CITY OF OKLAHOMA CITY

Oklahoma City Drainage Criteria Manual

The City of Oklahoma City

Public Works Department

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THE CITY OF OKLAHOMA CITY

Drainage Criteria Manual

Approval Sheet

Department of Public Works
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Oklahoma City, OK 73102

Approved by the City Engineer of the City of Oklahoma City this ______________ day of

__________________________, 2020.

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Eric J. Wenger, P.E., City Engineer

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1. Executive Summary

1.1 Introduction

The design of storm sewer, drainage, and flood control devices must comply with the requirements of Chapter 16 of the Oklahoma City Municipal Code. Chapter 16, entitled “Drainage and Flood Control”, lists design methods, equations, mathematical variables, floodplain management, and other criteria that are used to design all facets of drainage related facilities or analyses.

This Drainage Criteria Manual (DCM), at the direction and approval of the City Engineer, provides supplemental information related to the Drainage Ordinance requirements and engineering design criteria for surface runoff, storm sewer and floodplain improvements within the City of Oklahoma City.

The City Engineer may revise the DCM to provide for needed updates and changes. Updates will be posted to the City’s website at okc.gov for 60 days prior to changes becoming effective. The consulting engineer must contact the Public Works Department to obtain the most current DCM document available prior to use.

From time to time, in response to, and because of, field observations, comments from the public, and/or development community, the City Engineer may require additional requirements that must be complied with regardless of whether the requirements are mentioned elsewhere in the Drainage Ordinance or the DCM. The following list of design items must be complied with in the design of drainage facilities:

1.
Any desired variations from the requirements of the DCM must be approved by the City Engineer.

All drainage designs and devices shall conform to the City of Oklahoma City Standard Specifications. All approved standard construction details are available from the Public Works Department.

1.2 Base Vertical Datum Adjustment Factors NGVD29 to NAVD88

All elevations related to any design, base flood elevations, plan elevations, or else, shall be referenced to NAVD 88 vertical datum or most recently adopted control. The FEMA 2009 (or most current) publication of the various county Flood Insurance Studies (FIS) updated and converted all previous noted elevations from NGVD 29 to NAVD 88 datum.

However, Oklahoma City uses a locally produced "URBAN FLOOD ANALYSIS IN OKLAHOMA CITY OKLAHOMA" (USGS, 1983) publication for floodplain management purposes in development applications. This document lists higher urbanized flood flow rates and elevations than the FEMA FIS (circa 1983) for the 50-year and 100-year storm events to be used for development and floodplain management purposes.

For this reason, elevations listed in the 1983 Urban Flood Analysis in Oklahoma City (USGS, 1983) report shall be adjusted upward to the current NAVD 88 vertical datum or most recently adopted control. Each county has an adjustment value unique to that county. For any floodplain activity in each county containing any Oklahoma City property limit, add the following values to NGVD 29 elevations to adjust upward to current NAVD 88 datum:

County Adjustment Factors:

Oklahoma County	+0.425 feet
Canadian County	+0.547 feet
Cleveland County	+0.369 feet
Pottawatomie County	+0.295 feet

2. Storm Water Run-Off Calculation Methods

2.1 Introduction

This chapter provides the City approved sources for rainfall data and Hydraulic and Hydrology (H&H) calculations for the design of drainage conveyance systems to meet the requirements of the Drainage Ordinance and DCM.

2.2 Rainfall

Total rainfall is provided for calculation of flows using programs such as HEC-1, HEC-HMS, or WinTR-55. Rainfall intensities are provided for calculation of flow using the rational or modified rational methods. Annual average rainfall for the City is also provided for using the current USGS regression equations as in the National Stream Stats (NSS) methods.

Total rainfall is calculated from the current NOAA Atlas 14 rainfall records and presented in rainfall total depths varying in inches over a given duration and frequency as well as in the rainfall intensity in inches per hour varying over a given duration and frequency.

2.3 Runoff Calculations Methods

There are many methods for calculating runoff for a design of components of the storm drainage system. Methods acceptable within the City depend on the type of design analysis and include the Rational Method, Modified Rational Method for stormwater detention, Soil Conservation Service (SCS) Method, and USGS Regression Equation Methods used within StreamStats. Peak flow calculations are used for sizing drainage conveyance systems. Total volume of the flow is used in sizing detention facilities for storage quantity requirements.

Table 2-2: List of Runoff Calculation Methods

	Applicable Use		Use with Minimum Basin Area (Acres)	Use with Maximum Basin Area (Acres)
	Peak Flow	Total Volume		
Rational Method	Yes	No	0	200
SCS Method	Yes	Yes	200	2000
USGS Regression Equations	Yes	No	200	None
Modified Rational	No	Yes	0	200

Any drainage basin analyzed to calculate flow rates for any frequency storm shall be considered fully urbanized to produce urbanized flow rates for design purposes. All drainage calculations or flood studies shall consider fully urbanized runoff conditions and urbanized flow rates.

2.3.1 Rational Method

Runoff from surface drainage areas may be determined by the Rational Method formula:

$$Q = CIA$$

Where,

Q = Flow in cubic feet per second

A = Surface area to be drained in acres, determined by field topographic surveys or based on Oklahoma City most current contours

C = Area runoff coefficient, fraction of runoff, and may vary between 50-percent and 95-percent expressed as a dimensionless decimal fraction, that appears as surface runoff from the contributing drainage area.

I = Rainfall intensity based on the rainfall rate in inches per hour

Table 2-3: Runoff Coefficients, "C" Factors

Development Type	Zoning	Runoff Coefficients
Single Family Residential Including Mobile Homes	R-1	0.70
Acreage Residential 0.5-2.0 ac	RA, RA2 or R-1	0.65
Acreage Residential 2.0-5.0 ac	RA, RA2 or R-1	0.60
Duplex	R-2	0.75
Quad-Plex	R-3	0.80
Apartment Complexes	R-4	0.85
Commercial-Offices	C-1 through C-3	0.90
Shopping Centers	C-4	0.95
Industrial	I-1 through I-3	0.95

One of the basic assumptions underlying the Rational Method is that runoff is a function of the average rainfall rate during the time required for water to flow from the most hydraulically remote part of the drainage area to the point under consideration. The other significant assumption is that intensity of rainfall is constant over the entire basin during this time.

Time of concentration consists of overland flow time, T_o, plus the time of travel, T_f, in the storm sewer, paved gutter, roadside drainage ditch, or drainage channel. The latter portion, T_f, of the time of concentration can be estimated from the hydraulic properties (velocity) of the storm sewer, gutter, swale, ditch, or channel. Overland flow time, on the other hand, will vary with surface slope, surface cover and distance of surface flow.

The time of concentration can be calculated using the following equation:

$$\mathbf{T_c = T_o + T_f}$$

Where,

T_c = Time of concentration (minutes)

T_o = Initial or overland flow time (minutes)

T_f = Travel time in the ditch, channel, gutter, storm sewer, etc. (minutes)

NOTE: Minimum time of concentration, T_c, shall be 5-minutes.

The overland flow time, T_o, can be calculated using the following equation:

$$\mathbf{T_o = K\, L^{0.37}/S^{\,0.2}}$$

Where,

K = Retardance factor

L = Length of the overland flow in feet

S = slope of the ground (ft/ft)

NOTE: The maximum overland flow length shall be 1,000 feet

Table 2-4: Retardance "K" factor for type of Cover

Dense Grass	1.13
Average Grass	1.000
Poor Grass	0.942
Bare Soil	0.604
Acreage Residential 0.5 to 2.0 acres	0.633

Acreage Residential 2.0 to 5.0 acres	0.756
Residential / Duplex / Quad-Plex	0.511
Commercial / Apartment Complex	0.445
Industrial/Pavement	0.372

The total time of concentration shall be the combination of overland flow time with the remaining flow path travel time, T_f, which is calculated using the hydraulic properties (velocity) of the swale, ditch, or channel. The calculated velocity shall be based on Manning's equation. The following equation is used for calculating the travel time forward:

$$\mathbf{T_f = (FPL/V)/T}$$

Where,

FPL = Flow Path Length in feet

V = Velocity in feet per second

T = 60 seconds

Rainfall intensities for the Rational Method are calculated using the following method. The intensity, i, is the average rainfall rate in inches per hour for the period of maximum rainfall of a given frequency having duration equal to the time of concentration. For a given time of concentration, T_c, and a given design storm frequency, the rainfall intensity, i, can be obtained using the following equation:

$$\mathbf{i = B / (T_c + D)^E}$$

Where,

i = Rainfall Intensity in inches per hour

T_c = Time of Concentration in minutes

B, D, E = Parameters defined in Table 2-1 for various storm frequencies.

Table 2-1: Rainfall Intensity Parameters.

Return Period	Parameters for the IDF Equations		
	B	D	E
2-Year	104.332663	17.298017	0.934857
5-Year	79.655486	14.827708	0.825124
10-Year	87.535303	15.882422	0.811341

25-Year	101.481871	16.773612	0.805881
50-Year	98.924724	15.864806	0.775353
100-Year	102.769257	15.860016	0.760373

2.3.2 SCS Unit Hydrograph Method

The Soil Conservation Service (SCS) method is considered acceptable for certain analyses and for determining variable values for input to other software such as HEC-HMS or HEC-1. The NRCS program WinTR-55 or the U.S. Army Corps of Engineers computer programs HEC-HMS or HEC-1 are acceptable ways of utilizing the SCS methodology.

2.3.3 USGS Regression Equations

The United States Geological Survey (USGS) regression equations are used in the StreamStats methods for stormwater runoff calculations. The result of utilizing StreamStats is a non-urbanized flow. The non-urbanized flow is to be urbanized by applying a Basin Factor through NSS.

2.3.4 Modified Rational Method

The modified rational method (MRM) is an extension of the rational method to produce simple runoff hydrographs. The MRM is often called the rational hydrograph method. Application of the MRM produces a runoff hydrograph and runoff volume in contrast to application of the rational method, which produces only the peak design discharge (Qp).

2.4 Acceptable Methods for Hydraulic Calculations

Manning's method shall be used for the hydraulic calculation of drainage ditches and storm sewers. For drainage ditch structures draining up to 20-acres, Manning's equation for uniform flow can be used.

2.4.1 Manning's Equation

The size of closed storm sewers, open channels, culverts, and bridges shall be determined by using Manning's Equation which may be modified for use with runoff determined by the Rational Formula to:

$$\mathbf{Q} = \frac{\mathbf{1.486}}{\mathbf{n}} \mathbf{A} \, \mathbf{R}^{\frac{2}{3}} \mathbf{S}^{\frac{1}{2}}$$

Where:

Q = discharge in cubic feet per second

A = cross sectional area of water in conduit in square feet

R = hydraulic radius of water in conduit (R = water flow area/wetted perimeter)

S = mean slope of the flowline gradient in feet of vertical rise per foot of horizontal distance

n = Manning's roughness coefficient. The typical values of Manning's roughness coefficients for capacity calculations are provided in the following table:

Table 2-5: Manning's roughness coefficients

RCP & RCB	0.013
CGMP	0.024
HP	0.013
HDPE	0.013
Concrete Lined Channel	0.013
Grass Lined Channel	0.035
Concrete Curb & Gutter	0.013
Asphalt Pavement	0.016
Rip-Rap	$n = 0.0395(d_{50})^{1/6}$ d_{50}=nominal stone dia in feet

In addition to Manning's equation, use of the other design methods may be required to adequately size storm water facilities. Design of storm sewer systems shall maintain the hydraulic grade line below any gutter elevation and any manhole top lid/rim elevation to eliminate flooding inlets at the gutter line or system overflow along the design reach limit.

2.4.2 Backwater Profile Using HEC-RAS or HEC-2

The U.S. Army Corp of Engineers Programs HEC-RAS River Analysis System or HEC-2 Water Surface Profiles Program shall be used to analyze all open channels with drainage areas larger than 20-acres. Normal depth shall be used as the boundary condition if a beginning water surface elevation is not known. If a previous study is available downstream of the existing location, the boundary conditions should be based on the known water surface elevation of the approved study.

2.4.3 Use of Other Commercially Available Packages

Use of other software such as EPA-SWMM, XP-SWMM, AutoCAD Storm and Sanitary Analysis, or any other similar commercially available package is permitted if a justification for the value of parameters is provided by the engineering consultant.

3. Street, Inlets, and Closed Storm Sewer

3.1 Introduction

Streets, curb inlets, and closed storm sewers are used for providing drainage systems within areas of development. Streets are an integral part of an urban drainage system. Streets are used to provide drainage until its flow capacity is exceeded then curb inlets are provided to drain the street. A closed storm sewer system is provided to accept flow from inlets.

The following subsections describe design features and requirements for a drainage system for streets, curbs, and gutters.

Streets without curbs and gutters are permitted in accordance with the Drainage Ordinance. In this case, the use of borrow ditches are permitted for street drainage.

Open-top drop inlets shall not be used.

3.2 Roadway Drainage

3.2.1 Design Flow

The street shall be designed for fully urbanized conditions as determined by current zoning for the area. It is the responsibility of the Engineer to verify it uses the most updated zoning map for the area. The current zoning map can be found on the Oklahoma City website. However, the minimum composite runoff coefficient shall meet the requirements of Table 2-3.

3.2.2 Roadway Flow Capacity

Street capacities are calculated based on the area and wetted perimeter of the roadway cross-section when considering the street width and crown of the roadway. The minimum capacity for any stretch of roadway is based on the minimum slope of the roadway section. A minimum slope of 0.60% shall be maintained at every location along a proposed street. The roadway capacity may be calculated using the Manning equation. Depending on the standard paving section used, the curb height may vary from 4-inch to 8-inch; paving width may vary from 26-foot to 48-foot; the crown height will vary depending on the paving width:

$$\boldsymbol{Q = \frac{0.56}{n} S_x^{1.67} S^{0.5} T^{2.67}}$$

Where:

Q = discharge in cubic feet per second

S_x = paving cross slope from gutter to crown shall be 2%

S = mean longitudinal slope of paving shall be 0.60% minimum

T = width of flow in feet

n = Manning's roughness coefficient for paved sections = 0.013 minimum

A four-lane street shall be used for conveyance of flow provided the flow depth is limited to 6-inches or one lane in width each way, whichever is less.

3.2.3 Drainage Related Street Design Features

Paving crowns must be omitted at all intersections to avoid ponding. Vertical curves are not permitted at crests and sags (vertical high and low points of a roadway profile) within Oklahoma City. To eliminate possible ponding, grade changes shall be designed by using tangents with minimum lengths of 25-feet and a minimum slope of 0.6%. The maximum profile grade break shall be 1.2%.

3.3 Curb Inlets (Design 2 Inlets)

3.3.1 Inlet Design Flow and Location

Inlets must be designed for fully urbanized conditions as determined by current zoning for the area. However, the minimum composite runoff coefficient or shall meet the requirements of Table 2-3. Storm drain inlets shall be designed and placed at the following locations to provide quick and efficient removal of surface water from the street:

A. Curb inlet grates are required to drain the very low flow that usually cannot enter curb hoods. Grates shall be located at the lowest point of the sump or the downstream end of a curb inlet.

B. At least one curb inlet shall be located at a sump location unless the location is being served with a flume with a curb opening.

C. If a street/roadway is designed to drain towards a "T" intersection and the intersecting street is flowing at 70% or greater street capacity as described in Section 3.2.2 above, then inlets must be placed before the intersection to drain all of the upstream street discharge. If a street is designed to drain towards a "T" intersection, additional finished floor and driveway location restrictions are imposed to protect against driveways acting as a channel that may drain storm water runoff towards a garage causing flooding. A driveway edge for a lot along a T-intersection shall have a minimum offset of 20-feet from the center line of the intersecting street.

D. If the 25-year urbanized flow in the roadway exceeds the street capacity a curb inlet shall be provided to capture 25-year flow. The by-passed flow must be included in the capacity calculations for the next downstream inlet, whether it is on a continuous grade or within a sump.

E. Curb inlets located at sumps shall be designed to intercept a minimum of the peak discharge from the 50-year design event with an overflow structure designed to intercept the difference between the inlet capacity and the 100-year by-pass from all other upstream inlet locations. If there is no overflow structure, the curb inlets at sumps must be designed to carry the 100-year storm and the 100-year by-pass from all other upstream inlet locations. All streets must have inlets between Design 2-0 and Design 2-4. Curb inlets lager than Design 2-4 are not allowed, unless specifically approved by the City Engineer. Inlets located in cul-de-sacs can be no larger than a Design 2-0, unless specifically approved by the City Engineer.

F. The curb cut width for a flume opening or the entrance width of an overflow flume shall not exceed 15 feet. The minimum flume width shall be 4 feet.

3.3.2 Design and Construction Standards

The City of Oklahoma City Construction Standards contains engineering design and construction details for Design 2 Inlets. Design 2 Inlets are multiple curb openings and two grates. This type of inlet is usually the most practical type of roadway drainage because it resists clogging and offer little interference to vehicular, bicycle, or pedestrian traffic. The maximum inlet capacities are included in Table 3-1 below.

Table 3-1: Design 2 Inlet Capacities

Type	Total Capacity	Grate Capacity	Hood Capacity	Approx. Length
Design 2-0	8.2 cfs	3.2 cfs	5 cfs	5 ft
Design 2-1	13.2 cfs	3.2 cfs	10 cfs	10 ft
Design 2-2	18.2 cfs	3.2 cfs	15 cfs	15 ft
Design 2-3	23.2 cfs	3.2 cfs	20 cfs	20 ft
Design 2-4	28.2 cfs	3.2 cfs	25 cfs	25 ft

On a residential street, the first most upstream inlet is constructed when the 25-year flow in the street meets the top of curb or the drainage area exceeds 20-acres.

On streets other than a residential classification, the first most upstream inlet is constructed at a point such that no more than one driving lane will be inundated during a 25-year frequency storm.

3.4 Grated Street Inlets

3.4.1 Inlet Design Flow and Location

This type inlet is allowed only for addressing a drainage and flooding issue in an already developed area and use of these inlets in new subdivisions will not be allowed.

Grated street inlets shall be designed for fully urbanized conditions as determined by current zoning for the area. However, the minimum composite runoff coefficient shall meet the requirements of Table 2-3.

They are typically located at a sump or close to a sump location. The lots adjacent to a grated street inlet located at a sump shall be elevated 1-foot above the top of curb of the inlet.

3.4.2 Design and Construction Standards

The City of Oklahoma City Construction Standards contain engineering design and construction details for the Grated Street Inlets. This type of inlet shall be used when a Design 2 Inlet is not suitable due to a specific site condition. The maximum inlet capacities are included in Table 3-2 below.

Table 3-2: Grated Inlet Capacities

Type	26-foot on-grade	26-foot sump	32-foot on-grade	32-foot sump
Alternate “A” *	67 cfs	112 cfs	84 cfs	140 cfs
Alternate “B” **	Inlet capacities to be based on manufacturer’s design capacity			

* IKG Industries Type WL Size 20A Galvanized Steel Grate

** Neenah Foundry Type R-4999-NX with Type C Frame

3.5 Design 5, 6, and 7 Inlets

3.5.1 Design Flow

Similar to other types of inlet, design flow for these inlets shall be based on fully urbanized flow and based on current zoning for the area. However, the minimum composite runoff coefficient shall meet the requirements of Table 2-3. These inlets shall be designed for the 50-year urbanized flow with a 100-year overflow. In commercial areas where an overflow flume cannot be provided due to site conditions, inlets shall be designed for the 100-year urbanized flow in conjunction with an adequately sized closed storm sewer system in accordance with Section 3-7 design requirements.

3.5.2 Inlet Location and Other Considerations

This type of inlet shall be located in a sump within a parking lot or in paving within an apartment complex.

3.5.3 Design and Construction Standards

The City of Oklahoma City Construction Standards contains engineering design and construction details for the Grated Box Inlets. These types of inlets shall not be used in streets. They are designed to be used in paved areas such as parking lots and apartment complexes.

Table 3-3: Design 5, 6, & 7 Inlet Capacities

Inlet Name	Number of Grates	Capacity
Design 5	1	1.6 cfs
Design 6	2	3.2 cfs
Design 7-1	4	6.4 cfs
Design 7-2	6	9.6 cfs
Design 7-3	8	12.8 cfs

These types of inlets located in sump areas shall be designed for the 50-year urbanized flow with a 100-year overflow. In areas where an overflow flume cannot be provided due to site conditions, inlets shall be designed for the 100-year urbanized flow in conjunction with an adequately sized closed storm sewer system.

The capacity of the Design 5, 6, & 7 Inlets shall be as indicated in Table 3-3. A maximum allowable headwater of 9-inch shall not be exceeded. The minimum finished floor elevation of adjacent buildings must be 1-foot above the water surface elevation of the 100-year design event.

3.6 Box Inlets with Side Openings

3.6.1 Inlet Design Flow

The inlet capacity must be calculated to limit the 100-year event headwater elevation to 12-inches maximum above the weir elevation. The vertical height of the inlet openings shall not exceed 9-inches. The capacity must be calculated using the horizontal weir calculation until the weir flow depth equals or exceeds 9-inches (contact with lid). Above that point, the capacity must be calculated using the equation for a vertical orifice. The weir discharge coefficient must be 3.087 (producing critical depth) and the orifice discharge coefficient must be 0.60.

Weir equation:

$$Q = CLH^{3/2}$$

Where:

C = 3.087

L = Length in feet

H = Head in feet

Orifice Equation:

$$Q = CA(2GH)^{1/2}$$

Where:

C = 0.60

A = square feet

G = 32.2

NOTE: For a vertical orifice, H is measured from the center of the orifice opening in Feet.

All building structures adjacent to box inlets with a lid shall be elevated to 1 foot above the top of lid or the 100-year headwater elevation, whichever is greater.

3.7 Closed Storm Sewer

3.7.1 Calculations and Design

The Oklahoma City drainage ordinance requires on-grade storm sewer systems carrying urbanized runoff from streets shall be designed to capture a minimum 25-year frequency storm. The maximum area draining to the street shall not exceed 20 acres. If at any point a 25-year urbanized runoff exceeds street capacity, a set of inlets and a closed storm system to carry a minimum of the 25-year urbanized runoff shall be provided. At sump areas the storm sewer shall be designed to serve a 50-year urbanized flow with a concrete flume being constructed over the storm sewer to ensure that any overflow from a 100-year urbanized flow can reach a suitable outlet without threatening any existing and proposed structures.

The capacity calculations for a closed storm sewer shall be performed using Section 2-5. In addition to Manning's equation the use of the other design methods may be required to adequately size stormwater facilities.

Design of storm sewer systems shall maintain the hydraulic grade line (HGL) below any gutter elevation and any manhole top lid/rim elevation to eliminate flooding inlets or system overflow along the design reach limit. If the storm sewer system is discharging to a detention pond, creek or channel, the Q100 water surface elevation (WSEL) from the downstream drainage infrastructure shall be used as the tailwater elevation for the HGL analysis. However, if the storm sewer system is connecting to an existing storm sewer system, water surface elevation at the full flow condition of the downstream storm sewer pipe shall be used as the tailwater elevation for the HGL analysis.

3.7.2 Minimum Sizing and Other Design Standards

A closed storm sewer system shall be sized for urbanized flow conditions. A closed storm sewer shall meet the requirements of and be compliant with the drainage ordinance regardless of the capacity of the downstream storm sewer. A closed storm sewer within public right-of-way shall not be less than 18-inches in diameter. A closed storm sewer crossing a public street shall utilize Reinforced Concrete Pipe (RCP) with "O" rings or a Reinforced Concrete Box (RCB). A closed storm sewer within a public drainage easement, next to curbs, and between houses shall either be RCP with "O" rings, RCB, or High-Performance Polypropylene (HP) pipe with watertight (WT) gaskets. All joints on RCP, RCB, and HP shall be wrapped with a continuous filter fabric strip overlapping 2 feet on each side of the pipe joint to ensure proper protection. Corrugated Metal Pipe (CMP) shall not be used in publicly funded improvements or for any improvements to be dedicated to the City. CMP may be used in rural private improvements or developments. High-Density Polyethylene Pipe (HDPE) shall only be allowed in private improvements or developments.

A closed storm sewer shall be constructed with a minimum soil cover of 2 feet from the top of the finished grade to the top of the pipe. Any variation from this minimum depth must be pre-approved by the City Engineer. If 2-foot soil cover cannot be achieved, Class IV pipe shall be required. A closed storm sewer shall be constructed with crushed rock backfill under the public street and under paving within the public drainage easement. A closed storm sewer shall have a minimum flow velocity of 2.5 fps and a maximum velocity based on the type of material as shown in Table 3-4 below.

Table 3-4: Minimum Manning's "n" Value and Maximum Velocities for Sewer Materials

Material	Maximum Velocity (fps)	Minimum "n" value
Concrete	15	0.013
CGMP	12	0.024
HP	14	0.013
HDPE	14	0.013

3.7.3 Horizontal and Vertical Alignments

The diameter of the pipe shall not decrease proceeding down gradient within the closed storm sewer system. At points where pipe diameters change, the pipe soffit elevations shall match, and flow line elevations shall drop through the manhole or junction box. A diversion of flow is not allowed (i.e., the discharge point and all inlets of a closed storm sewer system shall be within the same watershed). Unless there is a difficulty providing the depth of cover, it is desirable to use closed storm sewer conduit with a circular cross-section. A closed storm sewer shall not be located under paving parallel to the centerline of the roadway unless specifically approved by the City Engineer. All closed storm sewers must be extended to the property limits of the improved development.

When tying two storm sewer reaches together, the crowns of the upstream pipe and the downstream pipe shall match.

3.7.4 Manhole, Inlets, and Junction Boxes

A manhole or junction box shall be required for any change in direction, pipe size or slope of any storm sewer in Oklahoma City. Separation for all manholes and junction boxes for RCP less than or equal to 60-inch diameter or RCB less than or equal to 5 feet in height, shall be a maximum of 375 feet. A structurally designed and adequately sized concrete junction box with a minimum 6-inch space between the outside of the pipes and inside wall shall be used for connecting three or more pipes of 18 inches or larger. A radius junction box shall be used to obtain a horizontal direction change for pipes larger than 30 inches. The minimum length of a storm sewer pipe between structures shall be 5 feet.

3.7.5 Outfall Condition and Grade to Drain Requirements

Pipe/Culvert Outfall shall be lowered to the flow line of receiving creek or shall tie into the existing low point at the property line. If these conditions cannot be met, the developer shall obtain a grade to drain easement from the adjacent property owner(s) of sufficient length and width to ensure the proper function of the storm sewer system. A 3-foot cut-off wall is required at all pipe/culvert outfalls. If the discharge velocities are higher than the existing downstream natural soil shear stresses and velocities shown in Table 4-1 and Table 4-2, permanent structural and/or non-structural erosion controls shall be required in accordance with Table 4-2. A temporary easement from the adjoining property owners shall be obtained by the developer if necessary. The 100-year water surface elevation at the storm sewer outfall must be shown on plans. The 100-year water surface in the receiving stream shall be used as the beginning elevation of any storm system hydraulic grade line (HGL) calculation.

4. Bridges, Culverts, and Other Special Structures

4.1 Introduction

Streamflow or continuous flow of water across continuous roadways must be through culverts or bridges. Design of bridges and culverts shall conform to city construction standard details and standard specifications.

4.2 Bridge and Culvert Design and Location

Bridges and culverts must be designed to pass the 50-year urbanized flow per zoning and shall also be designed such that the 100-year urbanized flow does not overtop the roadway. In addition, the 50-year water surface elevation shall be below the low chord of a bridge and no more than 1-foot above the top of the culvert at the upstream end of the culvert. Driveway pipes shall be designed to convey the 25-year design flow based on urbanized flow and zoning requirements.

The minimum size of a pipe culvert shall be an 18-inch diameter round concrete pipe or equivalent size and material. Multiple barrel culverts shall be acceptable, so long as each barrel meets minimum spacing, grade, and capacity criteria as required by the pipe product manufacturer's recommended individual design standard.

The minimum size of Reinforced Concrete Box culvert shall be a 4-foot span x 3-foot rise.

Analysis of bridges or culverts shall be prepared by using FHWA HY-8 Culvert Analysis, U.S. Army Corps HEC-RAS River Analysis System, or HEC-2 Water Surface Profiles Program (other acceptable programs may be used with the approval of the City Engineer).

4.3 Design Standards

Reinforced Concrete Pipe (RCP) or Reinforced Concrete Box (RCB) shall be required for all culverts crossing publicly funded streets or other improvements to be dedicated to the city. Corrugated Metal Pipe (CMP) shall not be used in publicly funded improvements or for any improvements to be dedicated to the City. CMP and High-Density Polyethylene Pipe (HDPE) may be used only in rural private improvements or developments. All joints on RCP, RCB, and CMP shall be wrapped with a continuous filter fabric strip overlapping 2 feet on each side of the pipe joint to ensure proper protection. Facilities shall be constructed with a minimum cover of 2 feet from the top of the finished grade to the top of the pipe. If the minimum cover cannot be achieved a Class IV pipe shall be used.

Bridges and culverts shall follow the alignment and grade of the natural channel whenever possible. Minimum slope of culverts shall equal 0.5% unless the site condition or slope of natural channel requires use of a flatter slope, with the approval of City Engineer. In cases where the barrel cannot be aligned with the channel flow line, additional alignment or transition protection against erosion shall be provided as approved by the City Engineer.

4.4 Erosion Control and Scour

4.4.1 Maximum Shear Stress

Storm water conveyance systems require a variety of structures and appurtenances to control, divert, redirect flows, and control velocities to minimize erosion and scour. Erosion and local scour can result in channel degradation, undermining and structural failures. Excessive suspended sediments result in undesirable environmental impacts, aesthetic problems, and burdensome maintenance.

Most unlined natural or man-made channels are affected by either tractive forces, shear forces or drag forces. These forces are applied on the submerged portions of the channel bed and side slopes acting in the direction of flow. The maximum unit tractive force or shear stress shall be calculated with 100-year urbanized flow depth as:

$$\boldsymbol{\tau_0 = \omega\, y\, s}$$

Where,

τ_0 = maximum shear stress (lb/ft^2)

ω = unit weight of water (62.4 lb/ft^3)

y = 100-year flood depth in feet

S = average bottom slope (ft/ft)

The maximum shear stress shall not exceed the values and velocities show in Tables 4-1 and 4-2. The maximum shear stress and maximum velocities are related to soil types. A more detailed design of channel protection based on “Design of Roadside Channels with Flexible Linings” (FHWA) or “Hydraulic Design of Energy Dissipators for Culverts and Channels” (USDOT) shall be used in accordance with the City Engineer’s approval.

Table 4-1: Typical Permissible Shear Stresses for Bare Soil and Stone Linings

Lining Category	Lining Type	Permissible Shear Stress (lb/ft^2)
Base Soil Cohesive (PI=10)	Clayey Sands	0.037 -0.095
	Inorganic Silts	0.027-0.11
	Silty Sands	0.024-0.072
Bare Soil Cohesive (PI≥ 20)	Clayey Sands	0.094
	Inorganic Silts	0.083
	Silty Sands	0.072
	Inorganic Clays	0.14
Base Soil Non-cohesive (PI<10)	Finer than coarse sand D_{75} < 0.05-inch	0.02
	Fine gravel D_{75} = 0.3-inch	0.12
	Gravel D_{75} = 0.6-inch	0.24
Gravel Mulch	Coarse gravel D_{50} = 1-inch	0.4
	Very coarse gravel D_{50} = 2-inch	0.8
Rock Riprap	D_{50} = 6-inch	2.4
	D_{50} = 12-inch	4.8

Table 4-2: Maximum Permissible Velocities for Open Channels

Type of Grass or Cover	Slope Range (%)	Maximum Permissible Velocity – Feet Per Second
Bermuda Grass	0-5	5
	5-10	4
	>10 Not Permitted use drop structures	
Buffalo Grass, Kentucky Grass, Smooth Brome, Blue Grama	0-5	5
	5-10	4
	>10 Not Permitted use drop structures	
Grass Mixture	0-5	4
	5-10	3
	>10 Not Permitted use drop structures	
Lespedeza sericea, weeping love grass, ischaemum (yellow bluestem), alfalfa, crabgrass	0-5	3.5
	>5 Not Permitted use drop structures	

4.4.2 Protected Outlets and Outfall

If exit shear stresses exceed the bare soils permissible maximum stress or maximum velocity permitted, the outlet area downstream of the location shall be protected.

4.4.2.1 Riprap

$$D_{50} = 0.2\, D \left(\frac{Q}{\sqrt{g}D^{25}}\right)^{\frac{4}{3}} \left(\frac{D}{TW}\right)$$

Where:

D_{50} = riprap size in feet

Q = design discharge in ft^3/s

D = culvert diameter (circular) in feet

TW = tailwater depth in feet

g = acceleration due to gravity (32.2 ft/s^2)

NOTE: Tailwater depth should be limited to between 0.4D and 1.0D. If tailwater is unknown, use 0.4D.

5. Open Channels

5.1 Introduction

The Drainage Ordinance requires conveyance of the stream flow by natural channel or through the utilization of engineered open channels. Open channel design flow calculations are very similar to the calculation of flows for other storm sewer structures. Hydraulic design calculations and construction standards are described in the following sections.

5.2 Design Flows

Fully urbanized conditions shall be used for calculation of flows. However, the minimum composite runoff coefficient shall meet the requirements of Table 2-3. The appropriate method as discussed in prior chapters of this document shall be used for calculation of design flows.

The City allows the use of the SCS method for calculation of flows or runoff with HEC-HMS and HEC-1. Calculation of time of concentration may be done using the TR-55 method.

5.3 Hydraulics of Open Channels

Presented in this section are the basic equations and computational procedures for uniform, gradually varied and rapidly varied flow. These flow conditions may be encountered in any open channel hydraulic analysis. HEC-RAS or HEC-2 computer programs shall be used to perform hydraulic analysis on open channels with drainage areas greater than 10 acres. Other methods of channel calculations may be used. However, any calculation method must account for the effects of any downstream culverts, permanent obstructions, or backwater effects. HEC-RAS is a hydraulic simulation model developed by the US Army Corps of Engineers and is the successor to HEC-2. Hydraulic behavior of open channels is dependent on the type of flow in the channel. Four different types of flow or flow regimes affect design, construction, and open channel performance. The flow types or regimes are described in the following sections.

5.4 Natural Channels

Natural channels are channels closely following historic alignments and without changes to the historic condition. A natural channel definition is voided if any realignment of this channel is proposed. Construction of a new earthen channel does not comply with the definition of a natural nhannel.

A natural channel shall be included in the platted "Common Area" and the maintenance of the common area shall be the responsibility of the Homeowner Association as per the requirements of the current drainage ordinance. The 100-year floodplain based on fully urbanized conditions shall be included in the private drainage easement or platted "Common Area".

5.5 Design and Construction Standards

For all design and construction details for channel designs shall include 1 foot of free board from 100-year water surface elevations as calculated.

5.5.1 Grass Channel

All improved grass channels shall be privately maintained regardless of size or contributing drainage basin. The side slopes of improved grass channels shall not exceed 3:1 (H:V). The analyses of all open channels shall use approved methods of flow calculations such as HEC-RAS or HEC-2. Additional erosion protection measures may be required as described in previous sections.

5.5.2 Concrete Channels

Concrete channels may be used to provide conveyance for publicly maintained secondary channels with over 40 acres of drainage area. The analyses of all open channels shall use approved methods of flow calculations such as HEC-RAS or HEC-2. The maximum velocities shall be limited to 15 fps. If the maximum limits are exceeded, drop structures or energy dissipators shall be considered to reduce the impacts of the excessive velocities. Concrete channels must be designed in accordance with the approved Oklahoma City Construction Standards.

5.5.3 Rip-Rap Channels

Rip-rap channels may be used to alleviate the possibility of erosion for channels not required to be concrete lined. All open channels shall use approved methods of flow calculations capacity analysis shall be performed using HEC-RAS or HEC-2. The side slope of the rip-rap channel shall not exceed a slope of 2:1 (H:V).

The Manning "n" value shall be computed by the following equation:

$$\mathbf{n = 0.0395(d_{50})^{1/6}}$$

Where:

d_{50} = nominal rip-rap stone diameter in feet
Example: n = 0.042 for 18-inch rip-rap.

The minimum stone diameter shall be 12 inch.

5.6 Wire-Wrapped Rip-Rap or Gabions

Gabion channels may be used in lieu of loose rip-rap if approved by the City Engineer. The minimum design criteria shall be the same as Rip-Rap Channels. Engineer shall provide design calculations supporting all use of wire-wrapped rip-rap or gabions.

6. Design and Construction of Detention Ponds

Development typically includes the addition of impervious surfaces resulting in increased runoff flow rates and increases in runoff volume of storm water that the basin released before the development. These increases are caused by the reduction of a catchments ability to infiltrate rainfall due to the construction of buildings, parking areas, and other developments. The Drainage Ordinance requires detention in order to reduce the detrimental impacts of additional impervious surfaces. Storm water detention is defined as the temporary storage of storm water runoff in a basin in which the outflow is controlled in order to reduce or eliminate flooding or other adverse effects downstream.

Stormwater detention is required for all development, unless the development meets one of the exemptions identified in the Drainage Ordinance. All designs must meet Drainage Ordinance requirements. The proposed site development will not cause any negative impact on the downstream flow rate or flood elevation.

6.1 Site Assessment for Detention Requirement

On-site stormwater detention, in the form of a detention pond, is required for all development in Oklahoma City, unless the development meets one of the exemptions identified in the Drainage Ordinance. Engineering plans for every development within the City will be reviewed to determine if the detention meets requirements established within the Drainage Ordinance. Detention requirements may be expanded to include areas with reported or projected flooding of downstream properties. Therefore, preliminary determinations can change prior to the approval of plans. If at any time during the review process, and before approval, it is determined that the subject development will cause or increase flooding downstream, improvement and enhancement to planned detention ponds will be required. The consulting engineer will be solely responsible for ensuring that all submitted design documentation meets specifications outlined in the DCM.

6.2 Design Flow or Runoff Calculations

6.2.1 Historic Condition

The determination of the historic (i.e. pre-developed) runoff rate determines the maximum rate of all combined developed pond outflow and un-detained site release. Unless granted a waiver by the City Engineer, the developer shall install detention facilities maintaining a discharge rate not to exceed the historical runoff rate prior to development. The historic runoff rate is determined by evaluating the contributing drainage area(s) as undeveloped in accordance with current City standards. Listed below are a few notable exceptions that will be considered:

- If an offsite upstream drainage area discharges onto the property considered for development, then the entire offsite area shall be evaluated in the current existing conditions at the time of the proposed development.

- If a previous developed hard surface exists on the development site, and was properly permitted, then the existing hard surface area shall be evaluated as fully developed.

6.2.2 "To Pond" Drainage Areas

The drainage areas draining into the storage facility are considered "to pond" areas. The "proposed conditions" will be the condition of a subject development after construction is completed based on the approved site plan. The hydrologic calculations must consider all the proposed buildings, parking areas, roads, and other hard surfaces.

6.2.3 "Bypass" Drainage Areas

Catchment areas that discharge from the property without flowing through the proposed detention pond outlet are considered bypass areas. The hydrologic calculations from bypass areas must consider and model all additional hard surfaces like the proposed conditions stated in the previous section. The total discharge from the proposed development must consider the combined effect of the pond discharge together with the un-detained "bypass" flow.

6.3 Design Details or Pond Configuration

6.3.1 General Details

Storm water detention is defined as the temporary storage of storm water runoff in a basin in which the outflow is controlled in order to reduce or eliminate flooding or other adverse effects downstream. The detention pond is analyzed as the area and volume of the development set apart for the temporary storage of storm water. All proposed detention ponds shall be located outside of existing public easements, rights-of-way, and neighboring properties. When a detention pond is designed for a platted area or multi-owner property, the limits of the entire detention pond facility will be contained in a private drainage easement. The detention pond will include all outlet structures, emergency spillways, and riprap (or other erosion protection). Proposed detention pond areas shall not be used to store, hold, or contain building structures or materials either permanently or temporarily. An exception to this would be recreational amenities such as playground equipment or benches that can be demonstrated not to interfere with the functionality of the pond. Parking areas may be used as detention storage if the water surface elevation generated from a 100-year event is less than or equal to 1 foot at the outlet. Calculations shall be provided for the storm durations that produce the highest water surface elevation in the pond and the maximum site/pond discharge for the designed pond and outlet configuration.

All pond areas shall have maximum side slopes of 3 vertical to 1 horizontal (3:1) unless paved with concrete. If unpaved embankments or cuts exceed the maximum slope, then a retaining structure shall be provided. A paved trickle channel shall be provided for unpaved ponding areas. The trickle channel must be designed to extend along the longest portion of the pond area. A concrete trickle channel is required for all dry ponds. The trickle channel shall be constructed of concrete, a minimum of 2 feet wide and 6 inches deep, with a minimum slope of 0.4%. On each side of the trickle channel shall be a minimum of 1-inch height of established grass in accordance with City details.

All detention pond facilities, except parking lot storage ponds, must be designed to allow for 1 foot of freeboard. Freeboard is described as the vertical distance between the top of the pond enclosure and the maximum water surface.

All pond surface cover must be composed of one or all of the following:

1. Solid slab grass sod
2. Concrete
3. Asphalt

Any other materials will require approval from the City Engineer prior to application.

The designed detention pond size will be demonstrated by stage versus storage data. This data shall be graphical or tabulated data showing the storage area at a given stage elevation in the pond.

6.4 Outlet Configuration

The outlet control structure allows detained storm water to discharge from a detention pond at a controlled rate. Outlet control structures shall be designed as simply as possible as to require little or no attention and/or maintenance for proper operation. No mechanical means such as pumping will be allowed as an outlet control structure.

All outlet control structures shall be configured and designed to maintain a discharge rate not to exceed the maximum allowable outflow, Q_o, described in the previous sections for all the following storm events:

- 50% event (2-year storm, Q_2)
- 20% event (5-year storm, Q_5)
- 10% event (10-year storm, Q_{10})
- 4% event (25-year storm, Q_{25})
- 2% event (50-year storm, Q_{50})
- 1% event (100-year storm, Q_{100})

Outlet control structures shall consist of hydraulic components such as weirs, culverts, standpipes, or any combination thereof, used in either a series or parallel configuration.

An overflow spillway will be included and provided as part of any proposed detention facility. This overflow spillway shall be constructed of concrete. The concrete spillway may be an extension of the outlet control structure or a separate structure altogether. The concrete overflow structure shall function with all other discharge elements fully blocked without exceeding the allowable historic discharge rate from the pond/site. The minimum finished floor elevations for structures adjacent to the pond shall be set a minimum of 1.0 foot above the calculated 100-year water surface elevation in the pond with all primary outlet elements blocked.

Rating curve data for the designed outlet control structure will be provided. This shall be graphical or tabulated data showing the outflow discharge at a given stage elevation in the pond. This data will be used and compared to the hydraulics of the outlet control structure shown in the plan sheets to verify the accuracy.

6.5 Underground Detention

Unless written permission is granted from the City Engineer, all detention facilities shall be surface ponds. Underground detention will only be considered if the designer can adequately demonstrate that the proposed development introduces site restraints such that a surface pond is impractical. If approved, the designer must show construction details for underground storage facilities that meet the following criteria:

1. Composed of reinforced concrete pipe (RCP), polyvinyl chloride pipe (PVC), or high-performance polypropylene pipe (HP),

2. All connection from underground detention facilities to public storm sewer system must be RCP or HP,

3. Outflow must be able to drain directly into an existing storm facility without mechanical assistance,

4. Storage area must have an access point for maintenance,

5. Must show no permanent habitable areas to be proposed on the overhead surface.