

# Chapter 9

## Storm Drains

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## 1.0 Introduction

This chapter summarizes design criteria and evaluation methods for storm drain systems (also commonly referred to as storm sewers). The review of all submittals will be based on the criteria presented herein.

## 2.0 Runoff Reduction and Stormwater Quality Considerations

Traditionally, urban development has relied on storm drain systems in the upper portions of watersheds to prevent local flooding and to carry flows away quickly. As storm drains pick up more drainage area, they increase in size and convey urban runoff quickly downstream with little to no reduction in rate or volume or improvement in water quality.

Today, with the emphasis on runoff reduction and water quality enhancement, stormwater management practices are being revised to promote infiltration, attenuation and water quality enhancement. Properly designed sites with grass swales and other conveyances that provide opportunity for infiltration can serve in place of storm drains and/or allow smaller and less extensive storm drains to be constructed downstream. Disconnecting impervious area through the use of downspout routing to pervious areas, grass buffers and/or porous landscape detention (bioretention) can reduce demands on the downstream conveyance system. These types of practices, often termed “minimizing directly connected impervious areas” or “Low Impact Development” can also improve the quality of stormwater runoff and reduce the amount of dedicated water quality features required.

Although grass swales are compatible with many land uses, such as residential, parks, institutional, and others with relatively low densities, grass swales may not be practical in areas where there are many access points across the planned drainage path. Therefore, storm drains will continue to be an integral part of many drainage systems.

## 3.0 Design Storms

Both the “minor” and “major” storm events must be considered for properly designing storm drains. In each case, storm drains are to be designed to carry the portion of runoff that cannot be conveyed on the surface, as dictated by the available capacity in streets and swales.

### 3.1 Minor Event

At a minimum, storm drains are to be designed to convey storm runoff for the minor (5-year) event. Inlets shall be located per the recommendations in Chapter 8 to intercept runoff before street capacities are exceeded. Additional information on storm drain design is provided in the Streets, Inlets and Storm Drains Chapter of the UDFCD Manual.

### 3.2 Major Event

Under certain conditions, the storm drain system must be designed to convey flows greater than the minor storm runoff, in some cases up to the major (100-year) storm runoff. These conditions include:

- Where the street capacity for the major storm is exceeded.
- Where street crown overtopping would otherwise exceed criteria.
- Where major storm flows can split off in undesirable directions (i.e., flow splits at intersections).

- Where the storm drain system is accepting flow from an upstream storm drain system or branch that is designed for the major storm.
- Where regional storm drains are designed for the major storm.
- Where storm drains must convey undetained flows to a detention pond.
- Situations where surface flow of the major storm event would unduly interfere with use of the property or cause unwarranted damage.

If a storm drain is designed to carry major storm flows, the inlets to the storm drain shall be sized accordingly. The major storm event hydraulic grade line may be allowed to rise above the top of the storm drain pipe and surcharge the system. The ability of the storm drain to convey the major storm event shall be based on its capacity when the hydraulic grade line elevation is at least 1 foot below the flowline of gutter. In no case shall the surcharge create system velocities in excess of the maximum defined in Section 9.1. Additional information on storm drain design is provided in the Streets, Inlets and Storm Drains Chapter of the UDFCD Manual.

## **4.0 Pipe Material and Size**

### **4.1 Pipe Material**

All storm drains located within public rights-of-way, public easements or tracts shall be constructed with reinforced concrete pipe (RCP), Corrugated Metal Pipe (CMP), or High Density Polyethylene Pipe (HDPE, up to 30 inches in diameter). Circular pipe is the most cost-effective option for reinforced concrete, but elliptical pipe or box conduits may be a more appropriate option in areas where available cover is limited or to avoid utility conflicts. Residential driveway culverts may be CMP or HDPE in lieu of RCP.

Alternate pipe materials may be considered with approval prior to submittal of drainage reports for review. Trench details, bedding material, installation specifications, minimum cover or fill height limits, service life and construction testing requirements for alternate pipe materials shall be consistent with those recommended by the manufacturer/supplier or as determined appropriate.

### **4.2 Minimum Pipe Size**

The minimum allowable pipe size for storm drains located within rights-of-way, public easements or tracts shall be 18 inches for laterals and 18 inches for trunk lines that collect flows from laterals or from upstream trunk lines.

### **4.3 Service Life**

The service life for storm drain systems shall be 50 years. An extended service life of 100 years shall be required under these conditions:

- The depth of cover exceeds 15 feet.
- The system is located within the travel lanes of 4-lane or major and minor arterial roadways.
- The centerline of the storm drain pipe is located 15 feet or less horizontally from any building/permanent structure.

## **4.4 Other Design Considerations**

### **4.4.1 RCP Pipe Class, Fill Height, and Installation Trench**

The minimum class of reinforced concrete pipe shall be Class III, however, the depth of cover, live load, and field conditions may require structurally stronger pipe. Trench installation requirements, trench installation details, and allowable fill heights are shown in the City of Colorado Springs Standard Specifications, Sheets D-30, D-31 and D-32. It is the responsibility of the design engineer to develop and submit alternate trench and installation details when project specific conditions or loadings require modification to the standard installation. Alternate designs shall follow ASTM C1479.

### **4.4.2 Joints**

Properly installed tongue-and-groove concrete pipe should have an interior joint gap of no more than 3/8-inch for pipe less than 36-inch diameter installed in a straight run. All storm drains shall have gasketed, water-tight joints. ASTM Standard C 443 covers flexible watertight joints for circular concrete sewer pipe and precast manhole sections, using rubber gaskets for sealing the joints.

### **4.4.3 Outfalls**

Where storm drains discharge into open channels or detention ponds, outlet protection of the bank and overbank or pond bottom shall be provided to prevent erosion due to flows discharged from the storm drain. Erosion protection shall be designed to convey the storm drain design flow assuming that no flow is in the receiving channel or pond. The stability of the outfall protection must also be evaluated based on the flow conditions in the receiving channel. Design guidance for outfall conditions is provided in Chapter 10 of this Manual.

### **4.4.4 Trash/Safety Racks**

Trash racks or grates should be used for safety purposes at any entrance to storm drains that are large enough that a child could become swept into or lodged in the entrance. Even relatively small diameter pipes can pose a risk due to the potential for hydrostatic forces to pin a person against the entrance to the storm drain. In Woodland Park, grates are also installed on many large culvert outfalls because of issues with some members of the public entering culverts. When trash racks are installed on culvert or storm drain outfalls, frequent inspection is recommended due to potential for accumulation of debris against the interior face of the downstream grate.

## **5.0 Easements**

### **5.1 Easement Conveyance**

Storm drains shall normally be installed within public right-of-way, easement or tracts, but when it is necessary to route a system through private property, drainage easements are required in order to ensure the proper construction, access and maintenance of storm drains and related facilities. All easements shall be conveyed by appropriate legal documents such as plats or grant of easements.

### **5.2 Minimum Easement Widths**

Generally, easement widths shall be 2 times the depth to the pipe invert plus the conduit width, rounded up to the nearest 5 feet, but not less than 20 feet. The pipe shall be centered on the easement. When more

than one utility pipe is within the easement, the pipes shall have a minimum separation distance of 10 feet from centerline to centerline of pipe, and no pipe shall be less than 5 feet from the edge of the easement. These minimum widths assume a relatively shallow pipe depth. Deeper pipes are required to be constructed in accordance with OSHA requirements, and appropriate easements are required to allow for construction and potential future repair or replacement. When relatively large diameter pipes are proposed or when design depths are excessive, greater easement widths will be required, as determined by the City Engineer, his/her designated representative or City Utilities Director.

Easements for storm drains should be located to one side of property lines and not centered on the lines. Additional easements necessary to provide access to the storm drain, outlet, and other appurtenances are required if not accessible from a public right-of-way. A minimum easement width of 15 feet shall be provided for access and provisions must also be made for appropriate physical access to the easements, such as for grading and obstructions.

In general, storm drain easements shall be established exclusively for drainage facilities. If agreed to by all parties and where appropriate, such as for non-motorized public access, joint easements may be permitted. The width of joint easements will be determined on a case-by-case basis.

### **5.3 Allowable Landscaping and Surface Treatment in Easements**

Although storm drain systems are designed to have a significant service life, there are circumstances which may require that the storm drain be accessed for inspection, maintenance, repair, and/or replacement. Storm drain easements should be designed to convey above ground flows in the event the storm drain or inlet becomes clogged or full flows exceed the design flow. It is, therefore, necessary to limit uses within the easement to ensure that surface conveyance redundancy and maintenance access is not impaired. Minor landscaping, including rock, shrubs, etc. may be appropriate where it can be demonstrated that the function of the easement is not compromised by the presence of the materials. Pavement over a storm drain easement may be allowable, providing that the property owner accepts responsibility for replacement in the event it is necessary to remove it to access the system. Improvements that are not allowed on storm drain easements include structures of any kind, retaining walls, permanent fencing, trees and others if determined to be a problem and/or costly to replace. Surface treatments on drainage easements shall be shown on the drainage report plan and final development plan.

## **6.0 Vertical Alignment**

### **6.1 Cover**

All storm drains shall be designed so that they will be structurally adequate for both minimum and maximum cover conditions. A minimum cover shall be maintained to withstand AASHTO HS-20 loading on the pipe in traffic areas. The minimum cover to withstand live loading depends upon the pipe size, type and class, and soil bedding condition, but shall be not less than 1 foot to the exterior pipe wall at any point along the pipe. There are numerous factors that ultimately affect the depth of cover over a pipe and in most cases it is likely that the cover will have to be greater than the minimum allowed due to other design factors. Some of the other factors that affect the depth of the pipe are hydraulic grade line elevations, inlet depths, adjacent utilities or utility crossings, including water and sewer services lines along residential streets, and connections to existing storm drain systems. When feasible, locating storm sewers below the frost depth (approximately 7 feet in Woodland Park) will aid with freezing and ice buildup; however, in practice, it is not always practical to have storm drains this deep due to conflicts with other utilities and elevations constraints. The maximum cover over storm drains shall also be considered and evaluated according to manufacturer's specifications. Should a design require a cover

depth of greater than 15 feet, an extended service life installation shall be provided.

## **6.2 Cover in Roadways**

The roadway subgrade, which supports the pavement section is typically plowed (or scarified) to a certain depth, moisture treated and compacted prior to the placement of the sub-base, base course, and surfacing. There are also instances where the subgrade material must be excavated and replaced or treated to a certain depth to mitigate swelling soils. Subgrade treatment is typically required when doing overlays (full depth reclamation of pavement). These efforts can impact the storm drain system if it has not been designed with adequate depth. The design engineer shall use the best information available, including pavement design or soils reports to ensure that storm drain pipes have adequate depth during and after construction, but a minimum cover of 1 foot should be provided below the pavement subgrade.

## **6.3 Utility Clearance**

For all storm drain crossings at utility lines, the appropriate agency shall be contacted to determine the requirements for the crossing. Generally, a minimum vertical clearance of 18 inches is required between a storm drain and a water main or a sanitary sewer, above or below (all clearances are defined as outside-of-pipe to outside-of-pipe). The design engineer shall give careful consideration to the potential impacts to existing utility construction trench and bedding.

## **6.4 Concrete Cut-off Walls and Anchoring**

Where the storm drain pipe trench is susceptible to erosion, reinforced cast-in-place concrete cut-off walls shall be installed at no greater than 30 foot horizontal intervals. In addition, where storm drain pipe is installed in a slope of 3:1 or steeper, anchoring shall be provided at intervals no greater than 30 feet. The Applicant should consult with the City Engineer to determine the need for and spacing of cut-off walls based on the specific project characteristics including soil erodibility, slope and other factors.

# **7.0 Horizontal Alignment**

## **7.1 Alignment**

In general, storm drain alignments between drainage structures (inlets or manholes) shall be straight. The angle of confluence where pipe lines intersect shall be 90 degrees or less and where a lateral pipe of 36 inches or greater intersects a trunk line, the angle of confluence shall be 60 degrees or less. Manhole covers shall not be closer than one foot to the edge of the gutter pan.

## **7.2 Stationing**

Storm drain system stationing shall increase from the downstream limit of the system to the upstream limit with the intersection of the alignment with the receiving system being the beginning point. Lateral pipes and inlets shall be stationed from the intersection with the alignment of the trunk line they are connected to. When a storm drain runs parallel to a roadway stationing, the roadway stationing may be used; however, pipe slope calculations must be based on the actual distances along the pipe line alignment. Vertical stationing and horizontal stationing must be the same for the same location in the system.

## 8.0 Manholes

### 8.1 Required Locations

Manholes or inlets are required whenever there is a change in size, direction, material type, or grade of a storm drain pipe to provide a hydraulic transition and maintenance and inspection access. A manhole shall also be constructed when there is a junction of two or more sewer pipes. The maximum spacing between manholes for various pipe sizes shall be as presented in Table 9-1.

**Table 9-1. Maximum Manhole Spacing**

Pipe Diameter	Maximum Distance Between Manholes
18 inch to 30 inch	400 feet
36 inch to 60 inch	500 feet
> 60	750 feet

### 8.2 Manhole Types

The required manhole type and size is dependent on the diameter of the largest pipe entering or exiting the manhole, and the horizontal and vertical alignments of all pipes entering or exiting the manhole. The appropriate manhole type shall be selected according to the guidance provided below.

There must be a minimum of 12-inches clearance from the outside of pipes adjacent to each other and pipes shall not enter or exit a manhole through the corner of a manhole structure. This 12-inch dimension must be measured on the inside wall of the manhole. It is the responsibility of the design engineer to determine the appropriate manhole type and required manhole size to achieve adequate space between the pipes entering or exiting the manhole structure. In those cases where modifications to standard manhole construction details are required, or where special junction structure designs are required, additional construction details must be developed and included in the construction drawing set.

Inlets may be used as junction structures in place of manholes to connect adjacent inlets if the interconnecting pipe can be fit within the standard inlet dimensions without modification to the inlet and if the additional flow can be passed through the structure in accordance with standard hydraulic criteria. Inlets may not be used as junctions along trunk lines.

1. **Type I Box Base Manhole.** This type of manhole is a cast-in-place concrete structure. It is appropriate to use this manhole for pipe diameters larger than 30-inch and with no change in the horizontal alignment. The typical dimensions shall be adjusted by the design engineer to accommodate specific project conditions. The Box Base Manhole shall be constructed per City of Colorado Springs Storm Sewer Manhole, Type I Standard Detail D-20A.
2. **Type II Circular Base Manhole.** This type of manhole is constructed from a cast-in-place base with precast riser sections. The Circular Base Manhole shall be constructed per City of Colorado Springs Storm Drain Manhole, Type II Standard Detail D-20B. Table 9-2 shows minimum manhole sizes, based on the diameter of the storm drain pipe.

**Table 9-2. Minimum Manhole Sizes**

<b>Pipe Diameter (inches)</b>	<b>Manhole Diameter (feet)</b>
18"	4'
21" - 42"	5'
48" - 54"	6'

The minimum manhole sizes shown for standard pipe sizes assume no change in alignment through the manholes, but in many cases the manhole diameter will need to be increased to account for changes in pipe alignment or multiple incoming pipes. Manhole bases shall be shaped to match the pipe section below the pipe springline. This shaping significantly reduces manhole losses. The appropriate loss coefficient can be determined using the UDFCD Manual for full shaping. The standard details in the UDFCD Manual provide guidance for shaping in the slab base.

3. **Type III Manhole.** This type of manhole is constructed using a modified pipe section as the base with precast riser sections. This manhole is appropriate for 48-inch pipe and larger, when there is no change in pipe size, material, alignment or slope. The Type III Manhole shall be constructed per City of Colorado Springs Storm Drain Manhole, Type III Standard Detail D-20C.
4. **Special Junction Structures.** Special junction structures may have to be designed when pipe sizes and alignment changes exceed those that can be accommodated by standard manhole types. Complete design and construction information must be provided to show conformance with all design standards and to provide sufficient detail for construction. Special junction structures must provide similar hydraulic benefits, structural characteristics and access features as the standard manhole types.
5. **Precast Structures.** Precast structures may be substituted for the standard manhole types and may serve as a special junction structure if they have prior approval and substantially conform to the standard dimensions and configuration of the approved types and conform to all design standards. Complete design and construction information must be provided to show conformance with all design standards and to provide sufficient detail for construction.

### 8.3 Steps and Platforms

Steps are required in all manholes exceeding 3.5 feet in height and shall be in accordance with AASHTO M 199. The Occupational Health and Safety Administration has specific standards for fixed ladders used to ascend heights exceeding 20 feet. Cages and/or landing platforms may be required to satisfy these requirements in excessively deep manhole structures. It is the design engineer's responsibility to ensure that the appropriate measures are designed and construction details are developed and included in the construction drawings, as needed to comply with the Occupational Health and Safety Administration standards. When landing platforms are proposed, consideration shall be given to the potential maintenance and inspection activities and the expected loadings on the platforms.

### 8.4 Drop Manholes

The drop within a manhole from the upstream to downstream pipe invert should normally not exceed 1 foot. There are cases when a drop larger than 1 foot may be necessary to avoid a utility conflict, reduce

the slope of the downstream pipe, or to account for the energy losses in the manhole. Drops that exceed 1 foot will be evaluated on a case-by-case basis, and additional analysis may be required.

## 8.5 Other Design Considerations

The following design criteria shall also be met:

- Pipes shall not decrease in diameter from upstream to downstream.
- The invert of a manhole shall be constructed with a drop between the upstream and downstream pipes. The drop shall be 0.2 feet on straight-through alignments, and 0.3 feet for lateral pipes of the same diameter. When different diameter pipes are used, crowns shall be matched.
- All manhole tops shall be eccentric to provide safe access by alignment with manhole steps and with benches in manhole bases.
- It is critical that gutter pans, curb heads, and any other problematic locations be avoided when determining the horizontal placement of manholes.

## 9.0 Hydraulic Design

Once the alignment of the storm drain system is determined, the peak flows in the system must be calculated followed by a hydraulic analysis to evaluate system characteristics and determine pipe capacity and size. The pipe size shall not decrease moving downstream (even if the capacity is available due to increased slope, etc.) in order to reduce clogging potential.

### 9.1 Allowable Velocity and Slope

The allowable storm drain velocity is dependent on many factors, including the type of pipe, the acceptable water level during the pipe design life, proposed flow conditions (open channel versus pressure flows), and the type and quality of construction of joints, manholes, and junctions.

1. **Maximum Velocity.** In consideration of the above factors, the maximum velocity in all storm drains shall be limited to 18 feet per second (feet/sec) for all design flows.
2. **Minimum Velocity.** The need to maintain a self-cleaning storm drain system is recognized as a goal to minimize the costs for maintenance of storm drain facilities. Sediment deposits, once established, are generally difficult to remove even with pressure cleaning equipment. Maintaining minimum velocities for frequently occurring flows will reduce the potential for sediment and debris accumulation. Storm drains should be designed with a minimum velocity of 2 feet/sec for a flow equal to 25 percent of the minor storm flow rate.
3. **Minimum Slope.** In general, the minimum allowable pipe slopes ensure that the minimum velocity is achieved, in those cases where the pipe is designed to flow near full. The minimum allowable longitudinal slope shall be 0.01 ft/ft (1.00 percent) for pipes smaller than 30 inches in diameter.

### 9.2 Minor Storm Event Hydraulic Evaluation

In the minor storm event, inlets are placed along the roadway where the flow in the roadway exceeds the minor event capacity of the street as defined in Chapter 7, Street Drainage. These inlets intercept flow, as

determined by the procedures in Chapter 8, Inlets, and convey it to a storm drain which must be sized to convey the intercepted flow.

The storm drain system shall be designed to convey the minor design storm without surcharging so that the design flow depth in the pipe is no greater than 80 percent of the pipe height. For the minor storm event, a storm drain is not flowing full, therefore the sewer acts like an open channel and the hydraulic properties can be calculated using Manning's Equation. Hydraulic grade line calculations must be performed to account for energy losses and to ensure that the system is not surcharged during the minor storm event. There may be some special cases where the proposed storm drain pipe is connected to an existing storm pipe (or a detention pond). If this existing pipe is surcharged, then the proposed system will receive backwater from the downstream pipe. In this situation, the minor event hydraulic grade line must be calculated to determine the impacts on the hydraulic grade line through the upstream portions of the system. Where the storm drain outfalls into a detention pond or channel, the tailwater condition will be determined based on the hydraulic grade elevation for the minor design storm event occurring in the receiving facility.

### **9.3 Major Storm Event Hydraulic Evaluation**

The storm drain system layout determined for the minor event analysis must also be evaluated for the major storm event. If necessary, larger or additional inlets must be placed along the roadway when the flow in the roadway exceeds the major storm event capacity of the street as defined in Chapter 7, Street Drainage. The interception rates for all of the inlets shall then be calculated for the major storm event, based on the procedures in Chapter 8 Inlets, and the minor storm pipe sizes must be adjusted to convey the additional flows.

In the major storm event, it is acceptable to have a surcharge in the system. Manning's equation is not applicable for pipes under pressurized flow conditions. For pressurized flow conditions, use the Bernoulli equation (Darcy-Weisbach Friction Loss) or the Hazen-Williams equation. There may be cases where the major storm event does not result in a surcharge of the system. In these pipes, the capacity can be calculated using Manning's equation.

Hydraulic grade line (HGL) and energy grade line (EGL) calculations for the storm drain system shall be provided for the major storm event. For the major event, the hydraulic grade line should be at least 1 foot below the flowline of the gutter. Additional information on calculation of the HGL and EGL including loss coefficients through a storm drain system (at bends, junctions, transitions, entrances, and exits) can be found in the UDFCD Manual. The computed HGL shall be plotted on the construction drawings for each design flow, and the design flow and design frequency shall be noted on the drawing. In addition, the computed EGL for the major design flow shall be shown. Where the storm drain outfalls into a detention pond or channel, the tailwater condition will be determined based on the hydraulic grade elevation for the major design storm event occurring in the receiving facility.

### **9.4 Hydraulic Calculations**

To show that a proposed design conforms to the design criteria described herein, appropriate hydraulic calculations must be completed and provided in an organized form. The methods and parameters described in the UDFCD Manual for analyzing storm drains are tools that may be applied. The City Engineer may approve alternative methods that produce similar, reasonable results to the UDFCD methods.

It is recommended that a computer program be used for the design or as a calculation "check" of a storm drain system. Computer programs such as StormCAD, EPA SWMM, HydroCAD, StormCAD, and

others may be used, if program documentation can be provided to show that the methodology and parameters applied in the program are similar to those recommended in the UDFCD Manual. See the UDFCD Manual for guidance on EPA SWMM and UDFCD methods for analyzing storm drains. In addition to description of the methods used to evaluate the hydraulic design of the storm drain system, adequate documentation of the system characteristics and configuration must be provided in both a detailed and summary format. The summary information for the entire system must show the parameters, coefficients and results for each system element in a tabular format. Documentation must include all input parameters including design flows by location, elevations, sizes, junction losses, coefficients, pipe roughness, alignment deflections, and other relevant information. Documentation must also show the results of the calculations including velocity by location, flow depth, Froude Number, HGL and EGL elevations (profiles), pipe capacities, and other information necessary to confirm that design criteria have been satisfied.