CITY OF LONGMONT
STORM DRAINAGE CRITERIA MANUAL

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SECTION 900 STREETS

901 INTRODUCTION

The criteria presented in this section shall be used in the evaluation of the allowable drainage encroachment within public streets. The review of all planning submittals (Section 200) will be based on the criteria herein.

902 FUNCTION OF STREETS IN THE DRAINAGE SYSTEM

Urban and rural streets, specifically the curb and gutter or the roadside ditches are part of the Minor Drainage System. When the drainage in the street exceeds allowable limits (Section 304.5), a storm sewer system (Section 800) or an open channel (Section 700) is required to convey the excess flows. The streets are also part of the Major Drainageway System when they carry floods in excess of the minor storm (Section 304.3), also subject to certain limitations (Section 304.5). However, the primary function of urban streets is for traffic movement and therefore the drainage functions are subservient and must not interfere with the traffic function of the street.

Design criteria for the collection and moving of runoff water on public streets is based on a reasonable frequency and magnitude of traffic interference. That is, depending on the character of the street, certain traffic lanes can be fully inundated once during the minor design storm return period. However, during less intense storms, runoff will also inundate traffic lanes but to a lesser degree. The primary function of the streets for the Minor Drainage System is therefore to convey the nuisance flows quickly and efficiently to the storm sewer or open channel drainage without interference with traffic movement. For the Major Drainageway System, the function of the streets is to provide an emergency passageway for the flood flows with minimal damage to the urban environment.

903 DRAINAGE IMPACTS ON STREETS

Storm runoff can influence the traffic function of a street in the following ways:

1. Sheet flow across the pavement resulting from precipitation runoff.
2. Runoff in the gutter.
3. Duration of the storm.
4. Ponded water.
5. Flow across traffic lanes.
6. Deterioration of the street

To minimize the drainage impact on the streets, each of the above factors must be understood and controlled to within acceptable limits. The effect of the above factors is discussed in the following sections.

903.1 Sheet Flow

Rainfall on the paved surface of a street or road must flow overland in what is referred to as sheet flow until it reaches a channel. In streets which have curbs and gutters, the curb and gutter become the channel, while on roads which have a drainage ditch, the ditch becomes the channel. The depth of sheet flow will be essentially zero at the crown of the street and will increase in the direction of the channel.

Traffic interference due to sheet flow is by hydro-planing or by splash. Hydro-planing is the phenomenon of vehicle tires becoming supported by a film of water which acts as a lubricant between the pavement and the vehicle. This phenomenon generally occurs at higher speeds associated with arterials and freeways and can result in loss of vehicle control. Drainage design can reduce the hydro-planing potential by increasing the street cross slope which drains the runoff more quickly.

Splashing of the sheet flows interferes with traffic movement by reducing visibility. The increase in cross slope of the street crown also reduces the splash potential. The crown slope must be kept within acceptable limits to prevent the sideways slipping of traffic during icy conditions. In general, a 2 percent cross slope is a desirable practical slope.

903.2 Gutter Flow

Water which enters a street as sheet flow from the pavement surface or as overland flow from adjacent land area will flow in the gutter of the street until reaching some outlet, such as a storm sewer or a channel. As the flow progresses downhill and additional areas contribute to the runoff, the width of flow will increase and progressively infringe upon the traffic lane. If vehicles are parked adjacent to the curb, the flow width will have little influence on traffic capacity until it exceeds the width of the vehicle by several feet. However, on streets where parking is not permitted, the flow width significantly effects traffic movement after exceeding a few feet, because the flow encroaches on a moving lane rather than a normal parking lane. Field observations show that vehicles will crowd adjacent lanes to avoid curb flow. This creates a traffic hazard which contributes to the rash of small accidents that occur during rainstorms.

As the flow width increases, the traffic must eventually move through the inundated lanes progressively reducing traffic movement as the depth of flow increases. Whereas some drainage effects on traffic movement are acceptable, emergency vehicles (i.e., fire equipment, ambulances, police vehicles) must be able to travel the streets, such as by moving along the street crown. Therefore, certain limitations on the depth of flow in the street are required.

903.3 Storm Duration

The storm duration also plays a role in the drainage impact on the streets. The high intensity, short duration thunderstorms typical of the region generally do not influence traffic for more than 30-minutes per storm, and generally do not occur during high traffic volume periods. Therefore, increased flow depths are tolerable for the shorter flood periods.

903.4 Ponding

Storm runoff ponded on the street, due to grade changes or intersecting street crowns, effects traffic movement by increasing flow depths and duration at the greater depths. Ponding is also localized and vehicles may enter the ponded area at high speeds unaware of the problem until too late. Ponding will often bring traffic to a complete halt to negotiate the ponded area without stalling the vehicle, resulting in reduced traffic movement. Therefore, depths of ponding must be controlled similar to gutter flow and in some cases eliminated on high traffic volume streets.

903.5 Cross Flow

Whenever storm runoff, other than sheet flow, moves across a traffic lane, traffic flow is effected. The cross flow may be caused by super-elevation of a curve by the intersection of two streets, by exceeding the capacity of the higher gutter on a street with cross fall, or simply poor street design. The problem associated with this type of flow is the same as for ponding in that it is localized in nature and vehicles may be travelling at high speed when they reach the location. If the speed limits are slow and the traffic volume is light, then the influence of cross street flow may be within acceptable limits.

903.6 Maintenance

1. Bituminous Pavements

   The efficient removal of storm runoff from pavement surfaces has a positive effect on street maintenance, and street maintenance procedures can in turn affect the efficiency of a street as a runoff carrier. Research has indicated that pavement deterioration is accelerated by the presence of storm runoff.

   Pavement surfaces are subject to numerous types of distress such as weathering, ravelling, long cracks, alligator cracks, chuck holes, bleeding, depression, and edge breakup. Water is probably the greatest cause of distress in a pavement structure. Flow of water across a bituminous pavement surface has little effect on the pavement so long as the pavement retains its watertight condition. A number of types of pavement distress may cause the pavement to become permeable, allowing water to reach the sub-grade. Once the water reaches the sub-grade the problems multiply as the sub-base and sub-grade weakens and increases the cracks through the surface.

   A common practice, to reduce the problem of bituminous surface deterioration, is to seal-coat or overlay the surface. This reduces the problem of pavement deterioration but indirectly creates a problem with the carrying capacity of the adjacent gutter. If an average street is over-laid or seal-coated every 5 to 10 years with a thickness which may vary from 1/4- to 3/4-inch, in a period of 20 to 40 years the pavement surface could be built up from 2- to 6-inches. If this thickness were carried uniformly to the curb, the curb may effectively disappear. If the outside edge of the over-lay is feathered to meet the gutter, the crown slope of the street will increase until it becomes difficult, if not impossible, to open automobile doors. Although the curb height is still present, the over-lay decreases the water carrying cross section.

A practical, inexpensive solution to the problem of overlaying streets has not been developed. Scarifying the surface to remove the upper layer of asphalt before applying the next overlay minimizes the problem, but the method is expensive. In any case, the gutter capacity must be maintained or additional drainage facilities (i.e., inlets and storm sewers) added to the system.

2. Curb and Gutter

The break-up of pavement adjacent to the gutter is a problem recognized by both traffic and drainage engineers. The character of this problem varies from cracking and potholes to actual peeling of long sections of pavement during high flows. The damage is basically caused by intrusion of water into the sub-base through the interface between the pavement and the gutter. Poor bonding of the pavement to the gutter concrete, combined with shrinkage of the pavement, results in a crack. Even small amounts of water from the pavement surface are intercepted by the crack. During the high flow periods, larger quantities of curb flow and ponded water will pass through the crack into the sub-base. These factors result in almost continuous wetting of the sub-grade adjacent to the gutter face, failure of the sub-grade, and deterioration of the pavement.

Several theories have been suggested to explain the peeling of pavement surfaces when subjected to storm runoff. These theories include consideration of tractive force, the washing out of fines from the supporting materials, and the uplift forces resulting from conversion of velocity head to pressure head when flowing water is trapped under the pavement surface. Although all these factors contribute to pavement peeling, uplift is the most significant. Uplift forces can be minimized by taking meaures to prevent water from getting under the pavement. The intrusion of water between the pavement and gutter face may be prevented by sealing the space with crack filler.

3. Sedimentation

A common problem on streets occurs when material carried by high velocity gutter flow settles out as the velocity decreases on shallow grades. As sediment builds up in areas of low velocity flow, the width of spread onto the paved surface will increase. The degree to which this occurs is dependent upon the amount of settleable solids in the runoff as well as the magnitude of the velocity. Certain areas, by nature of the type of development, will contribute runoff with larger amounts of sediment.

Maintenance of street surfaces in the form of regular sweeping can reduce both the occurrence and effects of sedimentation. By sweeping upstream areas, the source of much sediment is eliminated. Areas where sedimentation occurs should be swept after each storm to remove sediment and minimize accumulation between storms.

904 STREET CLASSIFICATION

The streets in City of Longmont are classified for drainage use as Type B, C, or D according to the average daily traffic (ADT) for which the street is designed. The larger the ADT, the more restrictive is the allowable drainage encroachment into the driving lanes. The limits of storm runoff encroachment for each Drainage Classification and storm condition is set forth under the Policy Section of this manual (Section 304.5).

Presented in Table-901 is the Traffic Classification (i.e., arterial, collector, etc), the corresponding Drainage Classification (i.e., Type B, C, or D) and the allowable flow depth for the initial and major storm. The limitations on the depth are based on the policy for encroachment (Section 304.5). To determine the maximum allowable street flow capacity (see Section 905), the allowable flow depth for the particular traffic classification is first obtained from Table-901.

905 HYDRAULIC EVALUATION

905.1 Allowable Capacity - Minor Storm

Based upon the policy of Section 304.5 and the Drainage Classification of each street in Section 904, the allowable minor storm capacity of each street section is calculated using the modified Mannings formula.

$$Q = (0.56)(Z/n)S^{1/2}\ Y^{8/3} \tag{901}$$

Where Q = discharge in cfs

$Z = 1/S_x$, where S_x is the cross slope of the pavement (ft/ft)

Y = depth of water at face of curb (feet)

S = longitudinal grade of street (ft/ft)

n = Mannings roughness coefficient

The solution to the above equation can also be obtained through the use of the nomograph of Figure-901.

The allowable capacity for each street cross-section has been calculated and is presented in Figure-902. The calculations are on file with City of Longmont and have been published in a Technical Memorandum (Reference-57). The calculations were performed for various allowable flow depths (Table-901) and street slopes. A Mannings n-value of 0.016 was used for the gutter and street flow areas. The theoretical capacity was calculated and then the reduction factor (Figure-6-2, Reference-1) was applied to reduce the potential for damage from regular recurring storm runoff and to prolong the life of the pavement (refer to Section 903). The use of Figure-902 is illustrated by example in Section 906.

905.2 Allowable Capacity - Major Storm

The allowable street capacity for the major storm is calculated using the Mannings formula (Equation 701, Section 703.1) by first dividing the street cross section into the pavement area and sidewalk/grass area and then computing the individual flow contributions. The capacity is subject to the limitations set forth in the Policy Section 304.5 and the drainage classification of Section 904. The capacity calculations were performed for each street cross section and published in a Technical Memorandum (Reference-57) on file with City of Longmont. The calculations were performed for various allowable flow depths and street slopes and plotted in Figure-903. A Mannings n-value of 0.016 for the pavement area and 0.025 for the sidewalk/grass area was used to determine the capacity. The reduction factor from Figure-6-2, Reference-1 was also applied to reduce the allowable storm runoff in the street. The backslope from the curb was assumed to be 2 percent until reaching the street ROW limits. The maximum allowable depth at the gutter is 12-inches (Section 304.5), but the street capacity is generally limited by the ROW. The use of Figure-903 is illustrated by an example in Section 906.

905.3 Rural Roads

Rural streets are characterized by roadside ditches rather than curb and gutters for urban streets. The capacity is limited by the depth in the ditch and the maximum flow velocity. For the initial storm, the 5-year flow depth in the ditch shall not exceed 18-inches due to the geometry limitations (see Figure-708). The capacity of the ditch is presented in Table-705 and is limited also by the maximum allowable Froude Number.

For the major storm, the capacity limitation is also controlled by the ditch geometry and the ROW of the street. The allowable capacity for the major storm is the same as for the initial storm unless additional ROW is provided and the backslope from the ditch will contain the flows within the ROW.

906 EXAMPLE

Example 18: Determination of Street Capacity

Given: Street with a traffic classification of "Local" within a high volume residential land use area, and a slope of 1 percent.

Find: Maximum allowable capacity for initial and major storm.

Solution:

Step 1: From Table-901 read the drainage classification as a Type B street. The maximum allowable depth for the initial storm is 0.50-feet. This limit is established by criteria that the flow must not overtop the curb (Section 304.5).

Step 2: From Figure-902 for an allowable depth of 0.50-feet and a slope of 1 percent, read the allowable gutter capacity of 11.0 cfs. The flow velocity can also be obtained from Figure-702 by interpolating between the velocity lines (V = 3.2 fps).

Step 3: From Table-901 read the allowable flow depth for the major storm (d = 0.60-feet). This limit is established by the criteria that the flow may not spread past the street ROW.

Step 4: From Figure-903 for the allowable depth of 0.60-feet and a slope of 1 percent read the allowable capacity of 16 cfs per gutter or 32 cfs for the total street.

STREET CLASSIFICATION

TRAFFIC CLASSIFICATION[1]	DRAINAGE CLASSIFICATION[2]	ADT[1]	ALLOW FLOW DEPTH[3] MINOR STORM (FT)	ALLOW FLOW DEPTH[3] MAJOR STORM (FT)
Principal Arterial	D	12,000 to 28,000	0.50	0.82
Minor Arterial-4 Lanes	D	10,000 to 18,000	0.50	0.88
Minor Arterial-2 Lanes	C	6,000 to 10,000	0.43	1.00
Major Collector	C	1,000 to 8,000	0.43	0.90
Residential Collector	B	500 to 2,500	0.48	0.75
Local Access-Urban	B	100 to 500	0.50	0.63
Local Access-Rural	B	100 to 500	(4)	(4)
Private Roads-2 Lanes	A	150 to 500	0.43	0.71
Private Driveway	A	0 to 150	(5)	(5)

NOTES:
1. Refer to Table 4-6, Section 4.4 of the "Boulder County Road Standards and Specifications.
2. Refer to Section 304.5 of this MANUAL.
3. Allowable flow depth measured from flowline at curb face.
4. Rural streets require roadside ditches. Refer to Section 704.5 of this MANUAL for capacity data.
5. Storm drainage capacity not required.

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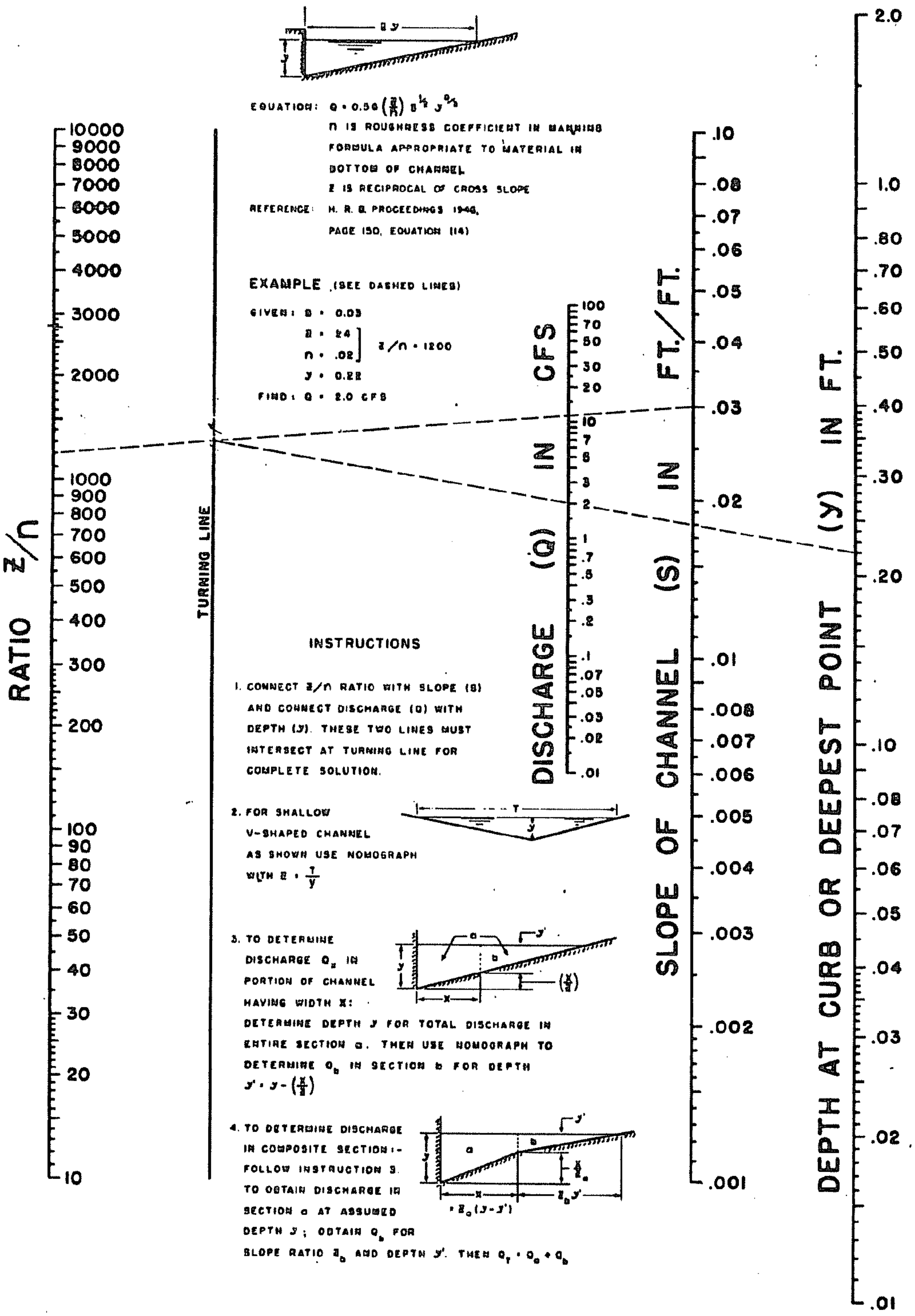
FIGURE 901

NOMOGRAPH FOR FLOW IN TRIANGULAR GUTTERS



EQUATION: $Q = 0.56 \left(\frac{z}{n}\right) S^{1/2} y^{8/3}$
n IS ROUGHNESS COEFFICIENT IN MANNING FORMULA APPROPRIATE TO MATERIAL IN BOTTOM OF CHANNEL
z IS RECIPROCAL OF CROSS SLOPE
REFERENCE: H. R. B. PROCEEDINGS 1946, PAGE 150, EQUATION (14)

EXAMPLE (SEE DASHED LINES)

GIVEN: $S = 0.03$
$z = 24$, $n = .02$ — $z/n = 1200$
$y = 0.22$
FIND: $Q = 2.0$ CFS

INSTRUCTIONS

1. CONNECT z/n RATIO WITH SLOPE (S) AND CONNECT DISCHARGE (Q) WITH DEPTH (y). THESE TWO LINES MUST INTERSECT AT TURNING LINE FOR COMPLETE SOLUTION.

2. FOR SHALLOW V-SHAPED CHANNEL AS SHOWN USE NOMOGRAPH WITH $z = \frac{T}{y}$

3. TO DETERMINE DISCHARGE Q_x IN PORTION OF CHANNEL HAVING WIDTH x: DETERMINE DEPTH y FOR TOTAL DISCHARGE IN ENTIRE SECTION a. THEN USE NOMOGRAPH TO DETERMINE Q_b IN SECTION b FOR DEPTH $y' = y - \left(\frac{x}{z}\right)$

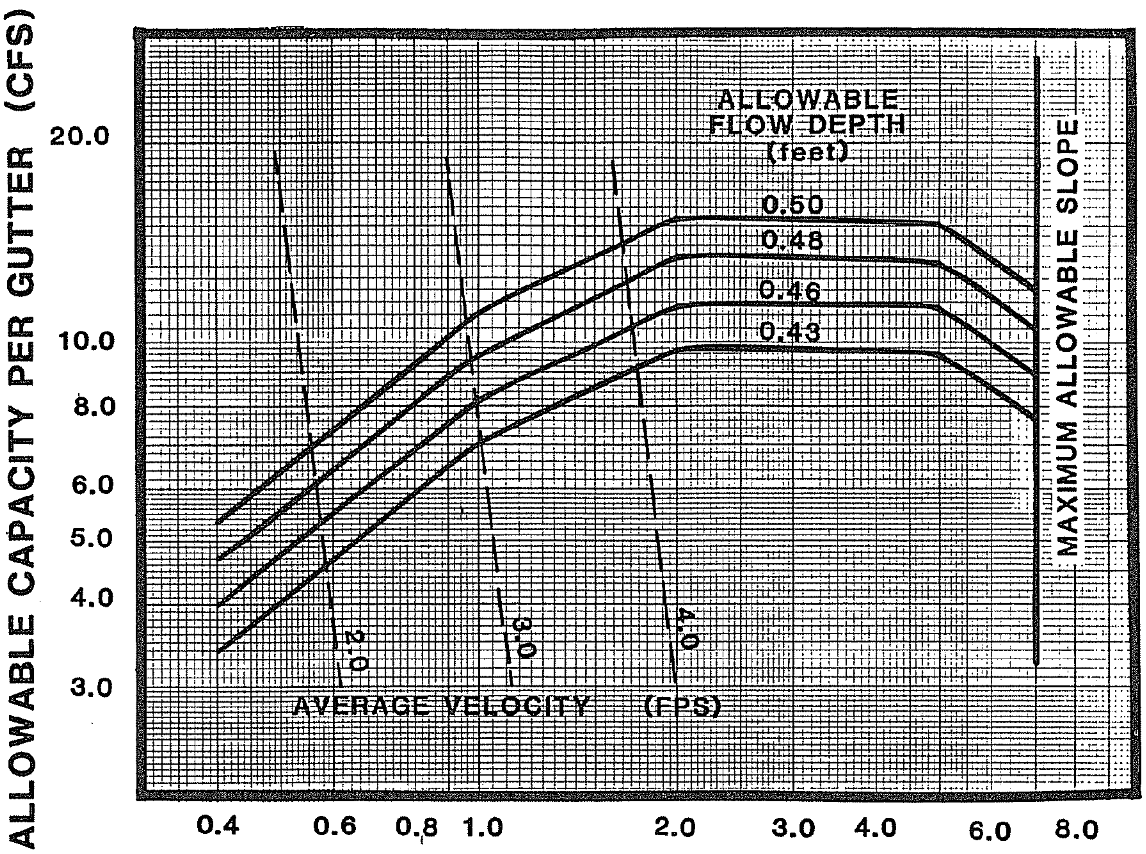
4. TO DETERMINE DISCHARGE IN COMPOSITE SECTION:- FOLLOW INSTRUCTION 3. TO OBTAIN DISCHARGE IN SECTION a AT ASSUMED DEPTH y; OBTAIN Q_b FOR SLOPE RATIO z_b AND DEPTH y'. THEN $Q_T = Q_a + Q_b$

WRC ENG.

REFERENCE: USDCM, DRCOG, 1969

ALLOWABLE GUTTER CAPACITY

MINOR STORM



STREET SLOPE (%)

DESIGN CONDITIONS

$Q = F(0.56 \frac{z}{n} S^{1/2} d^{8/3})$

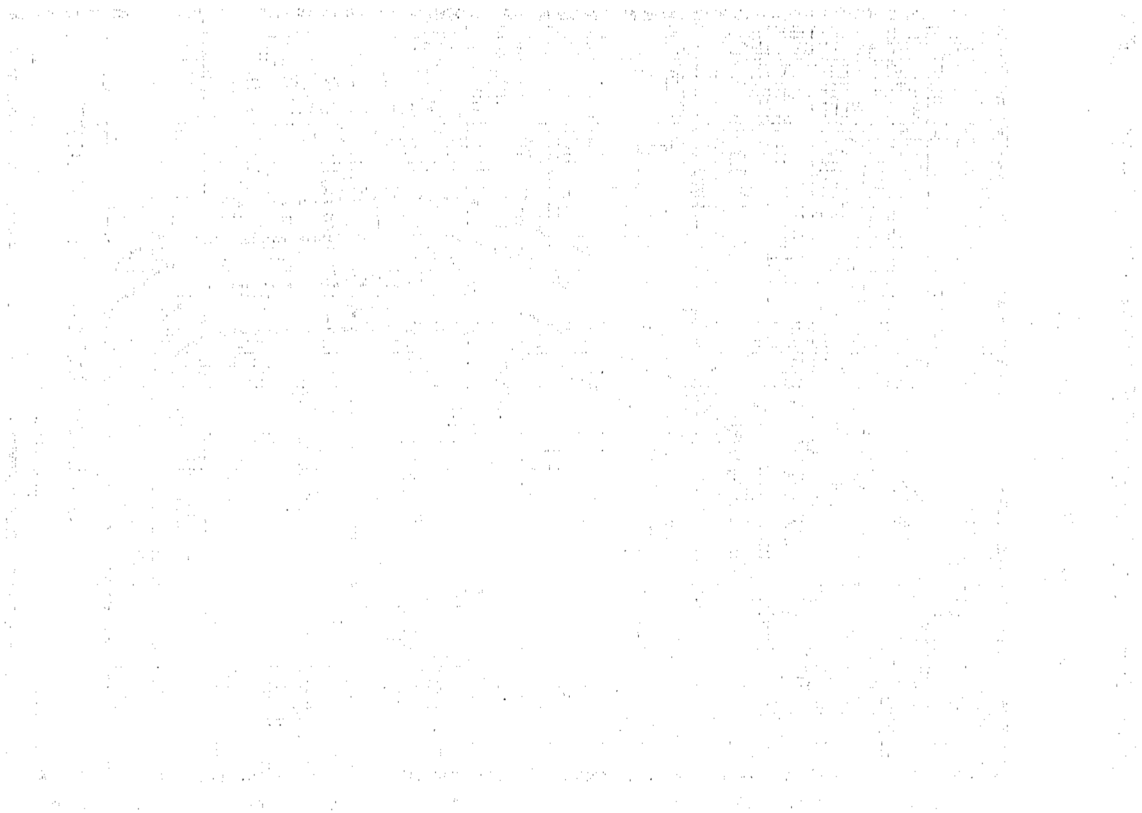
F = (from Fig. 6-2, Ref I)

n = 0.016 for STREETS

NOTE: See Table 901 for allowable depth of flow.

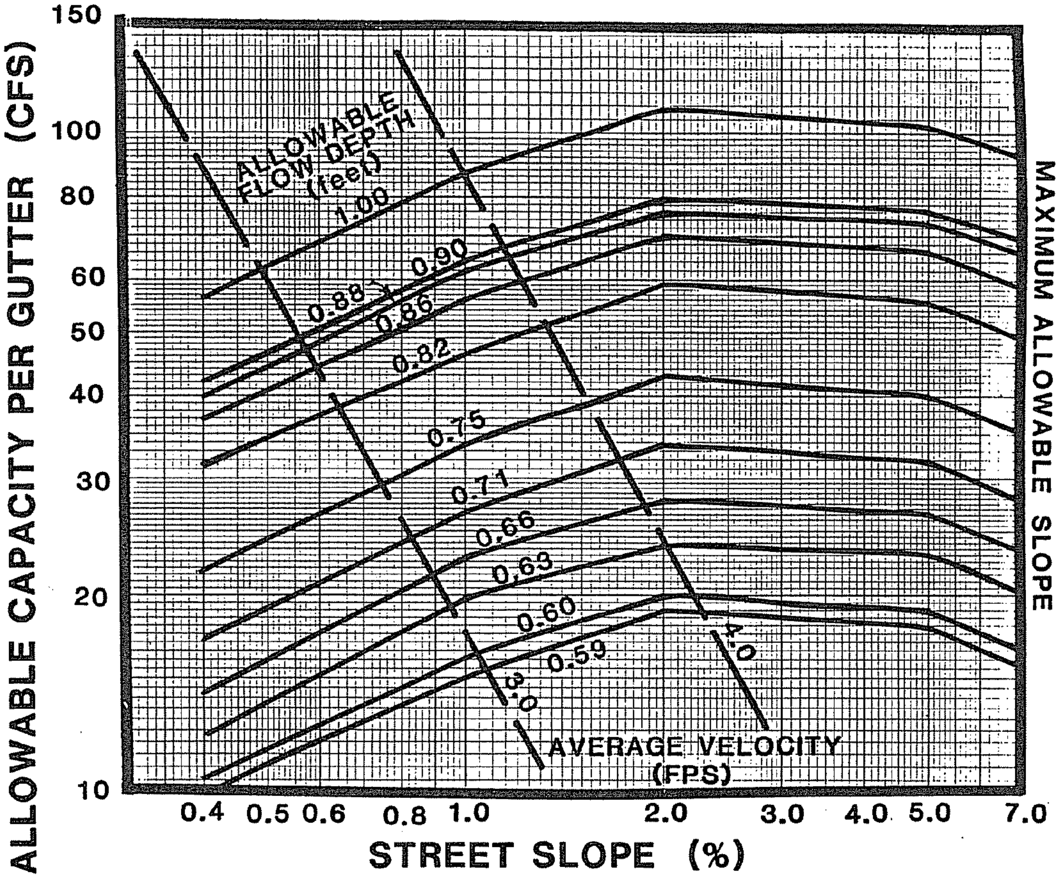
WRC ENG.

REFERENCE: WRC ENGINEERING, INC., TM-2 FEB 1984



ALLOWABLE GUTTER CAPACITY

MAJOR STORM



NOTE: See Table 901 for allowable depth of flow.

DESIGN CONDITIONS

$Q = F(0.56 \frac{z}{n} S^{1/2} d^{8/3})$

F = (from Fig. 6-2, Ref I)

n = 0.016 for STREETS

n = 0.025 for GRASS

WRC ENG.

REFERENCE:
WRC ENGINEERING, INC., TM-2 FEB 1984