CITY OF WARRENSBURG
STORMWATER DESIGN MANUAL
AUGUST 2016

INDEX

SECTION 101.1: GENERAL PROVISIONS

A. Scope. These design criteria set forth the minimum standards for design of storm drainage facilities on public right-of-way and private property within the city limits of Warrensburg (City), Missouri.

B. Authority. These design criteria and standards set forth herein have been adopted by the City, in accordance with the procedures and authority set forth in the City ordinance.
Any development or grading begun after the date of passage of these criteria and standards which does not comply with the requirements set forth herein shall be deemed to be in violation of the requirements established herein; and shall be subject to enforcement measures and penalties set forth in the City Code and these regulations.

C. Interpretations. Where any of the provisions contained herein may be unclear or ambiguous as they pertain to a particular site or situation, requests for interpretations of the policies, criteria, and standards set forth herein shall be made in writing to the City.
Such written interpretations shall be kept on file for future reference for use in similar situations, and shall be incorporated in subsequent revisions for the standards, if deemed necessary for general reference.

D. Approvals and Permits Required.

1. Procedure
   a. With application for a Land Disturbance Permit, the City shall require the developer to post a performance bond, irrevocable letter of credit, escrow agreement, lender's agreement, cash bond, cash or certified check of not less than the value of all work to be done under the Permit. An itemized construction cost estimate of each portion of the work shall be submitted with the security.
   b. After approval of all drawings, specifications and security, the City shall issue a permit to the developer for the specified work.
   c. Construction of detention/sedimentation basins shall be completed prior to any work on the site, including clearing & grubbing.
   d. Upon completion of the specified construction, a final inspection will be conducted by the City. A "punch-list" of unsatisfactory items will be provided to the developer. Upon satisfactorily completion of "punch-list" items and after As-Built Drawings or other approved design plan are provided to the City, the City will issue a letter of approval to the developer along with a release of the security.

2. Land Disturbance Permit. Storm drainage facilities may not be constructed or altered without review and approval of the plans by the City and issuance of a Land Disturbance Permit by the City for subdivisions or for commercial or other sites.

3. National Pollutant Discharge Elimination System (NPDES) Stormwater Permit.
   a. Provisions of the 1987 Clean Water Act require that certain stormwater discharges obtain an NPDES stormwater permit. In Missouri, these permits are administered by the Missouri Department of Natural Resources.
   b. Federal rules for NPDES stormwater discharges are contained in 40 CFR Parts 122, 123, and 124 of the Code of Federal Regulations.

State NPDES stormwater regulations are contained in 10 CSR 20-6.200 of the Code of State Regulations.

c. Per the State and Federal regulations cited above, a Storm Water Pollution Prevention Plan (SWPPP) must be prepared for all developments disturbing one (1) acre or more. A copy of this plan shall be submitted to the City with the application for a Soil Erosion & Sediment Control Permit. The EPA resource "Developing Your Stormwater Pollution Prevention Plan" should be used as a guide in preparing the SWPPP.

d. Additional provisions for NPDES stormwater permits for land disturbance activities and information regarding a City Soil Erosion & Sediment Control Permit for land disturbance activities are contained in Chapter 20, Article IV, Division 3 of the City's Ordinances.

4. "404" Permit.

For certain activities which involve the discharge of dredged or fill materials into the waters of the United States, a Department of the Army permit may be required as set forth in Section 404 of the Clean Water Act. Rules for 404 permits are contained in 33 CFR Parts 320 through 330 of the Code of Federal Regulations.

Determination of applicability for Section 404 requirements are generally made by the District Office of the Corps of Engineers.

A brochure regarding the Corps of Engineers regulatory program may be obtained from the Corps offices.

E. Coordination With Other Jurisdictions. Where proposed storm drainage facilities are located on property adjoining to other local government jurisdictions design of storm drainage facilities shall include provisions to receive or discharge storm water in accordance with the requirements of the adjoining jurisdiction, in addition to meeting City requirements. In these cases, 2 additional sets of plans shall be submitted and will be forwarded to the adjoining jurisdiction for review and comment.

No grading or construction of storm drainage facilities may commence without prior notification of the Missouri One Call utility warning system at 1-800-DIG-RITE, as required by law.

F. Communications and Correspondence. Communications and correspondence regarding storm water plan review, policies, design standards, criteria, or drainage complaints shall be directed to the City.

G. Ownership and Maintenance.

1. Improvements on public road right-of-way. Storm drainage improvements on public right-of-way or public easements shall become the property of; and shall be maintained by the City upon acceptance of the constructed improvements.

As-built drawings of storm drainage improvements shall be provided after Final Inspection but before Final Approval from the City.

2. Improvements on private property. Storm drainage improvements on private property shall be maintained by the owner of the lot upon which the improvements are located, or by the publically registered Homeowners' Association for improvements located in common areas.

All such improvements which serve a drainage area shall be located in a drainage easement dedicated to the responsible party, in a form approved by the City, and the responsible party shall have such rights of access to repair or maintain such facilities.

SECTION 101.2: STORMWATER PLANNING & DESIGN

A. Stormwater Management Goals. In order to ensure protection of the general health and welfare of the citizens of the City, planning and design of stormwater management measures shall meet the following goals:

1. Prevent damage to residential dwellings, and other building structures from floodwaters.

2. Maintain emergency vehicle access to all areas during periods of high water.

3. Prevent damage to roads, bridges, utilities, and other valuable components of the community's infrastructure from damage due to flood waters and erosion.

4. Prevent degradation of surface and groundwater quality from storm water runoff; preserve and protect quality of the environment; and promote conservation of the City's natural resources.

5. Minimize flood water and erosion damage to lawns, recreational facilities, and other outdoor improvements.

6. Minimize traffic hazards from runoff carried in streets and roads.

7. Comply with applicable State and Federal laws and regulations.

8. Meet the foregoing goals in a manner which is cost effective and which minimizes the cost of housing and development while encouraging sound development practices.

9. Encourage innovative and cost effective planning and design of stormwater management facilities.

10. Encourage multiple purpose design of stormwater management facilities, to provide opportunities for recreational use, and other benefits to the community wherever possible.

    The standards and criteria set forth herein provide the minimum standards for planning and design of stormwater facilities. Where a particular plan or design may be found to be in conflict with a specific standard, achievement of the goals set forth above will have precedence.

B. General Planning and Design Principles. The City recognizes that stormwater management is an important component of overall land use planning.
The City further recognizes that proper stormwater planning significantly reduces the long term costs to the community both in terms of infrastructure cost and property losses due to flood damage. It is much more cost effective to prevent flood damage by proper design and construction, than to repair and remediate problems, which have occurred through poor planning and design.

The following general principles must be followed in preparing the grading and storm drainage plans for all development sites:

1. Recognize the existing drainage system. The storm drainage system differs from other utility systems in very important ways:

a. There is an existing natural drainage system.
b. It is only needed when runoff occurs.
c. The system does not have to be constructed of man-made components in order to function.

Because of these characteristics there has been a historic inclination for fragmented planning and design of storm drainage facilities.

Proper planning of storm drainage facilities must begin with the recognition of the existing system, and include necessary provisions for preserving or altering the existing system to meet the needs of proposed development or construction.

Methods of delineating existing watercourses are outlined in Section 101.3.

2. <u>Provide for acceptance of runoff from upstream drainage areas.</u> It is critical that provisions be made to receive runoff from upstream drainage areas.
   Drainage easements or public right-of-way must extend to the point where existing watercourses enter the site. The drainage easement shall extend to the point of lowest elevation.

3. <u>Provide a means to convey runoff across the site.</u> Stormwater shall be conveyed across the site in a system of overland drainage ways and storm sewers. Overland drainage ways consists of natural waterways, streets, open channels, swales, and overland flow within drainage easements.

4. <u>Discharge of runoff to downstream properties.</u> Concentrated runoff shall be discharged only into existing watercourses, drainage easements, or public road rights-of-way. Where none of these exist, a drainage easement which extends to the nearest watercourse, drainage easement or public road right-of-way must be obtained from the downstream property owner, and proper provisions made for conveyance of the peak flow from the one percent (1%) Annual Probability (100-year) storm within the drainage easement. One of the typical results of urbanization is that surface flow or "sheet flow" is replaced with concentrated points of discharge. Where concentrated flows are discharged to downstream properties proper provisions must be made to:
   a. allow the flow to spread over the same area as would have occurred for the same rate of flow prior to the development, and
   b. reduce the rate of velocity to rates at least equal to the pre-development values at the same rate of flow.

5. <u>Assess potential downstream flooding problems.</u> It is important that a determination be made of conditions in the watershed downstream of each development site. Specifically it is important to determine whether there are existing structures, which are subject to an unacceptable flooding hazard.
   If areas having an unacceptable flooding hazard occur downstream of a development site, either on-site detention for peak flow control, or mutually agreed off-site improvements will be required, as set forth in Section 101.4.

6. <u>Assess potential water quality impacts on receiving waters.</u> Sediment, erosion and other water quality controls are required as set forth in Section 101.6.

SECTION 101.3: STORMWATER RUNOFF CALCULATIONS

This section outlines acceptable methods of determining stormwater runoff.

A. General Guidelines. For watersheds with a total tributary area less than 200 acres and a one percent annual probability (100-year) fully developed discharge less than 300 cfs, the design storm runoff may be analyzed using the rational formula.

   For watersheds with a total tributary area greater than 200 acres or with a one percent annual probability (100-year) fully developed discharge greater than 300 cfs, the design storm runoff shall be analyzed using an approved hydrograph method.

B. Rational Formula. The rational formula, when properly understood and applied, can produce satisfactory results for urban storm sewer design. The rational formula is as follows:

$$Q = CIA$$

   Where,

   Q = Peak discharge in cubic feet per second.

   C = Dimensionless runoff coefficient; recommended runoff coefficient values are given in Table I. The value used shall be the composite value based upon the type of surface coverage in the drainage area for the runoff condition being considered.

   I = Average rainfall intensity in inches per hour for a duration equal to or greater than the time of concentration for the contributing drainage area.

   A = Contributing watershed area in acres.

   The basic assumptions made when applying the rational formula are:

   1. The rainfall intensity is uniform over the basin during the entire storm duration.
   2. The maximum runoff rate occurs when the rainfall lasts as long or longer than the basin time of concentration.
   3. Runoff response characteristics are relatively uniform over the entire basin.
   4. The time of concentration is the time required for the runoff from the most hydraulically remote part of the basin to reach the point of interest.

   The drainage basin should be divided into sub-basins of a size where all of the basic assumptions apply.

TABLE I – RATIONAL RUNOFF COEFFICIENTS

Surface Type	*Runoff Coefficient*
Asphalt, concrete pavement	0.95
Roofs	0.95
Gravel	0.75
Lawns, pasture, hayfields	
Flat (<2% slopes)	0.15
Average (2-7% slopes)	0.20
Steep (>7% slopes)	0.30
Woods	0.10

C. Time of Concentration.

The time of concentration is defined as the travel time from the hydraulically most distant point in the contributing drainage area to the point under study, or, the rainfall intensity averaging time. Time of concentration may be computed by either of the following two methods:

1. Kirpich Method

   $t_c = 0.0078(L^{0.77}/S^{0.385})$

   Where,

   t_c = time of concentration in minutes

   L = maximum hydraulic length of travel in feet

   S = slope of flow path from the remote part of the basin to the calculation point divided by the horizontal distance between the two points (ft/ft).

2. Natural Resources Conservation Service Method (formally SCS)

   The method given in Chapter 3 of NRCS TR-55 may be used to compute times of concentration. In using this method it must be remembered that overland flow elements are limited to 300 feet in rural areas, and generally to 100 feet in urban areas. The designer must consider whether calculated runoff rate from directly connected impervious areas having a shorter time of concentration will exceed the runoff rate for the entire drainage area when pervious areas are included.

D. Hydrograph Methods.

1. Methodologies. The Corps of Engineers HEC-HMS and/or HEC-1 computer models are the preferred runoff models. Other models may be used with approval from the City.

   The runoff model must include the entire drainage basin upstream of the proposed development. The model shall be prepared in sufficient detail to ensure that peak runoff rates are reasonably accurate.

   The runoff model shall be developed for the following cases:

   Case 1: Existing conditions in the drainage basin prior to development of the applicant's property.

   Case 2: Existing conditions in the drainage basin with developed conditions on the applicant's property.

   Case 3: Fully developed conditions in the entire drainage basin.

2. Rainfall. Rainfall depth-duration-frequency and intensity-duration-frequency charts for the City are included in the following tables. The design rainfall data was developed from the *Rainfall Frequency Atlas of the Midwest, Bulletin* 71 (Reference 23).

Rainfall Depth for Warrensburg, Missouri

Duration	Rainfall Depth, Inches					
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
5-min	0.42	0.53	0.62	0.74	0.83	0.93
10-min	0.73	0.93	1.08	1.29	1.46	1.63
15-min	0.95	1.19	1.39	1.66	1.87	2.09
30-min	1.30	1.63	1.91	2.28	2.56	2.86
1-hr	1.64	2.07	2.43	2.90	3.26	3.64
2-hr	2.03	2.56	2.99	3.57	4.02	4.49
3-hr	2.24	2.82	3.30	3.94	4.44	4.95
6-hr	2.62	3.31	3.87	4.62	5.20	5.80
12-hr	3.05	3.84	4.49	5.36	6.03	6.73
18-hr	3.29	4.15	4.85	5.79	6.51	7.28
24-hr	3.50	4.41	5.16	6.16	6.93	7.74
48-hr	3.90	4.92	5.71	6.78	7.66	8.57
72-hr	4.25	5.33	6.20	7.39	8.32	9.30
120-hr	4.92	6.12	7.06	8.33	9.31	10.36
240-hr	6.10	7.59	8.62	9.88	10.87	11.72

Duration	**Rainfall Depth, Inches**					
(Hours)	**2-Year**	**5-Year**	**10-year**	**25-Year**	**50-Year**	**100-Year**
1	1.60	1.90	2.15	2.55	2.85	3.25
2	2.15	2.55	2.80	3.25	3.30	4.00
3	2.30	2.70	3.00	3.50	3.90	4.40
6	2.65	3.35	3.75	4.30	4.40	5.20
12	3.10	3.85	4.15	4.75	5.25	5.50
24	3.60	4.15	5.00	5.50	6.10	6.50
48	3.90	4.75	5.75	6.30	7.30	7.50
72	4.30	5.50	6.00	6.90	7.50	8.75
120	4.75	5.75	6.75	7.50	8.50	9.75
240	6.15	7.50	8.25	9.50	10.25	11.25

Rainfall Intensity, Warrensburg, Missouri

Duration	Rainfall Intensity (inches per hour)					
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
5-min	5.04	6.36	7.44	8.88	9.96	11.16
10-min	4.38	5.58	6.48	7.74	8.76	9.78
15-min	3.80	4.76	5.56	6.64	7.48	8.36
30-min	2.60	3.26	3.82	4.56	5.12	5.72
1-hr	1.64	2.07	2.43	2.90	3.26	3.64
2-hr	1.02	1.28	1.50	1.79	2.01	2.25
3-hr	0.75	0.94	1.10	1.31	1.48	1.65
6-hr	0.44	0.55	0.65	0.77	0.87	0.97
12-hr	0.25	0.32	0.37	0.45	0.50	0.56
18-hr	0.18	0.23	0.27	0.32	0.36	0.40
24-hr	0.15	0.18	0.22	0.26	0.29	0.32
48-hr	0.08	0.10	0.12	0.14	0.16	0.18
72-hr	0.06	0.07	0.09	0.10	0.12	0.13
120-hr	0.04	0.05	0.06	0.07	0.08	0.09
240-hr	0.03	0.03	0.04	0.04	0.05	0.05

Rainfall shall be distributed in time using Huff's Distribution adapted to local rainfall data (Reference 23) as shown in the following table. Other distributions may be used upon approval from the City.

Huff Distribution for Drainage Areas

Cumulative Storm Time (%)	Cumulative Storm Rainfall (%) for Given Storm Type			
	First Quartile (Duration ≤ 6 hours)	Second Quartile (6 < Duration ≤ 12 hours)	Third Quartile (12 < Duration ≤ 24 hours)	Fourth Quartile (Duration > 24 hours)
0	0	0	0	0
5	16	3	3	2
10	33	8	6	5
15	43	12	9	8
20	52	16	12	10
25	60	22	15	13
30	66	29	19	16
35	71	39	23	19
40	75	51	27	22
45	79	62	32	25
50	82	70	38	28
55	84	76	45	32
60	86	81	57	35
65	88	85	70	39
70	90	88	79	45
75	92	91	85	51
80	94	93	89	59
85	96	95	92	72
90	97	97	95	84
95	98	98	97	92
100	100	100	100	100

3. Storm Duration. A critical duration analysis of storm duration and corresponding rainfall depth shall be conducted to determine the storm duration producing the greatest peak flow from a particular watershed. The critical duration storm shall be used in all subsequent runoff calculations.

SECTION 101.4: STORMWATER DRAINAGE STRUCTURES

The following design criteria is required when these components are used:

A. Inlets.

1. Inlet locations. Inlets shall be provided at locations and intervals, and shall have a minimum inflow capacity such that maximum flooding depths set below are not exceeded for the specified storm; at all sump locations where ponding of water is not desired, and where drainage cannot be released at the ground surface.

2. Inlet interception capacities. Inlet capacities shall be determined in accordance with the Federal Highway Administration HEC-12 & HEC-22 Manuals (References 5 and 6).
Nomographs and methods presented in the Neenah Inlet Grate Capacities report (Reference 13) may also be used where applicable.

   The use of commercial software utilizing the methods of HEC-12 & HEC-22 is acceptable. It is recommended that software be pre-approved for use by the City.

3. Clogging factors. The inlet capacities determined as required in this section must be reduced as follows, in order to account for partial blockage of the inlet with debris:

INLET TYPE & LOCATION	CLOGGING FACTOR
Curb Inlets	
on grades	0.9
in sumps.	0.8
Grated Inlets:	
on grades	0.6
in sumps	0.5

   Inlet lengths or areas shall be increased as required to account for clogging.

4. Interception and bypass flow. It is generally not practical for inlets on slopes to intercept 100% of the flow in gutters. Inlets must intercept sufficient flow to comply with street flooding depth requirements. Bypass flows shall be considered at each downstream inlet, until all flow has entered approved storm sewers or drainage ways.

5. Allowable street depth. Urban streets are a necessary part of the City's drainage system. The design for the collection and conveyance of storm water runoff is based on a reasonable frequency and degree of traffic interference. Depending on the street classification, (ie: local, collector, etc.) portions of the street may be inundated during storm events. Drainage of streets are controlled by both minor (2-year) and major (25-year) storm events. The minor system is provided to intercept and convey nuisance flow. Flow depths are limited for the major storm to provide for access by emergency vehicles during most flood events. When the depths of flow exceed the criteria presented in this section a storm sewer or open channel system is required.

   a. General Design Guidelines
   Allowable Flow Depths: Flow in the street is permitted with maximum allowable depths as follows:

On Grades

1) Local streets: crown of the street for the runoff from a 2 year rainfall, top of curb for runoff from a 25 year rainfall. Runoff from a 100-year rainfall should be contained within the right-of-way.
2) Collector streets: the equivalent of one ten foot driving lane must remain clear of water during a 2 year rainfall, top of curb for runoff from a 25 year rainfall. Runoff from a 100-year rainfall should be contained within the right-of-way.
3) Arterials and Parkways: two ten foot lanes must remain clear of water, one in each direction, during a 2 year rainfall. Top of curb for runoff from a 25-year rainfall. Runoff from a 100-year rainfall should be contained within the right-of-way.

In Sumps

1) Local streets: top of curb from a 2-year rainfall. Runoff from a 25-year rainfall should be contained within the right-of-way. Maximum depth from a 100-year rainfall is 18” at the face of curb.
2) Collector streets: top of curb from a 2-year rainfall. Runoff from a 25-year rainfall should be contained within the right-of-way. Maximum depth from a 100-year rainfall is 18” at the face of curb.
3) Arterials and Parkways: Width of gutter from a 2-year rainfall. Runoff from a 25-year rainfall should be contained within the right-of-way. Maximum depth from a 100-year rainfall is 18” at the face of curb.

Where allowable depths are exceeded, a storm sewer system must remove the excess water.

b. Cross Flow. Cross flow at intersections is permitted up to the following depth.

STREET CLASSIFICATION	2-YEAR STORM ALLOWABLE DEPTH	25-YEAR STORM ALLOWABLE DEPTH
LOCAL	6" in cross pan flow line	12" at gutter
COLLECTOR	No cross flow permitted	6" at gutter
ARTERIAL OR PARKWAY	No cross flow permitted	No cross flow permitted

c. Hydraulics. The allowable storm capacity of each street section with curb and gutter is calculated using the modified Manning's formula for both the 2-year and 25-year storm event.

$$Q = 0.56(Z/n)S^{1/2}d^{8/3}$$

Where,
- Q = discharge in cubic feet per second
- Z = cross slope of the street in feet per foot
- d = depth of flow at the gutter in feet
- S = longitudinal slope of the street in feet per foot
- n = Manning's roughness coefficient (Table II)

TABLE II - MANNING'S n-VALUES

Closed conduit	*Manning's n*
Concrete pipe	0.013
Corrugated steel pipe	0.024
Corrugated polyethylene (smooth wall)	0.013

Open channels	*Manning's n*
Concrete	0.013 to 0.015
Gabions	0.035
Riprap	$0.0395\ d_{50}^{0.17}$
Grouted riprap	0.027
Gunite, shotcrete	0.016 to 0.019
Earth lined	0.020 to 0.040
Grass lined	0.029 to 0.100
Natural streams	0.025 to 0.100

6. Types of inlets allowed.
   a. *Public streets.*
      1) *Curb opening inlets. S*tandard curb opening inlets shall be used for public streets with curb and gutter.
      2) *Grated inlets.* Combination grated open throat inlets shall be permitted. However, grated inlets alone shall not be permitted.

      Where conditions are such that curb inlets cannot intercept the required rate of flow necessary to control street flooding depth or to provide diversion of flow to detention, sedimentation, or infiltration basins, "trench inlets" with vaned grates may be specified with approval of the City.

      Other types of inlets will not be permitted unless approved by the City.

   b. *Outside of public right-of-way.*
      The type of inlets specified outside of public right-of-way is left to the discretion of the designer provided the following criteria are met:
      1) Maximum flooding depths for the major or minor storm as set forth above are not exceeded.
      2) General safety requirements set forth below are met.
      3) All inlets shall be depressed a minimum of 2" below the surrounding grade to allow proper drainage to the inlet and prevent inadvertent ponding in the area around the inlet.
      4) Inlets in pavements shall be provided with a concrete apron.

7. General safety requirements.
   All inlet openings shall:

a. provide for the safety of the public from being swept into the storm drainage system; the maximum allowable opening shall not exceed 6" in height.

b. be sufficiently small to prevent entry of debris which would clog the storm drainage system;

c. be sized and oriented to provide for safety of pedestrians, bicyclists, etc.

B. <u>Storm Sewers.</u>

1. <u>Design criteria.</u>

a. *Design storm frequency.* The storm sewer system, beginning at the upstream end with inlets, is required when the 2-year peak flow in the street exceeds 5 cfs or when allowable street depths are exceeded. Allowable street depths are specified above.

b. *Construction materials.* Storm sewers may be constructed using reinforced concrete, corrugated metal (aluminum) or plastic pipe. The materials, pipes, or appurtenances shall meet applicable standards.

c. *Vertical alignment.* The storm sewer grade shall be such that a minimum cover is maintained to withstand AASHTO HS-20 loading on the pipe. The minimum cover depends upon the pipe size, type and class, and soil bedding condition, but shall not be less than 1 foot from the top of pipe to the finished grade at any point along the pipe. If the pipe encroaches on the street subgrade, approval is required. Manholes will be required whenever there is a change in size, direction, elevation grade and slope or where there is a junction of two or more sewers. The maximum spacing between manholes for storm sewers (cross sectional area less than 25 square feet) shall be 400 feet. For large storm sewers (cross sectional area greater than 25 square feet), manholes for maintenance access need only be placed a minimum of every 500 feet; access to the laterals can be obtained from within the larger storm sewer.

The minimum clearance between storm sewer and water main (for new construction), either above or below shall be 18 inches or what is required by the Utility Company (whichever is greater). Coordinate with Utility Company. Concrete encasement of the water line will be required for clearances of 18 inches or less when the clearance between existing water mains cannot be obtained.

The minimum clearance between storm sewer and sanitary sewer (for new construction), either above or below, shall be 18 inches or what is required by the Utility Company (whichever is greater). Coordinate with Utility Company. In addition, when an existing sanitary sewer main lies above a storm sewer, or within 18 inches below, the sanitary sewer shall have an impervious encasement or be constructed of structural sewer pipe for a minimum of 10-feet on each side of the storm sewer crossing.

Siphons or inverted siphons are not allowed in the storm sewer system.

d. *Horizontal alignment:* Storm sewer alignment between manholes shall be straight except when approved by the City. Approved curvilinear storm sewers may be constructed by using radius pipe. The radius requirement for pipe bends is dependent upon the manufacturer's specifications.

A minimum horizontal clearance of 10 feet is required between water utilities and the storm sewer.

The permitted locations for storm sewer within a street ROW are: (a) on centerline, (b) between centerline and curb and (c) behind the curb. Storm sewer shall not be placed on the area within the wheel lanes of the pavement unless approved by the City.

e. *Pipe size.* The minimum allowable pipe size for storm sewers is dependent upon a diameter practical from the maintenance standpoint. For storm sewers less than 50 feet in length the minimum allowable diameter is 15 inches. All other pipe shall have a minimum diameter of 18 inches.

f. *Storm sewer capacity and velocity.* Storm sewers should be designed to convey the design storm (25-year) flood peaks without surcharging the storm sewer. The sewer may be surcharged during larger floods and under special conditions when approved by the City. The use of storm sewers in areas without overland relief upon is discouraged. If this situation is unavoidable, 100-year capacity should generally be provided in the storm sewer system.

The capacity and velocity shall be based on the Manning's n-values presented in Table II. The maximum full flow velocity shall be less than 15 fps. Higher velocities may be approved by the City if the design includes adequate provisions for uplift forces, dynamic impact forces, and abrasion. The minimum velocity in a pipe based on full flow shall be 2.5 fps; and the minimum slope shall be 0.50% to avoid excessive accumulations of sediment. The energy grade line (EGL) for the design flow shall be no more than six inches below the final grade at manholes, inlets, or other junctions. To insure that this objective is achieved, the hydraulic grade line (HGL) and the energy grade line (EGL) shall be calculated by accounting for pipe friction losses and pipe form losses. Total hydraulic losses will include friction, expansion, contraction, bend, manhole, and junction losses. The methods for estimating these losses are presented in the following sections.

g. *Storm sewer outlets.* All storm sewer outlets into open channels shall be constructed with a headwall and wingwalls or a flared-end-section in accordance with City of Warrensburg Standard Details and Specifications. Geo Fabric and Riprap or other approved material shall be provided at all outlets.

h. *Pipe friction losses.* Pipe friction losses are estimated using the following equations:

$$H_f = S_f \times L$$

Where,

H_f = head loss due to friction (feet)
S_f = friction slope from Manning's equation (ft/ft)
L = length of pipe segment (feet)

and

$$V = (1.49/n)R^{2/3} \times S_f^{1/2}$$

Where,

V = velocity of flow (feet per second)
R = hydraulic radius = A/WP (feet)
S_f = friction slope (ft/ft)
A = area of flow (square feet)
WP = wetted perimeter (feet)
n = Manning's roughness coefficient (Table II)

i. *Pipe form losses.* Generally, between the inlet and outlet, the flow encounters, in the flow passageway, a variety of configuration such as changes in pipe size, branches, bends, junctions, expansions, and contractions. These shape variations impose losses in addition to those resulting from pipe friction. Form losses are the result of fully developed turbulence and can be expressed as follows:

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

Where,

HL = head loss (feet)
K = loss coefficient
$V^2/2g$ = velocity head (feet)
g = gravitational acceleration (32.2 ft/sec^2)

The following is a discussion of a few of the common types of form losses encountered in storm sewer design.

j. *Expansion losses.* Expansion losses in a storm sewer will occur when the storm sewer outlets into a channel. The expansion will result in a shearing action between the incoming high velocity jet and the surrounding outlet boundary. As a result, much of the kinetic energy is dissipated by eddy currents and turbulence. The head loss can be expressed as:

$$HL = K_x (V_1^2/2g)(1-(A_1/A_2))^2,$$

Where,

A = cross section area (square feet)
V_1 = average upstream pipe flow velocity (feet per second)
K_x = expansion loss coefficient.

Subscripts 1 and 2 denote the upstream and downstream sections respectively. The value of K_x is about 1.0 for a sudden expansion (such as an outlet to a channel) and about 0.2 for a well-designed expansion transition. Table III presents the expansion loss coefficient for various flow conditions.

k. *Contraction losses.* The form loss due to contraction is:

$$HL = K_c(V_2^2/2g)(1-(A_2/A_1)^2)^2$$

Where,

K_c = Contraction loss coefficient

K_c is equal to 0.5 for a sudden contraction and about 0.1 for a well-designed transition. Subscripts 1 and 2 denote the upstream and downstream sections respectively. Table III presents the contraction loss coefficient for various flow conditions.

l. *Bend losses.* The head losses for bends in excess of that caused by an equivalent length of straight pipe may be expressed by the relation:

$$HL = K_b(V_2/2g)$$

Where,

K_b = Bend coefficient

The bend coefficient has been found to be a function of: (a) the ratio of the radius of curvature of the bend to the width of the conduit, (b) deflection angle of the conduit, (c) geometry of the cross section of flow, and (d) the Reynolds Number and relative roughness. Recommended bend loss coefficients for standard bends, radius pipe, and bends through manholes are presented in Table III.

m. *Junction and manhole losses.* A junction occurs where one or more branch sewers enter a main sewer, usually at manholes. The hydraulic design of a junction is in effect the design of two or more transitions, one for each flow path. Allowances should be made for head loss due to the impact at junctions. The head loss at a junction for each pipe entering the junction can be calculated from:

$$HL = (V_2^2/2g) = K_j(V_1^2/2g)$$

Where,

V_2 = the outfall flow velocity (feet per second)
V_1 = the inlet velocity (feet per second)
K_j = junction loss coefficient

Because of the difficulty in evaluating hydraulic losses at junctions (Reference 7) due to the many complex conditions involving pipe size, geometry of the junction and flow combinations, a simplified table of loss coefficients has been prepared. Table III presents the recommended energy loss coefficients for typical manhole or junction conditions encountered in the urban storm sewer system.

n. *Storm sewer outlets.* When the storm sewer system discharges into an open channel, additional losses, in the form of expansions losses, occur at the outlet. For a headwall and no wing walls, the loss coefficient K_e is 1.0. For a headwall with 45-degree wing walls, the loss coefficient is approximately 1.14. For a flared-end-section (which has a D2/D1 ratio of 2 and a theta angle of 30 degrees) the loss coefficient is approximately 0.5.

o. *Connection pipes.* Connector pipes are used to convey runoff from an inlet to the storm sewer. If, however, the storm sewer runs through the inlet, then a connector pipe is not needed. Connector pipes can connect a single inlet to the storm sewer or they can be connected in a series.
These bends, turns, and flows through the connector pipe give rise to three hydraulic losses: a change from static to kinetic energy to get the water moving through the connector pipe, an

entrance loss from the inlet to the connector pipe, and a friction loss along the length of the connector pipe. The total head loss in the connector pipe can be calculated from the following equation:

$$H_{cp} = H_v + K_e \times H_v + S_f \times L$$

Where,

H_{cp} = head loss in the connector pipe (feet)
K_e = Entrance loss coefficient
H_v = velocity head in the pipe, assuming full pipe flow (feet)

Other variables are as previously defined. The value of the entrance loss coefficient is determined from Table III.

If the connector pipes are connected in series, the head loss in each pipe is calculated from equation above and the total head loss is the summation of the individual head losses.

TABLE III - LOSS COEFFICIENTS

A. EXPANSION LOSS COEFFICIENTS

Expansion Angle		*Coefficient, K_x*
	$D_2/D_1=3$	$D_2/D_1=1.5$
10	0.17	0.17
20	0.40	0.40
45	0.86	1.06
60	1.02	1.21
90	1.06	1.14
120	1.04	1.07
180	1.00	1.00

Where, D_2 = downstream diameter
D_1 = upstream diameter

B. CONTRACTION LOSS COEFFICIENTS

Entrance	*Coefficient, K_c*
Bell-mouthed	0.04
Square-edged	0.50
Groove-edged	0.20

TABLE III - LOSS COEFFICIENTS (Continued)

D_2/D_1	*Coefficient, K_c*
<0.4	0.5
0.4	0.4
0.6	0.3
0.8	0.1

C. BEND LOSS COEFFICIENTS, PIPE BENDS

Deflection Angle	*Coefficient, K_b*
90	0.50
60	0.43
45	0.35
22.5	0.20

D. BENDS AT MANHOLES (no special shaping)

Deflection Angle	*Coefficient, K_b*
90	1.30
60	0.68
45	0.44
22.5	0.14

E. BENDS AT MANHOLES (curved or deflector)

Deflection Angle	*Coefficient, K_b*
90	1.04
60	0.48
45	0.32
22.5	0.10

p. *Partially full pipe flow.* When a storm sewer is not flowing full, the sewer acts like an open channel and the hydraulic properties can be calculated using open channel hydraulics.

2. Easements.
Easements shall be provided for all storm sewers constructed within the City that are not located within public rights of way. The minimum easement widths are as follows:

a. For pipes 48 inches or less in diameter or width, the minimum easement width is 15 feet.

b. For pipes and boxes greater than 48 inches in diameter or width, the minimum easement width is 15 feet plus additional width may be required.

c. Storm sewers greater than 8 feet in depth to the flow line may require additional easement width.

All easements required for construction, which are not included on the final plat are required to be accepted by the City and recorded at the Johnson County Recorder's Office by the City.

C. Design Standards For Culverts.

1. Structural design. All culverts shall be designed to withstand an HS-20 loading in accordance with the design procedures of AASHTO "Standard Specifications for Highway Bridges". The designer shall also check the construction loads and utilize the most severe loading condition. The minimum allowable cover is one foot.

2. Design capacity. Culverts shall be designed to meet the guidelines based on street classification. Below is a table containing the design parameters relating street classification and the design storm each culvert must pass. Where existing constraints do not allow the design to meet the criteria above, the City may accept an alternative design capacity. In some instances, FEMA regulations may require greater than that specified above.

Street Classification	Design Storm
Local Street	10-Year Storm
Collector Street	25-Year Storm
Arterial Street	100-Year Storm

3. Headwater. The maximum headwater for the major storm design flow shall be 1.5 times the culvert diameter for round culverts or 1.5 times the culvert rise dimension for shapes other than round. In some instances, FEMA regulations may restrict headwater to less than that specified above.

4. Inlet and outlet protection. For road and driveway culverts larger than 15 inches, culverts are to be designed with protection at the inlet and outlet areas as provided in Section 101.6 of this manual. Headwalls or end sections are to be located a sufficient distance from the edge of the shoulder or the back of walk to allow for a maximum slope of 3H:1V to the back of the structure. The type of outlet protection required is as follows:
   a. Velocities less than 7 feet per second: Appropriately sized riprap protection is required. City approval of Rip Rap sized is required.
   b. Velocities greater than 7 feet per second and less than 15 feet per second: Appropriately sized riprap protection or an approved energy dissipater is required. City approval of Rip Rap size is required.
   c. Velocities greater than 15 feet per second are not allowed.

5. Velocity limitations. The maximum allowable discharge velocity is 15 feet per second. Velocities in excess of 15 feet per second will be considered by the City on a case by case basis and will require an energy dissipater.

6. Culvert hydraulics. It is recommended that the procedures outlined in the publication "Hydraulic Design of Highway Culverts" (Reference 4) be used for the hydraulic design of culverts. Backwater calculations demonstrating the backwater effects of the culvert may be required.

D. Design Standards For Bridges.

1. Structural design. All bridges shall be designed to withstand an HS-20 loading in accordance with the design procedures of AASHTO "Standard Specifications for Highway Bridges" (Reference 14). The designer shall also check the construction loads and utilize the most severe loading condition.

2. Design capacity. Bridges shall be designed to meet the guidelines based on street classification. Below is a table containing the design parameters relating street classification and the design storm each bridge must pass. Where existing constraints do not allow the design to meet the criteria above, the City may accept an alternative design capacity. Bridge capacity shall be designed such that all FEMA regulations are met.

Street Classification	Design Storm
Local Street	10-Year Storm
Collector Street	25-Year Storm
Arterial Street	100-Year Storm

3. Backwater. Backwater is defined as the rise in the water surface due to the constriction created by the bridge approach road fills. The maximum backwater for the 100-storm design flow shall be one foot. In some instances, FEMA regulations may restrict backwater to less than that specified above.

4. Velocity limitations. Discharge velocities through bridge openings shall be limited to 15 feet per second. Abutment and channel scour protection shall be provided at all bridges.

5. Bridge hydraulics. All bridge hydraulics shall be evaluated using the procedures presented in the publication "Hydraulics of Bridge Waterways" (Reference 15). Backwater calculations demonstrating the effects of the bridge and approach fills compared to the existing flood stages shall be submitted for all bridges.

E. Design Standards For Open Channels.

1. General design guidelines.
   a. *Natural channels.* Natural channels used as part of the drainage system must be evaluated for the effects of increased peak flow, flow duration and volume of runoff due to urbanization. Development in and around natural channels shall meet the requirements outlined in Section 101.4, *Section E. 5. Natural Channel Design Criteria* below.

   b. *Grass lined channels.* Grass lined channels are the most desirable of the artificial channels. The channel storage, lower velocities, and the greenbelt multiple use benefits obtained can create significant advantages over other artificial channels. Unless existing development restricts the availability of right of way, channels lined with grass should be given preference over other artificial types. The minimum slope in a grass-lined channel shall be 1.0% unless a concrete low flow channel is installed.

   c. *Concrete lined channels.*
   Concrete lined channels are sometimes required where right of way restrictions within existing development prohibit grass-lined channels. The lining must be designed to withstand the various forces and actions, which tend to overtop the bank, deteriorate the lining, erode the soil beneath the lining and erode unlined areas. The minimum slope in a concrete lined channel shall be 0.50%.

   d. *Rock lined channels.*
   Rock lined channels are constructed from ordinary riprap or wire enclosed riprap (gabions etc.). The rock lining permits higher design velocity than for grass lined channels. Rock linings

will normally be used only for erosion control at culvert/storm sewer outlets, at sharp channel bends, at channel confluences and at locally steepened channel sections.

e. *Roadside Ditches.*
Ditches constructed alongside and in conjunction with roadways shall be of sufficient capacity to meet the allowable street flow depth limits as specified in these criteria.

f. *Other lining types.*
The use of fabrics and other synthetic materials for channel linings has increased over the past several years. Proposed improvements of this type will be reviewed on an individual basis as for applicability and performance.

2. <u>Hydraulics.</u> An open channel is a conduit in which water flows with a free surface. The calculations for uniform and gradually varied flow are relatively straightforward and are based upon similar assumptions (e.g. parallel streamlines). The basic equations and computational procedures are presented in this section.

a. *Uniform flow.* Open channel flow is said to be uniform if the depth of flow is the same at every section of the channel. For a given channel geometry, roughness, discharge and slope, there is only one possible depth, the normal depth. For a channel of uniform cross section the water surface will be parallel to the channel bottom for uniform flow.

The computation of normal depth for uniform flow shall be based upon Manning's formula as follows:

$$Q = (1.49/n)AR^{2/3}\,S^{1/2}$$

Where,

Q = Discharge (cubic feet per second)
n = Roughness coefficient (Table II)
A = Cross sectional flow area (square feet)
R = Hydraulic radius, A/P (feet)
P = Wetted perimeter (feet)
S = Slope of the energy grade line (EGL) (ft/ft)

For channels with a uniform cross section the EGL slope and the bottom slope are assumed to be the same.

b. *Critical flow.* The design of earth or rock channels in the critical flow regime (Froude numbers from 0.9 to 1.2) is not permitted. The Froude number is defined as follows:

$$F = V/(gD)^{0.5}$$

Where,

F = Froude number
V = Velocity (feet per second)
g = Acceleration of gravity (32.2 ft/sec^2)
D = Hydraulic depth, A/T (feet)

A	=	Cross sectional flow area (square feet)
T	=	Top width of flow area (feet)

The Froude number shall be calculated for the design of all open channels.

c. *Gradually varied flow.* The most common occurrence of gradually varied flow in storm drainage is the backwater created by culverts, storm sewer inlets or channel constrictions. For these conditions the flow depth will be greater than normal depth in the channel and the water surface profile must be computed using backwater techniques.

Backwater computations can be made using the methods presented in Chow (Reference 8). Many computer programs are available for computation of backwater curves. The most widely used program is HEC-RAS, developed by the U.S. Army Corps of Engineers (Reference 2) and is the program recommended for backwater profile computations.

3. Design standards.

a. *Flow velocity.* Maximum flow velocities shall not exceed the following:

Channel Type	Max. Velocity
Grass lined*	5 feet per second
Concrete	15 feet per second
Rock Lined	10 feet per second

*Refer to item f. below

b. *Maximum depth.* The maximum allowable channel depth of flow is three feet for the 25-year flow.

c. *Freeboard requirements.* Freeboard is defined as the vertical distance between the computed water surface elevation for the design flow and the minimum top of bank elevation for a given cross section.

For all channels one-foot minimum of freeboard is required. Freeboard shall be in addition to super elevation.

d. *Curvature.* The minimum channel centerline radius shall be three times the top width of the design flow.

e. *Super elevation.* Super elevation shall be calculated for all curves. An approximation of the super elevation may be calculated from the following formula:

$$H = V^2T/(gr)$$

Where,

H	=	Super elevation (feet)
V	=	Velocity (feet per second)
T	=	Top width of flow area (feet)
g	=	Acceleration of gravity (32.2 ft/sec^2)

r = radius of curvature (feet)

Freeboard shall be measured above the super elevated water surface.

f. *Grass channels.* Side slopes shall be 3 (horizontal) to 1 (vertical) or flatter. Steeper slopes may be used subject to additional erosion protection and approval from the City.

For design discharges greater than 50 cfs, grade checks shall be provided at a maximum of 200' horizontal spacing.

The variation of Manning's n with the retardance, and the product of mean velocity and hydraulic radius as shown in Figure 7.23 in Reference 17 shall be used in the capacity calculations. Retardance curve C shall be used to determine the channel capacity and retardance curve D shall be used to determine the velocity.

4. Easements. Easements shall be provided for all open channels constructed within the city limits of Warrensburg that are not located within public rights of way. The minimum easement width for open channels is the flow width inundated by a 100-year event plus 15 feet.

All easements required for construction, which are not included on the final plat are required to be accepted by the City and recorded at the Johnson County Recorder's Office by the City.

5. Natural Channel Design Criteria.
This section sets forth requirements for the protection of natural channels as a conveyance for stormwater. Unless otherwise provided for by local, state, or federal ordinance, regulation, or standards, the City's policy is that existing natural streams shall be preserved and protected in accordance with this section. This applies to both newly developing and existing urban areas, including channels that have noncontiguous physical or structural modifications. The City may, at its discretion, waive this requirement for natural stream preservation for intensely urbanized stream reaches that are experiencing significant erosion, locations where existing structures are being compromised by channel degradation, or for other compelling circumstances. Where natural streams are not preserved, the drainage will be handled through systems designed in accordance with Section 101.3, 101.4, and 101.5.

a. Natural Channel Preservation and Buffer Zones:
Natural channels shall be preserved as continuous systems and not segmented on a project-by-project basis because the frequent intermixing of natural and man-made systems tends to degrade the function of both. The following buffer requirements shall apply to natural channels:

1) Natural channels shall be preserved to the maximum extent practicable. If a channel is to be disturbed, the provisions of Section 101.4 E. 5. b. *In Stream Construction – General Requirements* shall be followed. In cases where channel intervention is necessary, the use of natural materials and vegetation should be used to the maximum extent practicable. A channel intervention is any action that alters the shape, strength or roughness of bed, bank or riparian vegetation. Installation of culverts, bridges, outfalls, and below-grade crossings that involve surface cuts constitute interventions. Necessary federal and state permits must be obtained when a channel intervention is planned.

2) Buffer zones shall be maintained along natural channels. The limit of buffer zones shall be within an area maintained by an association and shall be formally designated on a plat, deed, easement, or restrictive covenant, as directed by the City. Buffer widths, as measured from the ordinary high water mark (OHM) outward in each direction, shall meet or exceed the distances specified in the table below. The OHM is defined as the line on the bank established by the fluctuation of water indicated by a physical characteristic such as a clear natural line impressed on the bank, shelving, changes in the character of the soil, absence of terrestrial vegetation, presence of litter or debris, or other appropriate means.

Contributing Drainage Basin Size (Acres)	Buffer Width (ft), from OHM outward, measured seperately in each direction
Less than 40 Acres	20 feet (recommended)
40 to 160 Acres	30 feet
160 to 640 Acres (1 square mile)	50 feet
1 to 4 square miles	75 feet
Greater than 4 square miles	100 feet

3) The City may require additional buffer width for less stable channels or special conditions to address water quality and ecological needs. The widths specified in the table above provide only moderate allowance for widening or migration in channels of average stability. Geotechnical studies may be required if there is a risk of slope failure due to the condition of underlying soil or rock materials. If necessary, the buffer width shall be expanded to contain the potential zone of failure as recommended by a geotechnical engineer. Smaller buffers in isolated locations may be allowed where provision of the full width is impractical and bank stability concerns have been addressed. Additional quality buffer areas may be considered as compensation for smaller buffers through part of the reach.

4) No construction or disturbance of any type, including clearing, grubbing, stripping, fill, excavation, linear grading, paving, or building is allowed in the buffer encouraged, particularly in the 25 feet closest to the top of bank. Exceptions to this policy will be allowed for trails, green space, recreation, and education purposes, provided that removing vegetation does not pose a threat to the stability or proper function of the waterway.

5) Unless otherwise accepted by the City, any maintenance of riparian buffers shall be the responsibility of the property owner. Healthy vegetation in the buffer zone and the capacity to convey floodwater without excessive backwater effects shall be maintained. Maintenance may include removal of vines and exotic or diseased vegetation. Trees may not be “topped” but may be trimmed to prevent damage to overhead utilities. If the property owner fails to maintain the buffer, the City may, at its discretion, hold the property owner financially responsible for maintenance conducted by the City.

6) For work on existing facilities already located closer to the channel than allowed, the new construction shall not encroach closer to the channel. Unstable banks shall be stabilized. Formal designation of the full buffer zone may not be required; however, the part of the buffer zone not encroached upon shall be formally designated.

7) The City may approve deviations of the buffer requirement, provided that they are consistent with the public interest, and where, due to special conditions, a literal enforcement of the provisions would result in unnecessary hardship. Criteria for variance from the buffer requirement are:
   a) Granting of the deviation does not adversely affect the rights of adjacent land owners;
   b) Granting of the deviation will not create a public nuisance, induce a public expense, cause fraud or victimization of the public, or conflict with existing local, federal, or state laws;
   c) The spirit of the requirement is observed; and
   d) Granting the requested deviation will not adversely affect public safety, convenience, order, or general welfare.

8) Edge-of-buffer outfalls, located in the outer half of the riparian buffer, shall be designed to disperse the discharge to promote overland flow, infiltration, and associated water quality benefits. Overland flow shall be directed to run in the outer portion of the buffer parallel to the channel direction. This will increase the length of flow and prevent short-circuiting directly into the stream. Low weirs and berms may be graded to direct flow and encourage short-term ponding. The buffer zone utilized for infiltration shall be maintained in dense, erosion-resistant grasses or grasses designed to withstand the shear stresses of a 10-year storm. Edge-of-buffer outfalls shall only be used if each individual outfall can be designed to operate without scour or the formation of gullies.

The City may also require mitigation for any deviation from the buffer requirement. The mitigation may include:
   a) A significant improvement of riparian corridor quality, as determined by density, forest structure, species, and diversity;
   b) Inclusion of Best Management Practices such as bioswales, micro-detention features, and vegetated roofs that mimic the thermal, hydrologic, and ecological benefits of the riparian corridor; and
   c) Restoration of physical and ecological stability of the channel system. Measures for local streambank stabilization such as retaining walls, gabions, and riprap banks do not constitute restoration and shall not be construed as mitigation.

b. <u>In Stream Construction – General Requirements.</u>
   If construction is proposed within the inner stream buffer as defined in the buffer zones requirements above, a stream assessment is required. The information generated by the stream assessment shall be used in designing the bridges, culverts, utility work, stormwater outfalls (other than edge of buffer outfalls) and any other in-buffer infrastructure. Construction in streams or their buffer zones shall conform to the general requirements of this subsection:

1) <u>Stream Assessment.</u>
A stream assessment shall be conducted for all construction within the inner stream buffer zone except for discharge outfalls. The purpose of a stream assessment is to provide basic knowledge about the stream: bed and bank material, vegetation, general erosion trends, debris and sediment, bank full depth, etc. These things have a direct effect on potential designs and understanding their conditions helps provide the framework for engineers to gather stream data needed to develop a general indication of the stream condition and to possibly help guide design.

The stream assessment shall provide an inventory of the existing components and characteristics of the stream, analyze the bank full depth and discharge, review profile and sections of the stream within the proposed work area, analyze bed and bank materials, and calculate critical shear stresses in the stream. The stream assessment shall extend a minimum of one wavelength up and downstream of the area to be impacted by construction (or 10 channel widths in streams with ill-defined meander patterns.) It shall include the components listed below, except as modified by the City to better fit project needs.

Along streams for which no official buffer exists, (i.e. streams in land which was platted prior to the passage of the stream buffer requirements) the language of the buffer requirements will be applied to determine how close to a stream work can be done without requiring an assessment.

2) <u>Hydraulic and Geomorphic Energy Management.</u>
The pre-project and post-project hydraulic and energy grade lines for the 100%, 10%, and 1% storm flows shall be plotted. The region of a stream where in-stream construction causes a change in these grade lines is considered the zone of influence. The engineer shall provide adequate sediment transport and channel protection designs within the zone of influence. The extent of the zone of influence downstream shall be generally limited by energy dissipation and grade control. The upstream limit of the zone may extend a distance beyond the construction as a drawdown or backwater curve. Within the zone of influence, the energy of the flow on the channel will be evaluated for the potential of excessive scour, deposition, initiation of headcuts, or other instability. Use of vegetation to increase bank resistance and minimize increases or abrupt changes in velocities is recommended. Bank or bed stabilization may be required in areas of unavoidable velocity or depth increase.

3) <u>Sediment Transport Continuity.</u>
The minimum post-project applied shear to the bed of the channel in the zone of influence at the 100%, 10%, and 4% ultimate-conditions storm flow shall not be less than 90% of the minimum pre-project applied shear in the zone, so as to maintain the ability of the channel to transport sediment. If such shear stresses cannot be maintained, the engineer will evaluate the potential for future sediment removal or maintenance.

4) <u>Transitions.</u>
In-stream structures shall be designed to gradually blend into the natural channel and provide a smooth transition of both geometry and roughness.

5) Repair of Disturbed Banks.
The side slopes of banks where construction occurs shall be restored with vegetation as quickly as possible.

6) Professional Judgment.
Natural streams are complex, variable, and strongly governed by local geology and climate. These standards are based on general guidelines of good practice on typical streams and may not be optimal or sufficient in all cases. Specific requirements may be increased or waived by the City if conditions warrant and decisions should be guided by prudent engineering judgment.

c. Discharge Outfalls.
Energy management and sediment continuity checks are not required; however, energy dissipation shall be provided to reduce post-development shear stress to pre-development shear stress at the outfall.

d. Culverts, Bridges, and Above Grade Crossings.

1) Crossings should generally be located on a riffle. If the width of the roadway, pathway or above grade crossing is large relative to the length of the riffle, then grade control structures shall be provided at the riffles upstream and downstream to isolate the impact of the crossings. If a crossing cannot be made at a riffle, avoid armoring a pool and place at-grade grade control structures at the riffle immediately upstream and downstream of the crossing. Maintain sediment transport continuity and avoid altering the channel cross-section.

2) Realignment of channels to accommodate crossings and their approach should be avoided and minimized as much as possible. Any areas relocated shall have the banks stabilized and shall be included in the reach isolated by upstream and downstream grade control.

3) For bridges the multi-stage channel shape should be maintained and additional area to convey the design flow shall be above the elevation of the bank-full discharge.

4) For multi-cell pipe and culvert crossings that have a cumulative width larger than the bank-full width, those cells wider than the bank-full width shall have a flowline located at the lowest estimated bank-full depth, or a weir wall or other structure upstream of the culvert opening shall be installed with a height to prevent access to the cell during flows less than bank-full flow. The weir wall shall be designed so that the hydraulic efficiency at the 1% ultimate conditions storm is not reduced. Without these features, the culvert will have a tendency to build up deposits and lose capacity or require frequent maintenance, particularly when crossings are located in sharp bends or streams with high sediment loads.

SECTION 101.5: STORMWATER DETENTION DESIGN

The following design criteria is required when these components are used:

A. Purpose. Detention facilities are used to reduce storm water runoff rates by storing excess runoff. The usual function of a detention facility is to provide sufficient storage such that peak runoff rates are not increased when development occurs.

   Detention facilities may also be utilized to improve the quality of urban stormwater runoff. The design of detention facilities for water quality improvement is covered in Section 101.7.

   Both flood and water quality benefits can be provided in one basin, if properly designed.

B. Policy. Prior to the development of the land, surface conditions provide a higher percentage of permeability and a longer time of concentration. With the construction of buildings, parking lots, etc., permeability and the time of concentration are significantly decreased, resulting in an increase in the rate, volume, and frequency of runoff.

   These changes result in increased flooding risk to downstream structures, since flooding depths will rise as the rate of runoff increases. The increased volume and frequency of runoff can cause erosion damage.

   In order to minimize these effects, stormwater detention requirements have been established as set forth in these guidelines. All new non-agricultural construction is required to provide stormwater detention facilities. Detention requirements may be waived upon written approval of the City in the following cases:

   1. Construction of such a facility would, due to timing of outflows, have an adverse effect on downstream properties by increasing peak rates of runoff, as demonstrated by engineering computations;

   2. The developer enters into a written agreement with the City and affected property owners to provide storm drainage improvements downstream of the development in lieu of constructing on-site detention facilities as set forth below; or

   3. Due to the small size of the development, it can be demonstrated that the detention facility would result in no beneficial effect to downstream properties. Detention basins having a required volume of five thousand (5,000) cubic feet or less are considered as providing only marginal benefits.

C. Definitions.

   a. Pre-project conditions: The topography, surface cover, and other hydrologic conditions in the watershed being considered, as they exist prior to the proposed project.

   b. Post-project conditions: The topography, surface cover, and other hydrologic conditions in the watershed as they will be after construction of the proposed project.

   c. Fully urbanized conditions: The topography, surface cover, and other hydrologic conditions in the watershed as they will be after all areas in the watershed have been developed in accordance with current zoning designations, as provided in the City zoning ordinances, or as can otherwise be reasonably anticipated.

d. High flooding risk: Residences or other structures will be defined as having a high flooding risk when the lowest point on the structure at which surface runoff may gain entry is located at, or below, the estimated flooding level which would result from a storm with an annual exceedance probability (AEP) of 10% (ten percent) or greater under conditions existing in the basin prior to development of the applicant's property (i.e. affected by the "10-year" storm for pre-project conditions).

e. Dry detention basin: A detention basin which holds water only during and shortly after runoff events.

f. Wet detention basin: A basin which contains a permanent impoundment of water. Flood storage volume is provided above the permanent water surface.

g. Retention basin: This term is often utilized for wet basins and basins which retain runoff for an extended period of time.

i. On-line detention basin: A basin which is located on the main stream of a watercourse and which intercepts on-site as well as off-site flows.

j. Off-line detention facility: A basin or basins located outside of the primary watercourse, which usually allows off-site flows to pass through the site without passing through the detention basin. Where needed for peak flow reduction at the point of interest, a portion of the flow in the main watercourse may be intercepted and passed through the detention basin through the use of side-flow weirs or similar diversions.

D. General Design Requirements:

1. Detention facilities should be designed and constructed in a manner to enhance the aesthetic and environmental quality of developments in the City as much as possible, adding to rather than detracting from property values. The City encourages designs which utilize and enhance natural settings, provide good quality open space, and minimize disturbance and destruction of wooded areas, natural channels, and wetlands.

2. Where detention volume can be provided by utilizing natural valleys, existing wooded areas should be allowed to remain. Detention ponds do not have to be graded to geometric shapes or cleared of forested areas in order to comply with City requirements.

3. The use of landscaping and alternative materials to improve the appearance of spillways, outlet structures, erosion control, and energy dissipation structures is encouraged.

4. Detention basins may be designed to be "wet" or "dry". Parking lots may be utilized for detention storage, provided the maximum depth does not exceed eighteen inches (18") and the parking lot detention may not inundate more than 10% of the total parking area. Underground detention storage may also be utilized. The use of rooftop detention is discouraged. Detention basins may be designed to be "on-line" or "off-line".

5. Construction of detention basins in designated floodplains is not prohibited. However, a floodplain development permit must be obtained. Due to timing problems and the large size of required overflow spillways structures, it will generally be impractical for individual developments to provide an on-line detention basin in floodplain areas. Off-line basins may encroach into the floodplain, provided the requirements of Section 101.8 are met.

6. Large regional detention basins are more effective in providing flood control, as well as water quality benefits, than smaller facilities provided on each site. The City currently has no program for regional detention. Where feasible, developers are encouraged to work together to provide common detention areas.

7. Detention basins are the future owner's responsibility and shall be located within a single lot or property.

8. <u>Easements:</u>
   a. All detention basins serving more than one (1) lot or property shall be located within a private drainage easement dedicated for that purpose.

   b. At a minimum, the easement shall include the area of the dam, the area downstream of the dam to a point twenty feet (20') downstream of the end of the outlet structure, including the area provided for erosion control or energy dissipation; and the area covered by the reservoir including freeboard, plus an additional twenty feet (20') around the perimeter.

   c. Detention basins for a development may be located on adjoining property downstream from the development provided that a drainage easement is obtained and adequate means of maintenance access (including ingress/egress easements where necessary) is provided.

   d. The easement shall be granted to the developer or to a property owners' association which is recognized by the state of Missouri. The property owners' association must present evidence that a mechanism is in place to collect fees for continued maintenance.

   e. Where the detention basin does not immediately adjoin the development, a drainage easement covering the area inundated by the peak flow from the 1% AEP (100-year) storm shall be provided to connect the development site with the detention basin.

E. <u>Ownership and Maintenance.</u> The City provides no maintenance of detention facilities located on private property. Maintenance must be provided by the owner of the property upon which the detention basin is located. Owner must be identified on Plat.

   Where detention basins are located in common areas or adjoining off-site areas, the property upon which the basin is located shall remain in the ownership of the property owners' association.

   Where a property owners' association is formed, restrictive covenants which provide for collection of fees for maintenance of the detention facilities shall be filed in the office of the City.

F. <u>Storage Volume Computations.</u>
   1. <u>Analytical Methods.</u> Detention storage volume shall be determined by hydrograph methodologies and reservoir routing techniques. Preferred methods for use in detention basin

design are those included in the Corps of Engineers HEC-1 and HEC-HMS Flood Hydrograph Package. Alternative methods will be required to be reviewed and approved by the City prior to acceptance.

2. Design Storms. Detention basins shall be designed on the basis of multiple storm recurrence frequencies to ensure that they provide flood protection for both frequent storms and large infrequent storms. A minimum of three recurrence frequencies, the 50%, 10%, and 1% AEP storms (the 2-year, 10-year, and 100-year storms) must be considered.

   The duration of the design storm used to compute the difference in runoff volume between pre-project and post-project conditions shall be that which produces the maximum rate of runoff at the point under consideration for post-project conditions. The minimum design storm duration utilized shall be one (1) hour.

3. Runoff Models. The runoff model must include the entire drainage basin upstream of the proposed detention pond. The model shall be prepared in sufficient detail to ensure that peak runoff rates are reasonably accurate.

   a. Runoff models shall be developed for the following cases:

      Case 1: Pre-project conditions.

      Case 2: Post-project conditions.

      Case 3: Fully urbanized conditions in the entire drainage basin.

   b. Cases 1 & 2 are utilized to determine the required detention volume and the type of outlet structure to be provided, and shall be analyzed for the three storm recurrence frequencies required above.

   c. The detention facility shall be designed such that peak outflow rates from the facility for Case 2 are no greater than the rates determined in Case 1 for each of the three storm recurrence frequencies required.

   d. The storage volume provided shall not be less than the difference in total runoff volume between Case 1 and Case 2.

   e. Case 3 is used determine the size of the overflow spillway. Case 3 need only be analyzed for the 1% AEP ("100-year") storm.

4. Spillways and Outlet Structure Hydraulics. Outlet structures shall be composed of culverts, weirs, orifices, and other hydraulic elements for which reliable data is available.

   a. Weir coefficients shall be as given in King's Handbook of Hydraulics (Reference 24). Coefficients for broad-crested weirs interpolated from the values given in King's Handbook are given in the table below.

Discharge Coefficients for Broad-Crested Weirs

Depth (feet)	Coefficient for 6" thick wall	Coefficient for 8" thick wall	Coefficient for 12" thick wall
0.20	2.80	2.77	2.69
0.25	2.83	2.79	2.70
0.30	2.86	2.80	2.71
0.40	2.92	2.84	2.72
0.50	3.00	2.90	2.74
0.60	3.08	2.95	2.75
0.70	3.19	3.03	2.80
0.75	3.25	3.08	2.83
0.80	3.30	3.12	2.85
0.90	3.31	3.16	2.92
1.00	3.32	3.20	2.98
1.25	3.32	3.25	3.11
1.50	3.32	3.29	3.24
1.75	3.32	3.31	3.27
2.00	3.32	3.32	3.30
2.50	3.32	3.32	3.31
>2.50	3.32	3.32	3.32

b. Capacity of broad-crested slot and V-notch weirs shall be determined by the following formula, developed by Joe Wilson, Kerry Scott, and Larry Wolf at the Missouri University of Science & Technology:

$$Q = 0.86H + (3.65w + 5.82z)H^{1.5}$$

Where,

Q = Flow rate in cubic feet per second

H = Upstream head (ponded depth above slot invert plus any velocity head) in feet. $H = 6$ feet maximum.

w = Slot invert width perpendicular to flow in feet. $0.333 < w < 2.0$ feet

z = Slope of slot sides expressed in terms of z horizontal to 1 vertical. $0 < z < 0.6$.

c. Weir coefficients for trapezoidal weirs shall be determined based upon the ratio of headwater depth to crest width (Reference 4).

d. Culvert capacities shall be determined using the methods in Federal Highway Administration HDS-5 (Reference 4).

e. Weir coefficients for trapezoidal weirs where the depth of flow over the weir is small in comparison to the width of the weir crest shall be determined in accordance with Federal Highway Administration HDS-5 (Reference 4).

f. Discharge coefficient for all orifice shapes shall be 0.6 unless supporting data is submitted for other values.

g. Where outlet structure capacities are determined automatically by the software used in performing the detention basin analysis, values included in the software package may be used provided they are generally accepted and properly documented.

5. Submittals. The following information must be submitted with detention basin designs:

a. Information regarding analytical methods and software to be used, including:
1) Name of software to be used.
2) Type and distribution of precipitation input.
3) Method for determining precipitation losses.
4) Type of synthetic hydrograph.
5) Method for routing hydrographs.
6) Method used for reservoir routing.

b. Map(s) showing sub-basin delineation, topography, presumed flow routes, and pertinent points of interest for pre-project, post-project and fully urbanized conditions.

c. Maps showing hydrologic soil types.

d. Routing diagram for each runoff model condition.

e. A summary of sub-basin characteristics used for program input.

f. Stage-area or stage-storage characteristics for the basin in tabular or graphic form.

g. Stage-discharge characteristics for the outlet structure and overflow spillway in tabular or graphic form; hydraulic data for weirs, orifices, and other components of the control structure.

h. A printout of the input data file.

i. A summary printout of program output, including plots of hydrographs. (These are intended to be the printer plots generated by the software.)

G. Construction Requirements.

1. Maximum and Minimum Slopes.
a. Maximum slopes of excavated or embankments slopes shall be 3:1. 4:1 slopes are preferred. Natural slopes exceeding 3:1 may be utilized provided that they remain undisturbed.

b. The minimum allowable slope on the bottom of the basin shall be 1% (one percent) unless a trickle channel is provided. Trickle channels shall have a minimum slope of 0.5% (one half of one percent).

2. Earth Dams.
    a. Dams shall be constructed to the maximum slopes specified above. Dams shall be constructed of properly compacted earth fill and shall be keyed into existing ground to reduce the risk of leakage or failure.

    b. Dams less than ten feet (10') in height shall be keyed in a minimum of two feet (2') below existing grade. Deeper keys may be required for taller dams.

    c. The minimum embankment width at the top of the dam shall be three feet (3'). Greater widths may be required for dams exceeding ten feet (10') in height.

    d. Dams greater than thirty-five feet (35') in height are subject to regulation by the State dam safety program, and shall meet requirements of the dam safety program.

3. Concrete Retaining Walls.
    a. The use of vertical retaining walls for detention basin impoundments is discouraged, due to cost and appearance considerations. However, concrete retaining walls are frequently utilized to minimize the area required for detention basins.

    b. Where concrete retaining walls exceed three feet and six inches (3' 6") in height, a four feet (4') high chain link or solid fence must be provided.

    c. The maximum depth of detention basins using vertical walls shall be four feet (4').

    d. Concrete retaining walls shall be designed to withstand earth and hydrostatic pressures. Walls longer than fifty feet (50') shall be provided with expansion and contraction joints at appropriate intervals.

4. Other Types of Retaining Walls.

    Where retaining walls must be utilized to conserve space, the use of other types of materials is encouraged in order to reduce cost and improve appearance of detention basins. Alternative retaining wall materials include gabions and precast concrete units, such as Keystone blocks, Loffelstein units, Windsor stone, and many other types of precast units.

    In specifying any type of these linings, the manufacturer's installation instructions shall be strictly followed.

5. Freeboard.

    The required freeboard limits set forth below shall apply for the post-project conditions. For basins with a surface area of two (2) acres of less, a minimum freeboard of twelve inches (12") shall be provided above the design stage for the 1% AEP (100-year) storm. For surface areas greater than two (2) acres but less than ten (10) acres, two feet (2') of freeboard shall be provided. Greater depths of freeboard may be required for impoundments having a surface area greater than ten (10) acres.

    The fully urbanized conditions shall be contained within the top of berm elevation of the basin; no additional freeboard will be required for fully urbanized conditions.

6. Spillways and Outlet Structures.
    a. Any type of outlet structure and overflow spillway can be utilized provided the required hydraulic characteristics of the structure can be maintained and provided that no undue maintenance burdens are placed upon the owner of the detention basin.

    b. Outlet structures and spillways shall be provided with an adequate stilling area downstream to reduce velocities to acceptable levels. Outlet structures shall be set back a minimum distance from the downstream property line to allow for the pre-project velocity and spread of flow to be maintained at the downstream property line.

    c. Spillways and outlet structures shall be provided with toewalls extending a minimum depth of eighteen inches (18") below finish grade at the upstream and downstream ends in order prevent undercutting.

    d. Spillway sidewalls shall extend in height to the top of the dam.

SECTION 101.6: GRADING, SEDIMENT & EROSION CONTROL
The following design criteria is required when these components are used:

A. Goals & Objectives.
The goal of the guidelines is to effectively minimize erosion and discharge of sediment by application of relatively simple and cost effective Best Management Practices.

This goal can be attained by meeting the following objectives:

1. Minimize the area disturbed by construction at any given time.
2. Stabilize disturbed areas as soon as possible by re-establishing sod, other forms of landscaping, and completing proposed structures, pavements and storm drainage systems.
3. Provide for containment of sediment until areas are stabilized.
4. Provide permanent erosion controls.
5. prevent runoff onto neighboring properties, sidewalks, curbs, gutters, storm water inlets, streets, right-of-ways and along channel edges.

B. General Design Guidelines.
The following items must be considered in preparing a sediment and erosion control plan:

1. Temporary vs. permanent controls.
The greatest potential for soil erosion occurs during construction. Temporary controls are those that are provided for the purpose of controlling erosion and containing sediment until construction is complete.

Temporary controls include straw or hay bale dikes, silt fences, erosion control blankets etc., which are not needed after the area is stabilized.

Permanent controls consist of riprap, concrete trickle channels, sedimentation/detention basins, etc., which will remain in place through the life of the development.

It is possible for the same facility to serve both a temporary and permanent purpose. The difference between temporary and permanent erosion control should be clearly recognized in preparing a sediment and erosion control plan.

2. Sheet flow vs. concentrated flow.
   In areas where runoff occurs primarily as sheet flow, containment of sediment is relatively simple. In these areas straw or hay bales, silt fences and vegetative filter areas can be very effective.

   Where concentrations of flow occur, containment of sediment becomes more difficult as the rate and volume of flow increase. In these areas more sophisticated controls such as sedimentation basins must be provided.

3. Slope. Control of erosion becomes progressively more difficult as the slope of the ground increases. Areas with steeply sloping topography, and cut and fill slopes must be given special consideration.

4. Soils and geologic setting. Area soils and the geologic setting must be considered in preparing the plan and any special considerations deemed necessary for a particular site provided.

5. Environmentally sensitive areas. Where construction occurs within the vicinity of permanent streams, springs, sinkholes, lakes or wetlands, special attention must be given to preventing discharge of sediment.

6. General conditions.
   Erosion and water runoff controls may be temporarily removed by the permit holder to accommodate short-term activities, such as passage of large vehicles. Erosion control measures shall be returned to the configuration as soon as possible using best management practices and approval by the City.

   Land disturbance activities may be initiated sufficiently close to a property line that might endanger any adjoining property, including a public street, sidewalk, alley or right-of-way. However, the adjoining property shall be supported and protected from damage that may result from land disturbance activities including, but not limited to, settling, cracking, vegetative damage, erosion, soil deposition and excessive construction dust. If, in the opinion of the City, the land disturbance activity creates a hazard to life or property that is not adequately safeguarded, the permit holder must construct walls, fences, guard rails, or other structures to safeguard the adjoining private property or public street, sidewalk, alley, right-of-way or other public property and persons. Such methods of protection shall first be approved by the City.

   Any persons performing utility related work under a permit shall be responsible for the repair or maintenance of all erosion and sediment control measures affected by the utility construction.

   Water removed from an excavation site by pumping shall not be discharged in a manner that causes erosion or flooding of the site, receiving channels, into streets, curbs, gutters, storm inlets, adjacent properties or a wetland.

C. Land Disturbance Permits.

1. Permit requirements. Reference Chapter 20, Division 3 of City Code of Ordinances.

D. Other Permits.

1. NPDES storm water permit. Construction sites where the area to be disturbed is one (1) acre or more must apply for a storm water discharge permit from the Missouri Department of Natural Resources. This requirement includes sites of less than one acre that are part of a larger common plan that will ultimately disturb one acre or more.

   Permit requirements are set forth in Regulation 10 CSR 20-6.200 of the Missouri Clean Water Commission.

   A Storm Water Pollution Prevention Plan (SWPPP) must be prepared in accordance with Missouri Clean Water Laws. A copy of the SWPPP must be submitted with the application for a Soil Erosion & Sediment Control Permit.

2. "404" permit. Grading activities in streams or wetlands may require a Department of the Army Permit under Section 404 of the Clean Water Act.

E. Design Standards & Criteria.

1. Grading.
   a. *Maximum grades.* Cut or fill slopes shall not exceed 3:1.

   b. *Maximum height.* Cut or fill slopes shall not exceed 15 feet in vertical height unless a horizontal bench area at least 5 feet in width is provided for each 15 feet in vertical height.

   c. *Minimum slope.* Slope in grassed areas shall not be less than 1%.

   d. *Construction Specifications.* Construction for streets must comply with specifications set forth by the City.

      For all other areas, construction specifications stating requirements for stripping, materials, subgrade compaction, placement of fills, moisture and density control, preparation and maintenance of subgrade must be included or referenced on the plans, or accompanying specifications submitted.

   e. *Spoil areas.*
      Broken concrete, asphalt and other spoil materials may not be buried in fills within proposed building or pavement areas.
      Outside of proposed building and pavement areas, broken concrete or stone may be buried in fills, provided it is covered by a minimum of 2 feet of earth.
      Burying of other materials in fills is prohibited.

f. *Stockpile areas.*
Location of proposed stockpile areas shall be outlined on the plans, and specifications for proper drainage included.

g. *Borrow Areas.*
The proposed limits of temporary borrow areas shall be outlined in the plans and a proposed operating plan described on the grading plan.

Temporary slopes in borrow areas may exceed the maximums set forth above. At the time that borrow operations are completed, the area shall be graded in accordance with the criteria set forth above, and reseeded.

2. <u>Sediment containment.</u>
   a. *Existing vegetative filter area.* Existing vegetative filter areas may be used where:
      1) unconcentrated sheet flow occurs.
      2) an area of existing vegetation a minimum of 30 feet in width can be maintained between the area to be graded and a property line, watercourse, sinkhole, spring, wetland or classified lake.
      3) existing ground slope is no greater than 5:1 (20%).
      4) the existing vegetative growth is of sufficient density and in sufficiently good condition to provide for filtration of sediment.

   Vegetative filter areas are a temporary and permanent practice.

   b. *Hay/straw bale dike, or silt fence*.
   Containment areas constructed of hay or straw bales, or silt fence may be provided in areas where:
      1) unconcentrated sheet flow occurs.
      2) an area of existing vegetation a minimum of 25 feet in width cannot be maintained between the area to be graded and a property line, watercourse, sinkhole, spring, wetland or classified lake.
      3) existing ground slope is no greater than 5:1 (20%).
      4) concentrated flow from an area no greater than 1 acre occurs and a minimum volume of 1000 cubic feet per acre is contained behind the dike. Either cereal grain straw or hay may be used for bale dikes.

   Straw/hale bale dikes and silt fences are temporary practices.

   c. *Temporary containment berms.*
   Temporary containment berms may be provided for areas where concentrated flow from areas greater than 1 acre and less than 5 acres occurs. Temporary containment berms must contain a volume of 1000 cubic feet per acre of drainage area.

   Temporary containment berms shall have a riprap outlet with a sediment filter or a perforated pipe outlet.

Temporary containment berms and accumulated sediment may be completely removed after the tributary area is stabilized, and must be removed prior to final acceptance and release of escrow.

d. *Permanent sedimentation/water quality basin.*
Permanent sediment/water quality basins shall be provided for all areas where concentrated flow occurs from an area of 5 or more acres or where 2 or more acres are stripped of vegetation. Sediment basins shall be designed in accordance with Section 101.7 of this manual.

3. Erosion protection.

a. *Seeding and mulching.*

1) *Permanent seeding and Fertilizer*
Permanent seeding and fertilizer shall be applied to all disturbed areas before temporary sediment controls can be removed.

Seed mix shall consist of sixty percent to eighty percent Kentucky 31 tall fescue and twenty percent to forty percent annual ryegrass. Purity shall be at least ninety-seven percent; germination shall be at least eighty-five percent. Seed mixture shall be applied at a rate of four hundred to five hundred points per acre.

Fertilizer shall be 13-13-13 (13 pounds each of nitrogen, phosphorus, and potassium per 100 pounds) and shall be applied at a rate of four hundred to five hundred pounds per acre.

Permanent seeding seasons are from March 1 to May 15, and August 15 to October 15.

2) *Topsoil*
Spreading of topsoil is required for permanent seeding areas. Topsoil stripped from the site shall be stockpiled for reuse. A minimum of four inches loose depth (before rolling or compacting) of topsoil must be spread on the area to be seeded.

3) Mulching.
Where slopes are less than 4:1, cereal grain mulch is required at the rate of 100 pounds per 1000 square feet (4500 pounds per acre). Cereal grain mulch shall meet the requirements of Section 802 of the State Standard Specifications (Reference 18) for Type 1 mulch.

Where slopes are 4:1 or greater, Type 3 mulch ("hydromulch") meeting the requirements of Section 802 of the State Standard Specifications (Reference 18) shall be used.

3) *Temporary seeding.*
Whenever grading operations are suspended for more than 30 calendar days between permanent grass or seeding periods, all disturbed areas must be reseeded with temporary cover.

Temporary seeding season runs from May 15 to November 15.

4) *Overseeding.*
During the winter season (November 15 to March 1) temporary seed and mulch shall be placed on all completed areas or areas where grading is suspended for more than 30 calendar days.

Areas seeded during this period shall be reseeded and mulched during the next permanent seeding season according to seeding requirements.

5) *Maintenance.* Seeded areas must be maintained for one year following permanent seeding.

6) *Other Specifications.* Other seeding and mulching specifications may be used with the written approval of the City.

b. *Cut and fill slopes.*
Cut and fill slopes shall be protected from erosion by construction of straw bale dikes, silt fences, diversion berms, or swales along the top of the slope.

Where drainage must be carried down the slopes, pipe drains, concrete flumes, riprap chutes, or other impervious areas must be provided. Suitable erosion control measures such as riprap stilling basins, must be provided at the bottom of the slope.

Diversions shall be maintained until permanent growth is firmly established on the slopes.

c. *Channels and swales.*
Permanent channels and swales shall be provided with a stabilized invert consisting of one of the following materials:

1) *Sod.* Where the average velocity of flow is 5 feet per second or less and there is no base flow, the channel shall be lined with sod.

For channels with a bottom width less than 15 feet, sod shall extend up the side slope to a minimum height of 6" above the toe.

Channels with a bottom width of 15 feet or greater, shall be graded and contain a low flow area, 15 feet in width lined with sod.

The remainder of the channel slopes shall be seeded and mulched as provided above.

2) *Erosion control blanket.*
Commercial erosion control blankets may be used in lieu of sod provided that samples are submitted and approved by the City. The guaranteed maintenance period shall be one year.

3) *Non-erosive lining.*
In grass channels where base flow occurs, a non-erosive low-flow channel of riprap or concrete must be provided. Low flow channels shall have a minimum capacity of 5 cubic

feet per second. Other suitable non-erosive materials may be specified with approval of the City.

For channels which have an average velocity of 5 feet per second or greater a non-erosive lining of riprap concrete or other approved material must be provided.

d. *Storm sewer and culvert outlets.*
Erosion protection shall be provided at storm sewer and culvert outlets. Minimum erosion protection shall consist of a concrete toe wall and non-erosive lining, meeting the City's specifications.

The required length of non-erosive lining will not be decreased where flared end sections or headwalls are provided unless calculations and data to support the decrease in length are submitted and approved.

Non-erosive lining shall consist of riprap, unless otherwise specified and approved. Field stone, gabions, or riprap shall extend to the point at which average channel velocity for the peak flow rate from the minor (5-year) storm has decreased to 5 feet per second maximum.

The length of riprap to be provided shall be as follows:
1) Average outlet velocity less than 5 feet per second:
   L = 3 times the pipe diameter or culvert width.
2) Average outlet velocity less than 5-10 feet per second:
   L = 5 times the pipe diameter or culver width (5' minimum).
3) Average outlet velocity greater than 10 feet per second:
   Use MoDOT standard energy dissipater headwall. (Reference 18.)

Where headwalls or flared end sections are specified, toe walls must be provided at the downstream end.

e. *Curb openings.*
Where drainage has been approved by the City to flow from paved areas to grass areas through curb openings, erosion protection shall be provided.

f. *Ditch checks & drop structures.*
In grass channels, grades and velocities may be controlled by use of ditch checks and drop structures.

Riprap ditch checks may be required in natural channels where average velocity for the peak flow rate from the 5-year storm exceeds 5 feet per second for post-development conditions.

g. *Spillways.*
Erosion protection must be provided at spillways and outlet structures for detention ponds. Erosion protection shall extend to the point where flow has stabilized and average velocity in the outlet channel is 5 feet per second or less.

4. Temporary construction entrance.
   A minimum of one temporary construction entrance is required at each site. Additional temporary entrances may be provided if approved. The location of each construction entrance shall be shown on the plan.

   Only construction entrances designated on the sediment and erosion control plan may be used. Barricades shall be maintained if necessary to prevent access at other points until construction is complete.

   Construction entrances shall be constructed of crushed limestone meeting the following specifications:

   a. Construction entrances shall be a minimum of 25 feet wide and 50 feet long.
   b. Minimum thickness of crushed limestone surface shall be 6". Additional 2" lifts of crushed limestone shall be added at the discretion of the City if the surface of the initial drive deteriorates or becomes too muddy to be effective.
   c. In locations where an existing drive or street extends at least 50 feet into the site, the existing drive may be designated as the construction entrance, and construction of a new gravel entrance is not required, unless job conditions warrant as set forth in the preceding paragraph.

   If these measures cannot be obtained or are otherwise impractical, the City reserves discretion.

5. Cleaning streets.
   Streets both interior and adjacent to the site shall be maintained throughout the duration of the project and completely cleaned of sediment at the end of construction and prior to release of security. Sidewalks, streets, curbs and gutters shall be protected from damage from vehicles, equipment and supplies for the duration of a construction project. City streets, right-of-ways or adjoining property shall not be used for cleaning construction vehicles including mud and concrete, disposing or storing of construction-related materials, parking automobiles, or for placing construction trailers.

6. Dust control.
   The contractor will be required to use water trucks to water all roads and construction areas to minimize dust leaving the site when conditions warrant.

7. Sequencing and scheduling.
   Costs of sediment and erosion control can be minimized if proper consideration is given to sequencing and scheduling construction.

   Any special sequencing and scheduling considerations should be noted in the grading plan.

SECTION 101.7: WATER QUALITY PROTECTION

A. Purpose.

1. This section covers the design of Best Management Practices (BMPs) to minimize the adverse effects of urban stormwater runoff on the quality of receiving waters. This policy applies only to developments in the residential, commercial, and manufacturing (R, C, and M) zoning districts and/or other special zoning districts meeting or exceeding the development densities allowed in the R, C, and M districts. It does not apply to the A-1, Agriculture District.

2. The objective of this policy is not to meet specific reductions of targeted pollutants, but rather to provide a generally effective level of pollutant removal by using reasonable, cost effective measures. The goal is to minimize, to the maximum extent practical, adverse impacts on the quality of the receiving waters.

3. It is important to recognize that the *structural Best Management Practices* (BMPs) for which design guidance is given in this section represent only one aspect of stormwater quality management. The most effective means of managing stormwater quality lie in overall watershed planning and zoning controls, and other *nonstructural* practices which are generally beyond the control of an individual development. Annual groundwater recharge rates shall be maintained by promoting infiltration through the use of structural and non-structural methods. At a minimum, annual recharge from the post-development site shall mimic the annual recharge from pre-development site conditions.

B. General Design Guidelines.

1. Minimize the amount of runoff. The total quantity of pollutants transported to receiving waters can be minimized most effectively by minimizing the amount of runoff. Both the quantity of runoff and the amount of pollutant wash-off can be minimized by reducing the amount of *directly connected impervious area (DCIA)*. Impervious areas are considered connected when runoff travels directly from roofs, drives, pavement, and other impervious areas to street gutters, closed storm drains or concrete, or other impervious lined channels. Impervious areas are considered disconnected when runoff passes as sheet flow over grass areas, or through properly designed BMP's, prior to discharge from the site.

2. Maximize contact with grass and soil. The opportunity for pollutants to settle out is maximized by providing maximum contact with grass and soil. Directing runoff over vegetative filter strips and grass swales enhances settling of pollutants as the velocity of flow is reduced. Infiltration of runoff into the soil is also increased.

3. Maximize holding and settling time. According to ASCE (Reference 25), the most effective runoff quality controls reduce the runoff peak and volume. The next most effective controls reduce peak runoff rates only. For small storms the runoff rate should not exceed the pre-project peak flow rate from the fifty percent (50%) AEP (2-year) storm. Most obnoxious pollutants (exceptions include water soluble nutrients and metals) can be settled out.

   By reducing the rate of outflow and increasing the time of detention storage, settling of pollutants and infiltration of runoff is maximized.

4. Design for small, frequent storms. Drainage systems for *flood control* are designed for large, infrequent storm events. In contrast, stormwater quality controls must be designed for small, frequent storm events. Most pollutants are washed off in the "first flush", generally considered the first one-half inch (½") of runoff.

5. Utilize BMP's in series where possible. The combined effect of providing several BMP's in a series can be much more effective in reducing the level of pollutants than providing a single BMP at the point of discharge. To the greatest extent practical, runoff should be directed first to vegetative filter strips, then to grass swales or channels, and then to extended detention basins, sand filters, etc.

6. Incorporate both flood control and water quality objectives in designs, where practical. Incorporating both flood control and water quality criteria into a single stormwater management facility is not only possible, but is encouraged. Whenever practical, combining several objectives, such as water quality enhancement and flood control, maximizes the cost-effectiveness of stormwater management facilities.

C. Requirements.
The following requirements will apply to any new development within the City:

1. Stormwater runoff from any new development for which the total impervious area exceeds ten percent (10%) of the total land area of the development, must be directed through an extended wet or dry detention basin, or other properly designed BMP, prior to discharge from the site.

2. Runoff from fueling areas and other areas having a high concentration of pollutants will be required to be directed to a sand filter or other properly designed BMP which provides filtration as well as settling.

3. The required volume for capture and treatment shall be designed as the *water quality capture volume* (WQCV), and shall be determined as set forth in Section D of this Section.

4. Detention storage must be provided to limit the peak flow rate from the fifty percent (50%) AEP (2-year) storm to pre-project values. Detention facilities for peak flow control shall be designed as set forth in Section 101.5.

5. Certain stormwater treatment practices are prohibited even with pretreatment in the following circumstances:

   a. Stormwater is generated from highly contaminated source areas known as "hotspots";
   b. Stormwater is carried in a conveyance system that also carries contaminated, non-stormwater discharges;
   c. Stormwater is being managed in a designated groundwater recharge area;
   d. Certain geologic conditions exist (e.g., karst) that prohibit the proper pretreatment of stormwater.

D. Design Criteria.

1. Water Quality Capture Volume.

   Water quality BMPs shall be designed to capture the runoff from the 90th percentile rainfall for the City as well as to capture the first flush of pollutants from directly connected impervious areas within the proposed development.

   The required water quality capture volume (WQCV) to be used in design of extended wet and dry detention basins and other BMPs whose design is based upon capture and treatment of storm water, shall be the greater of the following:

   a. The first one-half inch (½") of runoff from the directly connected impervious area (DCIA) in the development, or
   b. The *runoff* resulting from total rainfall depth of one inch (1") in twenty-four (24) hours over the entire development.

2. Directly Connected Impervious Area (DCIA). Impervious areas are considered connected when runoff travels directly from roofs, drives, pavement, and other impervious areas to street gutters, closed storm drains or concrete, or other impervious lined channels.

   In order for an impervious area to be considered disconnected, runoff from the area must pass through an approved vegetative filter strip or other approved BMP meeting the requirements set forth in this section. For determining the amount of impervious area, the following assumptions shall apply in the absence of more detailed data:

   a. Single Family Lots
      Average roof area: 2500 square feet
      Average drive area: 800 square feet
      Average impervious area per lot: 3500 square feet

      If gutter downspouts are directed to drain toward lawn areas, seventy-five percent (75%) of the roof area shall be considered disconnected.

   b. Duplexes and Patio Homes
      Average roof area: 2500 square feet
      Average drive area: 1600 square feet
      Average impervious area per lot: 4500 square feet

      If gutter downspouts are directed to drain toward lawn areas, seventy-five percent (75%) of the roof area shall be considered disconnected.

   c. Multi-Family, Commercial and Other Areas
      The amount of impervious area contained in multi-family, commercial, office and manufacturing developments shall be determined based upon the site plan for the development.

3. Vegetative Filter Strips.
    a. Vegetative filter strips consist either of areas of undisturbed vegetation in good condition, including trees, grass, sod or other vegetative cover which meets the objectives for this BMP, or areas where new vegetation has been established.

    b. Vegetative filter strips shall be provided in areas of sheet flow only. The hydraulic loading for filter strips shall not exceed 0.05 cfs per lineal foot of filter strip length for the fifty percent (50%) AEP (2-year) storm (equal to the runoff per unit width from a four hundred feet (400') length of impervious area).

    c. The minimum width of the filter strip shall not be less than twenty percent (20%) of the length of the sheet flow from the upstream impervious surface, and in no case shall be less than six feet (6').

    d. The slope along the width of the filter strip shall not exceed 4:1 (25%).

4. Grass Swales. Grass swales may be provided to convey runoff from vegetative filter strips and impervious areas to BMP’s designed for capture and temporary storage of runoff. Design criteria for grass swales shall be as follows:

    a. Maximum side slopes: 4:1.
    b. Maximum longitudinal slope: 5%.
    c. Minimum longitudinal slope: 1%.
    d. Maximum velocity: 2 feet per second for peak flow from the 50% AEP (2-year) storm.
    e. Roughness coefficients for use in the design of grass swales shall be determined as set forth in Section 101.4.
    f. Grass swales shall be lined with sod or seeded and covered with suitable erosion control blanket and mulch.

5. Extended Dry Detention Basins.
    Extended dry detention basins may be provided to capture and provide temporary storage for the required water quality capture volume. Extended dry detention basins shall be placed outside of the primary watercourses which allow off-site flows to pass through the development (i.e., “offline”) where possible.

    Design criteria for extended dry detention basins shall be as follows:

    a. Volume. Minimum volume shall be one hundred and twenty-five percent (125%) of the required water quality capture volume (WQCV). Detention basins for water quality may be combined with detention basins for flood control. Effects of the WQCV may be considered in the design for flood control.

    b. Drain time. The WQCV shall be released over a minimum period of forty (40) hours and a maximum period of seventy-two (72) hours.

    c. Outlet structure.
        1) Outlet structures shall consist of a perforated riser pipe, outlet pipe and gravel filter material. Perforated steel plates will also be acceptable.

2) The minimum allowable riser pipe diameter is eight inches (8"). The riser pipe shall be connected to an outlet pipe of equal of greater diameter. The outlet pipe shall have adequate capacity to carry the maximum rate of flow from the riser pipe. Material for the riser pipe shall be Schedule 40 PVC, ductile iron, or corrugated, galvanized metal.

3) A removable cap shall be provided at the top of the riser pipe. The cap shall have a one inch (1") diameter hole for air relief.

4) The outlet pipe shall be bedded in firmly compacted clay, free of stones. For dams exceeding ten feet (10') in height, an anti-seep collar shall be provided around the pipe.

5) Number of rows of perforations, number of perforations per row and diameter of perforations for the riser pipe shall be specified on the plans. Perforation pattern shall be determined based upon orifice calculations to provide for release of the WQCV over the specified time. Perforations shall meet the following requirements:

   Minimum perforation diameter: 1/4 inch
   Maximum perforation diameter: 1 inch
   Minimum number of holes per row: 4
   Maximum number of holes per row: 8
   Minimum row spacing: 4 inches
   Maximum row spacing: 12 inches

d. <u>Freeboard.</u> Where the basin is to be utilized as a water quality BMP only, twelve inches (12") minimum freeboard shall be provided above the WCQV.

e. <u>Forebay</u>. It is preferred that a forebay be provided to dissipate energy from incoming flows and to trap settleable sediment entering the basin.

1) The forebay should be separated from the remainder of the basin by an earth dike meeting the requirements of Section 101.5.

2) The top of the dike shall be set six inches (6") above the stage of the WQCV.

3) Outflow from the forebay to the basin shall be through a gravel filter. The top of the gravel filter shall be set equal to the stage of the WQCV.

4) The volume of the forebay shall be a minimum of ten percent (10%) and a maximum of twenty percent (20%) of the WQCV. The volume of the forebay is considered to be part of the required WQCV, not additional volume.

f. <u>General construction requirements</u>. The optimal length to width ratio for a water quality detention basin is four (4). The length to width ratio should be no less than two (2). The minimum allowable length to width ratio is one (1). Side slopes, dams or dikes, and retaining walls shall meet the requirements of Section 101.5.

g. Overflow spillways. Where the basin is to be utilized as a water quality BMP only, a spillway or outlet structure meeting the requirements of Section 101.5 and capable of passing the peak flow from a 1% AEP (100-year) storm for the drainage area upstream of the basin shall be provided. The lowest point on the spillway or outlet structure shall be set at the top of the WCQV.

h. Trickle channels. Trickle channels shall be provided to provide grade control and to minimize chronic wet areas. Trickle channels shall be constructed of six inch (6") stone or other porous medium.

6. Extended Wet Detention Basins.
Extended wet detention basins may be provided to capture and provide temporary storage for the required water quality capture volume. Extended wet detention basins shall be placed outside of the primary watercourses which allow off-site flows to pass through the development (i.e., “offline”) where possible.

Design criteria for extended wet detention basins shall be the same as for extended dry detention basins, with the following exceptions:

a. The volume of the permanent pool should not be less than 1.0 to 1.5 times the WQCV.

b. A bench area (littoral zone) with a width of ten feet (10') shall be provided. It is preferred that emergent aquatic vegetation be provided in this zone.

c. It is recommended that a minimum of twenty-five percent (25%) of the WQCV be provided in the upper eighteen inches (18") of depth. A maximum of fifty percent (50%) of the permanent pool volume shall be provided in the upper eighteen inches (18") of depth.

d. Depth of the principal portion of the permanent pool shall be a minimum of four feet (4').

e. It is preferred that a forebay meeting the same requirements as specified for dry detention basins, be provided.

f. Where perforated riser pipes are not encased in gravel, only corrugated metal or ductile iron pipe may be used.

7. Sand Filters. Runoff from fueling plazas, vehicle maintenance areas, solid waste storage or transfer areas, and other areas having potentially high concentrations of contaminants shall be passed through an approved sand filter prior to discharge to receiving waters.

Total impervious area draining to a sand filter will generally be one (1) acre or less. Sand filters shall be provided with a sedimentation chamber and a filtration chamber such as the Austin, Texas first flush filtration basin (full sedimentation design) as described in Debo and Reese pp. 596-598 (Reference 26) or approved equal.

8. Other Structural BMPs.
Constructed wetlands, porous pavements and other structural BMPs for which detailed design criteria can be documented in generally accepted literature can be provided in addition to, or in

lieu of, the BMPs described above, provided the objectives of this section can be met. The use of infiltration basins and trenches is discouraged due to possible adverse impacts on groundwater.

E. <u>Operation and Maintenance.</u>
The City provides no maintenance of water quality BMPs located on private property. Maintenance must be provided by the owner of the property upon which the BMP is located.

Extended detention basins and wetlands or other “capture and storage” BMPs shall be located within a single lot or property, within a designated drainage easement. Where BMPs are located in common areas or adjoining off-site areas, the property upon which the BMP is located shall remain in the ownership of the developer or property owners’ association.

Where a property owners’ association is formed, restrictive covenants which provide for collection of fees for maintenance of the BMPs shall be filed in the office of the City.

SECTION 101.8: FLOODPLAIN DEVELOPMENT

A. Permit requirements. Reference Chapter 6, Article VII of the City Code of Ordinances

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