.10 Checklists and Design Aids

All of the design criteria in this chapter must be followed. Several key considerations that the designer must take care to address include:

- Design the HGL not to exceed the pipe's crown more than five percent (5%) of the diameter of the pipe for the design storm.
- Account for all losses in the EGL and HGL calculations including pipe friction, manhole, junction, and outlet losses.
- Provide adequate erosion protection at the outlet of all sewers.
- Provide cross sections for riprap protection.
- Check for minimum pipe cover and cearancel with utilities.
- Non-gravity flow systems should only be considered as a last option.