CHAPTER V

STORM DRAINS

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ANNE ARUNDEL COUNTY DESIGN MANUAL

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STORM DRAINS

I. GENERAL

A. Introduction

This Chapter of the Design Manual outlines the acceptable methods, criteria and guidelines for the design of storm drainage systems.

Storm water runoff is to be collected and converted in closed conduit systems (inlets, inlet connections, and drains) or open system (ditches, streams, rivers, culverts, and improved open channels). Instructions for design of closed conduit systems and improved channels are contained in this section. Instructions for design of culverts are contained in Chapter IV, Bridges, Culverts, and Retaining Walls.

B. Ordinance and Authority

Under the Annotated Code of Maryland Article 25A 5, (G) Anne Arundel County is granted the express powers to provide for the drainage of low lands. These powers are further defined in the Anne Arundel County Code, Article 21, Floodplain Management, Article 25, Public Works, and Article 26, Subdivisions.

C. Definitions

Hydrology: The estimation of the volume and rate of stormwater runoff from precipitation data and other watershed parameters of statistical data.

Hydraulics: The calculation of flow depths and velocities for pipe and open channel systems.

Open Conduit Systems: A drainage system consisting of swales, ditches, and channels.

Culvert: A pipe or closed conduit permitting drainage to cross under an embankment. Generally culverts will be of one continuous size, without intermediate structures that significantly affect the hydraulic grade line.

Main Drainage Course: A well-defined stream or concentration of stormwater in a natural or man-made hydraulic system. For the purpose of this Manual, a Main Drainage Course shall transport greater than 100 cfs for a 10-year design storm or exceed thirty (30) acres in drainage area.

Floodplain: The area that would be inundated by storm water runoff equivalent to that which would occur from a rainfall of 100-year frequency after total development of the watershed and is defined by an elevation below which no development may take place unless consistent with this article.

Overland Flow: Unconcentrated sheet flow over either vegetated or paved surfaces.

Average Watershed Slope: The average slope of all the drainage paths in a watershed or sub-basin. It may be approximated using a weighted calculation of several drainage paths, including overland flow or by more rigorous alternative procedures.

Time of Concentration: The time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed or discharge (study) point.

Antecedent Moisture Condition: A measure of soil moisture prior to the occurrence of the design storm.

Hydraulic Grade Line: Piezometric head at any point on a hydraulic system. Used for design of pipe systems.

Energy Grade Line: The total head (Piezometric head plus velocity head) at any point on a hydraulic system. The energy grade line is the highest potential level of water in a manhole or inlet.

Normal Depth: A condition of uniform flow where the rate of head loss (hydraulic gradient) is equal to the channel bed slope or conduit invert slope and there is no pressure flow.

II. DESIGN CRITERIA

A. Pre-Design Meeting

Prior to commencing any design work on a Capital Project, a pre-design meeting shall be held as provided in Chapter I, General Instructions. For Developer Projects, a pre-sketch meeting may be held at the request of the developer. These meetings will discuss, at a minimum, the following design parameters pertinent to this Chapter, in addition to items, which pertain to any other Chapters, which will govern the design of the project:

- The design professional shall advise the County of the method to be used to compute water surface profiles and hydraulic gradients.
- The DPW shall advise if 2-way traffic is to be maintained in streets to receive storm drains.
- The DPW shall advise if prefabricated end sections are acceptable.
- The DPW shall advise if reinforced concrete box drains and special structures are acceptable.
- The DPW shall furnish approved established street grades.

- The DPW shall furnish hydraulic gradient computations for existing storm drains into which the project storm drain will connect.

B. Hydrologic Methods and Criteria

Hydrologic variables for storm drainage systems shall be computed using the Rational Method. Hydrologic variables for stormwater management shall be computed using the Soil Conservation Service Method described in the latest edition of TR-55 and TR-20. Each of these methods has limitations as to their use for specific systems design, and site conditions. Guidelines are given to aid the design professional in the selection of the appropriate method as well as limiting conditions, which will dictate the use of one method over another. Deviation from the stated limiting conditions, in some case, may be warranted. In such cases the design professional shall request permission from the Department of Public Works to deviate from the required methodology and provide justification for such request prior to proceeding with the design.

1. Soil Conservation Service (SCS) Method, TR-55 and TR-20

   a. The Soil Conservation Service (SCS) TR-55, "Urban Hydrology for Small Watersheds", may be used for small homogeneous watersheds.

   b. The Soil Conservation Service (SCS) TR-20, " Computer Program for Project Formulation- Hydrology" may be used when:

      - The subareas have different runoff characteristics.
      - There are or will be reservoir, dams and/or ponds within the study area.
      - Complete flow hydrograph is required.
      - Designing and/or analyzing bridges.
      - Designing and/or analyzing storm drain systems with drainage area of over 200 acres.

      Refer to Chapter VI, Stormwater Management, for a description of the methods and lists of runoff curve numbers by land use and soil type.

2. Rational Method

   The Rational Method shall be used for the design of closed storm drainage systems of 200 acres or less.

   The rational formula, Q=CIA, shall be used to determine quantities of runoff where:

   Q= Peak runoff rate, cubic feet per second
   C= Runoff coefficient (ratio of runoff to rainfall intensity)
   I= Rainfall intensity, inches per hour (based on time of concentration)
   A= Tributary area, acres

The time of concentration will be computed using the overland flow nomographs developed for the Rational Method.

a. Area: The surface area draining to the point of study should be measured from reliable topographic mapping of the largest scale available. The limits of the drainage area shall be field checked; especially drainage areas with existing storm drain systems. These systems may direct runoff into, or away from, the area under study. Unless approved by the Department of Public Works, the minimum scale for drainage area mapping shall be 1" =200'. When performing calculations for existing and proposed conditions it is important to use the same study points whenever possible, for direct comparisons.

b. Runoff Coefficient "C": The runoff coefficient shall be a weighted composite of the "C" factors of all the areas tributary to the study point in accordance with Article 26, Subtitle 2-418(d) of the County Code. Standard Storm Drain Design Drawings SD-2.01 through 2.05 in Appendix C list the typical runoff coefficients ("C" factors) for various ground covers, soil types, and ground slopes. The design professional shall use Drawing SD-2.01 for all drainage systems designs within County jurisdiction, and Drawings SD-2.02 through 2.05 for all drainage system designs, which are required to meet State Highway Administration criteria. Runoff coefficients for the various residential zoning classifications are minimum values and include lots, open space and impervious areas.

c. Time of Concentration: Time of concentration is the interval of time for water at the hydraulically most distant point of the watershed to flow to the point of investigation. It is possible for a developed portion of the drainage area with a shorter time of concentration to generate greater peak discharge than the entire drainage area. When this occurs the greater peak discharge should be carried:

   The flow path should be carefully selected to be representative of the drainage area. It is suggested that more than one path be investigated. When a time of less then five minutes is encountered, a five-minute duration will be used to determine the intensity. However, the actual time will be used to calculate the total time of concentration for the watershed.

   The time of concentration (TC) is the sum of overland flow (to), swale flows (ts), ditch flow (td), gutter flow (tg), channel flow (tch), and pipe flow (tp) in the following formula:

$$TC = to + ts + td + tg + tch + tp$$

   In most cases, some of the incremental time components will not be applicable. The following criteria will be used to derive the components of the time of concentration:

   1) Overland Flow (to) - Overland flow time shall be calculated using the SCS TR-55 method based on the manning equation for sheet flow and

corresponding resistance coefficients or using the "Overland Flow Nomograph" (Standard Storm Drain Design Drawing SD-4 in Appendix C). Maximum overland flow length shall be 200 feet.

2) Swale Flow (ts)- Swale flow time shall be calculated using the Mannings Equation or Standard Storm Drain Design Drawing SD-6 and SD-7 in Appendix C.

3) Ditch Flow (td) - Ditch flow time shall be calculated using the Mannings Equation or Standard Storm Drain Design Drawing SD-6 and SD-7 in Appendix C.

4) Gutter (tg)- Gutter Flow times shall be calculated using Standard Storm Drain Design Drawing SD-5 in Appendix C.

5) Channel Flow (tch) - Channel flow times in streams shall be calculated using the Mannings Equation or estimated using Standard Storm Drain Design Drawing SD-10 in Appendix C.

6) Pipe Flow (tp) - Pipe flow time shall be calculated using the Mannings Equation for partial depth. For pipe flow velocities in excess of 10 fps use the average of the partial depth velocity (Mannings formula) and critical velocity.

d. Rainfall Intensity: Rainfall intensity shall be determined from the rainfall intensity curves (see Standard Storm Drain Design Drawing SD-11 in Appendix C). The intensity curves are for Times of Concentration of 5 minutes to 2 hours, for storm frequencies of 2, 5, 10, 20, 50, and 100 years.

C. Hydraulic Methods and Criteria

1. Design Storm Criteria

For a list of the Design Storms for each road classification refer to Standard Storm Drain Design Drawing SD-1 in Appendix C.

For a main drainage course where the 10-year design flows exceed 100 cfs or where the drainage area exceeds thirty (30) acres, in either a closed conduit or open channel system, the design professional shall calculate the discharge for the 100-year storm and verify that freeboard as defined by Paragraph II.C.3.d. of this Chapter and maximum design velocities as presented in Table V-1 of this Chapter are not exceeded.

2. Permitted Hydrologic Methods

The Rational Method shall be used for drainage areas of 200 acres or less.

The SCS Method shall be used for drainage areas greater than 200 acres. If a system serves a drainage area in excess of 200 acres and the design professional has elected to design that portion of the system serving less than 200 acres using the Rational Method, he/she shall proceed as follows:

Compute the design discharge at the point on the drainage course that serves 200 acres using the SCS Method. Compare this peak discharge with that computed using the Rational Method and use the greater of the two. Repeat this process for drainage areas of more than 200 acres. Use greater discharge from Rational Method or SCS Method. Continue the analysis downstream on the main drainage course until the SCS Method exceeds the 200 acres Rational Method discharge. The peak discharge of tributaries with drainage areas less than 200 acres may be calculated using the Rational Method.

<u>Example:</u> DA = 200 ac

Rational Method	Q = 470 cfs
SCS Method	Q = 450 cfs
Use <u>470 cfs</u>	

Continuing downstream

DA = 220 ac

SCS Method	Q = 465 cfs
Use <u>470 cfs</u>	

Continuing downstream

DA = 235 ac

SCS Method	Q = 480 cfs
Use <u>480 cfs</u>	

If a storm drain system, with drainage area of less than 200 acres, outfalls into a stormwater management facility, the peak discharge from the storm drain system shall be computed using the Rational Method. The runoff discharge for the stormwater management facility, which may include the contributory area of the storm drain system, shall be computed using the SCS Method. The SCS Method shall be used in computing the runoff discharge along the main drainage course downstream of the stormwater management facility to the outfall. Runoff discharges for the tributary to the main drainage course shall be computed using the Rational Method unless the contributing area is more than 200 acres. Then, the SCS Method shall be used.

The runoff discharge of a stormwater management facility discharging into a closed storm drain system, even if the contributing area is less than 200 acres, shall be computed using the SCS Method. The runoff discharge of the main drainage course for the storm drain system from the stormwater management facility to the outfall shall also be computed using the SCS Method. The runoff discharge for the laterals of the storm drain system shall be computed using the Rational Method unless the contributing area is over 200 acres.

If the design professional has elected to use the SCS Method for the design of a closed conduit system he/she shall use the Rational Method to design inlets and branch systems serving less than 2 acres.

3. Open Channel Systems

Open channel systems shall consist of roadside swales and ditches, off-road drainage and flood channels, and natural streams.

a. Normal Depth Calculation Using Mannings Equation: For most applications, other than 100-year frequency design, the design of open channel systems based on normal depth will be sufficient. Normal depth is calculated iteratively by Manning's Equation using different estimates of depth as follows:

$$Q = A\frac{1,486}{n}R^{2/3}S^{1/2}$$

Where:
- Q = Flow rate, in cubic feet per second.
- A = Cross sectional area of flow, in square feet
- n = Mannings roughness coefficient (see Table 1)
- R = Hydraulic radius, in ft.
- S = Hydraulic gradient or the slope of the channel invert for normal depth calculations, in feet per foot.

The design professional may wish to use hydraulic tables found in the "Handbook of Hydraulics" by King & Brater, for calculation aids.

The design depths in steep channels shall not be less than critical depth. Maximum velocities for steep channels however, shall be calculated based on normal depth. Manning's roughness coefficient may be estimated using Table V-1.

b. Water Surface Profiles: Wherever the design or analysis is performed for the 100-year frequency storm, the design professional shall compute the backwater profiles using the "standard step" procedure. The design professional may elect to use the Corps of Engineers' HEC-2 or HECRAS program to calculate a backwater profile. Care should be exercised to determine if restrictions have an effect on the backwater analysis.

c. Transitions and Superelevation: Paved or lined channel transitions at bridges and channel junctions shall be designed to allow for 1.2 contraction and 1.4 expansion lengths to avoid scour due to turbulence.

Occasionally the design of steep channels will require the consideration of superelevation. The design professional shall refer to Chow V.T. "Open Channel Hydraulics" for analysis methods.

Table V-1

Mannings Roughness Coefficients, "n", for Open Channels

Surface	**"n"**	**Maximum Design Velocity Ft/sec**
Concrete	0.015	20
"Granite"	0.020	20
Riprap		
Flow depth ≤ 2		
Min. Diameter of Stones	0.050	based on stone size
Flow depth ≥ 2		
Min. Diameter of Stones	0.035	based on stone size
Gabions	0.030	15
Grouted Gabions	0.030	20
Masonry	0.030	20
Bare Earth	0.025	2-6 (dependent on
Sod - Cut grass	0.030	6 the type of soil)
Long grass	0.035	6
Dense weeds	0.050	6
Natural Streams		
Minor Streams, fairly regular sections		3.5 - 6
Some grass and weeds, little or no brush	0.035	
Dense growth of weeds, flow depth greater than weed length	0.050	
Some weeds, light brush on banks	0.050	
Some weeds, heavy brush on banks	0.070	
Trees within channel, with branches at high stage, increase above values by	0.020	
Minor streams with irregular sections, with pools, slight channel meander; increase all above values by	0.020	3. - 6.5
Flood plains (adjacent to natural streams)	0.035	
Pasture with short grass, no brush	0.050	
Pasture with high grass, no brush	0.040	
Cultivated, no crop	0.045	
Cultivated mature row crops	0.050	
Cultivated mature field crops	0.070	
Heavy weeds, scattered brush	0.080	
Light brush and trees	0.160	
Medium to dense grass	0.033	
Major streams (surface width at flood stage> 100 feet)		

d. Freeboard: Freeboard for floodplains will be established based on the type of structure. A freeboard of one foot will be required for any inhabitable structure, below the first floor elevation or the lowest adjacent grade whichever is lower, and for the travel lanes of any roadway. A freeboard of 0.5 feet will be required for other structures and for the edge of road shoulders. A different freeboard value may only be used if specifically approved by the Department of Public Works.

e. Materials:

1) Bioengineering - Bioengineering methods of stabilization will be considered in preference to structural methods for those portions of a channel where the design water velocities acting on the stabilized areas are less than the velocities that the stabilized areas can withstand. Consideration should be given to the variability of the strength of vegetative measures with respect to the variability of climatic conditions in the County. Methods must be locally appropriate and include habitats and aesthetic considerations.

2) Earth - Earth or unlined channels may be considered for cases of non-eroding velocities. Earth slopes will in no case be steeper than 2%. Side slope erosion potential may require vegetative cover if slopes are steeper than 4:1.

3) Erosion Protection Fabric - Several manufacturers of erosion protection fabric offer economical alternatives to gabions or riprap. The design for particular applications shall follow the design guidelines provided by the manufacturer. The design should include overlap dimensions and end burial, staking and check slot details.

4) Gabions - Gabion channel lining offers an effective, flexible and aesthetically satisfactory alternative to concrete and bituminous concrete materials. Gabion channel walls steeper than 1:1 shall be designed as gravity retaining walls with consideration of surcharge due to equipment loads. The design professional shall consider slope anchors, toe walls and aprons to protect the gabion foundation. All gabions shall be placed on filter cloth.

5) Riprap - The size of the riprap shall be determined using the methods outlined in the 1994 Maryland Standards and Specifications for Soil Erosion and Sediment Control, or latest edition thereof. All riprap channels shall be placed on filter cloth.

6) Concrete - Wire mesh reinforced concrete may be selected where the design discharge is less than 100 cfs. The use of concrete channels for greater design flows shall require prior approval by the Department of Public Works. The design of concrete channels shall consider flotation, the control of soil hydrostatic pressure with weep holes, adequate construction and expansion joints, drainage of subgrade and cutoff walls.

f. Limiting Velocities: Unless expressly waived by the Department of Public Works, the minimum velocity at the design flow shall be 2.5 feet per second. Maximum velocity will be based on the material selected but in all cases should be less than 15 feet per second. Channel geometry and slopes that would otherwise produce velocities in excess of 15 fps should be stepped to dissipate energy.

g. Channel Side Slopes: Side slopes for paved or lined channels are limited by the selection of the paving or lining material. In general, slopes of three horizontal to one vertical (3:1) will be acceptable for all materials. Side slopes steeper than 3:1 up to 2:1 will be permitted for all material except grass that needs to be mowed. Slopes steeper than 2:1, will not be permitted for vegetated channels. Slopes steeper than 1:1 will be considered a structural element for slope stability and could be designed as a retaining wall. The design professional should consider the incorporation of more than one material and side slope in the design to take advantage of the economies of material and construction methods.

h. Stream Restoration: Restoration of degraded stream channels will be performed where determined to be of public benefit by the Department of Public Works. Designs will restore the stream to as near natural condition as practical. Where channel geometry must be altered the Rosgen classification may be used as guide.

4. Closed Conduit Systems

Closed conduit systems shall consist of pipe drains and culverts subject to pressure flow.

a. Hydraulic Calculations Using Mannings Equation and Continuity Equation.

Hydraulic computations for determination of pipe capacity, depths of flow and velocities of flow will be based on the Mannings equation.

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

Where: V = Velocity of flow, in feet per second (fps)
n = Mannings roughness coefficient (See Table V-2)
S = Slope of hydraulic gradient (equal to the invert slope for normal depth case), in feet per foot
R = Hydraulic radius, in feet

All hydraulic computations shall satisfy the Continuity Equation as follows:

$$Q=VA$$

Where: Q = Flow rate, in cubic feet per second (csf)
V = Velocity, in feet per second
A = Cross sectional area of flow, in square feet, (s.f.)

Standard Storm Drain Design Drawing SD 19.01 may be used to calculate the capacity of full flowing pipes when the slope, size, and roughness coefficient "n" are known. Given the flow, size and "n" coefficient this plate will also find the hydraulic gradient slope (friction slope) for pressure flow.

b. Materials: The following factors shall be considered in selecting pipe materials for closed storm drain systems.

- Flow Characterectrics
- Durability
- Strength
- Type of Joints
- Availability of pipes
- Availability of special shapes
- Ease of handling and installation
- Cost of material and installation.

Listed below, with uses, specifications requirements, and Mannings "n" coefficient are acceptable pipe materials.

TABLE V-2

Mannings Roughness Coefficients
"n" for Closed Conduits

Materials	Specification	Mannings "n"	Maximum Design Velocity Ft./Sec.
(1) Reinforced Concrete Pipe	AASHTO M170 Class 4 ASTM C76 or C-361	0.013	20
(1) Reinforced Concrete Arch Culvert	AASHTO M 206	0.013	20
(2) Aluminized Corrugated Metal Pipe	AASHTO M 274	0.024	15
(2) Corrugated Aluminum Alloy Culvert Pipe	AASHTO M 196	0.024	15
(1) Structural Plate Pipe and Pipe Arches	AASHTO M 167	0.024	15
(3) Polyethylene Plastic Pipe (PE)	AASHTO M 252 or M 274	0.011	20
(3) Polyvinyl Plastic Pipe (PVC)	AASHTO Section 1B	0.011	20

(1) For general use
(2) 48 inches maximum diameter, minimum gage 14 unless a pH/resistivity test shows a 50 year design life, subject to DPW approval
(3) For use in non- paved areas only, outside public rights-of-way, and as approved by the DPW.

c. Energy/Hydraulic Gradient: Energy gradient and hydraulic gradient are as defined below in King & Brater, Handbook of Hydraulics:

"The energy gradient is the line showing the total energy at any point in the pipe, and the hydraulic gradient, or pressure gradient, is the line showing the pressure head, or piezometric head, at any point in the pipe. The energy gradient must always drop in the direction of flow, whereas the pressure gradient may rise at locations... where there is a conversion of kinetic energy to potential energy."

The hydraulic gradient can also be considered a line connecting points to which water will rise in manholes and inlets. These structures can be thought of as manometers, measuring static pressure head in the pipe below.

The hydraulic gradient shall be determined starting at the downstream end of the proposed closed drainage system. Where a proposed drainage system is connected to an existing closed drainage system, the hydraulic gradient at the point of junction shall be determined from the hydraulic gradient computations of the existing drain on file at the DPW. If hydraulic computations are not on file, the design professional shall determine the hydraulic gradient by field investigating the existing system. Where the proposed closed drainage system discharges into a stream, flow conditions of this stream shall be investigated. Where the tailwater elevation is higher than the proposed crown elevation, the hydraulic gradient shall begin at this tailwater elevation. Where free outfall conditions exist the hydraulic gradient shall begin at the crown of the proposed drain. To obtain the hydraulic grade elevation at the succeeding structure the friction loss in the drain is added to the starting hydraulic grade elevation. Also added is the loss in the structure (as discussed under Head Losses in Structures, this Chapter). The hydraulic gradient to the upstream end of the proposed drainage system shall be determined by adding the friction losses in the sections of drains and the losses in the structures. For closed street sections (curb and gutter) the hydraulic gradient shall not be above an elevation of 1'-6" below the established top of curb grade nor more than 6 feet over the crown of the pipe. For open road sections (shoulders and side ditches) the hydraulic gradient shall not be above the invert of the side ditch nor more than 6 feet over the crown of the pipe. Full consideration shall be given to possible future extensions of the system.

d. Friction Loss: Head loss due to friction in open channels and pipes with uniform flow shall be determined by the Manning's Formula rearranged to:

$$s = (nv)^2 / 2.2082r^{4/3}$$

(In which s = head loss in feet per linear foot of drain) as described under size of drains (this Chapter). For pipe installed on curves, "n" shall be increased by .001 for each 20 degrees of curvature i.e.:

$$n(\text{curved portion}) = n(\text{on tangent}) + \frac{0.287}{R}$$

Where: R = centerline radius of curve.

e. Head Losses in Structures: Design Figures (Head Losses in Structures) show curves prepared for the determination of head loss in cut-ins, wye branches, preformed concrete pipe fittings, manholes, brick bends (with or without connection and manhole) and Type 1 Junction Chambers. These curves are based on surcharged pipes entering rectangular structures but shall apply to monolithic structures as noted below.

These curves are indicated as "A", "B", "C", and "D" losses, as shown on Standard Storm Drain Design Drawings SD-20.01 and SD-20.02, respectively. The "A" curve depicts loss due to entrance and exit. The "B" curve depicts velocity head loss. Where the downstream velocity exceeds the upstream velocity, the head loss shall be the difference in velocity heads. Where the upstream velocity is the greater, the apparent gain may be used to offset other head losses in the structure. The "C" curve depicts loss in manholes due to change in direction, loss for wye branch and loss in brick bend. The "D" loss depicts loss due to incoming volume.

These curves shall be applied as discussed below:

Cut-ins - Brick wye branches and preformed concrete pipefittings. Use full value of "A", "B", "C", and "D" losses.

Manholes - Use full value of "A", "B", "C", and "D"losses for sizes 30-inch and under. For sizes 33-inch and larger substitute "C" loss for "A" loss. For inlets used as manholes compute head losses as described for manholes.

Bend Structures - Use full value of "B", "C", and "D" curves. For brick bends with connection or with manhole, increase the "C" loss 50 percent. For brick bends with both connections and manholes, increase "C" loss 100 percent.

Junction Chamber (Type I) - Use full value of "B" and "C" loss. Use 50 percent of the indicated "D" loss, increase the "C" loss 50 percent for junction chambers with manholes.

Monolithic Structures - Use full value of "B" and 50 percent of indicated "D" loss. Loss due to change of direction in monolithic structures shall be as discussed below for long and short radius bends.

Long Radius Bends - Head loss due to change of direction in long radius bends where radius of bend exceeds 20 times pipe diameter shall be allowed by increasing "n" by .001 for each 20 degrees of curvature.

Short Radius Bends - (Centerline radius less than 20 times diameter of pipe.) Head loss due to change of direction in short radius bends shall be computed by

Formula $h_b = K_b x \frac{V^2}{2g}$

Where: $\frac{V^2}{2g} =$ velocity head ("B" Curve)

K_b = Coefficient tabulated below

Coefficient (K_b)	For bends other than

For 90 degree bends		90 degrees use percentage of K_b indicated	
r/D	K_b	Bend	Percent of k_b
1	0.50		
2	0.30	22-1/2 degrees	35%
4	0.25	45 degrees	50%
6	0.30	60 degrees	70%
10	0.35	90 degrees	100%
15	0.40		
20	0.40		

r = centerline radius of bend
D = downstream pipe diameter

f. Computer Applications: With the prior approval of the County, computer methods may be used to determine hydraulic gradients.

D. Open Channel Design Criteria

1. Location and Alignment

Open channels shall be located so the existing channel alignment is changed as little as possible. However, it shall generally be considered desirable to eliminate bends, to cross normal to streets and future streets and to eliminate stream channels running through the center of a property where location near or on a property line is feasible. Preference will be given to maintaining the stream and its buffer in its natural condition. Degraded portions of channels will be restored to as near natural condition as practical. Where channel geometry must be altered, the Rosgen classification may be used as a guide.

2. Size and Shape

Where a storm drain size larger than 48 inches is required and not practical, open channels shall be used. Closure of drainage course is subject to PACE/DPW approval.

The shape will be in accordance with the Standard Details.

The area required shall be determined from the following relationship:

$$Q = AV \text{ and Manning's Formula, } V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

3. Materials

   Improved open channels shall be constructed of the materials shown in Table 1 providing that the DPW has approved the use of such materials and that the use of these materials is in accordance with other criteria stated herein.

   a. Paved Channels: Pavement for straight sections of channels shall be as shown in the Standard Details, Open Channels.

      Where the centerline radius of bends is less than 60 feet, paved side slope protection shall be detailed on the contract drawings.

      On sharp curves consideration shall be given to a steeper slope on the outside bank and additional depth of pavement.

   b. Earth Channels: Open channels constructed of earth shall be sodded or seeded. Refer to the Standard Details, Open Channels, for limits. Bioengineering methods of Stabilization shall also be considered as discussed in Section II C. 3, e.(1) of this Chapter.

4. Design Frequency

   All culverts, closed conduit systems and open channel systems for each classification of roadway shall be designed to meet the design storm criteria shown in Appendix C, on Standard Storm Drain Design Drawing SD-1. Any ditch which serves as an inlet or outlet for a culvert shall be designed for the same frequency storm as the culvert it serves. Design frequency for all other major flood channels or natural streams shall be approved by the DPW.

   For drainage facilities within the State Highway Administration right-of-way, the State Highway Administration design criteria shall be used.

5. Waterway Depth

   a. The design depths for all open channels must be approved by the DPW.

   b. For side ditches in road sections depth of flow shall not be allowed to exceed the depth of the side ditch or be less than 0.5 feet below the edge of the shoulder.

6. Freeboard

   The freeboard shall be approximately 30 percent of the design depth. The minimum freeboard shall be 0.5 feet for systems designed for all storm frequencies of less than 100-years. The freeboard for systems designed for the 100-year storm shall be one foot. The freeboard must be higher to provide for hydraulic jumps, superelevated sections, and other special situations.

7. Velocities

The minimum velocity for improved open channels shall be 2.5 fps. Lower velocities will be subject to approval by the County.

The Maximum velocities for improved open channels will depend on the lining material and its erodibility. The maximum allowable velocities for various materials are shown in Table 2. Where the topography and other factors prevent the maintaining of the maximum allowable velocities within the limits as specified, the following measures may be used to dissipate the energy:

a. Drop structures to dissipate energy at the entrance, at intermediate points, or at the outlets of drainage conduits.

b. Baffles at outlets of drainage conduits.

c. Stilling basins at the outlets of drainage conduits

E. Closed Conduit Systems Design Criteria

1. Locations of Drains and Inlets

a. New Subdivisions: In new subdivisions storm drains shall normally be installed at the centerline of the street. Storm drains shall be installed within the pavement area (no less than 6 feet from the curb or proposed curb in curbed streets, as shown on Drawing No. G-8 in Chapter I-General Instructions) or not less than 3.0 feet inside the right-of-way line (in non-curbed streets, as shown on Drawing No. G-9 in Chapter I - General Instructions), wherever possible. Where it is not feasible for manholes to be located within the pavement, they shall not be located within the sidewalk.

b. Existing Developments: In existing developments drains shall generally be located as discussed above. However, the location of other existing and proposed utilities and traffic conditions shall be fully considered in determining the location of drains. Where the DPW has determined that two-way traffic shall be maintained, design professionals shall consider locating the drain between the curb and the property line. Where the drain is thus located, exact location shall be determined from the distance required for inlet connections but shall be not less than 3 feet from the curb.

c. Parks or Public Rights-of-Way: Where location of drain would require removal of or damage to trees within parks or public rights-of-way, design professionals shall obtain approval from the Forest Service, Department of Natural Resources for drain alignment and trees to be removed.

2. Design Frequency

   The 10-year frequency curve shall be used in the design of closed storm drain conduits. For drains in sumps, the 20-year frequency curve shall be used. Where flow from a 10-year storm in any particular drain exceeds 200 cfs, the design professional shall check to determine that the flow from a 20 -year storm can be carried by a combination of the drain and surface storage. Surface storage shall consist of the street (considered as a channel to top of curb), swales or other satisfactory flood ways for which right-of-way has been obtained. The 100-year storm will have overland relief that will not flood buildings.

3. Clearance

   Clearance shall be measured between outside of pipes. Storm drains crossing water main and sanitary sewers shall be constructed with a minimum clearance of 12 inches.

   Storm drains shall have a minimum of 5 feet horizontal clearance from parallel utilities.

4. Size of Drains

   The minimum pipe size for public systems shall be 15-inch diameter or equivalent. The systems shall be sized to meet the hydraulic grade line criteria.

5. Velocities

   The minimum velocity in storm drains shall be 2.5 feet per second where possible. Lower velocities will require the approval of the DPW. The maximum velocity at the outfall will depend on the outfall lining material as shown in Table 1.

6. Cut-ins

   Cut-ins, wye branches preformed concrete pipe fittings, manholes, brick bends (with or without connections) and Type I Junction Chambers will be designed according to the Standard Details. Brick bends which are not in accordance with the limitations indicated on this design figure are special structures.

   Decrease in pipe size at structures will not be permitted for 21-inch and smaller pipe. For pipes 24 inches and larger, maximum decrease shall be the next smallest standard size (e.g., 42-inch to 36-inch).

   Cut-ins shall be permitted for inlet connection pipes where 15-inch pipes enter 33-inch and larger pipes and 18-inch pipes enter 42-inch and larger pipes.

   The centerline of pipes shall be at the same elevation at junction points.

7. Wye Structures

   Wye structures of manholes shall be used where 15-inch pipes enter 30-inch and smaller pipes or 18-inch pipes enter 36-inch and smaller pipes according to the Standard Details.

8. Manholes

   Manholes shall be used at all changes of pipe size or where there is change in direction. Manholes shall be used at all changes of pipe grade except as discussed under Vertical Curves (this Chapter). Maximum spacing of manholes shall be 600 feet.

9. Bends

   a. Bend Structures: Bend structures shall be used to accomplish a change in direction where the downstream pipe is 30-inch and larger. Manhole stacks shall be required on brick bends and shall be located at the upstream point of curvature (P.C.). Minimum centerline length of bends shall be 4 feet. For the short bends, use a Type "C" manhole. Prefabricated bend structures require a manhole stack at the upstream P.C.

   b. Bend for Box Conduits: Where reinforced concrete box conduits change direction, the bend shall have a centerline radius of two times the inside width of the conduit. Bends shall have 30-inch frames and covers for maintenance and suitable access.

10. Junction Chambers

    Type I Junction Chambers (see Design Figures and Standard Details) shall be used for 48-inch and smaller pipes where actual velocities are less than 15 feet per second as computed using partial depth of flow for the design discharge and where criteria prohibits the use of a less expensive structure.

11. Prefabricated End Sections

    These end sections will be permitted where approved by DPW.

12. Structural Considerations

    a. Pipe Loading: Minimum and maximum permissible depths shall be in accordance with the design figures D/7 and D/8 of the Anne Arundel County Standard Details. "Computed Loads on Conduits" gives the dead and live loads to the top of the conduit for various sizes and depths of pipes.

       The theory and assumptions used to compute the information on design figures are:

1) Marston Theory for loads on underground conduits for trench condition.

2) Weight of fill material: 110 pounds per cubic foot.

3) Load bedding factor: 1.3.

4) Live load: H-20 loading without impact.

5) Safety factor: 1.0 for reinforced concrete pipe.

Conduits that are not in a true trench condition require other formulas and the information on the figures cannot be used.

The dead load on a conduit using a different weight of fill material can be found by multiplying the direct proportion of the two weights by the dead load shown on the design figure for the size of pipe and depth of cover under consideration.

b. Pipe Joints: Design professionals shall specify the use of special joints where leakage from joints is likely to cause washing out of road foundations.

c. Reinforced Concrete Box Drains and Special Structures: These will only be permitted by approval of the DPW. Design (hydraulic and structural) shall suit all existing and future conditions.

d. Foundations: In all cases, proper foundations shall be provided for drains. Design professionals shall detail on contract drawings methods acceptable to DPW for supporting drains on unstable ground or fresh fill.

e. Underdrains: Underdrains shall be of the type and specifications following:

Polyethylene (PE) Plastic Pipe	AASHTO M 252
Polyvinyl Chloride (PVC) Pipe	AASHTO M 278
Corrugated Steel Pipe	AASHTO M 36
Polyvinyl Chloride (PVC) Perforated Plastic Pipe	F758, Type PS 28

The underdrains need not be shown on the contract drawings.

13. Outfall

An outfall is the discharge point of the downstream extreme terminus of a culvert or a closed storm drain system. The outfall may be an existing/proposed closed storm drain system, open ground, stream, channel, or open water as ponds, lakes, shoulders, etc. An outfall is considered adequate if:

a. The receiving closed storm drain system is not surcharged by the design discharge from the outfall pipe.

b. The receiving open ground, stream, channel or open water can accommodate higher velocities and shear stress values than created by the design discharge from the outfall pipe.

Rights to discharge or easements shall be required when the following occurs at an outfall which directs runoff to an offsite location:

a. The manner of flow is changed, e.g. from sheet flow to a concentrated flow.

b. The location of the discharge point is altered or moved.

c. The quantity of flow is increased.

F. Inlet Design Criteria

1. Location

Inlets, where required at intersections, shall be placed 5 feet from P.C. or P.T. of curb (or proposed curb) and at no time shall inlets be placed within the curb fillet.

2. Spacing and Spread

Inlets shall be constructed in all sumps and at all intersections where conditions of street crown and/or quantity of flow require. Inlets on grade shall intercept at least 85 percent of the design flow with any excess flow carried-over by the next downstream inlet. Inlets on sumps shall intercept 100 percent of the design flow. Sump inlets shall be designed with a provision for overflow directed so as not to cause damage to adjoining properties. Inlet spacing shall be governed by the following criteria:

a. Maximum allowable flow in standard curb and gutter streets shall be 5.0 cfs.

b. Maximum allowable flow in side ditches of roads shall be 10.0 cfs (provided that erosive velocities are not developed in the side ditch).

c. Maximum allowable flow across street intersections where valley gutters are used shall be 2.0 cfs.

d. Maximum allowable flow along curb fillets shall be 2.5 cfs.

e. Maximum allowable flow from commercial, apartment, and industrial developments shall be required to provide on-site private drainage systems for such developments which may be connected to the County-owned systems within the public streets.

f. Maximum allowable spread of flow for housing (single or multi-family) developments shall be 10 feet for curb and gutter street sections.

g. Maximum allowable spread of flow for commercial and industrial development shall be 15 feet.

III. CONTRACT DRAWINGS AND DOCUMENTS

Attention is called to Chapter I, General Instructions, of this Design Manual for additional information.

A. Preliminary Schematic Designs

Schematic designs shall be submitted as stipulated in Chapter I, General Instructions. Reports shall include a map at a scale of 1" = 200' of the entire drainage area showing the proposed storm drains in conjunction with existing drains. Also included shall be a flow tabulation and a preliminary estimate of project costs. Schematic Designs are required for subdivision projects.

B. Contract Drawings

Storm drain contract drawings shall be prepared separately from other utilities or road drawings. Drawings and submittals will conform to the requirements of the Department of Public Works.

All applicable items shown on the Check List (Appendix B) shall be clearly shown on the contract drawings and one copy of the Check List shall be submitted along with the final contract drawings.

1. Plan

The plan shall be shown at the upper portion of the drawing, north arrow toward the top or left side of the sheet.

a. Scale: Scale shall be 1" = 40'.

b. Method of Indicating Location: Generally, drains, inlets, and manholes shall be located in plan by dimensions from traverse lines, property markers, or other well-defined physical features. Curve radii shall be shown for inlet location purposes. However, in areas where physical features are not available, coordinates of manholes and bearings of storm drains based on the Anne Arundel County grid system shall be used.

c. Rights-of-Way: Minimum rights-of-way shall be 20 feet wide with a 10-foot easement on each side for construction. These shall be shown on the drawings.

2. Profile

   The profile shall be shown under the plan and shall extend a minimum distance of 200 feet downstream of the outlet to allow any pertinent information concerning the outfall channel to be shown.

   a. Scale: Scale of drain profiles and inlet profiles shall be 1"=40' horizontal, 1"=40' vertical. Drain profiles on straight streets shall be shown to correct scale. On curved streets, horizontal distances between structures shall be plotted using length of street centerline between radial projections to structures. The length between structures shall be shown by figures.

   b. Street Grades: Approved established grade shall be obtained from the DPW. When such grades are not available, they shall be established by the design professional and submitted to the DPW for approval.

      The established grade shall be the top of curb for closed street sections or the centerline for open road sections.

      Where the drain is located in present or proposed pavement or shoulders, the existing centerline grade of the road shall be shown. Where the drain is outside pavement or shoulders, existing ground over drain shall be shown. If the drain is to be constructed on fill, the profile of the undisturbed earth (at drain location) shall be shown.

   c. Hydraulic Gradient: A hydraulic gradient shall be shown for storm drains and open channels.

3. Other Utilities

   Other existing and proposed utilities shall be accurately and clearly shown in plan and profile according to the standard symbols in Chapter I, General Instructions.

4. Locations and Design Information

   The following information shall be shown on the first sheet of the contract drawings:

   a. A drainage area map indicating the entire drainage area to be served both presently and ultimately by the proposed drainage systems, with a scale of 1"=200'.

   b. A vicinity map with a scale 1"=2000', indicating the location of the proposed work in accordance with Chapter I, General Instructions.

   c. Storm drain flow tabulations including storm drain structures.

   d. Bench marks based on the Anne Arundel County vertical control system.

e. General notes and/or other special notes related to the project.

Structure, manhole, and inlet schedules, as well as special structures, etc., shall be shown on the corresponding plan and profile sheets.

5. Special Details

Structures or details not included in the standard details shall be clearly detailed on the contract drawings. (See Chapter I, General Instructions, for scale).

C. Contract Specifications

1. See Chapter I, General Instructions, of this Design Manual.

D. 2. Any roadway disturbed by the construction of a storm drain must be restored in conformance with requirements outlined in Chapter III, Section II, Design Criteria, Subsection "J".Estimate of Quantities

The design professional shall submit an estimate of quantities for each contract, including contingent items as set forth in Chapter I, General Instructions.

E. Design Calculations

Design professionals shall submit to the County DPW for capital projects and to the Planning and Code Enforcement for development projects, for review, design data and computations for the project as specified in Chapter I, General Instructions. The data shall generally be comprised of the following items:

1. Hydraulic Design

a. Flow Tabulation Form

b. Time of Concentration Form

c. Inlet and Gutter Capacity Form

d. Hydraulic Gradient Computation Form

2. Structural Design

a. Drains: Structural calculations for all drains other than pipes shown in loading tables shall be submitted.

b. Special Structure: Design computations for all special structures shall be submitted.

3. Coordinates

   Computations of coordinates shall be submitted where coordinates are shown on the contract drawings.

4. Results of Borings and Test Pits

   Where information pertinent to design, such as borings, has been collected, the information shall be submitted to the DPW.

F. Filing of Contract Documents

Approved originals or mylar reproductions of the approved contract drawings shall be filed with DPW. If, during the course of the construction, revisions are made to the plans after the approval of the DPW, revised approved original reproducibles or as-built drawings shall be submitted for filing.

IV. APPENDIX

A. References

B. Checklist, Storm Drain Contract Drawings

C. Standard Storm Drain Design Drawings

APPENDIX A

REFERENCES

1. Soil conservation Service, Urban Hydrology for Small Watershed, Washington, D.C., 1986

2. Soil Conservation Services, Computer Program for Project Formulation Hydrology, Washington, D.C., 1984, Revised 1992

3. Maryland Department of the Environment, 1994 Maryland Standards and Specifications for Soil Erosion and Sediment Control

4. Chow, Ven Te, Open-Channel Hydraulics, McGraw-Hill Book Company, New York, 1959

5. Brater & King, Handbook of Hydraulics, McGraw-Hill Book Company, New York, 1976

6. Bureau of Public Roads, Design Charts for Open-Channel Flow, Washington, D.C., 1961

7. Anne Arundel County, Standard Specifications, Latest Edition

8. Anne Arundel County, Standard Details, Latest Edition

APPENDIX B

CHECK LIST
STORM DRAIN CONTRACT DRAWINGS

LOCATION____

DATE ____

CHECKED BY ____

PLAN

A. Supplementary Information

1. Property -- all lines shown in proper symbols
2. Property -- lot numbers and front dimensions (Front only)
3. Property -- new and existing R/Ws shown and dimensioned
4. Roads and streets -- all shown in proper symbol
5. Roads and streets -- names and alignment with R/W and pavement widths shown
6. Roads and streets -- existing and/or proposed pavement labeled
7. Roads and streets -- existing and/or proposed curb line -- labeled if existing or proposed
8. Roads and streets -- curb radii indicated
9. Roads and streets -- State Highway Administration stamp, applied where required
10. Topography -- check with Record Drawings for poles, fences, building, driveways, hydrants, shrubs, trees, pavement, walks, etc.
11. Utilities, existing -- all shown (size and type noted)
12. Utilities, existing -- checked water, sewer and drains against Record Drawings
13. Utilities, existing -- checked with Telephone Company
14. Utilities, existing gas -- checked with Gas & Electric Company
15. Utilities, existing -- drawing and file number shown for sewer, water and drain record drawings
16. Utilities, existing -- storm drain manholes and structures shown in accordance with Record Drawings
17. Utilities, proposed -- all shown in proper symbols (size and type noted)
18. Utilities, proposed -- checked against construction plan for each proposed utility (Sewer, water, gas, etc.)
19. North arrow and three coordinate ticks shown and labeled at multiples of 250 feet
20. Scales -- notes at proper locations

B. Proposed Storm Drain

1. Drains -- all shown in proper symbol
2. Drains -- shown in proper location
3. Drains -- dimensioned for location (dimensioned from property lines or traverse lines)

4. Drains -- curve data shown for pipes laid on curves (min. L. 4')
5. Drains -- size between manholes, labeled
6. Drains -- in State roads, method of crossing labeled
7. Drains -- proper clearance from other utilities shown
8. Drain structures -- dimensioned for location (dimensioned from property lines or traverse lines)
9. Drain structures -- adequate access to structures provided
10. Drain structures -- numbered S-1, S-2, M-1, M-2, etc., starting from downstream end of system
11. Drain structures -- curve data for junction chambers checked
12. Inlet connections -- size indicated
13. Inlets -- numbered I-1, I-2, etc. starting from downstream end
14. Inlets -- shown in proper location
15. Inlets -- dimensioned for location (dimensioned from P.C. or P.T. of curb, property lines or traverse lines)

PROFILES (DRAIN AND INLETS)

A. Supplementary Information

1. Roads and Streets -- existing ground and/or pavement -- labeled and date noted
2. Roads and Streets -- established grade -- labeled and checked against approved established grade profile
3. Roads and Streets -- name of road or street and intersecting streets -- labeled
4. Utilities, existing -- crossing and parallel lines shown and labeled (Inv. shown and size)
5. Utilities, existing -- drainage structures and manholes shown, invert elevations shown and checked against Record Drawing
6. Utilities, proposed -- crossings and parallel lines shown and labeled (show diameter)
7. Scales -- shown in proper location

B. Proposed Storm Drain

1. Drains -- size, type, kind and grade shown
2. Drains -- quantity of flow and velocity of flow shown
3. Drains - manholes numbered and stationed
4. Drains -- manhole inverts labeled (upstream and downstream)
5. Drains -- arithmetic of invert elevations and grades checked
6. Drains -- profile labeled (street name) or R/W
7. Drains -- hydraulic gradients shown
8. Drains -- pipe checked for allowable maximum and minimum cover (See Pipe Loading Tables)
9. Drains -- the use of concrete cradle, or encasement, where necessary, checked (See Pipe Loading Tables)
10. Drain structures -- stations of manhole centerline, P.C. and P.T. of bend structures, cut-ins and inlets indicated (check stationing with Plan)

GENERAL

1. Title Block -- date of approval of road grade, plans and file number, designer and tracers initials, topographical base map number shown.
2. General Notes -- stamps (excavation) (subgrade) applied
3. Title of Drawing -- size and location of sewer, local subdivision name and section, and Council district shown
4. Engineer’s seal and engineer’s signature and license number shown
5. Bench mark reference, number, elevation and description shown
6. Location Plan -- scale 1" = 1000', site of proposed work shaded
7. Location Plan -- distance from nearest major road, intersection or existing subdivision
8. Location Plan -- well known streets leading to site shown
9. Location Plan -- names of streets on which work is proposed, shown
10. Drainage Area map shown -- (scale 1" = 200' except where this scale would require extra drawings, 1" = 500')
11. Drainage Area Map shown -- entire drainage area shown
12. Drainage Area Map -- entire proposed drainage system indicated schematically, complete with manhole, inlets and structures and numbers
13. Drainage Area Map -- each tributary area lettered for reference to schedules and runoff tabulation forms
14. Design Data -- area letters, total tributary area, time of concentration to points under consideration, rainfall intensity and flow listed
15. Design Data - pipe diameter, grade, velocity and storm frequency curve listed
16. Structure Schedule -- type, size, top elevation, invert elevation (downstream end) indicated opposite numbers S-1, S-2, etc. If special structure, sheet number indicated where detail appears (under type)
17. Manhole Schedule -- type, size, top elevation and invert elevation indicated for all manholes in contract
18. Inlet Schedule -- number, type, tributary area, rainfall intensity, runoff coefficient, flow, top elevation and invert elevation indicated for all inlets in contract
19. Inlets -- inlet flow checked against inlet capacity curves
20. Special Details -- shown in accordance with Standard Details as much as is feasible
21. Special Details -- check use of proper scales
22. Special Details -- reinforcing clearly detailed
23. Centerline stationing shown for all utilities in streets
24. Full trench compaction shown for all utilities in streets over 32' in width, and for all utilities within road right-of-way limits on all existing streets
25. Protective fill indicated for all drains with less than two feet of cover

APPENDIX C

STANDARD
STORM DRAIN
DESIGN DRAWINGS

APPENDIX C

STANDARD STORM DRAIN DESIGN

DRAINAGE SYSTEMS - DESIGN STORMS

ROADWAY FUNCTIONAL CLASSIFICATION	CULVERTS	* CLOSED CONDUIT SYSTEM (PIPES AND INLETS)	OPEN CHANNEL SYSTEM (ROADSIDE SWALES AND DITCHES)
PRINCIPAL ARTERIAL (URBAN)	50	10	10
MINOR ARTERIAL (URBAN)	50	10	10
ARTERIAL (RURAL)	50	10	10
COLLECTOR (URBAN)	25	10	10
COLLECTOR (RURAL) (RURAL RESIDENTIAL, A.D.T. 750-1500)	25	10	10
LOCAL (RURAL RESIDENTIAL, A.D.T. 300 - 750)	25	10	10
LOCAL ACCESS ROAD (RURAL RESIDENTIAL SERVING 4 LOTS OR LESS)	10	10	10
LOCAL STREET & CUL-DE-SAC STREET (URBAN)	10	10	10
LOCAL ROAD, CUL-DE-SACS AND LOOPS (RURAL RESIDENTIAL, A.D.T. 0-300)	10	10	10
CUL-DE-SAC (SOLID CORE & HOLLOW CORE) & "T" TURNAROUNDS	10	10	10

* ADJUSTMENT FOR 20 YEAR STORM FREQUENCY IN SUMPS

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED ____________ ____________ DATE: ____________	STANDARD STORM DRAIN DESIGN DESIGN STORMS BY ROAD CLASSIFICATION	SD - 1

RATIONAL METHOD RUNOFF COEFFICIENT - "C"

	AVERAGE DRAINAGE AREA SLOPE		
SURFACES - ALL SOIL TYPES	FLAT SLOPES LESS THAN 2%	AVERAGE SLOPES 2% TO 7%	STEEP SLOPES GREATER THAN 7%
PAVEMENT (BITUMINOUS AND CONCRETE)	0.90	0.90	0.90
ROOFS	0.90	0.90	0.90
WATER	0.95		
UNDEVELOPED LAND-SCS TYPE A AND B SOILS			
BARE GROUND	0.20	0.35	0.50
CROPLAND	0.18	0.33	0.48
SPARSE VEGETATION	0.15	0.30	0.45
LAWNS AND PASTURE	0.10	0.20	0.30
LIGHT WOODS	0.08	0.17	0.25
MEDIUM WOODS OR BRUSH	0.07	0.14	0.20
DENSE WOODS WITH BRUSH	0.05	0.10	0.15
GRAVEL SURFACE			
UNDEVELOPED LAND-SCS TYPE C AND D SOILS			
BARE GROUND	0.50	0.65	0.80
CROPLAND	0.45	0.60	0.75
SPARSE VEGETATION	0.40	0.55	0.70
LAWNS AND PASTURE	0.20	0.30	0.40
LIGHT WOODS	0.17	0.27	0.39
MEDIUM WOODS OR BRUSH	0.15	0.25	0.35
DENSE WOODS OR BRUSH	0.10	0.15	0.20
GRAVEL SURFACE			
DEVELOPED LAND-SCS TYPE A AND B SOIL			
COMMERCIAL - ALL C ZONES	0.78	0.80	0.81
INDUSTRIAL - W2 AND W3 ZONES	0.75	0.77	0.79
INDUSTRIAL PARKS - W1 ZONES	0.70	0.73	0.76
APARTMENTS/HIGH DENSITY RESIDENTIAL R44,R22, AND R15 ZONES	0.66	0.69	0.72
SINGLE FAMILY - R10 AND R15 ZONES	0.43	0.49	0.55
SINGLE FAMILY - R2 ZONE	0.30	0.38	0.46
SINGLE FAMILY - R1 ZONE	0.23	0.31	0.40
SINGLE FAMILY - RLD ZONE	0.20	0.28	0.37
SINGLE FAMILY AGRICULTURAL - RA ZONE	USE UNDEVELOPED LAND VALUES		
DEVELOPED LAND-SCS TYPE C AND D SOIL			
COMMERCIAL - ALL C ZONES	0.80	0.81	0.83
INDUSTRIAL - W2 AND W3 ZONES	0.77	0.79	0.81
INDUSTRIAL PARKS - W1 ZONE	0.75	0.77	0.79
APARTMENT/HIGH DENSITY RESIDENTIAL R44,R22, AND R15 ZONES	0.69	0.72	0.75
SINGLE FAMILY - R10 AND R5 ZONES	0.47	0.53	0.59
SINGLE FAMILY - R2 ZONE	0.38	0.45	0.53
SINGLE FAMILY - R1 ZONE	0.31	0.40	0.48
SINGLE FAMILY - RLD ZONE	0.28	0.37	0.46
SINGLE FAMILY AGRICULTURAL - RA ZONE	USE UNDEVELOPED LAND VALUES		

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN RATIONAL METHOD RUNOFF COEFFICIENT - "C"	SD-2.01

PART 1 RATIONAL FORMULA COEFFICIENTS FOR SCS HYDROLOGIC SOIL GROUPS (A, B, C, D)

Rural Land Uses

1) Storm Frequencies of Less Than 25 Years
2) Storm Frequencies of 25 Years or Greater

Land Use	Treatment/ Practice	Hydrologic Condition		A			B			C			D		
				0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or range		poor	(1)	0.23	0.25	0.26	0.31	0.33	0.34	0.37	0.38	0.39	0.40	0.41	0.42
			(2)	0.27	0.29	0.31	0.36	0.37	0.39	0.42	0.43	0.44	0.45	0.46	0.47
		fair		0.12	0.13	0.15	0.24	0.25	0.27	0.31	0.33	0.34	0.36	0.37	0.38
				0.15	0.17	0.19	0.28	0.30	0.32	0.36	0.37	0.39	0.40	0.41	0.43
		good		0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
				0.09	0.11	0.13	0.22	0.24	0.26	0.32	0.33	0.35	0.37	0.38	0.40
	Contoured	poor		0.11	0.12	0.14	0.22	0.24	0.26	0.33	0.34	0.36	0.39	0.40	0.41
				0.13	0.16	0.18	0.26	0.28	0.30	0.37	0.39	0.40	0.44	0.45	0.46
		fair		0.06	0.07	0.08	0.17	0.19	0.21	0.28	0.30	0.31	0.35	0.36	0.37
				0.07	0.08	0.10	0.21	0.23	0.25	0.32	0.34	0.36	0.39	0.41	0.42
		good		0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
				0.05	0.06	0.08	0.13	0.14	0.15	0.28	0.30	0.32	0.36	0.37	0.39
Meadow				0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
				0.08	0.11	0.14	0.13	0.18	0.22	0.16	0.20	0.26	0.21	0.25	0.32
Wooded		poor		0.10	0.12	0.13	0.13	0.15	0.20	0.16	0.19	0.25	0.18	0.22	0.26
				0.12	0.14	0.16	0.16	0.19	0.23	0.19	0.23	0.28	0.22	0.27	0.33
		fair		0.06	0.08	0.09	0.10	0.13	0.18	0.11	0.15	0.20	0.13	0.18	0.23
				0.08	0.10	0.12	0.13	0.17	0.21	0.15	0.18	0.24	0.18	0.22	0.29
		good		0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21
				0.06	0.09	0.11	0.11	0.15	0.18	0.13	0.17	0.21	0.15	0.19	0.25

SOURCE:
MARYLAND STATE HIGHWAY ADMINISTRATION

SD-2.02

PART 2A RATIONAL FORMULA COEFFICIENT FOR SCS HYDROLOGIC SOIL GROUPS (A, B, C, D)

Agricultural Land Uses

1) Storm Frequencies of Less Than 25 Years
2) Storm Frequencies of 25 Years or Greater

Land Use	Treatment/ Practice	Hydrologic Condition		A 0-2%	A 2-6%	A 6%+	B 0-2%	B 2-6%	B 6%+	C 0-2%	C 2-6%	C 6%+	D 0-2%	D 2-6%	D 6%+
Fallow	Straight row		(1)	0.41	0.48	0.53	0.60	0.66	0.71	0.72	0.78	0.82	0.84	0.88	0.91
			(2)	0.57	0.64	0.69	0.70	0.76	0.80	0.83	0.88	0.91	0.95	0.97	0.98
Row Crops	Straight row	poor		0.31	0.36	0.39	0.54	0.58	0.62	0.70	0.74	0.77	0.75	0.78	0.80
				0.45	0.50	0.54	0.65	0.70	0.73	0.82	0.86	0.88	0.86	0.88	0.89
		good		0.24	0.30	0.35	0.43	0.48	0.52	0.61	0.65	0.68	0.73	0.76	0.78
				0.38	0.44	0.49	0.60	0.64	0.67	0.75	0.77	0.79	0.83	0.85	0.86
	Contoured	poor		0.28	0.34	0.39	0.51	0.55	0.59	0.61	0.65	0.68	0.70	0.74	0.77
				0.43	0.48	0.52	0.64	0.68	0.71	0.73	0.76	0.78	0.84	0.86	0.88
		good		0.21	0.26	0.30	0.41	0.45	0.49	0.55	0.59	0.63	0.63	0.66	0.68
				0.33	0.38	0.42	0.56	0.60	0.64	0.69	0.72	0.74	0.74	0.76	0.77
	Contoured and terraced	poor		0.26	0.30	0.34	0.38	0.42	0.46	0.50	0.54	0.57	0.56	0.59	0.61
				0.38	0.42	0.46	0.52	0.57	0.62	0.66	0.70	0.74	0.69	0.72	0.74
		good		0.20	0.24	0.27	0.31	0.35	0.39	0.45	0.48	0.51	0.55	0.58	0.60
				0.34	0.37	0.40	0.45	0.49	0.53	0.61	0.64	0.67	0.68	0.70	0.72
Small grain	Straight row	poor		0.24	0.28	0.32	0.43	0.47	0.51	0.62	0.65	0.68	0.72	0.74	0.76
				0.37	0.40	0.43	0.59	0.63	0.66	0.73	0.76	0.78	0.84	0.86	0.87
		good		0.23	0.26	0.29	0.42	0.45	0.48	0.57	0.60	0.62	0.71	0.73	0.75
				0.35	0.38	0.41	0.57	0.60	0.63	0.70	0.73	0.75	0.83	0.85	0.86

SOURCE:
MARYLAND STATE HIGHWAY ADMINISTRATION

SD-2.03

Agricultural Land Uses

1) Storm Frequencies of Less Than 25 Years
2) Storm Frequencies of 25 Years or Greater

Land Use	Treatment/ Practice	Hydrologic Condition		A 0-2%	A 2-6%	A 6%+	B 0-2%	B 2-6%	B 6%+	C 0-2%	C 2-6%	C 6%+	D 0-2%	D 2-6%	D 6%+
Small Grain	Contoured	poor	(1)	0.21	0.26	0.30	0.38	0.42	0.46	0.55	0.59	0.62	0.63	0.65	0.67
			(2)	0.33	0.38	0.42	0.53	0.57	0.61	0.69	0.72	0.75	0.75	0.77	0.78
		good		0.17	0.22	0.27	0.33	0.38	0.42	0.54	0.58	0.61	0.62	0.65	0.67
				0.29	0.34	0.38	0.50	0.54	0.58	0.67	0.70	0.73	0.74	0.76	0.77
	Contoured and terraced	poor		0.18	0.22	0.26	0.32	0.36	0.40	0.52	0.55	0.58	0.56	0.59	0.61
				0.30	0.34	0.37	0.46	0.50	0.53	0.65	0.68	0.71	0.70	0.72	0.73
		good		0.16	0.20	0.24	0.31	0.35	0.38	0.45	0.48	0.50	0.55	0.58	0.60
				0.28	0.32	0.35	0.44	0.48	0.51	0.62	0.64	0.66	0.68	0.70	0.71
Closed-seeded legumes or rotation meadow	Straight row	poor		0.25	0.30	0.35	0.44	0.48	0.52	0.62	0.65	0.68	0.73	0.76	0.78
				0.37	0.42	0.46	0.60	0.64	0.67	0.74	0.77	0.80	0.83	0.85	0.86
		good		0.15	0.19	0.23	0.31	0.35	0.38	0.55	0.58	0.60	0.63	0.65	0.66
				0.20	0.24	0.28	0.47	0.50	0.53	0.67	0.70	0.72	0.75	0.77	0.78
	Contoured	poor		0.23	0.28	0.32	0.41	0.45	0.49	0.57	0.60	0.63	0.62	0.65	0.67
				0.35	0.40	0.44	0.56	0.60	0.63	0.70	0.73	0.76	0.74	0.77	0.79
		good		0.14	0.18	0.21	0.30	0.34	0.37	0.45	0.48	0.51	0.58	0.60	0.61
				0.24	0.28	0.31	0.42	0.46	0.49	0.61	0.64	0.66	0.71	0.73	0.74
	Contoured and terraced	poor		0.21	0.26	0.30	0.34	0.38	0.42	0.51	0.54	0.57	0.58	0.60	0.61
				0.33	0.38	0.42	0.50	0.54	0.57	0.67	0.70	0.72	0.71	0.73	0.74
		good		0.07	0.10	0.13	0.28	0.32	0.35	0.44	0.47	0.49	0.52	0.54	0.56
				0.20	0.24	0.28	0.40	0.44	0.47	0.61	0.63	0.65	0.68	0.70	0.71

SOURCE:
MARYLAND STATE HIGHWAY ADMINISTRATION

SD-2.04

PART 3 RATIONAL FORMULA COEFFICIENTS FOR SCS HYDROLOGIC SOIL GROUPS (A,B,C,D)

Urban Land Uses

1) Storm Frequencies of Less Than 25 Years
2) Storm Frequencies of 25 Years and Greater

Land Use	Treatment/ Practice	Hydrologic Condition	A 0-2%	A 2-6%	A 6%+	B 0-2%	B 2-6%	B 6%+	C 0-2%	C 2-6%	C 6%+	D 0-2%	D 2-6%	D 6%+
Paved Areas & Impervious surfaces		(1)	0.85	0.86	0.87	0.85	0.86	0.87	0.85	0.86	0.87	0.85	0.86	0.87
		(2)	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97
Open Space-lawns etc.			0.08	0.12	0.15	0.11	0.16	0.21	0.14	0.19	0.24	0.20	0.24	0.28
			0.11	0.15	0.19	0.15	0.20	0.26	0.19	0.24	0.32	0.25	0.29	0.37
Industrial			0.67	0.68	0.68	0.68	0.68	0.69	0.68	0.69	0.69	0.69	0.69	0.70
			0.85	0.85	0.86	0.85	0.86	0.86	0.86	0.86	0.87	0.86	0.86	0.88
Commercial			0.71	0.71	0.72	0.71	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
			0.88	0.88	0.89	0.89	0.89	0.89	0.89	0.89	0.90	0.89	0.89	0.90
Residental														
	Lot Size 1/8 acre		0.25	0.28	0.31	0.27	0.30	0.35	0.30	0.33	0.38	0.33	0.36	0.42
			0.33	0.37	0.40	0.35	0.39	0.44	0.38	0.42	0.49	0.41	0.45	0.54
	Lot Size 1/4 acre		0.22	0.26	0.29	0.24	0.29	0.33	0.27	0.31	0.36	0.30	0.34	0.40
			0.30	0.34	0.37	0.33	0.37	0.42	0.36	0.40	0.47	0.38	0.42	0.52
	Lot Size 1/3 acre		0.19	0.23	0.26	0.22	0.26	0.30	0.25	0.29	0.34	0.28	0.32	0.39
			0.28	0.32	0.35	0.30	0.35	0.39	0.33	0.38	0.45	0.36	0.40	0.50
	Lot Size 1/2 acre		0.16	0.20	0.24	0.19	0.23	0.28	0.22	0.27	0.32	0.26	0.30	0.37
			0.25	0.29	0.32	0.28	0.32	0.36	0.31	0.35	0.42	0.34	0.38	0.48
	Lot Size 1 acre		0.14	0.19	0.22	0.17	0.21	0.26	0.20	0.25	0.31	0.24	0.29	0.35
			0.22	0.26	0.29	0.24	0.28	0.34	0.28	0.32	0.40	0.31	0.35	0.46

SOURCE:
MARYLAND STATE HIGHWAY ADMINISTRATION

SD-2.05

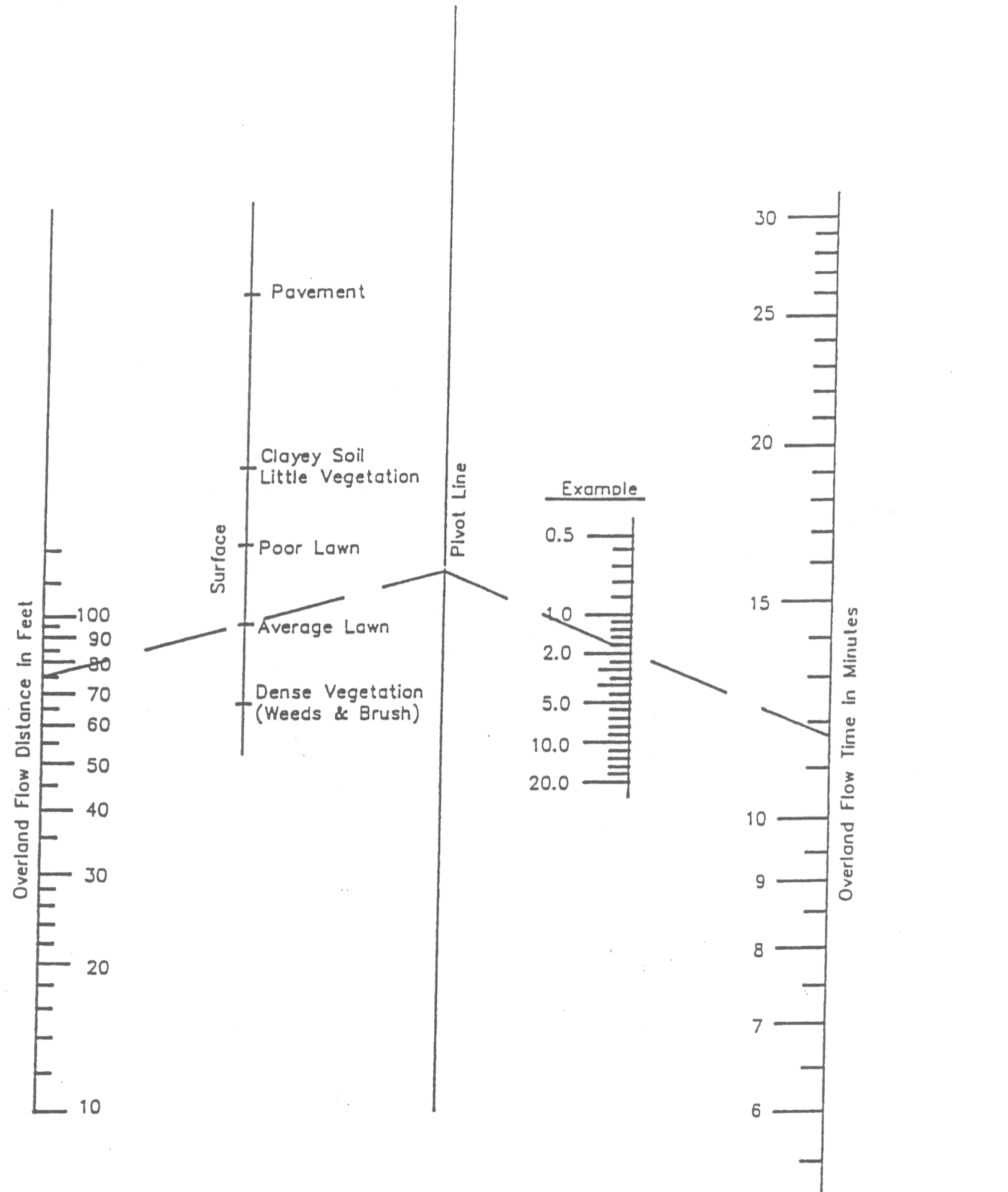
TIME OF CONCENTRATION FORM

LOCATION
DEVELOPMENT
LOT SIZE
JOB ORDER NO.

DATE:
SHEET TOTAL IN COMP.
COMPUTED BY:
CHECKED BY:

DESIGN POINT	OVERLAND FLOW TO	FLOW	FLOW	FLOW	REMARKS	TOTAL

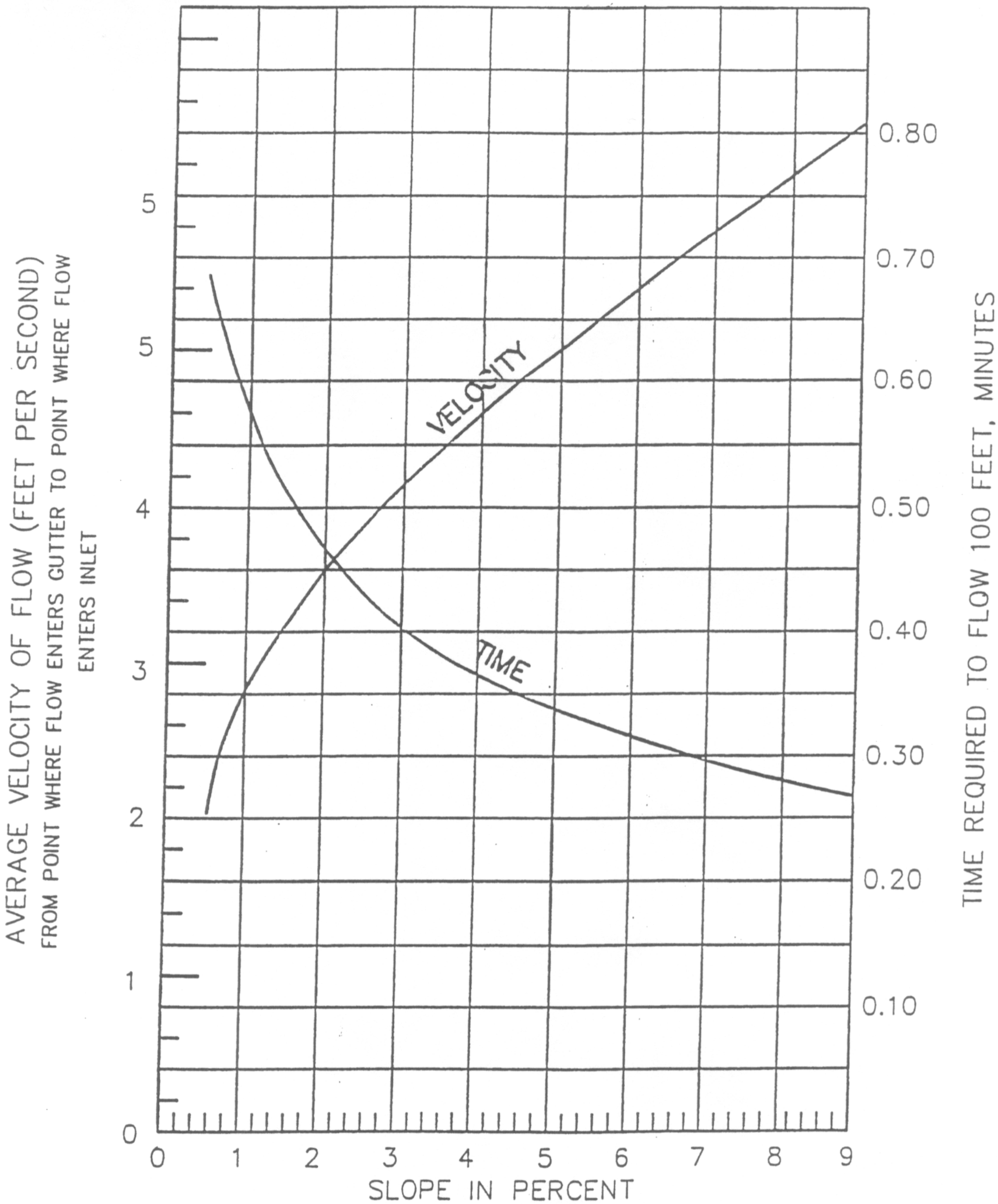
ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN TIME OF CONCENTRATION WORKSHEET	SD-3



Example: Overland flow time for 75' of Average lawn at 2% slope = 11.7 minutes.

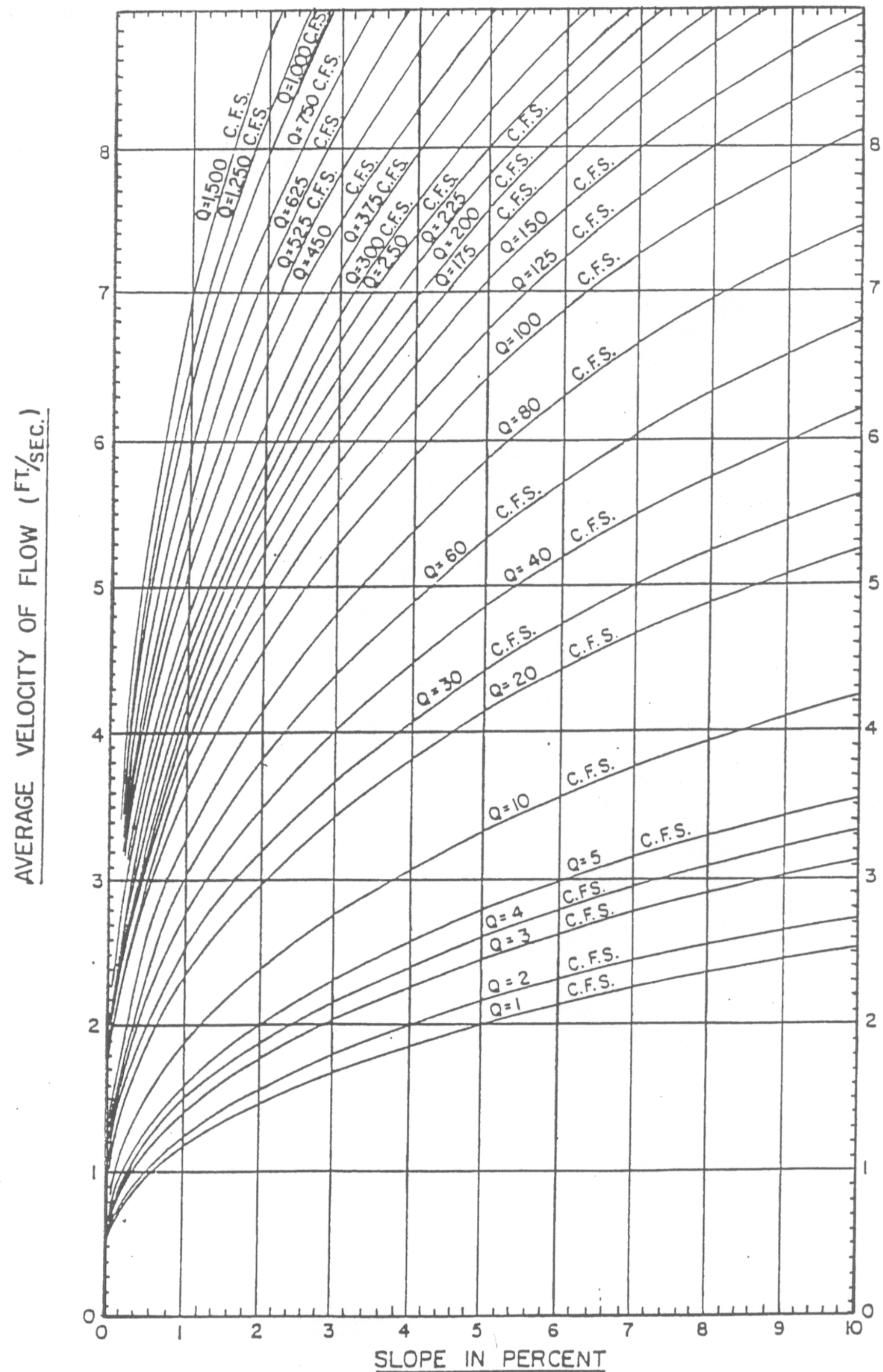
Minimum Inlet Time = 5.0 minutes

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN OVERLAND FLOW NOMOGRAPH	SD-4

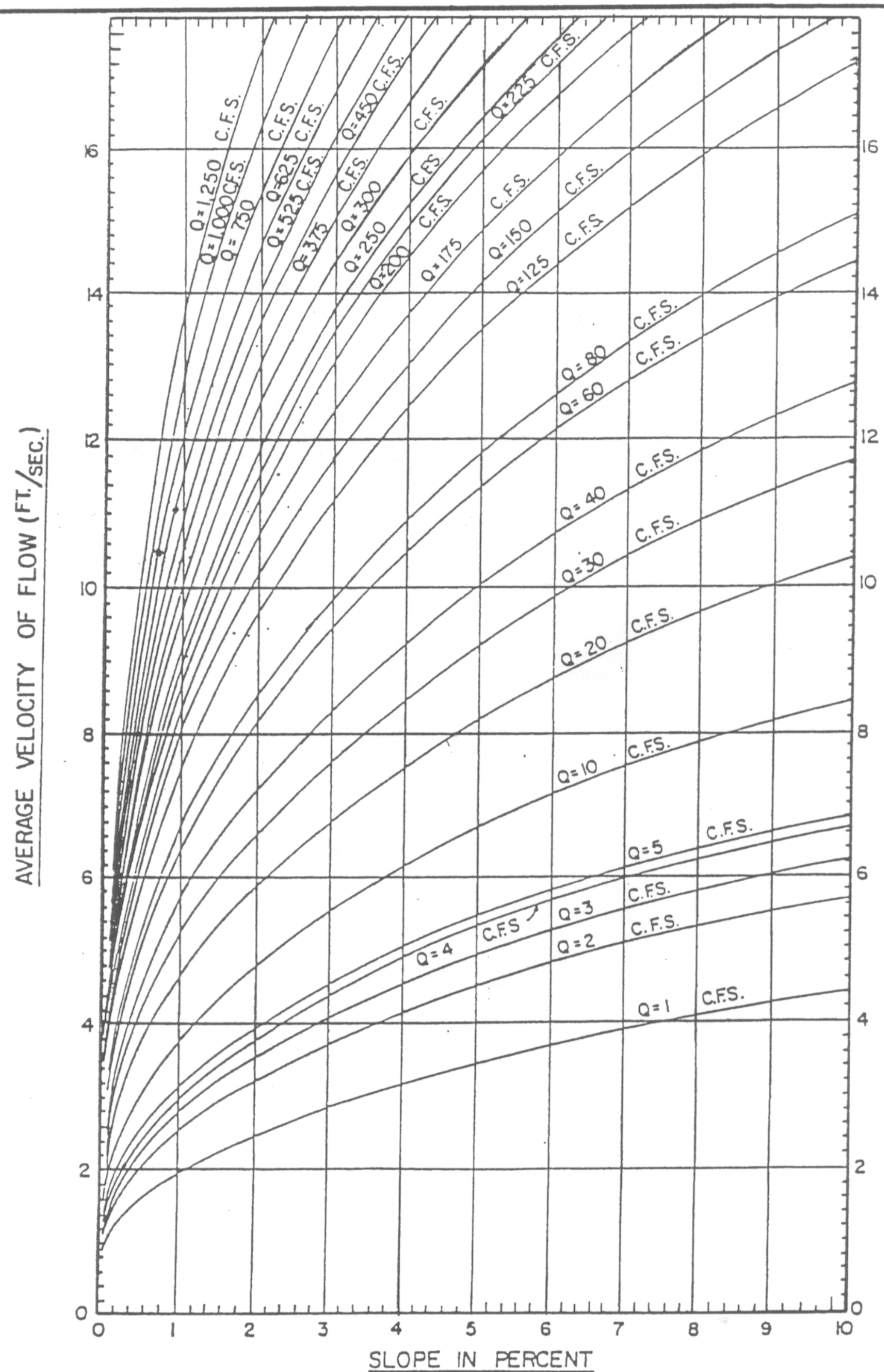


Example Given Slope = 5.6%, distance (beginning of gutter flow to inlet) = 305'
Determine Average velocity and time of gutter flow.
Solution Average velocity = 5.2 f.p.s. Time = (305 ÷ 5.2) ÷ 60 = 0.98 minutes

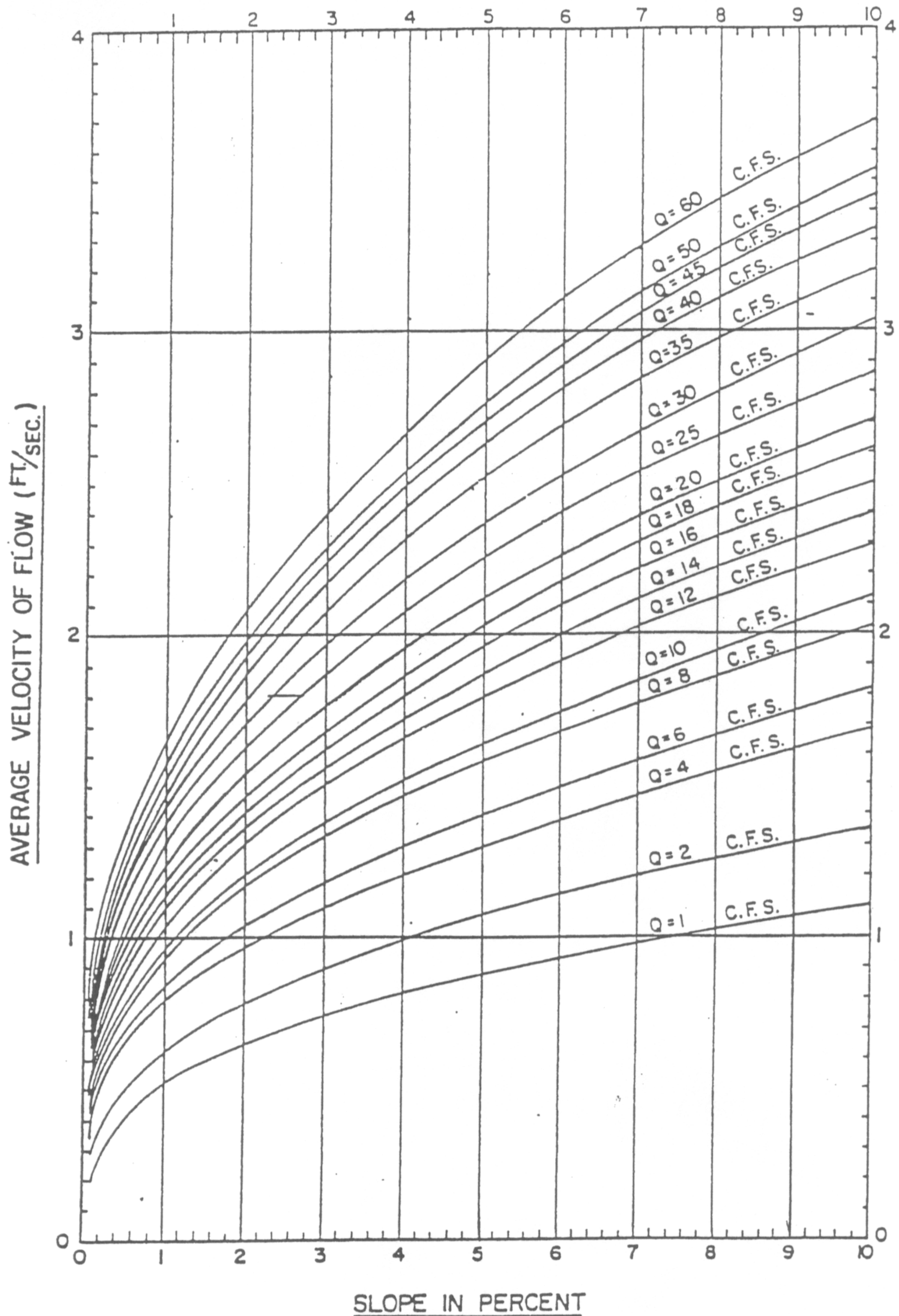
ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN GUTTER FLOW VELOCITY & TIME	SD-5



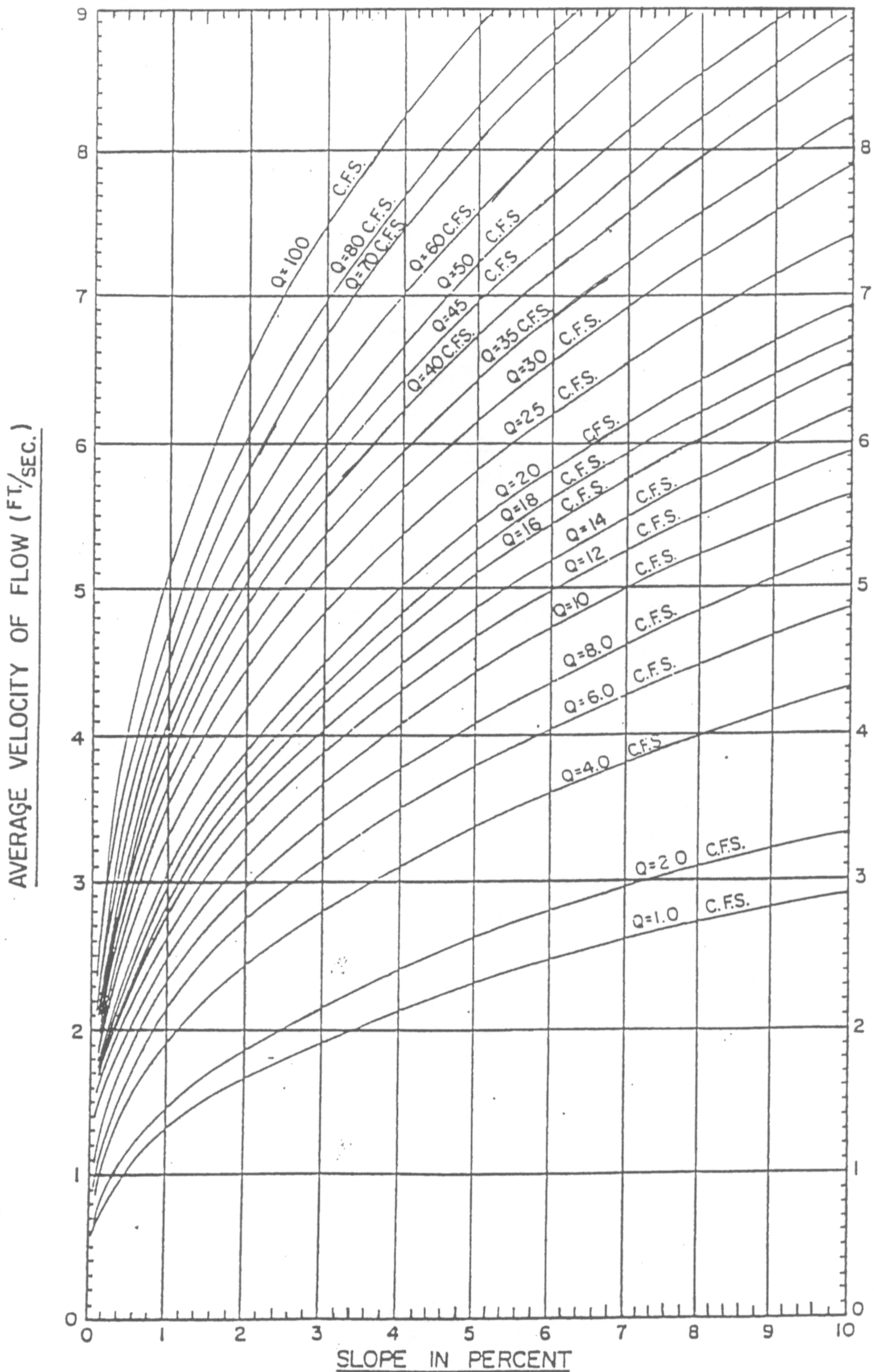
ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN DITCH FLOW VELOCITY (GRASS - n = 0.04)	SD-6



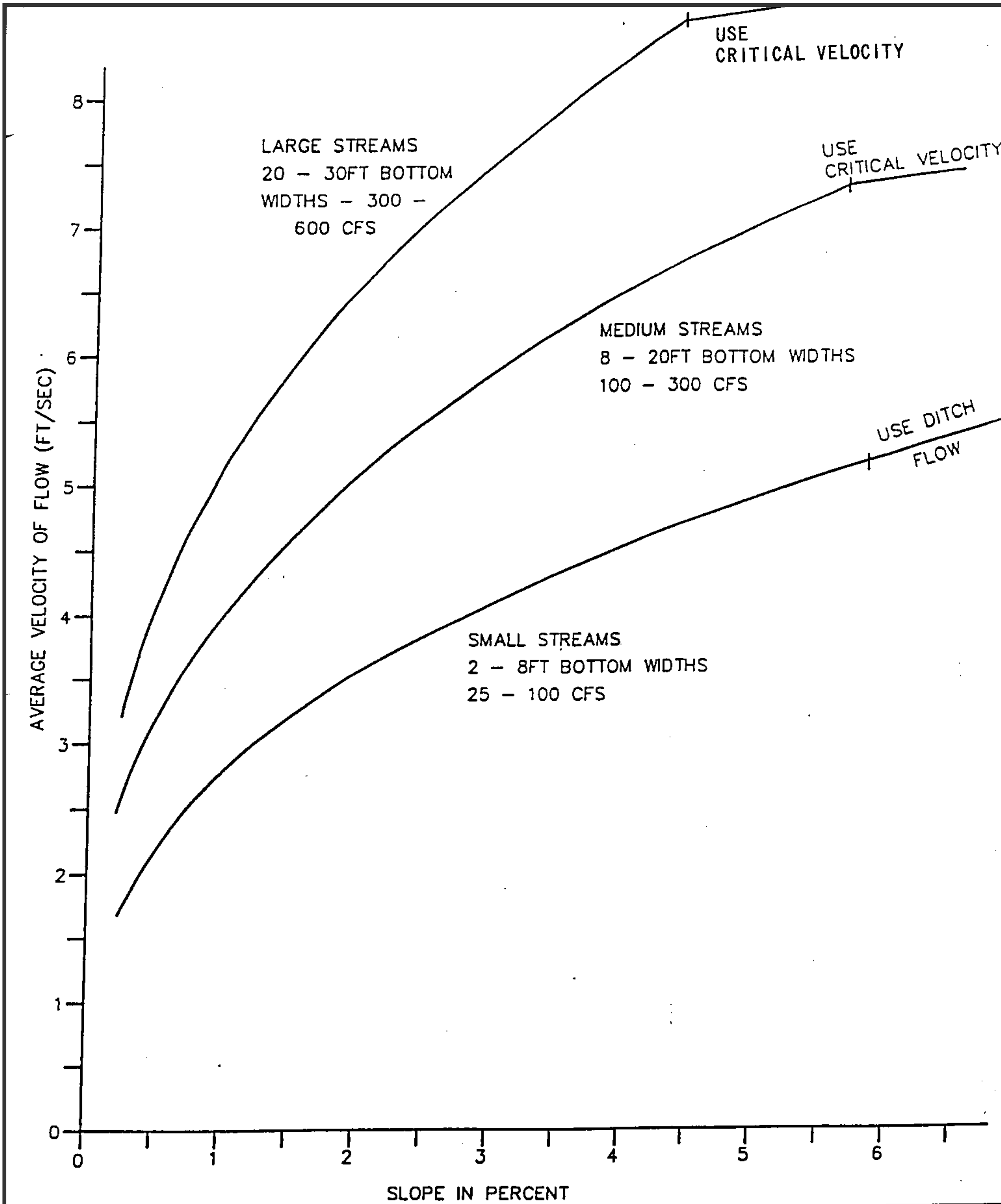
ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED ______ ______ DATE: ______	STANDARD STORM DRAIN DESIGN DITCH FLOW VELOCITY (Paved - n = 0.015)	SD-7



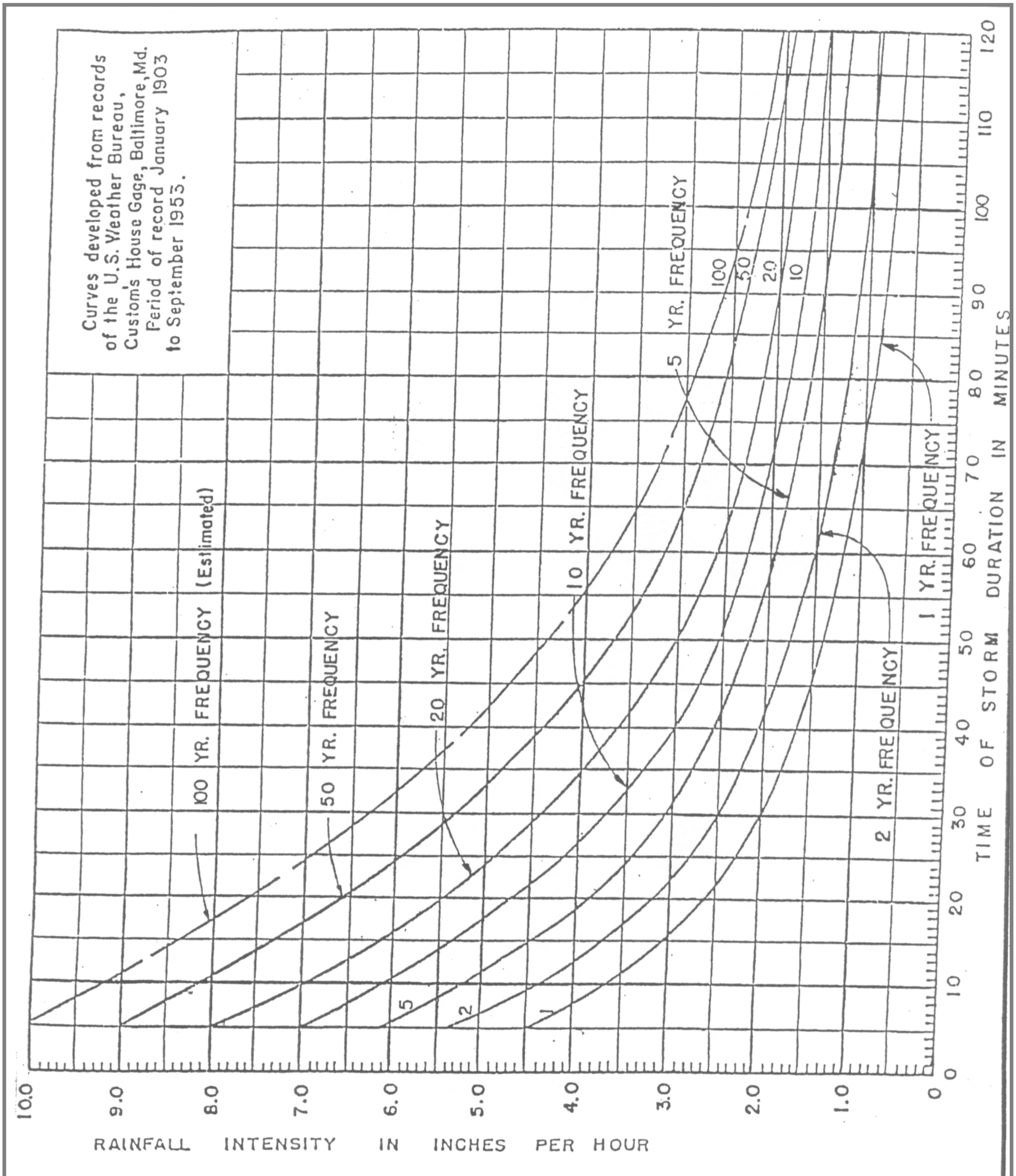
ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED ______ ______ DATE: ______	STANDARD STORM DRAIN DESIGN SWALE FLOW VELOCITY (GRASS - n = 0.06)	SD-8



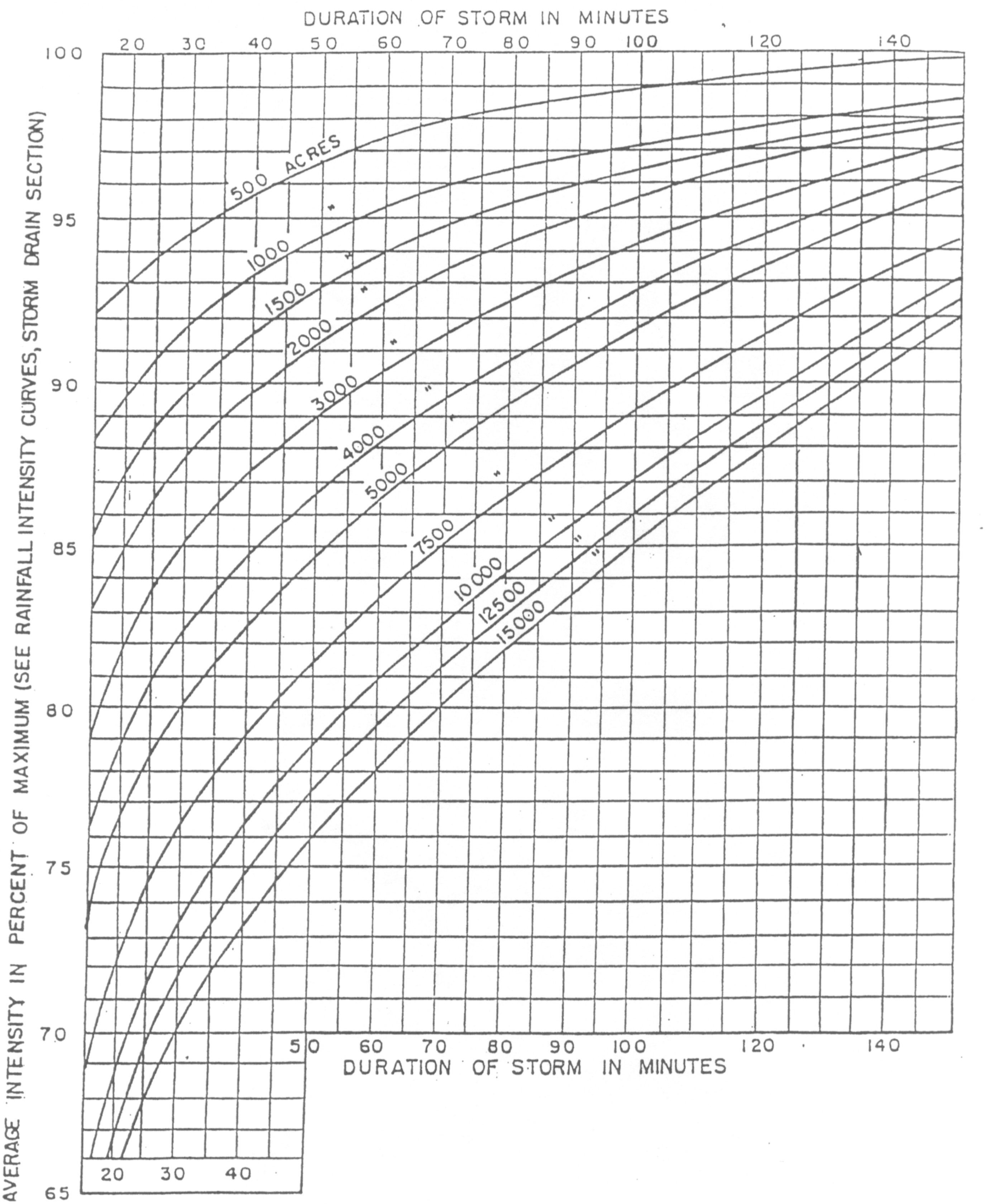
ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN SWALE FLOW VELOCITY (Paved - n = 0.015)	SD-9



ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN NATURAL CHANNEL FLOW VELOCITY (APPROXIMATION-USED FOR TIME-OF-CONCENTRATION CALCULATIONS)	SD-10



ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN RAINFALL INTENSITY BALTIMORE & VICINITY	SD - 11.01



ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN RAINFALL INTENSITY ADJUSTMENT FOR 500 TO 1500 ACRE AREAS	SD - 11.02

DEPARTMENT OF PUBLIC WORKS
INLET AND GUTTER CAPACITY WORKSHEET

LOCATION ________
DEVELOPMENT ________
LOT SIZE ________
JOB ORDER NO. ________

DATE: ________
SHEET ______ TOTAL IN COMP. ______
COMPUTED BY: ________
CHECKED BY: ________

INLET NO.	T.C.	I	AREA ACRES	C	CA	Q	Q+	GUTTER SLOPE	GUTTER VELOCITY	GUTTER SPREAD	INLET TYPE	INLET CAPACITY	BYPASS	REMARKS

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED ________ ________ DATE:	STANDARD STORM DRAIN DESIGN INLET AND GUTTER CAPACITY WORKSHEET	SD-12

DEPARTMENT OF PUBLIC WORKS
STORM DRAIN FLOW TABULATION FORM

LOCATION ______
DEVELOPMENT ______
JOB NUMBER ______
STORM FREQUENCY ______ YEARS

DATE: ______ 19 ___
SHEET ______ TOTAL IN COMP. ___
COMPUTED BY: ______
CHECKED BY: ______

LOCATION		AREA	ACRES		COEFF.	CA	∑ CA	TIME CONC.-MIN.			INTEN.	Q=CIA	PIPE n = 0.014				REMARKS
FROM	TO		SUB.	TOTAL	"C"			INLET	DRAIN	TOTAL	"I"	C.F.S.	SIZE	SLOPE	VEL.	LGTH.	

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS

APPROVED ______

DATE: ______

STANDARD STORM DRAIN DESIGN

FLOW TABULATION FORM

SD-13

DEPARTMENT OF PUBLIC WORKS
HYDRAULIC GRADIENT COMPUTATION FORM

LOCATION ____________
DEVELOPMENT ____________
LOT SIZE ____________
JOB ORDER NO. ____________

DATE ____________
SHEET ____ TOTAL IN COMB. ____
COMPUTED BY ____________
CHECKED BY ____________

TAILWATER ELEVATION ________
CROWN OF PIPE ELEVATION ________ HYDRAULIC GRADIENT ________

FROM ____ TO ____ ________ LIN. FT. ________ @ ____ %
STRUCTURE: NO. ____ TYPE ________ DEFLECTION ____
Q1 ________ V1 ________ LOSSES A ________
Q2 ________ V2 ________ B ________
Q3 ________ V3 ________ C ________
Q3/Q1 = ____ % D ________
TOTAL ________

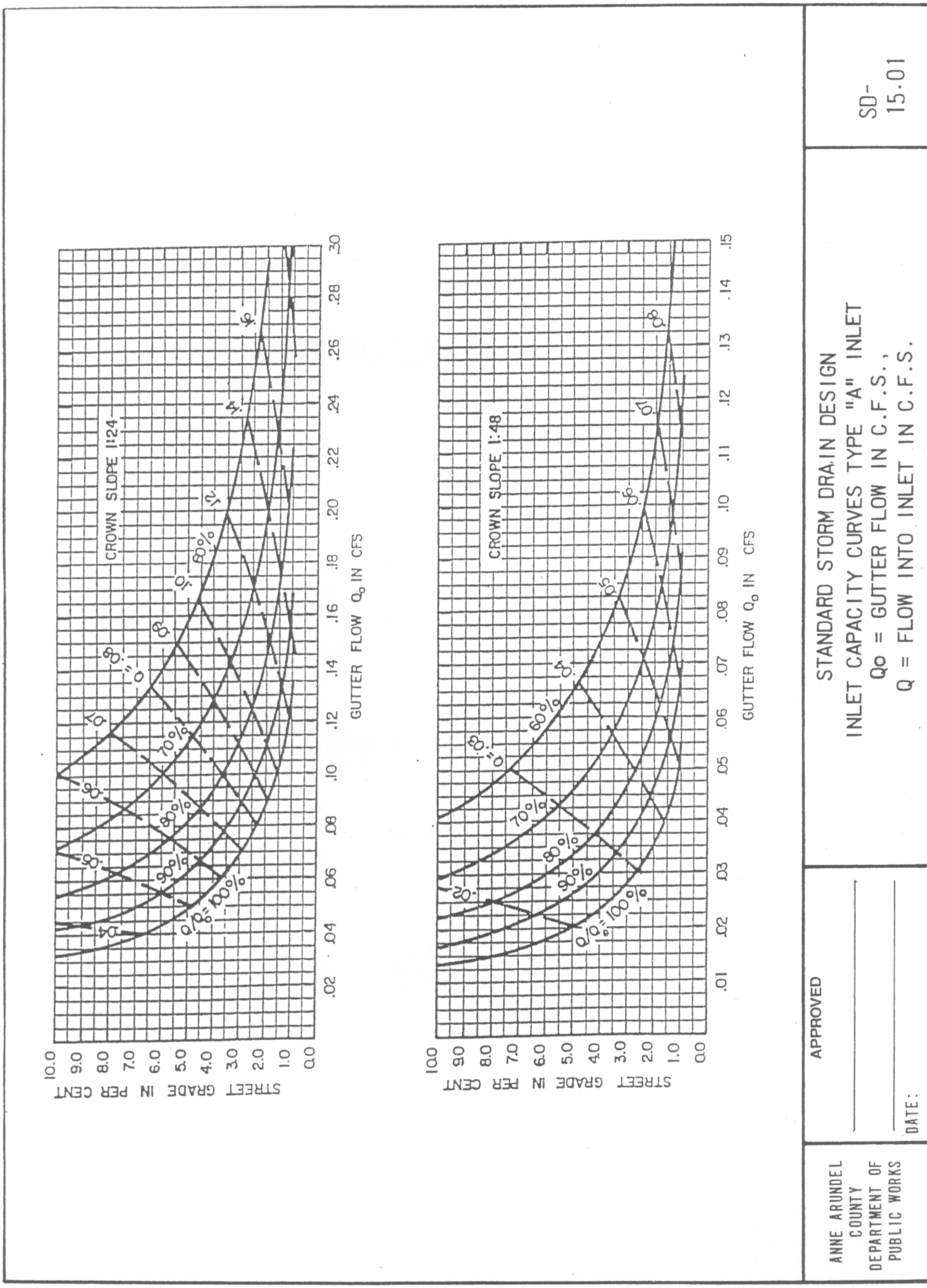
FROM ____ TO ____ ________ LIN. FT. ________ @ ____ %
STRUCTURE: NO. ____ TYPE ________ DEFLECTION ____
Q1 ________ V1 ________ LOSSES A ________
Q2 ________ V2 ________ B ________
Q3 ________ V3 ________ C ________
Q3/Q1 = ____ % D ________
TOTAL ________

FROM ____ TO ____ ________ LIN. FT. ________ @ ____ %
STRUCTURE: NO. ____ TYPE ________ DEFLECTION ____
Q1 ________ V1 ________ LOSSES A ________
Q2 ________ V2 ________ B ________
Q3 ________ V3 ________ C ________
Q3/Q1 = ____ % D ________
TOTAL ________

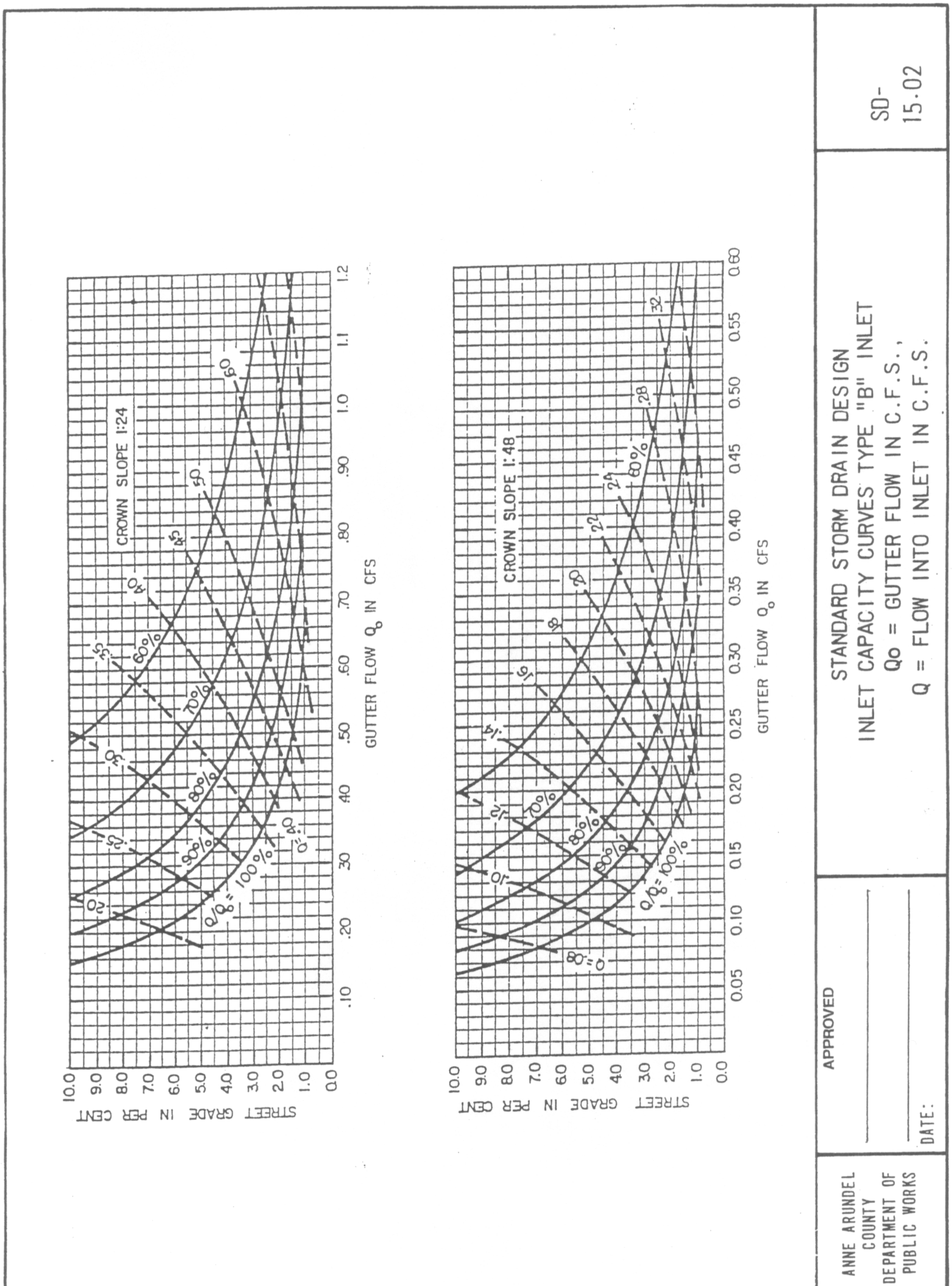
FROM ____ TO ____ ________ LIN. FT. ________ @ ____ %
STRUCTURE: NO. ____ TYPE ________ DEFLECTION ____
Q1 ________ V1 ________ LOSSES A ________
Q2 ________ V2 ________ B ________
Q3 ________ V3 ________ C ________
Q3/Q1 = ____ % D ________
TOTAL ________

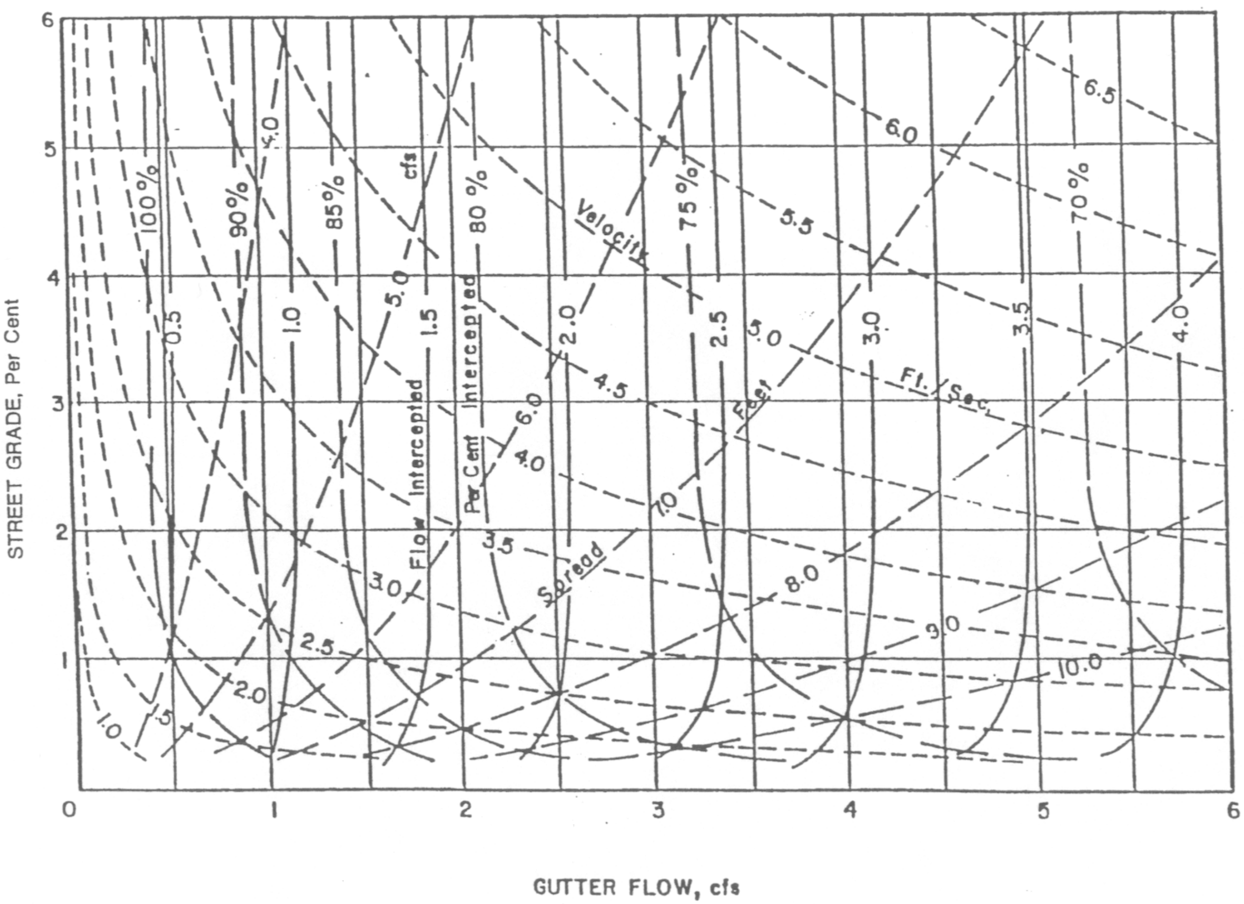
FROM ____ TO ____ ________ LIN. FT. ________ @ ____ %
STRUCTURE: NO. ____ TYPE ________ DEFLECTION ____
Q1 ________ V1 ________ LOSSES A ________
Q2 ________ V2 ________ B ________
Q3 ________ V3 ________ C ________
Q3/Q1 = ____ % D ________
TOTAL ________

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED ________ ________ DATE: ________	STANDARD STORM DRAIN DESIGN HYDRAULIC GRADIENT COMPUTATION	SD - 14



STANDARD STORM DRAIN DESIGN
INLET CAPACITY CURVES TYPE "A" INLET
Qo = GUTTER FLOW IN C.F.S.,
Q = FLOW INTO INLET IN C.F.S.
SD-15.01
APPROVED
DATE:
ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS
CROWN SLOPE 1:24
CROWN SLOPE 1:48
STREET GRADE IN PER CENT
GUTTER FLOW Qo IN CFS
Q/Qo=100%
90%
80%
70%
60%


CROWN SLOPE 1:24
CROWN SLOPE 1:48
STREET GRADE IN PER CENT
GUTTER FLOW Q_o IN CFS
STANDARD STORM DRAIN DESIGN
INLET CAPACITY CURVES TYPE "B" INLET
Qo = GUTTER FLOW IN C.F.S.,
Q = FLOW INTO INLET IN C.F.S.
SD-15.02
APPROVED
DATE:
ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS



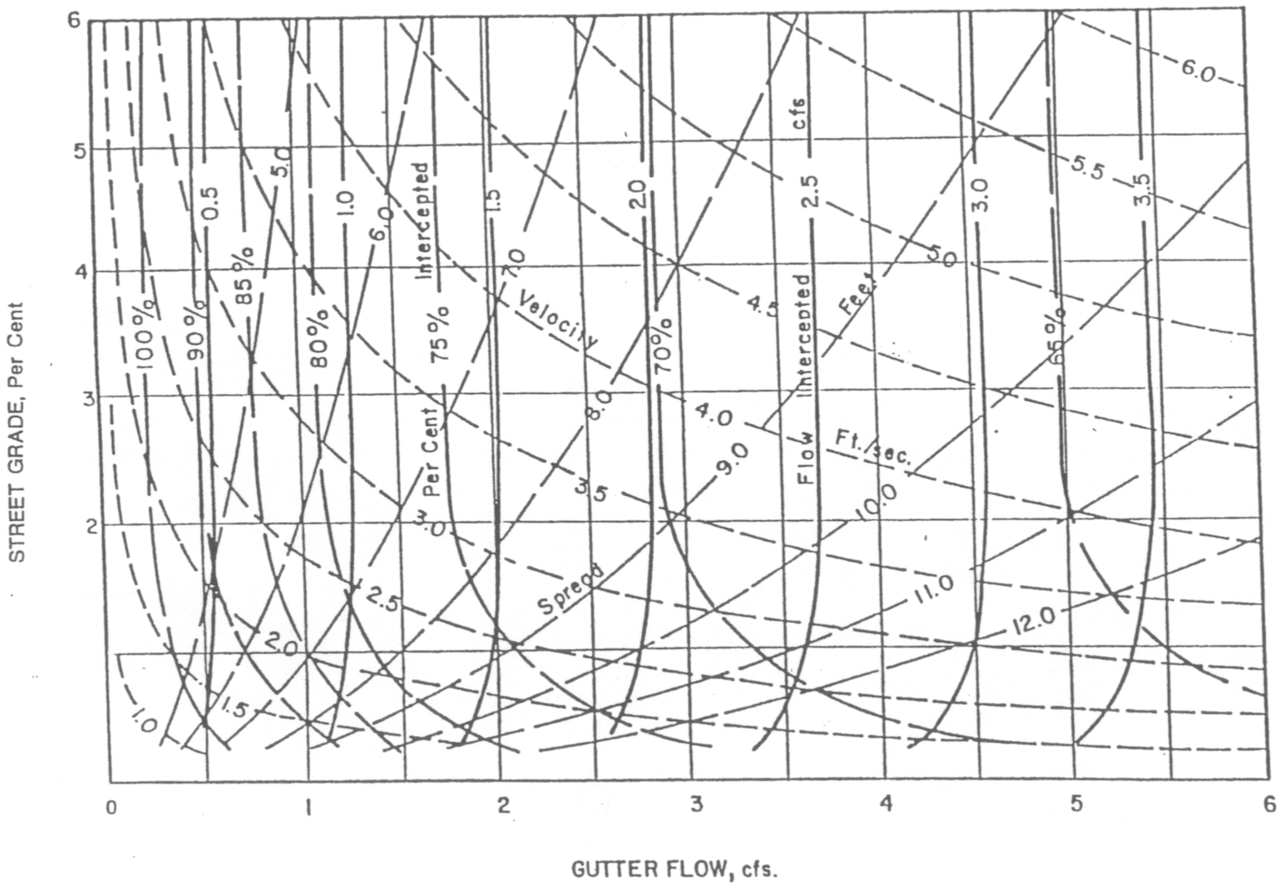
NOTES:

1. Gutter Capacities determined using $Q = 0.56\,(z/n)\, s^{1/2}\, y^{8/3}$; n= .015

2. Inlet Capacities based on Chapter 4, THE DESIGN OF STORMWATER INLETS, The Johns Hopkins University

3. For Combination Inlets, Undepressed Grates, Cross slope 1:32 (3/8":1') only

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN INLET CAPACITY CURVES "E" COMBINATION UNDEPRESSED CROSS SLOPE 1:32	SD-15.03



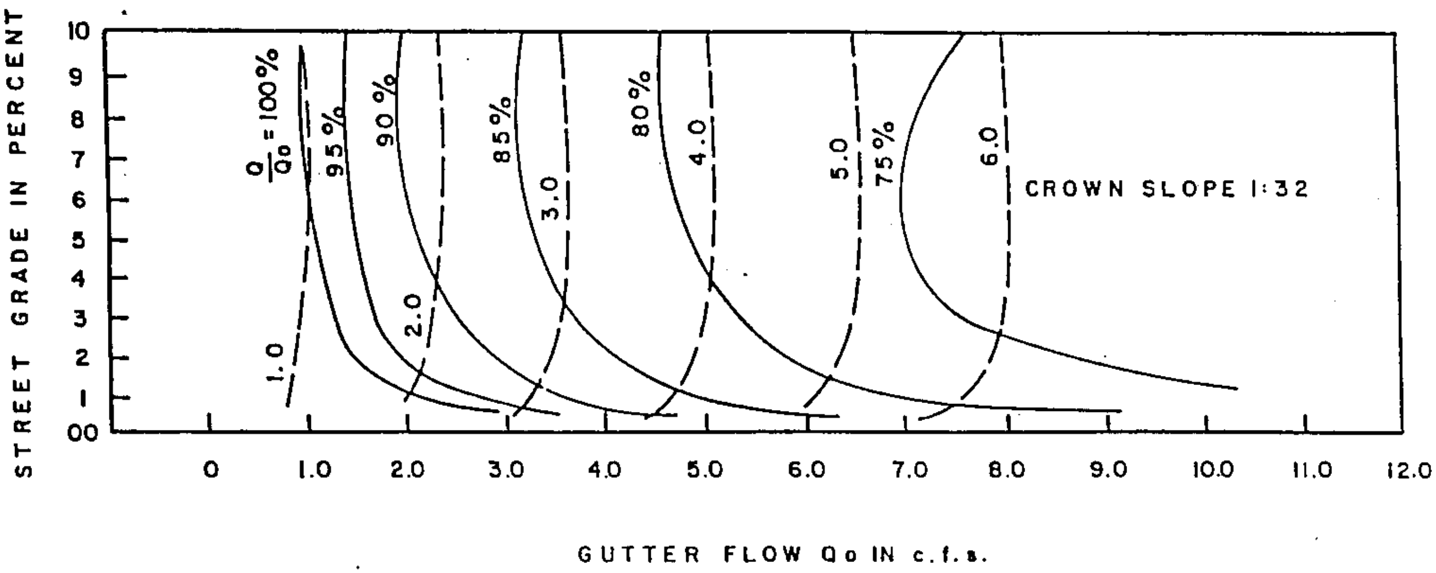
NOTES:

1. Gutter Capacities determined using $Q = 0.56 (z/n)\ s^{1/2}\ y^{8/3}$; $n = .015$

2. Inlet Capacities based on Chapter 4 THE DESIGN OF STORM WATER INLETS, The Johns Hopkins University

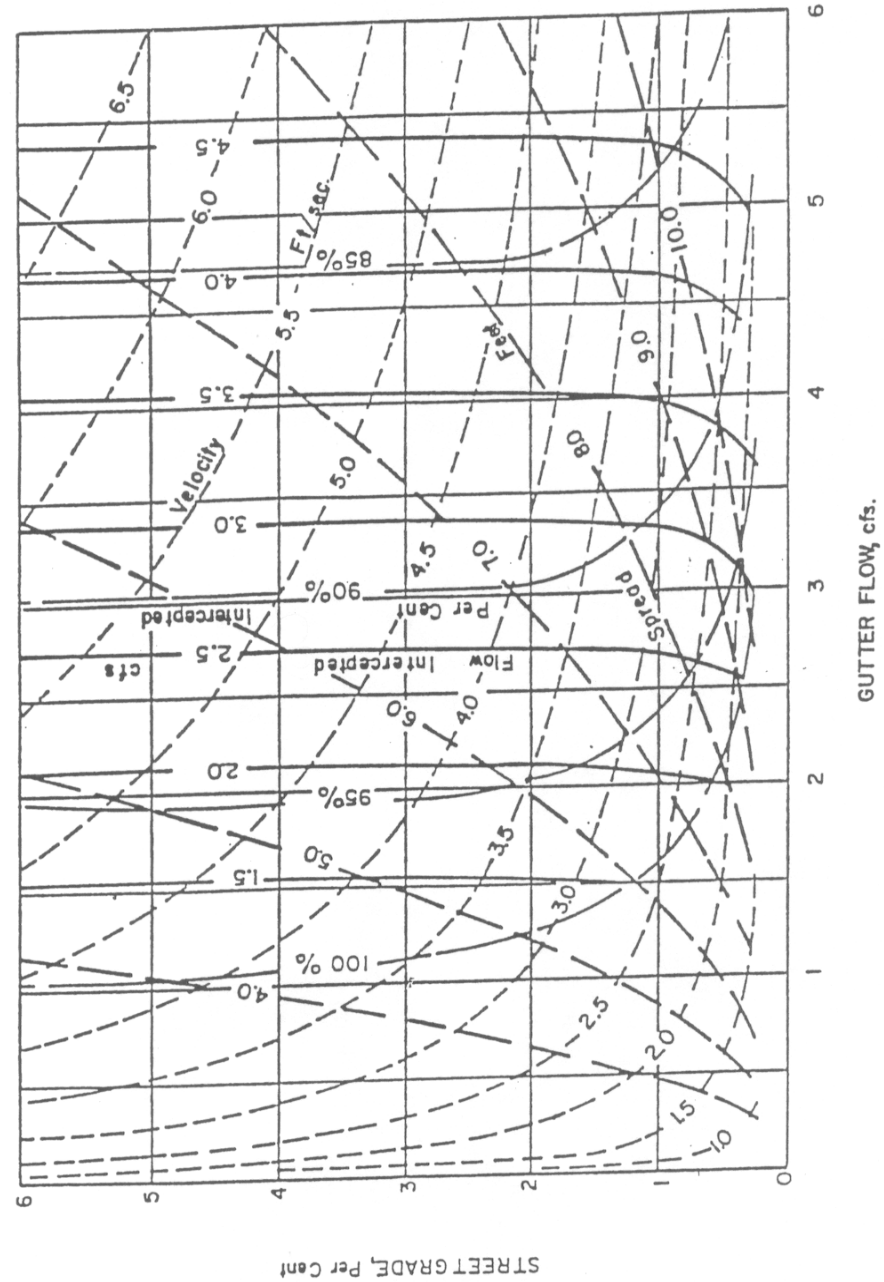
3. For Combination inlets, Undepressed Grates, cross slope 1:48 (1/4":1') only

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN INLET CAPACITY CURVES "E" COMBINATION UNDEPRESSED CROSS SLOPE 1:48	SD-15.04



MANNINGS n = 0.013

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN UNDEPRESSED DOUBLE "E" COMBINATION INLETS Qo = GUTTER FLOW IN C.F.S. Q = FLOW INTO INLETS IN C.F.S.	SD- 15.05



NOTES:

1. Gutter Capacities determined using $Q = 0.56(z/n)\, s^{1/2}\, y^{8/3}$, n=.015
2. Inlet Capacities based on Chapter 4 THE DESIGN OF STORM WATER INLETS, The Johns Hopkins University
3. For Combination Inlets, Undepressed Grates, Cross slope 1:32 (3/8":1') only
4. All Grates Parallel to Curb.

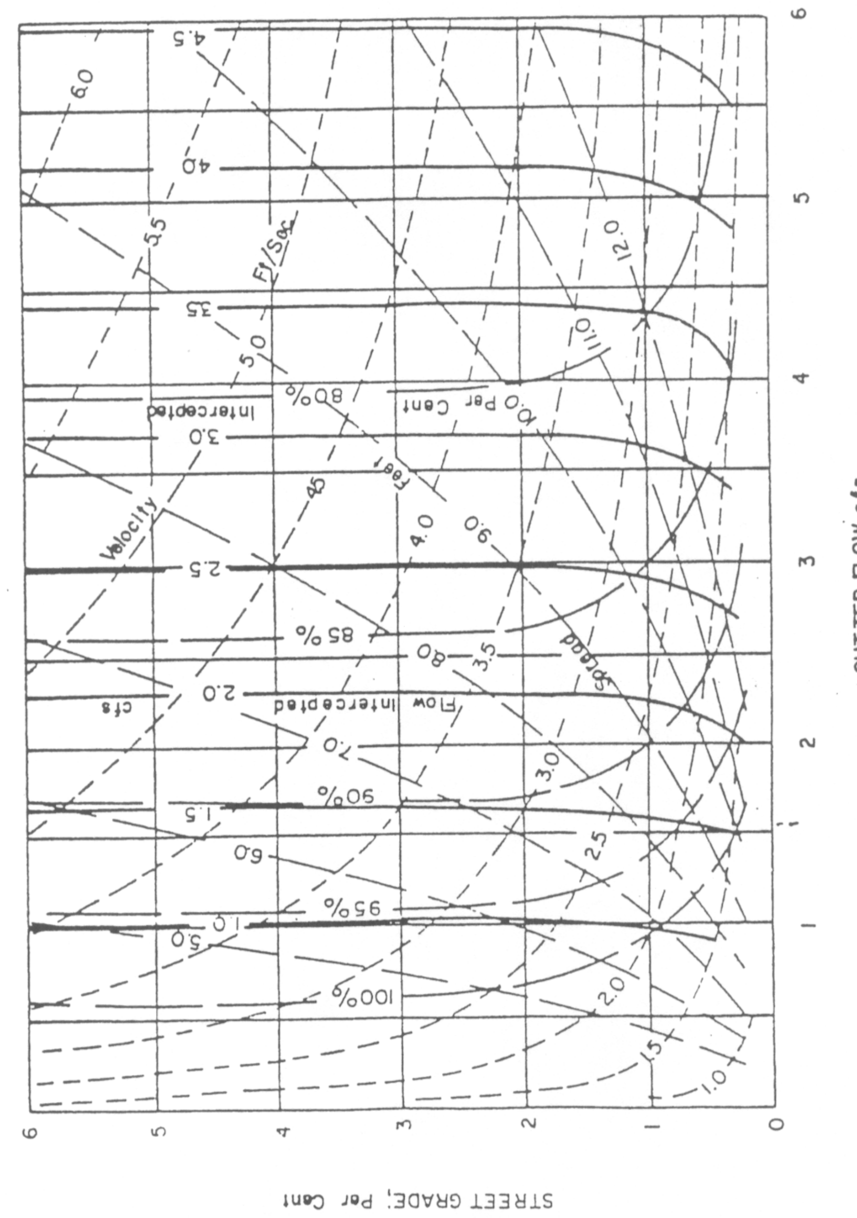
STANDARD STORM DRAIN DESIGN
INLET CAPACITY CURVES
DOUBLE TYPE "S" COMB. INLET (NORMAL TO CURB)
UNDEPRESSED-CROSS SLOPE 1:32

SD-15.06

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS

APPROVED

DATE:



NOTES:

1. Gutter Capacities determined using $Q = 0.56(z/n)\ s^{1/2}\ y^{8/3}$; n=.015
2. Inlet Capacities based on Chapter 4, THE DESIGN OF STORM WATER INLETS, The Johns Hopkins University
3. For Combination Inlets Undepressed Grates, Cross Slope 1:48 (1/4":1') only
4. All Grates Parallel to Curb.

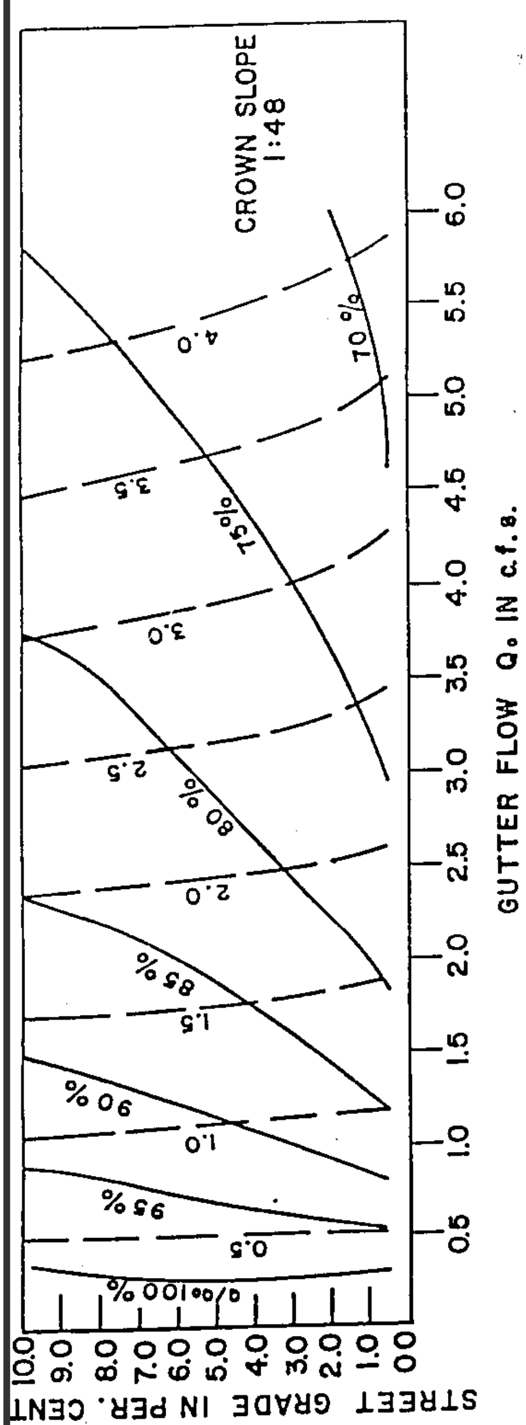
STANDARD STORM DRAIN DESIGN
INLET CAPACITY CURVES
DOUBLE TYPE "S" COMB. INLET (NORMAL TO CURB)
UNDEPRESSED-CROSS SLOPE 1:48

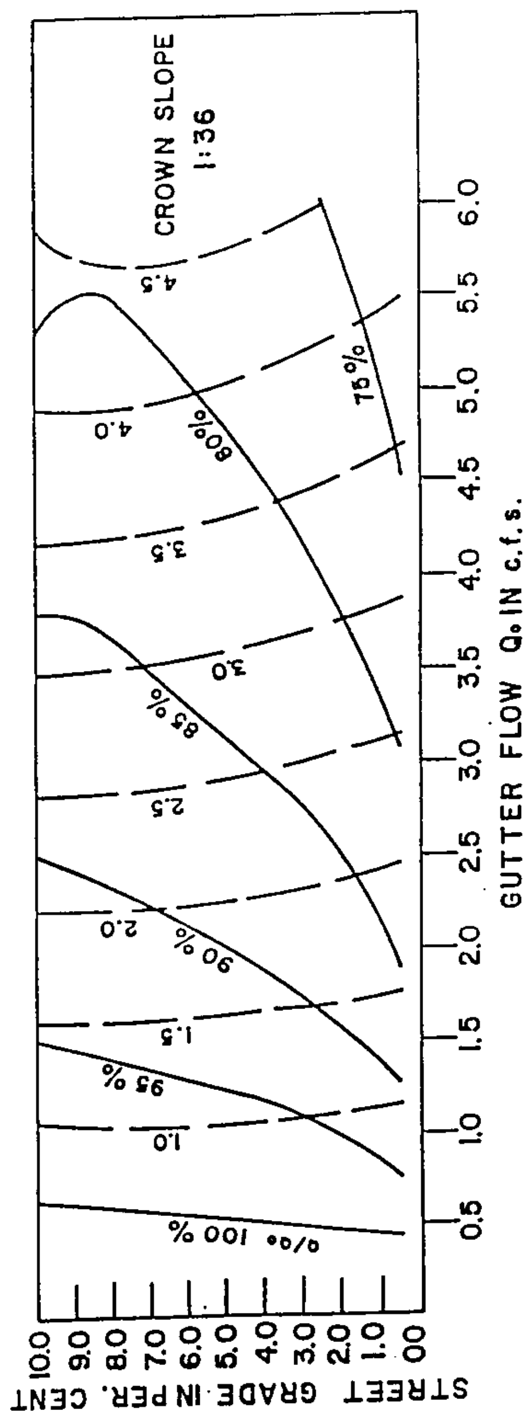
SD-15.07

APPROVED

DATE:

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS





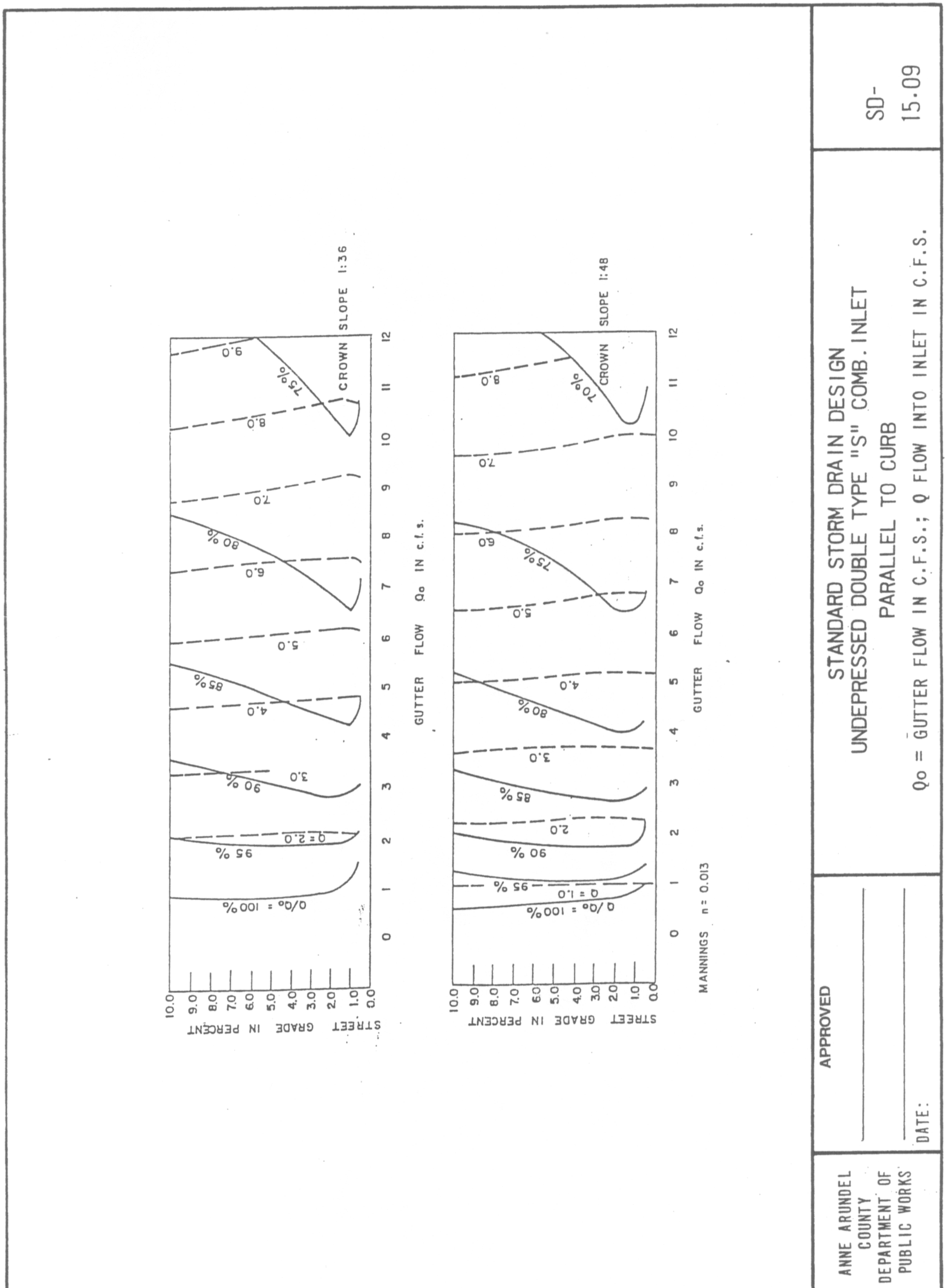
SD-15.08

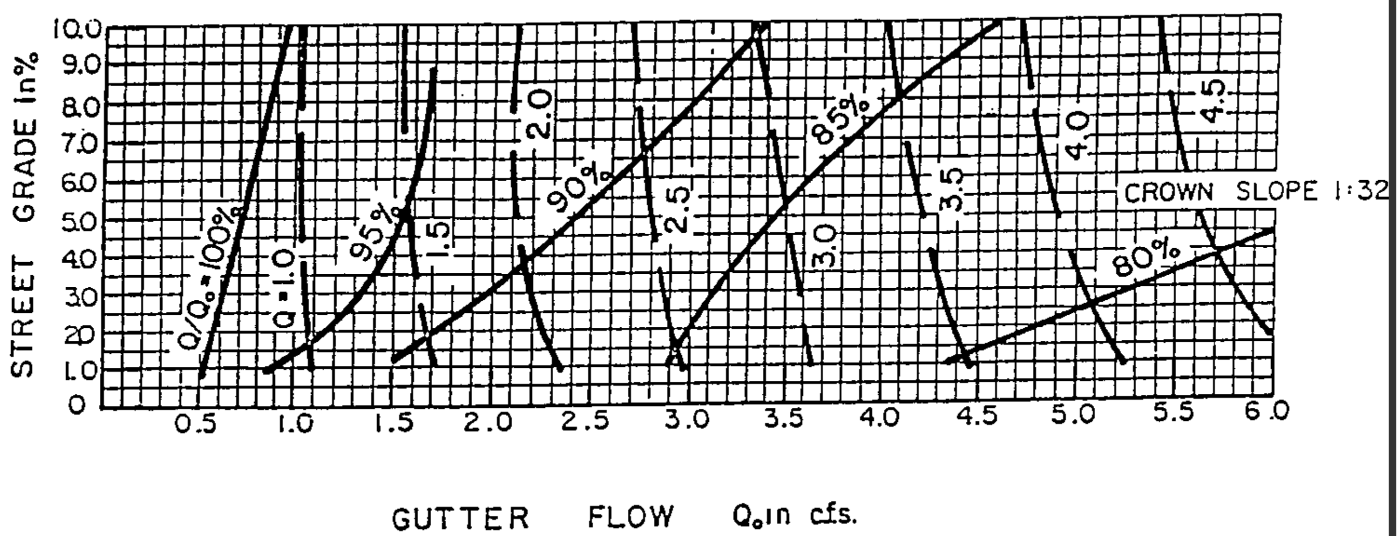
STANDARD STORM DRAIN DESIGN
UNDEPRESSED GUTTER INLET,S GRATE-MANNING
n = .013 Qo=GUTTER FLOW IN C.F.S.;
Q=FLOW INTO INLET IN C.F.S.

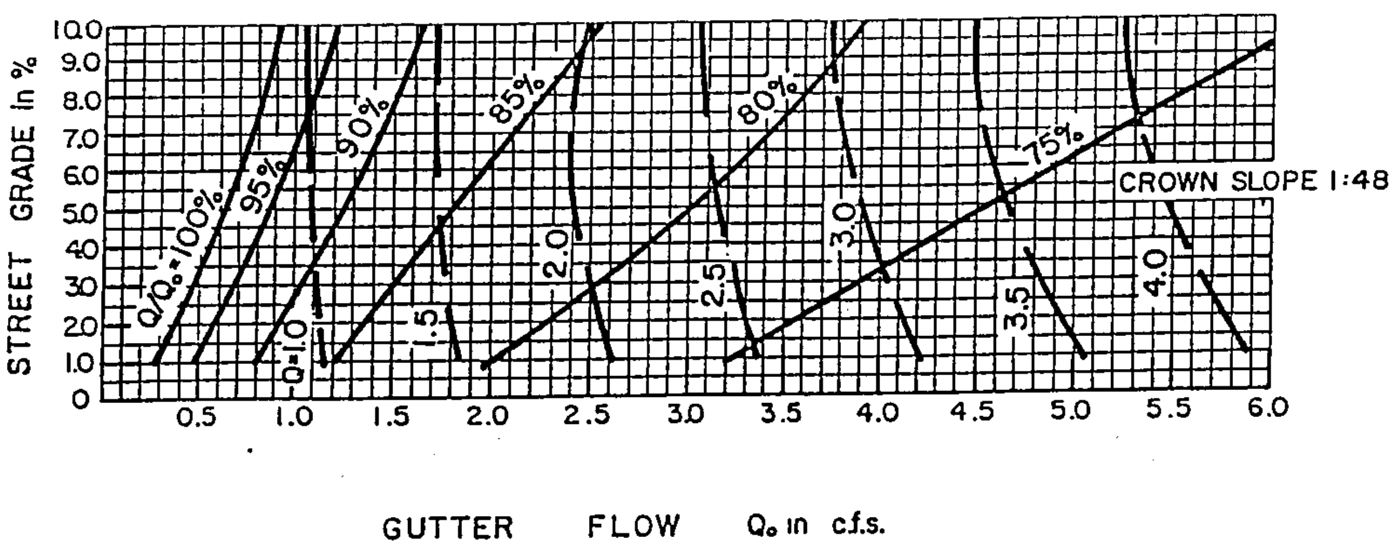
APPROVED

DATE:

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS

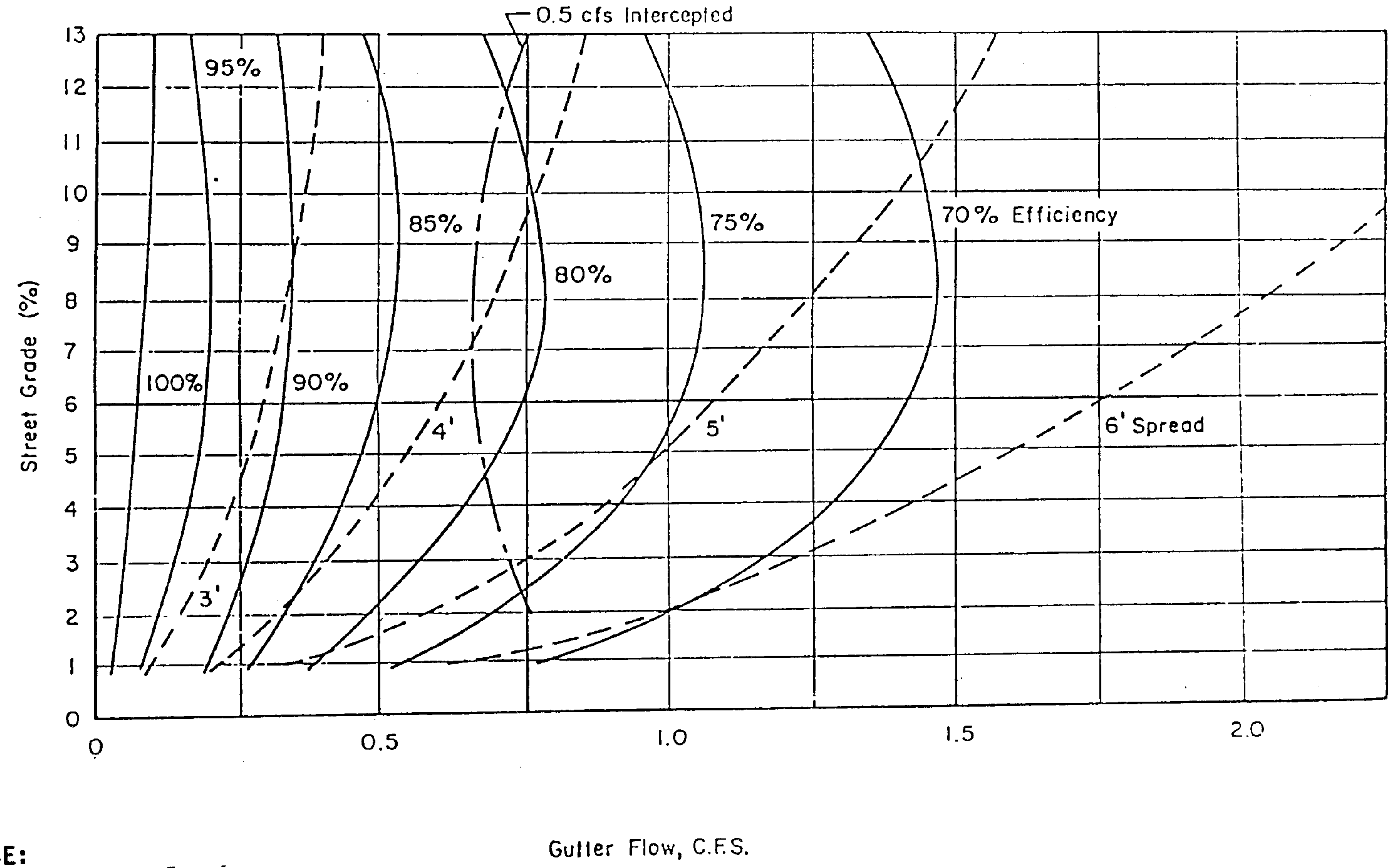

STANDARD STORM DRAIN DESIGN
UNDEPRESSED DOUBLE TYPE "S" COMB. INLET
PARALLEL TO CURB
Qo = GUTTER FLOW IN C.F.S.; Q FLOW INTO INLET IN C.F.S.
SD-15.09
ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS
APPROVED
DATE:
CROWN SLOPE 1:36
CROWN SLOPE 1:48
GUTTER FLOW Qo IN c.f.s.
STREET GRADE IN PERCENT
MANNINGS n = 0.013
Q/Qo = 100 %
95 %
90 %
85 %
80 %
75 %
70 %
Q = 1.0
Q = 2.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
0 1 2 3 4 5 6 7 8 9 10 11 12
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0





ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN UNDEPRESSED TYPE "S" COMB. INLET Qo GUTTER FLOW IN C.F.S.; Q FLOW INTO INLET IN C.F.S.	SD - 15. 10

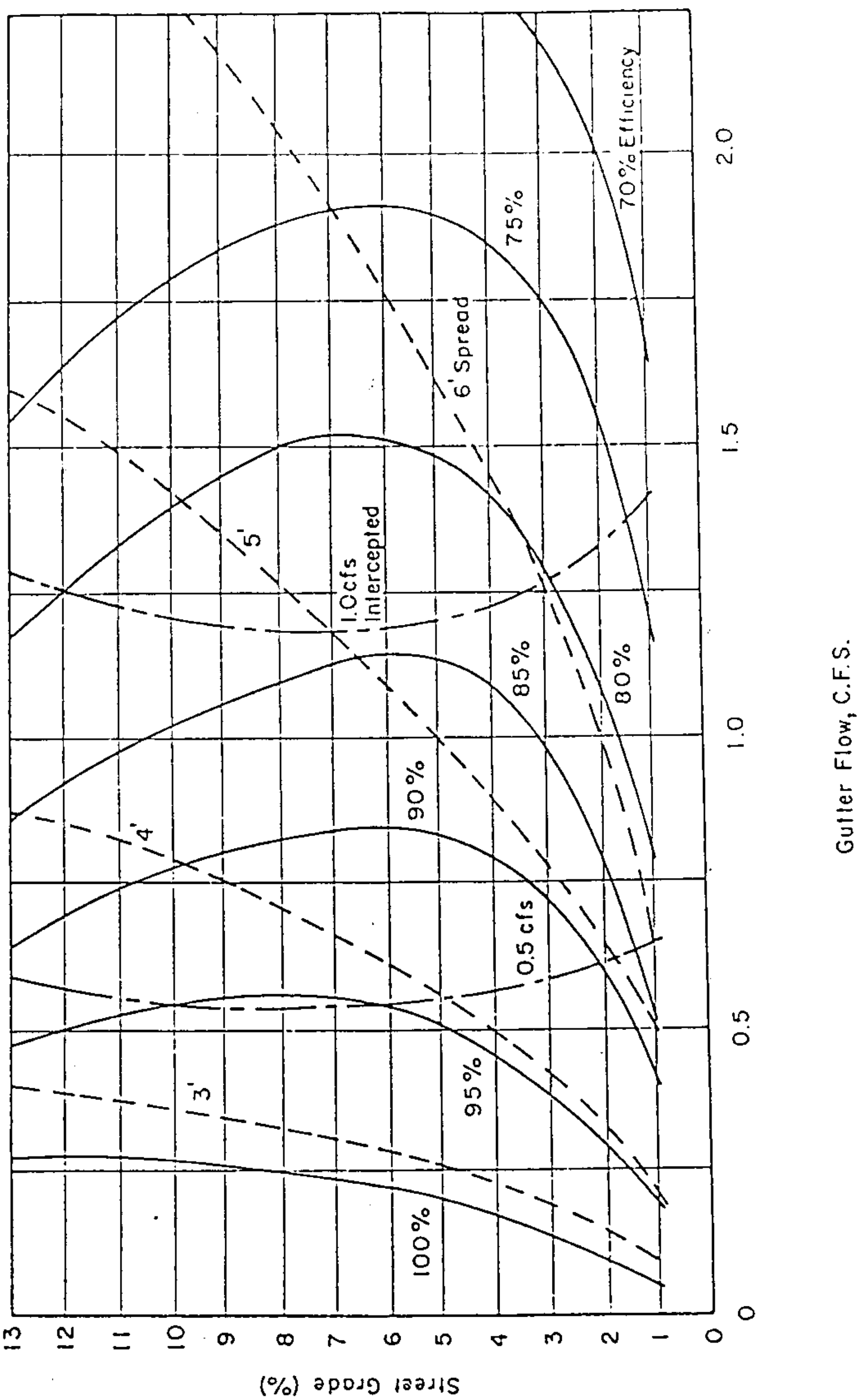
NOTE: FROM THE UNIVERSITY OF MARYLAND REPORT - "HYDRAULIC CHARACTERISTICS OF RETICULAR INLET GRATES" JANUARY, 1976



SOURCE:
MARYLAND STATE HIGHWAY ADMINISTRATION
BUREAU OF HIGHWAY DESIGN

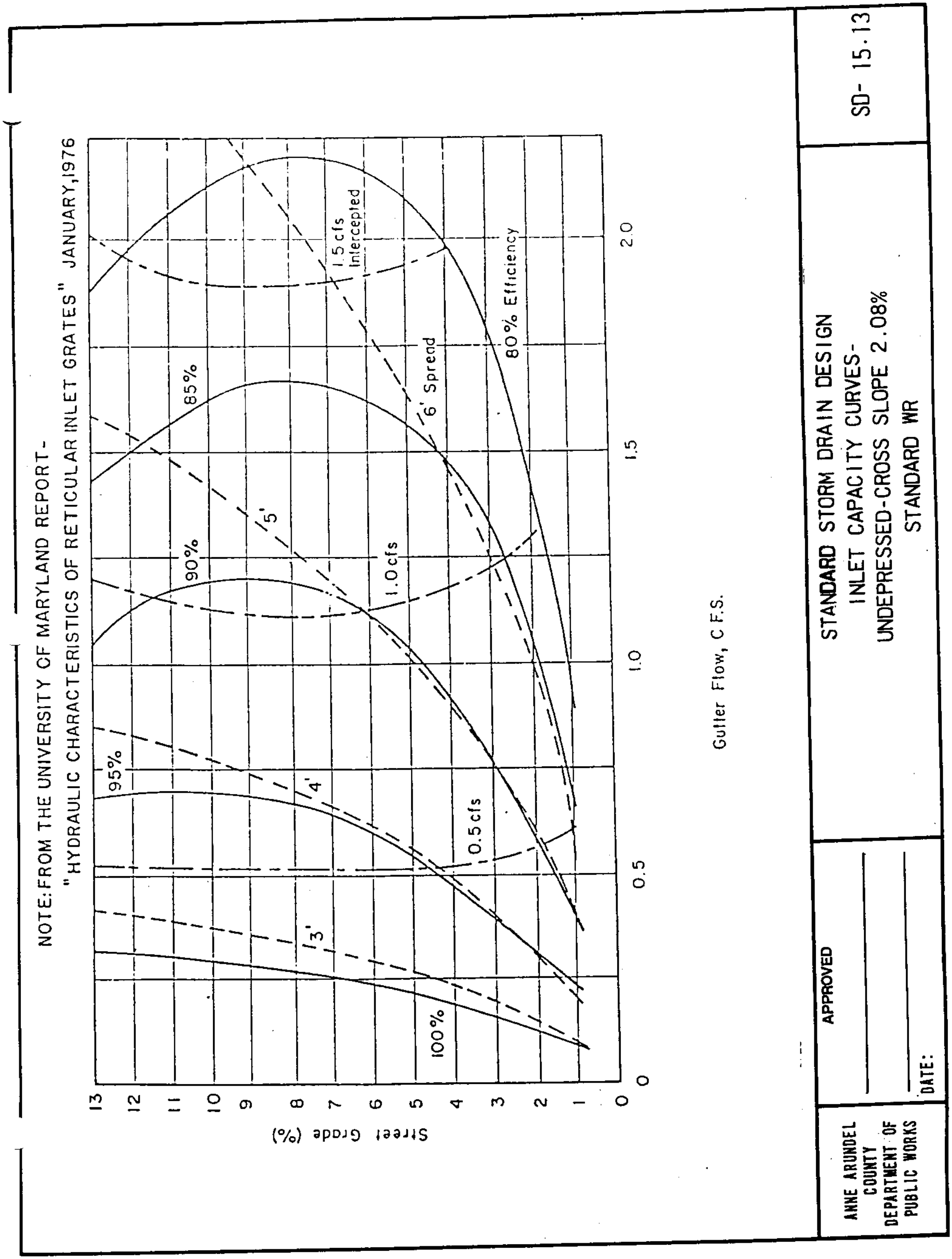
ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN INLET CAPACITY CURVES- UNDEPRESSED-CROSS SLOPE 2.08% STANDARD NR	SD-15.11

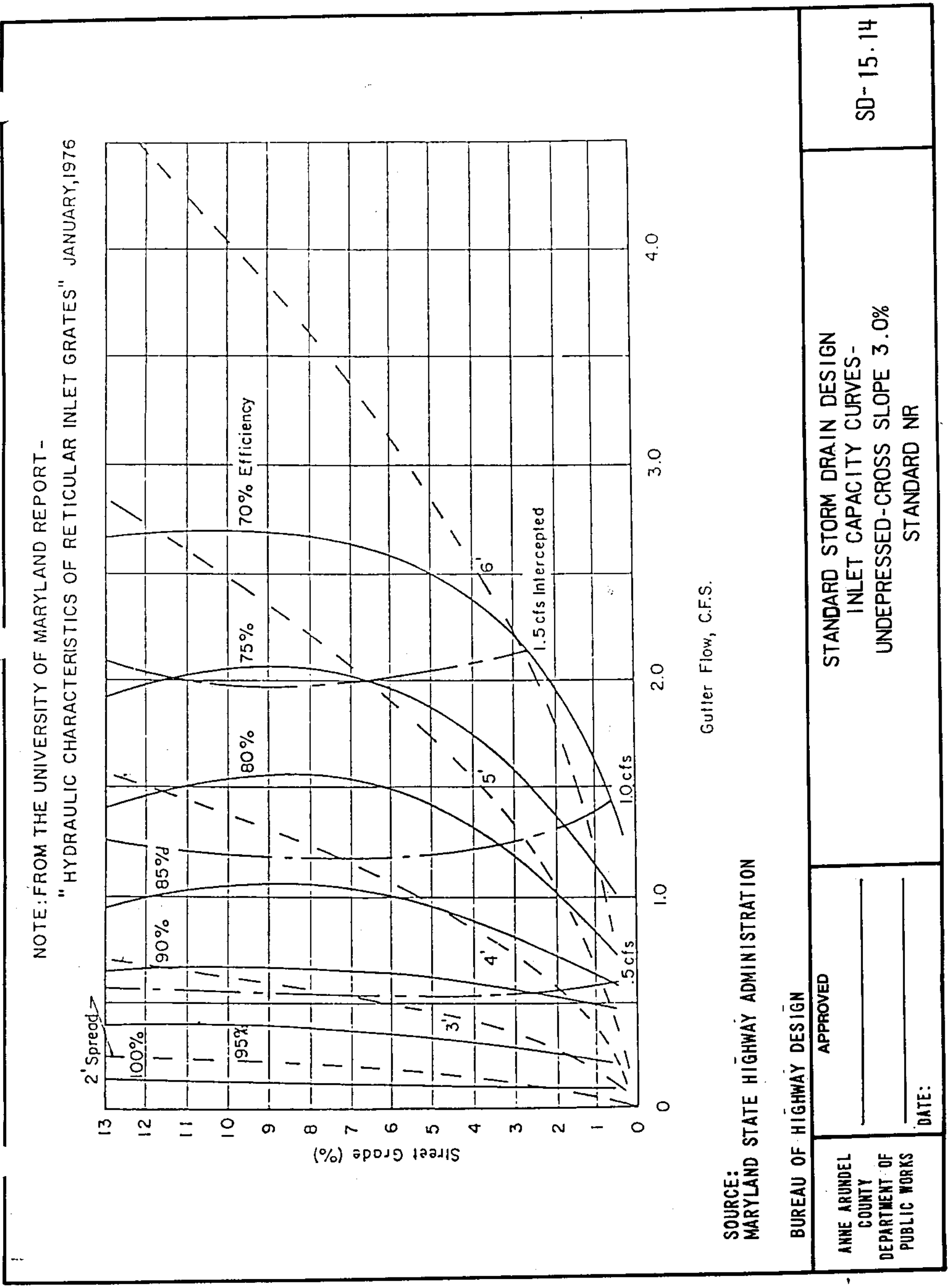
NOTE: FROM THE UNIVERSITY OF MARYLAND REPORT -
"HYDRAULIC CHARACTERISTICS OF RETICULAR INLET GRATES" JANUARY, 1976



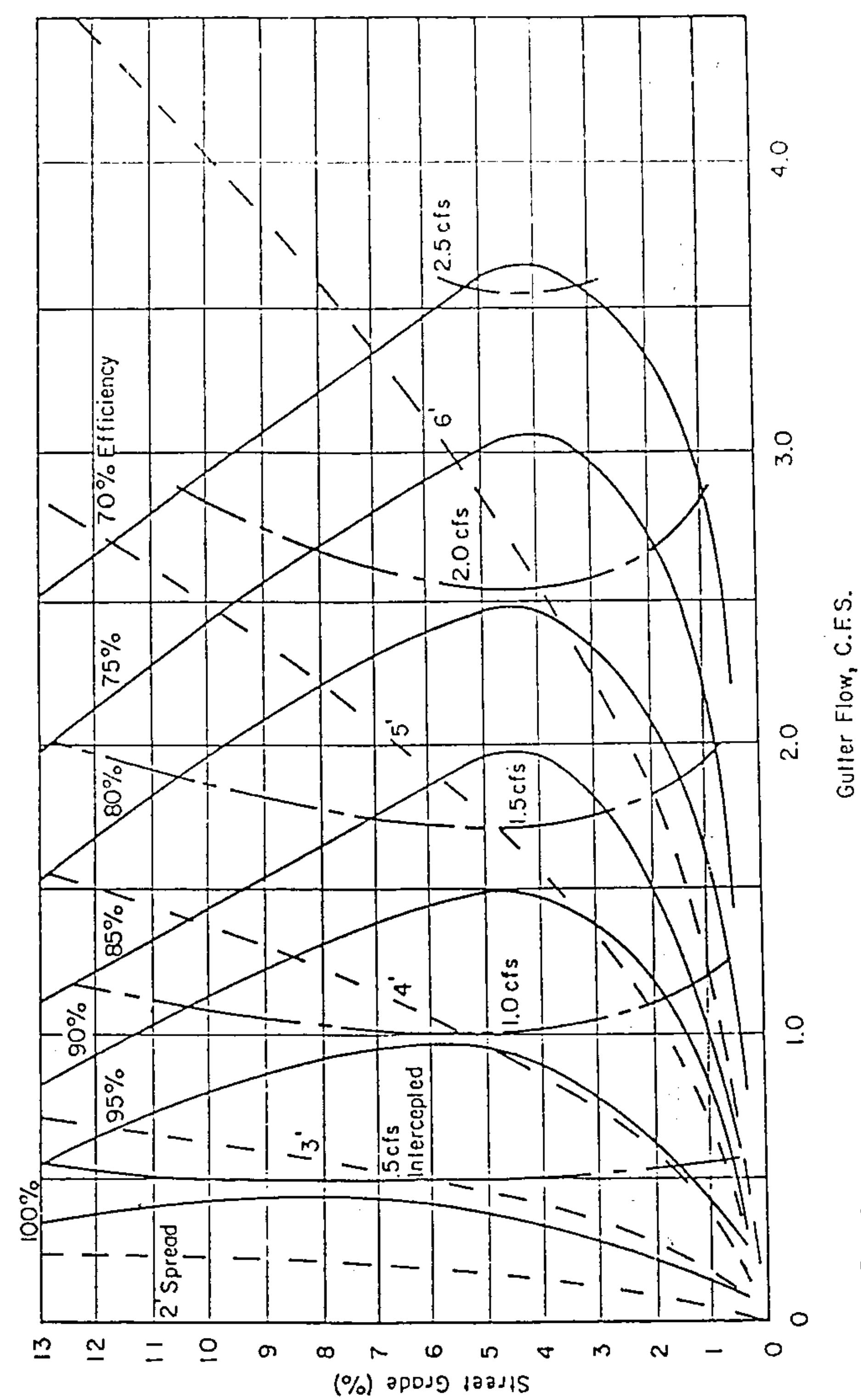
SOURCE:
MARYLAND STATE HIGHWAY ADMINISTRATION
BUREAU OF HIGHWAY DESIGN

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN UNDEPRESSED-CROSS SLOPE 2.08% SINGLE WR	SD-15-12


NOTE: FROM THE UNIVERSITY OF MARYLAND REPORT-
"HYDRAULIC CHARACTERISTICS OF RETICULAR INLET GRATES" JANUARY, 1976
Street Grade (%)
Gutter Flow, C.F.S.
100%
95%
90%
85%
80% Efficiency
3'
4'
5'
6' Spread
0.5 cfs
1.0 cfs
1.5 cfs Intercepted
STANDARD STORM DRAIN DESIGN
INLET CAPACITY CURVES-
UNDEPRESSED-CROSS SLOPE 2.08%
STANDARD WR
SD- 15.13
APPROVED
DATE:
ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS


NOTE: FROM THE UNIVERSITY OF MARYLAND REPORT -
"HYDRAULIC CHARACTERISTICS OF RETICULAR INLET GRATES" JANUARY, 1976
Street Grade (%)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Gutter Flow, C.F.S.
0
1.0
2.0
3.0
4.0
2' Spread
3'
4'
5'
6'
100%
95%
90%
85%
80%
75%
70% Efficiency
.5 cfs
1.0 cfs
1.5 cfs Intercepted
SOURCE:
MARYLAND STATE HIGHWAY ADMINISTRATION
BUREAU OF HIGHWAY DESIGN
ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS
APPROVED
DATE:
STANDARD STORM DRAIN DESIGN
INLET CAPACITY CURVES-
UNDEPRESSED-CROSS SLOPE 3.0%
STANDARD NR
SD-15.14

NOTE: FROM THE UNIVERSITY OF MARYLAND REPORT - "HYDRAULIC CHARACTERISTICS OF RETICULAR INLET GRATES" JANUARY, 1976



SOURCE:
MARYLAND STATE HIGHWAY ADMINISTRATION
BUREAU OF HIGHWAY DESIGN

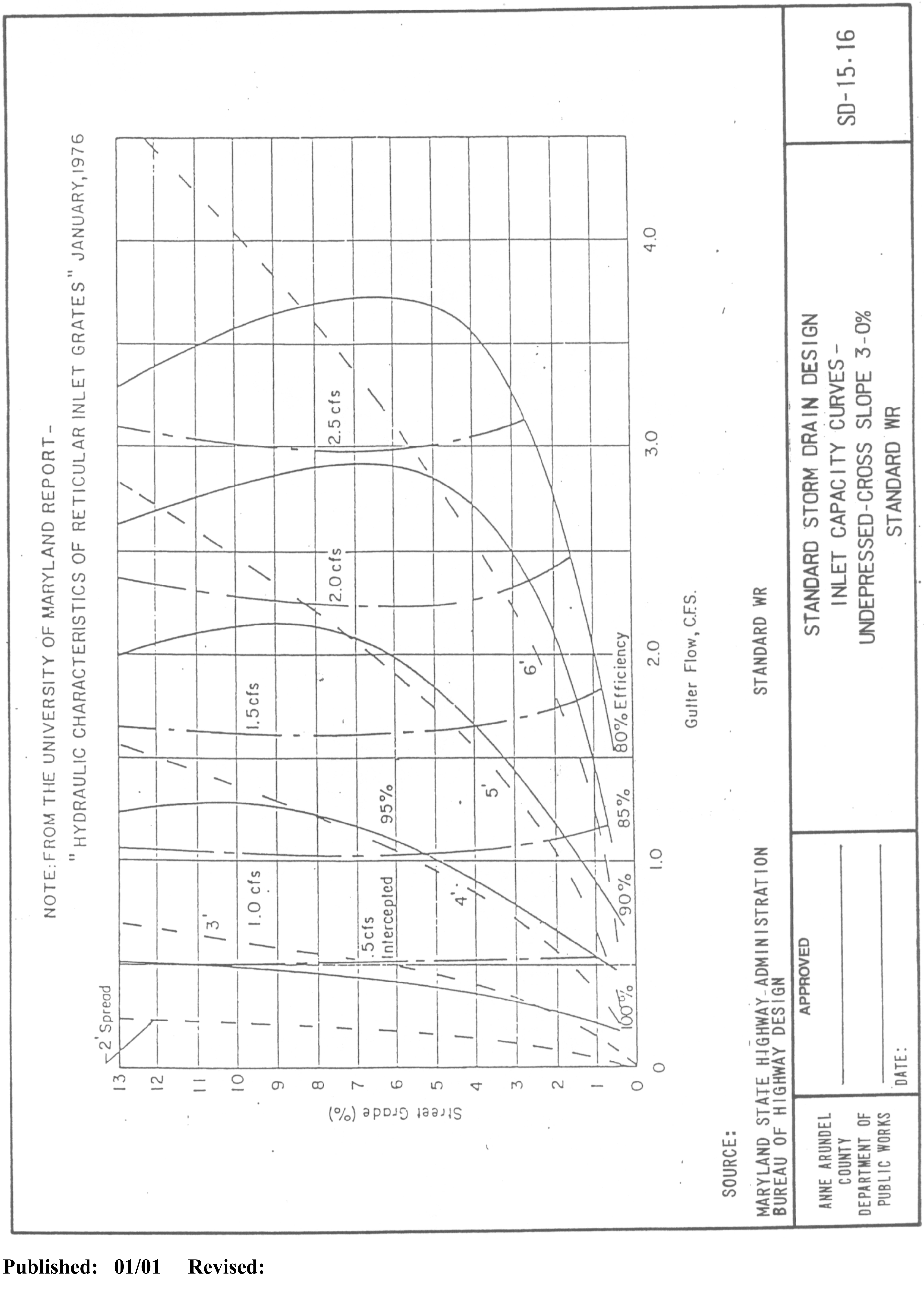
STANDARD STORM DRAIN DESIGN
INLET CAPACITY CURVES-
UNDEPRESSED-CROSS SLOPE 3.0%
SINGLE WR

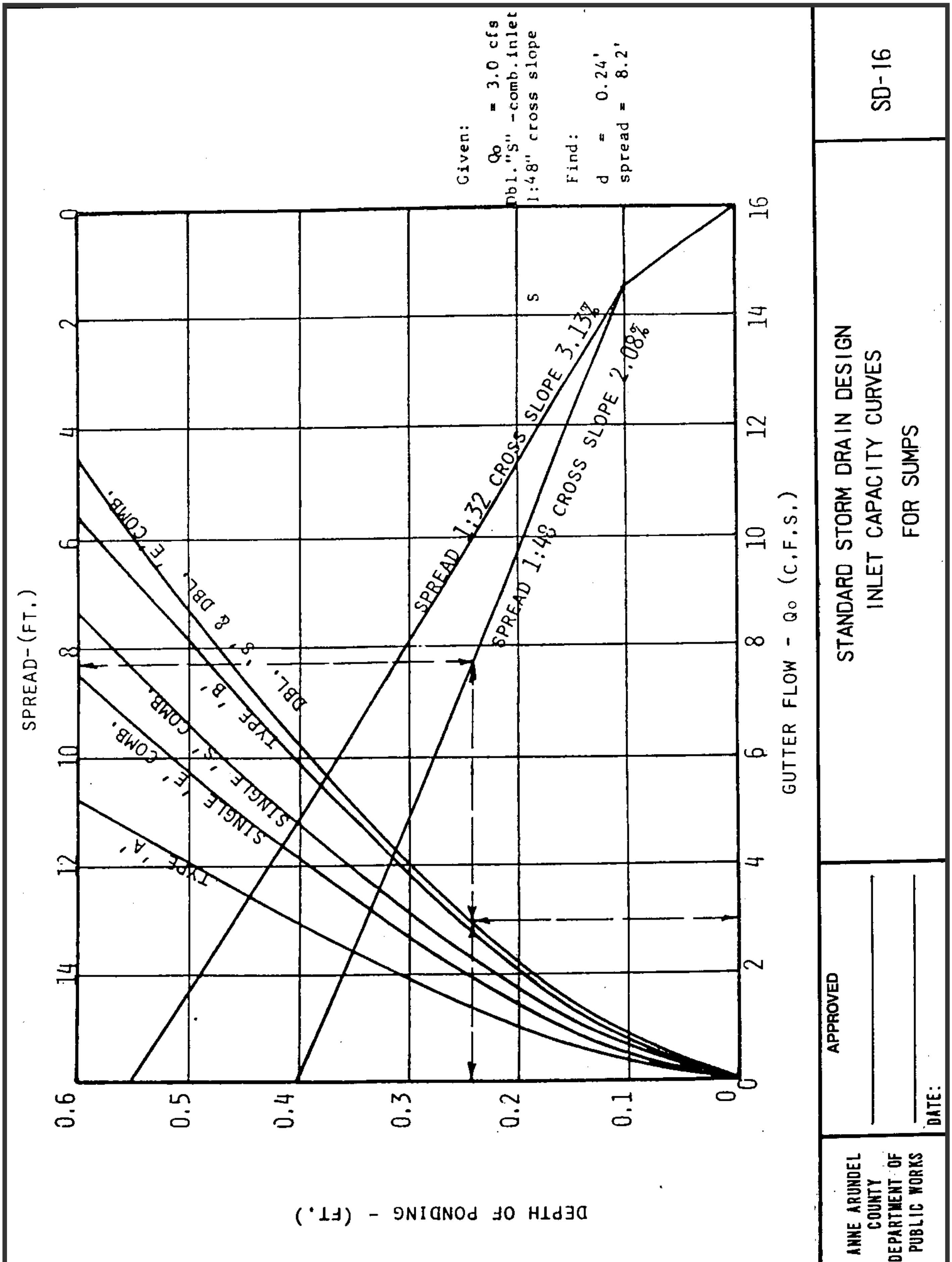
SD-15.15

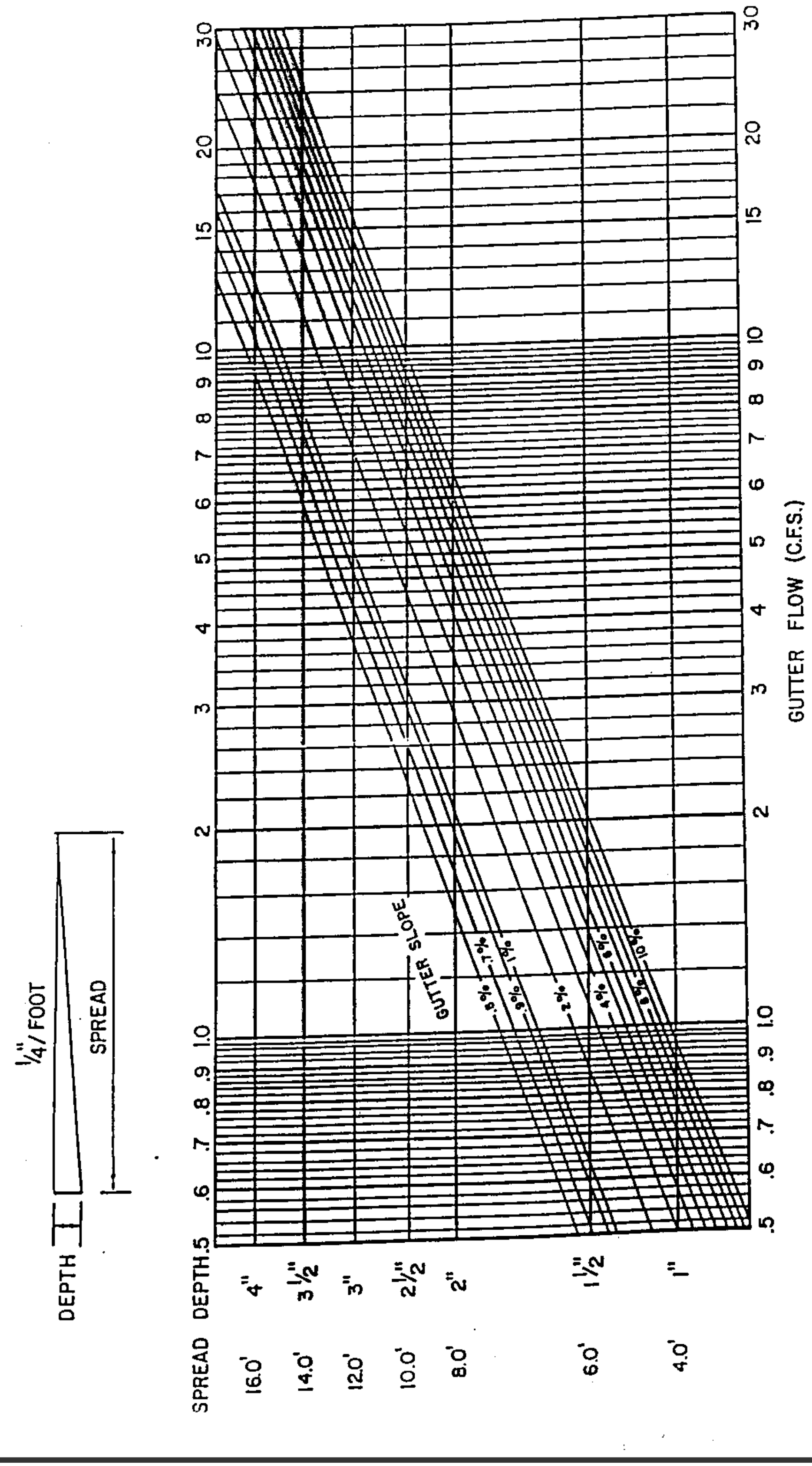
APPROVED

DATE:

ANNE ARUNDEL COUNTY
DEPARTMENT OF PUBLIC WORKS


NOTE: FROM THE UNIVERSITY OF MARYLAND REPORT -
"HYDRAULIC CHARACTERISTICS OF RETICULAR INLET GRATES" JANUARY, 1976
Street Grade (%)
Gutter Flow, C.F.S.
2' Spread
3'
4'
5'
6'
.5 cfs Intercepted
1.0 cfs
1.5 cfs
2.0 cfs
2.5 cfs
100%
95%
90%
85%
80% Efficiency
STANDARD WR
SOURCE:
MARYLAND STATE HIGHWAY ADMINISTRATION
BUREAU OF HIGHWAY DESIGN
ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS
APPROVED
DATE:
STANDARD STORM DRAIN DESIGN
INLET CAPACITY CURVES -
UNDEPRESSED-CROSS SLOPE 3-0%
STANDARD WR
SD-15.16


STANDARD STORM DRAIN DESIGN
INLET CAPACITY CURVES
FOR SUMPS
SD-16
Given:
Qo = 3.0 cfs
Dbl."S" -comb.inlet
1:48" cross slope
Find:
d = 0.24'
spread = 8.2'
SPREAD 1:32 CROSS SLOPE 3.13%
SPREAD 1:48 CROSS SLOPE 2.08%
DBL. 'S' & DBL. 'E' COMB.
TYPE 'B'
SINGLE 'S' COMB.
SINGLE 'E' COMB.
TYPE 'A'
SPREAD-(FT.)
GUTTER FLOW - Qo (C.F.S.)
DEPTH OF PONDING - (FT.)
APPROVED
DATE:
ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS



For Crown Slope = 1:32 Gutter Flow will be 50% greater than shown on this chart.

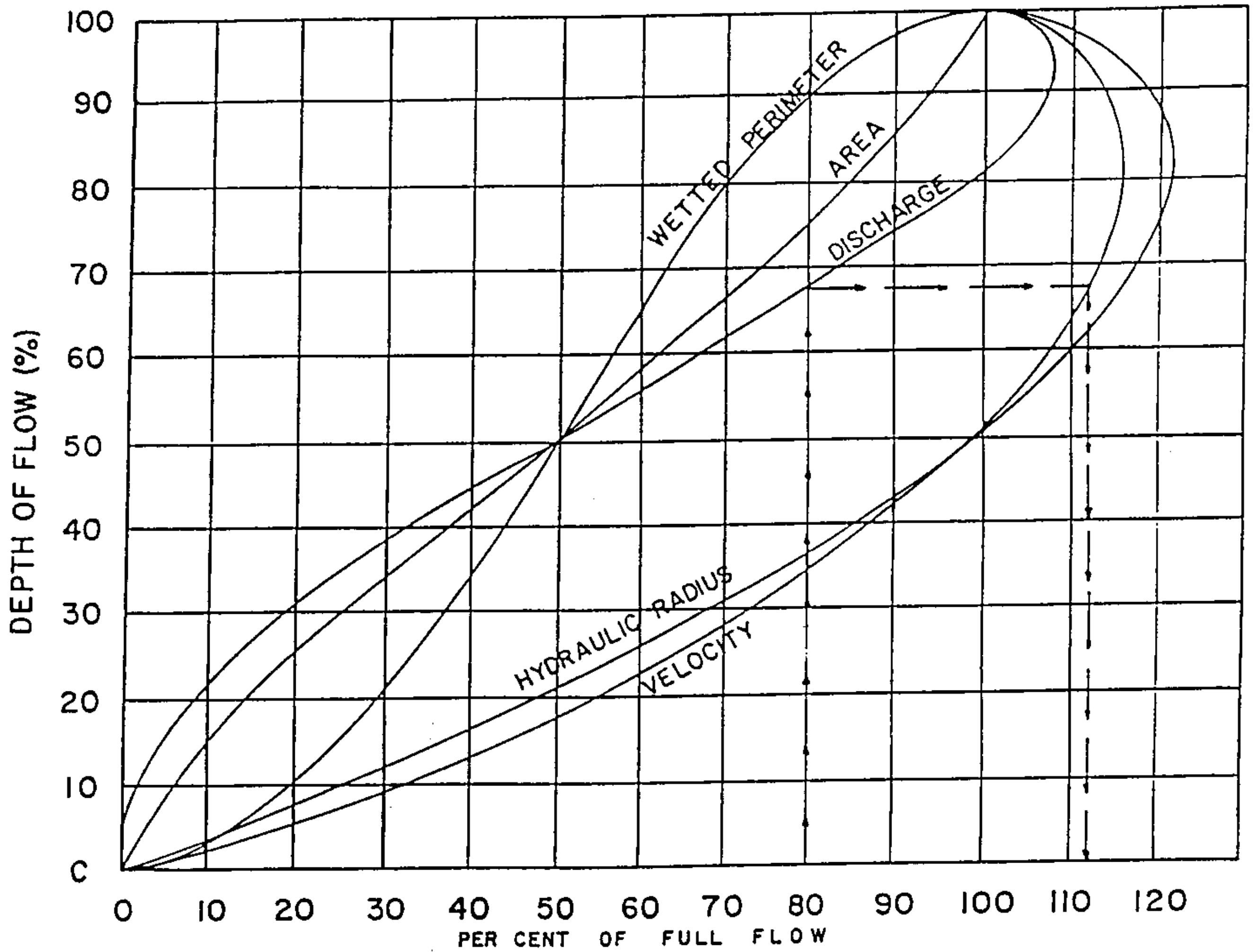
STANDARD STORM DRAIN DESIGN
FLOW IN TRIANGULAR GUTTER
CROWN SLOPE 1:48; n=0.013

SD-17

APPROVED

DATE:

ANNE ARUNDEL COUNTY
DEPARTMENT OF PUBLIC WORKS



HYDRAULIC ELEMENTS OF CIRCULAR SECTION APPROX.

EXAMPLE:

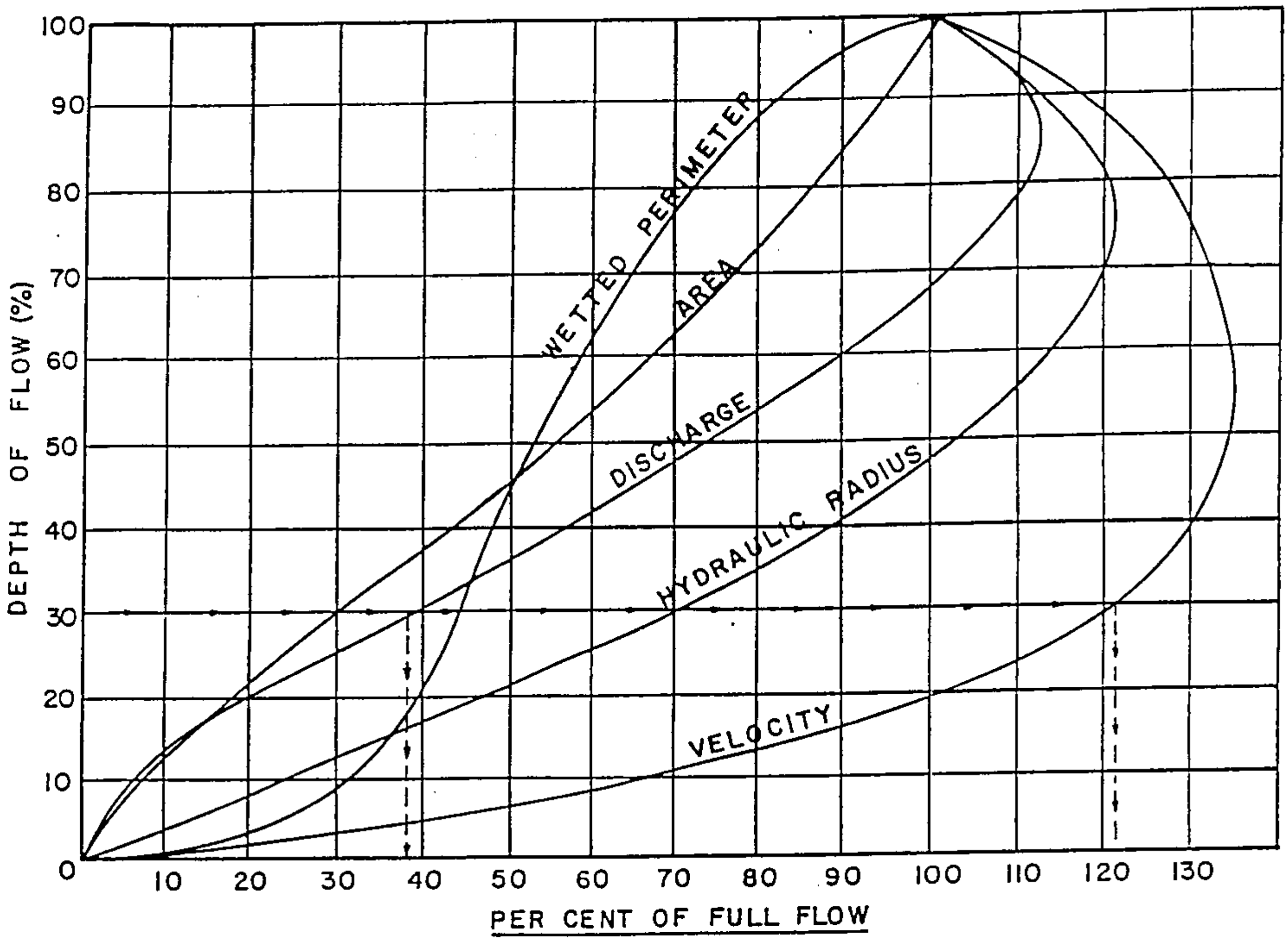
Given - Discharge flowing full 15 c.f.s., velocity =7 f.p.s.

Determine - Velocity and depth of flow when discharge is 12 c.f.s.

Solution — Enter chart at 80 % of value for full section of Hydraulic Elements. Obtain depth of flow 68% of full flow depth and velocity = 112.5% x 7 = 7.9 f.p.s.

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN HYDRAULIC ELEMENTS OF CIRCULAR SECTIONS	SD - 18.01

Composite "n" Arch Pipe (40% Paved) = .019 (Flowing full)



HYDRAULIC ELEMENTS
OF
ARCH PIPE SECTION

EXAMPLE: Given- Discharge flowing full 20 cfs; velocity =10 fps

Determine- Discharge & velocity when depth of flow is 30% of depth flowing full

Solution - Q = 38% of 20 cfs = 7.6 cfs

V = .122 % of 10 fps = 12.2 fps

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN HYDRAULIC ELEMENTS OF ARCH PIPE SECTION	SD - 18.02

Diameter (in.)	Area (sq ft)	D^2 $(ft)^2$	$D^{2/3}$ $(ft)^{2/3}$	$D^{5/2}$ $(ft)^{5/2}$	$D^{8/3}$ $(ft)^{8/3}$	$Q/S^{1/2}$ n=0.013	n=0.014	n=0.015	n=0.024	n=0.025	n=0.026
6	0.1963	0.2500	.6300	0.1768	0.1575	5.61	5.21	4.86	3.04	2.92	2.81
8	.3491	.4444	.7631	.3629	.3392	12.08	11.21	10.47	6.55	6.28	6.04
10	.5454	.6944	.8855	.6339	.6150	21.91	20.34	18.99	11.87	11.39	10.96
12	.7854	1.0000	1.0000	1.0000	1.0000	35.63	33.07	30.88	19.30	18.52	17.81
15	1.2272	1.5625	1.1604	1.7469	1.8131	64.60	59.97	55.98	34.99	33.58	32.30
18	1.7671	2.2500	1.3104	2.7557	2.9483	105.04	97.52	91.04	56.90	54.61	52.52
21	2.4053	3.0625	1.4522	4.0513	4.4474	158.45	147.11	137.33	85.83	82.38	79.23
24	3.1416	4.0000	1.5874	5.6569	6.3496	226.22	210.04	196.06	122.54	117.62	113.11
27	3.9761	5.0625	1.7171	7.5937	8.6927	309.70	287.56	268.41	167.76	161.03	154.85
30	4.9087	6.2500	1.8420	9.8821	11,5126	410.17	380.85	355.48	222.18	213.20	205.09
33	5.9396	7.5625	1.9629	12.5410	14.8441	528.87	491.08	458.35	286.47	275.01	264.43
36	7.0686	9.0000	2.0801	15.5885	18.7208	666.99	619.35	578.05	361.28	346.84	333.49
39	8.2958	10.5625	2.1941	19.0418	23.1751	825.68	766.74	715.59	447.25	429.37	412.84
42	9.6211	12.2500	2.3052	22.9177	28.2389	1006.10	934.29	871.95	544.97	523.20	503.05
48	12.5664	16.0000	2.5198	32.0000	40.3175	1436.43	1333.97	1244.91	778.07	747.02	718.22
54	15.9043	20.2500	2.7257	42.9567	55.1950	1966.49	1826.29	1704.29	1065.18	1022.72	983.24
60	19.6350	25.0000	2.9240	55.9017	73.1004	2604.42	2418.83	2257.17	1410.73	1354.55	1302.21
66	23.7583	30.2500	3.1158	70.9425	94.2541	3358.09	3118.89	2910.34	1818.97	1746.58	1679.04
72	28.2743	36.0000	3.3019	88.1816	118.8694	4215.08	3933.53	3670.41	2294.00	2202.78	2117.54
78	33.1831	42.2500	3.4829	107.7168	147.1529	5242.77	4869.60	4543.73	2839.83	2726.97	2621.39
84	38.4845	49.0000	3.6593	129.6418	179.3060	6388.32	5933.75	5536.55	3460.34	3322.90	3194.16
90	44.1786	56.2500	3.8315	154.0470	215.5245	7678.72	7132.49	6654.89	4159.30	3994.20	3839.36
96	50.2655	64.0000	4.0000	181.0193	256.0000	9120.78	8472.16	7904.68	4940.42	4744.41	4560.39
102	56.7450	72.2500	4.1650	210.6431	300.9196	10721.18	9958.94	9291.69	5807.30	5577.01	5360.59
108	63.6172	81.0000	4.3267	243.0000	350.4667	12486.44	11598.92	10821.58	6763.49	6495.40	6243.22
114	70.8822	90.2500	4.4856	278.1692	404.8209	14422.98	13398.06	12499.91	7812.45	7502.91	7211.49
120	78.5398	100.0000	4.6416	316.2278	464.1589	16537.07	15362.18	14332.13	8957.58	8602.82	8268.54

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS

APPROVED

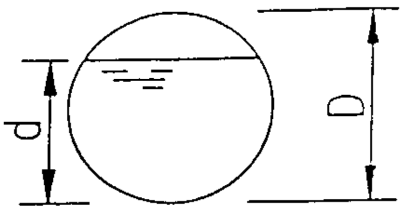
DATE:

STANDARD STORM DRAIN DESIGN

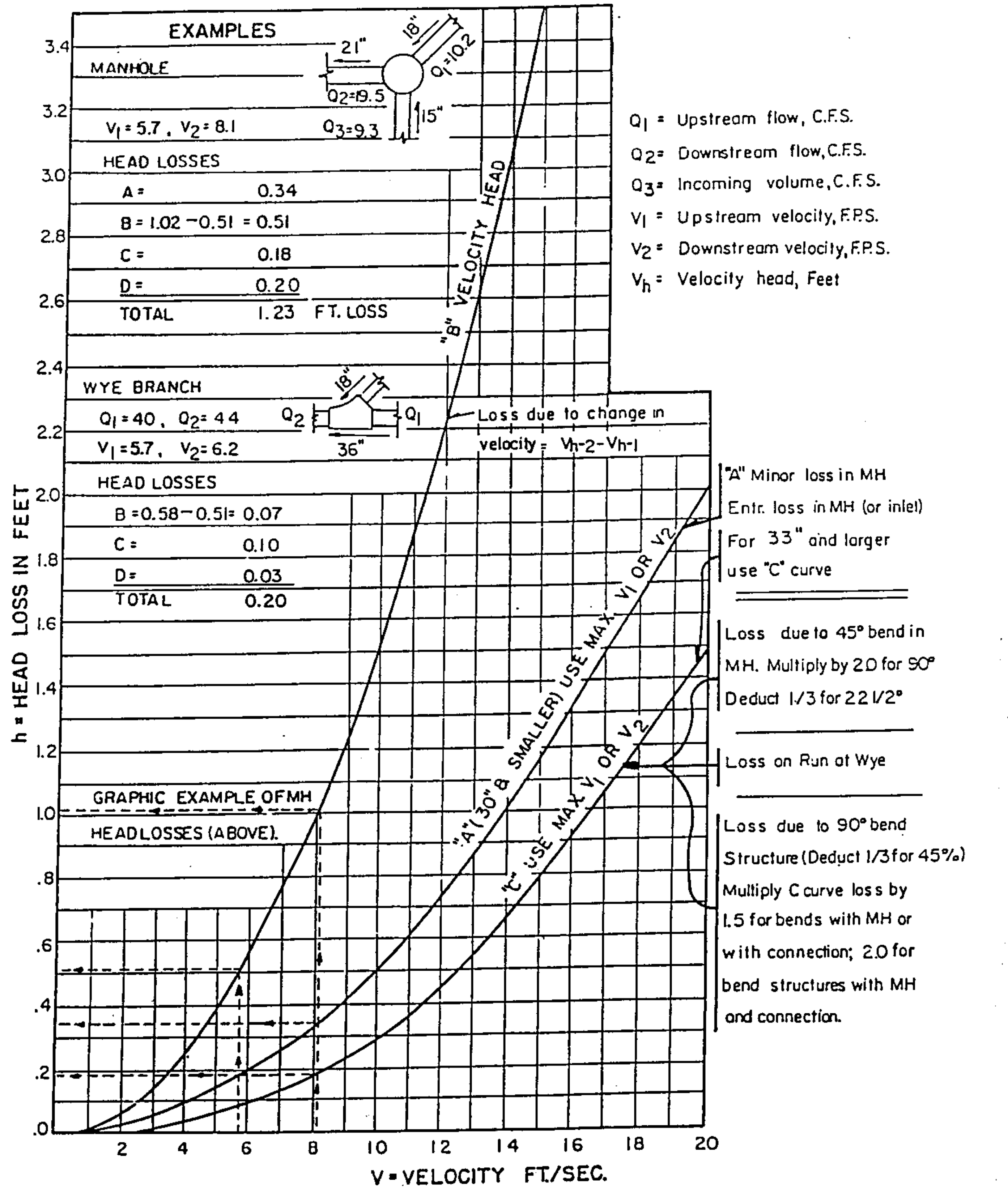
CONSTANTS FOR PIPE FLOW

SD-19.01

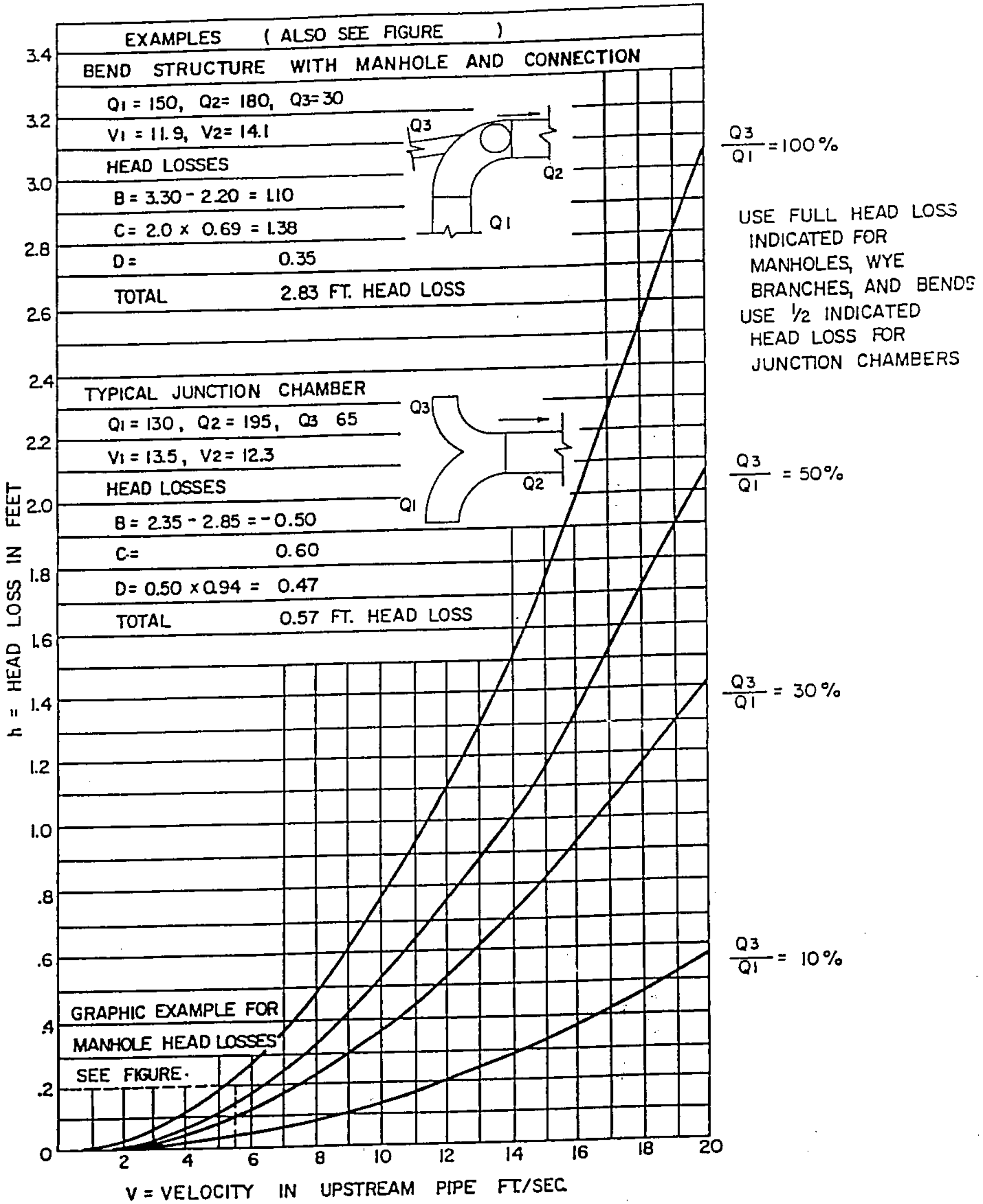
$\frac{d}{D}$	$\frac{A}{D^2}$	$\frac{Q_o}{D^{8/3}S^{1/2}}$	$\frac{Q_c}{D^{5/2}}$	$\frac{d}{D}$	$\frac{A}{D^2}$	$\frac{Q_o}{D^{8/3}S^{1/2}}$	$\frac{Q_c}{D^{5/2}}$
0.01	0.0013	0.00007	0.0006	0.51	0.4027	0.239	1.4494
0.02	0.0037	0.00031	0.0025	0.52	0.4127	0.247	1.5041
0.03	0.0069	0.00074	0.0055	0.53	0.4227	0.255	1.5598
0.04	0.0105	0.00138	0.0098	0.54	0.4327	0.263	1.6166
0.05	0.0147	0.00222	0.0153	0.55	0.4426	0.271	1.6741
0.06	0.0192	0.00328	0.0220	0.56	0.4526	0.279	1.7328
0.07	0.0242	0.00455	0.0298	0.57	0.4625	0.287	1.7924
0.08	0.0294	0.00604	0.0389	0.58	0.4724	0.295	1.8531
0.09	0.0350	0.00775	0.0491	0.59	0.4822	0.303	1.9147
0.10	0.0409	0.00967	0.0605	0.60	0.4920	0.311	1.9773
0.11	0.0470	0.01181	0.0731	0.61	0.5018	0.319	2.0410
0.12	0.0534	0.01417	0.0868	0.62	0.5115	0.327	2.1058
0.13	0.0600	0.01674	0.1016	0.63	0.5212	0.335	2.1717
0.14	0.0668	0.01952	0.1176	0.64	0.5308	0.343	2.2886
0.15	0.0739	0.0225	0.1347	0.65	0.5404	0.350	2.3068
0.16	0.0811	0.0257	0.1530	0.66	0.5499	0.358	2.3760
0.17	0.0885	0.0291	0.1724	0.67	0.5594	0.366	2.4465
0.18	0.0961	0.0327	0.1928	0.68	0.5687	0.373	2.5182
0.19	0.1039	0.0365	0.2144	0.69	0.5780	0.380	2.5912
0.20	0.1118	0.0406	0.2371	0.70	0.5872	0.388	2.6656
0.21	0.1199	0.0448	0.2609	0.71	0.5964	0.395	2.7416
0.22	0.1281	0.0492	0.2857	0.72	0.6054	0.402	2.8188
0.23	0.1365	0.0537	0.3116	0.73	0.6143	0.409	2.8977
0.24	0.1449	0.0585	0.3386	0.74	0.6231	0.416	2.9783
0.25	0.1535	0.0634	0.3667	0.75	0.6319	0.422	3.0606
0.26	0.1623	0.0686	0.3957	0.76	0.6405	0.429	3.1450
0.27	0.1711	0.0739	0.4259	0.77	0.6489	0.435	3.2314
0.28	0.1800	0.0793	0.4571	0.78	0.6573	0.441	3.3200
0.29	0.1890	0.0849	0.4893	0.79	0.6655	0.447	3.4111
0.30	0.1982	0.0907	0.5226	0.80	0.6736	0.453	3.5051
0.31	0.2074	0.0966	0.5569	0.81	0.6815	0.458	3.6020
0.32	0.2167	0.1027	0.5921	0.82	0.6893	0.463	3.7021
0.33	0.2260	0.1089	0.6284	0.83	0.6969	0.468	3.8062
0.34	0.2355	0.1153	0.6657	0.84	0.7043	0.473	3.9144
0.35	0.2450	0.1218	0.7040	0.85	0.7115	0.477	4.0276
0.36	0.2546	0.1284	0.7433	0.86	0.7186	0.481	4.1466
0.37	0.2642	0.1351	0.7836	0.87	0.7254	0.485	4.2722
0.38	0.2739	0.1420	0.8249	0.88	0.7320	0.488	4.4057
0.39	0.2836	0.1490	0.8672	0.89	0.7384	0.491	4.5486
0.40	0.2934	0.1561	0.9104	0.90	0.7445	0.494	4.7033
0.41	0.3032	0.1633	0.9546	0.91	0.7504	0.496	4.8724
0.42	0.3130	0.1705	0.9997	0.92	0.7560	0.497	5.0602
0.43	0.3229	0.1779	1.0459	0.93	0.7612	0.498	5.2727
0.44	0.3328	0.1854	1.0929	0.94	0.7662	0.498	5.5182
0.45	0.3428	0.1929	1.1410	0.95	0.7707	0.498	5.8119
0.46	0.3527	0.201	1.1900	0.96	0.7749	0.496	6.1785
0.47	0.3627	0.208	1.2400	0.97	0.7785	0.494	6.6695
0.48	0.3727	0.216	1.2908	0.98	0.7817	0.489	7.4063
0.49	0.3827	0.224	1.3427	0.99	0.7841	0.483	8.8261
0.50	0.3927	0.232	1.3956	1.00	0.7854	0.463	-------



ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN TABULAR VALUES OF HYDRAULIC ELEMENTS OF PIPES	SD-19.02



ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN HEAD LOSSES IN STRUCTURES "A", "B" & "C" LOSSES	SD - 20.01



ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN HEAD LOSSES IN STRUCTURES "D" LOSS	SD - 20.02

STRUCTURE LOSSES

A : ENTRANCE AND EXIT
B : DIFFERENCE IN VELOCITY HEADS
C : CHANGE IN DIRECTION
D : INCOMING VOLUME

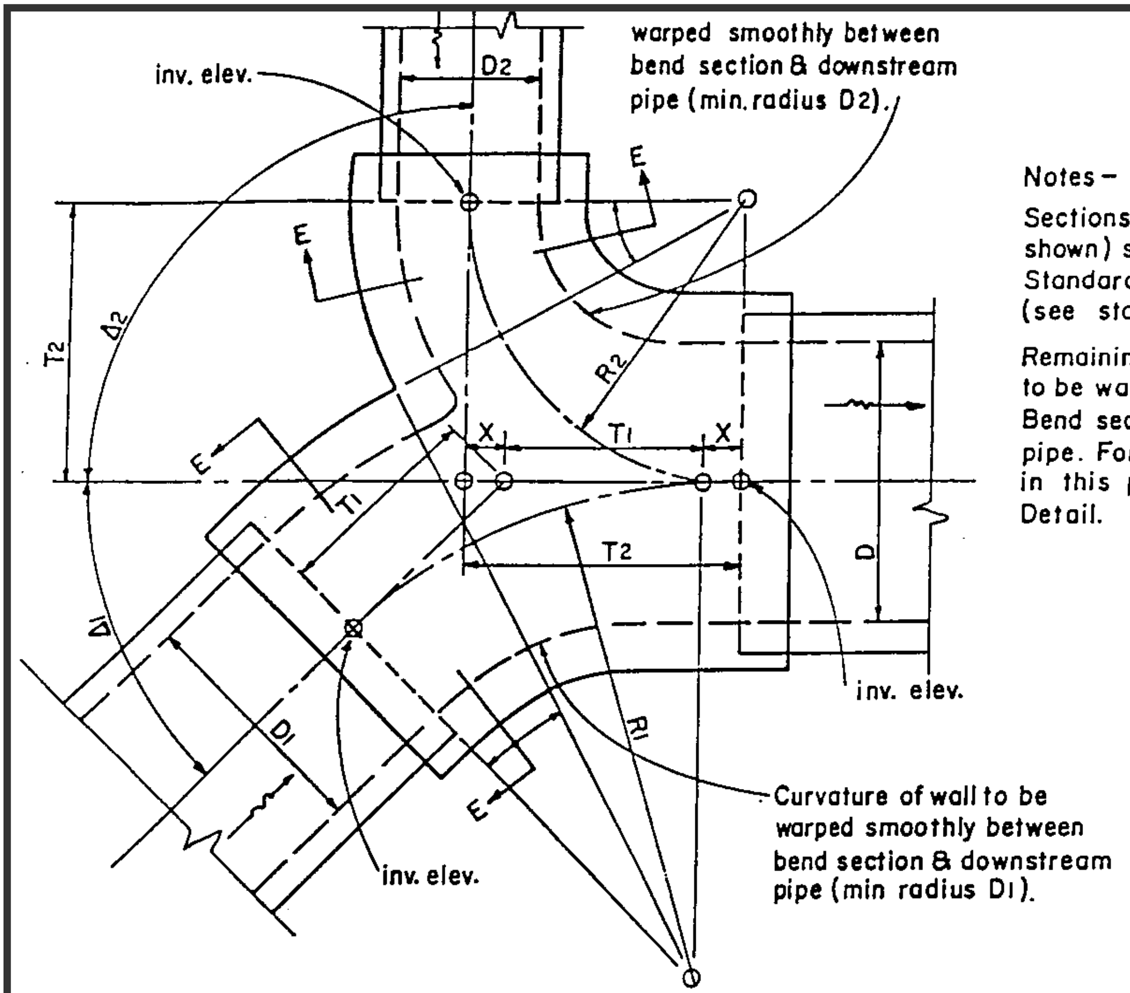
MULTIPLES APPLICABLE TO LOSSES THROUGH STRUCTURES

TYPE STRUCTURE	DEFLECTION	TYPE LOSS			
		A	B	C	D
BEND STRUCTURES	90° 45°		1 1	1 2/3	1 1
BEND STRUCTURE WITH MAN-HOLE OR CONNECTION	90° 45°		1 1	3/2 1	1 1
BEND STRUCTURE WITH MAN-HOLE AND CONNECTION	90° 45°		1 1	2 4/3	1 1
JUNCTION CHAMBER			1	1	1/2
JUNCTION CHAMBER W/MH			1	3/2	1/2
MANHOLES (30" AND SMALLER PIPE)	90° 45° 22 1/2°	1 1 1	1 1 1	2 1 2/3	1 1 1
MANHOLES (33" AND LARGER PIPE)	90° 45° 22 1/2°	C* C* C*	1 1 1	2 1 2/3	1 1 1
WYES			1	1	1
MONOLITHIC STRUCTURE			1	**	1

* THE "A" LOSS IS EQUAL IN VALUE TO THE "C" LOSS.

** FOR LOSSES DUE TO CHANGE IN DIRECTION IN LONG AND SHORT RADIUS BENDS, SEE PAGE D-12

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN HEAD LOSSES IN STRUCTURE	SD-20.03



Notes –

Sections E-E (between limits shown) shall conform to Standard Bend Structure (see standard detail).

Remaining Portion of Structure to be warped smoothly between Bend sections & downstream pipe. For top slab reinforcing in this portion see Standard Detail.

PLAN

(AS SHOWN ON CONTRACT DRAWINGS)

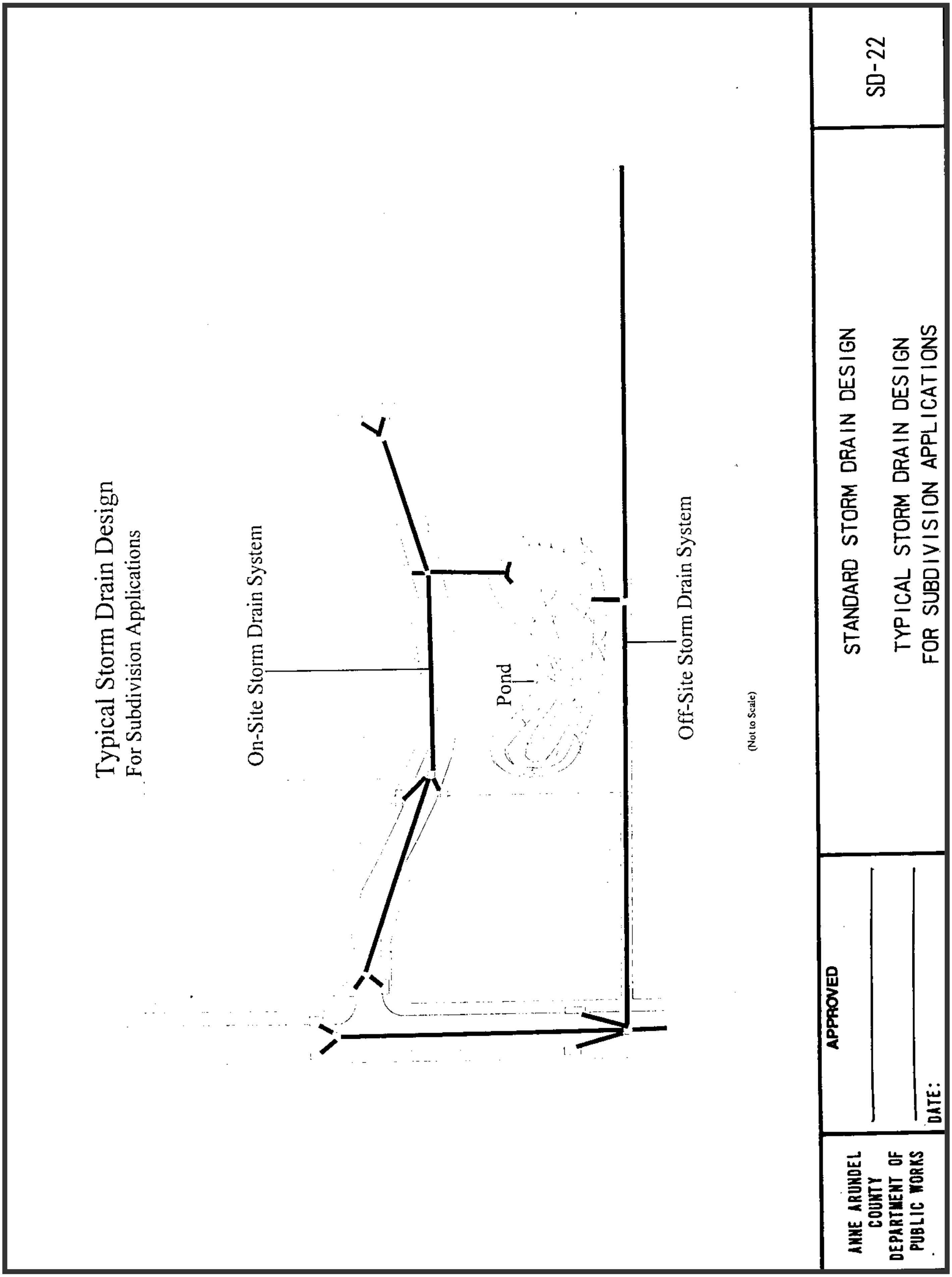
PROCEDURE AND CONSIDERATIONS FOR DETAILING

1. Determine Δ_1 & Δ_2 from pipe alignments.
2. Determine R_1 & R_2.
   $R_1 = 2D_1$
   $R_2 = 2D_2$
3. Compute T_1 & T_2.
4. Determine X.
   X = (Difference between T_1 & T_2) ÷ 2
5. Lay out structure on Contract Drawings as shown on above PLAN (with dimensions & notes as shown).

Note –

Type I Junction Chamber shall be used for 48" and smaller pipe where velocities are less than 15 ft. per second.
For pipe sizes larger than 48" Special Junction Chambers shall be designed and shown on Contract Drawings.

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS	APPROVED DATE:	STANDARD STORM DRAIN DESIGN TYPE I JUNCTION CHAMBER METHOD OF DETAILING	SD - 21


Typical Storm Drain Design
For Subdivision Applications
On-Site Storm Drain System
Pond
Off-Site Storm Drain System
(Not to Scale)
SD-22
STANDARD STORM DRAIN DESIGN
TYPICAL STORM DRAIN DESIGN
FOR SUBDIVISION APPLICATIONS
APPROVED
DATE:
ANNE ARUNDEL
COUNTY
DEPARTMENT OF
PUBLIC WORKS