DIVISION V
DESIGN CRITERIA

SECTION 5600 STORM DRAINAGE SYSTEMS AND FACILITIES

APPROVED AND ADOPTED THIS 11th DAY OF JULY, 2005

CITY OF BONNER SPRINGS, KS

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CITY OF BONNER SPRINGS, KANSAS

**SUPPLEMENT TO
KANSAS CITY METROPOLITAN CHAPTER OF THE
APWA STANDARD SPECIFICATION AND DESIGN CRITERIA
SECTION 5600**

This is the City of Bonner Springs, Kansas Supplement to Section 5600 of the Kansas City Metropolitan Chapter of the American Public Works Association, Standard Specifications and Design Criteria (Metro Chapter Standards). The following pages are approved and adopted as replacement to the section and paragraphs of the Metro Chapter Standards. The deletions and additions in the following replacement pages that revise and supplement the Metro Chapter Standards become a part of Section 5600 for use within the City of Bonner Springs, Kansas.

The attached supplement document shall replace in its entirety Section 5600 of the Kansas City Metropolitan Chapter of the American Public Works Association, Standard Specifications and Design Criteria, for use within the City of Bonner Springs, Kansas.

DIVISION V
DESIGN CRITERIA

SECTION 5600 STORM DRAINAGE SYSTEMS AND FACILITIES

SECTION 5601 GENERAL

5601.1 Introduction: This criteria provides uniform procedures for designing and checking the design of storm drainage systems under the rainfall and land characteristics typical of the Kansas City Metropolitan Area. Specific criteria have been developed and are applicable to the types of drainage systems and facilities ordinarily encountered in local urban and suburban areas. Other special situations may be encountered that require added criteria or more complex technology than included herein. Any design procedure conforming to current accepted engineering practice, including the application of computers, may be used for the design of storm drainage systems in lieu of the computation methods presented in this criteria, providing equivalent results are obtained.

5601.2 Definitions:

A. **Bank Line:** The line of intersection, above the normal depth of flow at design capacity, of the side slope of an open channel and the adjacent ground.

B. **City:** The municipality or body having jurisdiction and authority to govern.

C. **City Engineer:** The municipal public works official or body having jurisdiction and authority to review and approve plans and designs for storm drainage systems.

D. **Controlled Area:** That part of the tributary area for which a detention facility is designed to control peak discharge rates.

E. **Detention Storage:** The volume occupied by water above the level of the spillway crest during operation of a storm water detention facility.

F. **Dry Detention Facility:** Any detention facility designed to permit no permanent impoundment of water.

G. **Developer:** Any person, partnership, association, corporation, public agency, or governmental unit proposing to or engaged in "development" as defined below; except the widening, resurfacing, or other improvement to existing streets, alleys, and sidewalks.

H. **Development:** Any activity, including subdivision, that alters the surface of the land to create additional impervious surfaces, including, but not limited to, pavement, buildings, and structures; except:

1. Remodeling, repair, replacement, and improvements to any existing structure or facility and appurtenances that does not cause an increased area of impervious surface on the site in excess of 10 percent of that previously existing.

I. **Easement:** Authorization by a property owner for the use by another for a specified purpose, of any designated part of the property.

J. **Emergency Spillway:** A device or devices used to discharge water under conditions of inflow that exceed the design outflow from a detention facility. The emergency spillway functions primarily to prevent damage to the detention facility that would permit the sudden release of impounded water.

K. **Freeboard:** The difference in elevation between the top of a structure such as a dam or open channel and the maximum design water surface elevation or high water mark. It is an allowance against overtopping by waves or other transient disturbances.

L. **Improved Channel:** Any channel changed by grading or the construction of lining materials as approved by the City Engineer.

M. **Natural Channel:** An existing channel that has not been altered by previous construction.

N. **Owner:** The owner of record of real property.

O. **Principal Spillway:** A device such as an inlet, pipe, weir, etc.., used to discharge water during operation of the facility under the conditions of the 1% or less design storm.

P. **Private Detention Facility:** Any detention facility located on and controlling discharge from a site wholly owned and controlled by one owner and not platted for future subdivision of ownership. Also, all facilities incorporating detention storage of storm water in or on any of the following:

1. Roofs of buildings or structures also used for other purposes.

2. Paved or surfaced areas also used for other purposes.

3. Enclosed or underground pipes or structures on private property when the surface is used for other purposes.

Q. **Public Detention Facility:** Any detention facility controlling discharge from a tributary area owned by more than one owner and/or platted for future subdivision of ownership, except as defined as a private detention facility herein.

R. **Registered Professional Engineer:** A licensed engineer who is registered with and authorized by the "State Board" to practice within the state of registration.

S. **Return Frequency:** The statistical average interval between rainfalls of equal magnitude.

T. **Sediment Storage:** The volume allocated to contain accumulated sediments within a detention facility.

U. **Site:** A tract or contiguous tracts of land owned and/or controlled by a developer or owner. Platted subdivisions, industrial and/or office-commercial parks, and other planned unit developments shall be considered a single site.

V. **Storm Drainage System:** All of the natural and man-made facilities and appurtenances such as ditches, natural channels, pipes, culverts, bridges, open improved channels, street gutters, inlets, and detention facilities which serve to convey surface drainage.

W. **Storm Water Detention Facility:** Any structure, device, or combination thereof with a controlled discharge rate less than its inflow rate.

X. **Tributary Area:** All land draining to the point of consideration, regardless of ownership.

Y. **Wet Detention Facility:** A detention facility that is designed to include permanent storage of water in addition to the temporary storage used to control discharge rates from the facility.

5601.3 **General Requirements:** The design shall be accomplished under the direction of a Registered Professional Engineer. The design shall also be based on land use in the tributary area as zoned, actually developed, or indicated by an adopted future land use plan, whichever basis produces the greatest runoff.

A. **Earth Change Permit:**

1. **Requirements for obtaining Earth Change Permit:** All persons desiring to develop, redevelop, grade, regrade, excavate, landfill, berm or dike land within the City of Bonner Springs are required to obtain an Earth Change Permit and are subject to the following requirements:

a. Tracts of land one (1) acre or greater:

1.) Three (3) copies of the grading and drainage plans shall be submitted along with the Earth Change Permit application to the Planning Department for review and approval by the City Engineer prior to approval of an Earth Change Permit.

2.) A copy of the Notice of Intent (NOI) that has been sent to the Kansas Department of Health and Environment (KDHE).

3.) The filing fee for an Earth Change Permit is $50.00.

b. Tracts of land of less than one (1) acre:

1.) One (1) copy of the grading and drainage plan shall be submitted along with the Earth Change Permit application for review and approval by the City Building Official, City Planner, or City Engineer prior to approval of an Earth Change Permit.

2.) The filing fee of $50.00 is only charged if the City Engineer reviews the plan.

2. **Submittal Requirements:** Required number of copies of the grading and drainage plan as established above is required to obtain the Earth Change Permit. The following must be submitted to meet this requirement:

a. A vicinity sketch of the site for which a permit is requested, including a legal description of such property, and/or a boundary line survey as may be required by the City Engineer.

b. Site drawings indicating each separate land area to be excavated, filled, graded, or leveled, the finished depth of each separate land cut or fill, the present and future (as completed) points of entry and discharge for surface water on the subject property, and identification of all temporary or permanent structures or other devices to be erected or established for the purpose of controlling or regulating surface water and erosion on such property.

c. The applicant's plans for controlling on-site erosion and off-site sedimentation for the purpose of minimizing the deposit of sediment from the tract under application upon any other off-site public or private property or watercourse during all phases of project construction.

d. The applicants plans for receipt of surface water on the subject property and discharge of surface water from the subject property during periods of construction, and a statement specifying the anticipated time period for the completion of all drainage improvements.

3. **Reason for Denial of Earth Change Permit:** Any changes that cause an adverse affect downstream from a property and/or there is a change of hydraulic conveyance of storm water across or from the property may be grounds for denial of the Earth Change Permit and Building Permit.

5601.4 Existing Drainage System: Existing drainage system component pipes, structures, and appurtenances within the project limits may be retained as elements of an improved system providing:

1. They are in sound structural condition.

2. Their hydraulic capacity, including surcharge, is equal to or greater than the capacity required by this criteria.

3. Easements exist or are dedicated to allow operation and maintenance.

Discharge from an existing upstream storm drainage system shall be computed meeting the hydraulic capacity of this criteria. The computed discharge shall be used to design the new downstream system even if the actual capacity of the existing upstream system is less.

5601.5 System Types and Applications:

A. Enclosed Systems: Enclosed systems consisting of underground pipes, culverts, and similar functional underground structures shall be used to convey stormwater at all locations:

1. Where the design peak discharge of a 10% return period storm is equal to or less than the capacity of a 72-inch diameter round pipe having a Manning's "n" of 0.013, and designed in accordance with Section 5604.

2. Within the right-of-way of improved streets, regardless of system design capacity.

3. Within 60-feet of any existing or proposed habitable building, regardless of system design capacity.

4. Where the design peak discharge of a 10% storm equals or exceeds 8 c.f.s. and the collected drainage is generated from more than 1 lot.

Enclosed systems may be used to convey stormwater at all locations where open systems are permitted.

B. **Open Systems:** Open systems consisting of natural and/or improved open channels with intermittent culverts or bridges crossing streets and other surfaced areas may be used to convey stormwater at all locations where the use of an enclosed system is not required by the foregoing criteria.

C. **Stormwater Detention/Retention Facilities:** Detent be provided in connection with the development of:

1. Homes, buildings, or other structures downstream from a proposed development are flooded in a 1% flood.

2. Flood damage problem areas have been identified, or an engineering study as required by Section 5601.6 indicates the proposed development would cause or increase flooding.

These requirements to provide detention apply to all development except when downstream flooding is entirely confined within the limits of the 1% flood plain as defined by the Federal Flood Insurance Study current at the time development is proposed.

D. **Overflow Systems:** Each conveyance element of the stormwater drainage system (whether enclosed or open) shall include an overflow system having sufficient hydraulic capacity when combined with the capacity of the conveyance elements to convey the peak discharge generated by a 1% storm without damage to land or buildings, defined as:

> 1% stage, plus one foot freeboard, at an elevation equal to or greater than the lowest elevation at which water may enter any proposed or existing building or structure.

5601.6 **Waivers:** The City Engineer may waive requirements to provide specific types of stormwater elements as follows:

A. **Detention/Retention Facilities:** Detention may be waived and/or release rates other than those released by Section 5606 may be approved by the City Engineer when:

1. The developer makes arrangements to provide an improved downstream conveyance system of hydraulic capacity meeting the requirements of this criteria.

2. A detention facility would increase the downstream peak rate of discharge by creating a delayed peak.

B. **Study:** The Developer provides an adequate study by a registered professional engineer that quantifies the problems and demonstrates that a waiver of the requirement to provide detention facilities is appropriate.

C. **Overflow Channels:** In previously developed areas, requirements to provide for 1% storm conveyance may be reduced in circumstances where 1% storm protection is not reasonably attainable due to the location of damageable improvements with respect to the drainage system.

5601.7 Other References: Other agencies have criteria and regulations pertaining to drainage systems which may complement this criteria. When conflicts are encountered, the most rigorous criteria shall govern.

A. Federal Insurance Agency - Floodplain Regulations and Implementing Ordinances Adopted By Municipalities: Drainage systems designed within the limits of the designated 100-year storm floodplain on the principal stream shall be designed to convey the flood as defined by applicable published floodplain information studies. For areas located in FIA Zone "A" outside the detailed study area, the Developer shall prepare studies and calculations establishing the floodplain, and floodway elevation and width. These calculations shall be submitted to the reviewing agency for approval.

B. Kansas Department of Agriculture: Rules and regulations of the Water Resources Board shall apply.

5601.8 Return Frequencies: Enclosed and open channel conveyance system components shall be designed for the following return period storms, irrespective of the land use in which the system is located or the land use in the drainage area tributary to the system:

A. In-System Capacity:

1. Floodway in 100-year Flood Plain ………………………………………. 1%
2. Crossing Arterial Streets ………………………………………………… 1%
3. Crossing Collector Streets ……………………………………………….. 2%
4. Crossing Local Streets …………………………………………………… 4%
5. Commercial/Industrial Development ……………………………………. 4%
6. Parks, Greenbelts, Etc. ………………………………………………….. 4%
7. Residential Development ……………………………………………….. 10%

B. Overflow Channels: The combined capacity of the overflow channel and in-system conveyance element shall be sufficient to convey the 1% storm at all locations; except that an overflow depth not exceeding seven (7) inches at the lowest point of the travelled way will be permitted where culverts cross streets.

SECTION 5602 HYDROLOGY AND HYDRAULICS

5602.1 Scope: This section sets forth the hydrologic parameters to be used for computations involving the definition of runoff mass and peak rates to be accommodated by the storm drainage system.

5602.2 Runoff Coefficients: Runoff Coefficients relative to development and land use shall have the following values:

LAND USE/ZONING		AVERAGE PERCENT IMPERVIOUS	AVERAGE PERCENT PERVIOUS	RATIONAL METHOD "C"	S.C.S. CURVE NUMBER
a.	Business				
	Downtown Area	95	5	0.87	96
	Neighborhood Areas	85	15	0.81	94
b.	Residential				
	Single-Family Areas	35	65	0.51	83
	Multi-Family Areas	60	40	0.66	88
	Churches & Schools	75	25	0.75	92
c.	Industrial				
	Light Areas	60	40	0.66	88
	Heavy Areas	80	20	0.78	93
	Parks, Cemeteries	10	90	0.36	77
	Railroad Yard Areas	25	75	0.45	80
d.	Undeveloped Areas				
	Permanent Unimproved Areas, Greenbelts, etc.	0	100	0.3	75
e.	All Surfaces				
	Impervious: asphalt, concrete, roofs, etc.	100	0	0.9	98
	Turfed	0	100	0.3	75
	Wet detention basins	100	0	0.9	98

Land areas not zoned; but whose future land use is defined by an adopted land use plan, shall be assigned runoff coefficients for the land use indicated by such plan. Undeveloped areas designated as agricultural or those for which no specific future land use is indicated shall be assigned a minimum of 35 percent impervious surface for purposes of the design of storm drainage systems. (C = 0.51, CN = 83)

As an alternative to the above coefficients; and for areas not listed above (planned building groups, shopping centers, trailer parks, etc.) a composite runoff coefficient based on the actual percentages of pervious and impervious surfaces shall be used.

5602.3 Rainfall Mass: The U.S. Soil Conservation Service (SCS) Type 2 twenty-two hour rainfall distribution shall be used for all computations that employ the use of rainfall mass. That rainfall distribution is reproduced as follows:

TIME IN HOURS	**ACCUMULATED RAINFALL IN PERCENT OF 24-HOUR RAINFALL**
0	0
2.0	2.22
4.0	4.80
6.0	8.00
8.0	12.00
9.0	14.70
9.5	16.30
10.0	18.10
10.5	20.40
11.0	23.50
11.5	28.30
11.75	38.70
12.0	66.30
12.5	73.50
13.0	77.20
13.5	79.90
14.0	82.00
16.0	88.00
20.0	95.20
24.0	100.00

5602.4 Unit Hydrographs: The SCS Dimensionless Unit Hydrograph (either curvilinear or triangular) shall be the basis for computation of runoff hydrographs.

5602.5 Rainfall Intensity: Rainfall intensity shall be determined from Figure 1 or Table C using a Calculated Time of Concentration, T_C. T_C is equal to the overland flow time to the most upstream inlet or other point of entry to the system, Inlet Time, T_I plus the time for flow in the system to travel to the point under consideration Travel Time, T_T. ($T_C = T_I + T_T$).

A. **Inlet Time:** T_I shall be calculated by the following formula or determined graphically from Figure 2, but shall not be less than 5.0 minutes nor greater than 15.0 minutes:

$$T_I = \frac{1.8*(1.1-C)*D^{1/2}}{S^{1/3}}$$ where:

T_I = Inlet Time in minutes.

C = Rational Method Runoff Coefficient as determined in accordance with paragraph 5602.2

D = Overland flow distance parallel to slope in feet.

(300-feet shall be the maximum distance used for overland flow)

S = Slope of tributary area surface perpendicular to contour in percent.

B. **Travel Time:** T_T 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 Figure 3 in lieu of calculation.

To provide for future development when the upstream channel is unimproved, the following table shall be used for calculating T_T.

AVERAGE CHANNEL SLOPE, (%)	VELOCITY (FT./SEC.)
<2	7
2 to 5	10
>5	15

5602.6 Computation Methods for Runoff: Runoff rates to be accommodated by each element of the proposed storm drainage system shall be calculated using the foregoing criteria for land use runoff factors, rainfall, and system time. The following alternative computation methods are acceptable. Other methods, including computer models may be employed so long as they produce calculated runoff to the system that is substantially the same as that calculated by the foregoing criteria:

A. **Watersheds Less than 600 Acres:** The Rational Method may be used to calculate peak rates of runoff to elements of enclosed and open channel systems, including inlets, when the total upstream area tributary to the point of consideration is less than 600 acres. The Rational Method is defined as follows:

$Q = K\,C\,i\,A$, where

Q = Peak rate of runoff to system in C.F.S.

C = Runoff coefficient as determined in accordance with Paragraph 5602.2

i = Rainfall intensity in inches per hour as determined in accordance with Paragraph 5602.4

K = Dimensionless coefficient to account for antecedant precipitation as follows; except the product of *C* x *K* shall not exceed 1.0.

DESIGN STORM	K
10% and more frequent	1.0
4%	1.1
2%	1.2
1%	1.25

B. **All Watersheds:** The following methods are acceptable for all watersheds:

1. SCS Technical Release No. 55 - "Urban Hydrology for Small Watersheds", 2nd Edition, June 1986.

2. SCS Technical Release No. 20 - "Project Formulation - Hydrology", 2nd Edition, May 1983.

3. U.S. Army Corps of Engineers, Hydrologic Engineering Center - "HEC-1 Flood Hydrograph Package"

Copies of the above publications and micro-computer programs based thereon are available for purchase through National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161.

5602.7 Hydraulic Calculations for Pipes, Culverts, and Open Channels: Computations shall be by Manning's formula:

$$Q = \frac{1.486}{n} AR^{2/3} S^{1/2}$$ where:

Q = Discharge in cubic feet per second.

A = Cross sectional area of flow in square feet.

n = Roughness Coefficient (see Table A).

R = Hydraulic radius ($R = A/P$) in feet.

S = Slope in feet per foot.

P = Wetted perimeter in feet.

Minor losses shall be calculated by:

$$h = k \frac{V^2}{2g}$$ where:

h = Head loss in feet.

V = Velocity of flow in feet per second at point of interest.

$2g$ = 64.4 feet per second per second.

k = Coefficient as shown in Table B.

Hydraulic calculations for open channels may also be made by the U.S. Army Corps of Engineers "HEC-2 Water Surface Profiles" computer program.

5602.8 Entrance Control: Design variables for culverts operating under entrance control shall be determined from Figure 7-1 through 7-7.

5602.9 Outlet Control: Design variables for culverts operating under outlet control shall be determined from Figure 7-8 through 7-14.

SECTION 5603 INLETS, MANHOLES, AND JUNCTION BOXES

5603.1 Inlet Design:

A. **Type:** Only curb opening inlets shall be used on public streets, except as approved by the City Engineer.

B. **Capacity:** Inlet capacity shall be rated at 80 percent of the theoretical capacity indicated by Tables 8-1 through 8-3 and Figures 8-1 through 8-3 to allow for partial obstruction and clogging. Capacity for sizes not shown may be interpolated from these figures.

C. **Configuration:** Curb inlets shall be as follows (illustrated by Figure 8.0):

Opening length, inside ………………………………………………..	4.0 ft. (min)
Width, perpendicular to curb line, inside ………………………………..	3.0 ft. (min)
Setback curb line to face ……………………………………………….	1.0 ft. (min)
Opening, clear height ……………………………………………………	6.0 in. (min)
Gutter depression at inlet ……………………………………………….	$6^1/_4$ in. (min)
Gutter transition length:	
(a) Both sides in sump and upstream side on slopes ……………	5.0 ft. (min)
(b) Downstream side on slopes …………………………………	3.0 ft. (min)

5603.2 Freeboard Requirements: Any opening which surface water is intended to enter (or may backflow from) the system shall be 0.5-feet or more above an elevation calculated as follows:

1. Invert elevation of the outlet channel (pipe) of the structure, plus;

2. Depth (diameter) of the outlet channel (pipe), plus;

3. "h" minor losses as determined by Section 5602.7. When 50 percent or more of the discharge enters the structure from the surface, "k" shall be 1.0.

5603.3 Inverts and Pipes: The crown(s) of pipe(s) entering a structure shall be at or above the crown of the pipe exiting from the structure and provide a minimum fall of the invert in the structure of 0.2-feet for straight flow through the structure or 0.5-feet fall for all other types of flow (bends more than 22.5 deflection angle, multiple lines entering, enlargement transition,...etc.) through the structure. The desirable minimum fall across the invert is 0.5-feet.

5603.4 Gutter Flow: Inlets shall be located to limit the width of flow in street gutters at the time of peak discharge of a 10% storm to the following limits:

BACK TO BACK OF CURB STREET WIDTH (FEET)	MAXIMUM ALLOWABLE SPREAD IN EACH OUTSIDE CURB LANE FROM BACK OF CURB (FEET)
28 or less	10.5
Over 28 to 36	11.5
Over 36	12.0
Divided Roadways	As above for each direction of roadway
Arterial and Collector Street Intersections and Pedestrian Crosswalks	6.0

5603.5 Gutter Capacity: Izzard's Formula or Figure 9 shall be used to determine gutter flow:

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

Q = The gutter flow in cubic feet per second.

z = The reciprocal of the average cross-slope, including gutter section in feet per foot.

S = The longitudinal street grade in feet per foot.

D = The depth of flow at curb face in feet.

n = Manning's "n" see Table A.

5603.6 Street Grade on Vertical Curves: The following formula shall be used to determine the street grade (S_x) at any point on a vertical curve using plus for grades ascending forward and minus for grades descending forward, in feet per foot.

$$S_x = S_1 + \left(\frac{X}{L}\right)(S_2 - S_1)$$ where:

S_x = The street grade on a vertical curve at point x, in feet per foot.

S_1 = The street grade at the PC of a vertical curve, in feet per foot.

S_2 = The street grade at the PT of a vertical curve, in feet per foot.

X = The distance measured from the PC to point x on a vertical curve, in feet.

L = The total length of a vertical curve, in feet.

5603.7 Loading Conditions for Structures: shall be in accordance with Section 5700.

SECTION 5604 ENCLOSED PIPE SYSTEMS:

5604.1 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.

A. Permanent: 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.

B. Temporary: 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.

5604.2 Capacity: Capacity shall be based on either inlet or outlet control, whichever condition indicates the least capacity. Minimum design pipe size shall be 15-inch diameter.

5604.3 Surcharge: An enclosed system may be designed to operate with surcharge 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. Watertight joints capable of withstanding the internal surcharge pressure are used in the construction.

3. Appropriate energy loses for bends, transitions, manholes, inlets, and outlets, are used in computing the HGL.

4. Energy methods (Bernoulli's equation) must be used for the computations.

5604.4 Energy Dissipation: The outfall of all enclosed systems shall be designed so that the exiting velocity does not exceed the following. Effective energy dissipating structures shall be provided if necessary to meet these requirements:

OUTLET CHANNEL TYPE	MAXIMUM EXITING VELOCITY
Natural or Unimproved Channel …………………………………………	5 ft./sec.
Grass Lined Channel …………………………………………………..	5 ft./sec.
Improved Channel with Riprap Lining ………………………………….	10 ft./sec.
Concrete Lining, or Gabion Revetment or Grouted Riprap Lining, or Excavated in Rock …………………………………….	15 ft./sec.

5604.5 Velocity Within the System: The velocity within the system shall be between 3 and 20-feet per second.

5604.6 Loading:

A. Cover: Minimum depth of cover shall be 18-inches.

B. Minimum Loading Conditions:

1. Live load: H-20

2. Unit Weight of soil cover: 120 pcf.

3. Rigid pipes shall be bedded and backfilled to provide a minimum factor of safety of 1.5 at the 0.01-inch crack loading condition.

SECTION 5605 OPEN CHANNELS

5605.1 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 channel 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.

5605.2 Freeboard:

1. No "in-channel" freeboard is required above the 1% design storm water surface profile elevation.

2. Freeboard shall not be required above the design headwater pool elevation at culvert entrance.

5605.3 Channel Linings:

1. All improved channels shall be lined to the minimum of the 10% design storm water profile elevation plus 0.5-foot freeboard minimum.

2. All channel linings, except turf, shall contain provision for relieving back pressures and water entrapment at regular intervals.

3. Lining height on the concave side of curves shall be increased by:

   $y = D/4$ where:

y = Increased vertical height of lining in feet.

D = Depth of design flow in feet.

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

a. 30(*y*) feet downstream from the point of tangency (P.T.).
b. 10(*y*) feet upstream from the point of curvature (P.C.)

5605.4 Lining Material: The following types of lining material and minimum thicknesses shall be used to control damage and erosion. All riprap, grouted riprap, and gabion linings shall be designed with a filter fabric in conformance with Section 2605.2.C.2

A. Improved Open Channels: Below the 10% storm hydraulic grade line plus 0.5-foot freeboard elevation:

DESIGN FLOW VELOCITY-FPS	LINING MATERIAL
0 to 10	Riprap - 15-inches minimum thickness
0 to 15	Grouted riprap, gabion revetment or paved concrete
Over 15	Paved concrete or sound in situ bedrock

B. Overflow Open Channels: Above the elevation of the 10% storm hydraulic grade line plus 0.5-foot freeboard:

DESIGN FLOW VELOCITY-FPS	LINING MATERIAL
Less than 3	Seeded
0 to 5	Sod, staked
0 to 7	Erosion control blanket as approved by the City Engineer
0 to 10	Riprap - 15-inches minimum thickness
0 to 15	Grouted riprap, gabion revetment or paved concrete
Over 15	Paved concrete or sound in situ bedrock

C. Other Lining Materials: Other types of lining materials not specifically listed above may be used when approved by the City Engineer.

5605.5 Side Slopes: Side slopes shall not be steeper than:

1. 3 horizontal to 1 vertical for turf lining.

2. 2 horizontal to 1 vertical for all other lining materials.

3. Flatter if necessary for stability of slopes.

5605.6 Alignment Changes: Alignment changes shall be achieved by curves having a minimum radius of:

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

R = Minimum radius on centerline 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

5605.7 Special Improved Channels: Improved open channels having a design cross sectional flow area of greater than 100-square feet at peak discharge from a 10% storm may be designed to reduce the height of concrete/rock lining to that required to convey a 50% storm; subject to the following special requirements:

1. Sod or natural vegetation above the structural lining shall be provided.

2. The elevation of the structural lining material shall be a minimum of 18-inches above the adjacent channel flow line.

5605.8 Vertical Wall Channels: Vertical walls may be used for structural lining of improved channels; subject to the following special requirements:

1. Walls shall be designed and constructed to act as retaining walls.

2. Adequate provisions shall be made for pedestrian entry/exit from the channel.

SECTION 5606 STORMWATER DETENTION AND RETENTION

5606.1 Scope: This section governs the requirements and design of stormwater detention and retention facilities.

5606.2 Easements: Easements shall be dedicated to the city to provide adequate access for inspection, construction, and maintenance of all public detention facility components. The owner shall dedicate the detention facility and easements upon completion of construction and approval by the City Engineer. This shall be land occupied by the facility, plus a 20-foot wide strip around the perimeter of the highest elevation attained by the design storage volume, plus an access easement 20-feet in width between the facility and a public street, except:

1. Private detention facilities as described in Section 5601.2.

2. When multi-purpose wet facilities are planned or are suitable for use as private aquatic recreation or for aesthetic enhancement of the owner's property.

3. When multi-purpose dry facilities incorporate surface recreational improvements.

4. Other special cases.

5606.3 Maintenance and Continued Performance: Maintenance of private detention facilities shall be the responsibility of the property owner and shall include:

1. Debris removal and cleaning

2. Cutting of vegetation

3. Repair of erosion

4. Removal of silt

5. Maintenance of structural facilities, including outlet works, not located in a public drainage easement

6. Annual or more frequent inspections to assure that the detention basin has full storage capacity and all inlet and outlet structures are fully functional.

5606.4 Performance Criteria:

A. General Provisions: The criteria set forth herein are applicable to detention facilities:

1. Having 1,000 acres or less area tributary to the facility.

2. Impoundments formed by dams which are greater than 10-feet in height. Dams which are greater than 10-feet in height but do not fall into state or federal requirement categories shall be designed in accordance with SCS Technical Release No. 60, "Earth Dams and Reservoirs", August 1981, as Class "C" structures.

3. Other agencies have criteria and regulations pertaining to drainage systems which may complement this criteria. State and federal laws and regulations pertaining to dams shall take precedence over this criteria to the extent that detention facilities may be classified as "dams" thereunder.

   a. Federal Insurance Agency - Floodplain Regulations and Implementing Ordinances Adopted by Municipalities: Drainage systems designed within the limits of the designated 100-year floodplain on the principal stream shall be designed to convey the flood as defined by applicable published floodplain information studies. For areas located in FIA Zone "A" outside the detailed study area, the Developer shall prepare studies and calculations establishing the floodplain, elevation and width. These calculations shall be submitted to the reviewing agency for approval.

   b. Kansas State Board of Agriculture: Regulations of the Water Resources Division shall apply.

B. Release Rate: The maximum release rate from any development for the 1% and more frequent storms shall not exceed 1.8 c.f.s. per tributary acre. When areas outside the development are also tributary, their inflow hydrograph(s) may be added to the above maximum release rate to determine the total maximum release rate. If the downstream conditions dictate a lower release rate, then the above release rates do not govern.

C. **Detention Basin Size:** For purposes of evaluation, projects will be classified in two categories according to the acreage of tributary area.

1. Less than 10 acres: Volume of detention for projects having 10 acres or less tributary to the detention facility may be evaluated using either the "Simplified Volume" Figure 11 or by the more precise methods set forth in Section 5606.4.C.2.

2. Over 10 acres: For projects of more than 10 acres tributary area the owners/engineers may utilize methodology outlined in Technical Release No. 55 "Urban Hydrology for Small Watersheds," June, 1986. A Type 2 rainfall distribution shall be the required storm hydrograph. Hydrologic simulation models shall be based on not less than Antecedent Moisture Condition II. Detention storage shall be based upon the allowable release rate during the 1% storm with the development in place.

D. **Principal Spillways:** The principal spillway shall be designed to meet the following requirements:

1. 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.

2. All discharge from the detention facility when inflow is equal to or less than the 1% storm inflow shall be via the principal spillway(s).

3. The design shall allow for discharge of at least 80 percent of the detention storage volume within 24 hours after the peak or center of mass of the inflow has entered the detention basin.

4. The design discharge rate via the principal spillway shall continuously increase with increasing head and shall have hydraulic characteristics similar to weirs, orifices or pipes.

E. **Emergency Spillways:** 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 1% storm.

F. **Outlet Works:** Outlet works consisting of valves, gates, pipes, and other devices as necessary to completely drain the facility in 72 hours or less when required for maintenance or inspection shall be provided.

G. **Erosion Control:** Principal spillways and outlet works, as well as conveyance system entrances to detention basins, shall be equipped with energy dissipating devices as necessary to limit the peak discharge velocity. See Section 5604 for-velocity criteria.

5606.5 Detention Methods: In addition to the foregoing criteria, the following shall be applicable, depending on the detention alternative(s) selected:

A. Wet Bottom Basins/Retention Facility: For basins designed with permanent pools:

1. Minimum Depths: The minimum normal depth of water before the introduction of excess stormwater shall be four feet plus a sedimentation allowance of not less than 5 years accumulation determined in accordance with Figure 6. The side slopes of dry and wet basins shall conform as closely as possible to regraded or natural land contours, and should not exceed three horizontal to one vertical. Slopes exceeding this limit shall require erosion control and safety measures.

2. Depth for Fish: If the pond is to contain fish, at least one-quarter of the area of the permanent pool must have a minimum depth of ten-feet plus sedimentation allowance.

B. Dry Bottom Basins/Detention Facility: For basins designed to be normally dry:

1. Interior Drainage: Provisions must be incorporated to facilitate interior drainage to outlet structures. Grades for drainage facilities shall not be less than two percent on turf. Concrete swales, with a minimum gradient of 1.0 percent, may be used as needed to conduct storm water from turfed bottom areas to the outlet structure.

2. Earth Bottoms: Earth bottoms shall be seeded or sodded.

3. Multipurpose Feature: 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, if possible.

C. Anti-Clogging Protection: Trash racks or other approved devices shall be installed where required to insure that the principal spillway(s) will remain functional.

D. Rooftop Storage: Detention storage may be met in total or in part by detention on roofs. Details of such designs shall include the depth and volume of storage, details of outlet devices and downdrains, elevations and details of overflow scuppers, and emergency overflow provisions. Connections of roof drains to sanitary sewers are prohibited. Design loadings and special building and structural details shall be subject to approval by the City Engineer.

E. Parking Lot Storage: Paved parking lots may be designed to provide temporary detention storage of stormwater on a portion of their surfaces. Generally, such detention areas shall be in the more remote portions of such parking lots. Depths of storage shall be limited to a maximum depth of seven (7) inches, and such areas shall be located so that access to and from parking areas is not impaired.

F. Other Storage: All or a portion of the detention storage may also be provided in underground or surface detention areas, including, but not limited to, oversized storm sewers, vaults, tanks, swales, etc.

5606.6 Computational Methods:

A. **Time of Concentration and Travel Time:** Use methods as outlined in Technical Release No. 55, "Urban Hydrology for Small Watersheds," Chapter 3.

B. **Temporary Storage Volume:** A preliminary value of the storage requirement may be obtained through methods outlined in Technical Release No. 55, Chapter 6 or other acceptable methods. The storage shall be checked during routing of design hydrographs through the basin and adjusted appropriately.

C. **Hydrograph Routing:** The storage indication method (Modified Puls) of routing a hydrograph through a detention basin may be utilized. Reference: "Introduction to Hydrology," by Warren Viessman, Jr., John W. Knapp, Gary Lewis, Second Edition, Section 7-2.

5606.7 Required Submittals: The Owner shall submit the following information and data to the City Engineer.

1. Elevation-area-volume curves for the storage facility including notation of the storage volumes allocated to runoff, sediment, and permanent residual water storage for other uses (wet basins only).

2. Inflow hydrographs for the 10% and 1% design storms.

3. Stage-discharge rating curves for each spillway and for combined spillway discharges.

4. Routing curves for the 10% and 1% design storms with time plotted as the abscissa and the following plotted as ordinates:

   a. Cumulative inflow volume.
   b. Cumulative discharge.
   c. Stage elevation.
   d. Cumulative storage.

5606.8 Additional Requirements:

A. **Access:** Provisions shall be made to permit access and use of auxiliary equipment to facilitate emptying, cleaning, maintenance, or for emergency purposes.

B. **Underground Storage:** Underground detention facilities shall be designed with adequate access for maintenance (cleaning and sediment removal). Such facilities shall be provided with positive gravity outlets. Venting shall be sufficient to prevent accumulation of toxic or explosive gases.

SECTION 5607 PLAN REQUIREMENTS

5607.1 Scope: This section governs the preparation of plans for stormwater system projects.

5607.2 General: The plans shall include all information necessary to build and check the design of storm drainage systems. The plans shall be arranged as required by the City Engineer. Standard drawings of the City shall be included by reference only. Plans shall be sealed by a Registered Professional Engineer and shall be submitted to the City Engineer for review and approval.

5607.3 Scale: Plans shall be drawn at the following minimum scales. Larger scales may be needed to clearly present the design. Bar scales shall be shown on each sheet for each scale.

Plan:	1-inch = 50-feet
Profile:	
Vertical:	1-inch = 10-feet
Horizontal:	1-inch = 50-feet
Cross Sections:	
Vertical:	1-inch = 5-feet
Horizontal:	1-inch = 5-feet
Drainage Area Map:	
On site:	1-inch = 200-feet
Off site:	1-inch = 1,000-feet
Structural Plans:	1/4-inch = 1-foot
Graphic Drawings:	Varies

5607.4 Required Information:

A. Drainage Area Map: A drainage map shall be included and shall contain the following:

1. Ridge line of the area tributary to each principal element of the system.

2. Note the area in acres.

3. Note the runoff coefficient C for each area.

B. Plan View: All designed storm drainage systems shall be drawn in plan view and shall contain the following:

1. North arrow and bar scale.

2. Ties to permanent reference points for each system located outside of the street right-of-way.

3. Identification and location of each pipe, culvert, inlet, structure, and existing utility affecting construction.

4. Right-of-way, property, and easement lines. The 100-year flood plain and setback from the top of bank of an open channel to any building.

5. Existing man-made and natural topographic features, such as buildings, fences, trees, channels, ponds, streams, etc., and all existing and proposed utilities.

6. Location of test borings.

7. Existing and finish grade contours at intervals of 2.0-feet or less in elevation; or equivalent detail indicating existing and finish grades and slopes.

8. A uniform set of symbols subject to approval by the City Engineer.

9. The centerline of open channels within 50-feet of an enclosed drainage system and showing the direction of flow.

10. The existing and proposed drainage systems 100-feet upstream and 100-feet downstream from the development.

C. **Profile View:** All designed storm drainage systems shall be drawn in profile view and shall contain the following:

1. Existing and finish surface grade along the center line of pipe (except street centerline may be used when construction includes street construction).

2. Length, size and slope of each line or channel segment. Slope shall be expressed in percent.

3. Headwater elevation at the inlet end of each culvert.

4. Flow line (invert elevation in and out at each structure).

5. Each existing utility line crossing the alignment shall be properly located and identified as to type, size and material.

6. Test borings.

7. All station and invert elevations of manholes, junction boxes, inlets or other structures.

8. The profile shall show existing grade above the centerline as a dashed line, proposed finish grades or established street grades by solid lines; and shall show the flow line of any drainage channel, either improved and unimproved, within 50-feet of either side of the centerline. Each line shall be properly identified. The proposed sewer shall be shown as double solid lines properly showing the top of the pipe.

9. All manholes, inlets or other structures shall be shown and labeled with appropriate "Standard Drawing" designation.

D. **Cross Sections:** Cross sections shall be drawn for all open channels. Sections shall be at appropriate intervals not greater than 50-feet. Additional sections shall be drawn at all structures and intersecting drainage systems. The following shall be indicated on each section:

1. Ties from centerline to baseline.

2. Existing and proposed grade line.

3. Elevation of the proposed flow line.

4. Cut and fill end. areas if required for bid quantities.

E. Design Information for Each Part of the System: The plans shall present design information for each culvert, structure, facility, pipe and channel segment and shall contain the following:

1. Tributary area in acres.

2. Design discharge and capacity in cubic feet per second.

3. Runoff coefficient C, design storm return frequency rainfall intensity and Manning's "n".

4. Discharge velocity at design flow.

5. Hydraulic grade line.

6. Type and grade of material (gage, class .... etc.).

Schedules which indicate all variable dimensions and elevations covered by standards or "typical" drawings shall be shown on the plans. All design details for nonstandard structures shall be indicated on the plans. A minimum of one plan view and one sectional view shall be shown on the plans for each structure. Additional views may be required if necessary to clearly define the design. A reinforcing bar list is not required. However, the grade, type, size and location of the bars shall be clearly indicated on the plans.

TABLES

Table 5602-1
Design Aide for Calculating Rainfall Intensity Kansas City Metropolitan Area

Return Period	**Equation 1** $5 \leq T_c \leq 15$	**Equation 2** $15 < T_c \leq 60$
2 yr.	$i = \frac{119}{T_c + 17}$	$i = \frac{134}{T_c + 21.4}$
5 yr.	$i = \frac{154}{T_c + 18.8}$	$i = \frac{182}{T_c + 25}$
10 yr.	$i = \frac{175}{T_c + 18.8}$	$i = \frac{214}{T_c + 26.7}$
25 yr.	$i = \frac{203}{T_c + 18.8}$	$i = \frac{262}{T_c + 28.8}$
50 yr.	$i = \frac{233}{T_c + 19.8}$	$i = \frac{296}{T_c + 29.6}$
100 yr.	$i = \frac{256}{T_c + 19.8}$	$i = \frac{331}{T_c + 30}$

I = Rainfall intensity in inches per hour.

T_c = Time of concentration in minutes.

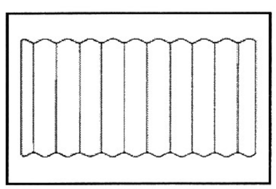
Note: Table 5602-2 is a design aide for use with computers to calculate rainfall intensity in the Kansas City Metropolitan Area using the Steel Formula.

Table 5602-2
MANNING'S ROUGHNESS COEFFICIENT

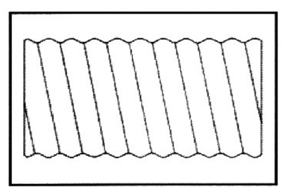
Type of Channel	n
Closed Conduits	
Reinforced Concrete Pipe (RCPs)	0.013
Reinforced Concrete Elliptical Pipe	0.013
Corrugated Metal Pipe (CMPs) (See Table 5602-2A on page 56-27)	
Vitrified Clay Pipe	0.013
Asbestos Cement Pipe	0.012
Open Channels (Lined)	
Gabions	0.025
Concrete	
Trowel Finish	0.013
Float Finish	0.015
Unfinished	0.017
Concrete, bottom float finished, with sides of	
Dressed Stone	0.017
Random Stone	0.020
Cement Rubble masonry	0.025
Dry Rubble or Riprap	0.030
Gravel bottom, side of	
Random Stone	0.023
Riprap	0.033
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 & 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

Corrugations	Annular 2 2/3 x ½ in.	Helical 1 ½ x ¼ in.	Helical 2 2/3 x ½ in.												
Flowing: Full-Unpaved Full-25% paved PartFull-Unpaved	Diameters	8 in. 10 in.	12 in.	15 in.	18 in.	24 in.	30 in.	36 in.	42 in.	48 in.	54 in. and larger				
	0.024 0.021 0.027	0.012 0.014	0.011 0.012	0.012 0.013	0.013 0.015	0.015 0.014 0.017	0.017 0.016 0.019	0.018 0.017 0.020	0.019 0.018 0.021	0.020 0.020 0.022	0.021 0.019 0.023				
Flowing: Full Unpaved Part Full	Pipe Arch			17 x 13	21 x 15	28 x 20	35 x 24	42 x 29	49 x 33	57 x 38	64 x 43 and larger				
	0.026 0.029			0.013 0.018	0.014 0.019	0.016 0.021	0.018 0.023	0.019 0.024	0.020 0.025	0.021 0.025	0.022 0.026				
Flowing: Full Unpaved 25% Paved	Annular 3 x 1 in.	Helical 3 x 1 in.													
								36 in.	42 in.	48 in.	54 in.	60 in.	66 in.	72 in.	78 in. and larger
	0.027 0.023							0.022 0.019	0.022 0.019	0.023 0.020	0.023 0.020	0.024 0.021	0.025 0.022	0.026 0.022	0.027 0.023
Flowing: Full Unpaved 25% Paved	Annular 5 x 1 in.	Helical 5 x 1 in.													
										48 in.	54 in.	60 in.	66 in.	72 in.	78 in and larger
	0.025 0.022									0.022 0.019	0.022 0.019	0.023 0.020	0.024 0.021	0.024 0.021	0.025 0.022
All pipe with smooth interior		All Diameters 0.012													

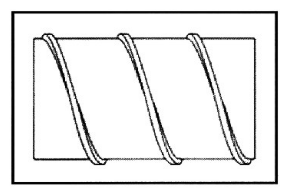
Table 5602-2A
Manning's Roughness for Various Types of CMPs



ANNULAR CMP
ANNULAR PIPE HAS CORRUGATIONS PERPENDICULAR TO THE CENTER LINE OF THE PIPE



HELICAL CMP
HELICAL PIPE HAS SPIRAL CORRUGATIONS



SPIRAL RIB PIPE
OUTSIDE RECTANGULAR HELICAL RIBBED PIPE

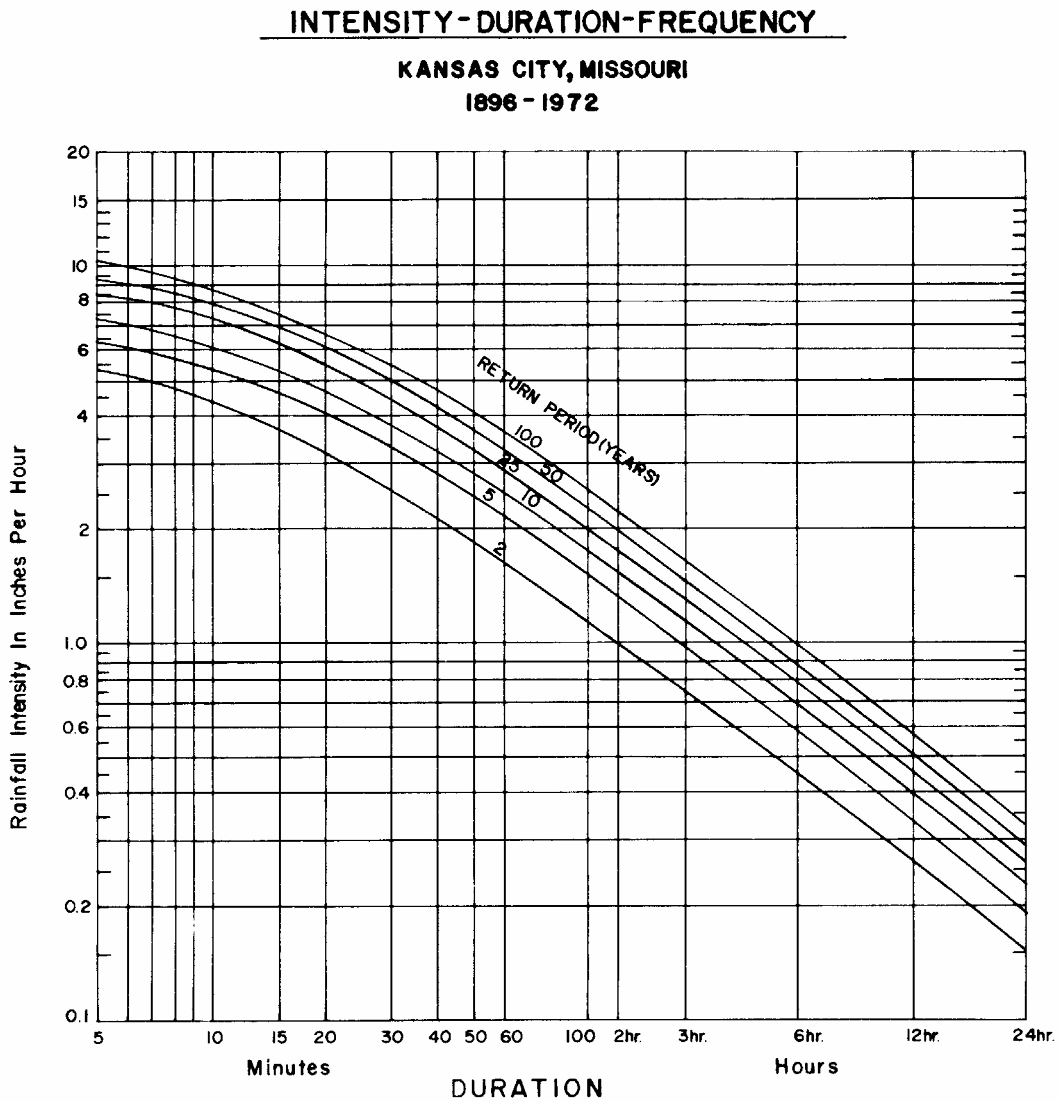
Table 5602-3
HEAD LOSS COEFFICIENT k

Condition $\left(Loss = k\frac{v^2}{2g}\right)$	k
Manhole, junction boxes and inlets with shaped inverts:	
Thru flow	0.15
Junction	0.4
Contraction transition	0.1
Expansion transition	0.2
90 degree bend	0.4
45 degree and less bends	0.3
Culvert inlets:	
Pipe, Concrete	
Projecting from fill, socket end (grove end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove end)	0.2
Square edge	0.5
Round (radius=1/12D)	0.2
Mitered to conform to fill slope	0.7
Standard end section	0.5
Beveled edges, 33.7º or 45º bevels	0.2
Side or slope-tapered inlet	0.2
Pipe, or Pipe-Arch, Corrugated Metal	
Projecting from fill (no headwall)	0.9
Headwall or headwall and wingwalls square edge	0.5
Mitered to conform to fill slope, paved or unpaved slope	0.7
Standard end section	0.5
Beveled edges, 33.7º or 45º bevels	0.2
Side or slope-tapered inlet	0.2
Box, Reinforced Concrete	
Headwall parallel to embankment (no wingwalls)	
Square edged on 3 edges	0.5
Rounded on 3 edges to radius of 1/12 barrel dim. or beveled edges on 3 sides	0.2
Wingwalls at 30º to 75º to barrel	
Square edged at crown	0.4
Crown edge rounded to radius of 1/12 barrel dimension or beveled top edge	0.2
Wingwalls at 10º to 25º to barrel - square edged at crown	0.5
Wingwalls parallel (extension of sides) - square edged at crown	0.7
Side or slope-tapered inlet	0.2

Note: When 50 percent or more of the discharge enters the structure from the surface, “k” shall be 1.0.

FIGURES

Figure 5602-1



REFERENCES

1. NOAA Technical Memorandum NWS HYDRO-35 National Oceanic and Atmospheric Administration Of The National Weather Service, Department Of Commerce Silver Spring, Md., June 1977.

2. Technical Paper No. 40, Rainfall Frequency Atlas For Durations From 30 Minutes To 24 Hours And Return Periods From 1yr To 100 Yrs. U.S. Weather Bureau, Department Of Commerce, Washington, D.C., January 1963.

3. Design Of Urban Highway Drainage - State Of The Art FHWA-TS-79-225 U.S. Department Of Transportation Federal Highway Administration, Washington, D.C., August 1979.

Figure 5602-2

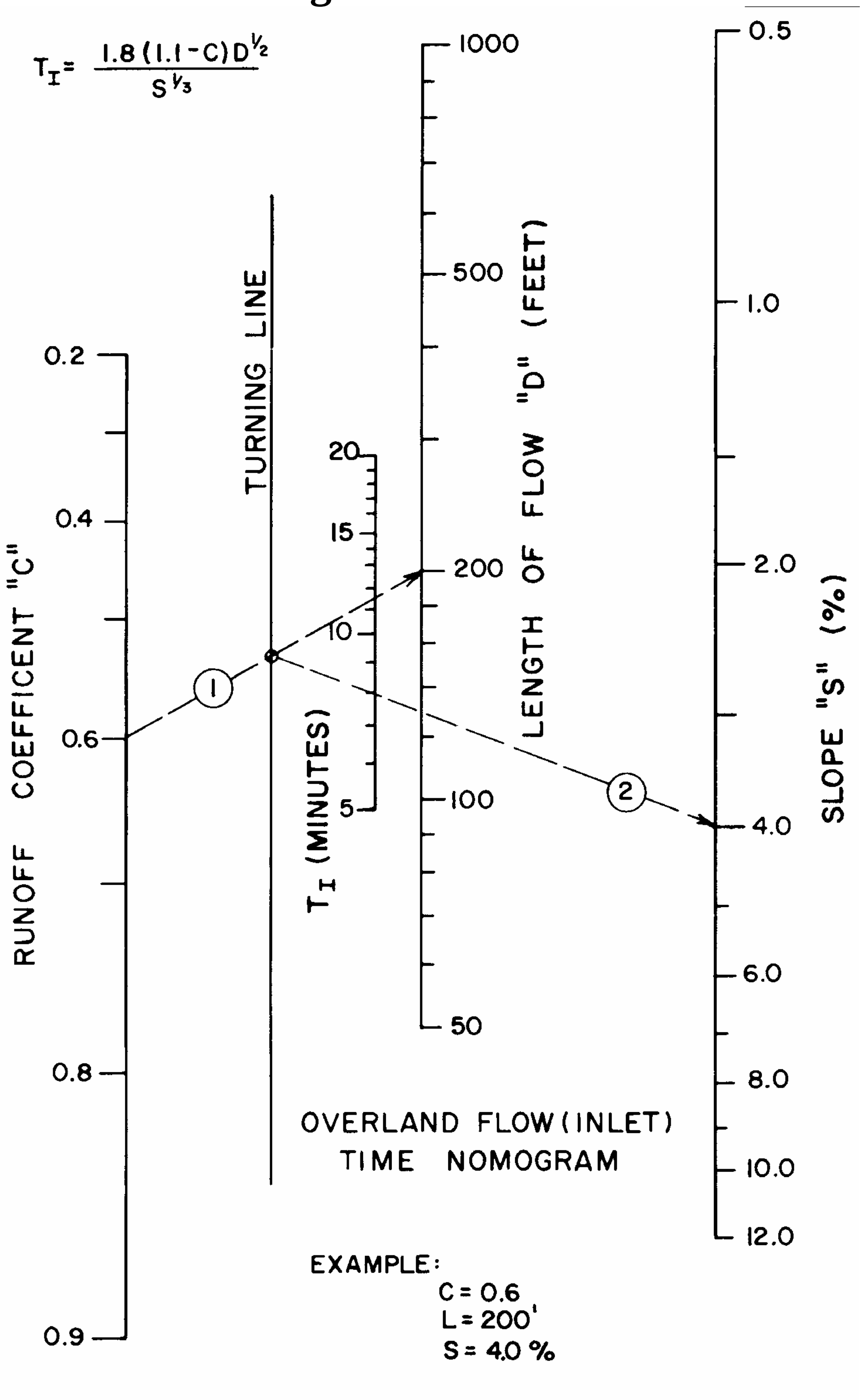
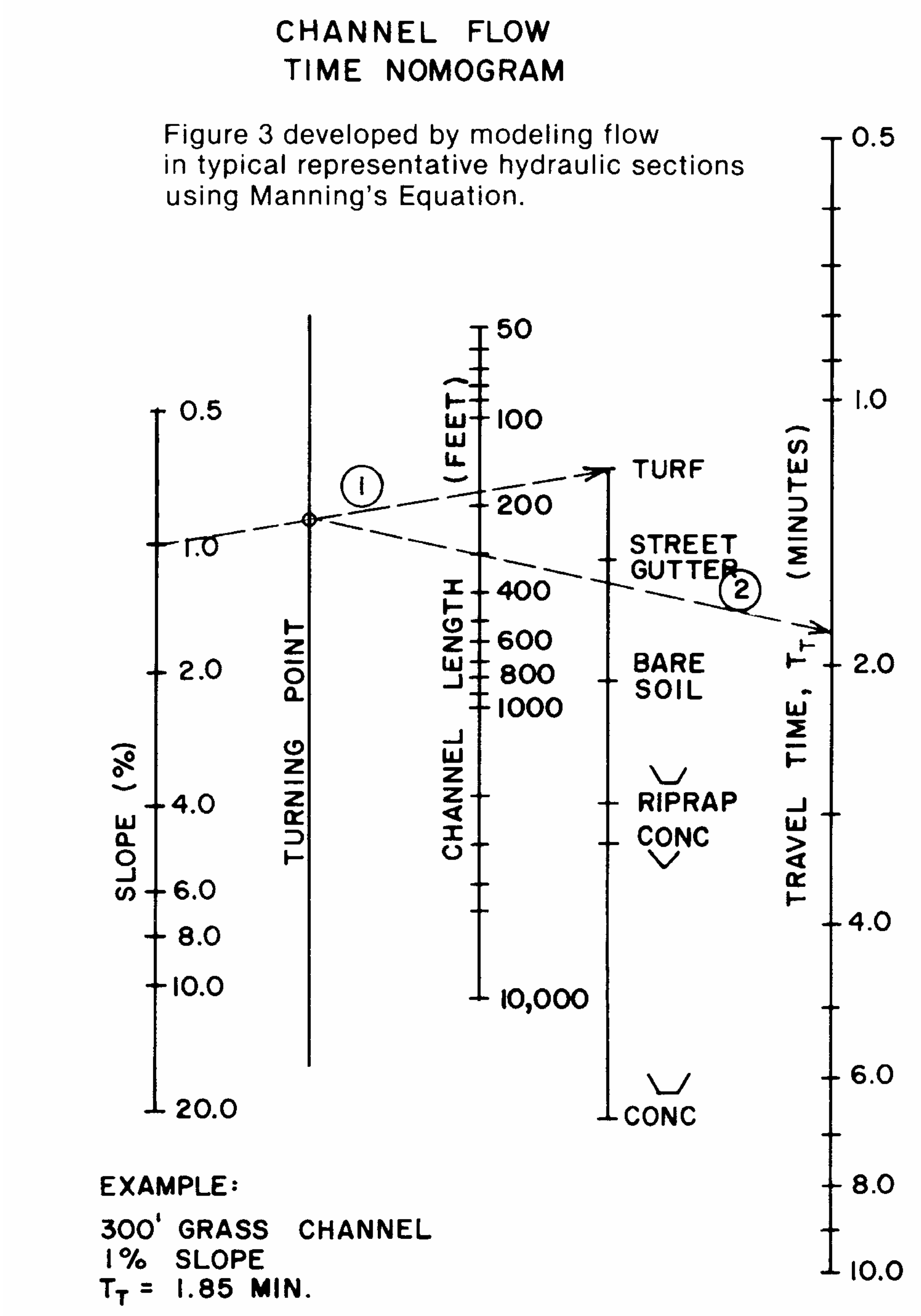


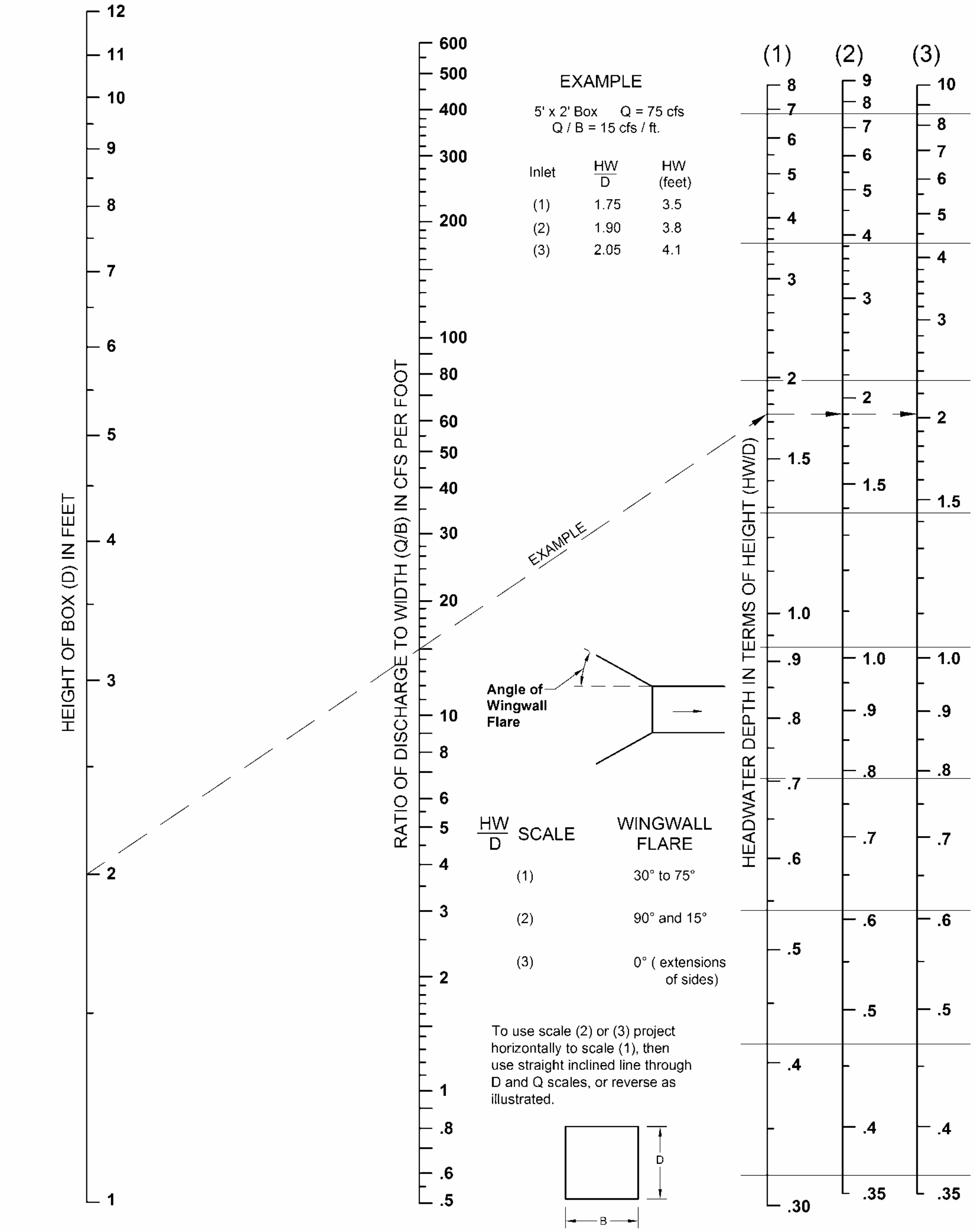
Figure 5602-3



(1) Connect Slope & Channel Condition to locate point on Turning Line

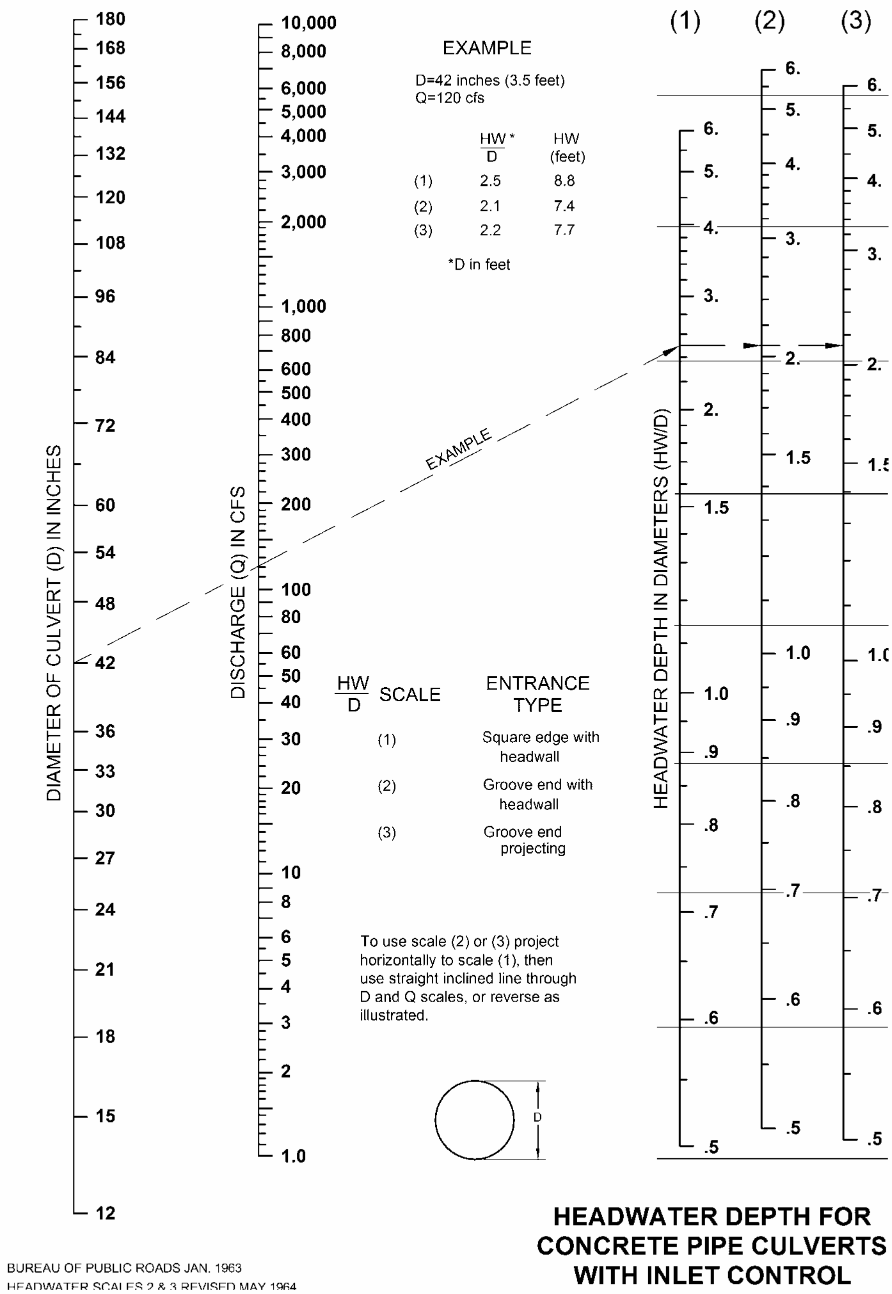
(2) Extend line from Turning Line through Channel Length, Read T_T

FIGURE 5603-1



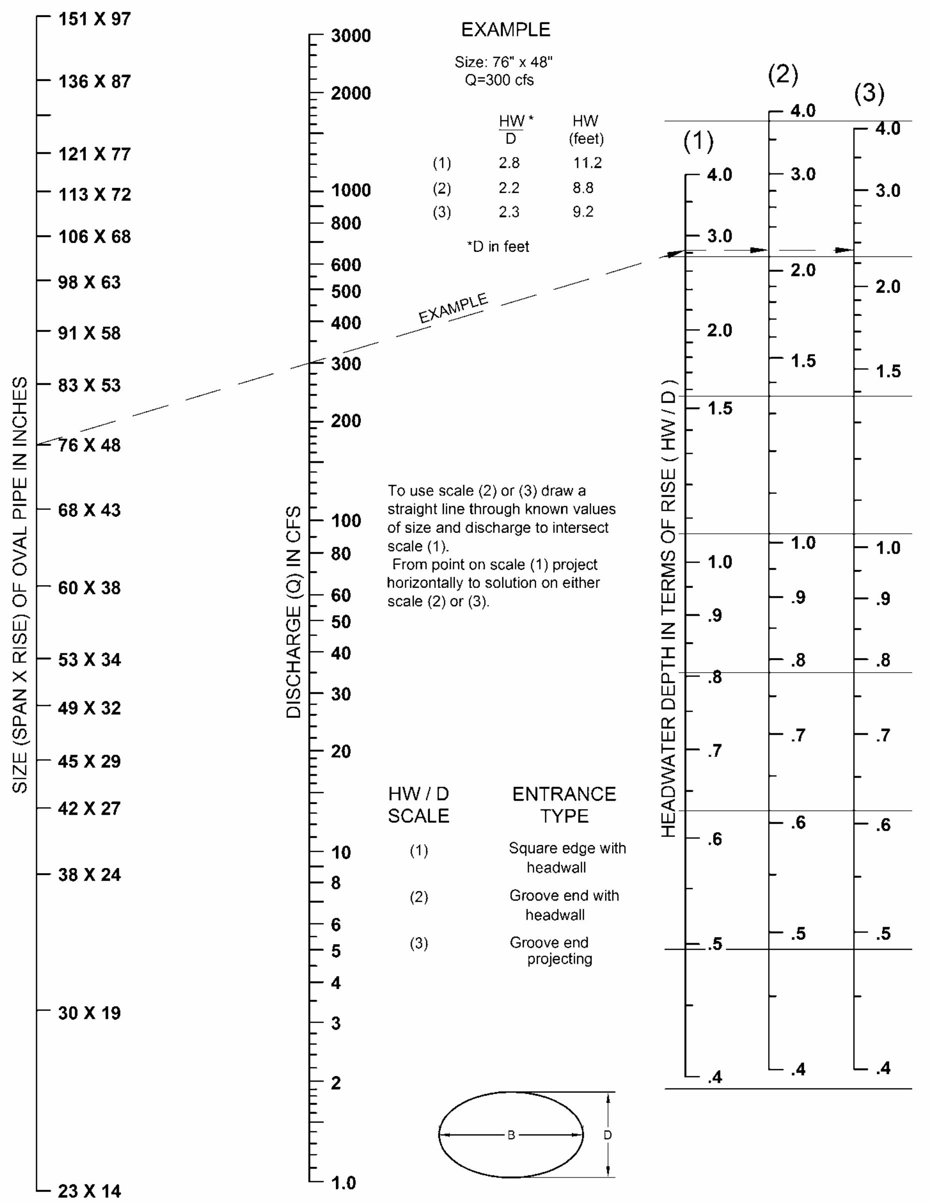
HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

FIGURE 5603-2



HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

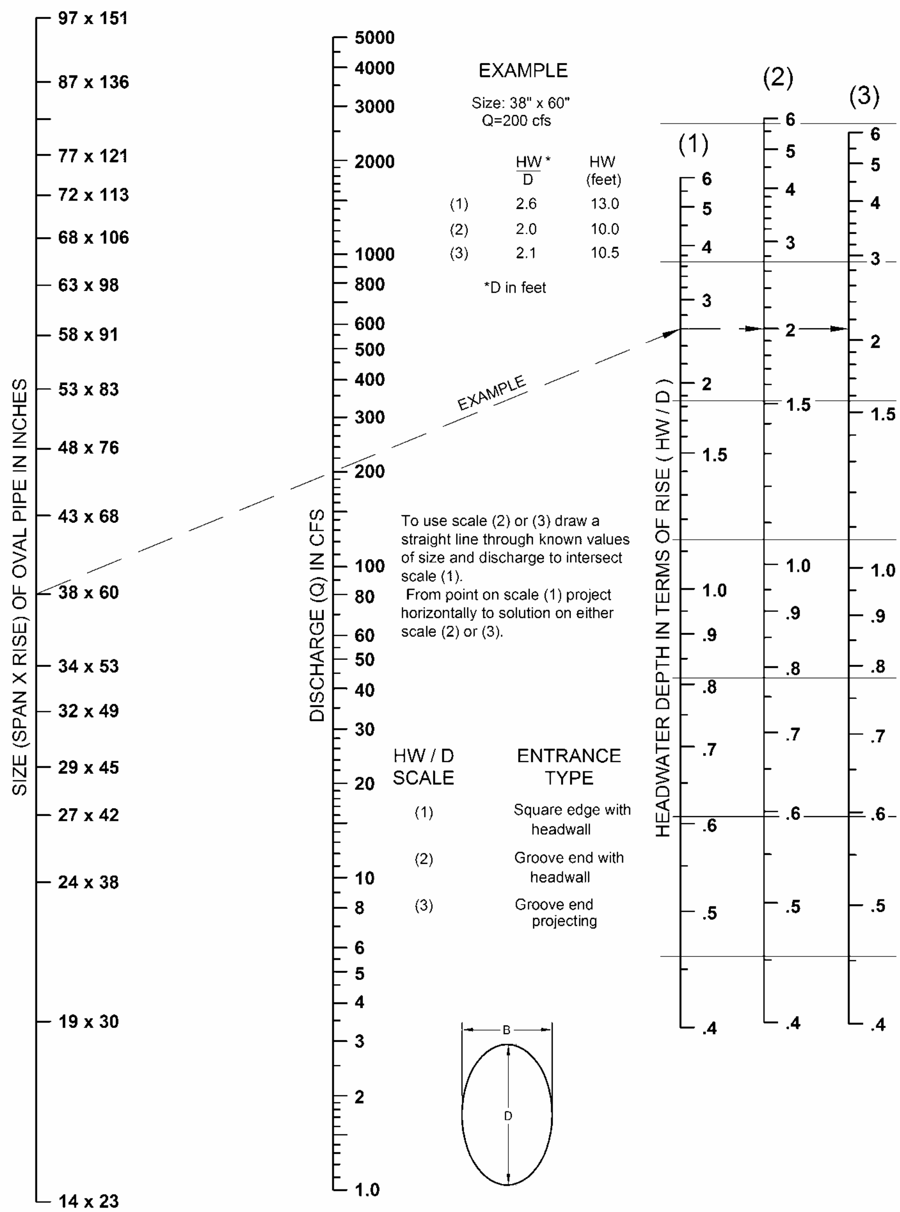
FIGURE 5603-3



HEADWATER DEPTH FOR OVAL CONCRETE PIPE CULVERTS LONG AXIS HORIZONTAL WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

FIGURE 5603-4



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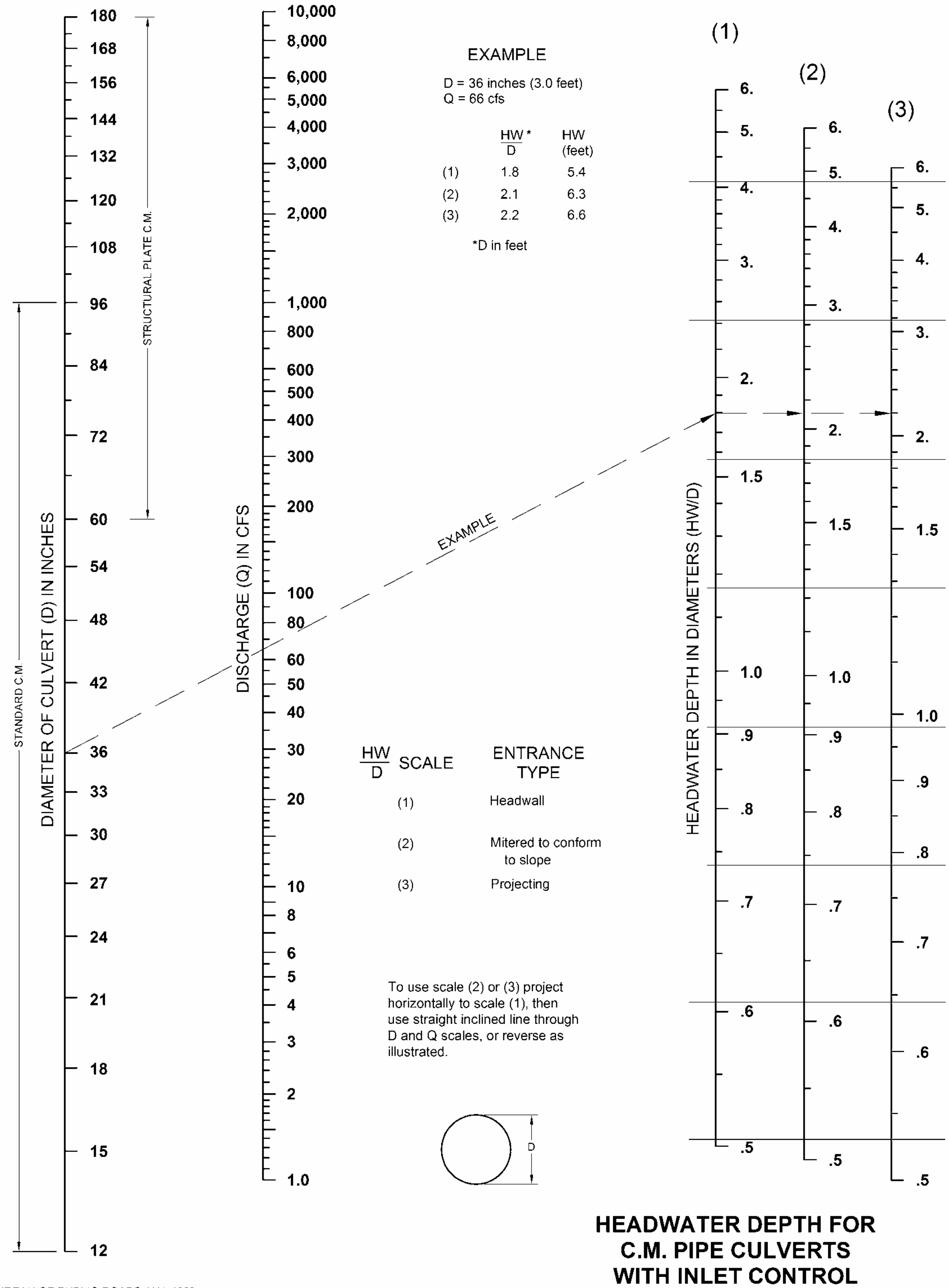
HEADWATER DEPTH FOR OVAL CONCRETE PIPE CULVERTS LONG AXIS VERTICAL WITH INLET CONTROL

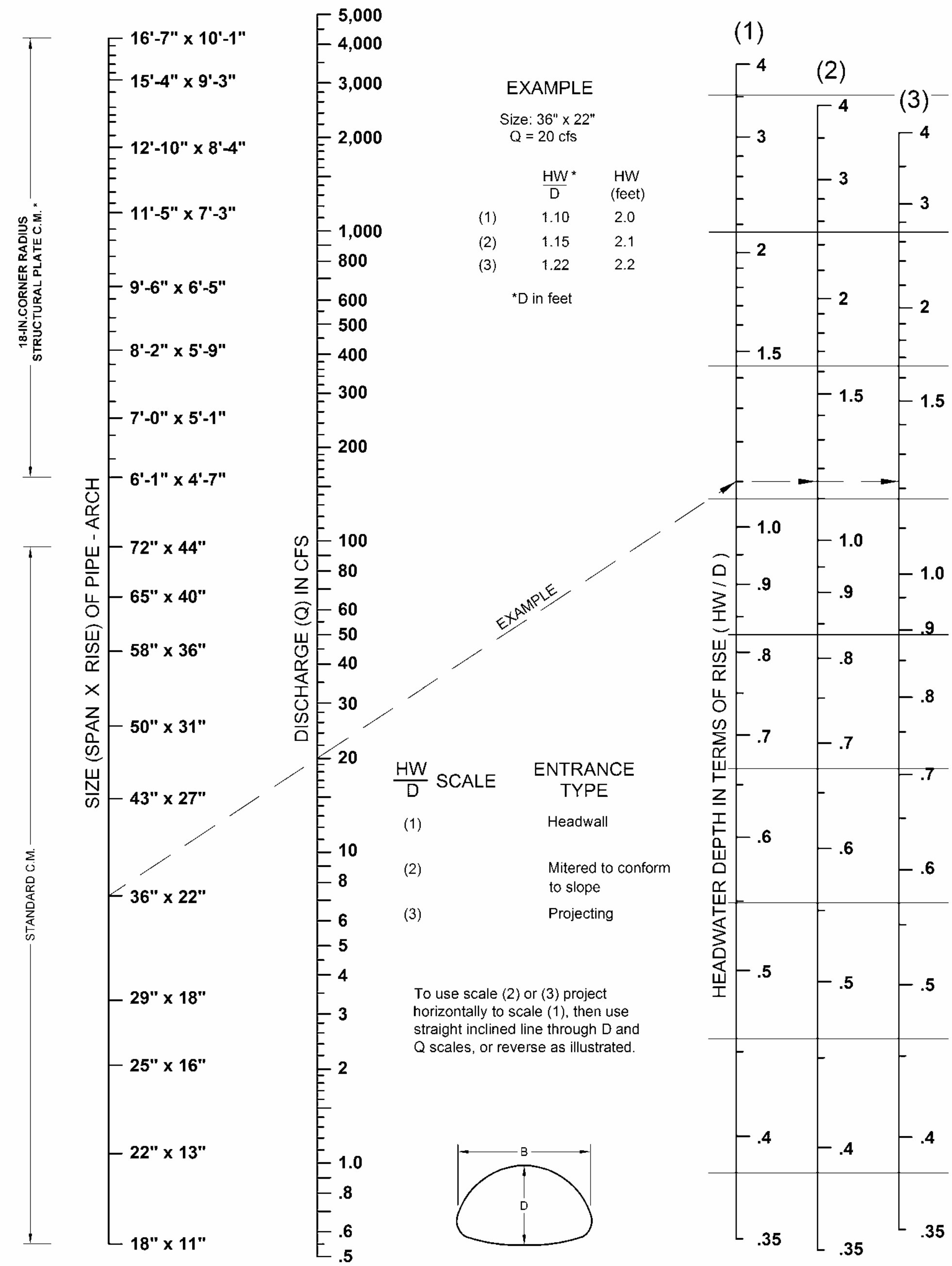
FIGURE 5603-5



HEADWATER DEPTH FOR C.M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

FIGURE 5603-6



* ADDITIONAL SIZES NOT DIMENSIONED ARE LISTED IN FABRICATOR'S CATALOG

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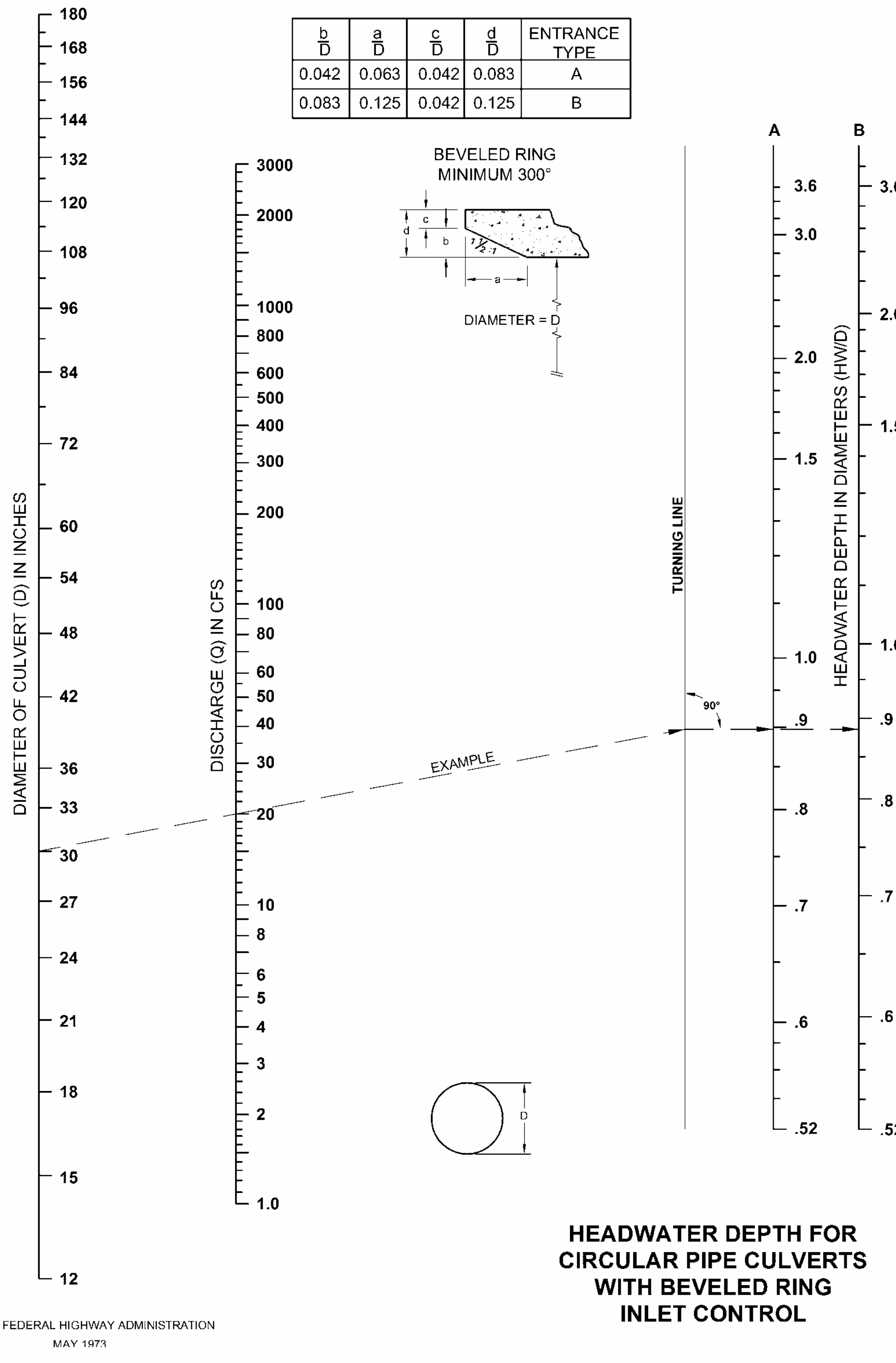
HEADWATER DEPTH FOR C. M. PIPE - ARCH CULVERTS WITH INLET CONTROL

FIGURE 5603-7

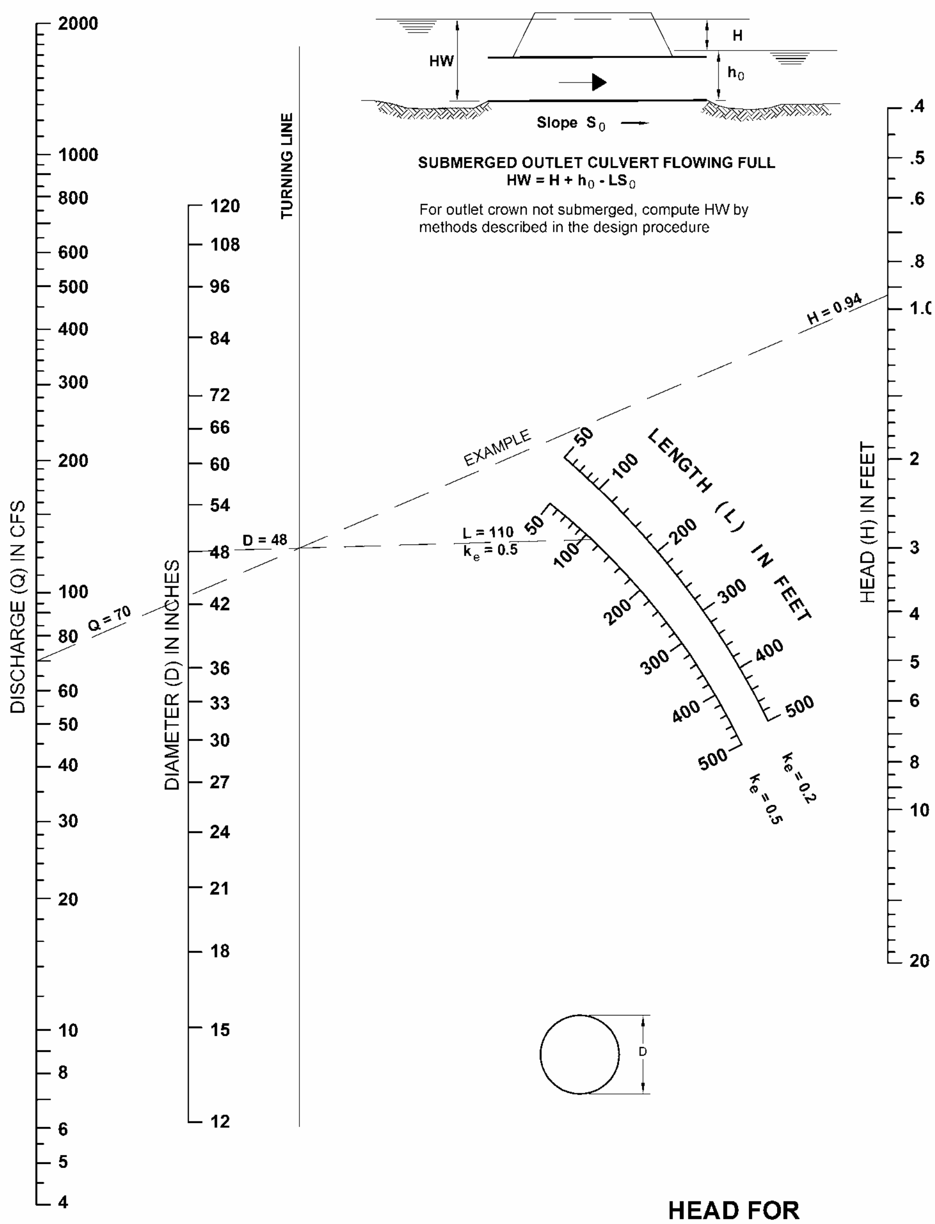
$\frac{b}{D}$	$\frac{a}{D}$	$\frac{c}{D}$	$\frac{d}{D}$	ENTRANCE TYPE
0.042	0.063	0.042	0.083	A
0.083	0.125	0.042	0.125	B



HEADWATER DEPTH FOR CIRCULAR PIPE CULVERTS WITH BEVELED RING INLET CONTROL

FEDERAL HIGHWAY ADMINISTRATION
MAY 1973

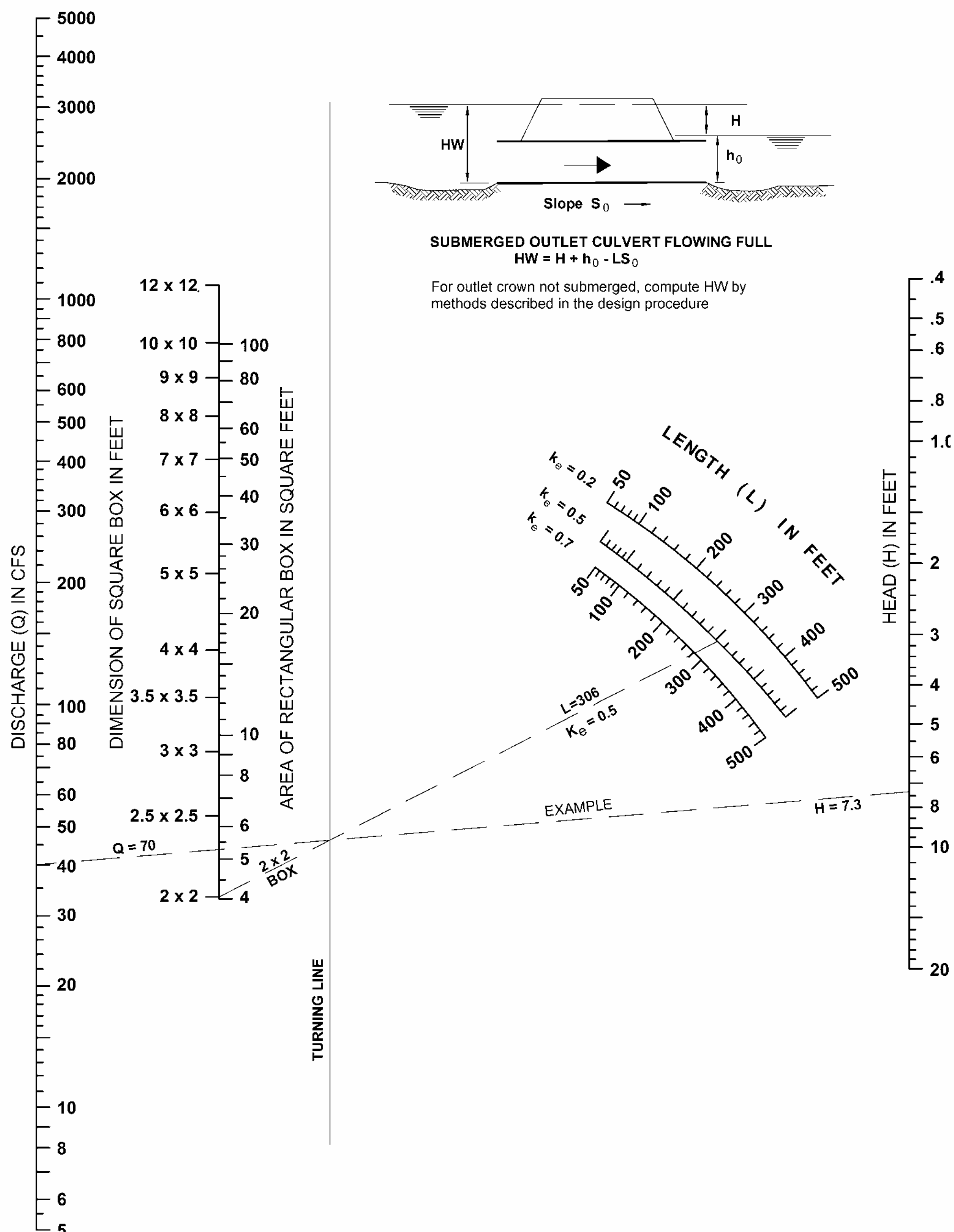
FIGURE 5603-8



HEAD FOR CONCRETE PIPE CULVERTS FLOWING FULL n=0.012

BUREAU OF PUBLIC ROADS JAN. 1963

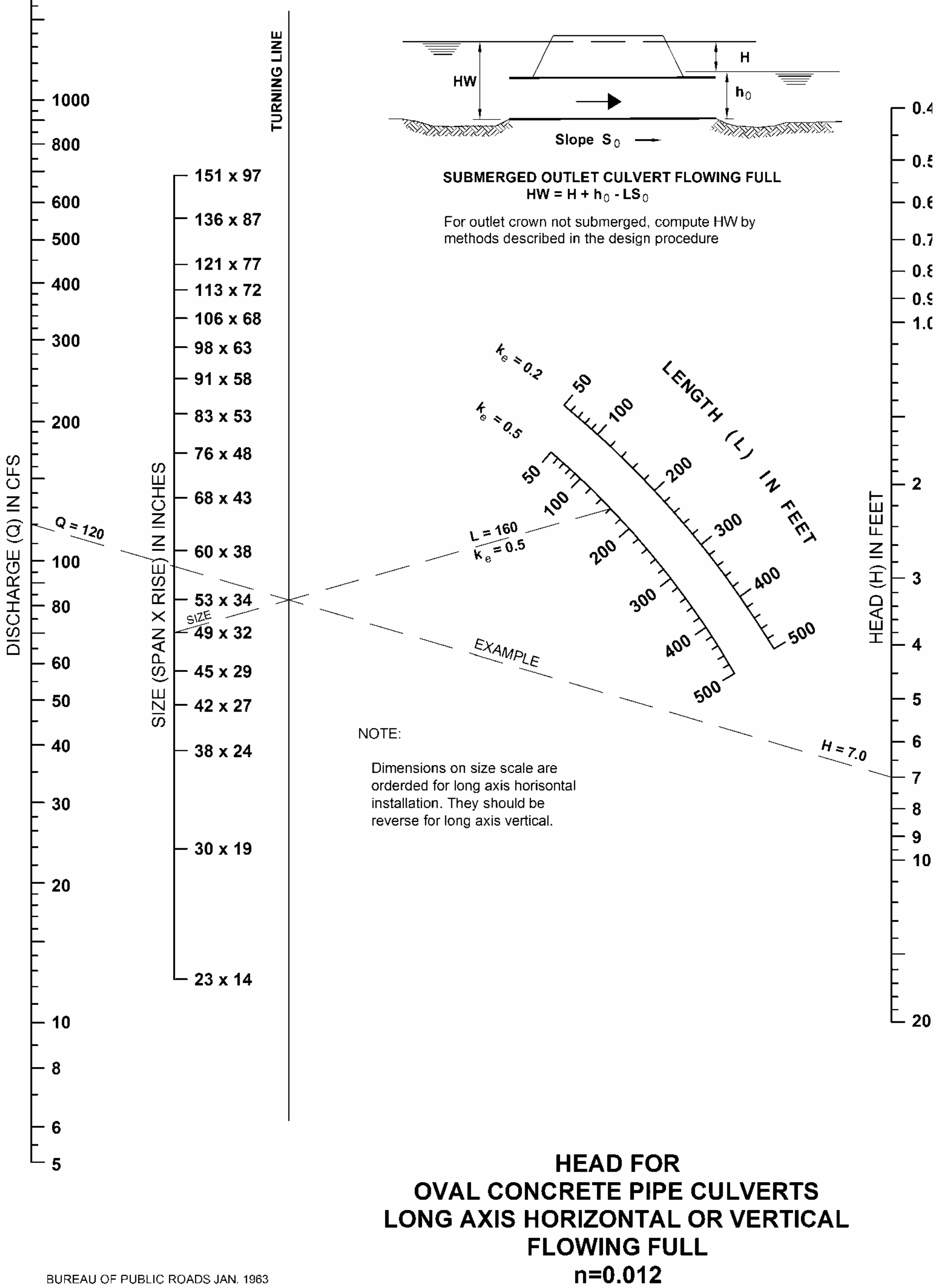
FIGURE 5603-9



HEAD FOR CONCRETE BOX CULVERTS FLOWING FULL n=0.012

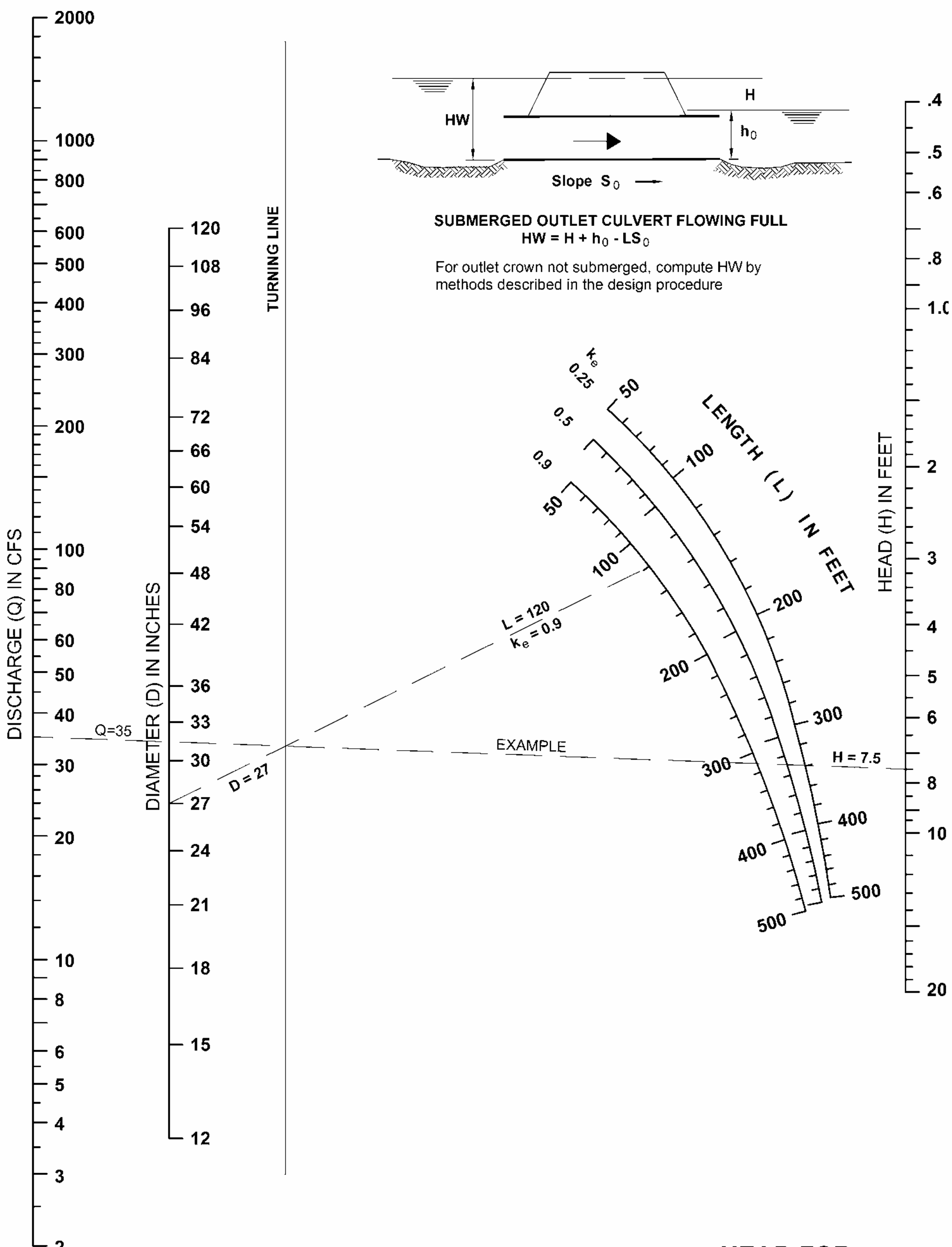
BUREAU OF PUBLIC ROADS JAN. 1963

FIGURE 5603-10



HEAD FOR
OVAL CONCRETE PIPE CULVERTS
LONG AXIS HORIZONTAL OR VERTICAL
FLOWING FULL
n=0.012

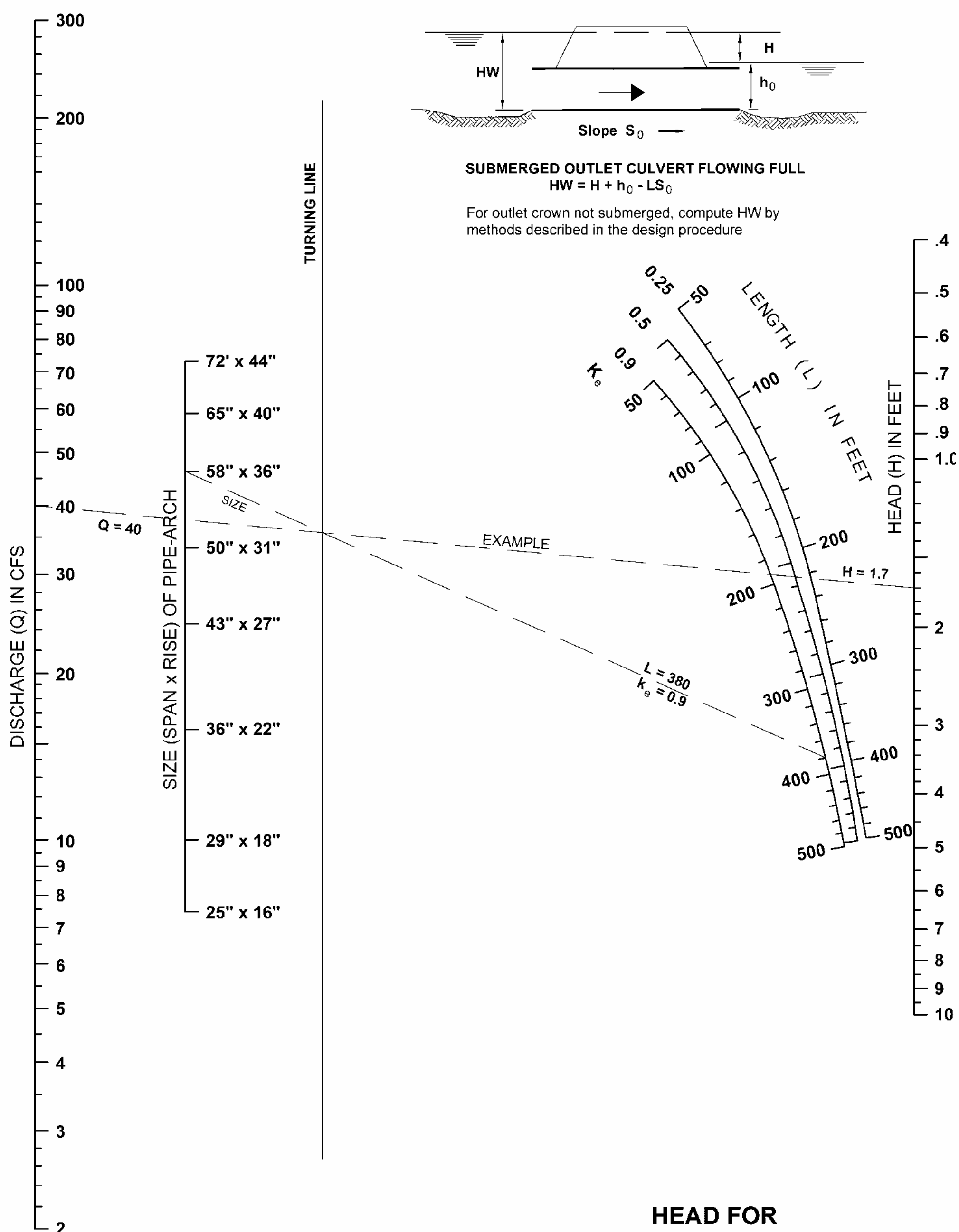
FIGURE 5603-11



HEAD FOR STANDARD C. M. PIPE CULVERTS FLOWING FULL n=0.024

BUREAU OF PUBLIC ROADS JAN. 1963

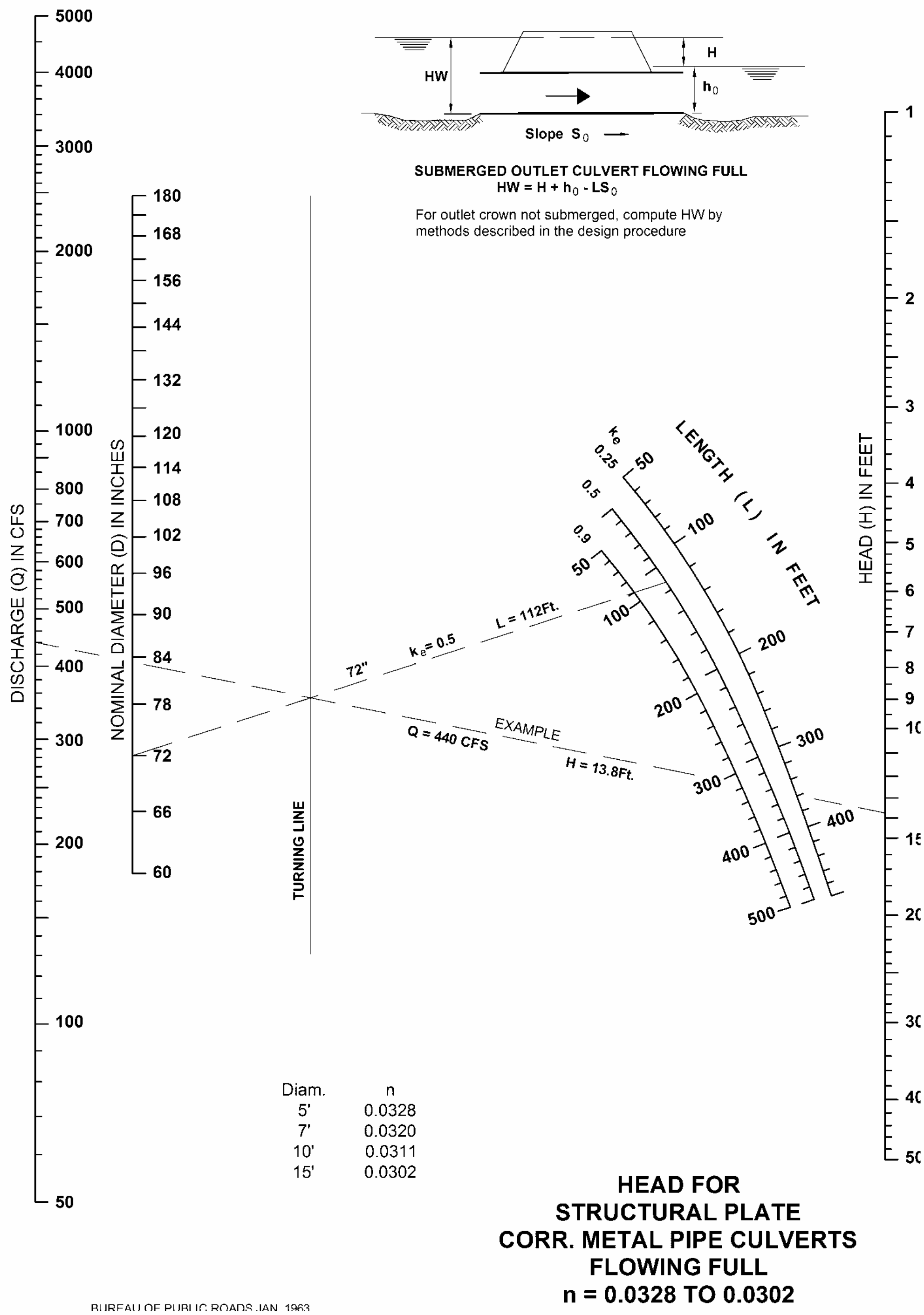
FIGURE 5603-12



HEAD FOR STANDARD C.M. PIPE-ARCH CULVERTS FLOWING FULL n=0.024

BUREAU OF PUBLIC ROADS JAN. 1963

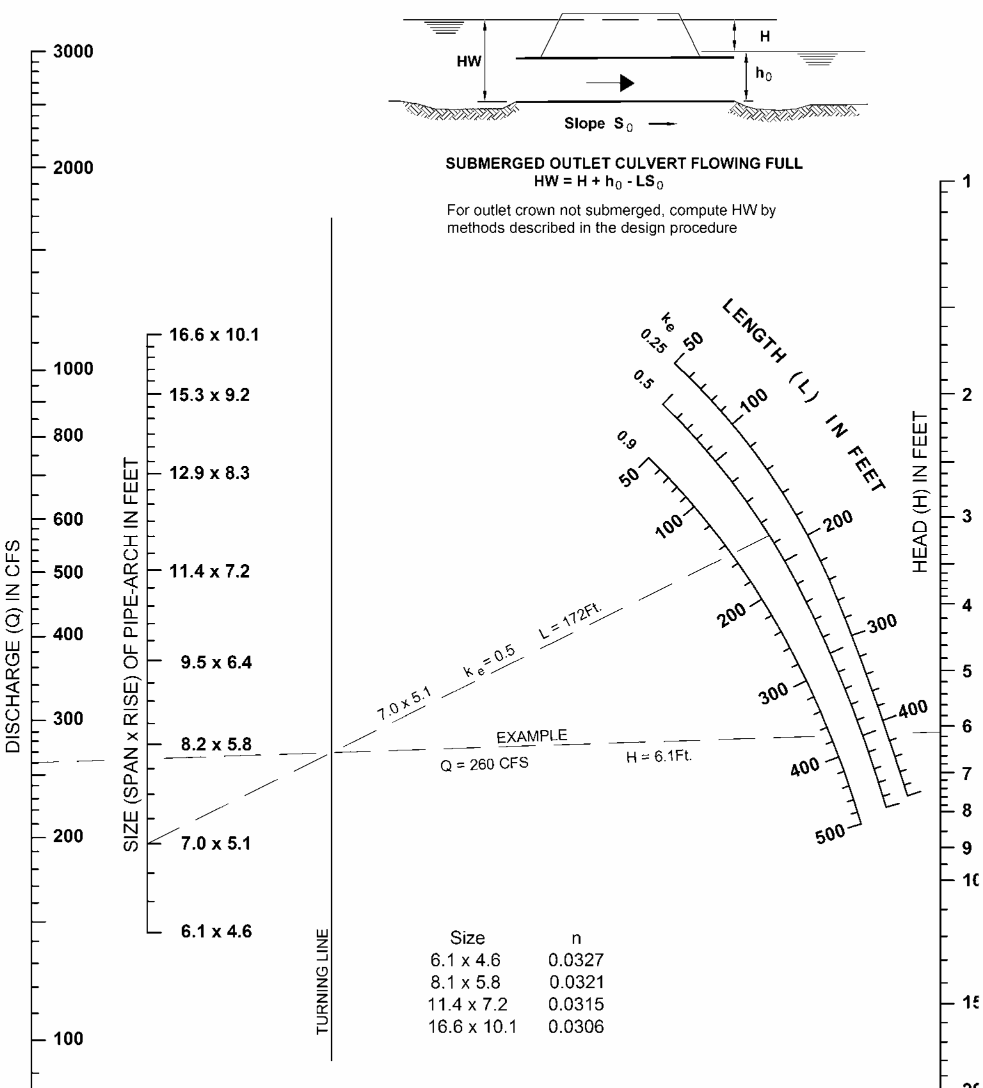
FIGURE 5603-13



Diam.	n
5'	0.0328
7'	0.0320
10'	0.0311
15'	0.0302

HEAD FOR STRUCTURAL PLATE CORR. METAL PIPE CULVERTS FLOWING FULL n = 0.0328 TO 0.0302

FIGURE 5603-14

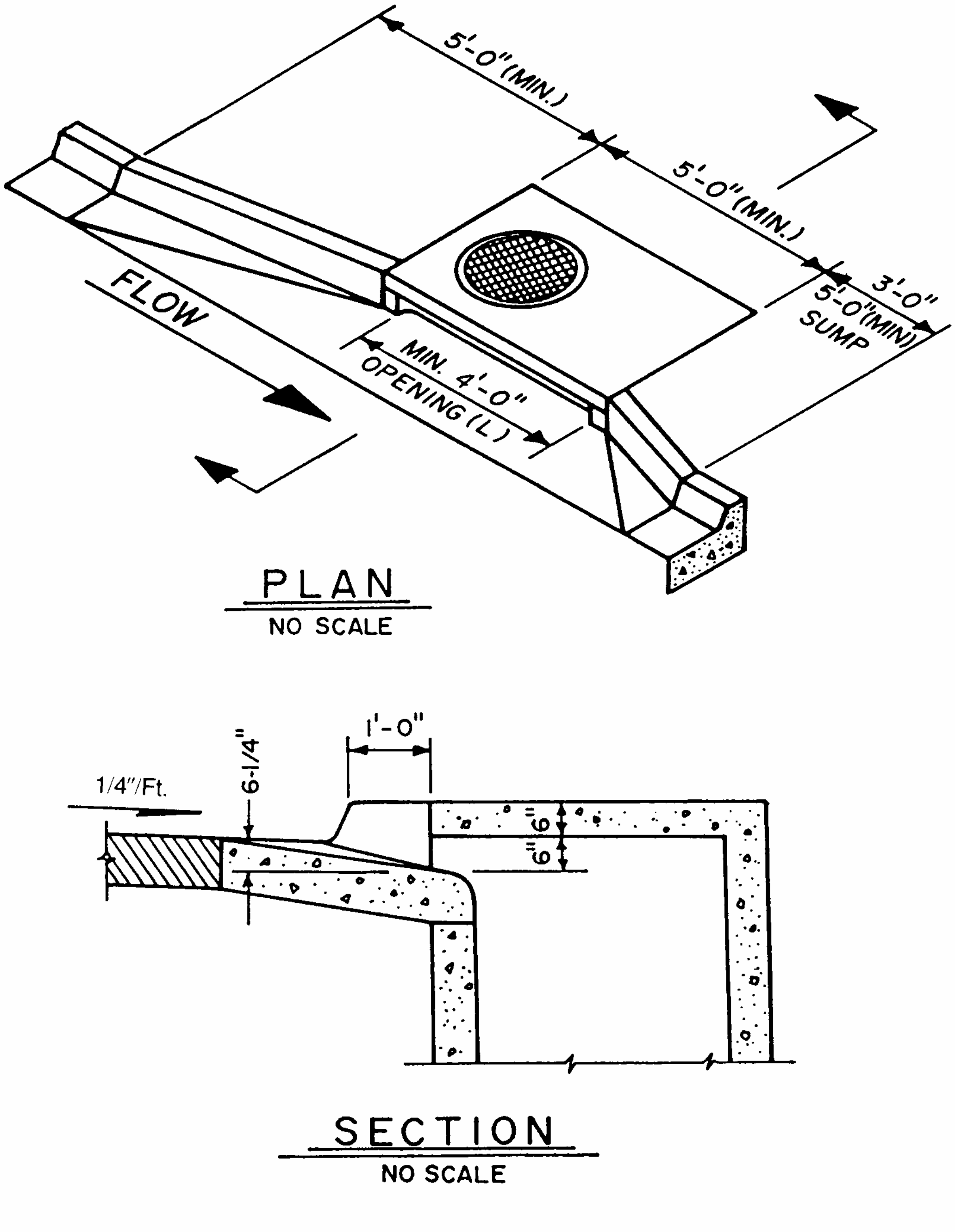


Size	n
6.1 x 4.6	0.0327
8.1 x 5.8	0.0321
11.4 x 7.2	0.0315
16.6 x 10.1	0.0306

HEAD FOR STRUCTURAL PLATE CORRUGATED METAL PIPE ARCH CULVERTS 18 IN. CORNER RADIUS FLOWING FULL $n = 0.0327$ TO 0.0306

BUREAU OF PUBLIC ROADS JAN. 1963

Figure 5603-1



CURB INLETS

MINIMUM HYDRAULIC DIMENSIONS

Curb Inlet Intercept Equations:

[1].“For any given set of conditions (curb type, inlet length, street grade and cross-slope), the relationship between the captured discharge and the total discharge can be approximated satisfactorily by an equation of the form

$$Q_c = \begin{Bmatrix} Q_t \quad for \quad Q_t \le Q_o \\ Q_o + (Q_a - Q_o)\left\{1 - \exp\left[-\left(\dfrac{Q_t - Q_o}{Q_a - Q_o}\right)\right]\right\} \quad for \quad Q_t > Q_o \end{Bmatrix}$$

in which Q_o and Q_a are constants. The constant Q_o represents the largest discharge that is captured completely, and the constant Q_a represents the upper limit on the captured discharge, which is approached asymptotically with increasing total discharge. For a particular curb type and street cross-slope, Q_o and Q_a vary with inlet length (L_o) and street grade (S_o) according to the formulas

$$Q_o = (a + b \cdot L_o)(S_o)^x$$

$$Q_a = (c + d \cdot L_o)(S_o)^x$$

in which a, b, c, d and x are constants. Table 2 shows these constants in U.S. customary units.

Table 1. Values of Coefficients and Exponent

Curb Type	S_x,%	a	b	c	d	x
CG-1 (B)	2	1.0	0	3.2	1.7	-0.5
CG-1 (B)	4	1.5	0.5	2.6	1.9	-0.5
CG-2 (A)	2	-0.4	0.1	3.5	0.8	-0.7
CG-2 (A)	4	-0.3	0.3	4.3	2.5	-0.8

NOTE: These equations were developed from model tests on curb inlets that in general were larger than the minimum dimensions given in Figure 5604-1. The inlet used in the model study had the inlet face setback 18" from the curb line (instead of the minimum 12"), had a 10" throat opening (instead of the minimum 6" opening), and had an upstream transition length of 10' and a downstream transition of 5' (instead of the 5' and 3' minimum transition lengths, respectively). There are no known model tests available for the minimum inlet given in Figure 5604-1. The Engineer is responsible for determining if proposed inlets will be less efficient than the ones used for the model study, and make appropriate adjustments in calculated capture.

[1.]”Hydraulic Performance of Set-Back Curb Inlets”, McEnroe et al., University of Kansas, 1998.

The following is a Microsoft Visual Basic function that can be added to a Microsoft Excel (97 or later) worksheet or template for inlet intercept calculations.

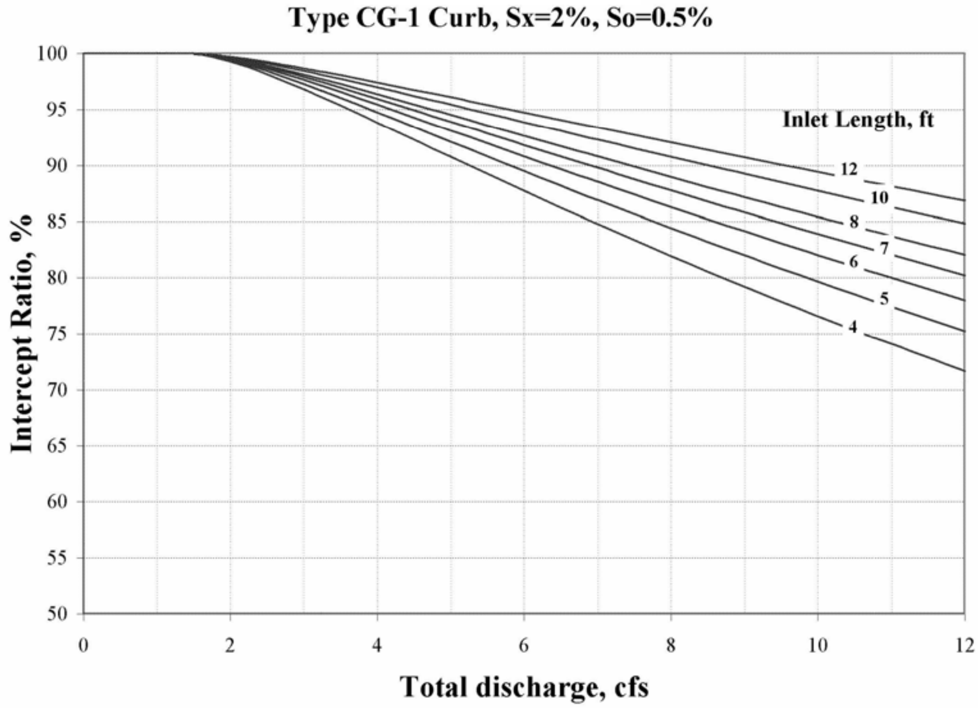
```
Function InletIntercept(slope, Qt, Optional CrossSlope = 2, _
                        Optional Length = 4#, Optional CurbType = "A", _
                        Optional Metric = False)
'
' InletIntercept Macro
' Determine the intercept ratio for setback curb
' inlets given length of opening, q, slope and cross slope
' All inputs in english units.
' Function written 04/19/1999 by Michael S. Ross
'
Dim a As Double, b As Double, c As Double, d As Double
Dim x As Double, Qo As Double, Qa As Double
Dim strAlert As String

CurbType = UCase(CurbType)
If CurbType <> "A" And CurbType <> "B" Then
    strAlert = "Curb type must be one of 'A' or 'B'. 'A' assumed. "
    CurbType = "A"
End If
If slope >= -0.00001 And slope <= 0.00001 Then
    InletIntercept = Qt
Else
Select Case CurbType
Case "A"
    Select Case CrossSlope
    Case 2
        If Metric Then
            a = -0.12
            b = 0.03
            c = 1.07
            d = 0.24
            x = -0.7
        Else
            a = -0.4
            b = 0.1
            c = 3.5
            d = 0.8
            x = -0.7
        End If
    Case 4
        If Metric Then
            a = -0.09
            b = 0.09
            c = 1.31
            d = 0.76
            x = -0.8
        Else
            a = -0.3
            b = 0.3
            c = 4.3
            d = 2.5
            x = -0.8
        End If
    Case Else
        strAlert = strAlert & "Cross slope must be either 2% or 4%," & _
                   "other cross slopes were not modelled. Assuming 2%. "
        If Metric Then
            a = -0.12
            b = 0.03
```

```
            c = 1.07
            d = 0.24
            x = -0.7
        Else
            a = -0.4
            b = 0.1
            c = 3.5
            d = 0.8
            x = -0.7
        End If
    End Select
Case "B"

    Select Case CrossSlope
    Case 2
        If Metric Then
            a = 0.3
            b = 0#
            c = 0.98
            d = 0.52
            x = -0.5
        Else
            a = 1#
            b = 0#
            c = 3.2
            d = 1.7
            x = -0.5
        End If
    Case 4
        If Metric Then
            a = 0.46
            b = 0.15
            c = 0.79
            d = 0.58
            x = -0.5
        Else
            a = 1.5
            b = 0.5
            c = 2.6
            d = 1.9
            x = -0.5
        End If
    Case Else
        strAlert = strAlert & "Cross slope must be either 2% or 4%," & _
                   "other cross slopes were not modelled. Assuming 2%. "
        a = 1#
        b = 0#
        c = 3.2
        d = 1.7
        x = -0.5
    End Select
End Select
Qo = (a + (b * Length)) * (slope) ^ x
Qa = (c + (d * Length)) * (slope) ^ x
If Qt <= Qo Then
    InletIntercept = Qt
Else
    InletIntercept = Qo + (Qa - Qo) * (1 - Exp(-((Qt - Qo) / (Qa - Qo))))
End If
End If
If strAlert <> "" Then MsgBox strAlert, vbExclamation
End Function
```

FIGURE 5603-2



Design Example

FIGURE 5603-3

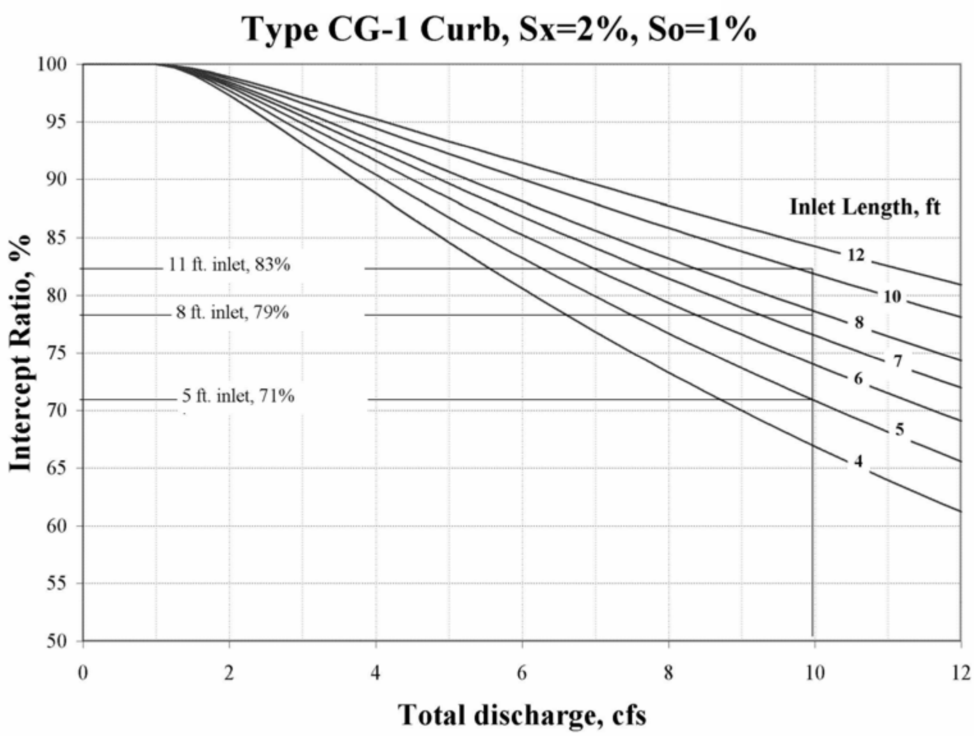


FIGURE 5603-4

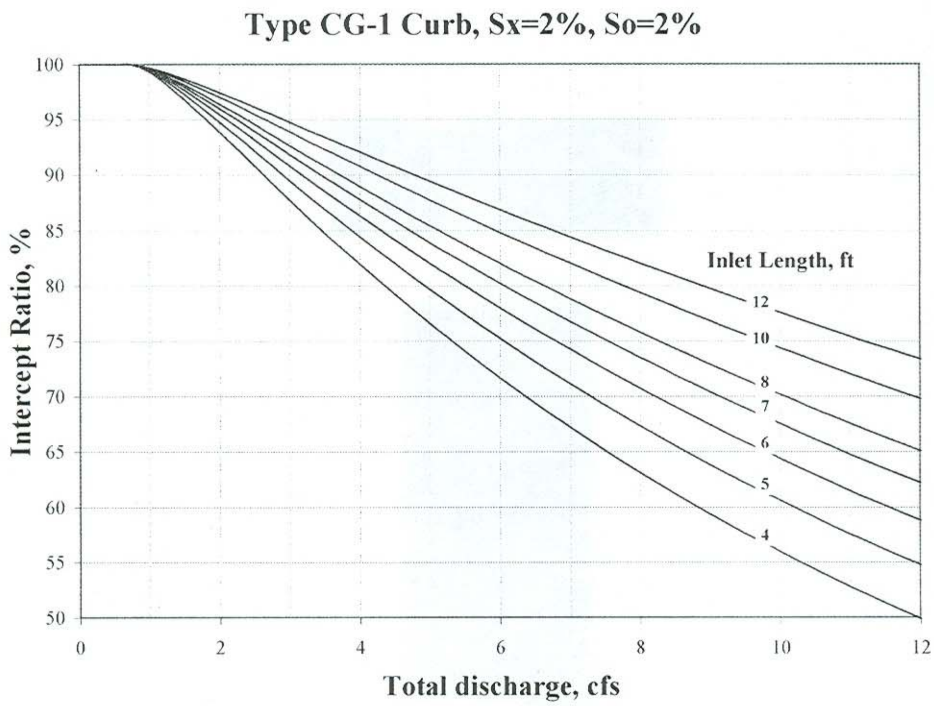


FIGURE 5603-5

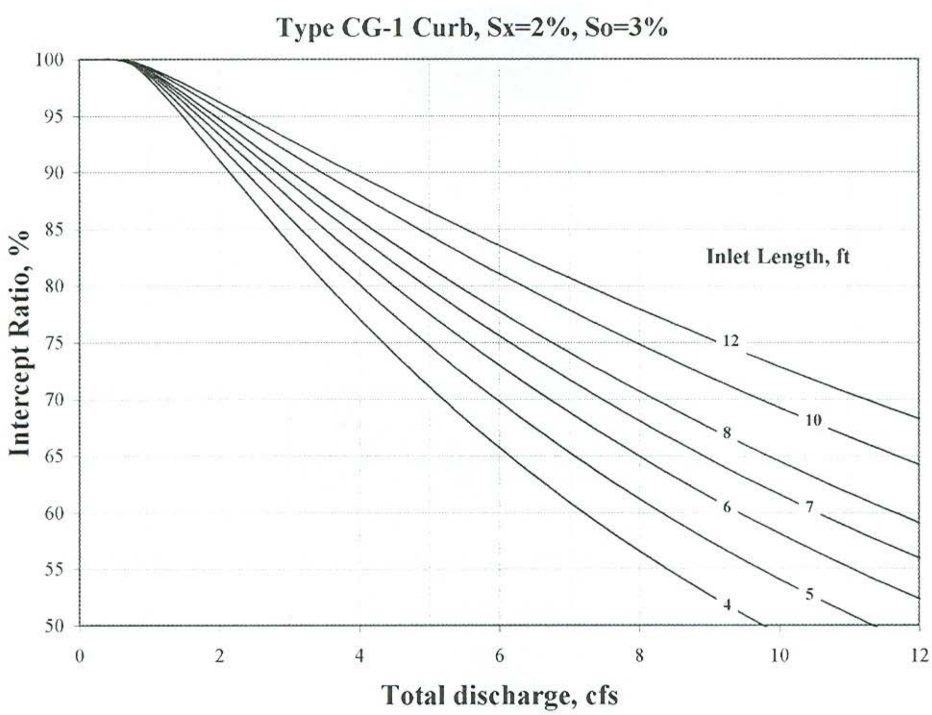


FIGURE 5603-6

Type CG-1 Curb, Sx=2%, So=4%

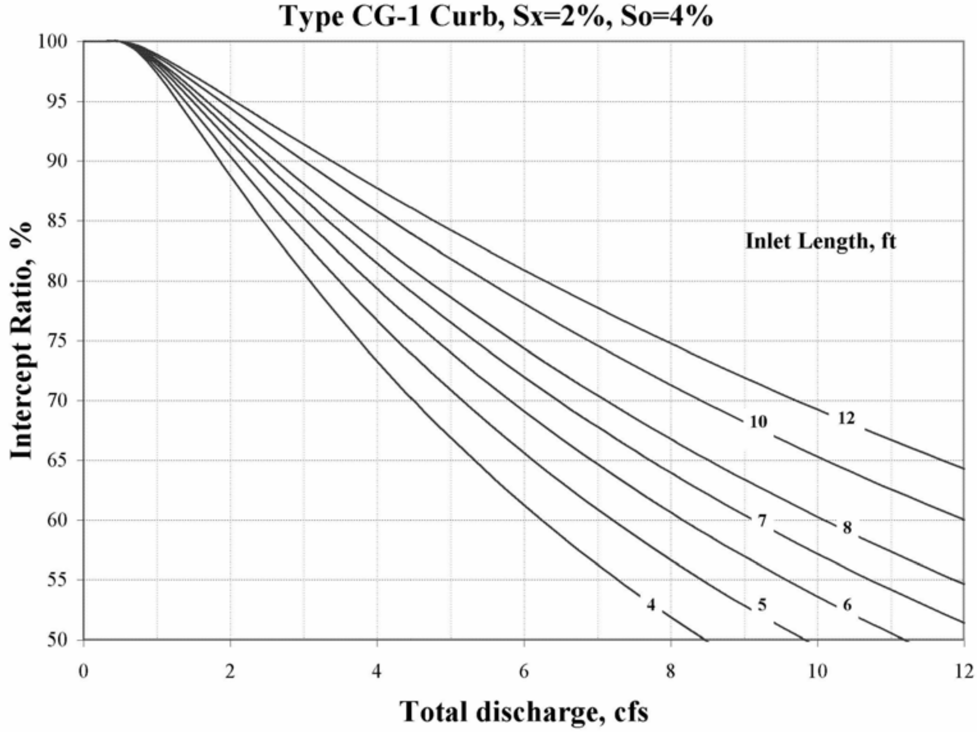


FIGURE 5603-7

Type CG-1 Curb, Sx=2%, So=6%

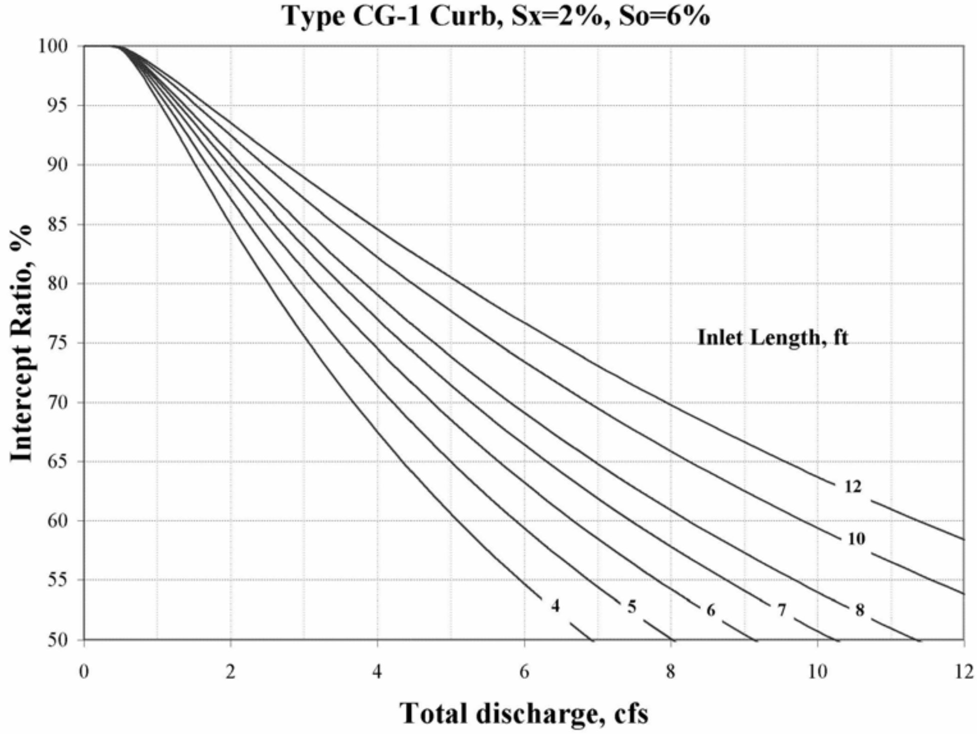


FIGURE 5603-8

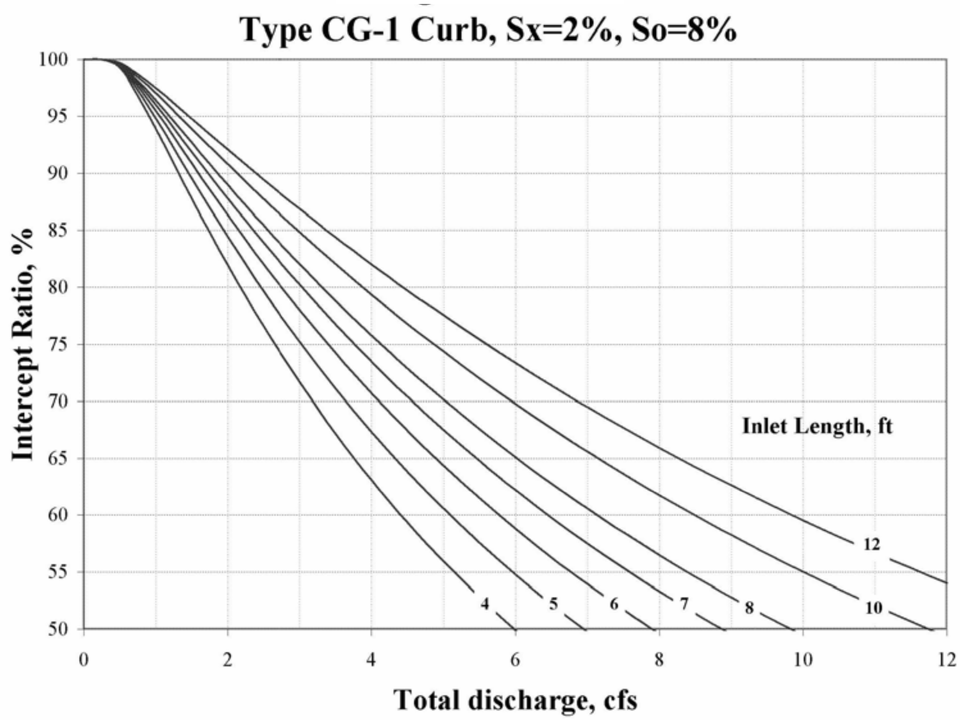


FIGURE 5603-9

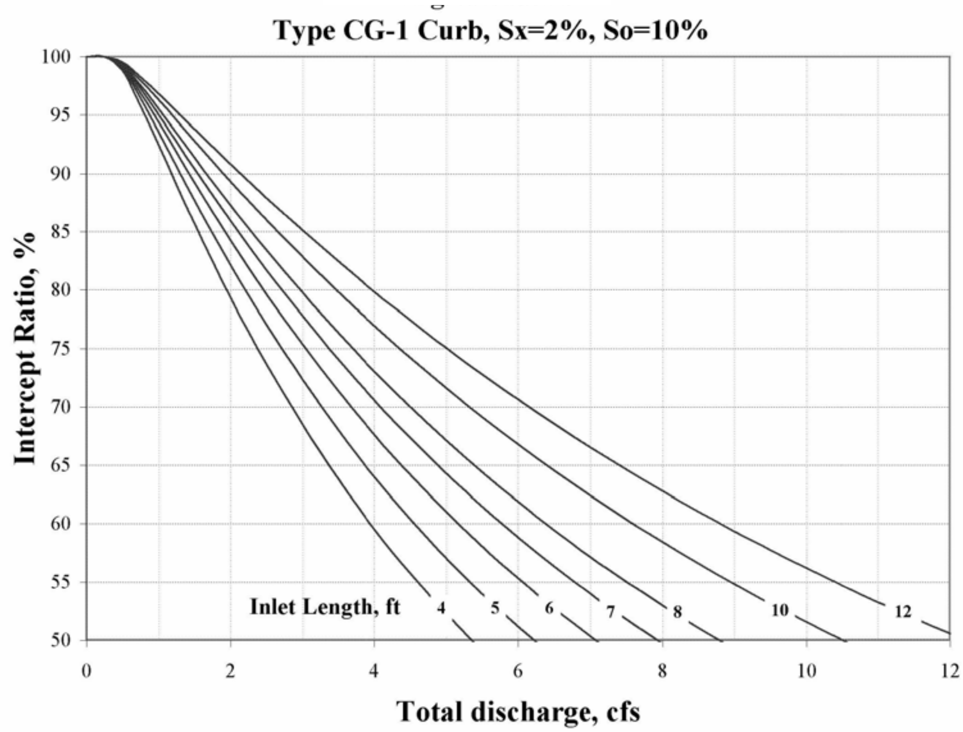


FIGURE 5603-10

Type CG-1 Curb, Sx=2%, So=12%

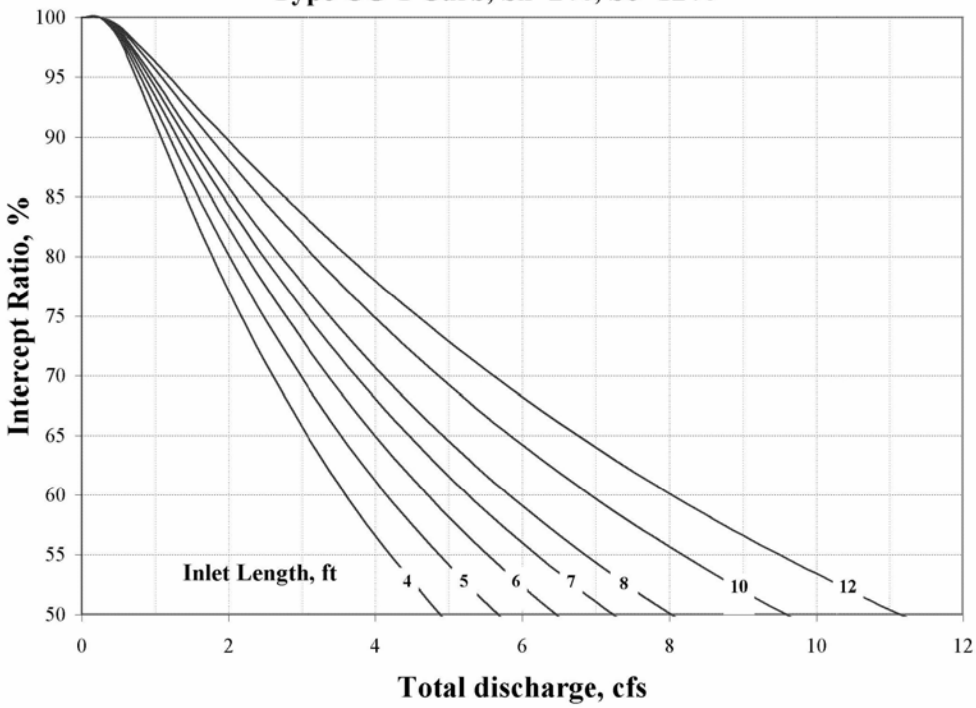


FIGURE 5603-11

Type CG-2 Curb, Sx=2%, So=0.5%

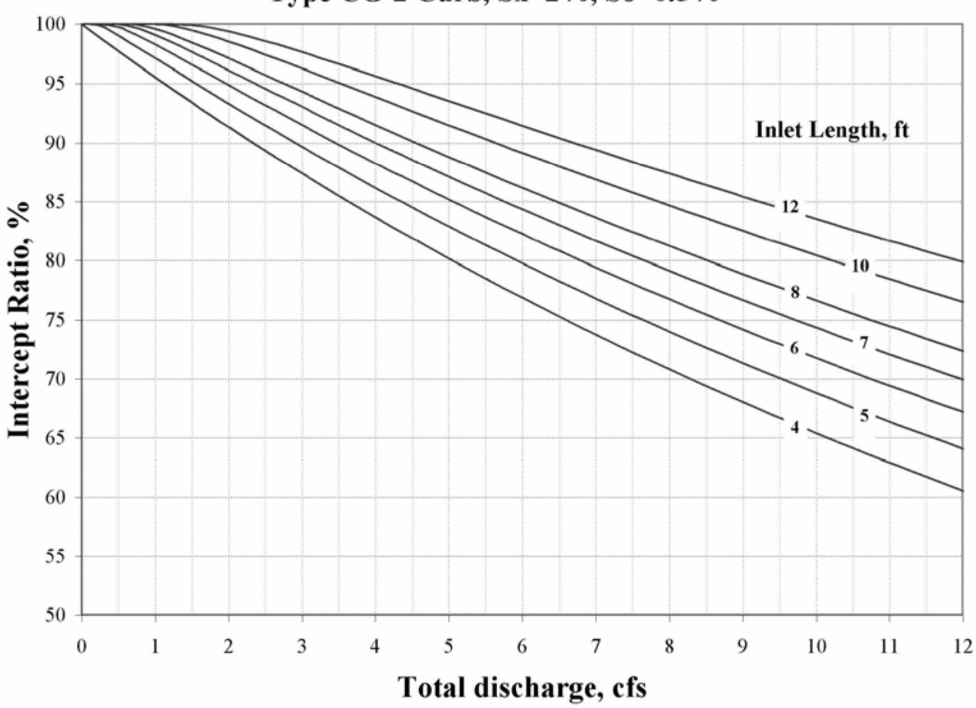


FIGURE 5603-12

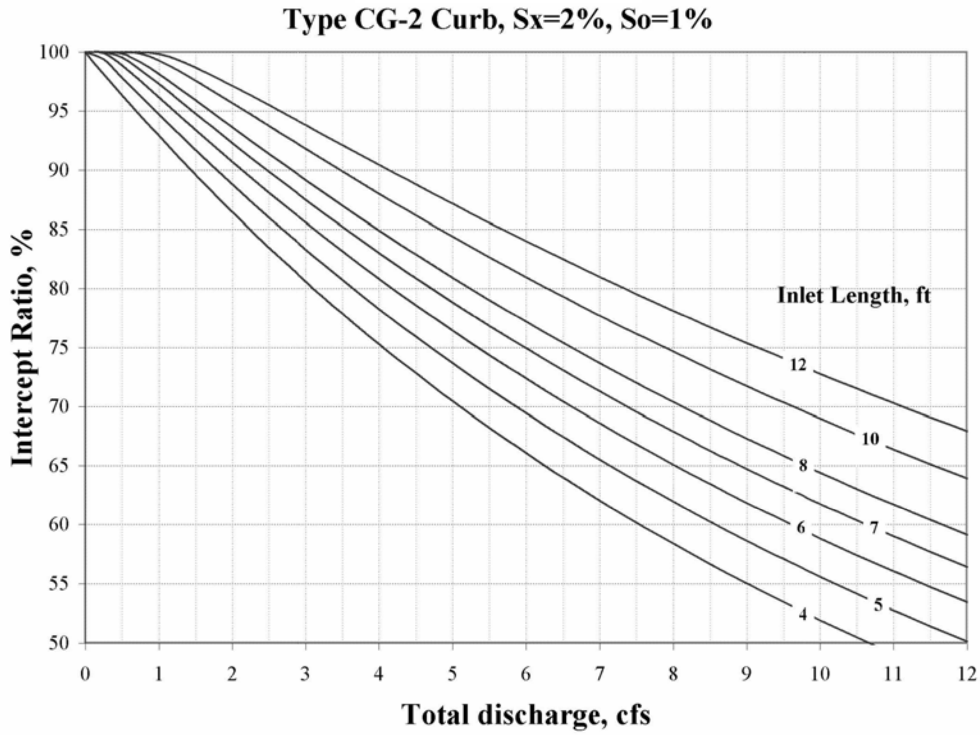


FIGURE 5603-13

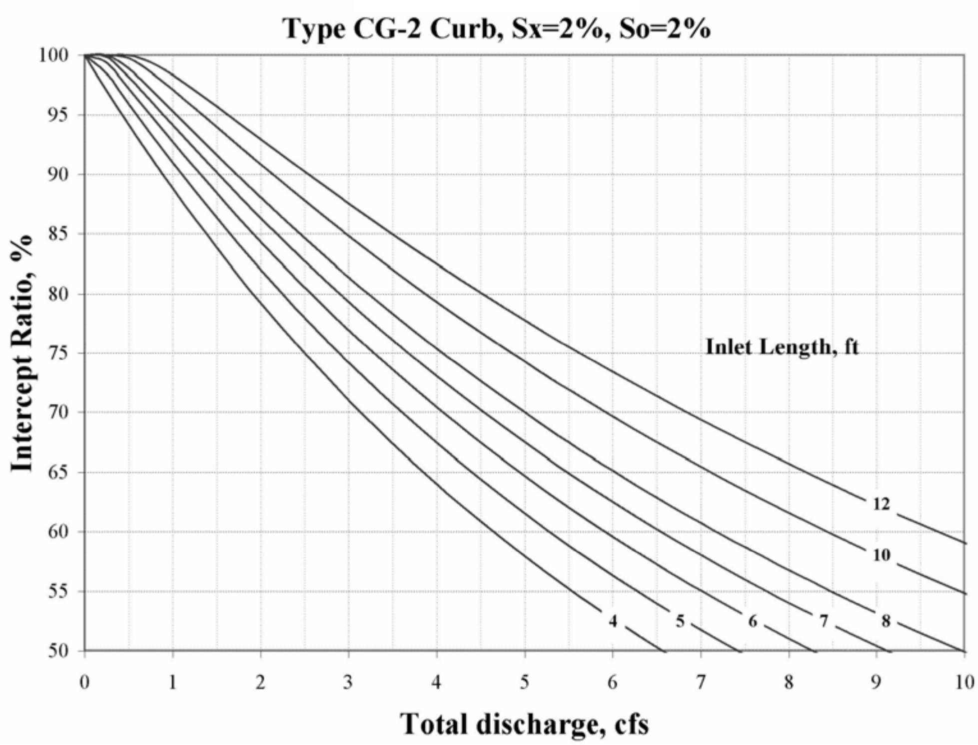


FIGURE 5603-14

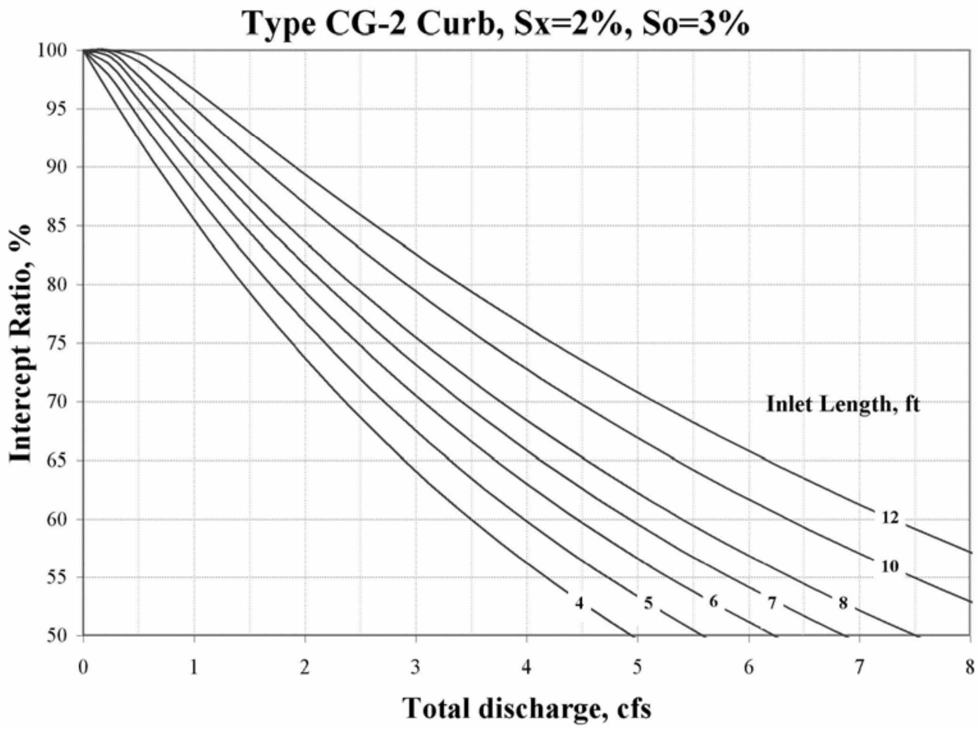


FIGURE 5603-15

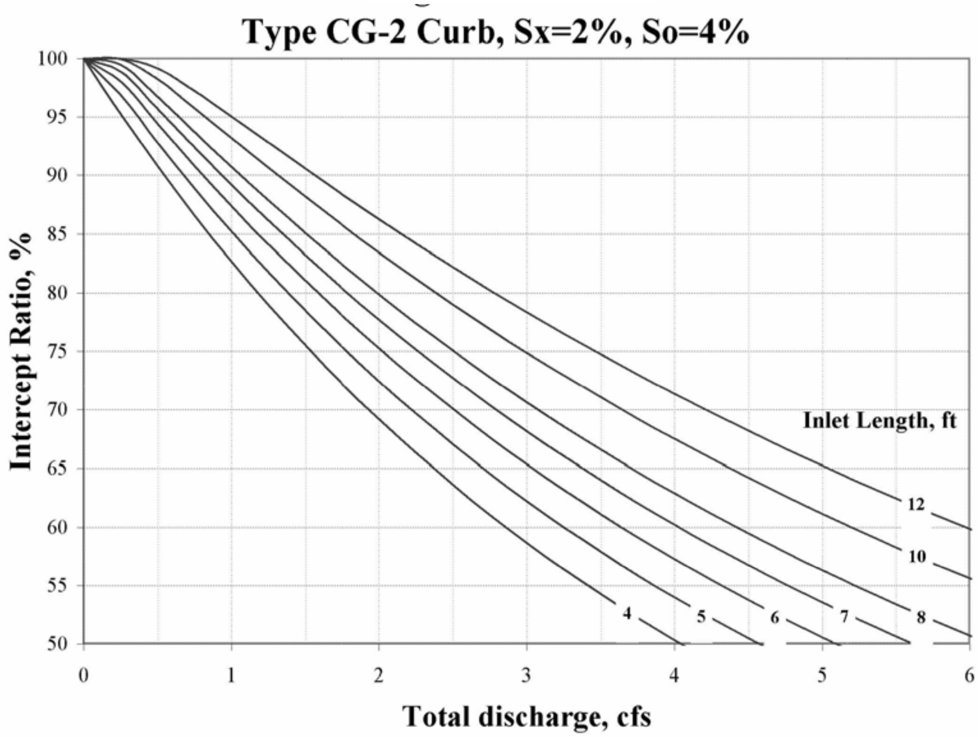


FIGURE 5603-16

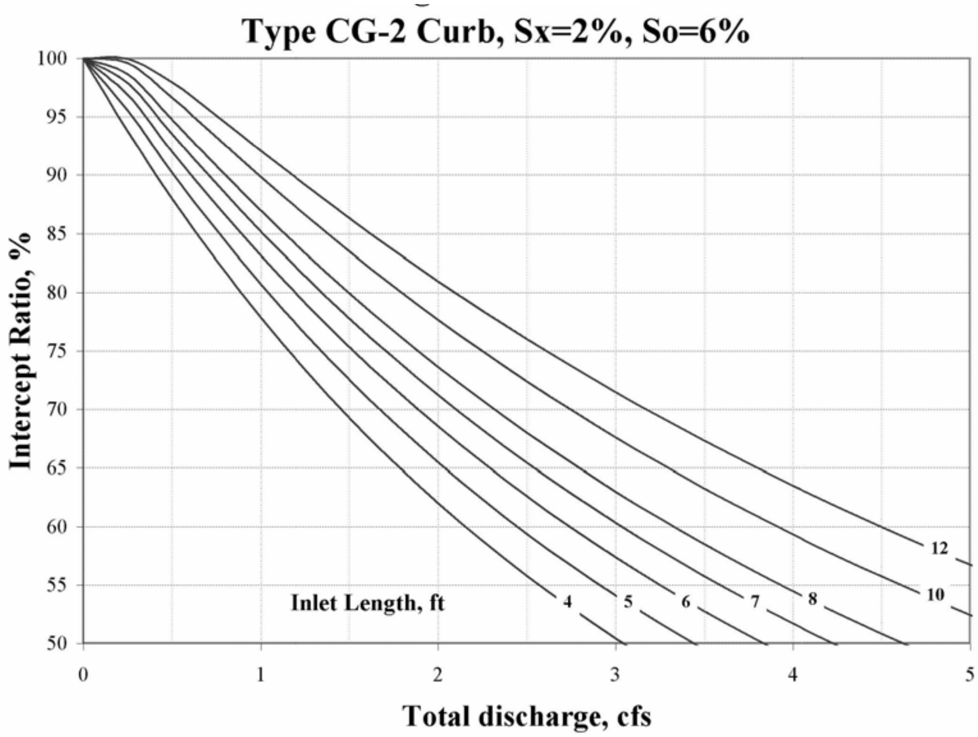


FIGURE 5603-17

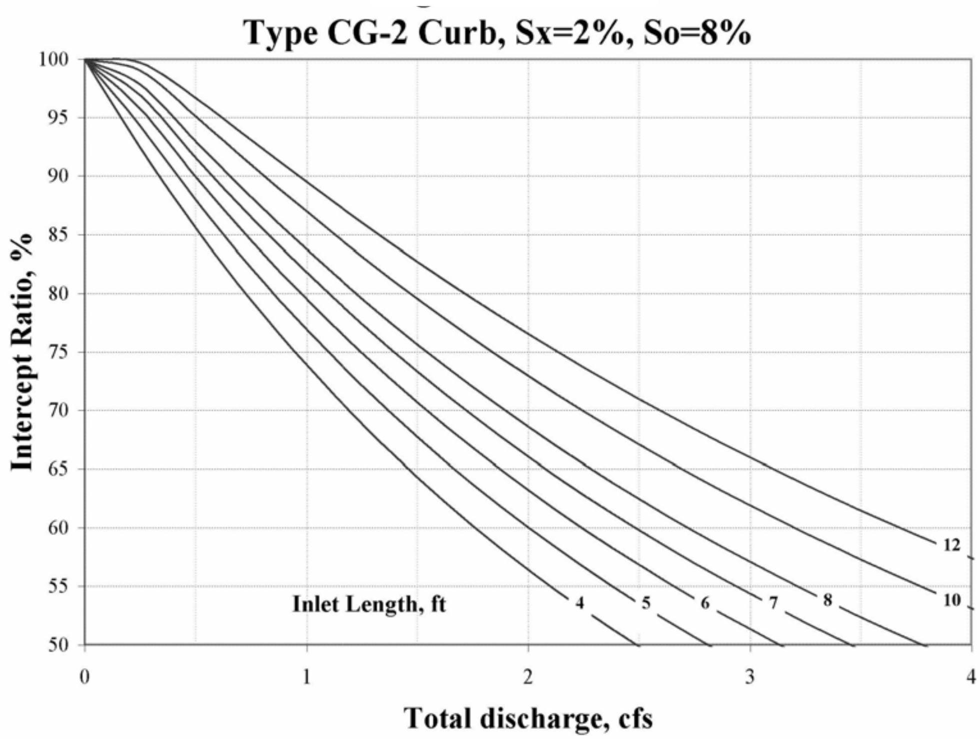


FIGURE 5603-18

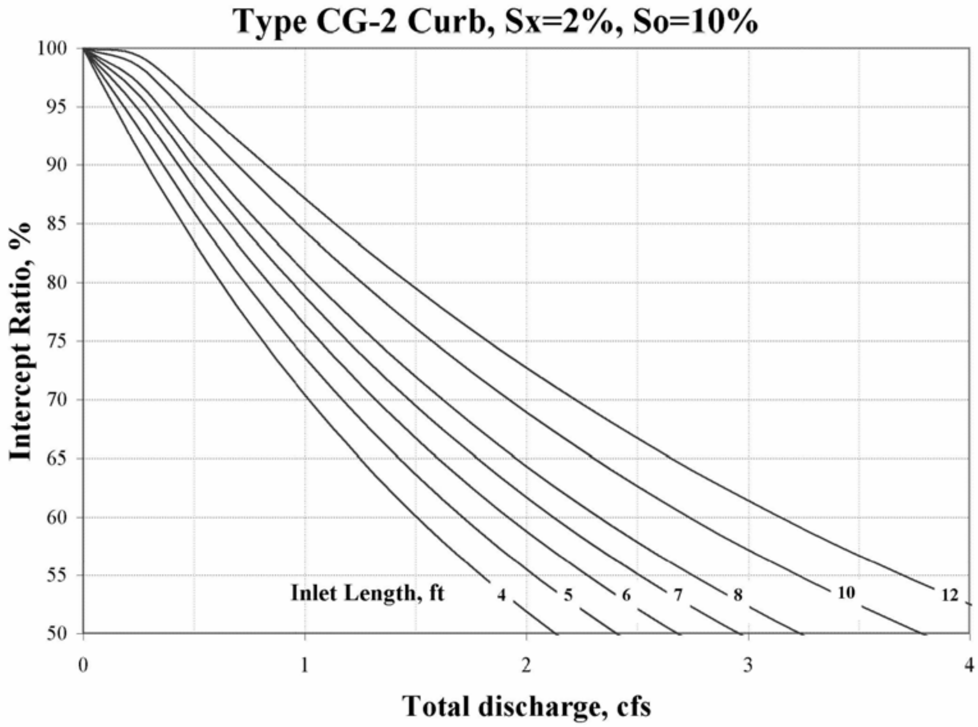


FIGURE 5603-19

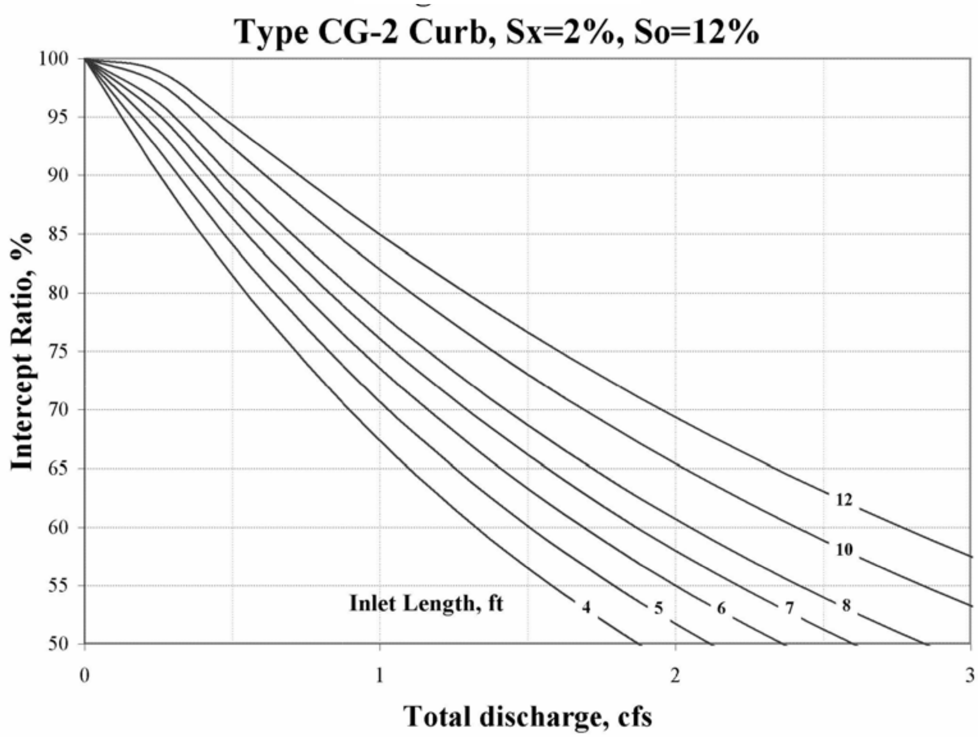


Figure 5603-20

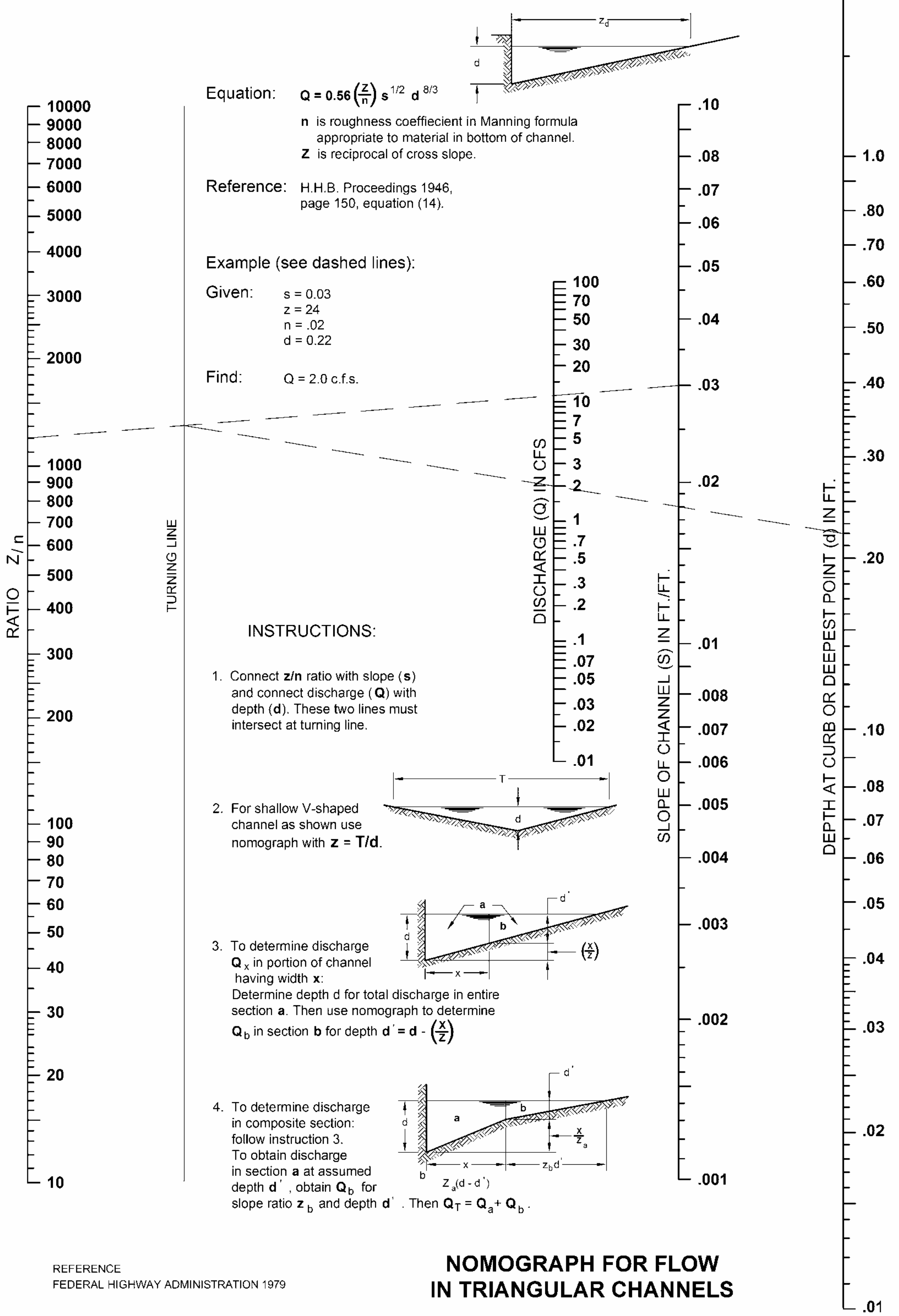
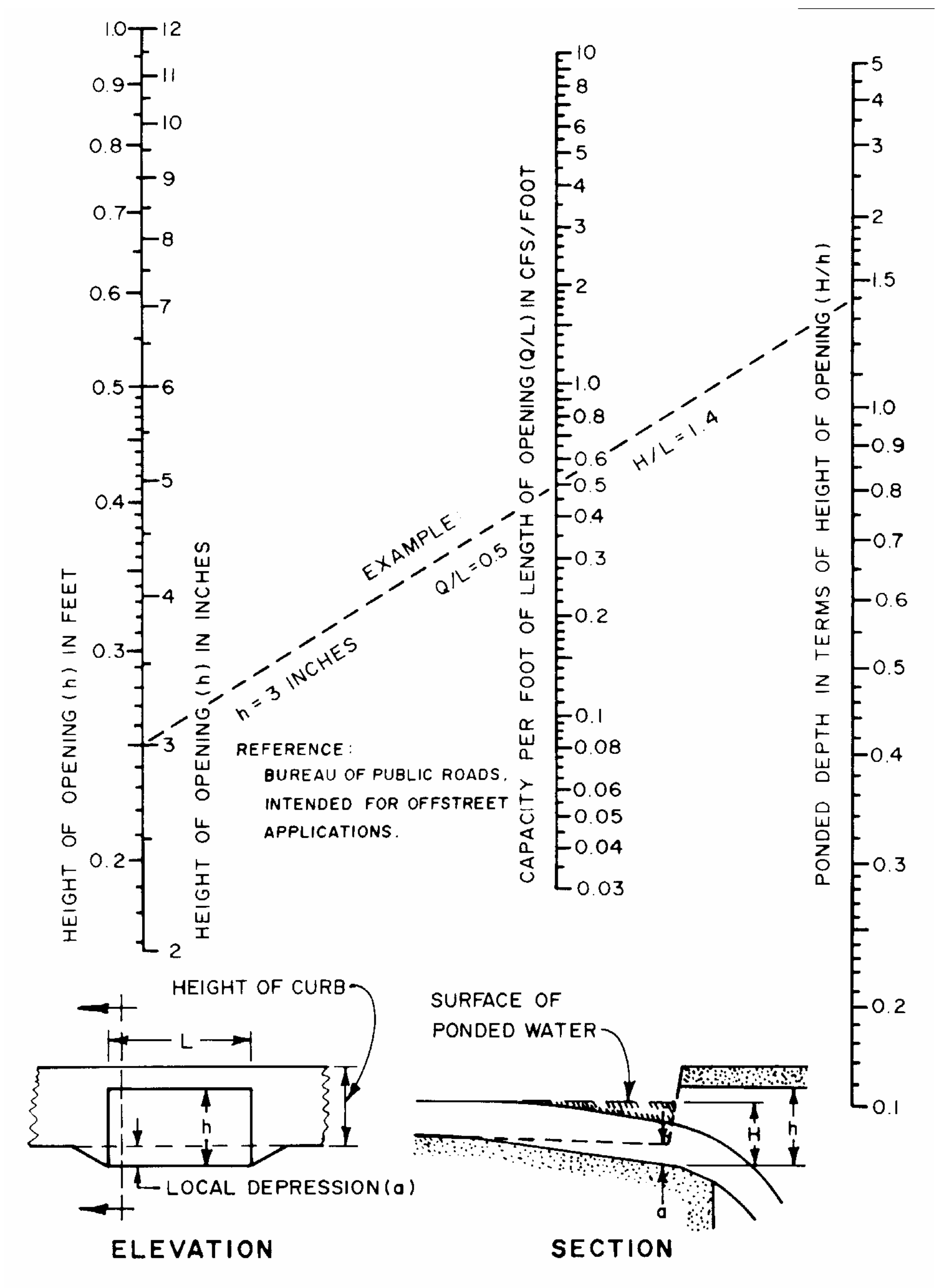
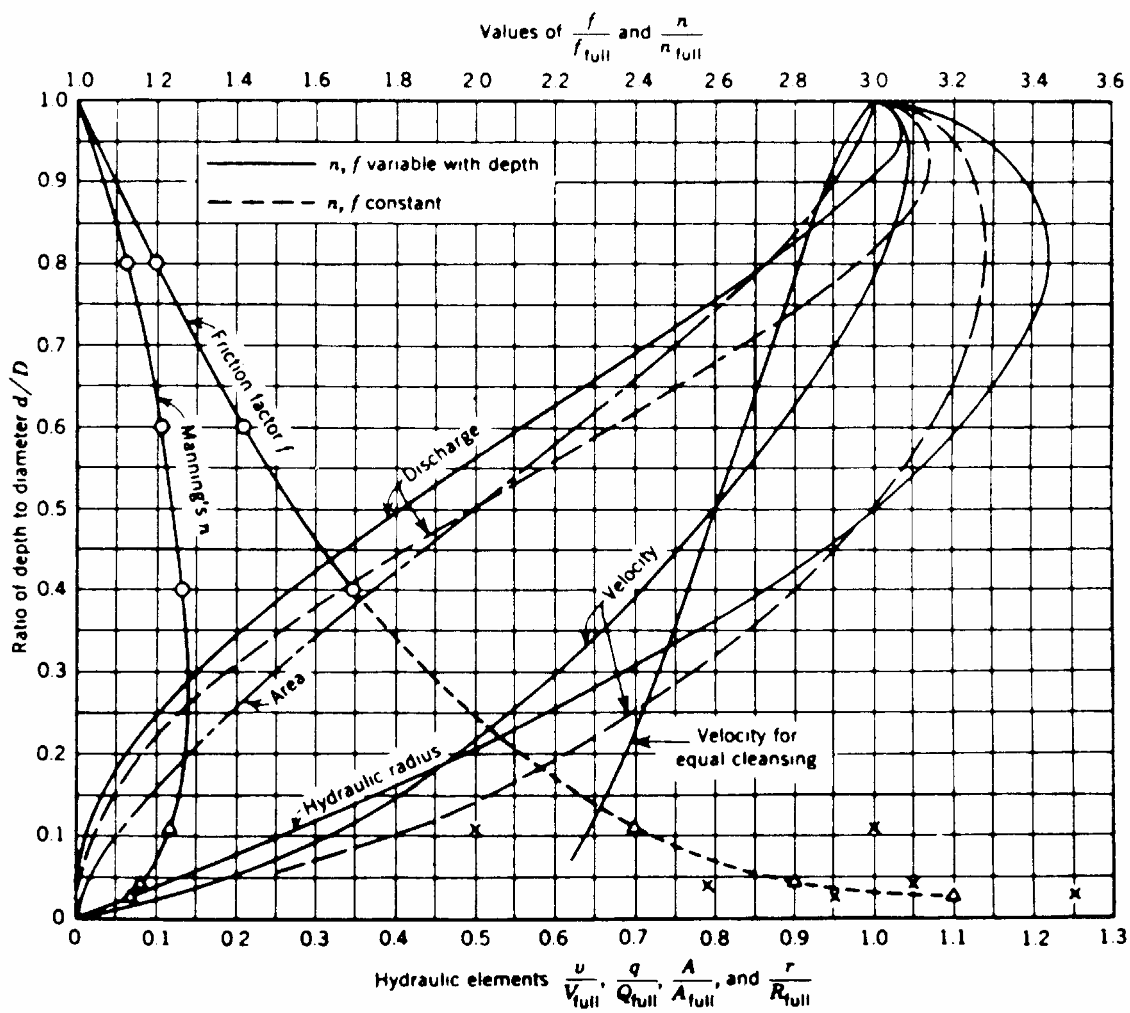


Figure 5603-21



CAPACITY OF CURB OPENING INLET
AT LOW POINT IN GRADE.

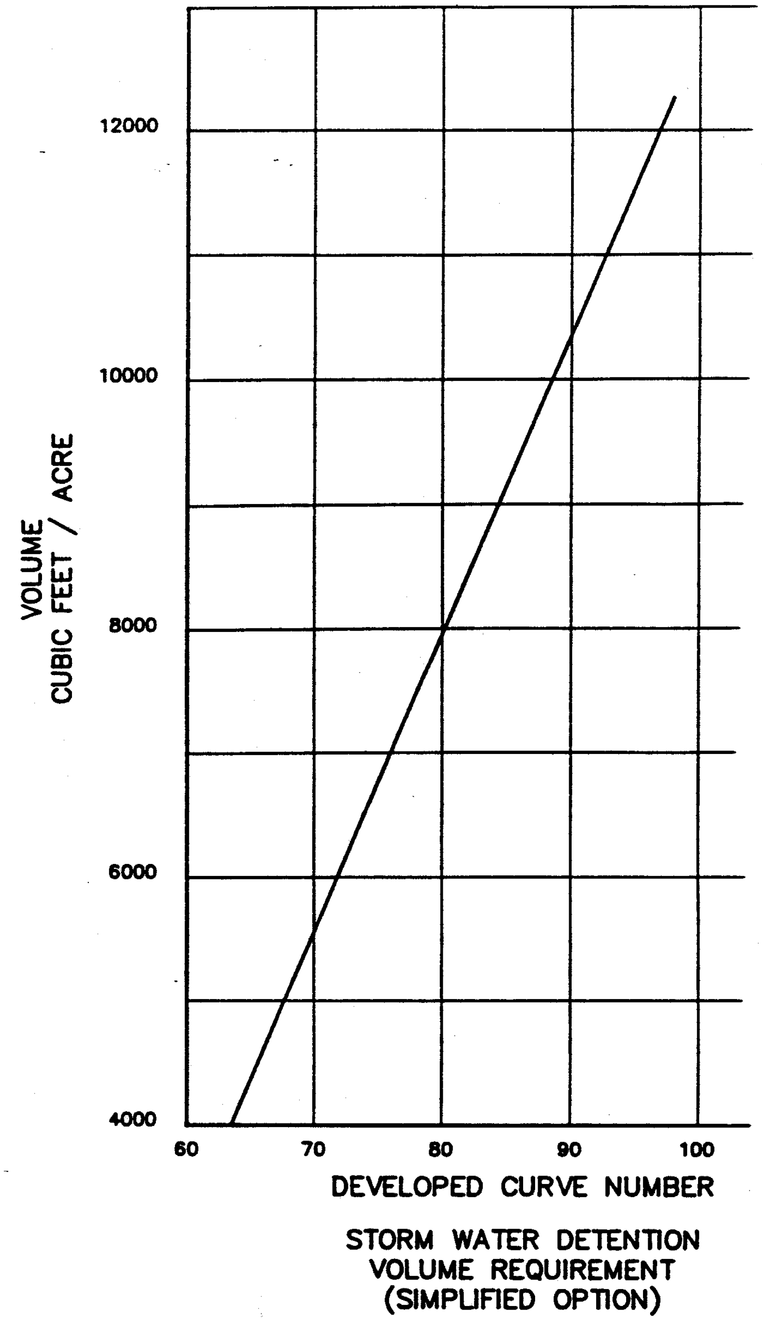
Figure 5604-1



v	=	Actual velocity of flow (fps)	A	=	Area occupied by flow (ft^2)
V_{full}	=	Velocity flowing full (fps)	A_{full}	=	Area of pipe (ft^2)
q	=	Actual quantity of flow (cfs)	r	=	Actual hydraulic radius (ft.)
Q_{full}	=	Capacity flowing full (cfs)	R_{full}	=	Hydraulic radius of full pipe (ft.)

HYDRAULIC ELEMENTS OF CIRCULAR CONDUITS (2)

Figure 5606-1

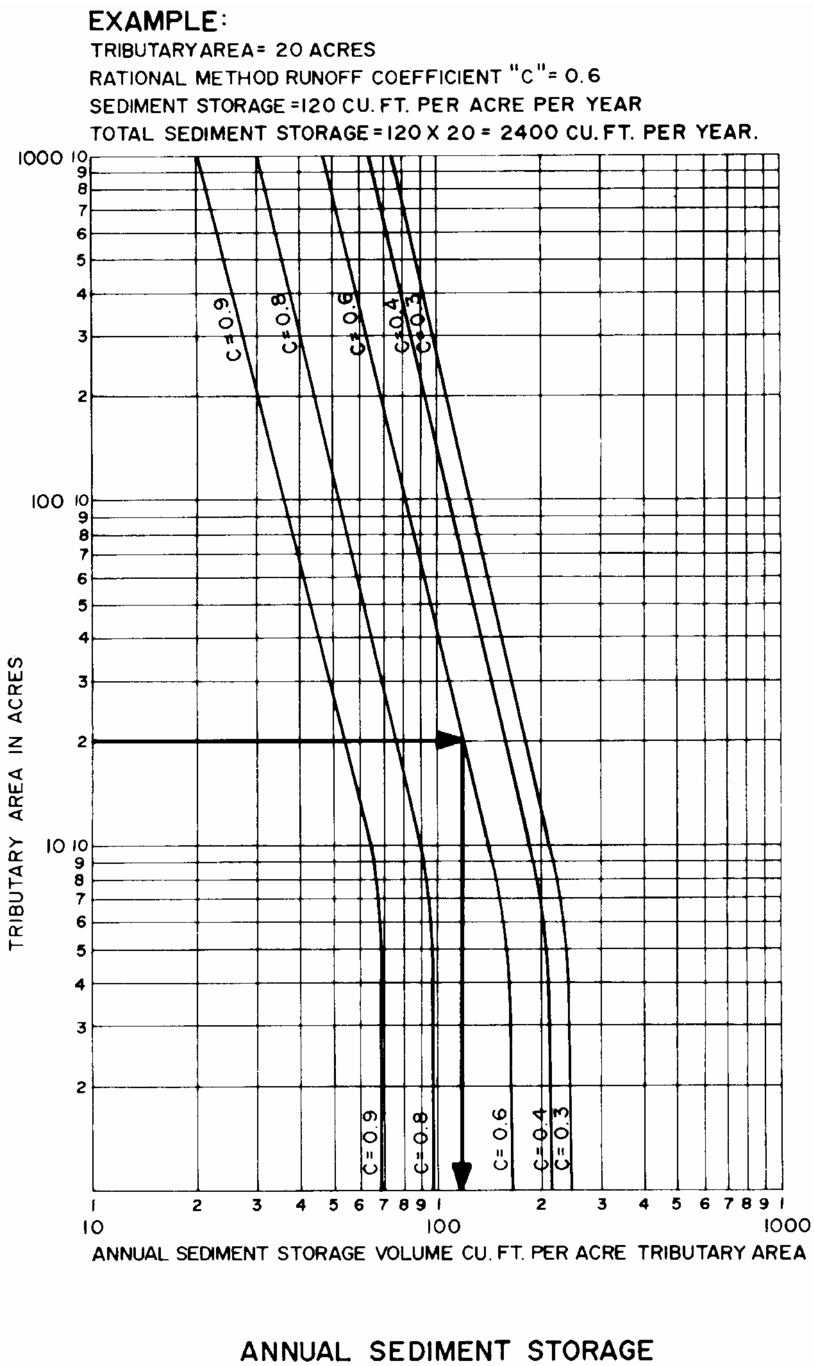


SIMPLIFIED VOLUME CHART
FOR DETENTION FACILITIES

NOTES:

1. For Release Rates – See Section 5606.4.B.
2. The developed curve number for the site is to be determined in accordance with TR-55 "Urban Hydrology for Small Watersheds".

Figure 5606-2



ANNUAL SEDIMENT STORAGE