SECTION 5

DRAINAGE

5-1 General

This section presents guidelines and methods for determining storm runoff for watersheds within the City of Belton and its extraterritorial jurisdiction area. It describes the method used for determining storm runoff from watersheds of less than 200 acres. It then briefly describes hydrologic models which can be used on watersheds greater than 200 acres. The recommended models for the major watersheds in Belton are provided.

There are several methods for determining the appropriate storm runoff from a watershed. The Rational Method may be used as the primary tool for the determination of peak storm water runoff rates from areas 200 acres or less and is especially useful for the design of storm sewer systems. In instances where detention is modeled, a hydrograph producing method is required, such as the Soil Conservation Service Tabular Method, TR-20, HEC-1 or HEC-RAS. The most extensively used methodology for computing runoff hydrographs is based on the Soil Conservation Services (SCS) Unit Hydrograph procedures. These procedures are used to quantify the effects of urbanization, to determine peaks flows for large drainage areas, and to design storm water storage facilities. The SCS Unit Hydrograph Method is used and accepted nationwide.

The presentation of these methods is not intended to preclude the use of other methods. However, the designer shall secure approval form the Director of Public Works before utilizing different methods.

5-2 Master Plan

All drainage design must be coordinated with the City of Belton Comprehensive Master Plan and the 1982 Floodway and Flood Boundary Map prepared by the Federal Emergency Management Agency. These documents were developed to provide for orderly growth in Belton and major deviations from these plans will not be allowed.

5-3 Design Storm Frequencies

Storm drainage planning requires establishment of standards to accomplish design objectives. Storm frequency is a basic criterion necessary in storm drainage design and refers to the magnitude of a storm. Therefore, the selected design frequency establishes the degree of protection desired. Initial storms, as referred to in this manual, designate a storm frequency with a 10-year reoccurrence cycle. Runoff from an initial storm is normally intercepted and conveyed by inlets and a pipe system. A major storm refers to a rainfall having a 1% probability of reoccurrence every day. Major storms are controlled and conveyed in open drainage systems. Design storm frequencies are as follows:

EXHIBIT 5.1
DESIGN STORM FREQUENCIES

Area or Facility	Frequency
Enclosed Pipe System	5 & 10 years
Channels and Creeks (1)	25 years
Culverts and Small Bridges	25 years
Large Bridges (2)	50 years
Floodways Between Building Lines	100 years

(1) Channels and creeks shall have one (1) foot of freeboard.
(2) Large bridges are those with a total span greater than 50 feet.

5-4 Water Spread Limit

Streets function primarily to serve traffic and for that reason must be expected to have some degree of usability during periods of rainfall. Water spread limits are an effective way of defining the protection required to achieve that usability. The following water spread limits are established:

EXHIBIT 5.2
WATER SPREAD LIMITS

Street Classification	Permissible Water Spread
Major Arterial	25-year storm - 1 traffic lane may be closed each direction
Minor Arterial	25-year storm - 1 traffic lane must remain open each direction
Collector	10-year storm - 1 traffic lane must remain open each direction
Residential Streets	5-year storm - water flow must not exceed top of curb

The permissible water spreads are based upon the initial storm frequencies (5 & 10 year), but consideration must be given to street conveyance of the major storm (100 year) and possible flooding. All streets shall be capable of conveying a major storm without water encroaching into adjacent buildings. Therefore, the maximum spread limits in streets for a major storm shall be the building lines. This requirement of utilizing the streets to convey the major storm runoff may require increasing the capacity of the enclosed drainage system.

5-5 Drainage System Requirements

The complete drainage system in an urban area is composed of; (1) the initial system, consisting of inlets, storm drains, and the associated appurtenances to convey the initial storm runoff (10 year), and; (2) the major system for the major runoff (100 year), which consists of swales, creeks, channels, floodways and emergency overflows to prevent water encroachment into residential and commercial facilities.

The initial storm drain system shall be required when the runoff exceeds the limitations established in Section 5-4. Inlets and storm drains shall be designed in accordance with applicable portions of this section. A closed pipe system shall normally convey quantities up to and including the flow of a 48-inch pipe. For quantities larger than that carried by a 48-inch pipe, channels or pipes will normally be utilized, depending upon the economics of the development. All pipe systems maintained as a public facility shall be constructed with reinforced concrete pipe. Channels shall normally be concrete lined. The reinforced concrete lining shall extend up to at least the water surface elevation of the 10-year frequency channel flow, and additional channel height shall be provided as required to convey the 25-yer channel flow with one (1) foot of freeboard. For all open channels, the 100-year flow shall be contained within the building lines; channels shall be expanded as necessary to meet this requirement.

Reinforced concrete lined channels shall have a maximum side slope of 2:1 (horizontal to vertical) and unlined channels shall be no steeper than 3:1 for stability and maintenance. All channels lined and unlined, shall have a one (1) inch per foot transverse bottom slope to the centerline.

Unlined channels will be considered for quantities larger than the equivalent flow of a 72-inch pipe. These channels shall provide one (1) foot of freeboard minimum. Additional freeboard shall be considered where wave action is anticipated.

All culverts crossing under streets shall extend from property line to property line, plus sufficient length on each end to permit a 3:1 slope to extend from the street property line to a point 6-inches beneath the top of the headwall. All culverts shall have adequate reinforced concrete headwalls, wingwalls for a 3:1 fill slope, and concrete aprons at each end.

Additional storm drain criteria follows:

1) Minimum velocity with the pipe flowing full shall be 3 feet per second.
2) Minimum storm drain pipe diameter shall be 15 inches.
3) Pipe diameters shall not decrease downstream.
4) Pipe crowns at change sizes should be set at the same elevation.
5) Vertical curves in the conduit will not be permitted, and horizontal curves will be permitted only with the approval of the Director of Public Works.
6) Inverted crown sections will be permitted only in alleys.
7) Street crowns shall be reduced for approximately 100 feet on each side of valleys and only one valley crossing for each street shall be used at an intersection.
8) Utilization of detention ponds are encouraged once proper location and design are achieved and approved by the City of Belton.
9) At streets with culverts or bridges, an emergency overflow shall be provided to contain the 100-year channel flow within the building lines.

5-6 Development Responsibilities

Drainage design is an integral part of any new development. Proper planning and coordination of the drainage scheme, along with the development plans, is required to achieve an economical storm drainage system. Lack of drainage consideration during the initial planning phase will lead to numerous complaints due to flooding and to added cost due to extension of the drainage system into areas not properly considered. Existing sites, new development and redevelopment areas shall require appropriate detention and/or mitigation measures to be designed and constructed as determined by the following guidelines:

A. Any proposed project that would cause damage to downstream properties or improvements or that would cause unsafe conditions for the general public due to an increase in storm water runoff;

B. Any receiving stream, drainage system or roadway system that is deemed inadequate to accommodate the increase in runoff or the redirection of runoff from a proposed project.

C. Any existing facilities that would be damaged or would otherwise cause the unsafe conveyance of storm water by a proposed project.

5-7 Design Parameters

Hydrology

The primary consideration in any drainage study must begin with determination of rainfall in terms of intensity, duration and frequency. The data to be used for calculating the amount of rainfall and the determination of runoff shall be that found in the Hydraulic Manual prepared and compiled by the Texas Department of Transportation - Bridge Division.

The Rational Method will be used due to its general simplicity and acceptance. The Rational Method is based on the principal that if rain persists at a uniform rate, the runoff will equal the rate of rainfall. This solution method is applicable to small areas and shall not be applied to areas exceeding 200 acres.

The Exhibits 5.3, 5.4 and 5.5 show the adopted values for minimum times of concentration, runoff coefficients for C, and percentage of impervious area to be used in the City of Belton.

EXHIBIT 5.3

MINIMUM TIMES OF CONCENTRATION

Areas	Minimum Time (Minutes)
Parks & Open Areas	20
Residential	15
Commercial	10
Roofs & Paved Areas	10

EXHIBIT 5.4

VALUES OF RUNOFF COEFFICIENT "C"

Land Use	Range of C	Adopted Value of C
Residential:		
Single Family (Lots < 1.0 Acre)	0.30 - 0.65	0.50
Single Family (Lots > 1.0 Acre)	0.25 - 0.50	0.40
Multi-family Detached (4 Units)	0.40 – 0.60	0.60
Multi-family Attached	0.60 – 0.75	0.70
Commercial:		
Industrial	0.50 – 0.90	0.70
Business	0.60 – 0.90	0.80
Business (downtown)	0.70 – 0.95	0.90
Parks & Cemeteries:	0.10 – 0.25	0.20
Playgrounds:	0.20 – 0.35	0.30
Railroad Yard Areas:	0.20 – 0.35	0.30

Values of Runoff Coefficient "C" Cont.

Land Use	Range of C	Adopted Value of C
Character of Surface		
Pavements	0.70 – 0.95	*0.90
Roofs:	0.75 – 0.95	0.90
Impervious Soils (heavy)	0.40 – 0.65	*0.65
Impervious Soils with Turf	0.30 – 0.55	*0.50
Slightly Pervious Soils	0.15 – 0.40	*0.40
Slightly Pervious Soils with Turf	0.10 – 0.30	*0.30
Moderately Pervious Soils	0.05 – 0.20	*0.20
Moderately Pervious Soils with Turf	0.05 – 0.10	*0.10

*These values of C will be used in conjunction with Figure A-0.

EXHIBIT 5.5

PERCENTAGE OF IMPERVIOUS AREA

Description	Plot Size (sq ft)	Average Impervious Area (Percentage)
Residential Estate	> 43,560	9
Residential Dwelling	43,560	17
Residential Dwelling	21,780	38
Residential Dwelling	16,000	43
Residential Dwelling	10,000	46
Residential Dwelling	7,500	46
Residential Dwelling	5,000	50
Multiple-Family Dwelling	Variable	72
Schools	Variable	35
Churches	Variable	85
Commercial District	Variable	85
Shopping Center District	Variable	100
Industrial District	Variable	72
Freeway	Variable	100
Open Land (1)		

(1) Open land in rural areas and public parks increased to 1.0 percent to account for roads, drives and scattered buildings.

5-8 Detention

The current state of the art in drainage design uses detention of stormwater as proper and correct in many situations. The Director of Public Works will determine in which instances detention will be required. The adopted detention calculation methods shall be those known as the modified Rational Method or the Soil Conservation Service (SCS) Method.

5-9 Hydraulics

Stormwater is conveyed usually on the upper end of a drainage basin by inlets and storm sewers (closed conduit systems) to channel and through culverts and bridges. All calculations and design procedures for this hydraulic work shall follow the Hydraulic Manual prepared and compiled by the Texas Department of Transportation - Bridge Division.

Exhibits 5.6, 5.7, 5.8 and 5.9 show adopted Manning's Coefficients, minimum pipe slopes, maximum channel velocities and roughness coefficients for channels to be used in Belton, Texas.

EXHIBIT 5.6

MANNING'S COEFFICIENT OF ROUGHNESS FOR PIPE

Material	Value of n	Adopted
Asbestos-Cement Pipe	0.011 - 0.015	0.013
Cast Iron Pipe Coated	0.010 - 0.014	0.012
Cast Iron Pipe Uncoated	0.011 - 0.016	0.013
Concrete Monolithic Conduit	0.012 - 0.017	0.015
Concrete Pipe	0.011 - 0.015	0.013
Corrugated Metal Pipe (1/2" x 2-2/3")	0.022 - 0.026	0.024
25% Paved	0.021 - 0.023	0.022
Fully Paved	0.012 - 0.015	0.013
Plastic Pipe (Smooth)	0.011 - 0.015	0.013
Vitrified Clay Pipe	0.011 - 0.015	0.013

EXHIBIT 5.7

MINIMUM PIPE SLOPES

Pipe Diameter	Slope in Feet Per Foot	
	n= 0.013	n= 0.024
12"	0.00435	0.0149
15"	0.00324	0.0111
18"	0.00254	0.00868
21"	0.00208	0.00709
24"	0.00174	0.00592
27"	0.00148	0.0051
30"	0.00129	0.00439
33"	0.00113	0.00386
36"	0.00101	0.00345
42"	0.00082	0.0028
48"	0.00069	0.00235
54"	0.00059	0.00201
60"	0.00051	0.00175
66"	0.00045	0.00154
72"	0.00040	0.00137

EXHIBIT 5.8 – Part I

ADOPTED MAXIMUM CHANNEL VELOCITIES

Channel Material	Maximum Channel Velocity, fps
Fine Sand	2.0
Coarse Sand	4.0
Fine Gravel	6.0
Earth	
Sandy Silt	2.0
Silt Clay	3.5
Clay	6.0
Grass Lined Earth	
Bermuda Grass – Sandy Silt	6.0
- Silt Clay	8.0
Poor Rock (usually sedimentary)	10.0
Soft Sandstone	8.0
Soft Shale	3.5
Reinforced Concrete Lining	15.0

EXHIBIT 5.8 – Part II

ADOPTED MAXIMUM STORM SEWER PIPE VELOCITIES

The maximum velocity of storm sewer piping shall be 15 feet per second for all collection trunk lines and selected lateral lines as determined by the Director of Public Works. Manning's Equation shall be used as the test standard for said velocity determinations with no entrance or exit head losses to be considered. Only pipe friction losses will be used as per Manning's Equation to wit:

$$V = \frac{1.486}{n} (R)^{2/3} (S)^{1/2}$$

EXHIBIT 5.9

MANNING'S COEFFICIENT OF ROUGHNESS FOR CHANNELS

	N Values*		Adopted
	Min.	Max	n Values
<u>Lined Channels</u>			
Metal corrugated	0.021	0.024	0.023
Concrete	0.012	0.030	0.025
Cement rubble	0.017	0.030	0.025
Concrete gutter	0.015	0.020	0.016
Rock Rip-rap	0.030	0.045	0.035
<u>Unlined Channels</u>			
Poor grass growth	0.025	0.035	0.030
Average grass growth	0.035	0.045	0.040
Dense grass growth	0.040	0.050	0.045
Stony beds, weeds on bank	0.025	0.040	0.035
Rock cuts, smooth & uniform	0.025	0.035	0.030
Rock cuts, rugged & irregular	0.035	0.045	0.040
<u>Natural Stream Channels</u>			
Some grass & weeds; little or no brush	0.030	0.035	0.035
Dense growth of weeds, depth of flow materially greater than weed height	0.035	0.050	0.045
Some weeds, light brush on banks	0.035	0.050	0.045
Some weeds, heavy brush on banks	0.050	0.070	0.060
For trees within channels with branches submerged at high stage, increase all values above by	0.010	0.020	0.015
<u>Pasture, no brush</u>			
Short grass	0.030	0.035	0.030
Tall grass	0.035	0.050	0.040
<u>Cultivated areas</u>			
No crop	0.030	0.040	0.035
Mature right-of-way crops	0.035	0.045	0.040
Mature field crops	0.040	0.050	0.045
Heavy weeds, scattered brush	0.050	0.070	0.060
Wooded	0.120	0.160	0.140

* Maximum and minimum "n" values adapted from the Texas Department of Transportation.

COMPUTATION SHEET A-1

RATIONAL METHOD SUB-AREA RUNOFF CALCULATIONS

Project: ____________________

Design Storm: ____________________

DESIGN POINT	DRAINAGE AREA		CA' VALUES FOR INDIVIDUAL SUB-AREAS									WEIGHTED 'CA' VALUE	TIME OF CONCENTRATION COMPUTATION							RAINFALL INTENSITY I	PEAK FLOW Q
													OVERLAND FLOW TIME			GUTTER FLOW TIME			TOTAL TIME T_C		
	AREA NO.	TOTAL ACRES	$(CA)_1$	$(CA)_2$	$(CA)_3$	$(CA)_4$	$(CA)_5$	$(CA)_6$	$(CA)_7$	$(CA)_8$	$(CA)_9$		L_o	S_o	t_o	L_g	S_g	t_g			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22

$(CA)_1$: C =

$(CA)_2$: C =

$(CA)_3$: C =

$(CA)_4$: C =

$(CA)_5$: C =

$(CA)_6$: C =

$(CA)_7$: C =

$(CA)_8$: C =

$(CA)_9$: C =

Computation Sheet A-1

COMPUTATION SHEET A-2

CURB INLETS AND DROP INLETS IN SUMPS

INLET NO.	FLOW TO INLET Q (cfs)	LENGTH OF INLET OPENING L (ft)	AREA OF INLET OPENING A (sq ft)	DISCHARGE PER UNIT FOOT OF OPENING $q = Q/L$ (cfs/ft)	COMPUTED HEAT AT INLET		MAXIMUM ALLOWABLE HEAD H (ft)	WATER SPREAD LIMITS S_p (ft)	NOTES
					WEIR FLOW $H = (q/3)^{2/3}$ (ft)	ORIFICE FLOW $H = [(Q/A)/4.82]^2$ (ft)			
1	2	3	4	5	6	7	8	9	10

Computation Sheet A-2

Column 1	Inlet number and designation
Column 2	Total Flow in c.f.s. to inlet. For inlets other than the first inlet in a system, flow is the sum of runoff from contributing area plus carry-over flow from inlet or inlets upstream.
Column 3	Assumed length of inlet opening or perimeter in feet.
Column 4	Total area of inlet opening based on assumed inlet opening length and opening height.
Column 5	Discharge per unit foot of inlet opening. Column 2 divided by Column 3
Column 6	Computed head at inlet for weir flow conditions based on Figures A-2 or A-3 or the following equation $H = (q/3)^{2/3}$
Column 7	Computed head at inlet for orifice flow conditions (submerged inlet) based on Figures A-2 or A-3 or the following equation $H = [(Q/A)/4.82]^2$
Column 8	Maximum allowable head at sump inlet. This value is determined from topographic conditions at the sump inlet site.
Column 9	Width of spread of water for curb inlets in sump. Use Figure A-1or Appendix B to determine Sp for roadways.

COMPUTATION SHEET A-3

CURB INLETS ON GRADE

INLET		DRAINAGE AREA NO.	SUB-AREA PEAK FLOW QP (cfs)	CARRY-OVER FROM UPSTRM INLET q (cfs)	TOTAL FLOW Q (cfs)	STRAIGHT CROWN SLOPES					PARABOLIC STREET SLOPES				CAPACITY PER FOOT OF INLET Q/L_o (cfs/ft)	LENGTH OF INLET REQ'D FOR Q_o (ft)	INLET LENGTH L (ft)	L/L_o	Q/Q_o	FLOW INTRCPTD $Q=Q_o x Q/Q_o$ (cfs)	CARRY-OVER FLOW q (cfs)	COMMENTS
TYPE & NO.	STATION					CROWN SLOPE Z	Z/N	STREET SLOPE S_o (ft/ft)	FLOW DEPTH Y_o (ft)	WIDTH OF SPREAD S_p (ft)	TYPE OF STREET SECTION	STREET SLOPE S_o (ft/ft)	FLOW DEPTH Y_o (ft)	WIDTH OF SPREAD S_p (ft)								
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

COMPUTATION SHEET A-3

Column 1 Inlet type and number.

Column 2 Location of inlet by station number.

Column 3 Drainage Area designation of area entering between the previous pick up point and the inlet being designed.

Column 4 Peak Discharge (Qp) from area of Column 3.

Column 5 Carry-over flow (q) which has been passed by the last proceding inlet to the inlet under consideration.

Columnb 6 Total gutter flow (Q_o) in c.f.s. For inlets other than the first inlet in the system, total gutter flow is the sum of the runoff from the contributing area plus carry-over flow from the inlet or inlets upstream. Column 4 plus Column 5.

Column 7 Reciprocal of the pavement cross slope for pavements with straight crown slopes.

Column 8 Reciprocal of the pavement cross slope (Z) divided by the pavement roughness coefficient (n).

Column 9 Slope of approach gutter (S_o) in ft. per ft.

Column 10 Depth of gutter flow "y_o" in approach gutter from Figure A-1 or Appendix B solution or direct from Manning's equation for triangular gutters:

$$y_o = 1.245\,(Q^{3/8})\left[\left(\frac{n^{3/8}}{S^{3/16}}\right)\left(\frac{1}{z}\right)\right]^{3/8}$$

Column 11 Spread of water (Sp) or width of ponding in the gutter measured from the face of curb. Column 7 times Column 10 (Figure A-1 or Appendix B).

Column 12 Width of street and height of parabolic crown.

Column 13 Slope of approach gutter (s_o) in ft. per ft.

Column 14 Depth of gutter flow "y_o" in approach gutter from Appendix B.

Column 15 Spread of water (Sp) or width of ponding in the gutter measured from face of curb from Appendix B.

Column 16 Discharge in cubic feet per second (Q) which will be intercepted by an inlet one foot in length for a given depth of flow in the approach gutter (y_o). Determined from Figure A-4 Or from the solution of the following equation:

$$Q/L_o = 0.7\left(\frac{1}{y_o}\right)\left((H)^{5/2} - (a)^{5/2}\right)$$

Column 17	Length of inlet (L_o) in feet which is necessary to intercept a given discharge Q_o. Column 6 divided by Column 16.
Column 18	Actual length (L) in feet of inlet which is to be provided.
Column 19	Ratio of the length of inlet provided (L), to the length of the inlet required for 100% interception (L_o). Column 18 divided by Column 17.
Column 20	Percentage of discharge intercepted by the inlet in question determined from Figure A-5 using the values determined in Column 19 and Column 10 or Column 14.
Column 21	Discharge (Q) in cubic feet per second which the inlet in question actually intercepts. Column 6 times Column 20.
Column 22	Carry-over flow (q) is the amount of water which passes any inlet, and is the difference between the total flow (Q_o) of Column 6 and the intercepted flow (Q) of Column 21.

COMPUTATION SHEET A-4

HYDRAULIC COMPUTATIONS FOR STORM DRAINS

LINE NO. : ____________ **n-VALUE:** ____________

MANHOLE OR INLET DESIGN PT. FROM	MANHOLE OR INLET DESIGN PT. TO	DISTANCE BETWEEN MANHOLE OR INLET (ft)	DRAINAGE AREA INCREMENTAL AREA AREA NO.	DRAINAGE AREA INCREMENTAL AREA NO. OF ACRES	DRAINAGE AREA TOTAL AREA (AC)	COEFFICIENT OF RUNOFF "C"	INCREMENTAL "CA"	TOTAL 'CA'	TIME OF CONCENTRATION INLET TIME (min)	TIME OF CONCENTRATION FLOW TIME IN PIPE (min)	TIME OF CONCENTRATION TOTAL TIME (min)	DESIGN FREQUENCY (yrs)	INTENSITY (in/hr)	DESIGN DISCHARGE (cfs)	SELECTED SIZE OF PIPE (in)	FRICTIONAL GRADIENT SLOPE S_f (ft/ft)	HYDRAULIC GRADIENT ELEVATION UP-STREAM (ft MSL)	HYDRAULIC GRADIENT ELEVATION DOWN-STREAM (ft MSL)	HEAD LOSS AT CHANGE IN SECTION INFLOW VELOCITY V_1 (fps)	HEAD LOSS AT CHANGE IN SECTION OUTFLOW VELOCITY V_2 (fps)	HEAD LOSS AT CHANGE IN SECTION $V_1^2/2g$ (ft)	HEAD LOSS AT CHANGE IN SECTION $V_2^2/2g$ (ft)	HEAD LOSS AT CHANGE IN SECTION K_j	HEAD LOSS AT CHANGE IN SECTION $K_jV_1^2/2g$ (ft)	HEAD LOSS AT CHANGE IN SECTION Hj	H.G. ELEVATION AT DESIGN POINT (Col. 18 + Col. 26) (ft MSL)	ELEV. OF INVERT AT DESIGN POINT (Col. 1) IN-COMING PIPE (ft MSL)	ELEV. OF INVERT AT DESIGN POINT (Col. 1) OUT-GOING PIPE (ft MSL)	COMMENTS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

COMPUTATION SHEET A-4

Column 1	Design Point; this point is the first junction point upstream. "Junction Point" refers to any inlet, manhole, bend, etc. that occurs which would cause a minor head loss.
Column 2	Junction point immediately downstream of design point.
Column 3	Distance between the design point in Column 1 and the design point in Column 2.
Column 4	Incremental drainage sub-area designation.
Column 5	Incremental drainage sub-area size contributing to the design point in column 1.
Column 6	Total drainage sub-area size contributing to the design point in Column 1.
Column 7	Weighted runoff coefficient for incremental drainage sub-area.
Column 8	Column 5 times Column 7.
Column 9	Total "CA" for all drainage sub-areas contributing to the design point in Column 1.
Column 10	Time of concentration to the design point in Column 1.
Column 11	Flow time in storm drain system from the design point in Column 1 to the design point in Column 2; Column 3 divided by Column 21 of previous row.
Column 12	Column 10 + Column 11.
Column 13	Design frequency of storm drain system.
Column 14	Rainfall intensity determined from the value calculated in Column 12 and the intensity curve for Bell County.
Column 15	Design discharge; Column 9 times Column 14.
Column 16	Size of pipe chosen to carry an amount equal to or greater than the design discharge (Figures A-6 and A-7 can be used to determine this)
Column 17	Slope of frictional gradient S_f (can be determined from Manning's Equation).

Column 18 Elevation of hydraulic gradient at upstream end of pipe = elevation of downstream end + column 17 times Column 3.

Column 19 Elevation of hydraulic gradient at downstream end of pipe.

Column 20 Velocity of flow in incoming pipe at design point (use Q=AV for full flow and Figures A-8 and A-9 for partial flow).

Column 21 Velocity of flow in outgoing pipe at design point.

Column 22 Velocity head loss for outgoing pipe at design point.

Column 23 Velocity head loss for incoming pipe at design point.

Column 24 Head loss coefficients at junction (see Figures A-10 and A-11).

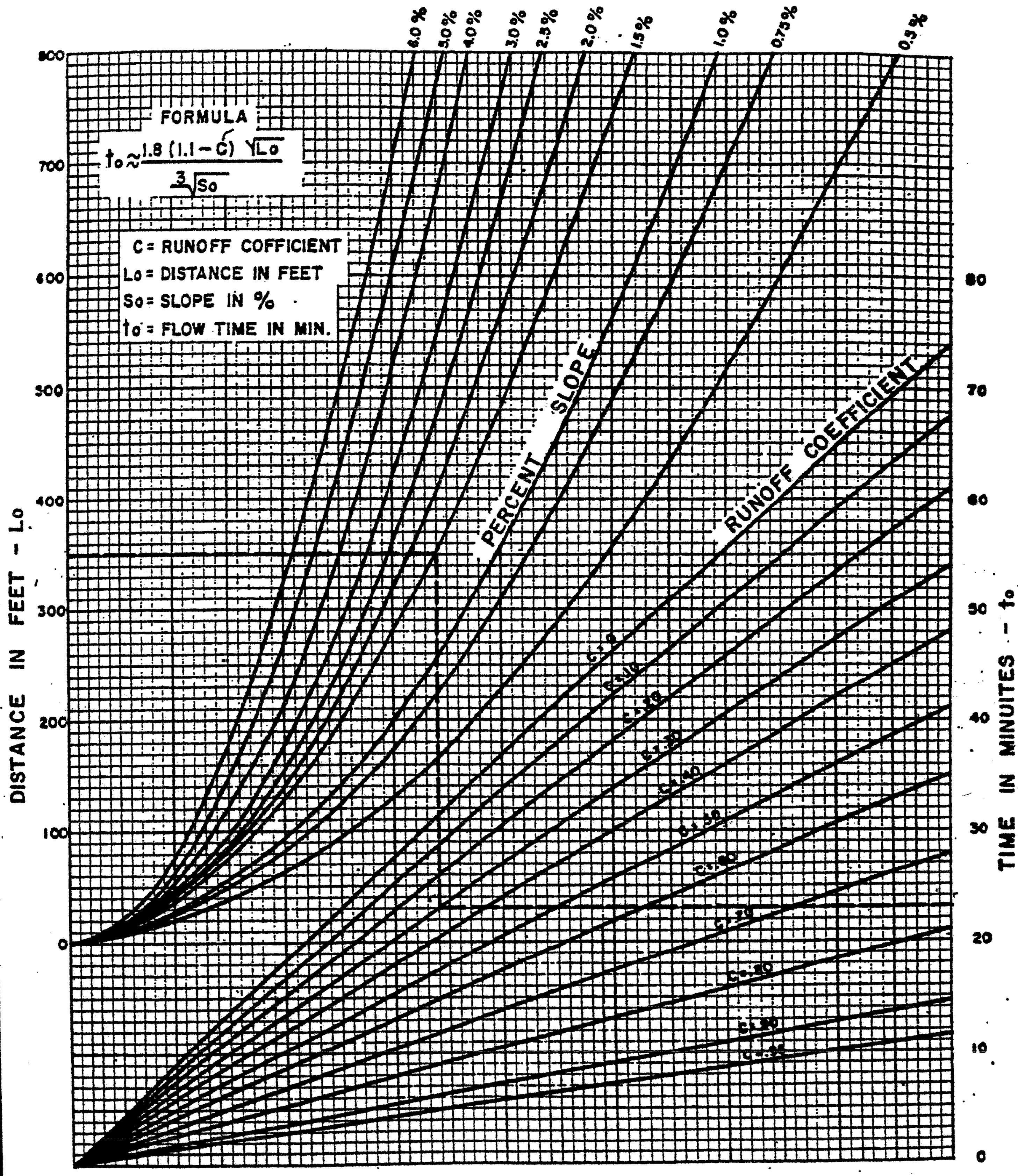
Column 25 Column 23 times Column 24

Column 26 Column 22 - Column 25 (note for bends and inlets or manholes at the beginning of a line $V_1 = V_2$ and the appropriate K_j value should be used in Column 25; Column 25 = Column 26.

Column 27 Column 18 + Column 26.

Column 28 Invert elevation at design point for incoming pipe.

Column 29 Invert elevation at design point for outgoing pipe.



EXAMPLE

Lo = 350 FT.

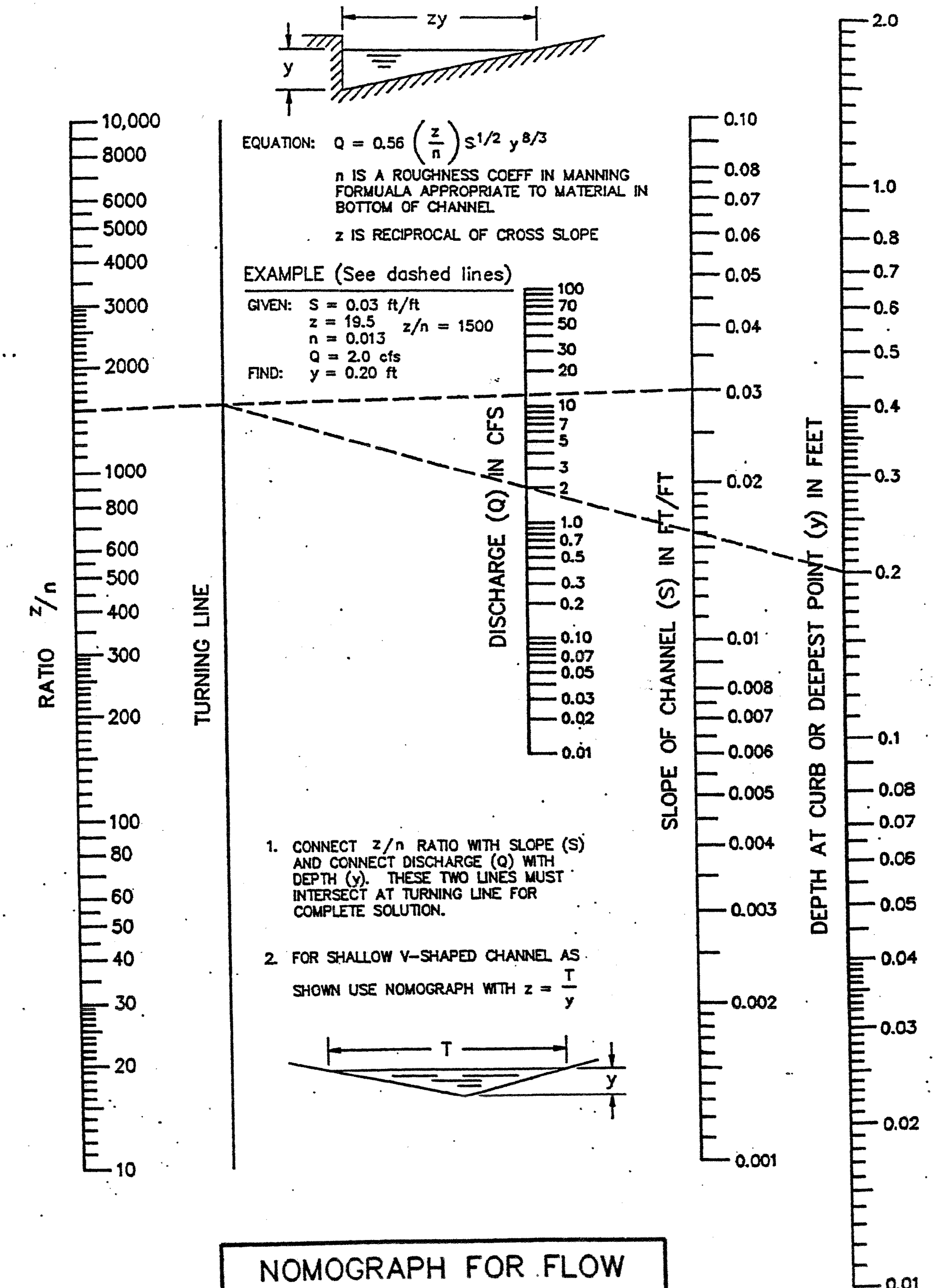
So = 1.5 %

C = 0.3

t = 23.0 min.

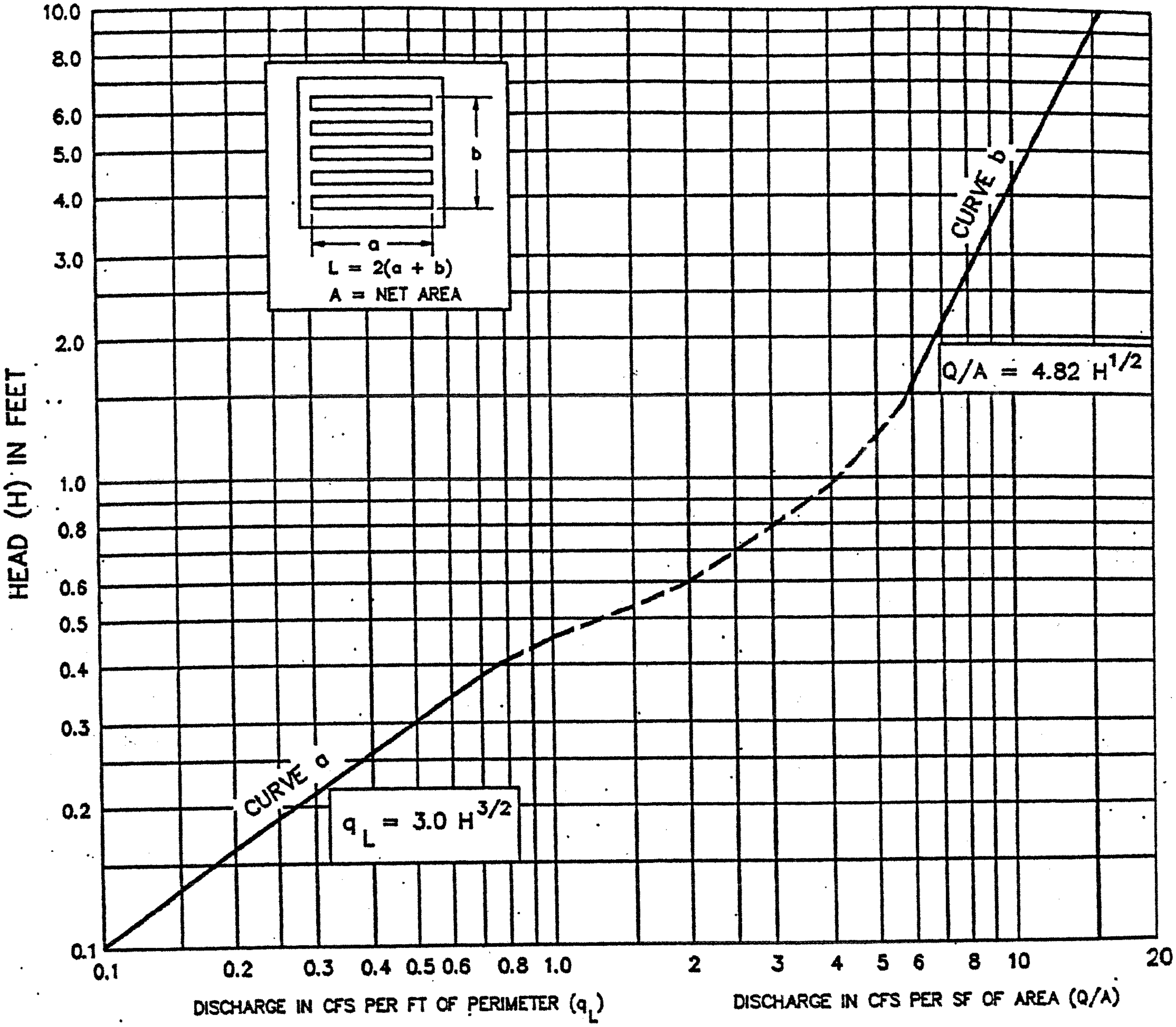
NOMOGRAPH
TIME OF CONCENTRATION FOR OVERLAND FLOW

FIGURE A – 0



NOMOGRAPH FOR FLOW IN TRIANGULAR CHANNELS

FIGURE A-1



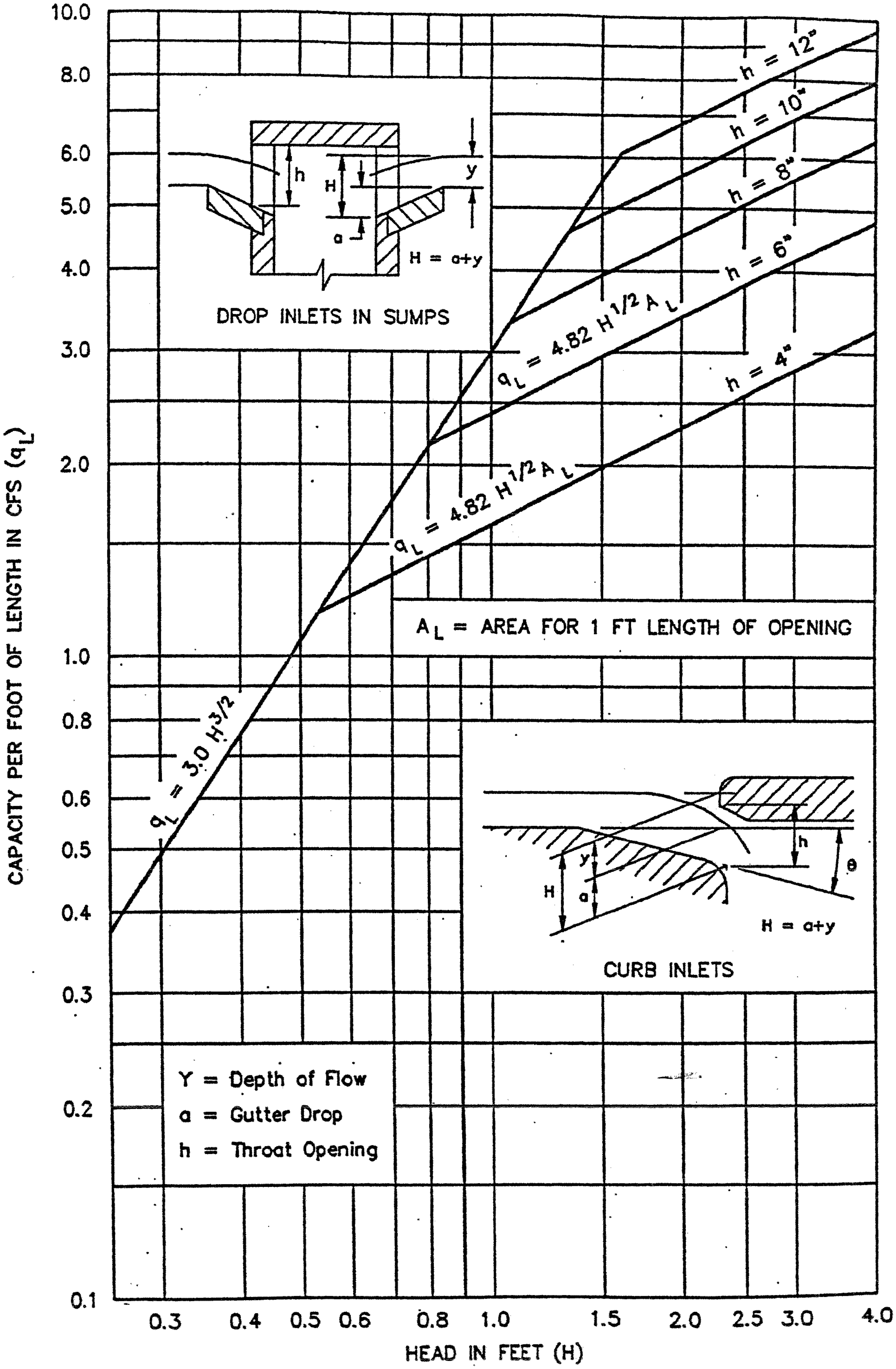
HEADS UP TO 0.4 USE CURVE (a)

HEADS ABOVE 1.4 USE CURVE (b)

AT HEADS BETWEEN 0.4 AND 1.4, TRANSITION SECTOR AND OPERATION ARE INDEFINITE

CAPACITY OF GRATE INLET IN SUMP

FIGURE A - 2



CAPACITY OF DROP INLETS AND CURB INLETS IN SUMPS

FIGURE A-3

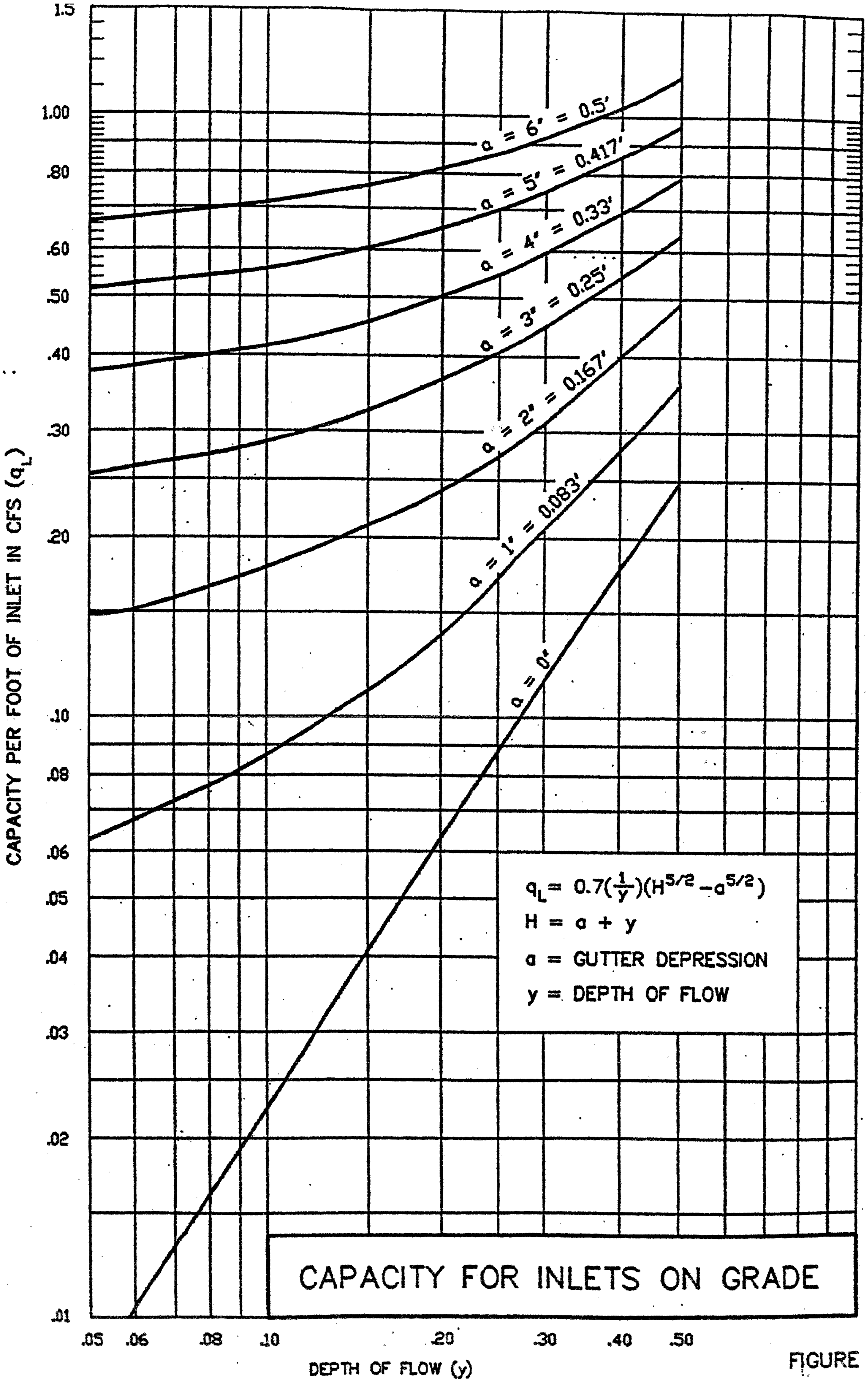
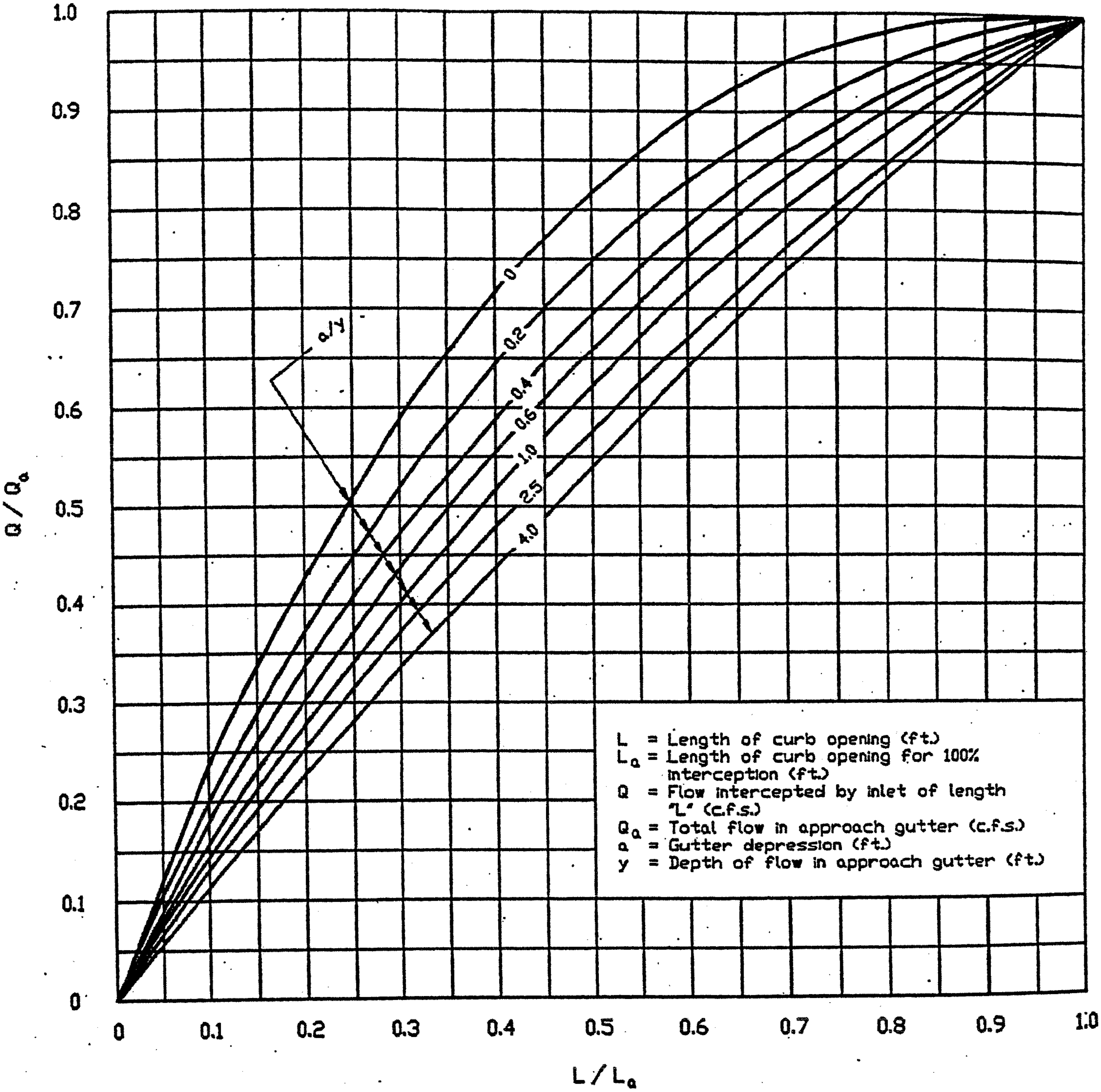
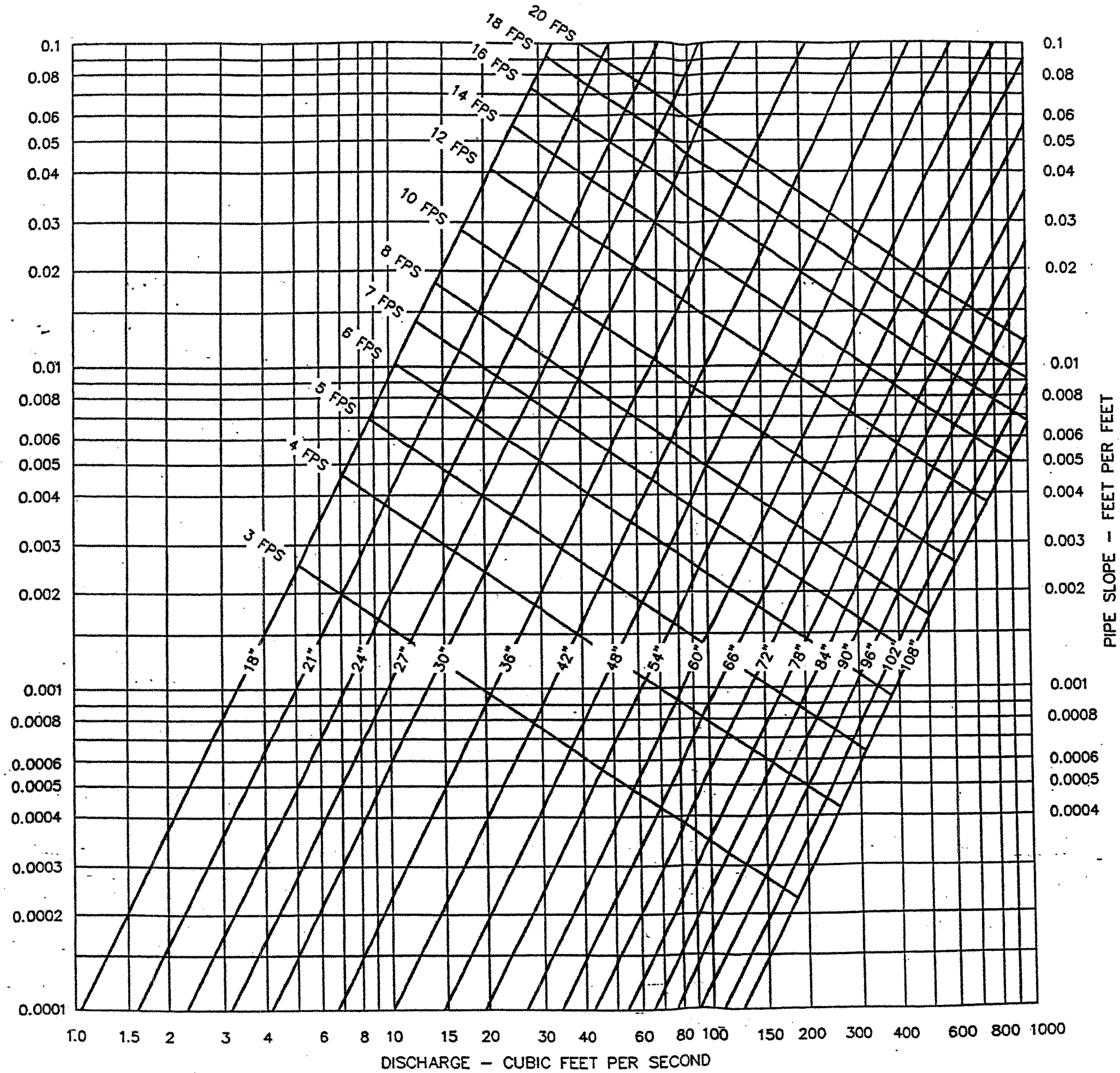

1.5
1.00
.80
.60
.50
.40
.30
.20
.10
.08
.06
.05
.04
.03
.02
.01
CAPACITY PER FOOT OF INLET IN CFS (q_L)
a = 6" = 0.5'
a = 5" = 0.417'
a = 4" = 0.33'
a = 3" = 0.25'
a = 2" = 0.167'
a = 1" = 0.083'
a = 0"
$q_L = 0.7(\frac{1}{y})(H^{5/2} - a^{5/2})$
H = a + y
a = GUTTER DEPRESSION
y = DEPTH OF FLOW
CAPACITY FOR INLETS ON GRADE
.05
.06
.08
.10
.20
.30
.40
.50
DEPTH OF FLOW (y)

FIGURE A - 4



RATIO OF INTERCEPTED FLOW TO TOTAL FLOW FOR INLET ON GRADE

FIGURE A - 5

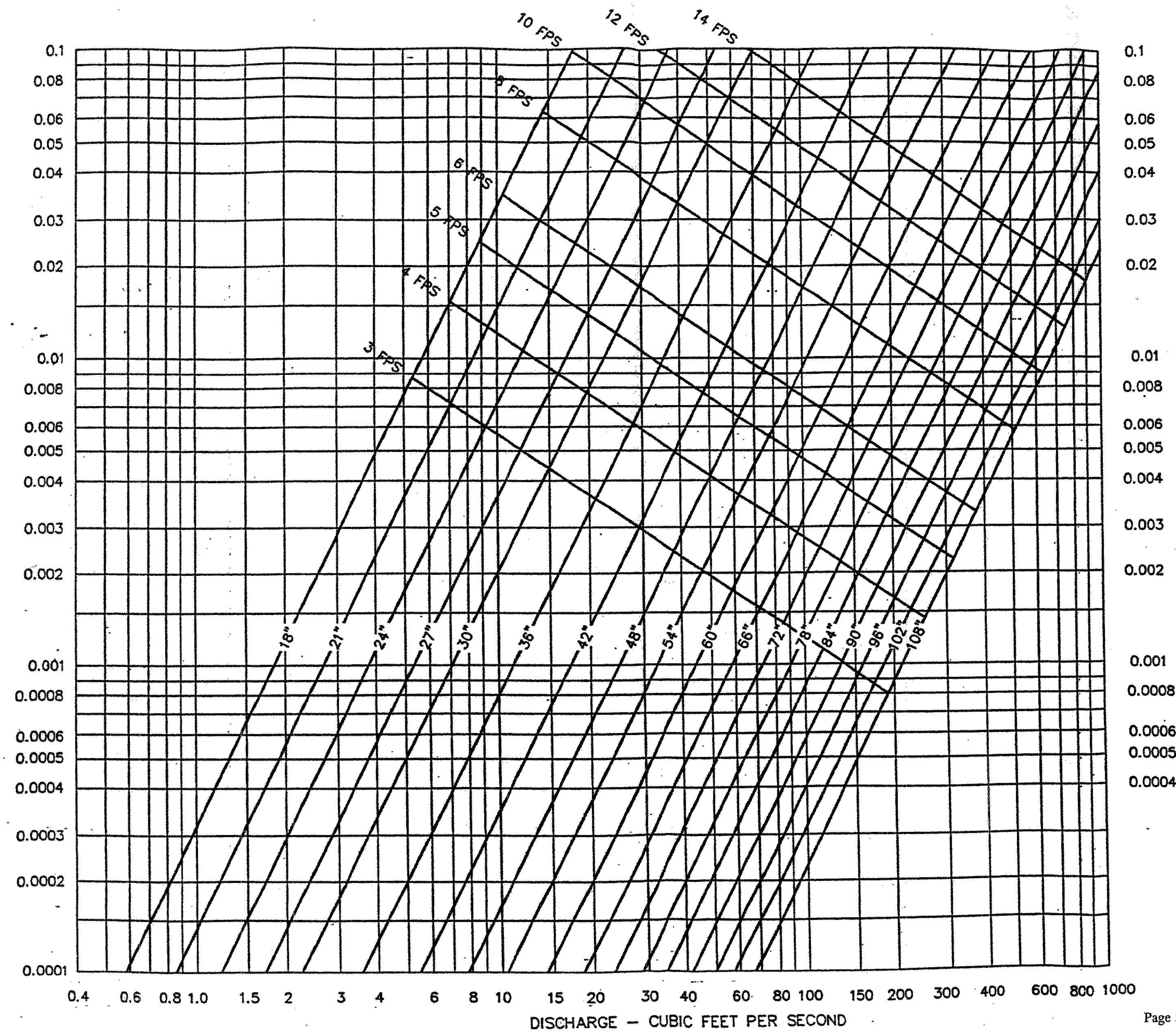


CAPACITY OF PIPES FLOWING FULL

MANNING'S FORMULA

n = 0.013

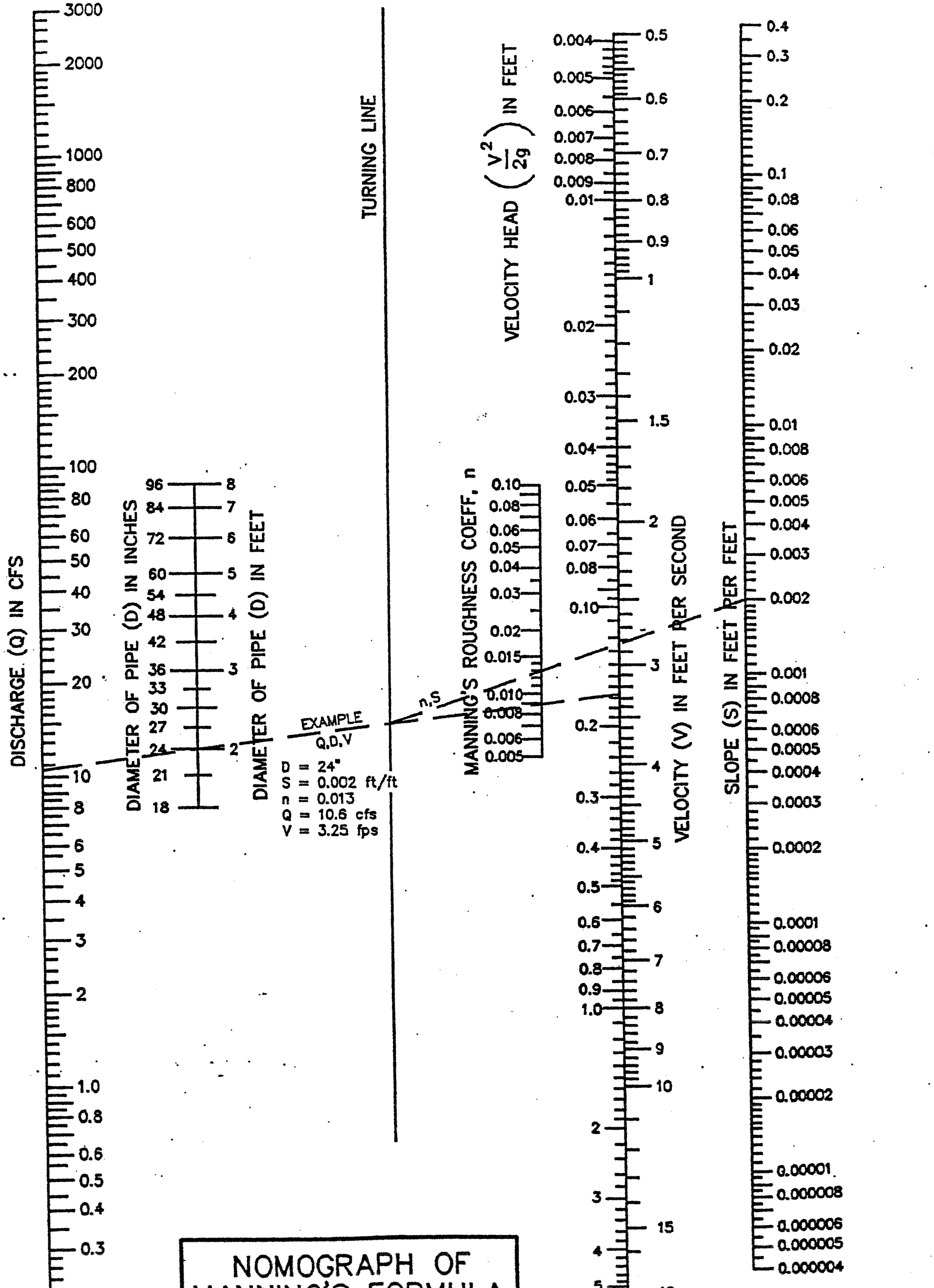
FIGURE A-6



CAPACITY OF PIPES FLOWING FULL

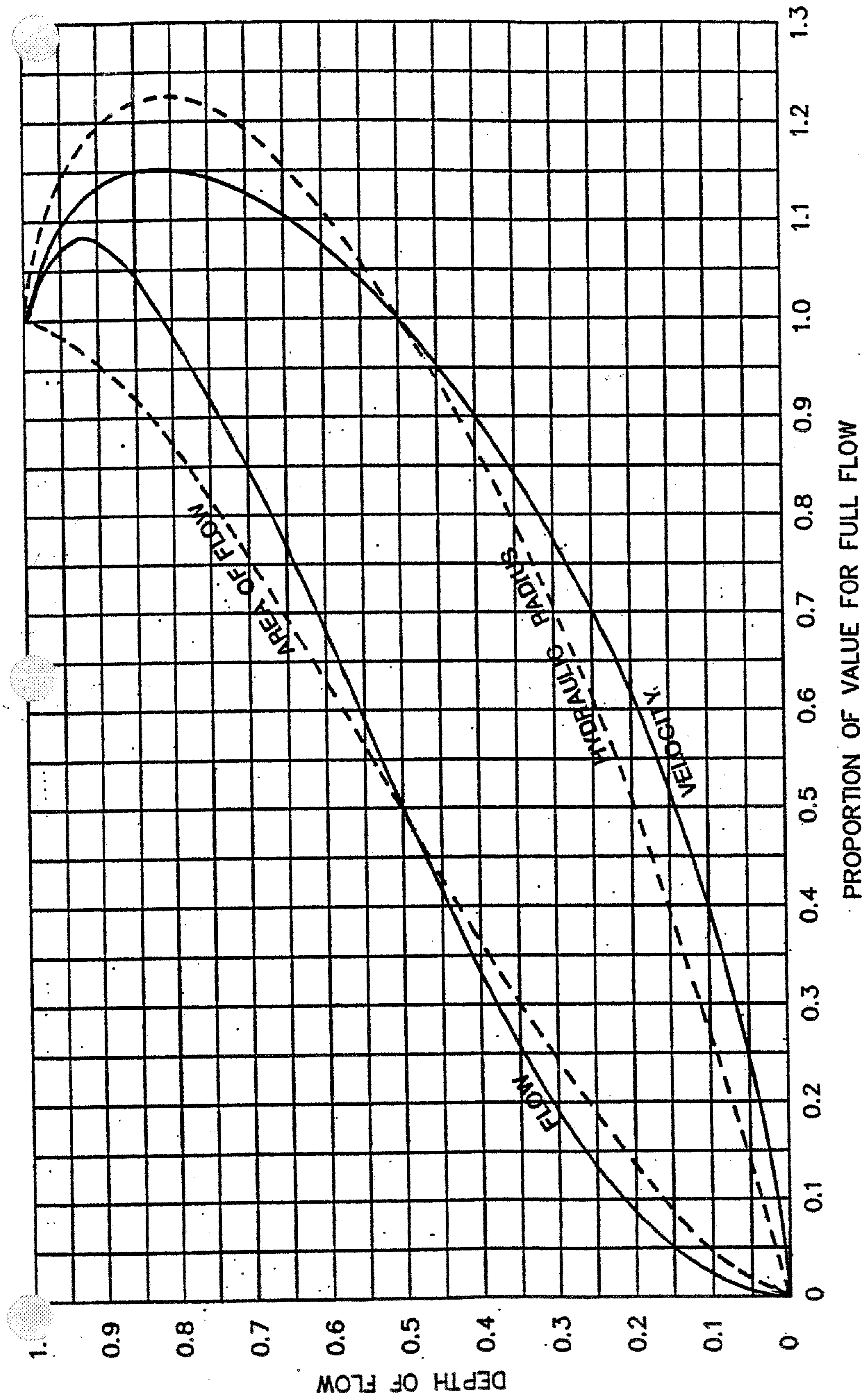
MANNING'S FORMULA
n = 0.024

FIGURE A-7



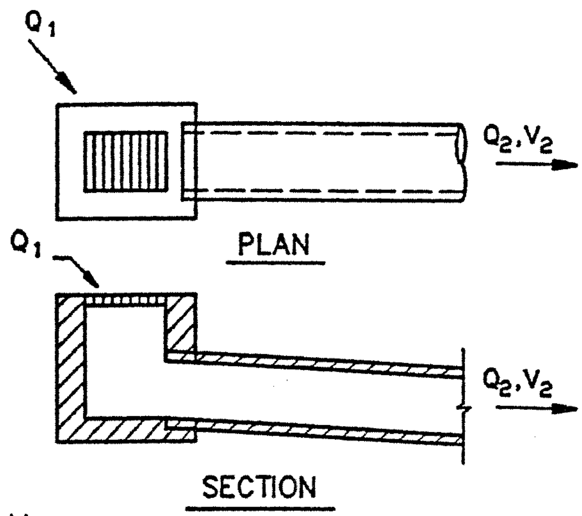
NOMOGRAPH OF MANNING'S FORMULA

FIGURE A-8



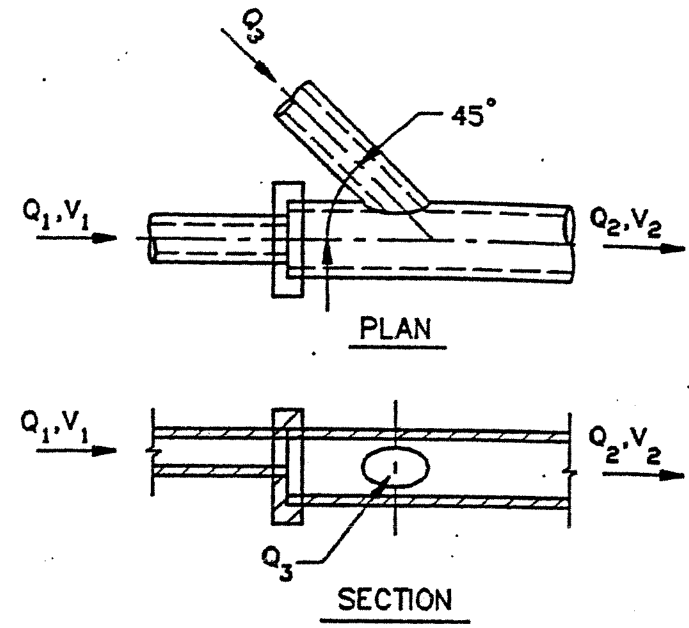
HYDRAULIC ELEMENTS OF CIRCULAR CONDUITS

Based On Manning's Formula



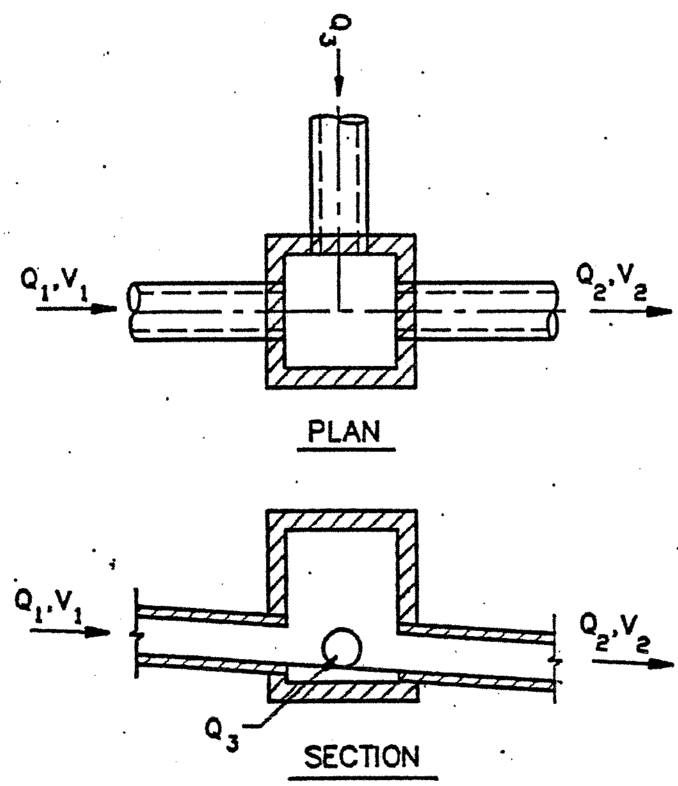
CASE I

INLET OR MANHOLE AT BEGINNING OF LINE



CASE II

45° WYE CONNECTION OR CUT IN



CASE III

MANHOLE ON MAIN LINE WITH 90° BRANCH LATERAL

CASE I : $h_j = \frac{1.25\, V_2^2}{2g}$

CASE II : $h_j = \frac{V_2^2}{2g} - \frac{0.75\, V_1^2}{2g}$

CASE III : $h_j = \frac{V_2^2}{2g} - \frac{0.25\, V_1^2}{2g}$

60° Lateral — $h_j = \frac{V_2^2}{2g} - \frac{0.35\, V_1^2}{2g}$

45° Lateral — $h_j = \frac{V_2^2}{2g} - \frac{0.50\, V_1^2}{2g}$

22½° Lateral — $h_j = \frac{V_2^2}{2g} - \frac{0.75\, V_1^2}{2g}$

MINOR HEAD LOSSES DUE TO TURBULENCE AT STRUCTURES

FIGURE A-10

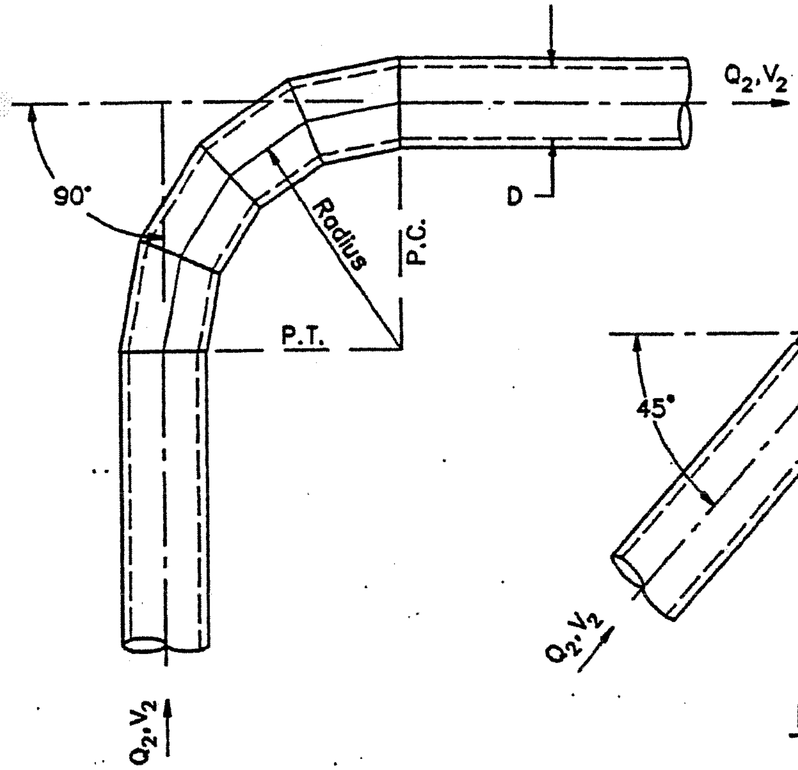
EXHIBIT 5.10

JUNCTION OR STRUCTURE COEFFICIENT OF LOSS

Cases	Reference Figure	Description of Condition	Coefficient Kj
A	7-1	Manhole on Trunk Line with 45° Branch Lateral	0.50
B	7-1	Manhole on Trunk Line with 90° Branch Lateral	0.25
C	7-2	45°Wye Connection or cut-in of Line	0.75
D	7-2	Inlet or Manhole at Beginning of Line	1.25
E	7-2	Conduit on Curves for 90°**	
		Curve radius = diameter	0.50
		Curve radius = 2 to 8 times the diameter	0.25
		Curve radius = 8 to 20 times the diameter	0.40
		Curve radius greater than 20 times the diameter	0.0
F	7-2	Bends where radius is equal to diameter	
		90° Bend	0.50
		60° Bend	0.43
		45° Bend	0.35
		22-½° Bend	0.20
		Manhole on line with 60° Lateral	0.35
		Manhole on line with 22-½° Lateral	0.75

**Where bends other than 90 degrees are used, the 90 degree bend coefficient can be used with the following percentage factor applied:

60° Bend - 85%; 45°Bend - 70%; 22-½° Bend - 40%



CASE I

CONDUIT ON 90° CURVES*

NOTE : Head loss applies at P.C. for length of curve.

Radius = Dia. of Pipe $h_j = 0.50 \frac{V_2^2}{2g}$

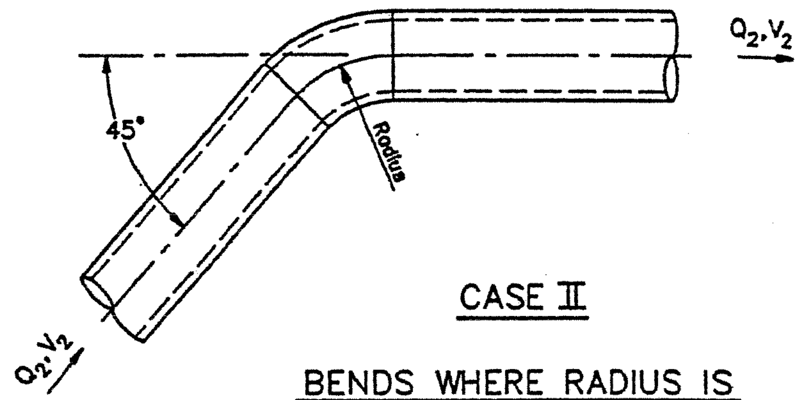
Radius = 2–8 times the pipe dia. $h_j = 0.40 \frac{V_2^2}{2g}$

Radius = 8–20 times the pipe dia. $h_j = 0.25 \frac{V_2^2}{2g}$

Radius = Greater than 20 Dia. of Pipe $h_j = 0$

* When curves other than 90° are used, apply the following factors to 90° curves:

CURVE	FACTOR
60°	85%
45°	70%
22 ½°	40%



CASE II

BENDS WHERE RADIUS IS EQUAL TO DIAMETER OF PIPE

NOTE : Head loss applied at beginning of bend.

90° Bends $h_j = 0.50 \frac{V_2^2}{2g}$

60° Bends $h_j = 0.43 \frac{V_2^2}{2g}$

45° Bends $h_j = 0.35 \frac{V_2^2}{2g}$

22 ½° Bends $h_j = 0.20 \frac{V_2^2}{2g}$

MINOR HEAD LOSSES DUE TO TURBULENCE AT BENDS

FIGURE A-11

EXHIBIT 5.11

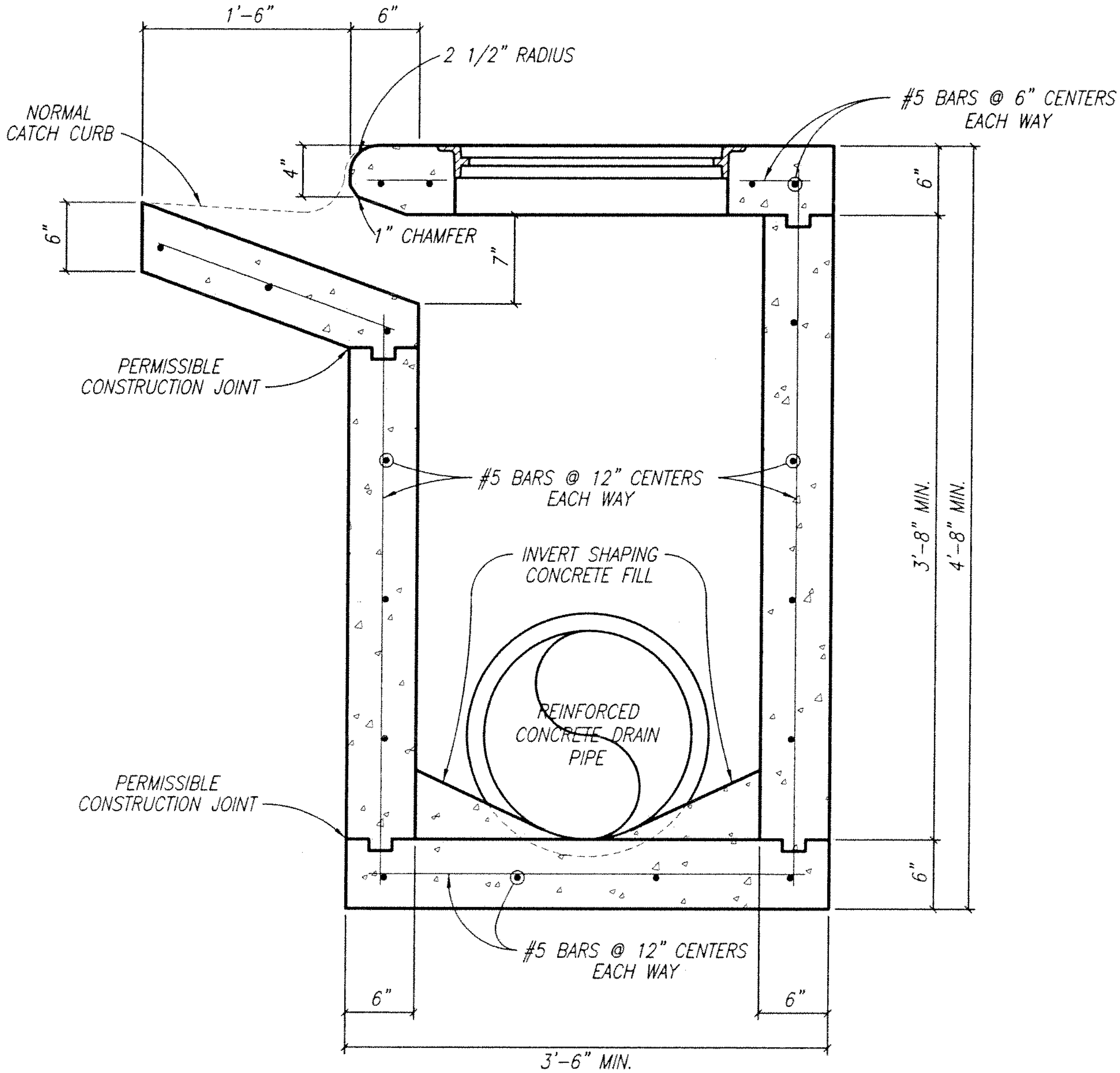
HEAD LOSS COEFFICIENTS DUE TO SUDDEN ENLARGMENTS AND CONTRACTIONS

D_2D_1*	Sudden Enlargements Kj	Sudden Contractions Kj
1.2	0.10	0.08
1.4	0.23	0.18
1.6	0.35	0.25
1.8	0.44	0.33
2.0	0.52	0.36
2.5	0.65	0.40
3.0	0.72	0.42
4.0	0.80	0.44
5.0	0.84	0.45
10.0	0.89	0.46
	0.91	0.47

* D_2D_1 = Ratio of Larger to smaller diameter

TYPICAL CURB DRAIN INLET

NOT TO SCALE



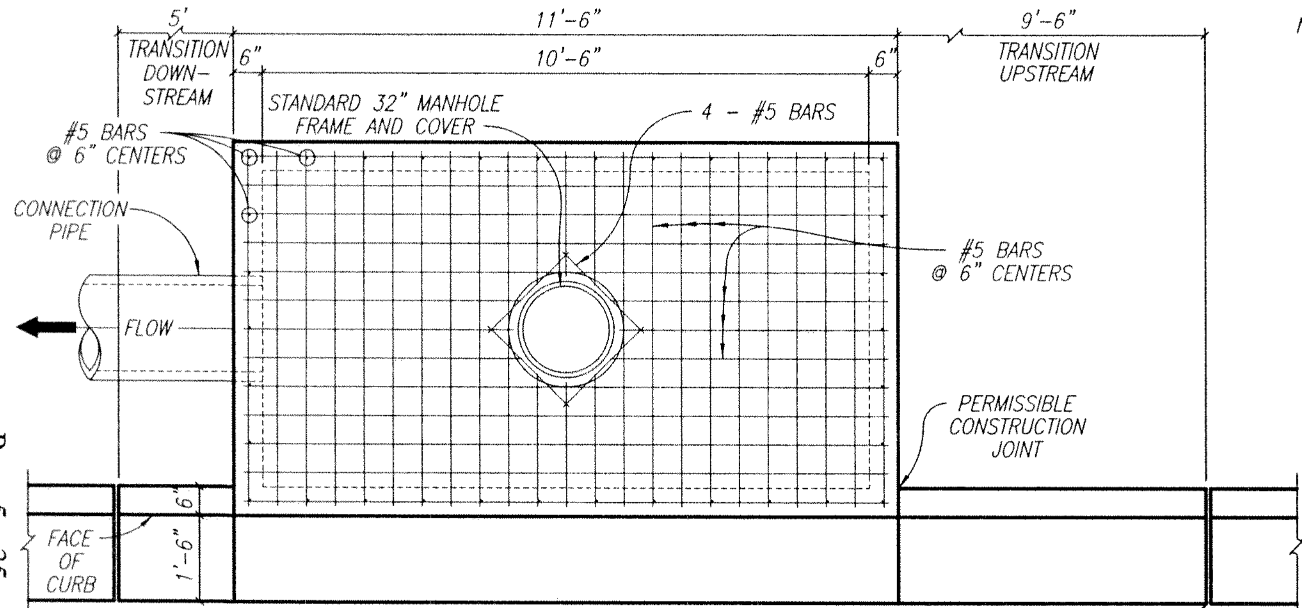
SIDE SECTION

NOTES:

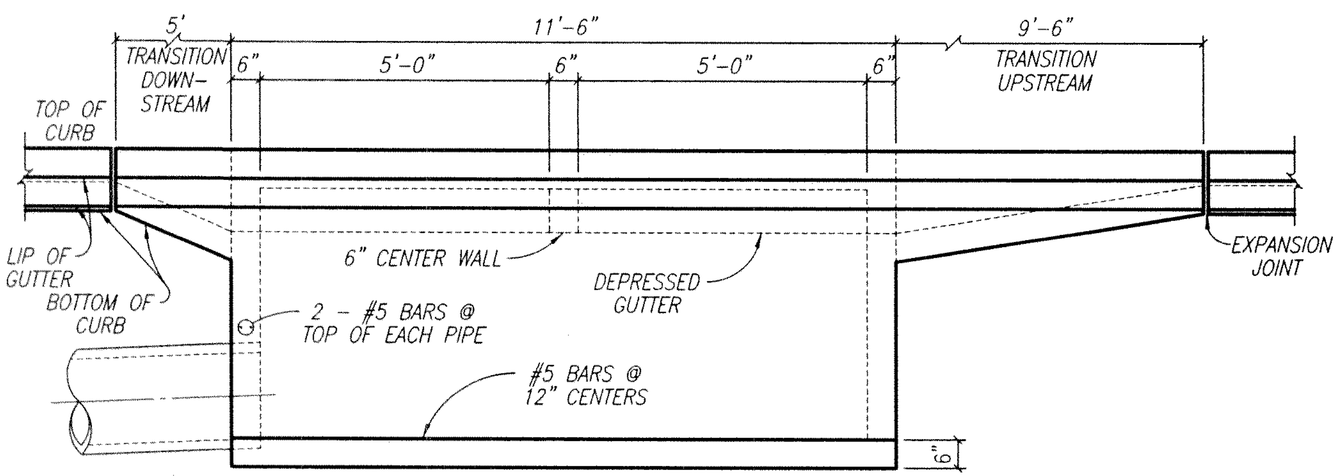
1. ALL CONCRETE SHALL BE CLASS "A" CONCRETE.
2. STORM SEWER PIPE MATERIAL TO BE REINFORCED CONCRETE PIPE CLASS III.
3. MANHOLE SHALL BE HEAVY DUTY, 350 LBS., EAST JORDON IRON WORKS REVERSIBLE, #1480 OR APPROVED EQUIVALENT.

TYPICAL CURB INLET

NOT TO SCALE



PLAN



FRONT ELEVATION

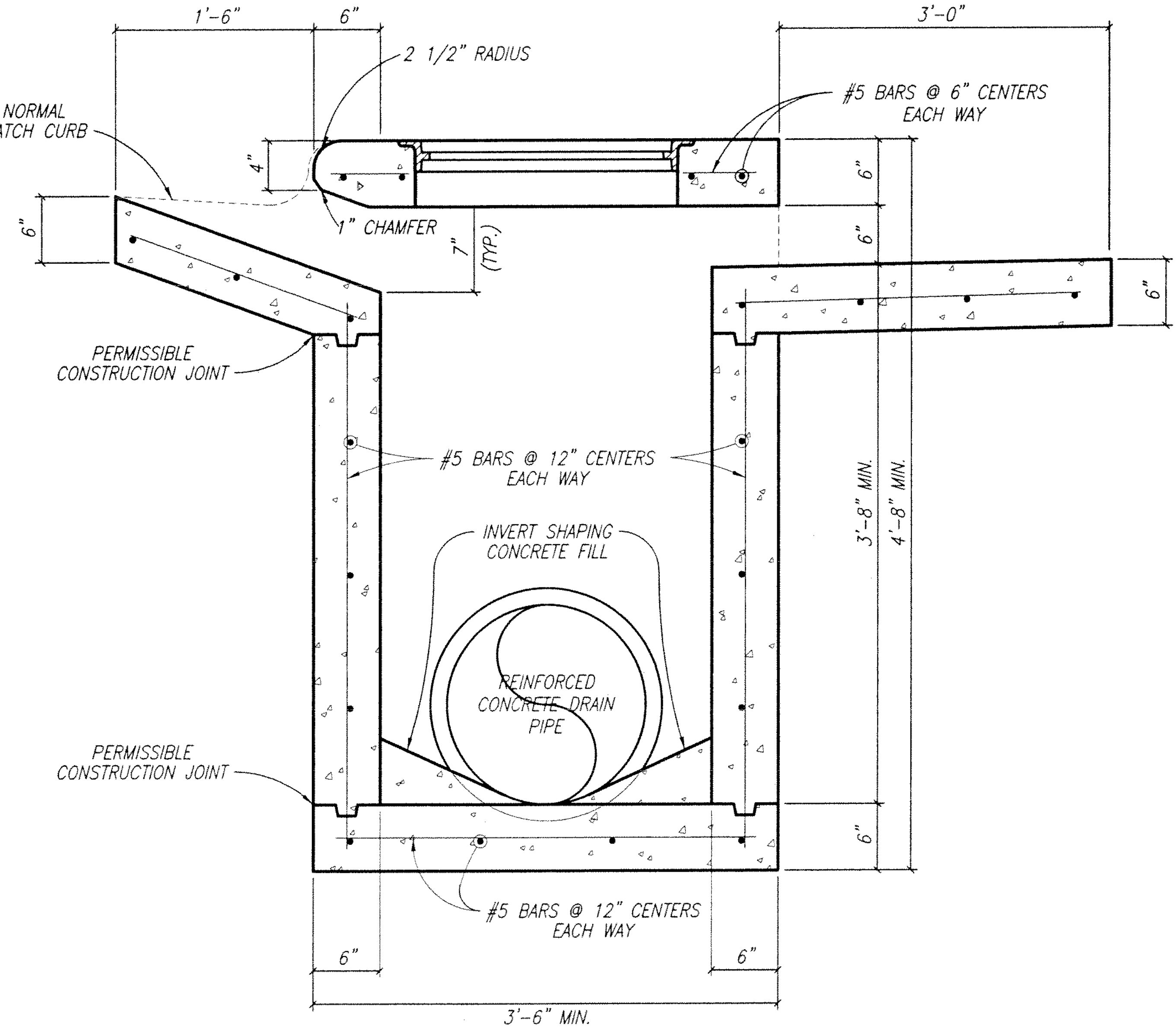
NOTES:

1. SHOULD THE CURB INLET BE LOCATED IN A SAG, CONTRACTOR SHALL TRANSITION 9'-6" ON BOTH SIDES OF CURB INLET.
2. THE MAXIMUM LENGTH OF CURB INLET, WITH EXTENSIONS, SHALL BE 20'.
3. EXTENSIONS OF 5' OF OPEN CURB SHALL BE ACCOMPANIED BY 6" WIDE POST SUPPORTS.

CURBINLETPV.DWG

TWO-SIDED DRAIN INLET

NOT TO SCALE



SIDE SECTION

NOTES:

1. ALL CONCRETE SHALL BE CLASS "A" CONCRETE.
2. STORM SEWER PIPE MATERIAL TO BE REINFORCED CONCRETE PIPE CLASS III.
3. MANHOLE SHALL BE HEAVY DUTY, 350 LBS., EAST JORDON IRON WORKS REVERSIBLE, #1480 OR APPROVED EQUIVALENT.

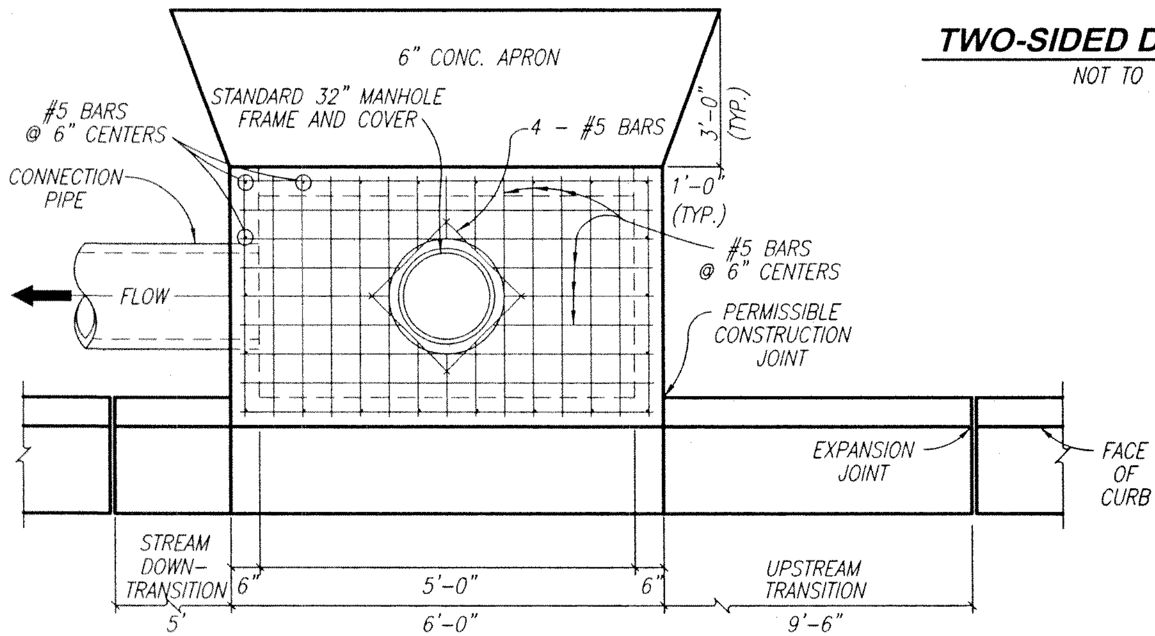
2SIDEDINLET.DWG

TWO-SIDED DRAIN INLET

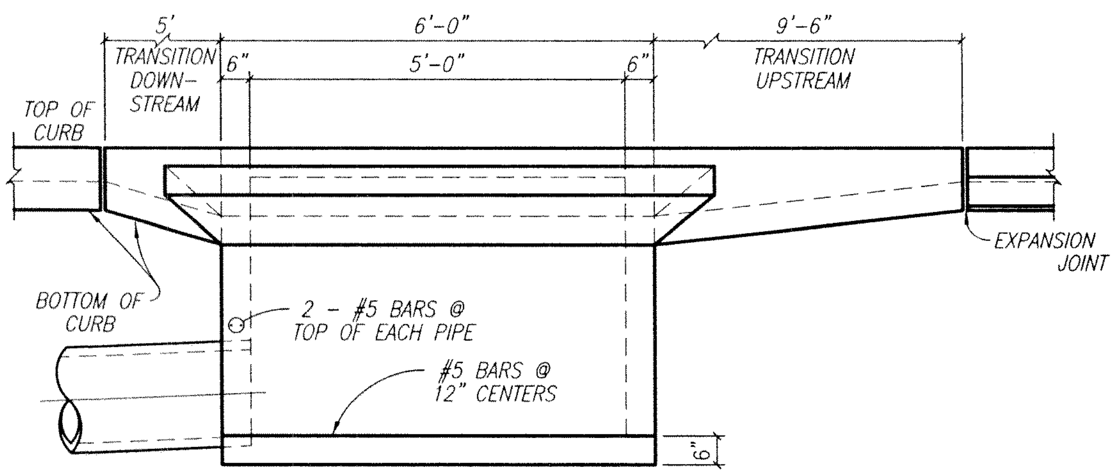
NOT TO SCALE

NOTES:

1. SHOULD THE CURB INLET BE LOCATED IN A SAG, CONTRACTOR SHALL TRANSITION 9'-6" ON BOTH SIDES OF CURB INLET.
2. THE MAXIMUM LENGTH OF CURB INLET, WITH EXTENSIONS, SHALL BE 20'.
3. EXTENSIONS OF 5' OF OPEN CURB SHALL BE ACCOMPANIED BY 6" WIDE POST SUPPORTS.



PLAN



BACK SIDE ELEVATION

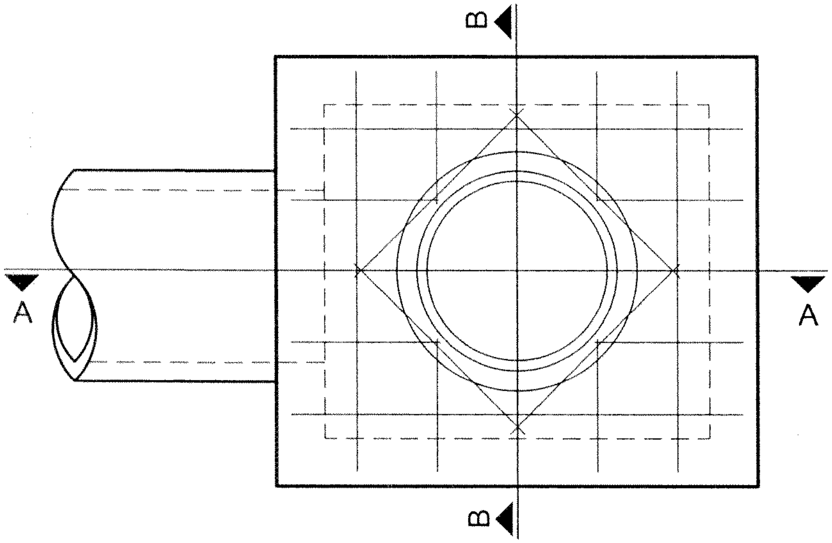
2SIDEDINLETPV.DWG

JUNCTION BOX DETAIL

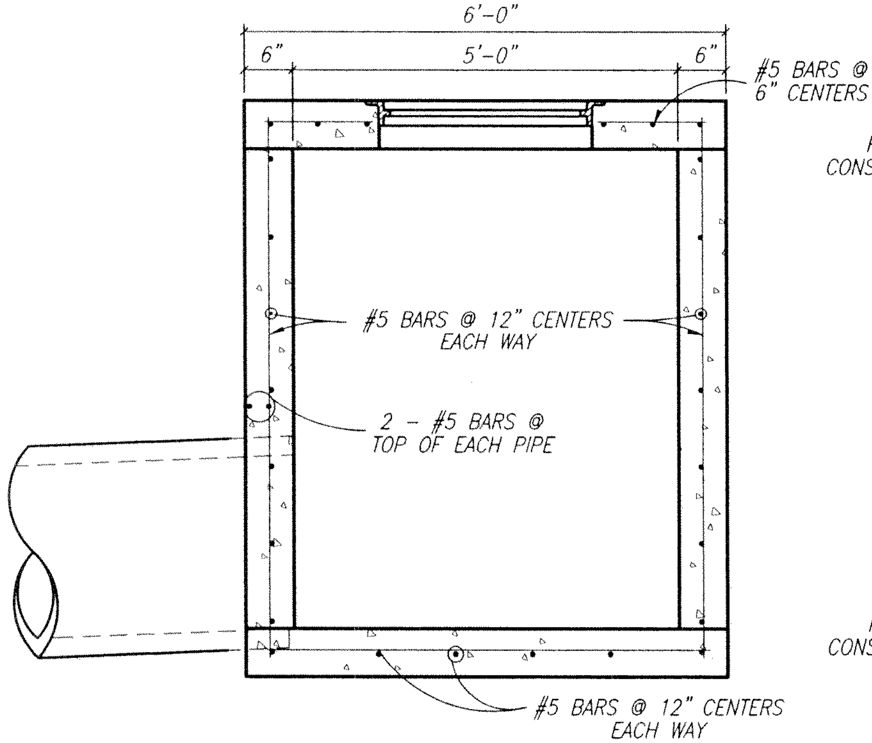
NOT TO SCALE

NOTES:

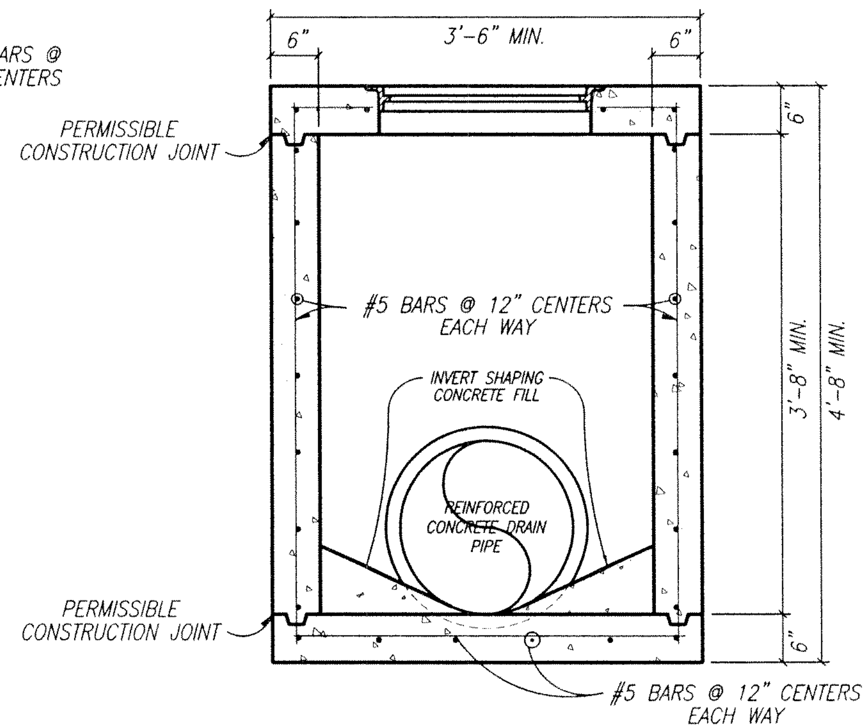
1. ALL CONCRETE SHALL BE CLASS "A" CONCRETE.
2. STORM SEWER PIPE MATERIAL TO BE REINFORCED CONCRETE PIPE CLASS III.
3. MANHOLE SHALL BE HEAVY DUTY, 350 LBS., EAST JORDON IRON WORKS REVERSABLE, #1480 OR APPROVED EQUIVALENT.



PLAN VIEW

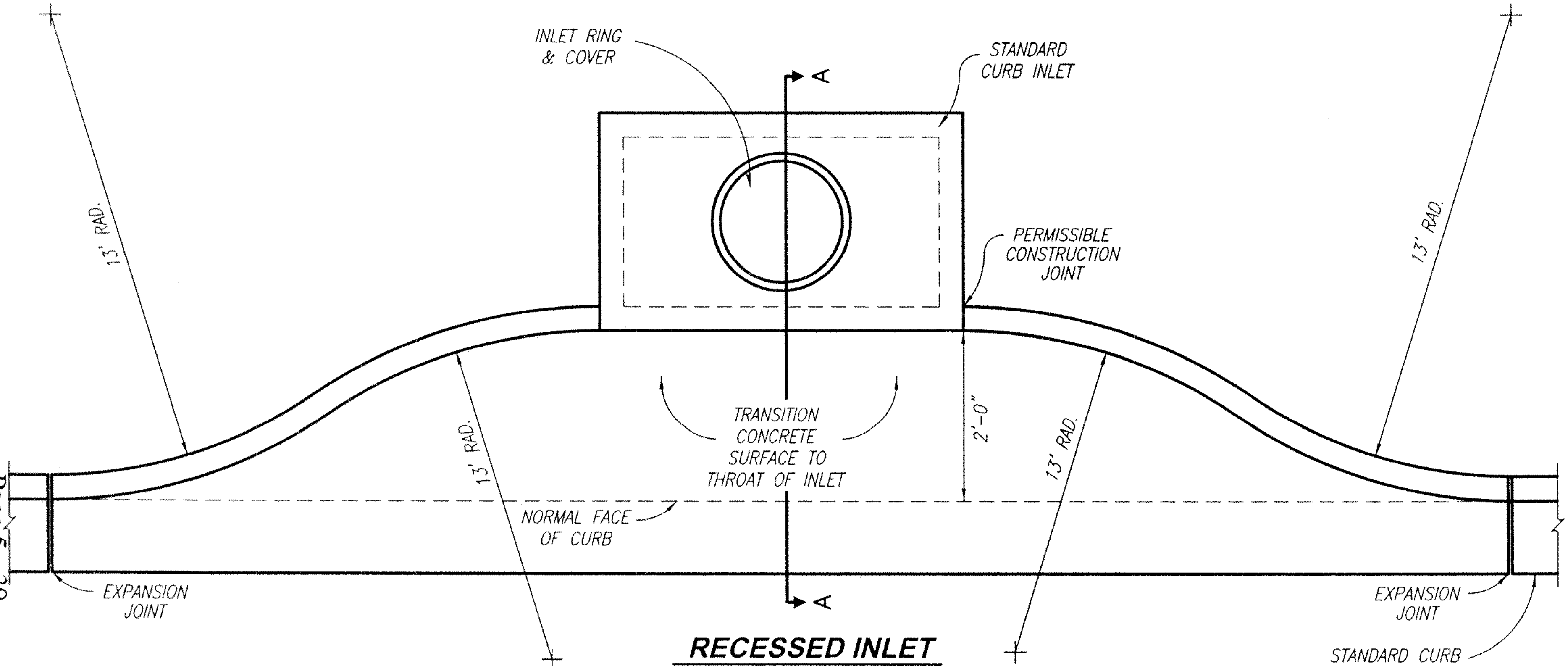


SECTION A-A



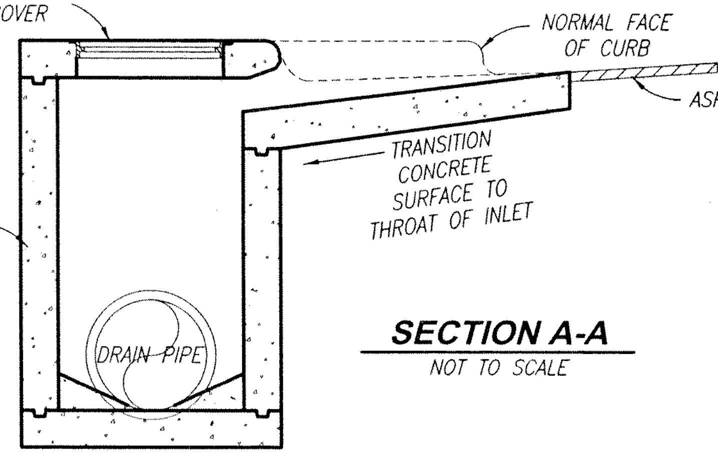
SECTION B-B

JUNCTIONBOX.DWG



RECESSED INLET

NOT TO SCALE



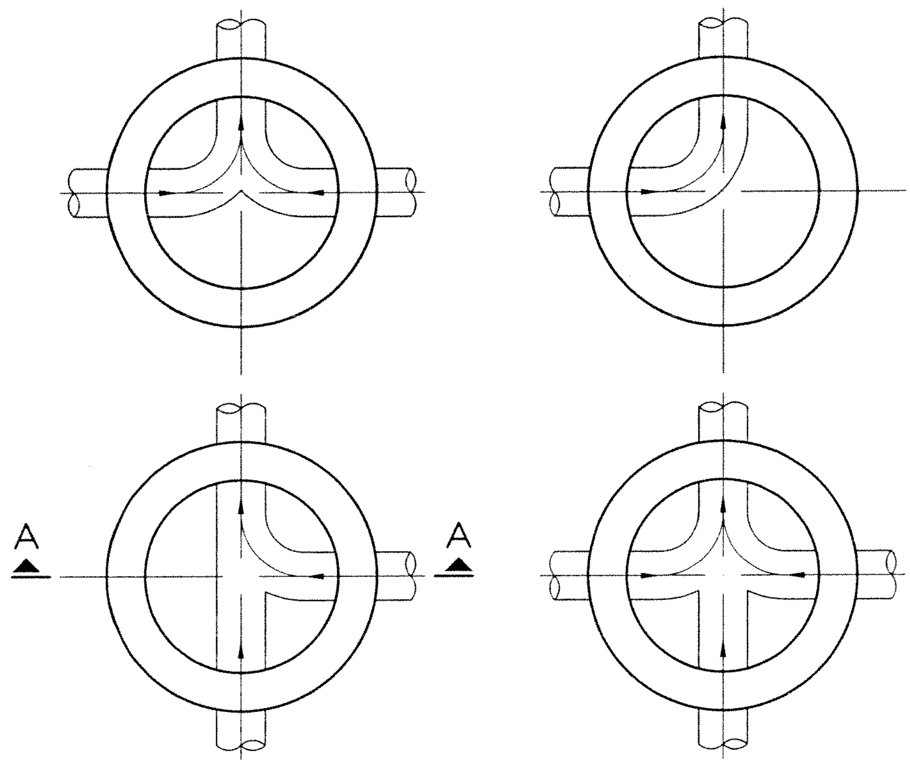
SECTION A-A

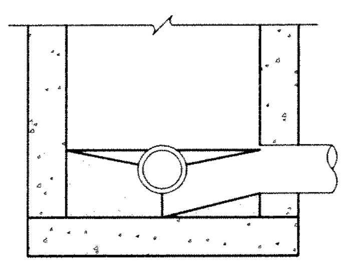
NOT TO SCALE

RECESSEDNLET.DWG

FLOW PATTERNS FOR INVERT CHANNELS

NOT TO SCALE





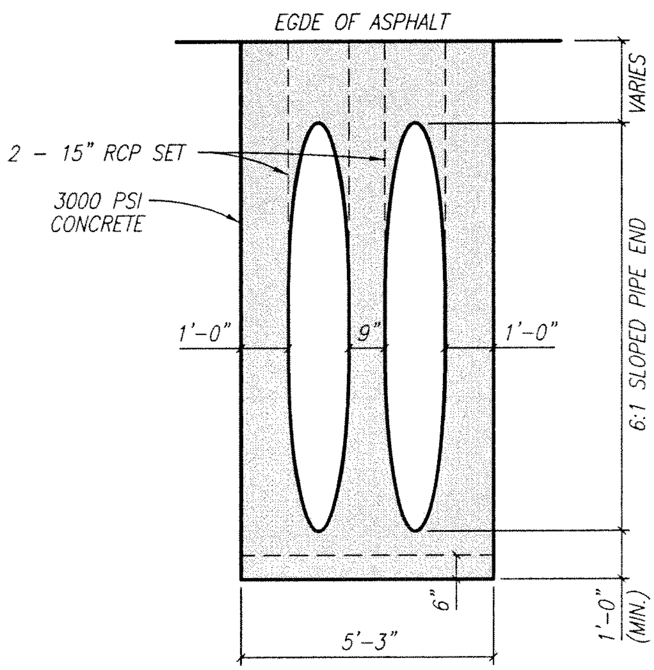
SECTION "A-A"

NOTES:

1. *INVERT CHANNELS TO BE CONSTRUCTED FOR SMOOTH FLOW WITH NO OBSTRUCTIONS.*
2. *SPILLWAYS SHALL BE CONSTRUCTED BETWEEN PIPES WITH DIFFERENT INVERT ELEVATIONS PROVIDING FOR SMOOTH FLOW.*
3. *CHANNELS FOR FUTURE CONSTRUCTIONS (STUBS) SHALL BE CONSTRUCTED, FILLED WITH SAND, AND COVERED WITH 1" OF MORTAR.*
4. *SLOPE MANHOLE ITSELF WITH A 1:2 SLOPE FROM MANHOLE WALL TO CHANNEL.*
5. *INVERT SHALL BE A MINIMUM OF 1/2 THE DIAMETER OF THE LARGEST PIPE OR 4" DEEP.*

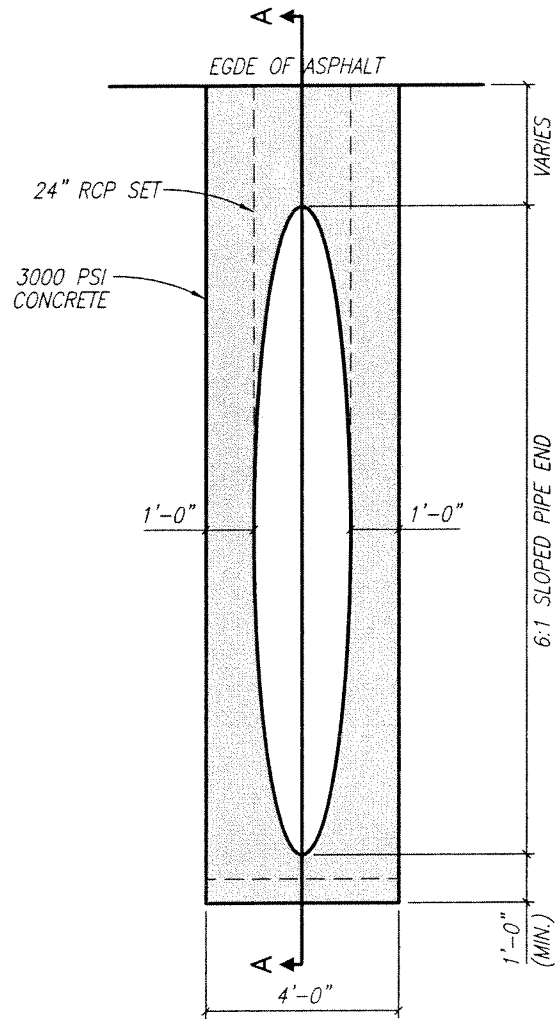
TYPICAL SLOPED END TREATMENT DETAIL

NOT TO SCALE



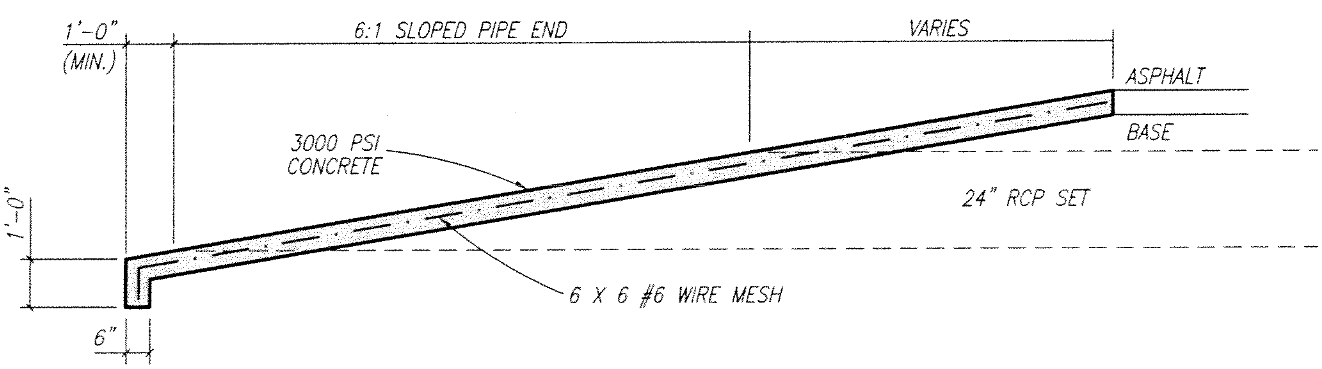
2 - 15" RCP SET

NOT TO SCALE



24" RCP SET

NOT TO SCALE



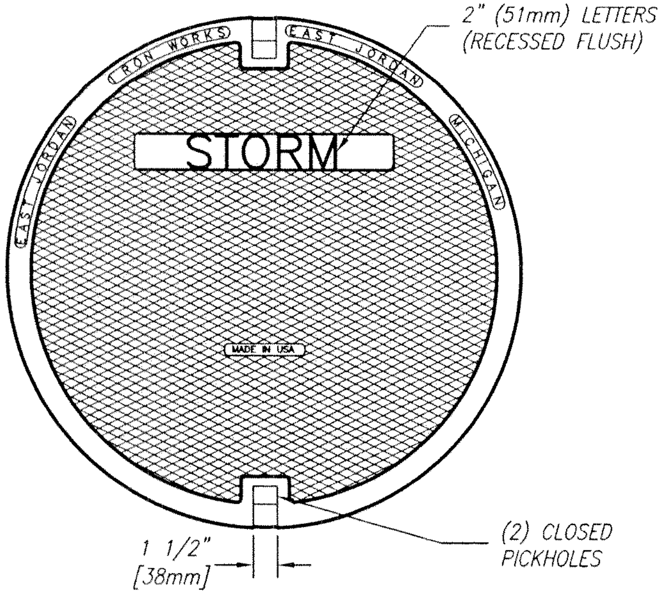
SECTION A-A

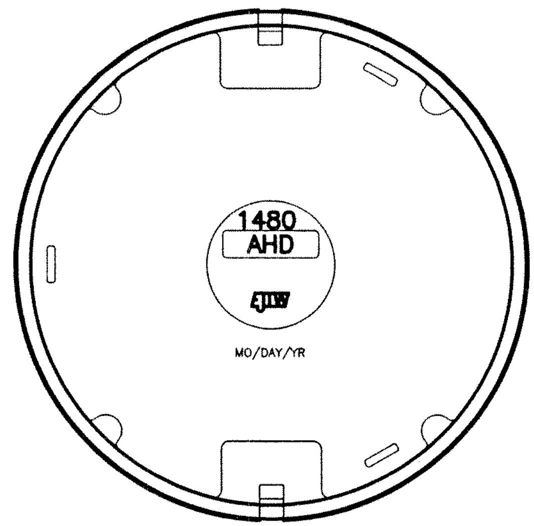
NOT TO SCALE

SLENDTRTMNTL.DWG

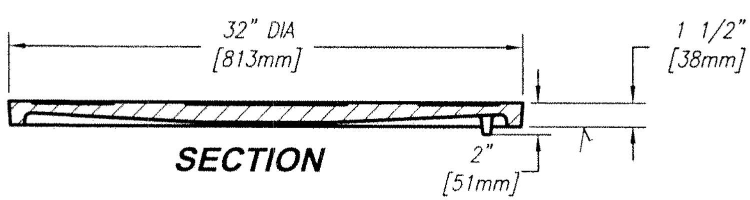
STANDARD STORM SEWER MANHOLE COVER

NOT TO SCALE

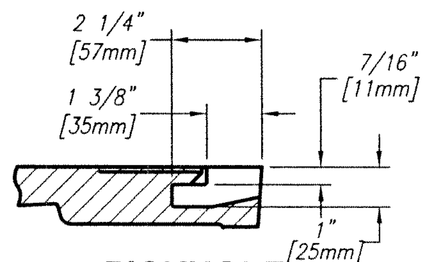




BOTTOM VIEW



SECTION



PICKHOLE

NOTE:

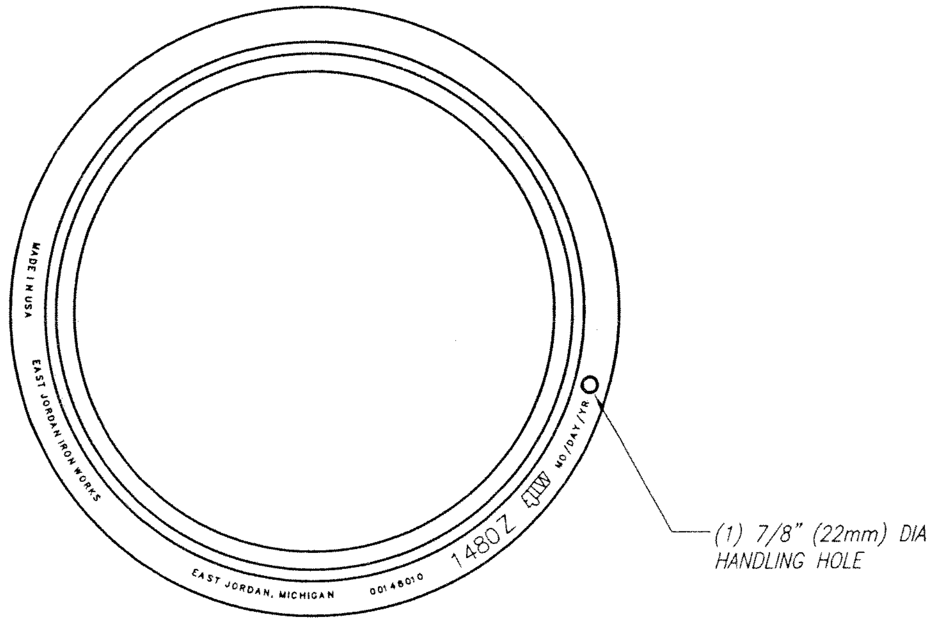
MANHOLE SHALL BE HEAVY DUTY, SPECIAL LETTERED, 200 LBS., EAST JORDON IRON WORKS #1480 OR APPROVED EQUAL.

√ MACHINED SURFACE

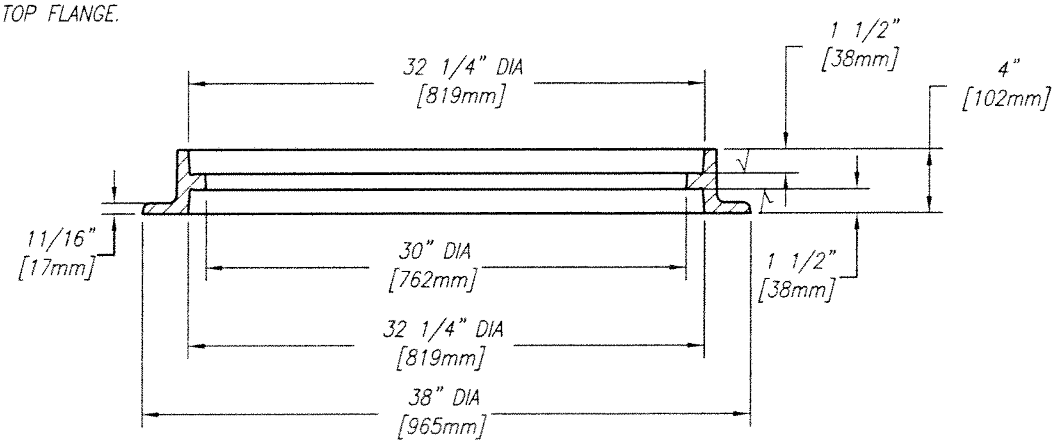
SSSMHCOV..DWG

STANDARD STORM SEWER MANHOLE FRAME

NOT TO SCALE



NOTE: THIS FRAME IS REVERSIBLE, AND CAN BE INSTALLED AS A TOP FLANGE.



SECTION

NOTE:

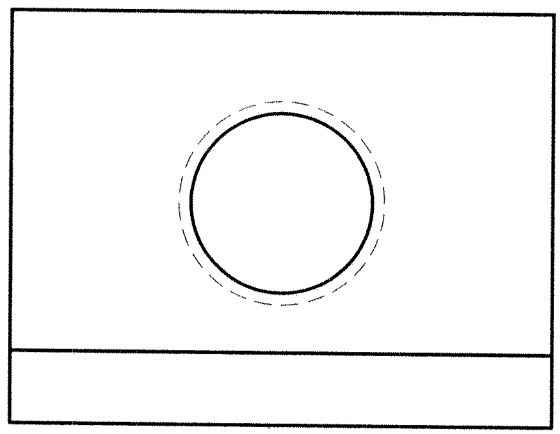
FRAME SHALL BE HEAVY DUTY, 155 LBS., EAST JORDON IRON WORKS REVERSABLE, #1480 OR APPROVED EQUAL.

SSSMHFRM.DWG

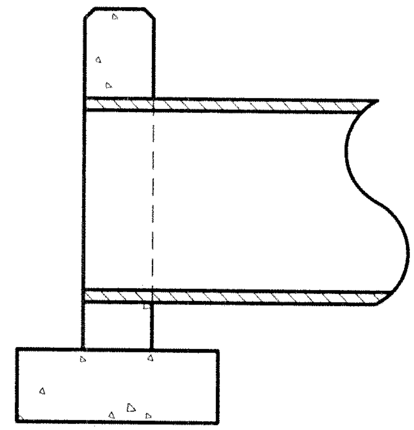
√ MACHINED SURFACE

CONCRETE HEADWALL - TYPE A

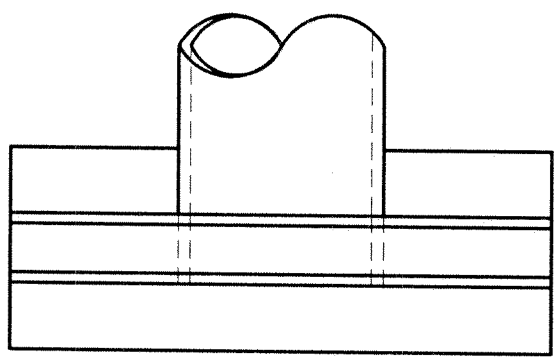
NOT TO SCALE



FRONT ELEVATION



SIDE SECTION



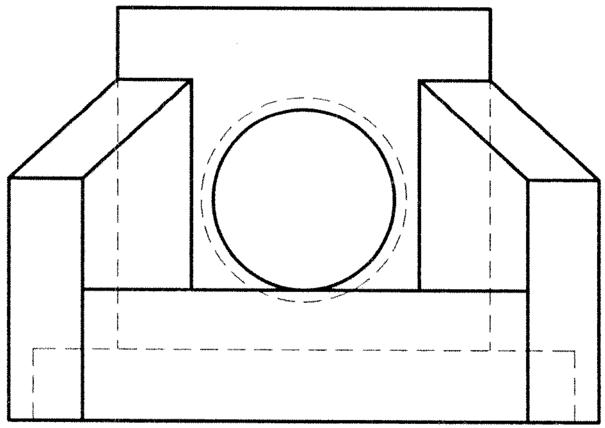
PLAN VIEW

NOTE:
DIMENSIONS AND MATERIAL REQUIREMENTS VARY FROM ONE APPLICATION TO ANOTHER. FOR COMPLETE DETAILS, MEASUREMENTS, MATERIALS LIST, AND OTHER COGNIZANT FACTORS REFER TO THE CURRENT TXDOT CHART ON CONCRETE HEADWALLS FOR PIPE CULVERTS.

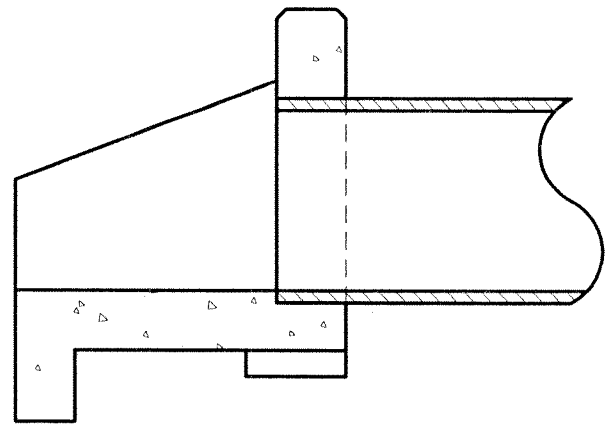
TYPEAHW.DWG

CONCRETE HEADWALL - TYPE B

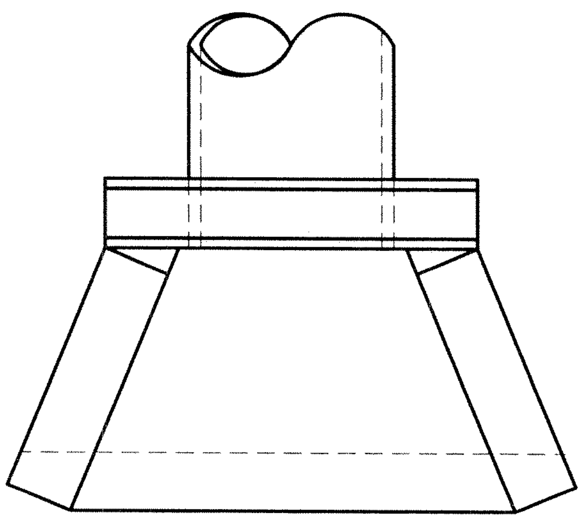
NOT TO SCALE



FRONT ELEVATION



SIDE SECTION



PLAN VIEW

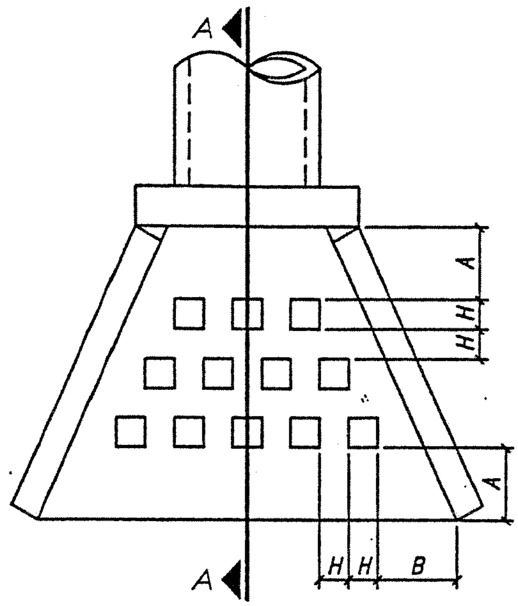
NOTE:

DIMENSIONS AND MATERIAL REQUIREMENTS VARY FROM ONE APPLICATION TO ANOTHER. FOR COMPLETE DETAILS, MEASUREMENTS, MATERIALS LIST, AND OTHER COGNIZANT FACTORS REFER TO THE CURRENT TXDOT CHART ON CONCRETE HEADWALLS FOR PIPE CULVERTS.

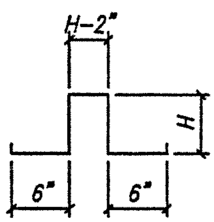
TYPEBHW.DWG

ENERGY DISSIPATOR DETAIL

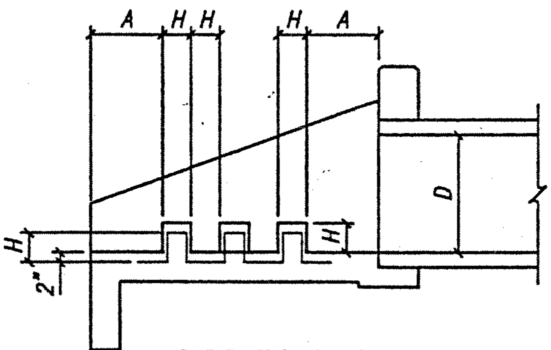
NOT TO SCALE



PLAN VIEW



BARS



SECTION "A-A"

NOTES:

1. USE CLASS "A" CONCRETE, FC = 3000 PSI AT 28 DAYS, UNLESS NOTED.
2. REINFORCING STEEL – ASTM A615, GRADE 40, UNLESS NOTED.
3. LAP REINFORCING 30 BAR DIAMETERS MIN. AT SPLICES, UNLESS NOTED.
4. CHAMFER EXPOSED EDGES OF CONCRETE 3/4", UNLESS NOTED.
5. PLACE REINFORCING WITH THE CENTER OF THE OUTSIDE BARS 2 INCHES FROM THE SURFACE OF THE CONCRETE.

TABLE OF DIMENSIONS FOR ENERGY DISSIPATOR DETAIL

D PIPE DIAMETER (INCHES)	NUMBER OF ROWS OF DISSIPATORS	NUMBER OF DISSIPATORS IN FRONT ROW	H (INCHES)	A (INCHES)	B (INCHES)
12	1	3	4	4	9.1875
18	2	4	4 1/2	9 1/2	15.5625
24	2	5	6	14 3/4	16 1/2
30	3	6	7 1/2	12 1/2	14 3/8
36	3	6	9	16 1/4	18 5/16
42	3	6	10 1/2	20	22 1/4
48	3	6	12	23 3/4	26 1/4
54	3	6	13 1/2	27 1/2	27 3/4
60	3	6	15	31 1/4	31 5/8

ERGYDIS.DWG