Chapter 48-Design Requirements for Storm Drainage Facilities

48.010 General

Stormwater sewers or channels provide the facility for removing and transporting surface runoff produced from rainfall. Design requirements differ from those for either sanitary or combined sewers.

This section gives the minimum technical design requirements of the City of Moscow Mills drainage facilities. In general, the formulae presented herein for hydraulic design represent "acceptable" procedures not necessarily to the exclusion of other sound and technically supportive formulae. Any departure from these design requirements should be discussed before submission of plans for approval and should be justified. All construction details pertaining to storm sewer improvements shall be prepared in accordance with the Metropolitan St. Louis Sewer District (MSD) Standard construction Specifications Latest edition unless otherwise noted.

Bioretention for both storm sewers and detention facilities for the City of Moscow Mills.
Bioretention is an upland water quantity and quality control practice that uses the chemical, biological and physical properties of plants and soils for stormwater filtration, absorption (retention) and storage (detention). The Maryland Stormwater Design Manual shall be used as a basis for all Bioretention designs in conjuncture with the requirements of this chapter (chapter 48) of the City Code. Each Bioretention design shall be reviewed and approved by both the City Engineer and the City of Moscow Mills Planning and Zoning Commission.

48.020 General Requirements of Storm Sewer Construction

All storm sewers shall meet the following general requirements:

48.020.01 Size and Shape

The minimum diameters of pipe for storm water sewers and combined sewers shall be twelve (12) inches. Sewers shall not decrease in size in the direction of the flow unless approved by the City. Circular pipe shall be used for storm water sewers unless the City's engineer approves otherwise in writing.

48.020.02 Materials

All materials shall conform to MSD Standard Construction Specifications, latest edition, except as specified herein. Reinforced Concrete Pipe (RCP), Class III, or High Density Poly Ethylene (HDPE) Corrugated Pipe may be used for storm water sewers and combined sewers, except that HDPE Corrugated Pipe cannot be used under or through existing street right of ways or through an area where potential future right of ways may occur. HDPE Corrugated Pipe must be installed in accordance with the manufacturer's specifications and the City's specifications as set forth herein.

48.020.02(A) Specifications for HDPE Corrugated Pipe

High Density Polyethylene (HDPE) Corrugated Pipe shall be specified and inspected in accordance with MoDOT Standard Construction Specification Section 730, latest revision. Installation shall be in accordance with MoDOT Standard Plan drawing 730.00, latest revision. As directed in MoDOT's specifications, this shall include, but not be limited to the following:

1. 12" to 60" nominal metric inside diameters.
2. Visual inspection of all pipe prior to final acceptance. If the City believes a section is deflected greater than 5%, no less than 10% of the pipe runs will be dimensional inspected.

3. Minimum cover as follows:
    a. 12” to top of rigid pavement or bottom of flexible pavement for pipe sizes 12” to 48”.
    b. 24” to top of rigid pavement or bottom of flexible pavement for 60” pipe.
    c. 12” of temporary additional cover is required where heavy construction load traffic is anticipated.
4. Flared-end sections are required when outfall erosion is a concern. Flared-end sections shall be metal or precast concrete in accordance with MoDOT Standard Drawing 732.00, latest revision.
5. In areas of a high groundwater table, the burial depth and resulting cover must be sufficient to balance the hydrostatic uplift force.

48.020.03 **Bedding**

The project plans and Specification shall indicate the specific type or types of bedding, cradling, or encasement required in the various parts of the storm sewer construction if different than current MSD Standard Construction Specifications. Special provisions shall be made for pipes laid under or over fills or embankments in shallow or partial trenches, either by specifying extra strength pipe for the additional loads due to differential settlement, or by special construction methods to prevent or to minimize such additional loads.
Pipes having a cover of less than three (3) feet shall be encased in concrete.

If the storm and sanitary sewers are parallel and in the same trench, the upper pipe shall be placed on a shelf and the lower pipe shall be bedded in compacted granular fill to the flow line of the upper pipe.

48.020.04 **Pipe or conduit Under Streets and Pavements**

Reinforced concrete pipe shall be Class III, Minimum.

Any pipe or conduit material beneath a highway, road, street, or pavement, or with reasonable probability of being so located, shall have ample strength for all vertical loads, including the live load required by the highway authority having jurisdiction, and in no case shall provide for less than an AASHTO
HS-20 loading. For other locations, the minimum live load shall be the HS-10 loading. Special considerations may be required for adverse conditions. Compacted granular backfill shall be utilized to the base of the pavement.

Monolithic reinforced concrete structures shall be designed structurally as continuous rigid units. Las much concrete as is practical shall be poured in one single operation with the reinforcing steel not terminated at the ends of a member but carried over at the joints into adjacent members.

48.020.06 **Alignment**

Sewer alignments are normally limited by the available easements which in turn should reflect proper alignment requirements. Since changes in alignment affect certain hydraulic losses, care in selecting possible alignments can minimize such losses and use available had to the best advantage.
Sewers shall be aligned:

1. To be in a straight line between structures, such as manholes, inlets, inlet manholes and junction chambers, for all pipe sewers thirty (30) inches in diameter and smaller.

2. To be parallel with or perpendicular to the centerlines of straight streets unless otherwise unavoidable. Deviations may be made only with approval of the City.
3. To avoid meandering, off-setting and unnecessary angular changes.
4. To make angular changes in alignment for sewers thirty (30) inches in diameter or smaller in a manhole located at the angle point, and for sewers thirty-three (33) inches in diameter or larger, by a uniform curve between two tangents. Curves shall have a minimum radius of ten times the pipe diameter.
5. To angular changes in direction greater than necessary and any exceeding ninety (90) degrees,

48.020.07 <u>Location</u>

Storm sewer locations are determined primarily by the requirements of service and purpose. It is also necessary to consider accessibility for construction and maintenance, site availability and competing uses, and effects of easements on private property.

Storm sewers shall be located:

1. To serve all property conveniently and to best advantage.
2. In public streets, roads, alleys, rights-of-way, or in sewer easements dedicated to the City of Moscow Mills.
3. In easements on private property and streets only when unavoidable.
4. On private property along property lines or immediately adjacent to public streets, avoiding diagonal crossings through the central areas of the property.
5. At a sufficient distance from existing and proposed buildings including footings, and underground utilities or other sewers to avoid encroachments and reduce construction hazards.
6. To avoid interference between other stormwater sewers and house connections to foul water or sanitary sewers.
7. In unpaved or unimproved areas whenever possible.
8. To avoid, whenever possible, any locations known to be or probably to be beneath curbs, paving or other improvements particularly when laid parallel to centerlines.
9. To avoid sinkhole areas if possible. However, if sinkhole areas cannot be avoided, see sub-section 48.020.08 for requirements.
10. Crossing perpendicular to street, unless otherwise unavoidable.

48.020.08 <u>Sinkhole Areas</u>

1. <u>Sinkhole Report</u>

Where improvements are proposed in any area identified as sinkhole areas, a sinkhole report will be required. This report is to be prepared by a Professional Engineer, registered in the State of Missouri, with demonstrated expertise in geotechnical engineering, and shall bear his or her seal.

The sinkhole report shall verify the adaptability of grading and improvements with the soil and geologic conditions available in the sinkhole areas. Sinkhole(s) shall be inspected to determine its functional capabilities with regard to handling drainage.

The report shall contain provisions for the sinkholes to be utilized as follows:

a. All sinkhole crevices shall be located on the plan. Functioning sinkholes may be utilized as a point of drainage discharge by a standard drainage structure with a properly sized outfall pipe provided to an adequate natural discharge point, such as a ditch, creek, river, etc.

b. Non-functioning sinkholes and sinkholes under a proposed building may be capped.

c. If development affects sinkholes, they may be left in their natural state; however they will still require a properly sized outfall pipe to an adequate natural discharge point.

d. Special siltation measures shall be installed during the excavation of sinkholes and during the grading operations to prevent siltation of the sinkhole crevice.

2. Procedure for Utilization of Sinkholes

a. Excavation. Prior to filling operations I the vicinity of a sinkhole, the earth in the bottom of the depression will be excavated to expose the fissure(s) in the bedrock. The length of fissure exposed will vary, but must include all unfilled voids or fissure widths greater than one-half (2) inch maximum dimensions which are not filled with plastic clay.

b. Closing Fissures. The fissure or void will be exposed until bedrock in its natural attitude is encountered. The rock will be cleaned of loose material and the fissures will be hand-packed with quarry-run rock of sufficient size to prevent entry of this rock into the fissures, and all the voids between this hand-packed quarry-run rock filled with smaller rock so as to prevent the overlying material's entry into the fissures. For a large opening, a structural (concrete) dome will be constructed with vents to permit the flow of groundwater.

c. Placing Filter Material. Material of various gradations, as approved, will be placed on top of the hand-packed rock with careful attention paid to the minimum thicknesses. The filter material must permit either upward or downward flow without loss of the overlying material.

The fill placed over the granular filter may include may include granular material consisting of clean (no screenings) crushed limestone with 10 inch maximum size and one inch minimum
size or an earth fill compacted to a minimum density of 90 percent modified Proctor as determined by ASTM D-1557.

d. Supervision. Periodic supervision of the cleaning of the rock fissures must be furnished by the Engineer who prepared the Soil Report. Closing of the rock fissures will not begin until the cleaning has been inspected and approved by that Engineer.

During the placement and compaction of earth fill over the filter, supervision by the Engineer shall be continuous. Earth fill densities will be determined during the placement and compaction of the fill in sufficient number to insure compliance with the specification. The Engineer is responsible for the quality of the work and to verify that the specifications are met.

48.020.09 Flow line

The flow line of storm sewers shall meet the following requirements;

1. The flow line shall be straight or without gradient change between the inner walls of connected structures; that is, from manhole to manhole, manhole to

junction chamber, inlet to manhole, or inlet to inlet.

2. Gradient changes in successive reaches normally shall be consistent and regular. Gradient designations less than the nearest 0.001 foot per foot, except under special circumstances and for large sewers, shall be avoided.
3. Sewer depths shall be determined primarily by the requirements of pipe or conduit size, utility obstructions, required connections, future extensions and adequate cover.
4. Stormwater pipes discharging into lakes shall have the discharge flow line a minimum of three feet above the lake bottom at the discharge point or no higher than the normal water line.
5. A concrete cradle is required when the grade of a sewer is twenty (20) percent or greater. A special design and specification is required for grades exceeding fifty (50) percent.

48.020.10 <u>Manholes</u>

Manholes provide access to sewers for purposes of inspection, maintenance and repair. They also serve as junction structures for lines and as entry points for flow. Requirements of sewer maintenance determine the main characteristics of manholes.

1. For sewers thirty (30) inches in diameter or smaller, manholes shall be located at changes in direction; changes in size of pipe; changes in flow line gradient of pipes, and at junction points with sewers and inlet lines.

   For sewers thirty-three (33) inches in diameter and larger, manholes shall be located on special structures at junction points with other sewers and at changes of size, alignment change and gradient. A manhole shall be located at one end of a short curve and at each end of a long curve.
2. Spacing of manholes shall not exceed four hundred (400) feet for sewer pipes thirty-six (36) inches in diameter and smaller; five hundred (500) feet for sewer pipes forty-two (42) inches in diameter and larger, except under special approved conditions. Spacing shall be approximately equal, whenever possible.
3. When large volumes of stormwater are permitted to drop into a manhole from lines twenty-one (21) inches or larger, the manhole bottom and walls below the top of such lines shall be of reinforced concrete.
4. Manholes shall be avoided in driveways or sidewalks.
5. Connections to existing structures may require rehabilitation or reconstruction of the structure being utilized. This work will be considered part of the project being proposed.

48.020.11 <u>Overland Flow System</u>

The design components of the drainage system include the inlets, pipe, storm sewers, and improved and unimproved channels that function during typical rainfall events. The overland flow system comprises the major overland flow routes such as swales, streets, floodplains, detention basins, and natural overflow and ponding areas. The purpose of the overland flow system is to provide a drainage path to safely pass flows that cannot be accommodated by the design system without causing flooding of adjacent structures.

The criteria for the overland flow systems shall be as follows:

1. The overland flow system shall be designed for the 100-year, a 24-hour

event, assuming the design system is blocked. The Natural Resources Conservation Service (NRCS) Unit Hydrograph method shall be used to calculate the overland flow peak flow rate. (100 yr., 24 hr. rainfall 7.21 inches).

2. The capacity of the overland flow system shall be verified with hydraulic calculations at critical cross-sections. The overland flow system shall be directed to the detention facility, or as approved by the City.

3. The low sill of all structures adjacent to the overland flow system swales shall be above the 100-year high-water elevation.

4. Where the topography will not allow for an overland flow path:

   a. The storm sewer shall be designed for the 100-year, 24-hour storm; and

   b. If this storm pipe is smaller than thirty-six (36) inches in diameter, a designated ponding area shall be identified, assuming the pipe is blocked; and

   c The ponding area shall be based on the 100-year, 24-hour storm; and

   d. The low sill of all structures adjacent to the ponding area shall be above the 100-year high-water elevation.

5. The overland flow system shall be clearly designated on the drainage area map and on the grading plan.

6. All overland flow systems will be considered on a site-specific basis.

48.030 <u>Stormwater design Criteria</u>

48.030.01 <u>Flow Quantities</u>

Flow quantities are to be calculated by the "Rational Method" in which:

$$Q = API$$

where:

Q = runoff in cubic feet per second

A = tributary area in acres.

I = Average intensity of rainfall (inches per hour) for a given period and a given frequency.

P = runoff factor based on runoff from pervious and impervious surfaces.

P (runoff Factors) for various impervious conditions are shown in Table 4-1.

P.I. Values for various impervious conditions are shown in Table 4-2.

1. <u>Rainfall Frequency</u>
   A fifteen (15) year, Twenty (20) minute duration rainfall shall be used for all stormwater sewer design in the city of Moscow Mills unless otherwise directed by

the City's Engineer Figure 4-1 gives rainfall curves for 2, 5, 10, 15, 20 and 100 year frequencies.

2. Impervious Percentages and Land Use

Minimum impervious percentages to be used are as follows:

a. For manufacturing and industrial areas, 100%.*

b. For business and commercial areas, 100%.*

c. For residential areas, including all areas for roofs of dwellings and garages; for driveways, streets, and paved areas; for public and private sidewalks; with adequate allowance in area for expected or contingent increases in imperviousness:

In apartment, condominium and multiple dwelling areas: 75%*****

In single family areas:

1/4 Acre or less	50%
1/4 Acre to 2 Acre	40%
One acre or larger	30%
Playgrounds (Non-Paved)	20 - 35%*****

d. For small non-perpetual cemeteries,
For parks and large perpetual charter cemeteries 5%

***NOTE**: Drainage areas may be broken into component areas with the appropriate run-off factor applied to each component, i.e.; a proposed development may show 100% impervious for paved areas and 5% impervious for grassed areas.

The planning engineer shall provide adequate detailed computations for any proposed, expected or contingent increases in imperviousness and shall make adequate allowances for changes in zoning use. If consideration is to be given to any other value than the above for such development, the request must be made at the beginning of the project, must be approved in writing before its use is permitted.

Although areas generally will be developed in accordance with current Zoning requirements, recognition must be given to the fact that zoning ordinances can be amended to change the currently proposed types of development, and any existing use. Under these circumstances the possibility and the probability of residential areas having lot sizes changed or re-zoned to business, commercial, or light manufacturing uses should be given careful consideration.

e. Average 20-minute values of P.I. (Cfs per acre) to be used are as follows:

Percent Imperviousness	15 year interval 20 Minute Duration
5	1.7
10	1.8
20	2.0
30	2.2
40	2.6
50	2.6
90	3.4
100	3.5

Roofs	4.2

3. <u>Reduction in P. I. with Time and Area</u>
Reduction in P. I. Values for the total time of concentration
Exceeding twenty (20) minutes and for tributary areas exceeding three hundred (300) acres will be allowed only in trunk sewers and main channels. The reduced average P. I. value for the tributary area shall not be less than the value determined as follows on the basis of:
   a. Time. As the time of concentration increases beyond twenty (20) minutes, select the appropriate P. I. Value from Table 4-1. The travel time through a drainage channel should be based on an improved concrete section. These reduced values shall be used unless a further reduction is allowed for area.
   b. Area. As the total tributary area at any given location in a channel increases in excess of three hundred (300) acres, the P. I. Value may be further reduced by multiplying it by an area coefficient "Ka". The average rainfall rate, for a given storm, for a given period for the tributary area, is less than the corresponding point value as determined from recording rainfall gauges. The curve data is as follows:

P. I. Coefficients Ka

Area (Asbscissass)	"Ka" (Ordinates)
300 to 449 Acres	1.00
450 to 549 Acres	.99
550 to 549 Acres	.98
750 to 999 Acres	.97
1000 to 1280 Acres	.96
1281 to 1600 Acres	.95
1601 to 1920 Acres	.92
1921 to 2240 Acres	.91

48.030.02 <u>Hydraulic grade Line for Closed conduits</u>

1. <u>Computation Methods</u>
The hydraulic grade line is a line coinciding with (a) the level of flowing water at any given point along an open channel, or (b) the level to which water would rise in a vertical tube connected to any point along a pipe or closed conduit flowing under pressure.

The hydraulic grade line shall be computed to show its elevation at all structures and junction points of flow in pipes, conduits and open channels, and shall provide for the losses and the differences in elevations as required below. Since it is based on design flow in a given size of pipe or conduit or channel, it is of importance in determining minimum sizes of pipes within narrow limits. Sizes larger than the required minimum generally provide extra capacity, however consideration must still be given to the respective pipe system losses.

There are several methods of calculating "losses" in storm sewer design. The following procedures are presented for the engineer's information and consideration.

It is expected that the design will recognize the reality of such "losses" occurring and make such allowances as good engineering judgment requires.

a. Friction Loss

The hydraulic grade line is affected by friction loss and by velocity head transformations and losses. Friction loss is the head required to maintain the required flow in a straight alignment against frictional resistance because of pipe or channel roughness. It is determined by the equation:

$hf = L \times S_h$

Where:

hf = differences in water surface elevation, or head in feet in length L

L = length I feet of pipe or channel

S_h = hydraulic slope required for a pipe of given diameter or channel of given cross-section and for a given roughness "n", expressed As feet of slope per foot of length.

From Manning's formula: $S_h = [V\ n\ /(1.486\ \mathbf{R}^{\mathbf{0.667}})]^2$

Where:

R = hydraulic radius of pipe, conduit or channel (feet)
(Ratio of low area/wetted perimeter)

V = velocity of flow in feet per second (fps)

n = Manning's value for coefficient of roughness

Use:

n = .013 for pipes of concrete, vitrified clay, and PVC pipe

n = .0112 for formed monolithic concrete, i.e., vertical wall channels, box culverts and for R.C.P. over 48" in diameter.

n = .015 for concrete lining in ditch or channel inverts and trapezoidal channels

n = .020 for grouted riprap lining on ditch or channel side slopes

n = .033 for gabion walled channels

Note:

"n" will have a weighted value for composite lined channels.

"n" values for unlined channels to be determined on an individual basis

b. Curve Loss

Curve loss in pipe flow is the additional head required to maintain the required flow because of curved alignment, and is in addition to the friction loss of an equal length of straight alignment. It should be determined from Figure 4-2 which includes an example.

c. Entrance Loss at Terminal Inlets

Entrance loss is the additional head required to maintain the required flow because of resistance at the entrance. The entrance loss at a terminal inlet is calculated by the formula:

$H_{ti} = (V^2 /2g)$

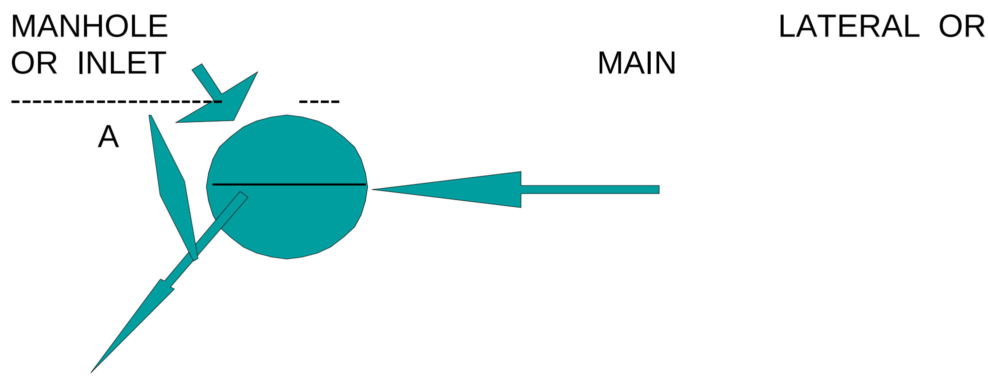
Where: V = Velocity in flow of outgoing pipe
g = Acceleration of gravity (32.2 Ft./Sec/Sec)

d. Turn Loss

Head losses in structures due to change in direction of flow (turns) in a structure, will be determined in accordance with the following:

Change in Direction of Flow (A)	Multiplier of Velocity Head of Water Being Turned (K)
90 Deg.	0.7
60 Deg.	0.55
45 Deg.	0.47
30 Deg.	0.35
0 Deg.	0.0

DIAGRAM:



Formula: $H_L = K(V_L)^2 / 2g$

Where:

H_L = Feet of head lost in manhole due to change in direction of lateral flow

V_L = Velocity of flow in lateral, (Ft./Sec)

g = Acceleration of gravity, (32.2 Ft./Sec/Sec)

K = Multiplier of Velocity Head of water being turned

e. Junction Chamber Loss

A sewer junction occurs for large pipes or conduits too large to be brought together in the usual forty two (42) inch diameter manhole or inlet where one or more branch sewers enter a main sewer. Allowances should be made for head loss due to curvature of the paths and due to impact at the converging streams.

Losses in a junction chamber for combining large flows shall be minimized by setting flow line elevations so that pipe centerlines (spring lines), will be approximately in the same planes.

At junction points for combining for combining large storm flows, a manhole with a slotted cover shall be provided.

A computation method for determining junction chamber losses is presented below:

$$H_j = \Delta y + V_{h1} - V_{h2}$$

Where:

H_j = junction chamber loss (ft.)

V_{h1} = upstream velocity head

V_{h2} = downstream velocity head

Δy = change in hydraulic grade line through the junction in feet

Where:

$$\Delta y = \frac{\square[(Q_2V_2) - (Q_1V_1) - \{(Q_3V_3 \text{Cos } e_3) - (Q_nV_n \text{Cos } e_n)\}]}{0.5(A_1+A_2)g}$$

Where:

Q_2 = Discharge in cubic feet per second (cfs) at the exiting conduit.

V_2 = Velocity in feet per second (fps) at the exiting conduit.

A_2 = Cross sectional area of flow in sq. ft. for the exiting conduit.

Q_1 = Discharge in cfs for the incoming pipe (main flow).

V_1 = Velocity in fps for the incoming pipe (main flow).

A_1 = Cross sectional area of flow in Sq. Ft. For the incoming pipe (main flow).

Q_3Q_n = Discharge (s) in cfs for the branch lateral (s).

V_3V_n = Velocity (ies) in fps for the branch lateral (s).

e_3e_n = The angle between the axes of the exiting pipe and the branch laterals(s).

g = Acceleration of gravity (32.2 ft./sec/sec)

Where:

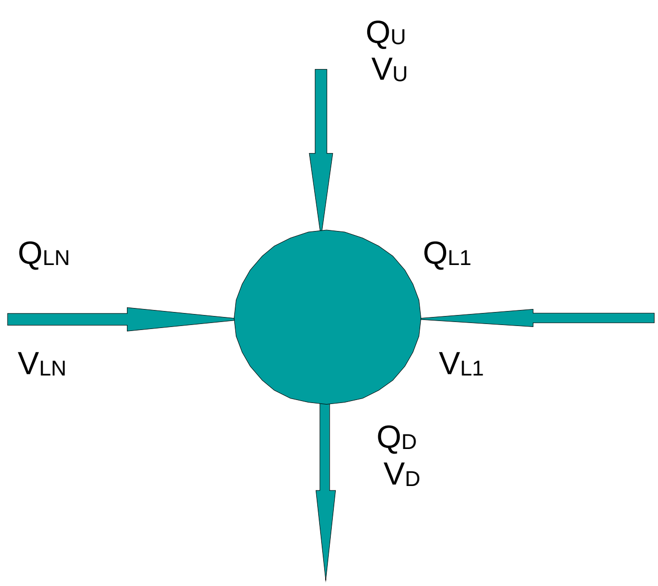
e = is the angle between the axes of the outfall and the incoming laterals.

The terms within [ ] indicate the summation of all incoming laterals (not on main sewer).

f. Losses at Junctions of Several Flows in Manholes and/or Inlets

The computation of losses in a manhole, inlet or inlet manhole with several flows entering the structure should utilize the principle of the conservation of energy. This involves both the elevation of water surface and momentum (mass times the velocity head). Thus, at a structure (manhole, inlet or inlet manhole). Thus, at a structure (manhole, inlet or inlet manhole) with laterals, the sum of the energy content for inflows is equal to the sum of the energy content of the outflows plus the additional energy required by the turbulence of the flows passing through the structure.

DIAGRAM:



The upstream hydraulic grade line may be calculated as follows:

$$H_u = [V_D^2/2g] - [(Q_U/Q_D)\ (1\text{-}K)\ (V_U^2/2g)] - [Q_{L1}/Q_D)\ (1\text{-}K)\ V_{L1}^2/2g] + [(Q_{LN}/Q_D)\ (1\text{-}K)\ (V_{LN}^2/2g)] + H_D$$

Where:

H_U	=	Upstream hydraulic grade line in feet
Q_U	=	upstream main line discharge in cubic feet per second
Q_D	=	Downstream main line discharge in cubic feet per second
Q_{L1}-Q_N	=	Lateral discharges in cubic feet per second
V_U	=	Upstream main line velocity in feet per second
V_D	=	Downstream main line velocity in feet per second
V_{L1}-V_{LN}	=	Lateral velocities in feet per second
H_D	=	Downstream hydraulic grade line in feet
K	=	Multiplier of Velocity of Water being turned
g	=	Acceleration of gravity, 32.2 ft. /sec/sec

The above equation does not apply when two (2) almost equal and opposing flows, each perpendicular to the downstream pipe, meet and no other flows exist in the structure. In this case the head loss is considered as the total velocity head of the downstream discharge.

g. Transition Loss

The relative importance of the transition loss is dependent on the velocity head of the flow. If the velocity and velocity head of the flow are quite low, the transition losses cannot be very great. However, even small loses may be significant in flat terrain. The sewer design shall provide for the consideration of the necessary transitions and resulting energy losses. The possibility of objectionable deposits is to be considered in the design of transitions.

For design purposes it shall be assumed that the energy loss and changes in depth, velocity and invert elevation, if any, occur at the center of the transition. These changes shall be distributed throughout the length of the transition in actual detailing. The designer shall carry the energy head, piezometric head (depth in an open channel), and invert as elevations, and work from the energy grade line. Because of inherent differences in the flow, transitions for closed conduits will be considered separately from those for open channels.

(1) Closed Conduits

Transitions in small sewers may be confined within a manhole. Special structures may be required for larger sewers. If a sewer is flowing surcharged, the form and friction losses are independent of the invert slope; therefore, the transition may vary at the slopes of the adjacent conduits. The energy loss in a transition shall be expressed as a coefficient multiplied by the change in velocity head ($\Delta V^2/2g$) in which ΔV is the change in Velocity before and after the transition. The coefficient may vary from zero to one, depending on the design of the transition.

If the areas before and after a transition are known, it is often convenient to express the transition loss in terms of the area ratios and either the velocity upstream or downstream.

For an expansion:

$$H_L = K(V_1-V_2)^2/2g = [K(V_1)^2/2g]\ [1-(A_1/A_2]^2$$

In which H_L is the energy loss; K is a coefficient equal to 1.0 for a sudden expansion and approximately 0.2 for a well-designed transition and the subscripts 1 and 2 denote the upstream and downstream sections, respectively, i.e., A_1 = Area Before Transition and A_2 = Area After Transition.

For a Contraction:
$H_L = [K(V_2)^2/2g]\ [(1/C_c)-1]^2 = [K(V_2)^2/2g]\ [1-(A^2/A_1)]^2$
In which K is a coefficient equal to 0.5 for a well-designed transition, C_c is a coefficient of contraction, and the other terms and subscripts are similar to the previous equation. Losses in closed conduits of constant area are expressed in terms of $(V^2/2g)$.
The above equations may be applied to approximate the energy loss through a manhole for a circular pipe flowing full. If the invert is fully developed, that is, semi-circular on the bottom and vertical on the sides from one-half depth up to the top of the pipe, for the expansion $(A_1/A_2) = 0.88$, and for the contraction $(A_2A_1) = 0.88$. The expansion is sudden; therefore, K = 1. The contraction may be rounded if the downstream pipe has a bell or socket. In this case, K may be assumed to be 0.2.

The expansion energy loss is 0.014 $[(V_1)^2/2g]$ and the contraction energy loss is 0.010 $[(V_2)^2/2g]$. If the invert is fully developed, the manhole loss is small, but if the invert is only developed for one-half of the depth, or not at all, the losses will be of considerable magnitude.

(2) Open Channel Transitions

The hydraulics of open channel transitions are further complicated by possible changes in depth. As a first approximation to the energy loss, unless a jump occurs, the equations given above may be used with a trial-and-error solution for the unknown area and velocity. The K value for a well-designed expansion should probably be increased to 0.3 or 0.4 Whether the properties of the upstream or downstream section will be known will depend on the characteristics of the flow and the channel, but can be determined by a profile analysis. In transitions for supercritical flow, additional factors shall be considered. Standing waves of considerable magnitude will be produced in transitions. The height of these waves must be estimated to provide a proper channel depth. In addition, in long transitions, air entrainment will cause bulking of the flow with resultant greater depths of the air-water mixture.

48.030.03 Hydraulic Grade Line Limits

The hydraulic grade line shall not rise above the following limits as determined by flow quantities calculated per Section 4.030.01.

1. The hydraulic grade line at any inlet shall not be higher than six (6) inches below the inlet sill. The hydraulic grade line at any storm manhole shall be no higher than one (1) foot below the top.
2. Storm sewers shall not flow with greater than three (3) feet of head without special pipe joint requirements.
3. The beginning point for the hydraulic grade line computations shall be the higher elevation as determined below:
   a. For connection to existing pipe system:
      (1) Top of pipe intrados of one reach downstream of the connection point of the existing system; or
      (2) The hydraulic grade line computed for the existing system.
   b. For connection to channels or ditches:
      (1) Top of pipe intrados of the proposed pipe, or
      (2) The computed hydraulic grade line for the channel or ditch as approved by city's engineer.
      (3) The computed 100 yr. base flood elevation if channel or ditch is in Floodplain.
   c. For upstream storm sewer system connection to dry or wet detention basins.
      (1) The invert elevation of the emergency overflow pipe or_sill capable of passing 100 yr., 20 min. storm event.
      (max. operation elevation of basin)
      (2) If the basin is located within a floodplain, us the 100 year base flood elevation.

Inlets function entirely as entry points for stormwater flow. They also may be constructed to serve as a manhole on separate stormwater sewers, and are then termed inlet-manholes. Steep gradients may give such low inlet capacities that additional inlets should be located at more favorable grade locations or special inlets designed for steep gradients must be used. Provisions must be made to control by-pass flow and to provide additional capacity in the inlet and line affected by such increased flow. Six (6) inch open throat inlets should be used at all times.

Grated inlets, without an open throat or other provision for overflow shall be avoided except under exceptional conditions, and are
prohibited in grade pockets. Any exceptions shall be used only with the City's approval.

Curb inlets shall be placed at street intersections or driveways such that no part of the inlet structure or sump Is within the curb rounding.

1. Inlets are shown in the MSD Standard Details of Sewer Construction, latest edition. The minimum depth of a terminal inlet is four (4) feet from the top of the inlet to the flow line of the outlet pipe. Greater depth shall be used for intermediate inlets if necessary for the required depth of the hydraulic grade line.
2. Inlet capacity should not be less than the quantity flow tributary to the inlet and by-pass flow shall be avoided whenever possible.

   Inlets at low points or grade pockets should have extra capacity to compensate for possible flow by-pass of upstream inlets.

   Figure 4-3 shows inlet capacity/maximum gutter capacity with a given gutter line grade and flow.
3. Connections to existing structures may require rehabilitation or reconstruction of the structure being utilized. This work will be considered part of the project being proposed.

48.030.05 **<u>Open Channels</u>**

All open channels shall meet the following requirements:

1. <u>Size and Shape</u>
   Open channels shall not decrease in size in the direction of flow. Open channels shall be vertical and constructed of reinforced concrete or other materials approved by the City Engineer. Where possible the bottom of open channels should be constructed of pervious materials and protected with non-armored erosion protection. All open channel designs shall be approved by the City Engineer.
2. <u>Materials</u>
   All materials used in construction of open channels shall be approved by the City Engineer.
3. <u>Bedding</u>
   Special provisions shall be made for channels or paved swales laid over fill on non-supportive soils to support the channel on paved swales. Pipes extended to the channel in a fill area shall have compacted crushed limestone bedding for support.
4. <u>Structural Considerations</u>
   Provisions must be made for all loads on the channel.
5. <u>Alignment</u>
   Open channel alignments may be limited by available easements, physical topography, existing utilities, buildings, residential development, maintenance access and roadways.
6. <u>Locations</u>
   Storm channel locations are determined primarily by natural drainage conditions. It is also necessary to consider accessibility for construction and maintenance, site availability and competing uses, and evaluating effects of easements on private property.

Storm Channels shall be located:

a. To serve all adjacent property conveniently and to best advantage.
b. In easements or rights-of-way dedicated to the City.
c. In easements on common ground when feasible.
d. On private property along property lines or immediately adjacent to

public streets, avoiding crossings through the property.

e. At a sufficient distance from existing and proposed buildings and underground utilities or sewers to avoid future problems of flooding or erosion.

f. To avoid interference between stormwater sewers and house connections to foul water or sanitary sewers.

g. In unpaved or unimproved areas whenever possible.

h. Crossing perpendicular to streets, unless unavoidable.

7. Flow line

The flow line of open channels shall meet the following requirements.

a. Gradient changes shall be kept to a minimum and be consistent and regular.

b. Gradient designations less than the nearest 0.001 foot per foot shall be avoided.

c. Channel and swale depths shall be determined primarily by the requirements of the channel size, utility obstructions and any required connections.

8. Other Open Channel Considerations and Requirements

a. All natural channels and ditches shall be improved unless otherwise authorized by the City.

b. Drainage within private property should be controlled to prevent damage to the property crossed. Swales, or broad shallow grass lined ditches with non-erosive slopes, are generally located at or near rear lots and along common property lines. If erosion protection is necessary, a non-armored type of erosion protection is preferred by the City (where feasible). All erosion protection shall be approved by the City Engineer.

c. Drainage channels and water courses draining through a subdivision shall be enclosed if the required pipe size does not exceed sixty (60) inches. When it is undesirable or impractical to enclose a channel with a pipe across a road or street, a suitable bridge or culvert shall be required.

d. For flows greater than four (4) cfs, area inlets or inlet manholes are required to intercept the gutter or swale flow.

e. All improved concrete channels shall have a forty eight (48) inch chain link fence on each side of the channel, or other protective measures as directed by the City.

f. Channels and water courses draining large areas shall be located in rights-of-way or easements previously approved by the City as a part of an adequate overall plan for drainage.

9. Design limitations

a. The flow quantity shall be calculated by the method presented in Section 4.030.01 of this manual.

b. If the channel is within an area designated in a community's flood insurance study, then the channel shall also meet all of the city at Moscow Mills floodplain requirements.

c. Other agencies of jurisdiction may have requirements which must be met. An Army corps of Engineers permit may be required for any construction affecting a watercourse.

10. Hydraulic Grade Line

a. Computation Methods

In open channels the water surface is identical with the hydraulic grade line. The hydraulic grade line shall be computed throughout the channel each to show its elevation at junctions with incoming pipes or channels and at the ends of the channel reach under consideration. It shall also provide for the losses and differences in elevations as required below. Since it is based on design flow in a given channel, it is of importance in determining minimum sizes within narrow limits. The depth at which the actual flows will occur is controlled by the two end conditions of the reach considered, and by the relationship between the energy available and by the energy required to overcome the losses that are encountered along the channel.

There are several methods of calculating “losses” in channel design. The following procedures are presented for the engineer’s information and consideration.

It is required that the design recognize the reality of such “losses” occurring and make such allowances as good engineering judgment indicates.

(1) <u>Control Sections</u>

The engineer should locate all possible control sections for the reach in question. A control section refers to any section at which the depth of flow is known or can be controlled to a required stage. At the control section, flow must pass. through a control depth which may be the critical depth, the normal depth or any other known depth. Three types of control sections include (a) Upstream Control Section; (b) Downstream Control Section; Artificial Control Section, which occurs at a control structure, such as a weir, dam, sluice gate, roadway embankment, culvert, bridges or at the confluence with a major river or stream.

(2) <u>Friction Loss</u>

The friction loss may be calculated by the same procedure as is presented in section 4.030.02 of this chapter.

(3) <u>Flow in curved channels</u>

The centrifugal force caused by flow around a curve reduces a rise in the water surface on the outside wall and a lowering of the inner wall. This phenomenon is called superelevation. The flows tend to behave differently according to the state of flow.

In sub critical flow, fiction effects are of importance, whereby in supercritical flow, the formation of cross-waves is of major concern.

(a) Curve Losses

Curve losses may be estimated from Figure 4-2 by replacing D, diameter, with b, width of channel.

(b) Superelevations

In addition to curve losses, an evaluation of superelevations should be considered and, if required, an allowance made in the top elevation of outside wall. Equations are presented below which may be used to determine the superelevation at channel bends.

1) Trapezoidal Channels

Sub critical Flow:

$\Delta H_W = 1.15(V^2/2gr_c)\ [b+(D(ZL+Zr))]$

Supercritical Flow:

$\Delta H_W = 2.6(V^2/2gr_c)\ [b+(D(ZL+ZR))]$

2) Rectangular Channels

Sub critical Flow:

$\Delta H_W = (V^2b/2gr_c)$

Supercritical Flow:

$\Delta H_W = (V^2b/gr_c)$

Where:

ΔH_W	=	Change in water height above the centerline water surface elevation.
V	=	Average velocity of design flow in Fps
g	=	Acceleration of gravity (32.2 Ft./Sec/Sec)
r_c	=	Radius of curve on horizontal alignment in feet
b	=	Base width of channel in feet
D	=	Depth of flow in straight channel
ZL	=	Left side slope (ft./ft.)
ZR	=	right side slope (ft./ft.)

(4) <u>Transitions</u>

Transitions should be designed to accomplish the required change in cross section with as little flow disturbance as possible.

The following features are to be considered in design of transition structures.

(a) Proportioning

1) The optimum maximum angle between the channel axis and a line connecting the channel sides between the entrance and exit sections is 12.5°.

2) Sharp angles in the structure should be avoided.

(b) Losses

The energy loss in a transition consists of the friction loss and the conversion loss. The friction loss may be estimated by the Manning Formula. The conversion loss is generally expressed in terms of the change in velocity head between the entrance and exit sections of the structure.

$H_t = K_t\ \Delta V_H$

Where:

H_t	=	Conversion Loss
K_t	=	Coefficient of head loss in transition
ΔV_H	=	Absolute change in velocity head

Average design values for K_t are presented in the table

Below:

Type of Transition	Contraction Section	Expanding Section
Warped	0.10	0.20
Wedge	0.20	0.50
Cylinder-Quadrant	0.15	0.25
Straight Line	0.30	0.50
Square End	0.40	0.75

See Figure 4-4 for sketches of each type of transition.

(c) Freeboard

A transition shall have a minimum of one (1) foot of freeboard above the hydraulic grade line.

(d) Hydraulic Jump

The existence of a hydraulic jump in a transition may become objectionable, and the design of the transition should be checked for such.

(e) Sudden Enlargement and Contraction

A sudden enlargement results when an intense shearing action occurs between incoming high-velocity jet and the surrounding water. As a result, much of the Kinetic energy of the jet is dissipated by eddy action. The head loss at a sudden enlargement, H_{Le}, is:

$$H_{Le} = K_e (\Delta V^2/2g)$$

Where:

K_e = Coefficient of had loss for enlargements = 1

ΔV = Change in velocities between incoming and outgoing sections

G = Acceleration of gravity (32.2 Ft./Sec/Sec)

The flow in a sudden contraction is first contracted and then expanded resulting I high losses as compared to a sudden enlargement. Thus the head loss at a sudden contraction, H_{Le}, is:

$$H_{Lc} = K_c(\Delta V^2/2g)$$

Where:

K_c = Coefficient of head loss for contractions - 0.5.

ΔV = Change in velocities between incoming and outgoing sections.

g = Acceleration of gravity, Ft./Sec/Sec.

(5) Constrictions

A constriction results in a sudden reduction in channel cross section. The effect of the constriction on the flow depends mainly on the boundary geometry, the discharge and the state of flow. When the flow is sub critical, the constriction will induce a backwater affect that extends a long distance upstream. If the flow is supercritical, the disturbance is usually local and will_only affect the water adjacent to the upstream side of the constriction. A control section may or may not exist at a constriction. The control section, when it exists, may be at either side of the constriction upstream or downstream), depending on whether the slope of the constricted channel is steep or mild. The entrance and outlet of the constriction then acts as a contraction and an expansion, respectfully.

(6) <u>Obstructions</u>

An obstruction is open-channel flow creates at least two paths of flow in the channel. Typical obstructions include bridge piers, pile trestles, and trash racks. The flow through an obstruction may be sub critical or supercritical.

(a). <u>Hydraulic Grade Line limits</u>

(1) The hydraulic grade line at any point along a channel shall not be higher than one (1) foot below the top of the channel wall.

(2) The hydraulic grade line at any point along a channel shall not cause the hydraulic grade limits of the storm sewer system to be exceeded as stated in Section 4.030.03 of this manual.

11. <u>Hydraulic Jump</u>

When flow changes from the supercritical to sub critical state, a hydraulic jump may occur. A study should be made on the height and location of the jump, and for discharges less than the design discharge, to endure adequate wall heights extend over the full ranges of discharge.

12. <u>Open Channel Junctions</u>

a. <u>General</u>

(1) Consideration shall be given in the design of open channel junctions to the geometry of the confluence of flows in order to minimize undesirable hydraulic effects due to supercritical velocities.

(b) <u>Confluence Design Criteria</u>

(1) The momentum equation can be applied to the confluence design if the below stated criteria is used.

(2) The design water-surface elevations in the two joining channels should be approximately equal at the upstream end of the confluence.

(3) The angle of the junction intersection can vary from 0-12 degrees.

(4) The width of the main channel shall be expanded below the junction to maintain approximate flow depths throughout the junction.

(5) Flow depths should not exceed 90 per cent of the critical depth.

13. <u>Erosion Protection</u>

A Rock blanket, minimum one (1) foot thick, shall be required at each end of the improved channel. The minimum length of the rock blanket shall be twenty five (25) feet. A rock toe wall, minimum two (2) foot deep, shall be constructed at the free end of each blanket.

14. <u>Sanitary Sewer Crossings</u>

The characteristics of any sanitary sewer crossing shall be given consideration in the design of the channel floor

48.030.06 **<u>Culverts</u>**

The design of culverts shall include consideration of many factors relating to requirements of hydrology, hydraulics, physical environment, imposed exterior loads, construction and maintenance.

With the design discharge and general layout requirements determined, the design requires detailed consideration of such hydraulic factors as shape and slope of approach and exit channels, allowable head at entrance (and ponding capacity, if appreciable), tail water levels, hydraulic and energy grade lines, and erosion potential.

1. <u>Hydraulic Design</u>
   The hydraulic design of a culvert for a specified design discharge involves (1) selection of a type and size, (2) determination of the position of hydraulic control, and (3) hydraulic computations to determine whether acceptable headwater depths and outfall conditions will result. Hydraulic computations will be carried out by standard methods based on pressure, energy, momentum and loss considerations.
2. <u>Entrances and Headwalls - Outlets and End walls</u>
   Where an existing culvert is to be extended, the possibility for maintaining or improving existing capacity should be investigated. Marked improvement may be obtainable by proper entrance design. All culverts shall be designed for possible extension unless there are extenuating circumstances.

48.040 **<u>Bridges</u>**

Bridges shall be designed to meet the current criteria of the governing agencies.

48.040.01 **<u>Waterway capacity and Backwater Effects</u>**

Sufficient capacity will be provided to pass the runoff from the design storm determined in accordance with principles given elsewhere in this manual.

48.040.02 **<u>Clearance</u>**

The lowest point of the bridge superstructure shall have a (freeboard) clearance of two (2) feet above design water surface elevation for the 15 year frequency and one (1) foot for the 100 year frequency.

48.040.03 **<u>Waterway Alignment</u>**

The bridged waterway will be aligned to result in the least obstruction to stream-flow, except that for natural streams consideration will be given to future realignment and improvement of the channel.

48.040.04 **<u>Erosion Protection</u>**

To preclude failure by scouring, abutment and pier footings will usually be laced either to a depth of not less than five (5) feet below the anticipated depth of scour, or on firm rock if such is encountered at a higher elevation. Large multispan structures crossing alluvial streams may require extensive pile foundations. To protect the channel, revetment on channel sides and/or bottom, consisting of concrete or rock blanket should be placed as required. The governing authority should be contacted regarding their design requirements.

48.050 Outlet Erosion Protection

If outlet velocities exceed 5 f.p.s., an appropriate erosion protection must be provided. Erosion protection may be required at outlets where velocities are less than 5 f.p.s. if soil conditions warrant.

All erosion protection shall be approved by the City Engineer. Non-armored erosion protection is preferred.

48.060 Limits of overland flows

Area inlets shall be required to intercept overland flows greater than one (1) cfs to prevent that flow from crossing sidewalks of curbs.

48.070 Impervious Areas

Any area which is to be paved, repaved, expanded or otherwise improved, that is over 3,000 square feet in area, whether presently paved or not, shall at such time as it is to be paved, repaved, expanded or be otherwise improved, be provided with storm water drainage facilities constructed in accordance with plans and specifications submitted to and approved by the City.

48.080 Storm Water Detention

48.080.01 Requirements and submittals

A. The requirement of stormwater detention shall be evaluated for all projects submitted to the City for plat approval. The Planning & Zoning Commission may request review by the City's engineer prior to plat approval. The applicant for plat approval shall reimburse the City for any engineer fees incurred as a result of said review. Detention facilities shall be designed and provided as required by the City's engineer.

B. A Storm Water Drainage and Detention Design Report, with three extra copies, shall be submitted with all applications for plat approval. Said report shall contain a written summary and all hydraulic calculations. The Report shall be signed, dated and sealed by the Missouri Professional Engineer who is responsible for its preparation.

C. The City's Superintendent of Public Works may issue a written stop work order to any person who is found violating the provisions of this Chapter or otherwise failing to conform to their submitted plans or the City's specifications for storm drainage facilities. Violation of a stop work order shall be unlawful and shall constitute a misdemeanor and shall be punished by a fine of not less than one dollar ($1.00) and not more than five hundred dollars ($500.00) or by imprisonment not exceeding ninety (90) days or both, recoverable with cost of court. Each day of violation shall constitute a separate offense.

48.080.02 Design Considerations

1. The rates (pre-developed and post developed) of runoff are determined by the Rational Method for the 2, 5,10, and 15 year frequencies, with 20 minute rainfall intensity.

   The City reserves the right to require higher rainfall frequencies and intensities as downstream conditions (problems) would warrant it.

2. Stormwater shall be detained on site or off site as approved and released at the rate of an existing pre-development site for 2, 5, 10 and 15 year rainfall event, unless downstream conditions (problems) warrant otherwise. Note that the stormwater pipes, downstream from control structures, shall be sized to carry the total tributary upstream watershed. No reduction in outfall pipe size shall be permitted because of detention.

3. The volume of detention may be provided through permanent detention facilities such as dry basins or ponds, permanent ponds or lakes or underground storage facilities, parking lot detention will not be acceptable.

   Flows from offsite upstream areas should be bypassed around the detention facility to ensure that the proposed detention facility will function as designed and will provide effective control of downstream flows with development in place. If offsite flows are directed into a detention facility, the allowable release rates shall not be modified without the City's approval. Modifying the release rate to accommodate offsite flows may reduce or eliminate the effectiveness of the detention facility, because it will no longer control the increased volume of runoff during the critical time period of the watershed.
4. Detention basin volume will be based on routing each predeveloped runoff hydro graph through the detention facility while satisfying the appropriate allowable release rate. The routing computations shall be based on an application of the continuity principle.
5. Detention basins shall be located on common ground and have a minimum fifteen (15) foot strip maintenance access for vehicles.
6. Detention basin shall not be located in floodway.
7. Detention basin shall have an overflow structure capable of passing a 100 year, 20 minute design storm. An emergency spillway, capable of passing a 100 year, 20 minute storm event, may also be required by the City to safely route any basin overflow away from developed areas to a natural drainage channel.
8. Design of underground Detention system
   a. Adequate access for basin maintenance and inspection shall be provided. A means of visual inspection from the ground surface of the low flow device, overflow weir, and outlet structure is necessary. Access shall also be provided to allow for cleaning of the low flow device from the ground surface.
   b. The basin should have sufficient volume and spillway capacity to pass/contain the 100 year 24 hour event with the low flow outlet blacked. In some situations it may be desirable to have control structures with at least 2 outlet openings, one above the other.
   c. Underground detention facilities shall be acceptable for non-residential projects only, unless pre-approved by City.
   d. Acceptable materials for underground detention facilities are aluminized corrugated metal pipe, gauge of pipe approved by city engineer and polyethylene (PE) pipe.
   e. Provide immediate manhole access from ground surface for both sides of the low flow device. Also provide a manhole at upstream end of underground basins, for access, inspection, to facilitate maintenance and air release.
   f. Adequate flow line spot elevations, sections and profiles including pipe length and slope shall be labeled to define basin and pipe geometry.
9. The Engineer must submit the following for review of a detention facility:
   a. Elevation vs Discharge tables or curves for all frequencies.
   b. Elevation vs Storage tables or curves for all frequencies.

c. Inflow calculations and data for all frequencies.
d. Hydraulic grade line computations for pipes entering and leaving the basin for all frequencies.
e. If the embankment contains fill material a geotechnical report may be required.
f. Site plan showing appropriate design information
g. Structural calculations for the outlet control structures (if required)

10. All pipes discharging into a dry basin or pond shall be reinforced concrete pipe with a concrete flared-end, concrete toe and head wall with rip-rap as per MSD standard flared-end detail. PAVED SWALES CONNECTING THE INLET PIPE WITH THE OUTFLOW CONTROL STRUCTURE WILL NOT BE ALLOWED.
11. Railroad tie walls cannot be used where water will be in contact with the railroad tie wall.
12. Permanent detention ponds or lakes are to be designed to minimize fluctuating lake levels. Maximum fluctuation from the permanent pool elevation to the maximum ponding elevation shall be three (3) feet.
13. The maximum side slopes for basins or ponds, and the fluctuating area of permanent ponds or lakes shall be 3:1 (three feet horizontal, one foot vertical) without fencing.
14. Dry basins or ponds are to be sodded. The slopes are to be kept mowed. The bottoms are to be allowed to grow (unmowed).
15. Control structures and overflow structures are to be reinforced concrete.
16. The outflow pipe shall be sized for the developed flow rate.
17. In basins with concrete walls or rock blanket covered slopes, the bottoms shall be left unmowed. This will allow for better infiltration of water into the ground.

48.080.03 **Maximum Depths**

1. The maximum depth of water in a dry detention basin or pond shall not exceed eight (8) feet. Projects which need a deeper basin to attain the required detention volume due to physical constraints may be evaluated on a case-by-case basis. The design and construction of dams greater than eight (8) feet must be sealed and certified by a Professional Engineer registered in the State of Missouri with demonstrated expertise in geotechnical engineering.

48.080.04 **Limits of Maximum Ponding**

1. The limits of maximum ponding elevation shall be calculated based on a routing of the design storm assuming the low flow outlet is blocked with water ponded to the overflow structures sill.
2. The limits of maximum ponding elevation in dry basins or ponds and permanent lakes or ponds shall not be closer than thirty (30) feet horizontally to any building and not less than two (2) feet vertically below the lowest sill elevation of any building.
3. A minimum of two (2) feet of freeboard shall be provided from the top of the basin to the maximum ponding elevation.

48.080.05 **Easement Required**

In subdivisions, the detention basin, access roads or paths, control structures and outfall pipes are to be located in easements dedicated to the subdivision trustees.

48.080.06 **Maintenance Agreement**

The owner(s) of the project shall execute a City Maintenance Agreement for the detention basin; pond or Underground Facilities to ensure the detention area will be kept in working order, prior to plan approval. **The City will not be responsible for maintenance of detention basins or Underground Detention Facilities.**

48.080.07 **Detention Basin Fencing**

A four (4) foot (minimum height) approved fence shall be provided around the perimeter of any basin where the side slopes exceed 3:1 (three (3) feet horizontal, one (1) foot vertical).

48.080.08 **Detention Basin Elevation**

The low elevation of the detention basin shall be above the 15-year, 20-minute hydraulic elevation of the receiving channel or pipe system.

48.090 Dam Permit Requirements

Dams with a height of thirty five (35) feet or greater will require approval from the Missouri Department of Natural Resources.

48.100 Permit Requirements

A copy of all pertinent Federal, State and County permits shall be submitted to the city before final approval. They shall include but not be limited to the following:

(a) 404 permit from Corp. of Engineers-(land disturbance)
(b) 401 permit from MDONR-(land disturbance)
(c) Sewer line extension permit from MDONR
(d) Water line extension permit from MDONR

P FACTOR FOR RUNOFF

% IMPERVIOUS	DURATION OF RAIN IN MINUTES					
	15	20	30	60	90	120
0	0.30	0.35	0.41	0.51	0.58	0.60
5	0.32	0.37	0.43	0.53	0.58	0.62
10	0.34	0.39	0.48	0.58	0.60	0.64
15	0.36	0.41	0.48	0.58	0.82	0.66
20	0.38	0.44	0.50	0.60	0.64	0.67
25	0.40	0.46	0.52	0.62	0.66	0.69
30	0.42	0.48	0.54	0.64	0.68	0.71
35	0.44	0.50	0.57	0.66	0.70	0.73
40	0.46	0.52	0.59	0.68	0.72	0.74
45	0.48	0.54	0.61	0.71	0.74	0.76
50	0.50	0.56	0.63	0.73	0.75	0.78
55	0.52	0.58	0.65	0.75	0.77	0.80
60	0.54	0.60	0.68	0.77	0.79	0.81
65	0.56	0.63	0.70	0.79	0.81	0.83
70	0.58	0.65	0.72	0.81	0.83	0.85
75	0.60	0.67	0.74	0.84	0.85	0.87
80	0.62	0.69	0.76	0.86	0.87	0.88
85	0.64	0.71	0.79	0.88	0.89	0.90
90	0.66	0.73	0.81	0.90	0.91	0.92
95	0.68	0.75	0.83	0.92	0.93	0.94
100	0.70	0.77	0.85	0.94	0.95	0.95

RAINFALL INTENSITY OF 1 INCH PER HOUR ON 1 ACRE = 1.008 CU. FT. PER SECOND ON 1 ACRE
= 1 CU. FT. PER SECOND ON 1 ACRE (APPROXIMATELY)

P x I = Q = RUNOFF IN CU. FT. PER SEC. PER ACRE FOR GIVEN % IMPERVIOUSNESS OF CONTRIBUTING AREA DURING A RAINFALL OF GIVEN INTENSITY CORRESPONDING TO THE GIVEN DURATION AND A SELECTED FREQUENCY.

I = INTENSITY OF RAINFALL IN INCHES PER HOUR FOR GIVEN DURATION AND GIVEN FREQUENCY

RUNOFF / RAINFALL = P = RATIO OF RUNOFF CONTRIBUTED BY AN AREA OF GIVEN % IMPERVIOUSNESS FOR A GIVEN DURATION PERIOD TO THE RAINFALL OF A GIVEN INTENSITY CORRESPONDING TO THE SAME DURATION PERIOD AND A SELECTED FREQUENCY.

TABLE 4-1

P (RUNOFF FACTORS) FOR VARIOUS IMPERVIOUS CONDITIONS

P.I. FACTOR IN CUBIC FEET PER SECOND PER ACRE

DURATION OF RAIN IN MINUTES	% IMPERVIOUS	2-YEAR RAINFALL FREQUENCY						5 - YEAR RAINFALL FREQUENCY					
		15	20	30	60	90	120	15	20	30	60	90	120
	0	1.08	1.09	1.00	0.79	.66	0.58	1.31	1.33	1.25	1.00	0.83	0.72
	5	1.15	1.15	1.05	0.82	0.68	0.60	1.40	1.41	1.31	1.04	0.86	0.74
	10	1.22	1.21	1.11	0.86	0.70	0.61	1.48	1.48	1.38	1.09	0.89	0.76
	15	1.30	1.27	1.16	0.89	0.73	0.63	1.57	1.56	1.44	1.13	0.92	0.79
	20	1.37	1.35	1.22	0.92	0.74	0.64	1.66	1.65	1.52	1.17	0.94	0.80
	25	1447	1.41	1.27	0.96	0.77	0.66	1.74	1.73	1.58	1.22	0.97	0.83
	30	1.51	1.47	1.32	0.99	0.79	0.68	1.83	1.81	1.64	1.25	1.00	0.85
	35	1.58	1.54	1.38	1.02	0.81	0.70	1.92	1.88	1.72	1.29	1.03	0.87
	40	1.66	1.61	1.43	1.05	0.84	0.71	2.01	1.88	1.78	1.33	1.06	0.89
	45	1.73	1.67	1.49	1.09	0.86	0.73	2.09	2.05	1.85	1.38	1.09	0.91
	50	1.80	1.74	1.54	1.12	0.88	0.74	2.18	2.13	1.92	1.42	1.11	0.93
	55	1.87	1.80	1.59	1.16	0.90	0.76	2.27	2.20	1.98	1.46	1.14	0.95
	60	1.94	1.86	1.65	1.19	0.92	0.78	2.35	2.28	2.05	1.51	1.17	0.97
	65	2.02	1.94	1.70	1.23	0.95	0.80	2.44	2.36	2.11	1.55	1.20	1.00
	70	2.09	2.00	1.76	1.26	0.97	0.81	2.53	2.45	2.19	1.59	1.23	1.01
	75	2.16	2.06	1.81	1.29	0.99	0.83	2.62	2.53	2.25	1.64	1.26	1.04
	80	2.23	2.12	1.85	1.33	1.02	0.85	2.70	2.60	2.31	1.68	1.29	1.06
	85	2.30	2.19	1.92	1.36	1.04	0.86	2.79	2.68	2.39	1.72	1.31	1.08
	90	2.38	2.26	1.96	1.40	1.06	0.88	2.88	2.77	2.45	1.76	1.34	1.10
	95	2.45	2.33	2.03	1.43	1.08	0.90	2.96	2.85	2.52	1.80	1.37	1.12
	100	2.52	2.39	2.07	1.46	1.11	0.91	3.05	2.93	2.58	1.84	1.40	1.14
	RAINFALL	3.60	3.10	2.44	1.55	1.17	0.96	4.36	3.80	3.04	1.96	1.48	1.20

P.I. VALUES FOR VARIOUS IMPERVIOUS CONDITIONS TABLE 4-3
(2 YEAR & 5 YEAR RAINFALL FREQUENCIES)

P.I. FACTOR IN CUBIC FEET PER SECOND PER ACRE

DURATION OF RAIN IN MINUTES	% IMPERVIOUS	15-YEAR RAINFALL FREQUENCY						20 - YEAR RAINFALL FREQUENCY					
		15	20	30	60	90	120	15	20	30	60	90	120
	0	1.59	1.61	1.52	1.22	1.04	0.92	1.65	1.68	1.60	1.29	1.08	0.96
	5	1.70	1.70	1.59	1.27	1.08	0.95	1.76	1.78	1.68	1.34	1.11	0.99
	10	1.80	1.79	1.68	1.33	1.12	0.97	1.87	1.87	1.77	1.40	1.15	1.02
	15	1.91	1.89	1.76	1.38	1.15	1.00	1.98	1.97	1.85	1.45	1.19	1.05
	20	2.01	2.00	1.85	1.43	1.18	1.03	2.09	2.09	1.95	1.50	1.22	1.07
	25	2.12	2.09	1.92	1.49	1.22	1.06	2.20	2.18	2.03	1.56	1.26	1.10
	30	2.23	2.19	2.00	1.54	1.26	1.08	2.31	2.28	2.11	1.61	1.30	1.13
	35	2.33	2.28	2.09	1.58	1.29	1.11	2.42	2.38	2.20	1.66	1.33	1.16
	40	2.44	2.39	2.16	1.63	1.33	1.13	2.53	2.50	2.28	1.71	1.37	1.18
	45	2.54	2.48	2.26	1.69	1.37	1.16	2.64	2.59	2.38	1.78	1.41	1.22
	50	2.65	2.58	2.33	1.74	1.40	1.19	2.75	2.69	2.46	1.83	1.44	1.24
	55	2.76	2.67	2.41	1.79	1.43	1.22	2.86	2.78	2.54	1.88	1.48	1.27
	60	2.86	2.76	2.50	1.85	1.47	1.24	2.97	2.88	2.63	1.94	1.52	1.30
	65	2.97	2.88	2.57	1.90	1.51	1.27	3.08	3.00	2.71	1.99	1.56	1.33
	70	3.07	2.97	2.66	1.94	1.54	1.29	3.19	3.10	2.81	2.04	1.59	1.35
	75	3.18	3.06	2.74	2.00	1.58	1.32	3.30	3.19	2.89	2.10	1.63	1.38
	80	3.29	3.15	2.81	2.05	1.62	1.35	3.41	3.29	2.96	2.15	1.67	1.41
	85	3.39	3.24	2.90	2.10	1.65	1.38	3.52	3.38	3.06	2.21	1.70	1.44
	90	3.50	3.36	2.98	2.16	1.68	1.40	3.63	3.50	3.14	2.27	1.74	1.46
	95	3.60	3.45	3.07	2.21	1.72	1.43	3.74	3.60	3.24	2.32	1.78	1.50
	100	3.71	3.54	3.15	2.26	1.76	1.45	3.85	3.70	3.32	2.37	1.81	1.52
	RAINFALL	5.30	4.60	3.70	2.40	1.86	1.53	5.50	4.80	3.90	2.52	1.92	1.60

P.I. VALUES FOR VARIOUS IMPERVIOUS CONDITIONS TABLE 4-2
(15 YEAR & 20 YEAR RAINFALL FREQUENCIES)

P.I. FACTOR IN CUBIC FEET PER SECOND PER ACRE													
DURATION OF RAIN IN MINUTES	% IMPERVIOUS	10-YEAR RAINFALL FREQUENCY						100 - YEAR RAINFALL FREQUENCY					
		15	20	30	60	90	120	15	20	30	60	90	120
	0	1.48	1.51	1.42	1.15	0.95	0.83	2.10	2.17	2.06	1.68	1.40	1.18
	5	1.57	1.59	1.49	1.19	0.99	0.86	2.24	2.29	2.16	1.75	1.45	1.22
	10	1.67	1.68	1.57	1.25	1.02	0.88	2.38	2.42	2.28	1.83	1.50	1.24
	15	1.77	1.76	1.64	1.29	1.05	0.90	2.52	2.54	2.38	1.90	1.55	1.28
	20	1.87	1.87	1.73	1.34	1.08	0.92	2.66	2.70	2.51	1.96	1.59	1.31
	25	1.97	1.96	1.80	1.40	1.11	0.95	2.80	2.82	2.61	2.05	1.64	1.35
	30	2.07	2.04	1.87	1.44	1.15	0.97	2.94	2.95	2.71	2.11	1.69	1.38
	35	2.16	2.13	1.95	1.49	1.18	1.00	3.08	3.07	2.84	2.18	1.74	1.42
	40	2.26	2.24	2.02	1.53	1.22	1.02	3.22	3.22	2.94	2.24	1.79	1.45
	45	2.36	2.32	2.11	1.59	1.25	1.05	3.36	3.35	3.06	2.33	1.84	1.49
	50	2.46	2.41	2.18	1.63	1.28	1.07	3.50	3.479	3.16	2.39	1.88	1.52
	55	2.56	2.49	2.25	1.68	1.31	1.10	3.64	3.60	3.26	2.46	1.93	1.56
	60	2.66	2.58	2.34	1.73	1.34	1.12	3.78	3.72	3.39	2.54	1.98	1.59
	65	2.76	2.69	2.40	1.78	1.38	1.15	3.92	3.88	3.49	2.61	2.03	1.63
	70	2.85	2.77	2.49	1.82	1.41	1.17	4.06	4.00	3.61	2.67	2.07	1.66
	75	2.95	2.86	2.56	1.88	1.44	1.19	4.20	4.12	3.71	2.76	2.13	1.70
	80	3.05	2.95	2.63	1.92	1.48	1.21	4.34	4.25	3.82	2.82	2.18	1.72
	85	3.15	3.03	2.72	1.97	1.50	1.24	4.48	4.37	3.94	2.89	2.21	1.76
	90	3.25	3.14	2.79	2.03	1.54	1.26	4.62	4.53	4.04	2.97	2.26	1.79
	95	3.35	3.23	2.87	2.07	1.57	1.29	4.76	4.65	4.17	3.04	2.31	1.83
	100	3.44	3.31	2.94	2.11	1.61	1.31	4.90	4.77	4.27	3.10	2.36	1.86
	RAINFALL	4.92	4.30	3.46	2.25	1.70	1.38	7.00	6.20	5.02	3.30	2.50	1.96

P.I. VALUES FOR VARIOUS IMPERVIOUS CONDITIONS TABLE 4-4
(10 YEAR & 100 YEAR RAINFALL FREQUENCIES)

Adopted by Ord. #366, 11/20/06. Amended by: Ordinance #420, 10/9/07. Amended by: Ordinance #556, 6/14/10; Ordinance #574, 12/20/10. Ordinance #585, 4/18/11.