Leavenworth, Kansas
Stormwater Master Plan
Storm Drainage Design Criteria

B&V Project 26529.110
May 28, 1999

Drainage Criteria Manual, City of Leavenworth, Kansas

I. General Design Criteria

I.1. General. The following design criteria are the minimum standards to be used in the design and construction of drainage system improvements for the City of Leavenworth.

I.2. Policies. The drainage design criteria are based on the following policies adopted by the City and developed as part of the Stormwater Master Plan completed in 1999.

I.2.1. A drainage report must be submitted by a professional engineer registered in the State of Kansas. The report shall be signed and sealed.

I.2.2. Subdivision plans shall include plans for the conveyance of stormwater and shall be signed and sealed by a professional engineer registered in the State of Kansas. The stormwater facilities shall be designed in accordance with design criteria set forth in "Drainage Criteria Manual, City of Leavenworth, Kansas," (Design Criteria) developed as part of the Stormwater Master Plan.

I.2.3. Easements shall be granted to the City for access to underground drainage improvements and along open channels where the flow is greater than what could be contained in a 72 inch diameter pipe. Minimum easement requirements are listed in the Design Criteria.

I.2.4. Curb and gutter shall be provided on all new roadways.

I.2.5. Off-site drainage improvements shall be provided if peak flow rates are greater than those shown in the Stormwater Master Plan.

I.2.6. Underground drainage systems shall be installed in all areas where the flow can be contained in a 72 inch diameter pipe.

I.2.7. Systems shall be designed to address State and Federal regulations regarding stormwater quality.

I.2.8. Runoff resulting from a 100 year design storm shall be routed through the major drainage system, which consists of the drainage system designed to pass the design storm plus surface routing such as swales, open channels, and roadways. The 100 year design storm shall be routed through the major system without causing structural flooding.

Section II. Design Requirements

II.1. Runoff Calculations. Peak runoff rates shall be calculated using the Rational method for areas smaller than 300 acres. For areas greater than or equal to 300 acres and where detention/retention storage will affect peak runoff rates, a hydrograph method shall be used to calculate peak flow rates.

II.1.1. Rational method. The Rational equation consists of the following formula:

Q=k*C*i*A where,
Q = Peak rate of runoff in cubic feet per second
k = Antecedent precipitation coefficient
C = Runoff coefficient
i = Rainfall intensity in inches per hour
A = Tributary area in acres

II.1.1.1. Antecedent precipitation coefficient (k). The antecedent precipitation coefficient is used to adjust the runoff coefficient (C) for less frequent design storms. The following k factors shall be used:

Antecedent Precipitation Factor, k	
Return Period Design Storm, Years	k Factor
10 and less	1.0
25	1.1
50	1.2
100	1.25

The product of C and k shall not exceed 1.0.

II.1.1.2. Runoff coefficient (C). The runoff coefficient is a ratio of the rate of runoff to rate of precipitation. The table below shall be used to determine C values.

Runoff Coefficient, C and Percent Impervious				
Land Use	Average Runoff Coefficient	Range for Runoff Coefficient	Average Percent Impervious	SCS Curve Number
Business				
Downtown	0.87	0.70-0.95	95	92-94
Neighborhood	0.81	0.5-0.7	85	92-94

Residential				
Single-family	0.51	0.3-0.6	35	75-83
Multi-family	0.66	0.4-0.8	60	85-90
Apartments	0.6	0.5-0.7	60	85-90
Churches and schools	0.75	0.7-0.9	75	88-92
Industrial				
Light	0.66	0.5-0.8	60	88-91
Heavy	0.78	0.6-0.9	80	88-91
Parks, Cemeteries	0.30	0.1-0.30	10	61-86
Railroad yard	0.40	0.2-0.4	25	70-80
Undeveloped	0.3	0.1-0.3	0	61-86
Impervious	0.9	0.8-0.95	100	98
Turf	0.3	0.1-0.3	0	61-86
Agricultural	0.3	0.1-0.3	0	61-91

II.1.1.3 Rainfall Intensity. Intensity-duration-frequency curves are tabulated in Table 1. The duration of the design storm shall be equal to the time of concentration of the tributary area.

Time of concentration shall be calculated using the following formula:

$$T_c = T_i + T_t$$

Where:
T_c = Time of concentration
T_i = Inlet time
T_t = Travel time

Inlet time is the time required for runoff to be conveyed from the most remote location in the watershed to the channelized system. Inlet time shall be calculated using the following formula:

$$T_i = (1.8*(1.1-C)*D^{1/2})/S^{1/3}$$

Where:
C = Rational method runoff coefficient
D = Overland flow distance (300 feet maximum)
S = Slope of tributary area in percent

Inlet time shall be greater than or equal to 5 minutes and less than 15 minutes.

Travel time is the time required for runoff to be conveyed through the channelized system within the watershed. Travel time shall be calculated using Manning's equation. Travel time may include flow in street gutters, swales, open channels, and enclosed pipe systems.

II.1.2 Hydrograph Methods. Numerous hydrograph methods and computer programs are available and it is not the intention of these criteria to include an approved list. Developer shall use methods acceptable to the City.

The design storm duration shall be of adequate length to evaluate the entire watershed area. If detention/retention basins are being considered, the design storm duration shall be a minimum of 24 hours. If detention/retention basins are not being evaluated, the design storm shall be of adequate length to calculate a peak flow rate assuming the whole watershed is contributing runoff. Generally, the duration must be greater than two times the time of concentration of the watershed.

The design storm distribution shall be acceptable to the City. A composite storm developed from the intensity-duration-frequency curves in Table 1 was used to estimate peak flows in the Stormwater Master Plan and is shown in Table 2. Another widely used distribution is the SCS Type II distribution shown in Table 3.

II.2. Drainage System Design

II.2.1. Return Frequencies. Drainage system components shall be designed to convey peak flow rates and volumes resulting from the following design storm return frequencies:

Design Storm Return Frequencies	
10 or 25 year	Enclosed drainage systems
50 year	Crossings of collector roads
100 year	Open channels, crossings of arterials, overflow channels, and emergency spillways

II.2.2 Capacities. Drainage system capacities shall be calculated as follows.

II.2.2.1. Gravity Flow Conditions. New enclosed drainage systems shall be designed for gravity flow conditions. Capacity shall be calculated using Manning's equation:

$$Q=(1.49*A*R^{2/3}*S^{1/2})/n$$

Where:

Q = Flow in cubic feet per second

A = Cross-sectional area of flow in square feet
R = Hydraulic radius which is the cross-sectional area divided by the wetted perimeter in feet
S = Slope of the energy grade line in feet per feet
n = Manning's roughness coefficient, see below

Manning's Roughness Coefficient, n	
Type of Channel	n
Closed Conduits	
Reinforced Concrete Pipe	0.013
Reinforce Concrete Elliptical Pipe	0.013
22/3 x 1/2 inch Annular Corrugations Metal Pipe, unpaved	0.024
22/3 x 1/2 inch Annular Corrugations Metal Pipe, paved invert	0.021
3 x 1 inch Annular Corrugations Metal Pipe, unpaved	0.027
3 x 1 inch Annular Corrugations Metal Pipe, paved invert	0.023
6 x 2 inch Annular Corrugations Metal Pipe, unpaved	0.033
6 x 2 inch Annular Corrugations Metal Pipe, paved invert	0.028
Vitrified Clay Pipe	0.013
Asbestos Cement Pipe	0.012
Stone Arch	0.025
Open Channels (Lined)	
Gabions	0.025
Concrete trowel finish	0.013
Concrete float finish	0.015
Concrete, unfinished	0.017
Concrete, bottom float finished with sides of Dressed Stone	0.017

Concrete, bottom float finished sides of Random Stone	0.020
Concrete, bottom float finished sides of Cement Rubble masonry	0.025
Concrete, bottom float finished sides of Dry Rubble or Riprap	0.030
Gravel bottom, sides of Random Stone	0.023
Gravel bottom, sides of Riprap	0.030
Grass (Sod)	0.030
Riprap	0.035
Grouted Riprap	0.030
Open Channels (Unlined) Excavated or Dredged	
Earth, straight and uniform	0.027
Earth, winding and sluggish	0.035
Channels, not maintained, weeds and brush uncut	0.090
Natural Stream	
Clean stream, straight	0.030
Stream with pools, sluggish reaches, heavy underbrush	0.100
Flood Plains	
Grass, no brush	0.030
With some brush	0.090
Street Curbing	0.014

For materials or conditions not included above, refer to Chow's Open Channel Hydraulics.

II.2.2.3. Surcharge Systems. Existing systems may be evaluated for surcharge conditions, if the following conditions are met:

1. The Hydraulic Grade Line (HGL) must be 0.5 feet below any openings to the ground or street at all locations.
2. Pipe joints are capable of withstanding internal surcharge pressure.

Surcharge capacity shall be determined using Bernoulli's equation accounting for friction losses and minor losses.

II.2.3. Enclosed System Size Requirements. Minimum pipe diameter shall be 15 inches.

Enclosed pipe systems shall be used to convey runoff when peak flows can be conveyed in a 72 inch or smaller diameter concrete pipe. If larger pipe sizes are required, flows can be conveyed either in an enclosed system or open channels.

II.2.3.1. Enclosed System Velocities. Velocities shall be a minimum of 3 feet per second and a maximum of 15 feet per second.

II.2.3.2. Outlet Velocities. The following tables shall be used to determine allowable outlet velocities and erosion control requirements.

II.2.3.2.1. Unimproved (Natural) Receiving Channels. Soil types in Leavenworth are predominantly silty or clay loam, with some sandy loam. For unimproved receiving channels, the following table shows allowable velocities.

Maximum Permissible Velocities for Unimproved Channels of Small Slope

Soil Type	Manning's n	Permissible Clear Water Velocity, ft/s	Permissible Silty Water Velocity, ft/s
Silt loam, noncolloidal	0.020	2.00	3.00
Stiff clay, very colloidal	0.025	3.75	5.00
Sandy loam, noncolloidal	0.020	1.75	2.50
Ordinary firm loam	0.020	2.50	3.50
Alluvial silts, colloidal	0.025	3.75	5.00
Shales and hardpan	0.025	6.00	6.00
Fine sand, colloidal	0.020	1.50	2.50
Fine gravel	0.0205	2.50	5.00

Graded loam to cobbles when noncolloidal	0.030	3.75	5.00
Graded silts to cobbles when colloidal	0.030	4.00	5.50
Coarse gravel, noncolloidal	0.025	4.00	6.00
Cobbles	0.035	5.00	5.50

Where outlet velocities exceed permissible velocities shown above, energy dissipation or channel lining will be required.

II.2.3.2.2. Improved Receiving Channels. If the receiving stream is an improved channel with lining, the following tables shall be used to determine permissible outlet velocities.

II.2.3.2.3. Grass Lined

Permissible Velocities for Channels Lined with Grass		
Cover	Slope Range, %	Permissible Velocity, ft/s
Bermuda grass	0-5 5-10 >10	6 5 4
Buffalo grass, Kentucky bluegrass, blue grama	0-5 5-10 >10	5 4 3
Grass mixture	0-5 5-10 >10	4 3 do not use

II.2.3.2.2.1. Other Types of Channel Lining. This table provides general guidelines for permissible outlet velocities for the various types of channel lining. The lining material shall be designed specifically for the conditions encountered.

Permissible Velocities for Other Types of Channel Lining	
Material	Permissible Velocity, ft/s
Riprap	5-10

Grouted riprap, gabion revetment, or paved concrete	10-15
Paved concrete or sound in situ bedrock	Over 15

II.2.3.2.3 Easements. Permanent easements shall be dedicated to the City for operation and maintenance of the storm drainage facilities. Easement width shall not be less than 15-feet, or the outside width of the pipe or conveyance structure plus 10 feet; whichever is greater. Easements shall be centered on the pipe. The City Engineer may require wider easements when other utilities are located within the same easement and/or when the depth of cover is greater than 4 feet. Temporary construction easements of sufficient width to provide access for construction shall be acquired when the proposed work is located in areas developed prior to construction.

II.2.3.3 Materials

Pipes shall be constructed of reinforced concrete unless otherwise approved by the City.

II.2.3.3.1. Pipe thickness. Thickness shall be determined based on loading conditions.

II.2.3.3.2. Bedding. Pipe bedding shall be as recommended by pipe manufacturer.

II.2.3.3.3. Trenching and Backfill. Trenching and backfill shall be in accordance with KDOT standards.

II.2.3.3.4. Cover. Minimum cover shall be 30 inches.

II.2.4. Open Channels. Open channel capacities shall be determined using Manning's equation. Constrictions such as bridges and culverts tend to create nonuniform flow conditions; and therefore, design of open channels should include evaluation of backwater conditions. Backwater conditions shall be evaluated using the standard-step backwater procedure or computer models such as HEC-2, SWMM, or other models acceptable to the City.

II.2.4.1. Natural Channels. Drainage improvements may include the use of unimproved natural channels provided the improvements do not significantly alter peak flow rates, velocities, or alignment of the channel, and the provisions of Section II.2.3.1 are met. Existing conditions and post development conditions shall be evaluated. If peak flow rates or velocities are increased significantly, an improved channel shall be provided.

II.2.4.2. Improved Channels. Improved channels shall be used when development will cause significant erosion in existing natural channels.

II.2.4.2.1. Channel Lining. The allowable velocities summarized in Section 2.2 shall apply to improved open channel design.

II.2.4.2.2. Side slopes. Side slopes for improved channels shall not be steeper than:

1. 3 horizontal to 1 vertical for turf lining.
2. 2 horizontal to 1 vertical for other lining materials.
3. Flatter if necessary for slope stability.

II.2.4.2.2.1. Vertical walls. Channels shall be designed to avoid the use of vertical walls. If conditions require the use of vertical walls, they shall be constructed of reinforced concrete, to act as retaining walls, and provisions shall be made for access for maintenance equipment and pedestrians.

II.2.4.2.3. Alignment Changes. Alignment changes shall be achieved by a curve having a minimum radius of:

$$R = (V^2 * W)/(8 * D) \text{ where:}$$

R = Minimum radius of curve along the center line in feet.
V = Design velocity of flow in feet per second
W = Width of channel at water surface in feet
D = Depth of flow in feet

II.2.4.2.4. Freeboard. Channels shall be designed to provide one foot of freeboard for the 100 year flow.

II.2.4.3 Easements. Permanent easements shall be dedicated to the City for operation and maintenance of open channels.

A. Improved Open Channels. Easements shall be as wide as the top of bank width; plus 10 feet on each side. Easements shall be continuous between street right-of-ways. When an improved channel begins or ends at a point other than the right-of-way of a dedicated street, a 15-foot or wider easement graded so as to permit access by truck shall be dedicated from the end of the channel to a street right-of-way.

B. Natural Channels. Natural open channels easements shall be the area between the lines of intersection of the natural ground with a plane 12 inches above the design water surface, plus 10 feet measured horizontally on each side thereof; however the width of the easement shall not be less than 30 feet and the width shall be increased if necessary to permit access by truck along the entire length of the channel.

II.2.5. Manholes and Junction Boxes.

II.2.5.1. Location. Manholes or junction boxes shall be installed at the following locations:

a. All changes in alignment and grade.

b. Changes in conduit size.
c. Branch connections.
d. Probable future connections.
e. Maximum spacing shall be 400 feet for 15 inch pipe, 500 feet for 18 to 36 inch pipe, 600 feet for 42 to 48 inch pipe, and 700 feet for 54 inch and larger pipe.

II.2.5.2. Size. Minimum inside dimensions shall be as follows:

a. 4 feet for 24 inch or less diameter pipe.
b. 5 feet for 27 to 36 inch diameter pipe.
c. 6 feet for 42 to 48 inch diameter pipe.
d. For larger diameter pipe, junction boxes shall be cast-in-place and shall be detailed on the engineering plans.

II.2.6. Culverts.

II.2.6.1. Capacities. Culverts shall be evaluated for both inlet and outlet control. Capacities shall be determined using Federal Highway Administration nomographs or by other means acceptable to the City.

II.2.6.2. Headwalls, Endwalls, and End Sections. Headwalls, endwalls, and/or end sections shall be installed to anchor the culvert and to prevent erosion.

II.2.6.3. Materials. Culverts shall be constructed of reinforced concrete unless otherwise approved by the City.

II.2.6.4. Structural. Culverts shall be designed for the appropriate loading conditions.

II.2.6.5. Bedding. Proper bedding and foundation shall be provided.

II.2.6.6. Trenching and Backfill. Trenching and backfill shall be in accordance with KDOT standards.

II.2.7. Inlets, Curbs, and Gutters

II.2.7.1. Allowable Spread. The following table shall be used to determine the allowable spread of runoff in roadways for the appropriate design storm event.

Allowable Spread	
Type of Road	Allowable Inundation
Residential and Lateral	Maximum 6 inches deep at crown
Collector	One lane open
Arterial and Highways	One lane open each direction

II.2.7.2. Curb Capacity. Curb capacity shall be calculated using Izzard's formula:

$$Q=(0.56*z*S^{1/2}*D^{8/3})/n \text{ where:}$$

Q = Flow in cubic feet per second
z = Reciprocal of the average cross-slope, including gutter section, in feet per foot
S = Longitudinal slope of roadway in feet per foot
D = Depth of flow at curb face in feet
n = Manning's "n"

II.2.7.3. Inlets. Inlets shall be designed according to Detail 1 unless otherwise approved by the City. Only curb opening type inlets shall be permitted unless otherwise approved by the City.

II.2.7.3.1. Inlet Capacity. Inlet capacity shall be 80 percent of the theoretical capacity provided in Tables 4-6 and/or Nomographs A through D.

II.2.7.3.2. Inlet Spacing. Maximum inlet spacing shall be 400 feet.

II.2.7.3.4. Inlet Location. Inlets shall be located in sumps where possible. Inlets shall be placed at intersections of cul-de-sacs.

II.2.7.3.5. Hydraulic Grade Line. The hydraulic grade line within the storm drainage system shall be a minimum of 0.5 feet below the minimum inlet opening elevation.

II.2.8. Stormwater Detention. Detention storage can be provided in lieu of off-site drainage improvements. Storage shall be provided so that peak discharge rates are equal to or less than those shown in the Master Plan.

II.2.8.1. Size. Detention basin volume shall be determined by routing a 24-hour design storm. An SCS Type 2 24-hour storm shall be the required storm hyetograph.

II.2.8.2. Principal Spillway. The principal spillway shall be designed to function without requiring attendance or operation of any kind or requiring use of equipment or tools, or any mechanical devices. At least 80 percent of the detention storage volume shall be discharged within 24 hours after the peak flow has entered the basin.

II.2.8.3. Emergency Spillway. The emergency spillway may either be combined with the principal spillway or be a separate structure or channel. Emergency spillways shall be designed so that their crest elevation is 0.5 feet or more above the maximum water surface elevation in the detention facility attained by the 100-year storm.

II.2.8.4. Outlet Works. Outlet works consisting of valves, gates, pipes, and other devices as necessary to completely drain the facility in 72 hours or less shall be provided.

II.2.8.5. Access. Provision shall be made to permit access and use of auxiliary equipment for maintenance.

II.2.8.6. Underground Storage. Underground detention facilities shall be designed with adequate access for maintenance. Such facilities shall be provided with positive gravity outlets. Venting shall be provided.

References:

1. Urban Hydrology for Small Watersheds, Soil Conservation Service, 1986.
2. Section 5600 Storm Drainage Systems and Facilities Kansas City Metropolitan Chapter of the American Public Works Association, March 1990.
3. City of Topeka Design Criteria and Drafting Standards, January 1993.
4. City of Lee's Summit Design and Construction Manual, September 1992.
5. KDOT idf curves
6. Standard Specifications for State Road and Bridge Construction, Kansas Department of Transportation, 1990.
7. Hydraulic Design of Highway Culverts, Federal Highway Administration, September 1985.

Table 1

RAINFALL INTENSITY TABLES FOR COUNTIES IN KANSAS

KANSAS DEPARTMENT OF TRANSPORTATION

Revised, September 1991

RAINFALL INTENSITY TABLES

FOR

COUNTIES IN KANSAS

Developed for the

Kansas Department of Transportation

by

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These tables were developed from data published in Technical Memorandum NWS HYDRO-35 for the U.S. National Weather Service (Frederick et al. 1977) for durations of five (5) minutes through 60 minutes, and Technical Paper No. 40 (TP-40) of the U.S. Weather Bureau (Hershfield 1961) for longer durations as part of:

K-TRAN Research Program
Project KU-92-1

September, 1991

RAINFALL INTENSITY TABLE

LEAVENWORTH COUNTY
KANSAS

THIS TABLE CONTAINS AVERAGE RAINFALL INTENSITIES IN INCHES PER HOUR.

DURATION, HR:MIN	RETURN PERIOD						
	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
0:05	4.63	5.40	6.48	7.26	8.41	9.31	10.20
0:06	4.40	5.15	6.20	6.96	8.08	8.95	9.81
0:07	4.22	4.94	5.97	6.71	7.79	8.64	9.48
0:08	4.05	4.76	5.76	6.48	7.53	8.35	9.17
0:09	3.91	4.59	5.56	6.26	7.28	8.08	8.87
0:10	3.78	4.44	5.38	6.05	7.04	7.81	8.58
0:11	3.66	4.30	5.20	5.86	6.81	7.56	8.30
0:12	3.54	4.16	5.04	5.67	6.60	7.32	8.04
0:13	3.44	4.04	4.89	5.50	6.39	7.09	7.79
0:14	3.33	3.92	4.74	5.34	6.21	6.89	7.57
0:15	3.23	3.80	4.61	5.19	6.04	6.70	7.36
0:16	3.13	3.69	4.48	5.05	5.88	6.53	7.17
0:17	3.04	3.59	4.36	4.92	5.74	6.37	7.00
0:18	2.95	3.49	4.25	4.80	5.60	6.22	6.85
0:19	2.86	3.39	4.15	4.69	5.48	6.09	6.70
0:20	2.78	3.30	4.05	4.58	5.36	5.96	6.56
0:21	2.70	3.22	3.96	4.48	5.25	5.84	6.43
0:22	2.63	3.14	3.87	4.39	5.14	5.73	6.31
0:23	2.56	3.06	3.78	4.30	5.04	5.62	6.19
0:24	2.49	2.99	3.70	4.21	4.94	5.51	6.08
0:25	2.43	2.92	3.63	4.13	4.85	5.42	5.97
0:26	2.37	2.85	3.56	4.05	4.76	5.32	5.87
0:27	2.31	2.79	3.49	3.98	4.68	5.23	5.77
0:28	2.26	2.73	3.42	3.90	4.60	5.14	5.68
0:29	2.21	2.67	3.36	3.84	4.52	5.06	5.59
0:30	2.16	2.62	3.29	3.77	4.45	4.98	5.50
0:31	2.11	2.57	3.24	3.70	4.37	4.90	5.41
0:32	2.07	2.52	3.18	3.64	4.30	4.82	5.33
0:33	2.03	2.47	3.13	3.58	4.24	4.74	5.25
0:34	1.99	2.43	3.07	3.53	4.17	4.67	5.17
0:35	1.95	2.38	3.02	3.47	4.11	4.60	5.10
0:36	1.91	2.34	2.97	3.42	4.05	4.53	5.02
0:37	1.88	2.30	2.93	3.36	3.99	4.47	4.95
0:38	1.85	2.26	2.88	3.31	3.93	4.40	4.88
0:39	1.81	2.23	2.84	3.26	3.87	4.34	4.81
0:40	1.78	2.19	2.80	3.22	3.82	4.28	4.74
0:41	1.75	2.16	2.75	3.17	3.76	4.22	4.68
0:42	1.73	2.12	2.71	3.13	3.71	4.16	4.62
0:43	1.70	2.09	2.68	3.08	3.66	4.11	4.55
0:44	1.67	2.06	2.64	3.04	3.61	4.05	4.49
0:45	1.65	2.03	2.60	3.00	3.56	4.00	4.43

RAINFALL INTENSITY TABLE

LEAVENWORTH COUNTY
KANSAS

THIS TABLE CONTAINS AVERAGE RAINFALL INTENSITIES
IN INCHES PER HOUR.

DURATION, HR:MIN	RETURN PERIOD 1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
0:46	1.62	2.00	2.57	2.96	3.52	3.95	4.38
0:47	1.60	1.97	2.53	2.92	3.47	3.90	4.32
0:48	1.58	1.95	2.50	2.88	3.42	3.85	4.27
0:49	1.56	1.92	2.47	2.84	3.38	3.80	4.21
0:50	1.53	1.90	2.43	2.81	3.34	3.75	4.16
0:51	1.51	1.87	2.40	2.77	3.30	3.70	4.11
0:52	1.49	1.85	2.37	2.74	3.26	3.66	4.06
0:53	1.48	1.82	2.34	2.70	3.22	3.61	4.01
0:54	1.46	1.80	2.32	2.67	3.18	3.57	3.96
0:55	1.44	1.78	2.29	2.64	3.14	3.53	3.91
0:56	1.42	1.76	2.26	2.61	3.10	3.49	3.87
0:57	1.41	1.74	2.23	2.58	3.07	3.44	3.82
0:58	1.39	1.72	2.21	2.55	3.03	3.40	3.78
0:59	1.37	1.70	2.18	2.52	3.00	3.36	3.73
1:00	1.36	1.68	2.16	2.49	2.96	3.33	3.69
1:05	1.29	1.59	2.04	2.36	2.80	3.14	3.49
1:10	1.23	1.51	1.94	2.23	2.65	2.98	3.30
1:15	1.17	1.44	1.85	2.13	2.52	2.83	3.14
1:20	1.12	1.38	1.76	2.03	2.40	2.70	2.99
1:25	1.08	1.32	1.68	1.94	2.30	2.58	2.85
1:30	1.04	1.27	1.62	1.86	2.20	2.46	2.73
1:35	1.00	1.22	1.55	1.78	2.11	2.36	2.62
1:40	0.96	1.18	1.49	1.71	2.03	2.27	2.51
1:45	0.93	1.14	1.44	1.65	1.95	2.19	2.42
1:50	0.90	1.10	1.39	1.59	1.88	2.11	2.33
1:55	0.87	1.06	1.34	1.54	1.82	2.04	2.25
2:00	0.85	1.03	1.30	1.49	1.76	1.97	2.18
2:05	0.82	1.00	1.26	1.44	1.71	1.91	2.11
2:10	0.80	0.97	1.22	1.40	1.66	1.85	2.05
2:15	0.77	0.94	1.19	1.36	1.61	1.80	1.99
2:20	0.75	0.92	1.16	1.32	1.56	1.75	1.94
2:25	0.73	0.89	1.12	1.29	1.52	1.71	1.89
2:30	0.71	0.87	1.10	1.26	1.48	1.66	1.84
2:35	0.69	0.85	1.07	1.22	1.45	1.62	1.79
2:40	0.68	0.82	1.04	1.20	1.41	1.58	1.75
2:45	0.66	0.80	1.02	1.17	1.38	1.55	1.71
2:50	0.64	0.79	0.99	1.14	1.35	1.51	1.67
2:55	0.63	0.77	0.97	1.12	1.32	1.48	1.64
3:00	0.61	0.75	0.95	1.09	1.29	1.45	1.60

RAINFALL INTENSITY TABLE

LEAVENWORTH COUNTY
KANSAS

THIS TABLE CONTAINS AVERAGE RAINFALL INTENSITIES IN INCHES PER HOUR.

DURATION, HR:MIN	RETURN PERIOD 1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
3:15	0.57	0.70	0.89	1.03	1.22	1.36	1.51
3:30	0.54	0.66	0.84	0.97	1.15	1.29	1.43
3:45	0.51	0.63	0.80	0.92	1.09	1.22	1.35
4:00	0.48	0.60	0.76	0.87	1.04	1.16	1.29
4:15	0.46	0.57	0.72	0.83	0.99	1.11	1.23
4:30	0.44	0.54	0.69	0.80	0.95	1.06	1.18
4:45	0.42	0.52	0.66	0.77	0.91	1.02	1.13
5:00	0.40	0.50	0.64	0.74	0.87	0.98	1.09
5:15	0.39	0.48	0.61	0.71	0.84	0.95	1.05
5:30	0.37	0.46	0.59	0.68	0.81	0.91	1.01
5:45	0.36	0.45	0.57	0.66	0.79	0.88	0.98
6:00	0.35	0.43	0.56	0.64	0.76	0.86	0.95
6:30	0.33	0.41	0.52	0.60	0.72	0.81	0.90
7:00	0.31	0.38	0.49	0.57	0.68	0.76	0.85
7:30	0.29	0.36	0.47	0.54	0.65	0.73	0.81
8:00	0.28	0.35	0.45	0.52	0.62	0.69	0.77
8:30	0.27	0.33	0.43	0.49	0.59	0.66	0.74
9:00	0.26	0.32	0.41	0.47	0.57	0.64	0.71
9:30	0.25	0.31	0.39	0.46	0.54	0.61	0.68
10:00	0.24	0.29	0.38	0.44	0.52	0.59	0.65
10:30	0.23	0.28	0.37	0.42	0.50	0.57	0.63
11:00	0.22	0.27	0.35	0.41	0.49	0.55	0.61
11:30	0.21	0.26	0.34	0.39	0.47	0.53	0.59
12:00	0.20	0.25	0.33	0.38	0.45	0.51	0.57
13:00	0.19	0.24	0.31	0.36	0.43	0.48	0.53
14:00	0.18	0.23	0.29	0.34	0.40	0.45	0.50
15:00	0.17	0.21	0.28	0.32	0.38	0.43	0.47
16:00	0.16	0.20	0.26	0.30	0.36	0.41	0.45
17:00	0.15	0.19	0.25	0.29	0.34	0.39	0.43
18:00	0.15	0.18	0.24	0.27	0.33	0.37	0.41
19:00	0.14	0.18	0.23	0.26	0.31	0.35	0.39
20:00	0.13	0.17	0.22	0.25	0.30	0.34	0.37
21:00	0.13	0.16	0.21	0.24	0.29	0.32	0.36
22:00	0.12	0.15	0.20	0.23	0.28	0.31	0.34
23:00	0.12	0.15	0.19	0.22	0.27	0.30	0.33
24:00	0.12	0.14	0.19	0.21	0.26	0.29	0.32

BLACK & VEATCH

MEMORANDUM

Leavenworth, Kansas
Stormwater Master Plan
New Development Plan Review Criteria

B&V Project 26529.110
B&V File W
May 24, 1999

To: Mike McDonald

From: Jeff Henson

New Development Plan Review Policies and Procedures

I. OBJECTIVE

This document lists the policies and procedures to be used by the City in reviewing drainage plans associated with new developments. A new development is defined as a tract of land containing four (4) or more lots to be developed.

II. POLICIES

The following policies relating to storm drainage were adopted by the City as part of the development of a Stormwater Master Plan (Master Plan).

II.1. A drainage report must be submitted by a professional engineer registered in the State of Kansas. The report shall be signed and sealed.

II.2. New Development plans shall include plans for the conveyance of stormwater and shall be signed and sealed by a professional engineer registered in the State of Kansas. The stormwater facilities shall be designed in accordance with design criteria set forth in "Drainage Criteria Manual, City of Leavenworth, Kansas," (Design Criteria) developed as part of the Master Plan.

II.3. Easements for drainage shall be granted to the City for access to underground drainage improvements and along open channels where the flow is greater than which could be conveyed by a 72 inch diameter pipe. Minimum easement requirements are listed in the Design Criteria.

II.4. Curbs and gutters shall be provided on all new roadways.

II.5. Off-site drainage improvements or detention storage shall be provided if peak flow rates resulting from the new development are greater than those shown in the Master Plan.

II.6. Underground drainage systems shall be installed in all areas where the flow can be contained in a 72 inch diameter pipe.

II.7. Systems shall be designed to address State and Federal regulations regarding stormwater quality.

III. PLAN REVIEW PROCEDURES

As part of the site plan approval process, Drainage Plans shall be reviewed by the Engineering staff. The drainage plan submittal shall consist of a Drainage Report and Drainage System Plans.

III.1. Drainage Report. The drainage report shall be submitted by the developer and it shall be signed and sealed by a professional engineer in the State of Kansas. The Drainage Report shall consist of the following:

III.1.1. Assumptions. A listing of the assumptions used in calculation of peak runoff rates and capacities of the proposed system and the existing receiving system.

III.1.2. Topographic Map. A topographic map showing the location of the site. The map shall include a plan of the existing surface features; the proposed development; the proposed drainage system location, size, and capacity; the existing receiving system location, size, and capacity; delineation of tributary areas to points of concentration in the drainage system; and delineation of individual lot drainage patterns. The map shall be at a scale of 1"=100' with 2 foot ground elevation contour lines.

III.1.3. Watershed Information. A table showing the land use, soil type, area, and slope of each tributary area.

III.1.4. Runoff Information. Tables summarizing the runoff characteristics shall be provided. The Rational method shall be used for estimating peak runoff for areas less than 300 acres. A hydrograph method for estimating peak runoff shall be used for areas larger than 300 acres. Computer models such as TR-55, TR-20, HEC-1, or SWMM are acceptable.

III.1.4.1. Rational Method Runoff Information. A table shall be provided showing the Rational method calculations including: cumulative area to the point of concentration, cumulative C value, time of concentration, rainfall intensity, and peak flow rate, drainage system size, and drainage system capacity. These calculations should be provided for both the pre-development and post-development conditions.

III.1.4.2. Hydrograph Method Runoff Information. A table shall be provided showing the runoff information including: drainage areas to each point of concentration, cumulative percent impervious, time of concentration for the watershed, design storm, peak flow rates, drainage system size, and drainage system capacity. These calculations should be provided for both the pre-development and post-development conditions.

III.1.5. Receiving System Information. A comparison of the ultimate development peak flow rate shown in the Master Plan versus the peak flow rate calculated in the report should be made. If the new development increases peak flows above those shown in the Master Plan, then off-site drainage improvements or a detention basin will be required.

III.1.5.1. Off-Site Drainage. Off-site drainage improvements required in section III.1.5. shall be identified in the Drainage Report. A topographic map, watershed information, and runoff information shall be provided for off-site drainage improvements in accordance with sections III.1.1. through III.1.4.

III.1.5.2. Detention Storage. Detention storage can be provided in lieu of off-site drainage improvements. Storage shall be provided so that peak discharge rates are equal to or less than those shown in the Master Plan. A topographic map meeting the requirements of III.1.2 shall be included. Additional items shall include stage-storage-discharge curves, inflow and outflow hydrographs, and spillway configuration and capacity.

III.2. Drainage System Plans. Plan and profile of the drainage system shall be submitted. The drainage system drawings shall be in conformance with the following.

- Plan: 1-inch = 50-feet
- Profile:
  - Vertical: 1-inch = 10-feet
  - Horizontal: 1-inch = 50-feet
- Cross-Sections:
  - Vertical: 1-inch = 10-feet
  - Horizontal: 1-inch = 50-feet

III.3. City Review. Drainage Plans shall be reviewed by Engineering staff. Comments shall be provided to the developer within 60 days of receipt. Building permits shall not be granted until final approval of the Drainage Plans is obtained.

III.4. Construction Inspection. City building inspectors shall verify that the drainage system and site grading are constructed according to plans. Any changes in the plan during construction shall be approved by the City.

III.5. Permit to Occupy. The developer must show proof that the drainage system and site grading were constructed in accordance with plans to receive the permit to occupy. Proof shall consist of a final site survey including spot elevation checks. Verification of any changes to the plans during construction shall also be submitted with the final site survey and shall show altered drainage patterns. Comments shall be provided to the developer within 30 days of receipt of the final site survey.

COMPOSITE METHOD STORMS

RETURN PERIOD = 10 YEARS
RAIN INTERVAL = 15 MINUTES

Storm Duration Hour	Storm Duration Minute	Duration in Min.	Average Intensity rate	Rainfall Actual inches	Rainfall Increment inches	Rainfall Increment rate	Decreasing Intensity rate	Rearranged Intensity rate	Computed Rearranged Rainfall inches	Manually Rearranged Rainfall inches
0	0	0								
0	15	15	5.10	[illegible]	[illegible]	5.20	5.20	0.00	0.00	0.00
0	30	30	3.77	1.88	0.58	[illegible]	[illegible]	0.00	0.00	0.00
0	45	45	3.00	2.25	0.37	1.48	1.48	0.00	0.00	0.00
1	0	60	2.48	2.48	0.24	0.96	0.96	0.00	0.00	0.00
1	15	75	2.11	2.66	0.17	0.68	0.68	0.00	0.00	0.00
1	30	90	1.86	2.79	0.13	0.52	0.52	0.00	0.00	0.00
1	45	105	1.65	2.89	0.10	0.40	0.40	0.00	0.00	0.00
2	0	120	1.49	[illegible]	[illegible]	[illegible]	[illegible]	0.00	0.00	0.00
2	15	135	1.36	[illegible]	0.08	[illegible]	[illegible]	0.00	0.00	0.00
2	30	150	1.26	3.15	[illegible]	[illegible]	[illegible]	0.00	0.00	0.00
2	45	165	1.17	[illegible]	0.07	0.28	[illegible]	0.04	0.01	0.00
3	0	180	1.09	[illegible]	0.05	[illegible]	0.28	0.04	0.01	0.00
3	15	195	1.03	[illegible]	[illegible]	[illegible]	0.28	0.04	0.01	0.00
3	30	210	0.97	[illegible]	0.05	[illegible]	[illegible]	0.04	0.01	0.00
3	45	225	0.92	[illegible]	0.05	0.20	[illegible]	0.04	0.01	0.00
4	0	240	0.87	[illegible]	0.03	0.12	[illegible]	0.04	0.01	0.00
4	15	255	[illegible]	[illegible]	0.05	[illegible]	[illegible]	0.04	0.01	0.00
4	30	270	0.80	[illegible]	[illegible]	0.20	0.24	0.34	0.01	0.01
4	45	285	0.77	[illegible]	[illegible]	0.24	[illegible]	[illegible]	0.02	0.02
5	0	300	[illegible]	1.70	[illegible]	0.16	[illegible]	[illegible]	0.02	0.02
5	15	315	[illegible]	[illegible]	[illegible]	0.12	0.20	[illegible]	0.02	0.02
5	30	330	[illegible]	[illegible]	0.01	0.04	0.20	[illegible]	0.02	0.02
5	45	345	0.66	[illegible]	[illegible]	0.24	0.20	[illegible]	0.02	0.02
6	0	360	0.64	[illegible]	[illegible]	0.16	0.20	[illegible]	0.02	0.02
6	15	375	0.62	[illegible]	[illegible]	0.16	0.20	0.12	0.03	0.03
6	30	390	[illegible]	[illegible]	0.03	0.12	0.20	0.12	0.03	0.03
6	45	405	[illegible]	[illegible]	0.05	0.20	0.16	0.12	0.03	0.03
7	0	420	0.57	[illegible]	[illegible]	0.16	0.16	0.12	0.03	0.03
7	15	435	0.56	4.02	0.05	0.12	0.16	0.12	0.03	0.03
7	30	450	0.54	4.05	0.03	0.12	0.16	0.12	0.03	0.03
7	45	465	0.53	[illegible]	[illegible]	0.24	0.16	0.12	0.03	0.03
8	0	480	0.52	4.16	0.04	[illegible]	0.16	0.16	0.04	0.04
8	15	495	0.51	4.17	0.01	0.04	0.16	0.16	0.04	0.04
8	30	510	0.49	4.17	0.00	0.00	0.12	0.16	0.04	0.04
8	45	525	0.48	[illegible]	[illegible]	0.16	0.12	0.20	0.05	0.05
9	0	540	0.47	4.23	0.03	0.12	0.12	0.20	0.05	0.05
9	15	555	0.47	[illegible]	[illegible]	[illegible]	0.12	0.20	0.05	0.05
9	30	570	0.46	[illegible]	[illegible]	[illegible]	[illegible]	0.20	0.05	0.05
9	45	585	0.45	[illegible]	[illegible]	[illegible]	0.12	0.24	0.06	0.06
10	0	600	0.44	[illegible]	0.01	0.04	0.12	0.24	0.06	0.06
10	15	615	0.43	[illegible]	0.01	0.04	0.12	0.28	0.07	0.07
10	30	630	0.42	[illegible]	[illegible]	[illegible]	0.12	0.28	0.07	0.07
10	45	645	0.42	[illegible]	[illegible]	[illegible]	0.12	[illegible]	0.08	0.08
11	0	660	0.41	4.51	0.05	0.20	0.12	[illegible]	0.09	0.09
11	15	675	0.40	[illegible]	0.01	0.00	0.12	0.52	0.13	0.13
11	30	690	0.39	[illegible]	0.01	0.00	0.12	0.96	0.24	0.24
11	45	705	[illegible]	4.52	0.04	0.16	0.12	[illegible]	0.59	0.59
12	0	720	[illegible]	[illegible]	0.04	0.16	[illegible]	5.20	1.30	[illegible]
12	15	735	[illegible]	[illegible]	0.03	0.12	[illegible]	1.48	0.37	0.37
12	30	750	[illegible]	4.63	0.03	0.12	[illegible]	0.68	0.17	0.17
12	45	765	0.37	4.65	0.03	0.12	[illegible]	0.40	0.10	0.10
13	0	780	[illegible]	4.68	0.03	0.12	[illegible]	[illegible]	0.09	0.09
13	15	795	0.36	4.70	[illegible]	[illegible]	[illegible]	[illegible]	0.08	0.08
13	30	810	0.35	4.73	[illegible]	[illegible]	[illegible]	[illegible]	0.07	0.07
13	45	825	0.35	4.74	0.02	[illegible]	[illegible]	[illegible]	0.07	0.07
14	0	840	[illegible]	4.76	0.02	[illegible]	[illegible]	0.24	0.06	0.06
14	15	855	[illegible]	4.77	0.01	0.04	[illegible]	0.20	0.05	0.05
14	30	870	[illegible]	[illegible]	0.01	0.04	[illegible]	0.20	0.05	0.05
14	45	885	0.33	[illegible]	0.01	0.04	0.04	0.20	0.05	0.05
15	0	900	0.32	[illegible]	0.01	0.04	0.04	0.20	0.05	0.05
15	15	915	0.32	[illegible]	[illegible]	0.00	[illegible]	0.16	0.04	0.04
15	30	930	0.31	4.81	[illegible]	0.00	[illegible]	0.16	0.04	0.04
15	45	945	0.31	[illegible]	[illegible]	[illegible]	0.04	0.16	0.04	0.04
16	0	960	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.16	0.04	0.04
16	15	975	[illegible]	[illegible]	0.03	0.12	0.04	0.12	0.03	0.03
16	30	990	[illegible]	[illegible]	0.03	0.12	0.04	0.12	0.03	0.03
16	45	1005	[illegible]	[illegible]	0.03	0.12	0.04	0.12	0.03	0.03
17	0	1020	[illegible]	[illegible]	0.03	0.12	0.04	0.12	0.03	0.03
17	15	1035	[illegible]	[illegible]	0.01	0.00	0.04	0.12	0.03	0.03
17	30	1050	[illegible]	[illegible]	0.03	[illegible]	0.04	0.12	0.03	0.03
17	45	1065	[illegible]	[illegible]	0.03	[illegible]	0.04	0.12	0.03	0.03
18	0	1080	[illegible]	[illegible]	0.02	0.00	0.04	0.08	0.02	0.02
18	15	1095	[illegible]	[illegible]	[illegible]	[illegible]	0.04	[illegible]	0.02	0.02
18	30	1110	0.27	4.90	0.02	[illegible]	0.04	0.08	0.02	0.02
18	45	1125	0.26	4.92	0.02	[illegible]	0.00	0.08	0.02	0.02
19	0	1140	0.26	4.94	0.02	[illegible]	0.00	0.08	0.02	0.02
19	15	1155	0.26	[illegible]	0.02	[illegible]	0.00	0.04	0.01	0.01
19	30	1170	0.26	4.97	0.02	0.08	0.00	0.04	0.01	0.00
19	45	1185	0.25	4.99	0.01	0.04	0.00	0.04	0.01	0.00
20	0	1200	0.25	5.00	0.01	0.04	0.00	0.04	0.01	0.00
20	15	1215	0.25	5.01	0.01	0.04	0.00	0.04	0.01	0.00
20	30	1230	0.25	[illegible]	0.01	0.04	0.00	0.04	0.01	0.00
20	45	1245	0.24	5.03	0.01	0.04	0.00	0.04	0.01	0.00
21	0	1260	0.24	5.04	0.01	0.04	0.00	0.04	0.01	0.00
21	15	1275	0.24	5.05	0.01	0.04	0.00	0.00	0.00	0.00
21	30	1290	0.24	5.05	0.01	0.04	0.00	0.00	0.00	0.00
21	45	1305	0.23	5.06	0.00	0.00	0.00	0.00	0.00	0.00
22	0	1320	0.23	5.06	0.00	0.00	0.00	0.00	0.00	0.00
22	15	1335	0.23	5.06	0.00	0.00	0.00	0.00	0.00	0.00
22	30	1350	0.23	5.06	0.00	0.00	0.00	0.00	0.00	0.00
22	45	1365	0.22	5.06	0.00	0.00	0.00	0.00	0.00	0.00
23	0	1380	0.22	5.06	0.00	0.00	0.00	0.00	0.00	0.00
23	15	1395	0.22	5.06	0.00	0.00	0.00	0.00	0.00	0.00
23	30	1410	0.22	[illegible]	0.00	0.00	0.00	0.00	0.00	0.00
23	45	1425	0.21	[illegible]	0.01	0.00	0.00	0.00	0.00	0.00
24	0	1440	0.21	5.04	0.01	0.00	0.00	0.00	0.00	0.00
								Total rain inches	5.18	5.04

COMPOSITE METHOD STORMS

RETURN PERIOD = 100 YEARS
RAIN INTERVAL = 15 MINUTES

Storm Duration Hour	Storm Duration Minute	Duration in Min.	Average Intensity rate	Rainfall Actual inches	Rainfall Increment inches	Rainfall Increment rate	Decreasing Intensity rate	Rearranged Intensity rate	Computed Rearranged Rainfall inches	Manually Rearranged Rainfall inches
0	0	0								
0	15	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0	30	30	5.5	2.75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0	45	45	[illegible]	[illegible]	0.57	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	0	60	[illegible]	[illegible]	[illegible]	1.40	1.40	[illegible]	[illegible]	[illegible]
1	15	75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	30	90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
								Total rain inches	7.77	7.66

COMPOSITE METHOD STORMS

RETURN PERIOD = 500 YEARS
RAIN INTERVAL = 15 MINUTES

Storm Duration Hour	Storm Duration Minute	Duration in Min.	Average Intensity rate	Rainfall Actual inches	Rainfall Increment inches	Rainfall Increment rate	Decreasing Intensity rate	Rearranged Intensity rate	Computed Rearranged Rainfall inches	Manually Rearranged Rainfall inches
0	0	0								
0	15	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	30	1410	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	45	1425	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	0	1440	0.41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
								Total rain inches	10.5	[illegible]

Table 2

Table 3

SCS TYPE II DISTRIBUTION DESIGN STORM METHOD

RETURN PERIOD = 10 YEARS
STORM DURATION = 24 HOURS
P* RAINFALL DEPTH 5.04 INCHES
NWS ADJUSTMENT** = 1

NONDIMENSIONAL TIME fract of 24 hr	RAINFALL Px/P24 **	Cumulative Minutes	Accumu. Rainfall inches	Increment Rainfall inches	Adjusted Rainfall inches
0	0	0	0.000	0.000	0.000
0.01	0.002	14	0.010	0.010	0.010
0.021	0.005	30	0.025	0.015	0.015
0.031	0.008	45	0.040	0.015	0.015
0.042	0.011	60	0.055	0.015	0.015
0.052	0.014	75	0.071	0.015	0.015
0.063	0.017	91	0.086	0.015	0.015
0.073	0.02	105	0.101	0.015	0.015
0.083	0.023	120	0.116	0.015	0.015
0.094	0.026	135	0.131	0.015	0.015
0.104	0.029	150	0.146	0.015	0.015
0.115	0.032	166	0.161	0.015	0.015
0.125	0.035	180	0.177	0.015	0.015
0.135	0.038	194	0.192	0.015	0.015
0.146	0.041	210	0.207	0.015	0.015
0.156	0.044	225	0.222	0.015	0.015
0.167	0.048	240	0.242	0.020	0.020
0.177	0.052	255	0.262	0.020	0.020
0.188	0.056	271	0.282	0.020	0.020
0.198	0.06	285	0.302	0.020	0.020
0.208	0.064	300	0.323	0.020	0.020
0.219	0.068	315	0.343	0.020	0.020
0.229	0.072	330	0.363	0.020	0.020
0.24	0.076	346	0.383	0.020	0.020
0.25	0.08	360	0.403	0.020	0.020
0.26	0.085	374	0.429	0.025	0.025
0.271	0.09	390	0.454	0.025	0.025
0.281	0.095	405	0.479	0.025	0.025
0.292	0.1	420	0.504	0.025	0.025
0.302	0.105	435	0.529	0.025	0.025
0.313	0.11	451	0.554	0.025	0.025
0.323	0.115	465	0.580	0.025	0.025
0.333	0.12	480	0.605	0.025	0.025
0.344	0.126	495	0.635	0.030	0.030
0.354	0.133	510	0.670	0.035	0.035
0.365	0.14	526	0.706	0.035	0.035
0.375	0.147	540	0.741	0.035	0.035
0.385	0.155	554	0.781	0.040	0.040
0.396	0.163	570	0.822	0.040	0.040
0.406	0.172	585	0.867	0.045	0.045
0.417	0.181	600	0.912	0.045	0.045
0.427	0.191	615	0.963	0.050	0.050
0.438	0.203	631	1.023	0.060	0.060
0.448	0.219	645	1.099	0.076	0.076
0.458	0.236	660	1.199	0.091	0.091
0.469	0.257	675	1.295	0.106	0.106
0.479	0.283	690	1.426	0.131	0.131
0.49	0.387	706	1.950	0.524	0.524
0.5	0.663	720	3.342	1.391	1.391
0.51	0.707	734	3.563	0.222	0.222
0.521	0.735	750	3.704	0.141	0.141
0.531	0.758	765	3.820	0.116	0.116
0.542	0.776	780	3.911	0.091	0.091
0.552	0.791	795	3.987	0.076	0.076
0.563	0.804	811	4.052	0.066	0.066
0.573	0.815	825	4.108	0.055	0.055
0.583	0.825	840	4.158	0.050	0.050
0.594	0.834	855	4.203	0.045	0.045
0.604	0.842	870	4.244	0.040	0.040
0.615	0.849	886	4.279	0.035	0.035
0.625	0.856	900	4.314	0.035	0.035
0.635	0.863	914	4.350	0.035	0.035
0.646	0.869	930	4.380	0.030	0.030
0.656	0.875	945	4.410	0.030	0.030
0.667	0.881	960	4.440	0.030	0.030
0.677	0.887	975	4.470	0.030	0.030
0.688	0.893	991	4.501	0.030	0.030
0.698	0.898	1005	4.526	0.025	0.025
0.708	0.903	1020	4.551	0.025	0.025
0.719	0.908	1035	4.576	0.025	0.025
0.729	0.913	1050	4.602	0.025	0.025
0.74	0.918	1066	4.627	0.025	0.025
0.75	0.922	1080	4.647	0.020	0.020
0.76	0.926	1094	4.667	0.020	0.020
0.771	0.93	1110	4.687	0.020	0.020
0.781	0.934	1125	4.707	0.020	0.020
0.792	0.938	1140	4.728	0.020	0.020
0.802	0.942	1155	4.748	0.020	0.020
0.813	0.946	1171	4.768	0.020	0.020
0.823	0.95	1185	4.788	0.020	0.020
0.833	0.953	1200	4.803	0.015	0.015
0.844	0.956	1215	4.818	0.015	0.015
0.854	0.959	1230	4.833	0.015	0.015
0.865	0.962	1246	4.848	0.015	0.015
0.875	0.965	1260	4.864	0.015	0.015
0.885	0.968	1274	4.879	0.015	0.015
0.896	0.971	1290	4.894	0.015	0.015
0.906	0.974	1305	4.909	0.015	0.015
0.917	0.977	1320	4.924	0.015	0.015
0.927	0.98	1335	4.939	0.015	0.015
0.938	0.983	1351	4.954	0.015	0.015
0.948	0.986	1365	4.969	0.015	0.015
0.958	0.989	1380	4.985	0.015	0.015
0.969	0.992	1395	5.000	0.015	0.015
0.979	0.995	1410	5.015	0.015	0.015
0.99	0.998	1426	5.030	0.015	0.015
1	1	1440	5.040	0.010	0.010

* NWS Adjustment of point rainfall depth to average over an area from 1967 B&V report, contributing drainage area,acres 10,000

** Px/P24 is the ratio of accumulated rainfall at time 'x' to the accumulated rainfall in 24 hours

Total rain, inches 5.040

SCS TYPE II DISTRIBUTION DESIGN STORM METHOD

RETURN PERIOD = 100 YEARS
STORM DURATION = 24 HOURS
P* RAINFALL DEPTH 7.68 INCHES
NWS ADJUSTMENT** = 1

NONDIMENSIONAL TIME fract of 24 hr	RAINFALL Px/P24 **	Cum. Min	Accumu. Rainfall inches	Increment Rainfall inches	Adjusted Rainfall inches
0	0	0	0.000	0.000	0.000
0.01	0.002	14	0.015	0.015	0.015
0.021	0.005	30	0.038	0.023	0.023
0.031	0.008	45	0.061	0.023	0.023
0.042	0.011	60	0.084	0.023	0.023
0.052	0.014	75	0.108	0.023	0.023
0.063	0.017	91	0.131	0.023	0.023
0.073	0.02	105	0.154	0.023	0.023
0.083	0.023	120	0.177	0.023	0.023
0.094	0.026	135	0.200	0.023	0.023
0.104	0.029	150	0.223	0.023	0.023
0.115	0.032	166	0.246	0.023	0.023
0.125	0.035	180	0.269	0.023	0.023
0.135	0.038	194	0.292	0.023	0.023
0.146	0.041	210	0.315	0.023	0.023
0.156	0.044	225	0.338	0.023	0.023
0.167	0.048	240	0.369	0.031	0.031
0.177	0.052	255	0.399	0.031	0.031
0.188	0.056	271	0.430	0.031	0.031
0.198	0.06	285	0.461	0.031	0.031
0.208	0.064	300	0.492	0.031	0.031
0.219	0.068	315	0.522	0.031	0.031
0.229	0.072	330	0.553	0.031	0.031
0.24	0.076	346	0.584	0.031	0.031
0.25	0.08	360	0.614	0.031	0.031
0.26	0.085	374	0.653	0.038	0.038
0.271	0.09	390	0.691	0.038	0.038
0.281	0.095	405	0.730	0.038	0.038
0.292	0.1	420	0.768	0.038	0.038
0.302	0.105	435	0.806	0.038	0.038
0.313	0.11	451	0.845	0.038	0.038
0.323	0.115	465	0.883	0.038	0.038
0.333	0.12	480	0.922	0.038	0.038
0.344	0.126	495	0.968	0.046	0.046
0.354	0.133	510	1.021	0.054	0.054
0.365	0.14	526	1.075	0.054	0.054
0.375	0.147	540	1.129	0.054	0.054
0.385	0.155	554	1.190	0.061	0.061
0.396	0.163	570	1.252	0.061	0.061
0.406	0.172	585	1.321	0.069	0.069
0.417	0.181	600	1.390	0.069	0.069
0.427	0.191	615	1.467	0.077	0.077
0.438	0.203	631	1.559	0.092	0.092
0.448	0.219	645	1.674	0.115	0.115
0.458	0.236	660	1.812	0.138	0.138
0.469	0.257	675	1.974	0.161	0.161
0.479	0.283	690	2.173	0.200	0.200
0.49	0.387	706	2.972	0.799	0.799
0.5	0.663	720	5.092	2.120	2.120
0.51	0.707	734	5.430	0.338	0.338
0.521	0.735	750	5.645	0.215	0.215
0.531	0.758	765	5.821	0.177	0.177
0.542	0.776	780	5.960	0.138	0.138
0.552	0.791	795	6.075	0.115	0.115
0.563	0.804	811	6.175	0.100	0.100
0.573	0.815	825	6.259	0.084	0.084
0.583	0.825	840	6.336	0.077	0.077
0.594	0.834	855	6.405	0.069	0.069
0.604	0.842	870	6.467	0.061	0.061
0.615	0.849	886	6.520	0.054	0.054
0.625	0.856	900	6.574	0.054	0.054
0.635	0.863	914	6.628	0.054	0.054
0.646	0.869	930	6.674	0.046	0.046
0.656	0.875	945	6.720	0.046	0.046
0.667	0.881	960	6.766	0.046	0.046
0.677	0.887	975	6.812	0.046	0.046
0.688	0.893	991	6.858	0.046	0.046
0.698	0.898	1005	6.897	0.038	0.038
0.708	0.903	1020	6.935	0.038	0.038
0.719	0.908	1035	6.973	0.038	0.038
0.729	0.913	1050	7.012	0.038	0.038
0.74	0.918	1066	7.050	0.038	0.038
0.75	0.922	1080	7.081	0.031	0.031
0.76	0.926	1094	7.112	0.031	0.031
0.771	0.93	1110	7.142	0.031	0.031
0.781	0.934	1125	7.173	0.031	0.031
0.792	0.938	1140	7.204	0.031	0.031
0.802	0.942	1155	7.235	0.031	0.031
0.813	0.946	1171	7.265	0.031	0.031
0.823	0.95	1185	7.296	0.031	0.031
0.833	0.953	1200	7.319	0.023	0.023
0.844	0.956	1215	7.342	0.023	0.023
0.854	0.959	1230	7.365	0.023	0.023
0.865	0.962	1246	7.388	0.023	0.023
0.875	0.965	1260	7.411	0.023	0.023
0.885	0.968	1274	7.434	0.023	0.023
0.896	0.971	1290	7.457	0.023	0.023
0.906	0.974	1305	7.480	0.023	0.023
0.917	0.977	1320	7.503	0.023	0.023
0.927	0.98	1335	7.526	0.023	0.023
0.938	0.983	1351	7.549	0.023	0.023
0.948	0.986	1365	7.572	0.023	0.023
0.958	0.989	1380	7.596	0.023	0.023
0.969	0.992	1395	7.619	0.023	0.023
0.979	0.995	1410	7.642	0.023	0.023
0.99	0.998	1426	7.665	0.023	0.023
1	1	1440	7.680	0.015	0.015

* NWS Adjustment of point rainfall depth to average over an area from 1967 B&V report, contributing drainage area acres 10,000

** Px/P24 is the ratio of accumulated rainfall at time 'x' to the accumulated rainfall in 24 hours

Total rain, inches 7.680

SCS TYPE II DISTRIBUTION DESIGN STORM METHOD

RETURN PERIOD = 500 YEARS
STORM DURATION = 24 HOURS
P* RAINFALL DEPTH 9.84 INCHES
NWS ADJUSTMENT** = 1

NONDIMENSIONAL TIME fract of 24 hr	RAINFALL Px/P24 **	Cum. Min	Accumu. Rainfall inches	Increment Rainfall inches	Adjusted Rainfall inches
0	0	0	0.000	0.000	0.000
0.01	0.002	14	0.020	0.020	0.020
0.021	0.005	30	0.049	0.030	0.030
0.031	0.008	45	0.079	0.030	0.030
0.042	0.011	60	0.108	0.030	0.030
0.052	0.014	75	0.138	0.030	0.030
0.063	0.017	91	0.167	0.030	0.030
0.073	0.02	105	0.197	0.030	0.030
0.083	0.023	120	0.226	0.030	0.030
0.094	0.026	135	0.256	0.030	0.030
0.104	0.029	150	0.285	0.030	0.030
0.115	0.032	166	0.315	0.030	0.030
0.125	0.035	180	0.344	0.030	0.030
0.135	0.038	194	0.374	0.030	0.030
0.146	0.041	210	0.403	0.030	0.030
0.156	0.044	225	0.433	0.030	0.030
0.167	0.048	240	0.472	0.039	0.039
0.177	0.052	255	0.512	0.039	0.039
0.188	0.056	271	0.551	0.039	0.039
0.198	0.06	285	0.590	0.039	0.039
0.208	0.064	300	0.630	0.039	0.039
0.219	0.068	315	0.669	0.039	0.039
0.229	0.072	330	0.708	0.039	0.039
0.24	0.076	346	0.748	0.039	0.039
0.25	0.08	360	0.787	0.039	0.039
0.26	0.085	374	0.836	0.049	0.049
0.271	0.09	390	0.886	0.049	0.049
0.281	0.095	405	0.935	0.049	0.049
0.292	0.1	420	0.984	0.049	0.049
0.302	0.105	435	1.033	0.049	0.049
0.313	0.11	451	1.082	0.049	0.049
0.323	0.115	465	1.132	0.049	0.049
0.333	0.12	480	1.181	0.049	0.049
0.344	0.126	495	1.240	0.059	0.059
0.354	0.133	510	1.309	0.069	0.069
0.365	0.14	526	1.378	0.069	0.069
0.375	0.147	540	1.446	0.069	0.069
0.385	0.155	554	1.525	0.079	0.079
0.396	0.163	570	1.604	0.079	0.079
0.406	0.172	585	1.692	0.089	0.089
0.417	0.181	600	1.781	0.089	0.089
0.427	0.191	615	1.879	0.098	0.098
0.438	0.203	631	1.998	0.119	0.119
0.448	0.219	645	2.145	0.148	0.148
0.458	0.236	660	2.322	0.177	0.177
0.469	0.257	675	2.529	0.207	0.207
0.479	0.283	690	2.785	0.256	0.256
0.49	0.387	706	3.808	1.023	1.023
0.5	0.663	720	6.524	2.716	2.716
0.51	0.707	734	6.957	0.433	0.433
0.521	0.735	750	7.232	0.276	0.276
0.531	0.758	765	7.459	0.226	0.226
0.542	0.776	780	7.636	0.177	0.177
0.552	0.791	795	7.783	0.148	0.148
0.563	0.804	811	7.911	0.129	0.129
0.573	0.815	825	8.020	0.109	0.109
0.583	0.825	840	8.118	0.098	0.098
0.594	0.834	855	8.207	0.089	0.089
0.604	0.842	870	8.286	0.079	0.079
0.615	0.849	886	8.354	0.069	0.069
0.625	0.856	900	8.423	0.069	0.069
0.635	0.863	914	8.492	0.069	0.069
0.646	0.869	930	8.551	0.059	0.059
0.656	0.875	945	8.610	0.059	0.059
0.667	0.881	960	8.669	0.059	0.059
0.677	0.887	975	8.728	0.059	0.059
0.688	0.893	991	8.787	0.059	0.059
0.698	0.898	1005	8.836	0.049	0.049
0.708	0.903	1020	8.886	0.049	0.049
0.719	0.908	1035	8.935	0.049	0.049
0.729	0.913	1050	8.984	0.049	0.049
0.74	0.918	1066	9.033	0.049	0.049
0.75	0.922	1080	9.072	0.039	0.039
0.76	0.926	1094	9.112	0.039	0.039
0.771	0.93	1110	9.151	0.039	0.039
0.781	0.934	1125	9.191	0.039	0.039
0.792	0.938	1140	9.230	0.039	0.039
0.802	0.942	1155	9.269	0.039	0.039
0.813	0.946	1171	9.309	0.039	0.039
0.823	0.95	1185	9.348	0.039	0.039
0.833	0.953	1200	9.378	0.030	0.030
0.844	0.956	1215	9.407	0.030	0.030
0.854	0.959	1230	9.437	0.030	0.030
0.865	0.962	1246	9.466	0.030	0.030
0.875	0.965	1260	9.496	0.030	0.030
0.885	0.968	1274	9.525	0.030	0.030
0.896	0.971	1290	9.555	0.030	0.030
0.906	0.974	1305	9.584	0.030	0.030
0.917	0.977	1320	9.614	0.030	0.030
0.927	0.98	1335	9.643	0.030	0.030
0.938	0.983	1351	9.673	0.030	0.030
0.948	0.986	1365	9.702	0.030	0.030
0.958	0.989	1380	9.732	0.030	0.030
0.969	0.992	1395	9.761	0.030	0.030
0.979	0.995	1410	9.791	0.030	0.030
0.99	0.998	1426	9.820	0.030	0.030
1	1	1440	9.840	0.020	0.020

* NWS Adjustment of point rainfall depth to average over an area from 1967 B&V report, contributing drainage area,acres 10,000

** Px/P24 is the ratio of accumulated rainfall at time 'x' to the accumulated rainfall in 24 hours

Total rain, inches 9.840

Table 4
CURB INLET CAPACITY
FOR
12.0-FOOT GUTTER SPREAD

GUTTER SLOPE IN PERCENT	GUTTER CAPACITY C.F.S.	CURB INLET DESIGN CAPACITY C.F.S. FOR INLET LENGTH						
		4 FOOT	5 FOOT	6 FOOT	8 FOOT	10 FOOT	11 FOOT	12 FOOT
0.5	2.7	G	G	G	G	G	G	G
1	3.7	G	G	G	G	G	G	G
2	5.3	5.3	G	G	G	G	G	G
3	6.5	5.4	5.6	5.7	G	G	G	G
4	7.5	5.4	5.9	6.0	6.8	7.1	7.3	7.4
6	9.1	5.6	6.4	6.5	7.4	8.1	8.5	8.9
8	10.6	5.7	6.8	6.9	8.0	9.0	9.4	9.8
10	11.8	6.4	7.2	7.9	9.1	10.1	10.6	11.1
12	12.9	7.1	7.9	8.6	10.0	11.2	11.7	12.2
14	14.0	7.6	8.6	9.4	10.8	12.1	12.7	13.2

NOTES & REFERENCES:

1. Inlet capacities derived from "The Design of Stormwater Inlets" Johns Hopkins University, 1956
2. Gutter capacity calculated by Izzard's Equation
3. Inlet capacity is for ¼" per foot street crown and inlet throat and transition geometry per Figure 8-0
4. Gutter deflectors are required for inlets on slopes of 4 percent and steeper.
5. Linear interpolation within the range of the table is permitted for slopes and corresponding capacities not shown.
6. Reduce above theoretical capacities by 20% for clogging allowance per Section 5603.1.B.
7. "G" indicates inlet capacity is greater than gutter capacity and the 20% capacity reduction is not required.

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Section 5600 Storm Drainage Systems and Facilities

Table 5
CURB INLET CAPACITY
FOR
11.5-FOOT GUTTER SPREAD

GUTTER SLOPE IN PERCENT	GUTTER CAPACITY C.F.S.	CURB INLET DESIGN CAPACITY C.F.S. FOR INLET LENGTH						
		4 FOOT	5 FOOT	6 FOOT	8 FOOT	10 FOOT	11 FOOT	12 FOOT
0.5	2.4	G	G	G	G	G	G	G
1	3.3	G	G	G	G	G	G	G
2	4.7	G	G	G	G	G	G	G
3	5.7	5.5	G	G	G	G	G	G
4	6.6	5.3	5.9	6.0	6.3	6.6	6.6	6.6
6	8.1	5.1	6.1	6.5	7.2	7.9	8.1	8.1
8	9.4	5.7	6.3	6.9	8.0	8.9	9.1	9.2
10	10.5	6.3	7.0	7.7	8.9	9.9	10.1	10.3
12	11.5	6.9	7.7	8.4	9.7	10.8	11.1	11.4
14	12.4	7.6	8.5	9.3	10.8	12.0	12.4	12.4

NOTES & REFERENCES:

1. Inlet capacities derived from "The Design of Stormwater Inlets" Johns Hopkins University, 1956
2. Gutter capacity calculated by Izzard's Equation
3. Inlet capacity is for ¼" per foot street crown and inlet throat and transition geometry per Figure 8-0
4. Gutter deflectors are required for inlets on slopes of 4 percent and steeper.
5. Linear interpolation within the range of the table is permitted for slopes and corresponding capacities not shown.
6. Reduce above theoretical capacities by 20% for clogging allowance per Section 5603.1.B.
7. "G" indicates inlet capacity is greater than gutter capacity and the 20% capacity reduction is not required.

From Kansas City Metropolitan Chapter of the
American Public Works Association
Section 5600 Storm Drainage Systems and Facilities

Table 6
CURB INLET CAPACITY
FOR
10.5-FOOT GUTTER SPREAD

GUTTER SLOPE IN PERCENT	GUTTER CAPACITY C.F.S.	CURB INLET DESIGN CAPACITY C.F.S. FOR INLET LENGTH						
		4 FOOT	5 FOOT	6 FOOT	8 FOOT	10 FOOT	11 FOOT	12 FOOT
0.5	1.8	G	G	G	G	G	G	G
1	2.6	G	G	G	G	G	G	G
2	3.7	G	G	G	G	G	G	G
3	4.5	G	G	G	G	G	G	G
4	5.1	4.6	4.8	5.1	G	G	G	G
6	6.3	4.9	5.3	5.7	6.3	7.2	G	G
8	7.3	5.1	5.7	6.3	7.2	G	G	G
10	8.2	5.9	6.6	7.2	8.1	G	G	G
12	8.9	6.3	7.1	7.8	8.9	G	G	G
14	9.6	6.9	7.7	8.4	9.6	G	G	G

NOTES & REFERENCES:

1. Inlet capacities derived from "The Design of Stormwater Inlets" Johns Hopkins University, 1956
2. Gutter capacity calculated by Izzard's Equation
3. Inlet capacity is for ¼" per foot street crown and inlet throat and transition geometry per Figure 8-0
4. Gutter deflectors are required for inlets on slopes of 4 percent and steeper.
5. Linear interpolation within the range of the table is permitted for slopes and corresponding capacities not shown.
6. Reduce above theoretical capacities by 20% for clogging allowance per Section 5603.1.B.
7. "G" indicates inlet capacity is greater than gutter capacity and the 20% capacity reduction is not required.

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Nomograph A

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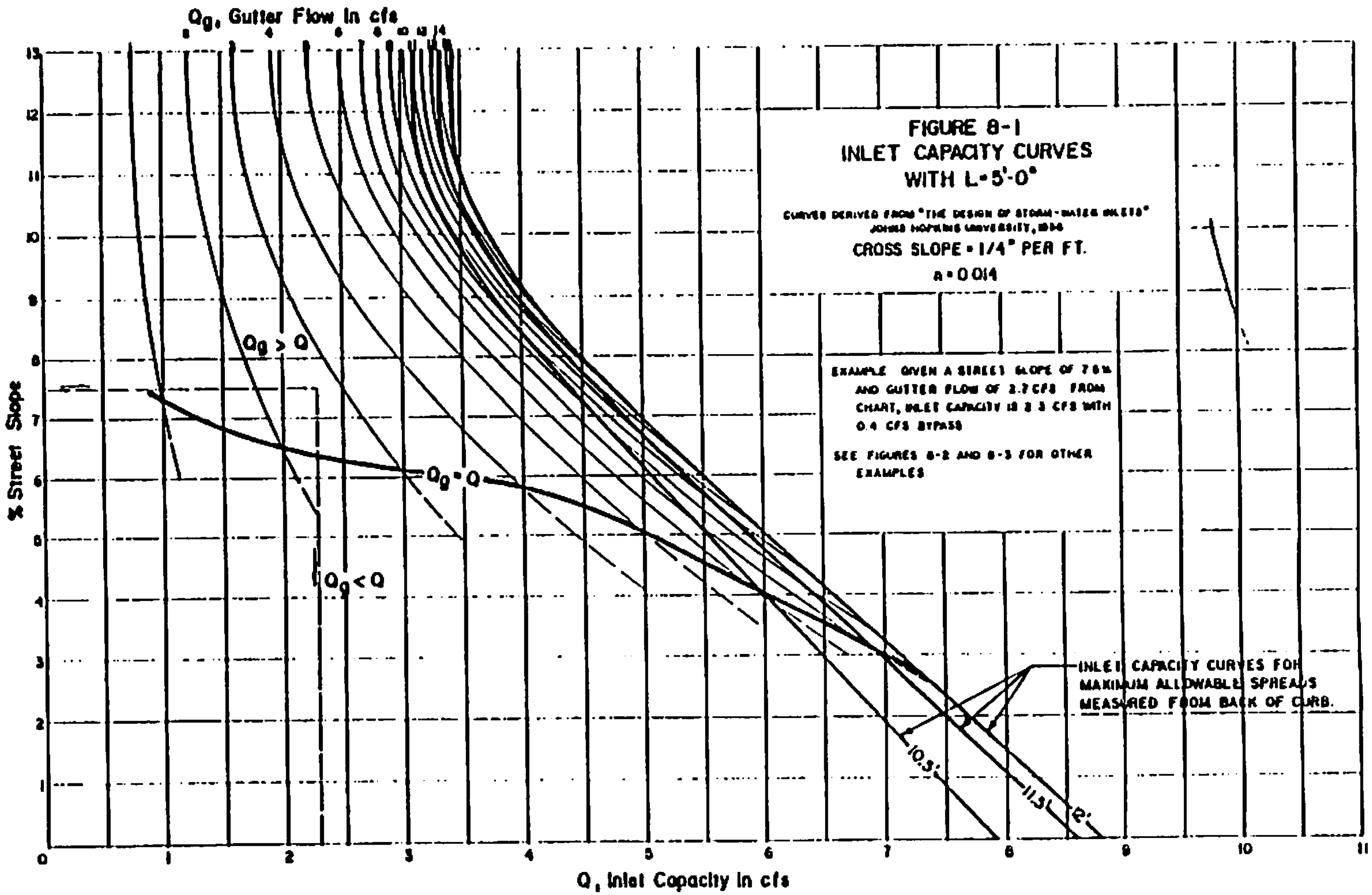

FIGURE 8-1
INLET CAPACITY CURVES
WITH L=5'-0"

CURVES DERIVED FROM "THE DESIGN OF STORM-WATER INLETS" JOHNS HOPKINS UNIVERSITY, 1956

CROSS SLOPE = 1/4" PER FT.

n = 0.014

EXAMPLE GIVEN A STREET SLOPE OF 7.5% AND GUTTER FLOW OF 2.7 CFS FROM CHART, INLET CAPACITY IS 2.3 CFS WITH 0.4 CFS BYPASS

SEE FIGURES 8-2 AND 8-3 FOR OTHER EXAMPLES

INLET CAPACITY CURVES FOR MAXIMUM ALLOWABLE SPREADS MEASURED FROM BACK OF CURB.

Reduce above theoretical capacities by 20% for clogging allowance per Section 5603.1.B.

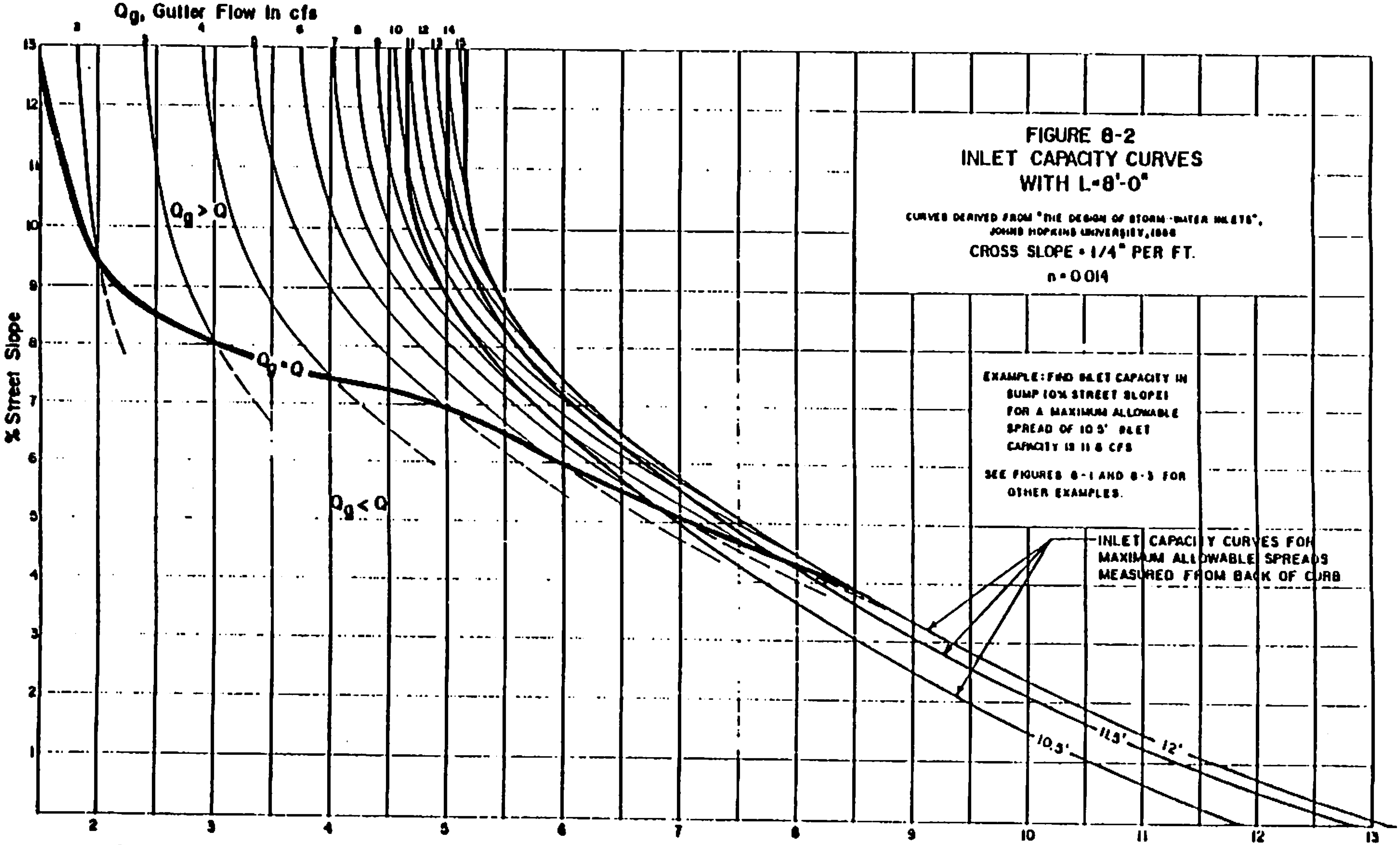

FIGURE 8-2
INLET CAPACITY CURVES
WITH L=8'-0"

CURVES DERIVED FROM "THE DESIGN OF STORM-WATER INLETS",
JOHNS HOPKINS UNIVERSITY, 1956

CROSS SLOPE = 1/4" PER FT.

n = 0.014

EXAMPLE: FIND INLET CAPACITY IN SUMP (0% STREET SLOPE) FOR A MAXIMUM ALLOWABLE SPREAD OF 10.5'. INLET CAPACITY IS 11.6 CFS.

SEE FIGURES 8-1 AND 8-3 FOR OTHER EXAMPLES.

INLET CAPACITY CURVES FOR MAXIMUM ALLOWABLE SPREADS MEASURED FROM BACK OF CURB

Nomograph B

Reduce above theoretical capacities by 20% for clogging allowance per Section 5603.1.B.

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Nomograph C

From Kansas City Metropolitan Chapter of the
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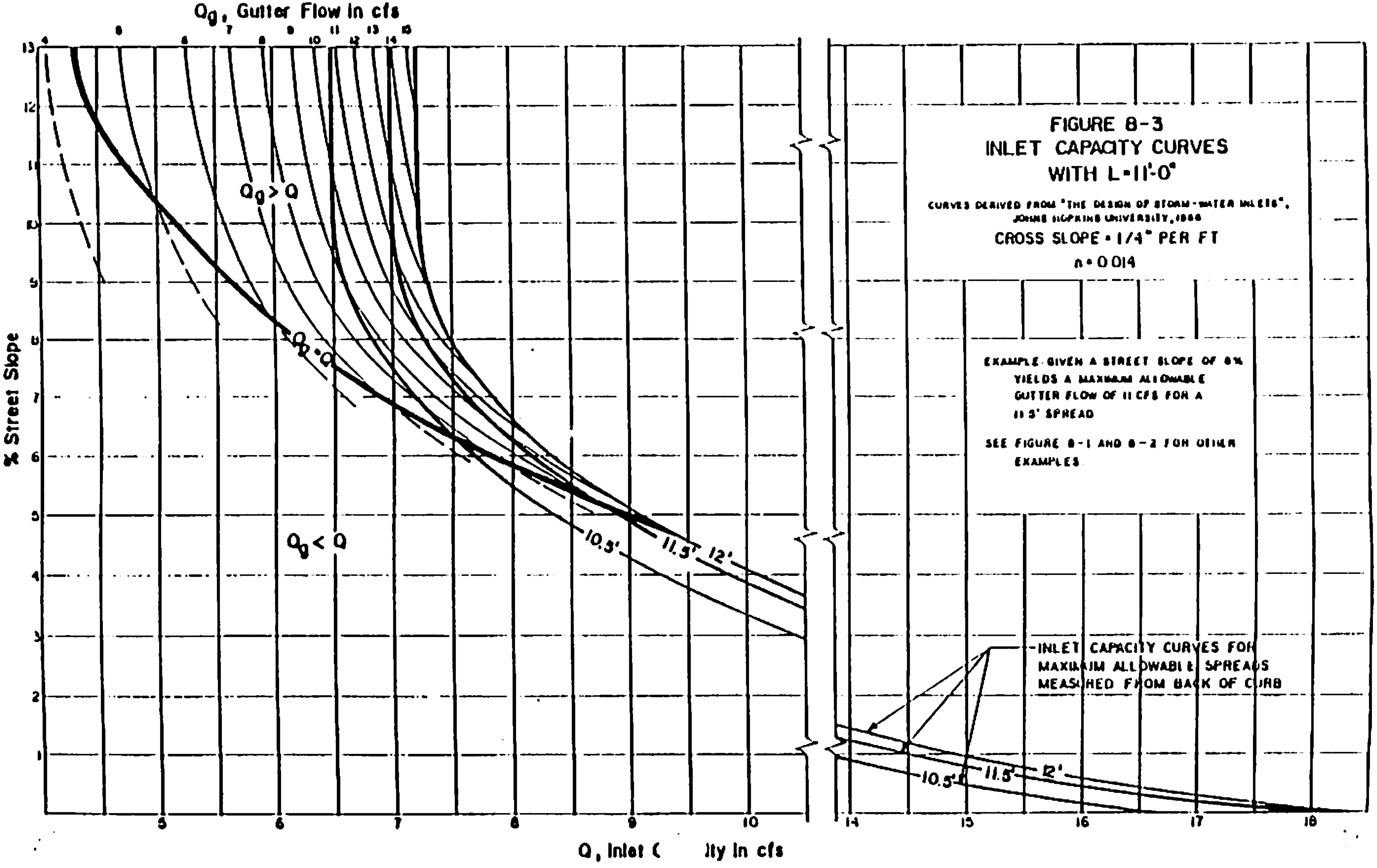


FIGURE 8-3
INLET CAPACITY CURVES
WITH L=11'-0"

CURVES DERIVED FROM "THE DESIGN OF STORM-WATER INLETS", JOHNS HOPKINS UNIVERSITY, 1956

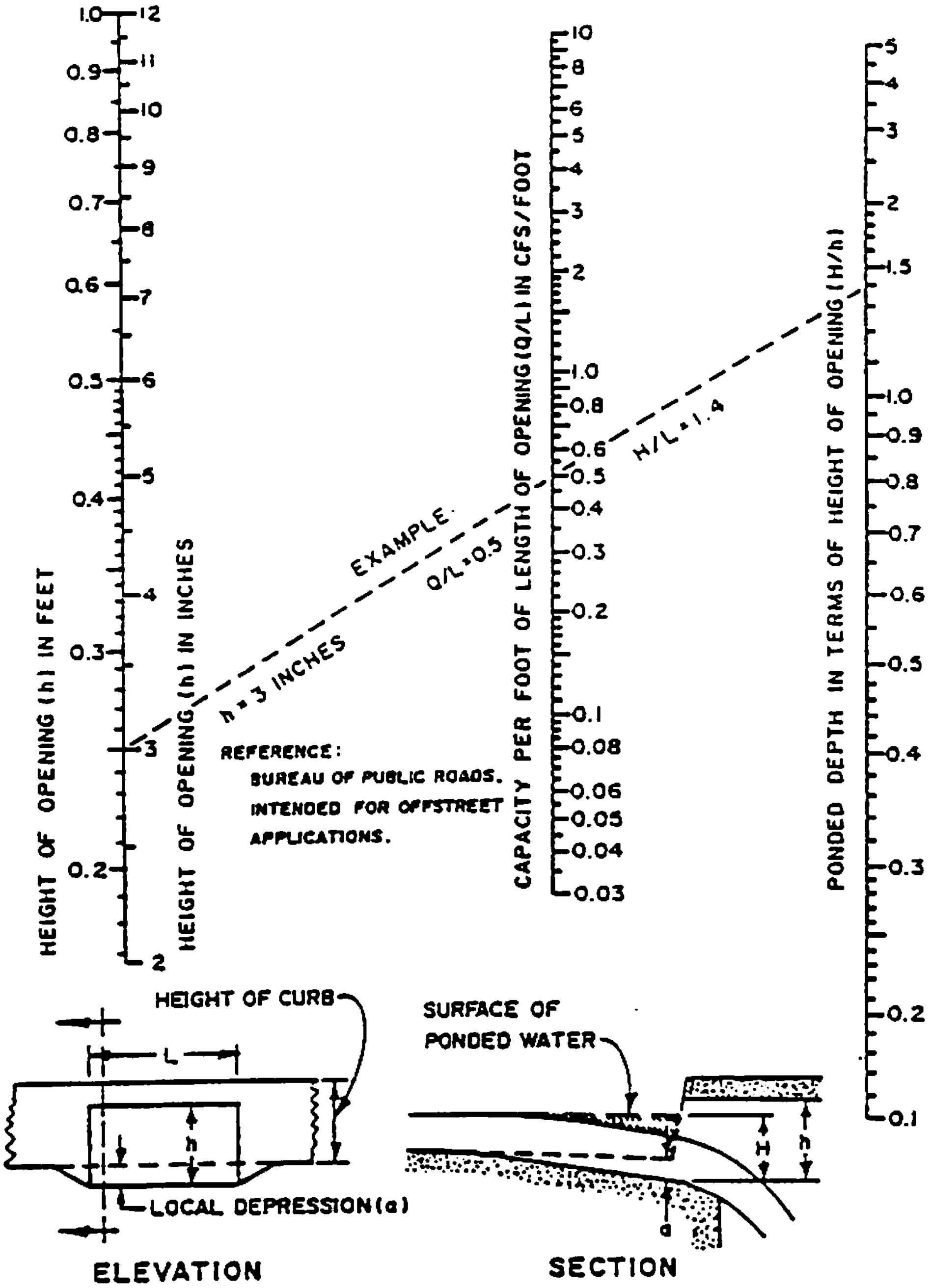
CROSS SLOPE = 1/4" PER FT

n = 0.014

EXAMPLE: GIVEN A STREET SLOPE OF 8% YIELDS A MAXIMUM ALLOWABLE GUTTER FLOW OF 11 CFS FOR A 11.5' SPREAD

SEE FIGURE 8-1 AND 8-2 FOR OTHER EXAMPLES

INLET CAPACITY CURVES FOR MAXIMUM ALLOWABLE SPREADS MEASURED FROM BACK OF CURB



CAPACITY OF CURB OPENING INLET
AT LOW POINT IN GRADE.

FIGURE 8-4

Nomograph D

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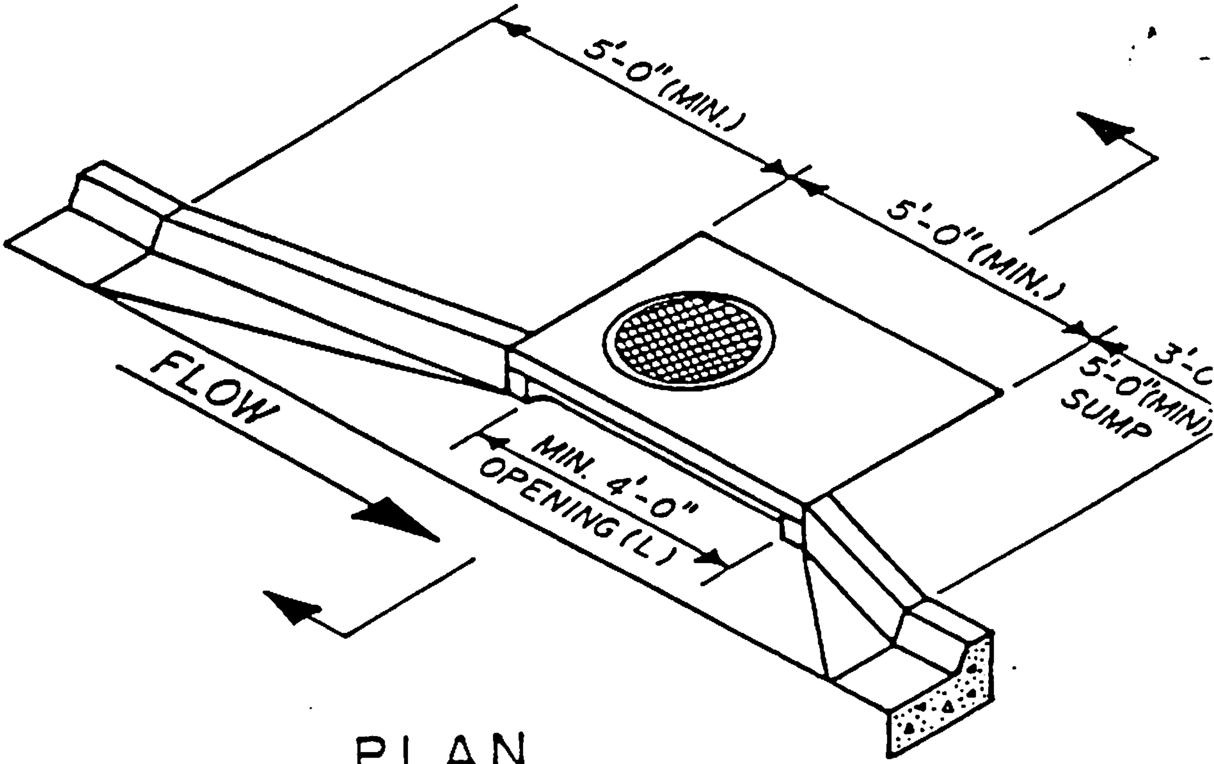
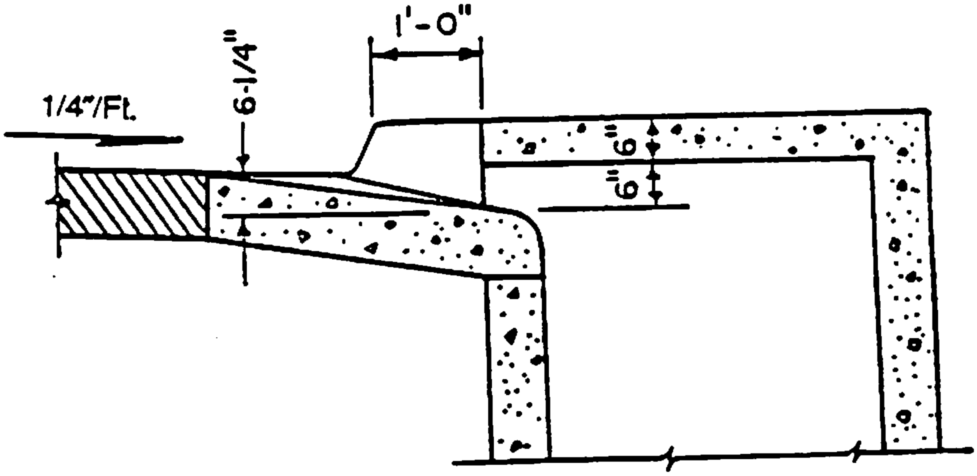


PLAN

NO SCALE



Detail 1

SECTION

NO SCALE

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FIGURE
8-0

CURB INLETS
MINIMUM HYDRAULIC DIMENSIONS