SECTION 3 – STREET FLOW

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3.1.0 GENERAL

The location of inlets and permissible flow of water in streets should be related to the extent and frequency of interference to traffic and the likelihood of flood damage to surrounding property for the 25 and 100 year frequency storms. Interference to traffic is regulated by design limits of the spread of water into traffic lanes, especially in regard to arterials. Flooding of surrounding property from streets is controlled by limiting curb buildup to the top of curb for a 25 year storm which is designated as the design storm. Conveyance provisions for the 100 year storm must also be made within defined right of way and easements.

3.1.1 Interference Due to Flow in Streets

Water which flows in a street, whether from rainfall directly onto the pavement surface or overland flow entering from adjacent land areas, will flow in the gutters of the street until it reaches an overflow point or some outlet, such as a storm sewer inlet. As the flow progresses downhill and additional areas contribute to the runoff, the width of flow will increase and progressively encroach into the traffic lane. On streets where parking is not permitted, as with many arterial streets, flow widths exceeding one traffic lane become a traffic hazard. Field observations show that vehicles will crowd adjacent lanes to avoid curb flow.

As the width of flow increases, it becomes impossible for vehicles to operate without moving through water in an inundated lane. Splash from vehicles traveling in the inundated lane obscures the vision of drivers of vehicles moving at a higher rate of speed in the open lane. Eventually, if width and depth of flow become great enough, the street loses its effectiveness as a traffic-carrier. During these periods, it is imperative that emergency vehicles such as fire trucks, ambulances and police cars be able to traverse the street by moving along the crown of the roadway.

3.1.2 Interference Due to Ponding

Storm runoff ponded on the street surface because of grade changes or because of the crown slope of intersecting streets has a substantial effect on the street-carrying capacity. The manner in which ponded water affects traffic is essentially the same as for curb flow; that is, the width of spread into the traffic lane is critical. Ponded water will often completely halt all traffic. Ponding in streets has the added hazard of surprise to drivers of moving vehicles, producing erratic and dangerous responses.

3.1.3 Street Cross Flow

Whenever storm runoff, other than limited sheet flow, moves across a traffic lane, a serious and dangerous impediment to traffic flow occurs. Cross-flow is allowed only in case of superelevation of a curve or overflow from the higher gutter on a street with cross fall. No more than three (3) cubic feet per second for the 25 year storm shall be allowed to cross flow from the higher elevation to the lower elevation.

3.1.4 Allowable Flow of Water Through Intersections

As the storm water flow approaches an arterial street or tee intersection, an inlet is required if more than three (3) cubic feet per second (cfs) for the 25 year storm shall enter the intersection. For a cul-de-sac with a slope greater than seven (7) percent, no more than three (3) cfs for the 25 year storm shall be allowed to enter the bulb of the cul-de-sac. In both situations the inlet cannot be placed inside the curb return.

3.1.5 Valley Gutter

Concrete valley gutters are useful in diminishing the deterioration of pavements, at intersections where slope across the intersection is less than one and two tenths (1.2%) percent. At the intersection of two (2) arterial streets, a valley gutter cannot be used. At the intersection of two (2) collector streets or local streets, a valley gutter shall be installed when slope across the intersection is less than one and two tenths (1.2 %) percent. At an intersection of two (2) different types of streets, the valley gutter may be used across the smaller street only.

3.2.0 PERMISSIBLE SPREAD OF WATER

The flow of water in gutters of various streets of different categories shall be limited by those values found on Table 3-1. These clear widths at the crown of the roadway or at the high point on a divided roadway are necessary to provide access for vehicles in the event of an emergency. Equation 3-1 may be used to determine the spread of gutter flow for a specific street width and flow depth.

$$\text{Spread} = W/2 \quad [(W^2/4) \quad 30y_o W^2/(30 + W)]^{1/2}, \qquad \text{(Eq. 3-1)}$$

where

W = Street Width, feet

y_o = Water depth in the gutter, feet

3.3.0 DESIGN METHOD

3.3.1 Gutter Flow Velocities

To insure scouring velocities for low flows, the gutter shall have a minimum slope of 0.004 feet per foot (0.4 percent).

3.3.2 Straight Crowns

Flow in gutters on straight crown pavements is normally assumed to be uniform, with Manning's Equation being used to determine the flow. However, because the hydraulic radius assumption in the Manning's Equation is not able to adequately describe the hydraulic characteristics of the gutter cross section, modification of the equation is necessary to accurately compute the flow. The modified Manning's Equation is:

$$Q_o = 0.56\ (z/n)\ S_o^{1/2} Y_o^{8/3} \qquad \text{(Eq. 3-2)}$$

where,

Q_o = Gutter discharge, cfs
z = Reciprocal of the crown slope, ft/ft
S_o = Street or gutter slope, ft/ft
n = Roughness coefficient
Y_o = Depth of flow in gutter, feet

Table 3-1
Minimum Clear Widths for Roadway Design Due to Gutter Flow*

Roadway Type	Proposed Usage	Minimum Clear Width (Feet)
1. Local Street	a. Residential b. Commercial/Industrial	0 0
2. Collector	a. Minor b. Commercial/Industrial c. Major 4 Lanes 5 Lanes 4 Lanes Divided 6 Lanes Divided	8 12 24 24 12 (each way) 12 (each way)
3. Arterial	a. 4 Lanes, Undivided b. 3 Lanes, One way c. 4 Lanes, One way d. 4 Lanes, with continuous left turn lane e. 4 Lanes, Divided f. 6 Lanes, Divided g. 8 Lanes, Divided	24 12 24 24 12 (each way) 12 (each way) 24 (each way)

The nomograph in Figure 3-1 in Appendix B of this Manual provides a direct solution for flow conditions in triangular channels. For a concrete pavement gutter, an n value equal to 0.016 is recommended. For gutters with small slope less than one (1) percent where sediment may accumulate, an n value of 0.02 is recommended.

3.3.3 Parabolic Crowns

Flows in the gutter of a parabolically crowned pavement are calculated from a variation of Manning's Equation, which assumes steady flow in a prismatic open channel. However, this equation is complicated and difficult to solve for each design case.

To provide a means of determining the flow in the gutter, generalized gutter flow equations for combinations of parabolic crown heights, curb splits and street grades of different street widths have been prepared. All of these equations have a logarithmic form.

Note: The street width used in this section is measured from face of curb to face of curb.

A. **Streets Without Curb Split.** Curb split is the vertical difference in elevation between curbs at a given street cross section. The gutter flow equation for parabolic crown streets without any curb split is:

$$\log Q = K_0 + K_1 \log S_0 + K_2 \log y_0 \qquad \text{(Eq. 3-3)}$$

where,

Q = Gutter flow, cfs
S_0 = Street grade, ft/ft
y_0 = Water depth in the gutter, feet
K_0, K_1, K_2 = Constant coefficients shown in Table 3-2 for different street widths:

Table 3-2
Coefficients for Equation 3-3, Streets Without Curb Split

Street Width* (ft)	Coefficients		
	K_0	**K_1**	**K_2**
30	2.85	0.50	3.03
36	2.89	0.50	2.99
40	2.85	0.50	2.89
44	2.84	0.50	2.83
48	2.83	0.50	2.78
60	2.85	0.50	2.74

*__Note:__ Based on the City of Round Rock DACS - Transportation Criteria Manual the street width is measured from face of curb to face of curb (FOC-FOC).

Source: City of Austin, Watershed Engineering Division

B. **Streets With Curb Split - Higher Gutter**. The gutter flow equation for calculating the higher gutter flows is as follows:

$$\log Q = K_0 + K_1 \log S_0 + K_2 \log y_0 + K_3(CS) \quad \text{(Eq. 3-4)}$$

where,

Q = Gutter flow, cfs

S_0 = Street grade, ft/ft

y_0 = Water depth in the gutter, feet

C_S = Curb split, feet

K_0, K_1, K_2, K_3 = Constant coefficients shown in Table 3-3 for different street widths:

Table 3-3
Coefficients for Equation 3-4, Streets With Curb Split - Higher Gutter

Street Width (ft)	Coefficients				**Curb Split Range (ft)**
	K_0	**K_1**	**K_2**	**K_3**	
30	2.85	0.50	3.03	-0.131	0.0-0.6
36	2.89	0.50	2.99	-0.140	0.0-0.8
40	2.85	0.50	2.89	-0.084	0.0-0.8
44	2.84	0.50	2.83	-0.091	0.0-0.9
48	2.83	0.50	2.78	-0.095	0.0-1.0
60	2.85	0.50	2.74	-0.043	0.0-1.2
Source: City of Austin, Watershed Engineering Division					

C. **Streets with Curb Split - Lower Gutter.**

The gutter flow equation for the lower gutter is:

$\log Q = K_0 + K_1 \log S_0 + K_2 \log y_0 + K_3(CS)$ (Eq. 3-5)

where,

Q = Gutter flow, cfs
S_0 = Street grade in ft/ft
y_0 = Water depth in the gutter in feet
CS = Curb split in feet
K_0, K_1, K_2, K_3 = Constant coefficients shown in Table 3-4 for different street widths:

Table 3-4
Coefficients for Equation 3-5, Streets With Curb Split - Lower Gutter

Street Width (ft)	Coefficients				**Curb Split Range (ft)**
	K_0	**K_1**	**K_2**	**K_3**	
30	2.70	0.50	2.74	-0.215	0.0-0.6
36	2.74	0.50	2.73	-0.214	0.0-0.8
40	2.75	0.50	2.73	-0.198	0.0-0.8
44	2.76	0.50	2.73	-0.186	0.0-0.9
48	2.77	0.50	2.72	-0.175	0.0-1.0
60	2.80	0.50	2.71	-0.159	0.0-1.2
Source: City of Austin, Watershed Engineering Division					

All the crown heights for different street widths are calculated by the following equation:

Crown Height (feet) = $0.5 + [(W \quad 30)/120]$ (Eq. 3-6) where,

W = street width, feet

D. Parabolic Crown Location.

The gutter flow equation presented for parabolic crowns with split curb heights is based on a procedure for locating the street crown. The procedure allows the street crown to shift from the street center line toward the high one fourth (¼) point of the street in direct proportion to the amount of curb split. The maximum curb split occurs with the crown at the one fourth (¼) point of the street. The maximum allowable curb split for a street with parabolic crowns is 0.02 feet per foot of street width.

Example: Determination of Crown Location

Given: 0.4 feet Design split on 30-foot wide street.

Maximum curb split	= 0.02 x street width
	= 0.02 x 30 feet = 0.6 feet
Maximum Movement	= ¼ street width for 30 foot street
	= ¼ x 30 feet = 7.5 feet
Split Movement	=(Design split x W/Maximum Split x 4)
	= (0.4 x 30/.6 x 4) = 5 feet

Curb splits that are determined by field survey, whether built intentionally or not, should be considered when determining the capacity of the curb flow.

Special consideration should be given when working with cross sections which have the pavement crown above the top of curb. When the crown exceeds the height of the curb the maximum depth of water is equal to the height of the curb, not the crown height. It should be noted that a parabolic section where the crown equals the top of curb will carry more water than a section which has the crown one (1) inch above the top of curb.