DESIGN CRITERIA FOR

STORM DRAINAGE FACILITIES

DC4-001 GENERAL. This section sets forth the minimum technical criteria for the analysis and design of drainage systems in the city of Kirksville. All development plans submitted for approval to the city of Kirksville must be accompanied by an adequate storm drainage system analysis and design in accordance with the criteria as hereinafter described.

DC4-002 MINIMUM STANDARDS OF ANALYSIS. Unless otherwise approved by the city engineer, the following criteria will be utilized to determine the adequacy of any storm drainage facility design submitted for approval.

A. Methodology of Analysis. In determining the amount of storm-water runoff resulting from a development and the amount of flow at various points throughout the drainage system, it is important for the designer to relate the methodology to be utilized in his calculations to the proportionate size of the tributary watershed areas. In developments where the area contributing runoff is two hundred (200) acres or less, the Rational Method of calculating the quantity of runoff shall be utilized. Developments where the area contributing runoff exceeds two hundred (200) acres shall be designed using the unit hydrograph method (SCS).

B. Criteria for Drainage System. All calculations relating to runoff analysis shall be based upon the proposed land use and shall take under consideration any contributing runoff from areas adjacent to the development site. Storm water runoff analysis from adjacent existing developed areas shall be based upon current land usage and topographical features. Property adjacent to the study area which is undeveloped shall be considered as fully developed in accordance with the most probable anticipated future land use. Such land use shall be determined from the city Comprehensive Plan and the city zoning map. In the event that the future land use of a specific undeveloped property cannot be adequately projected from available information, the average runoff coefficient (C) to be used shall not be less than 0.65 for use in the Rational Method or an appropriate equivalent value as approved by the city engineer for any other method. The most likely flow pattern to be utilized for an undeveloped area shall be based upon existing natural topographical features.

Average land slopes in both developed and undeveloped areas may be utilized to calculate runoff rates. The exception to this shall be in areas with existing well-defined drainage patterns and slopes, in which case the actual slope shall be used.

Existing runoff flow rates and velocities at locations of discharge from adjacent upstream developments shall be utilized in drainage system design. Drainage facilities shall be designed to minimize the velocity of overland flow so as not to cause erosion damage. In areas where excessive velocities exist, adequate dissipating structures shall be provided as required to result in velocities appropriate for the type of erosion control to be utilized.

The primary function of roadways within a development shall be reserved for the conveyance of traffic. The use of these facilities as a storm runoff facility shall be restricted to the requirements established and set forth in these design criteria.

The utilization of on-site or on-stream detention and natural drainage ways is recommended and encouraged where feasible. Relocation of existing natural drainage ways will not be approved unless such relocation has been substantiated as a result of a thorough and complete analysis of the resultant consequences.

The designer shall consider all problem areas of his design and analysis to prevent the transfer of these problems from one location to another. All points of drainage outfall shall be designed to preclude creation of downstream flooding problems and hazards to the public. Approval will not be given to any project which involves the construction of any structure or the placement of fill material which will hinder or impair surface or subsurface drainage from surrounding areas.

DC4-003 MINIMUM STANDARDS OF DESIGN. Storm water runoff shall be carried by enclosed systems or open channels on the basis of criteria established in this section and subject to the final determination and approval of the city engineer.

Enclosed drainage systems shall be used to collect and convey drainage on, across and through public right-of-way. The enclosed system shall extend at least to the limits of the right-of-way and energy dissipating structures shall be provided at the outlet to limit velocities to seven (7) feet per second and/or as needed to prevent erosion damage.

Where enclosed storm drainage is located along side property lines, it shall remain enclosed to the rear property line or an existing channel at least thirty (30) feet beyond the rear corner of the adjacent buildings. A surface swale shall be designed over this area to contain additional runoff from a 50-year storm. At the point of intersection with an open channel, energy-dissipating structures shall be provided to limit velocity to the capacity of the receiving channel or seven feet per second whichever is less.

Existing open channels, natural or improved, may remain along the rear or side of properties when the design provides adequate protection to the adjacent property. Such protection shall be through the provision of a 50-year floodplain setback and a minimum clearance from the top of bank to any building of 30 feet.

The use of open channels is generally acceptable for conveying storm runoff from tributary watersheds if the runoff cannot be contained in a 72-inch (72") diameter pipe. **All open channels shall be analyzed for a minimum of 500 feet downstream of the development or to a point where the increased runoff from the development has no adverse impact on downstream structures.**

A. Design Storm Frequencies. The minimum rainfall event to be utilized in determining the intensity of rainfall for storm flow calculations shall be based on the following:

Land Use/Zoning	Storm Return Frequency
Residential	10 Year
Commercial	25 Year
Industrial	25 Year
Parks, Greenbelts, etc.	10 Year
Open Channels	25 Year
Flood Plains	100 Year
Crossing Arterial Streets and with 40 acres or more tributary	50 Year

Storm drainage systems having more than one land use or zoning classification tributary to the system, shall be designed on the basis of the highest runoff producing land use comprising 30 percent (30%) or more of the total tributary area.

B. Runoff Computation. The rational method of calculating storm water quantities, $Q = KCIA$, shall be used with the following definitions of terms and arbitrary values:

Q is the quantity of runoff in cubic feet per second and is the basis for design of the storm drainage system.

K is a dimensionless coefficient to account for antecedent precipitation.

C is the weighted coefficient of runoff from the tributary area and shall have the following values where applicable:

			AVERAGE SURFACE USE	
			PERCENT	PERCENT
	LAND USE/ZONING	"C"	IMPERVIOUS	PERVIOUS
a.	BUSINESS			
	Downtown Areas	0.90	95	5
	Neighborhood Areas	0.80	85	15

			AVERAGE SURFACE USE	
			PERCENT	PERCENT
	LAND USE/ZONING	“C”	IMPERVIOUS	PERVIOUS
b.	RESIDENTIAL			
	Single-Family Areas	0.50	35	65
	Multi-Family Areas	0.65	60	40
	Churches & Schools	0.75	75	25
c.	INDUSTRIAL			
	Light Areas	0.65	60	40
	Heavy Areas	0.80	80	20
	Parks, Cemeteries	0.35	10	90
	Playgrounds	0.35	10	90
	Railroad Yard Areas	0.45	25	75
d.	UNDERDEVELOPED AREAS			
	Permanent Unimproved Areas, Greenbelts, etc.	0.30	0	100
	Temporary Unimproved Areas that can be considered as fully developed in the future	0.65		

As an alternate to the above coefficients or for areas not specifically listed above (planned building groups, shopping centers, trailer parks, etc.), a composite runoff coefficient based on the percentage of the different types of surfaces involved shall be used.

Coefficients with respect to surface type shall not be less than those listed in the following table:

Asphalt Surfaces	0.90
Concrete Surfaces	0.90
Roof Areas	0.90
Turf	0.30

I is intensity of rainfall in inches per hour and shall be determined for the yearly frequency stipulated previously and as specified from the intensity duration curves included as a part of this criteria.

TC Time of concentration (*TC*) equals the overland flow time to the most upstream inlet or other point of entry to the system plus the time of flow in the system upstream from the point under consideration. (*TC = Ti + Tt*)

Ti (inlet time) shall be calculated utilizing the following formula or determined graphically from Design Aid **4**-5A but shall not be less than 5.0 minutes or greater than 15.0 minutes:

$$Ti = \frac{1.8\,(1.1 - C)\,D^{1/2}\ \text{(minutes)}}{S^{1/3}}$$

<u>C</u> is the Rational Method runoff coefficient.

<u>D</u> is the overland flow distance parallel to slope.

<u>S</u> is the slope of the tributary area surface perpendicular to contour in percent.

Tt (Travel time) shall be calculated as the length of travel in the channelized system divided by the velocity of flow. Velocity shall be calculated by Manning's equation assuming all system elements are flowing full without surcharge. Travel time may be determined graphically from Design Aid 3-5B in lieu of calculation.

When the upstream channel is unimproved, it shall be assumed that future construction of drainage system improvements will increase the velocity of flow. Velocity used for calculating *Tt* shall be:

Average Channel Slope (Percent)	Velocity (fps)
<2	7
2 to 5	10
>5	15

A is the area in acres contributing to the drainage system. All upstream tributary areas are to be considered as fully developed as zoned or planned at the time of design.

C. Antecedent Precipitation. "*K*" represents the frequency factor used to account for antecedent precipitation and shall have the following values:

Storm Return Period (Years)	K*
10	1.0
25	1.1
50	1.2
100	1.25

* The product of *K x C* shall not exceed 1.0.

D. Pipe Sizing. Pipe sizes in integrated underground systems shall be determined in accordance with the Manning Formula

$$V = \frac{1.486}{n} r^{2/3} s^{1/2}.$$

Values of "*n*" to be used in the Manning Formula shall be as shown in Design Aid 3-7A.

The minimum size storm sewer shall be fifteen (15) inches in diameter.

Storm sewers and inlets shall be of sufficient capacity to adequately carry the anticipated runoff from the design storm. Capacity shall be rated at either inlet or outlet control, whichever condition indicates the least capacity. The drainage system and appurtenant storm inlets shall commence at all locations where the allowable street capacity for the conveyance of storm water runoff is exceeded or where there is a possibility of ponding.

All storm drainage systems shall be designed so as to maintain a minimum velocity of flow at the outlet of three feet (3') per second and a maximum velocity of seven feet (7') per second when flowing full.

E. Pipe Slope. Pipe slopes may not be greater than 15 percent (15%) and water velocities in pipe may not be greater than fifteen feet (15') per second without a variance from the city engineer. If a variance is allowed, then pipe runs whose slope is 15 percent (15%) or greater and/ or whose water velocity is 25 fps or greater, will be required to have concrete collars on every sixth joint unless the conditions necessitate a greater or lesser spacing. The city engineer will review spacing calculations from the design engineer for these conditions. Proof of proper abrasion resistance in pipe must also be provided.

F. Depth. All storm drainage lines shall have a minimum cover of eighteen inches (18") where practical. Cover may be decreased to avoid conflicts or on short laterals, as approved by the city engineer. Special bedding and backfill may be required where cover is decreased below eighteen inches (18").

G. Curb Inlets, Junction Boxes and Other Points of Entry. In general, curb inlets shall be installed at intersections and as required at intermediate points to limit gutter flow width during runoff occurring from the design peak discharge from the tributary watershed area to that which will not encroach on the following center widths of streets:

Arterial	24 feet
Collector/Service Streets	14 feet
Local Streets	10 feet

Because of the potential for street debris to clog inlets and to reflect potential cross section changes due to resurfacing, inlet capacity shall be rated at 80 percent of the theoretical inlet capacity unless otherwise approved by the city engineer.

Design shall provide that the hydraulic gradient at any opening through which surface water may enter (or backflow from) the system is 0.5-foot or greater below the opening elevation. The hydraulic gradient elevation is defined as:

1. Channel invert elevation;

2. Plus depth (diameter) of outlet channel (pipe);

3. Plus "h" calculated in accordance with Design Aid 3-7B; except for structures where 50 percent or more of the discharge enters the system from the surface of the structure "h" shall be calculated as = $V/64$.

   The hydraulic gradient elevation shall be calculated at the entrance to the outlet line of each structure.

   The crown(s) of pipe(s) entering a structure shall be at the same elevation, and at or above the crown of the line exiting from the structure when practicable.

H. Open Channels. Unless in a designated flood plain or a critical area as determined by the city engineer, open channels shall be designed for the 25-year frequency storm. Open channels shall be sized to adequately carry the design rate of flow without damage. Whenever practical, the channel shall be characterized as slow flowing, be wide and shallow, and be natural in its appearance and functioning.

Channel capacities shall be computed using the Manning Formula for uniform flow.

Design flow rates shall be carried within the confines of the open channel with a minimum allowable freeboard of 1.0 foot measured from the water surface to the top of bank.

Pipe culverts, box culverts, and other structures entering channels shall not project into the normal waterway area.

Channel design shall include lining or treatment of the invert and sides as required to minimize erosion. Minimum treatment shall include seeding. Channel inverts and sides shall be lined in accordance with the following table:

Mean Flow Velocity	Type of Lining
Less than 3 F.P.S.	Seeded
3 to 5 F.P.S.	Sod, staked
5 to 10 F.P.S.	Stone riprap (15" Min. Thickness)
0 to 15 F.P.S.	Grouted stone riprap, gabion revetment or concrete paving
Over 15 F.P.S.	Concrete paving or sound in-situ rock

Lining materials having equivalent erosion control properties to those shown in the foregoing table may be used in lieu thereof with the approval of the city engineer.

Channel sections shall be compatible with the type of lining and maintenance practical to be used. Side slopes shall be as flat as practical. Side slopes of 3:1 shall be considered a normal maximum. Under special circumstances where acceptable lining material is to be utilized, slopes of 2:1 may be considered. Such use in the channel design shall be only where approved by the city engineer. Friction factors used in design shall consider the type of lining and are listed in Design Aid 3-7A.

Alignment changes shall be achieved by curves having a minimum radius of:

$$R = \frac{V^2 W}{8D}$$

R = Minimum radius on centerline in feet.

V = Average velocity of flow in feet/sec.

W = Width of channel at water surface in feet.

D = Depth of flow in feet.

Lining height on the outside (concave) side of curves shall be increased by:

$$y = \frac{D}{4}$$

y = Increased vertical height of lining in feet.

Increased lining height shall be transitioned from y to zero feet over a minimum distance of:

30 (y) feet downstream from the point of tangency (p.t.).

10 (y) feet upstream from the point of curvature (p.c.).

I. Natural Channels. Shall conform to the criteria for improved channels except:

1. Mean flow velocity may be 5 feet/sec without lining.

2. Freeboard requirements may be satisfied by dedication of an easement to the freeboard elevation plus 1.0-foot vertically.

J. Culverts. Culverts under major arterials (thoroughfares) shall have sufficient capacity to pass the runoff from the appropriate design storm considering 20% of the inlet opening plugged.

The following design criteria shall be utilized for all culvert design:

1. The culvert including inlet and outlet structures shall properly take care of water, bed-load and debris at all stages of flow.

2. Inlet. Culvert inlets shall be designed to minimize entrance and friction losses. Inlets shall be provided with either flared-end sections or headwalls with wingwalls. Projecting ends will not be acceptable. For large structures, provisions shall be made to resist possible structural failure due to hydrostatic uplift forces.

3. Outlets. Culvert outlets shall be designed to avoid sedimentation, undermining of the culvert, and erosion of the downstream channel. Outlets shall be provided with either flared-end sections or headwalls with wingwalls. Projecting outlets will not be acceptable. Additional outlet control in the form of riprap, channel shaping, etc., may be required where excessively high discharge velocities occur.

4. Slopes. Culvert slopes should be such that neither silting nor excessive velocities and scour occur. Generally, the minimum slope of culverts shall be limited to 0.005.

5. Headwater. Generally, the headwater to diameter ratio (HW/D) should not exceed those recommended as follows:

Storm Frequency	HW/D
10 Year	≤ 1.0
25 Year	≤ 1.2
50 Year	≤ 1.5
100 Year	≤ 1.5

6. Tailwater. The depth of tailwater at the outlet shall be subject to the criteria set forth for headwater.

7. Hydraulic Design. Culverts shall be analyzed to determine whether discharge is controlled by inlet or outlet conditions for design storm discharge. The value of the roughness coefficient (n) used shall not be less than those specified in Design Aid 3-7A.

8. Structural Design. The structural design of culverts, whether pipe or concrete box, shall be sufficient for the situation anticipated to be encountered at the site of the proposed work. Such design shall conform fully to all requirements set forth in this criteria and in the technical specifications of the city of Kirksville and shall be as approved by the city engineer. Design Aids 3-9 and 3-10 are provided for determining the gauge requirements for corrugated metal pipe.

DC4-004 EASEMENTS. Drainage easements shall be a minimum of fifteen feet (15') for enclosed structures and twenty feet (20') or open (paved or grass-lined) channels where they cross private property or as designated by the city engineer.

DC4-005 STORMWATER DETENTION. The city engineer shall determine whether a proposed plan will cause or increase downstream local flooding conditions. This determination shall be made on the basis of existing downstream development and drainage system capabilities and an analysis of stormwater runoff prior to and after the proposed development. If the city engineer determines that the proposed development will cause or increase downstream local flooding conditions during the design storm, provisions to minimize such flooding conditions shall be included in the design of storm drainage improvements and/or the temporary controlled detention of stormwater runoff and its regulated discharge to the downstream system.

Temporary detention of stormwater runoff may be required for any industrial or commercial development. Residential developments may also be required to provide detention if the total development area, including future proposed plats of the same development, is ten acres or larger. Generally, stormwater detention basins shall be designed and constructed for the attenuation of the peak rate of runoff to an amount not greater than that occurring prior to development. The following design criteria for stormwater detention shall be in effect unless superseded by a revision to the city of Kirksville "Stormwater Management Ordinance".

A. Storage Volume Requirements. Storage volume shall be adequate to contain the differential volume of runoff which would result from the design storm occurring on a fully developed site over the maximum allowable release rate. The minimum rainfall event to be utilized in determining the detention storage volume shall be based upon the planned land usage and intensity within the tributary area. The intensity to be used for a residential development shall be a 10-year rainfall event while a commercial and industrial development shall use a 25-year rainfall event.

B. Maximum Allowable Release Rate. In general, the maximum release rate shall be defined as the rate of runoff occurring prior to the proposed development taking place and shall be determined mathematically as the runoff resulting from a 10-year return-frequency rainfall calculated using the rational formula. Deviations from the use of this rainfall frequency in design calculations shall be only where approved by the city engineer.

C. Freeboard. The minimum elevation of the top of the detention storage basin storage basin embankment shall be at least one foot (1’) above the water surface with the emergency spillway flowing at design, or a minimum of two feet (2’) above the crest of the emergency spillway.

D. Sediment Storage. A sediment storage volume of at least 5 percent (5%) of the total required temporary storage volume for runoff detention shall be provided.

E. Outlet Control Works. Outlet control works shall not include any mechanical components or devices and shall function without requiring attendance or control during operation. Size and hydraulic characteristics shall be such that all water in detention storage is released to the downstream storm sewer system within twenty-four hours after the end of the design rainfall.

F. Emergency Overflow. A method of emergency overflow shall be designed and provided to permit the safe passage of runoff generated from a one-hundred-year storm.

G. Structure Integrity. The basin shall be designed with the capability of passing a one-hundred-year storm event from a fully developed watershed basin through the outlet works without causing failure of the embankment.

H. Design Data Submittal. In addition to completed plans, the design engineer shall submit the following for all projects that include temporary detention facilities: rainfall hydrograph, capacity curve for proposed detention facility, discharge characteristics curve, and storage capacity inflow and outflow curves.

I. Optional Detention Methods. Some possible types of detention facilities can be (but are not limited to) the following:

1. Wet-bottom basins. The minimum normal pool elevation prior to the introduction of excess stormwater shall be four feet (4'). If fish are to be used to keep the basin clean, at least one quarter of the area of the permanent pool must have a minimum depth of ten feet (10'). For emptying purposes, cleaning of shoreline maintenance, facilities shall be provided or plans prepared for the use of auxiliary equipment to permit emptying and draining.

2. Dry-bottom basins. Where possible these shall be designed to serve secondary purposes for recreation, open space or other types of use which will not be adversely affected by occasional or intermittent flooding. To facilitate interior drainage, concrete paved swales shall be required from the inflow to the outlet structures.

3. Paved parking lots. Parking lots may be designed to provide temporary storage of stormwater on all or a portion of their surfaces to a maximum depth of nine inches. Outlets will be designed so as to empty the stored waters in such a time to create the least amount of inconvenient to the public. Minimum slopes of 1 percent and maximum slopes of 4 percent (4%) are to be utilized.

The minimum freeboard from the maximum water ponding elevation to lowest sill elevation of adjacent buildings to structures shall be one foot (1').