# SECTION 3
# FLOW IN GUTTERS

## 3.01 GENERAL

The location of inlets and permissible flow of water in the gutter should be related to the extent and frequency of interference to traffic and the likelihood of flood damage to surrounding property. Interference to traffic is regulated by design limits of the spread of water into traffic lanes, especially in regard to arterials.

Interference Due to Gutter Flow - Water which enters a street, either sheet flow from the pavement surface or overland flow from adjacent land areas, will flow in the gutter of the street until it reaches an overflow point or some outlet, such as a storm sewer or a channel. On streets where parking is not permitted, as with many arterial streets, whenever the flow width exceeds a few feet it becomes a traffic hazard. Field observations show that vehicles will crowd adjacent lanes to avoid curb flow.

As the width of flow increases further it becomes impossible for vehicles to operate without moving through water, and they again use the now inundated lane. Splash from vehicles traveling in the inundated land 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 will lose it's effectiveness as a traffic-carrier. During these periods it is imperative that emergency vehicles such a fire trucks, ambulances, and police cars be able to traverse the street by moving along the crown of the roadway.

Interference Due to Ponding - Storm runoff ponded on the street surface because of grade changes or the crown slope of intersecting streets has a substantial effect on the street-carrying capacity. Because of the localized nature of ponding, vehicles moving at a relatively high speed may enter a pond. 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.

Interference Due to Water Flowing Across Traffic Lane - Whenever storm runoff, other than limited sheet flow, moves across a traffic lane, a serious and dangerous impediment to traffic flow occurs. The cross-flow may be caused by super-elevation of a curve, a street intersection, overflow from 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 and autos may be traveling at high speed when they reach the location. If the velocity of vehicles is slow and street use is light, such as on residential streets, limited cross flows do not cause sufficient interference to be objectionable.

The depth and velocity of cross flows shall always be maintained within such limits that they will not have sufficient force to threaten moving traffic.

## 3.02 PERMISSIBLE SPREAD OF WATER

Industrial Streets and Arterials - Inlets shall be spaced at such an interval as to provide one clear traffic lane in each direction during the design storm.

The use of depressed inlets adjacent to a traffic lane is discouraged. In any case, however, gutter depression may not exceed 2-1/2" unless specifically approved by the Director of Engineering. The design storm will have a 5 year return frequency.

Example: Street width 60 feet, street flow in each gutter shall not exceed $\frac{60' - 24'}{2} = 18$ feet.
Therefore: 2-12' traffic lanes remain clear.

Neighborhood Collector Streets - The flow of water in gutters of a neighborhood collector street shall be limited so that one standard lane will remain clear during the design storm. Inlets shall be located at low points or wherever the flow exceeds the one standard lane requirement. Gutter depression at the inlet is discouraged, but shall not exceed 5" in any case. The design storm will have a 5 year return frequency.

Example: Street width 44', street flow in each gutter shall not exceed $\frac{44 - 12}{2} = 16$ feet.
Therefore: 1-12' traffic lane remains clear.

Residential Collector Streets - The flow of water in gutters of a residential collector street shall be limited so that one standard lane will remain clear during the design storm. Inlets shall be located at low points or wherever the flow exceeds the one standard lane requirement. Gutter depression at the inlet is discouraged, but shall not exceed 5" in any case. The design storm will have a 5 year return frequency.

Example: Street width 36', street flow in each gutter shall not exceed $\frac{36 - 12}{2} = 12$ feet.
Therefore: 1-12' traffic lane remains clear.

Residential Streets - The flow of water in gutters of a resedential street shall be limited to the top of the curb. Inlets shall be located at low points, or wherever the gutter flow exceeds the permissable spread of water. In no case shall the gutter depression at the inlet exceed 5 inches. The design storm will have a 5 year return frequency.

In addition, the 50-year frequency flow must be carried within the cross section between the building set-back lines.

## 3.03 MINIMUM AND MAXIMUM VELOCITY

To insure cleaning velocities at very low flows, the gutter shall have a minimum slope of 0.025 ft/ft (0.25%) unless approved by the city engineer. The maximum velocity of curb flow shall be 10 fps.

## 3.04 DESIGN METHOD

A. STRAIGHT CROWNS - Flow in gutters which are on straight crown pavements is normally calculated by using Manning's Equation for various hydraulic properties for uniform flow in pavement gutters or triangular channels. The equation is:

$$Q_o = 0.56 \frac{z}{n} So^{1/2} Yo^{8/3}$$

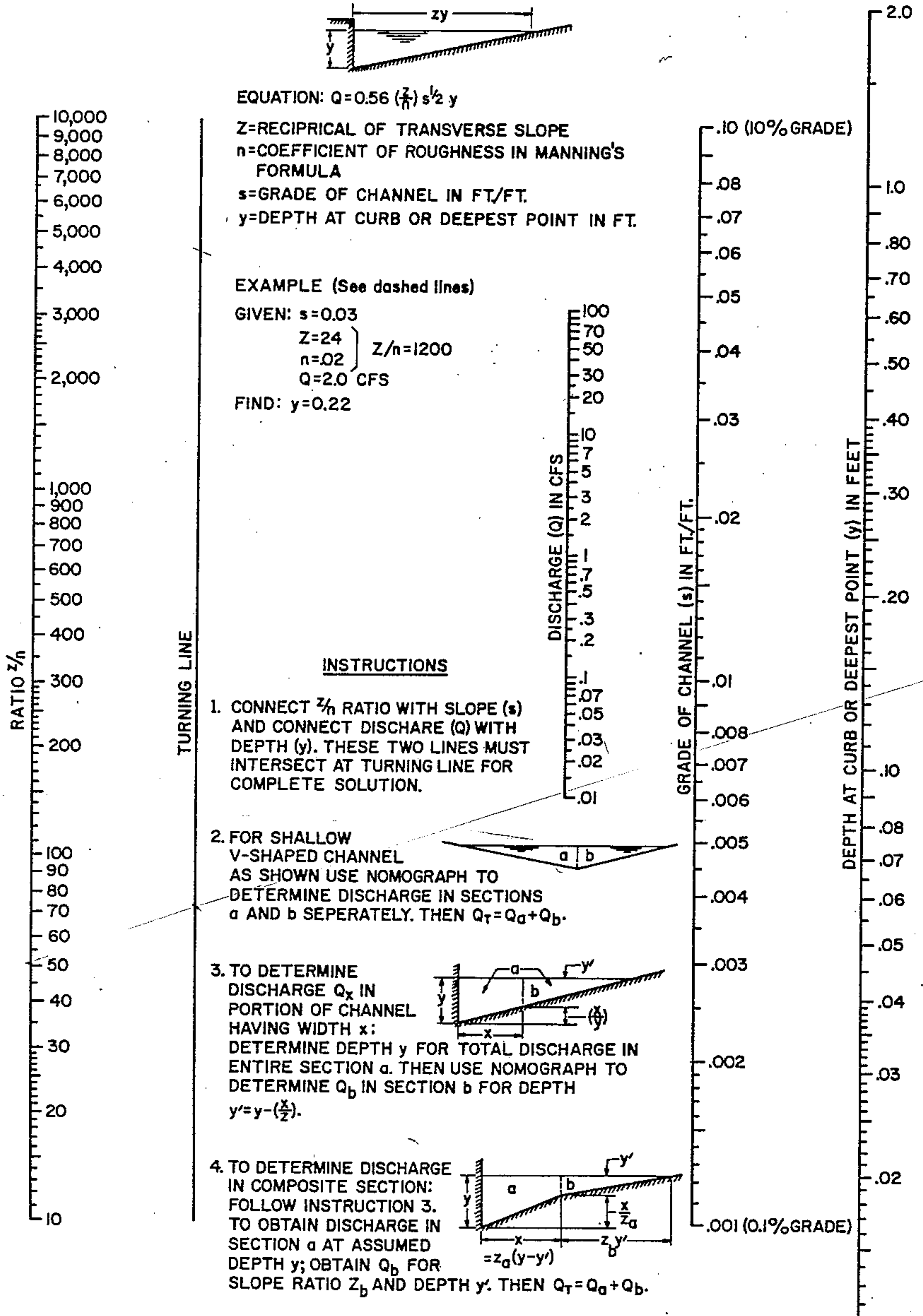
$Q_o$ = gutter discharge (cfs)
$z$ = reciprocal of the crown slope (ft/ft)
$S_o$ = street or gutter slope (ft/ft)
$n$ = roughness coefficient
$Y_o$ = depth of flow in gutter (ft)

The nomograph in Fig. 3-1 provides for direct solution of flow conditions for triangular channels most frequently encountered in urban drainage design. For the usual concrete gutter a value of 0.016 for "n" is recommended.

B. PARABOLIC CROWNS - Flow in gutters which are on parabolic crown pavements is calculated from a variation of Manning's Equation for steady flow in a prismatic open channel. The equation is:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}, \text{ where}$$

Q = flow in channel
n = roughness coefficient
A = cross-sectional area of flow
R = hydraulic radius of flow
S = slope of channel




NOMOGRAPH FOR FLOW
IN TRIANGULAR CHANNELS

Figure 3-1

TEXAS HIGHWAY DEPARTMENT

This equation is modified for the parabolic crown as follows:

$$Q_o = \frac{1.49}{n} \left[ \frac{4c}{W^2} \int_{x_a}^{x_b} x^2 dx - \left( \frac{4c}{W^2} x_a^2 \right) \left( x_b - x_a \right) \right] \cdot$$

$$\left[ \frac{ \frac{4c}{W^2} \int_{x_a}^{x_b} x^2 dx - \left( \frac{4c}{W^2} x_a^2 \right) \left( x_b - x_a \right) }{ \int_{x_a}^{x_b} 1 + \left( \frac{4c}{W^2} x^2 \right)^2 {}^{1/2} dx + \frac{4c}{W^2} \left( x_b^2 - x_a^2 \right) } \right]^{2/3} \cdot S_o^{1/2}$$

where

$Q_o$ = gutter discharge (cfs)

$c$ = street crown (ft)

$W$ = street width from face to face of curb (ft)

$n$ = roughness coefficient (0.016 for gutters)

$S_o$ = street or gutter slope (ft/ft)

Figs. 3-1 and 3-2 through 3-6 have been prepared to determine readily the depth of flow in the gutter and the spread of water into the traffic lane.

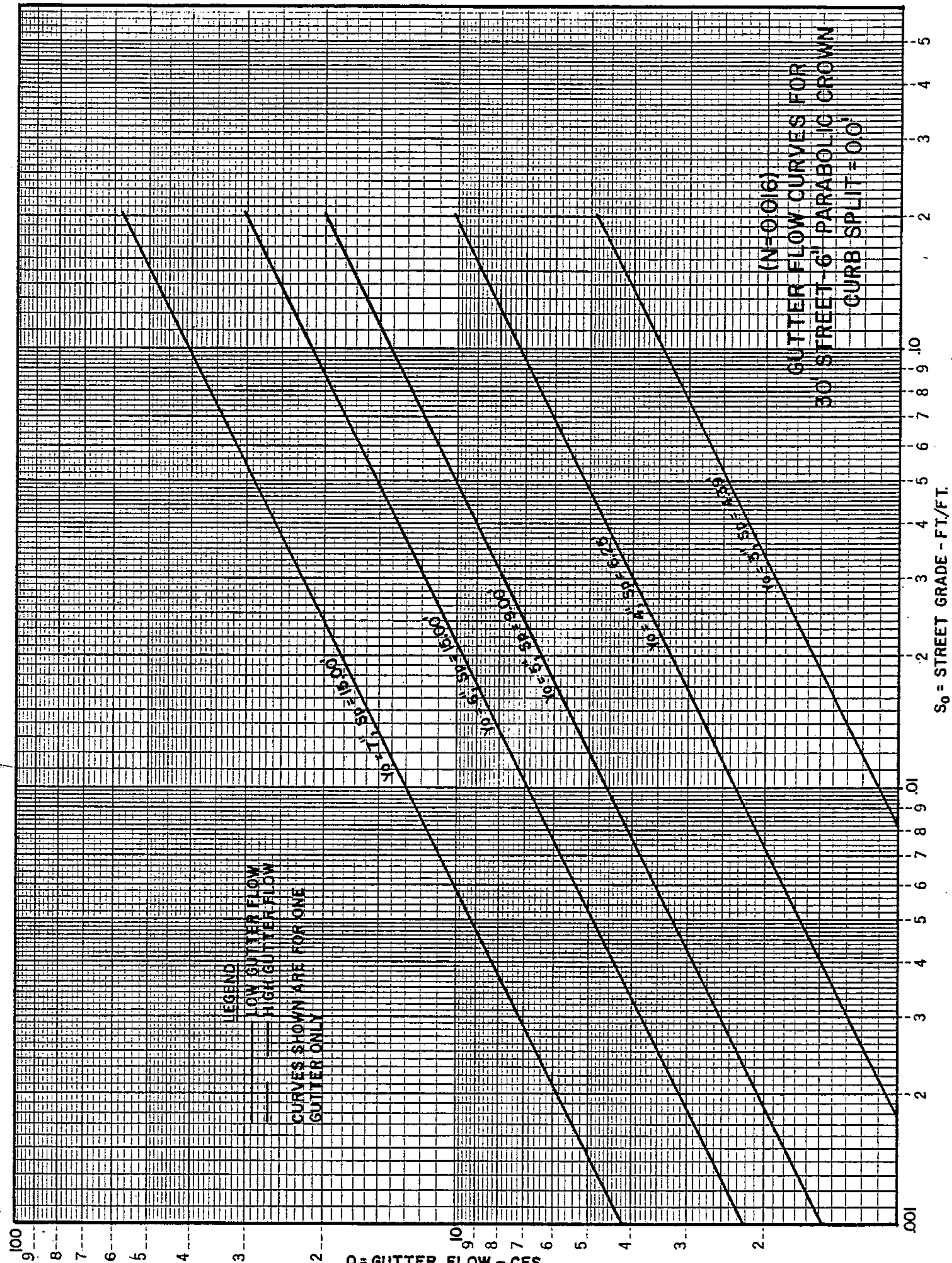

(N=0.016)
GUTTER FLOW CURVES FOR
30' STREET-6" PARABOLIC CROWN
CURB SPLIT = 0.0'
LEGEND
LOW GUTTER FLOW
HIGH GUTTER FLOW
CURVES SHOWN ARE FOR ONE GUTTER ONLY
Q = GUTTER FLOW - CFS
$S_o$ = STREET GRADE - FT./FT.

Figure 3-2

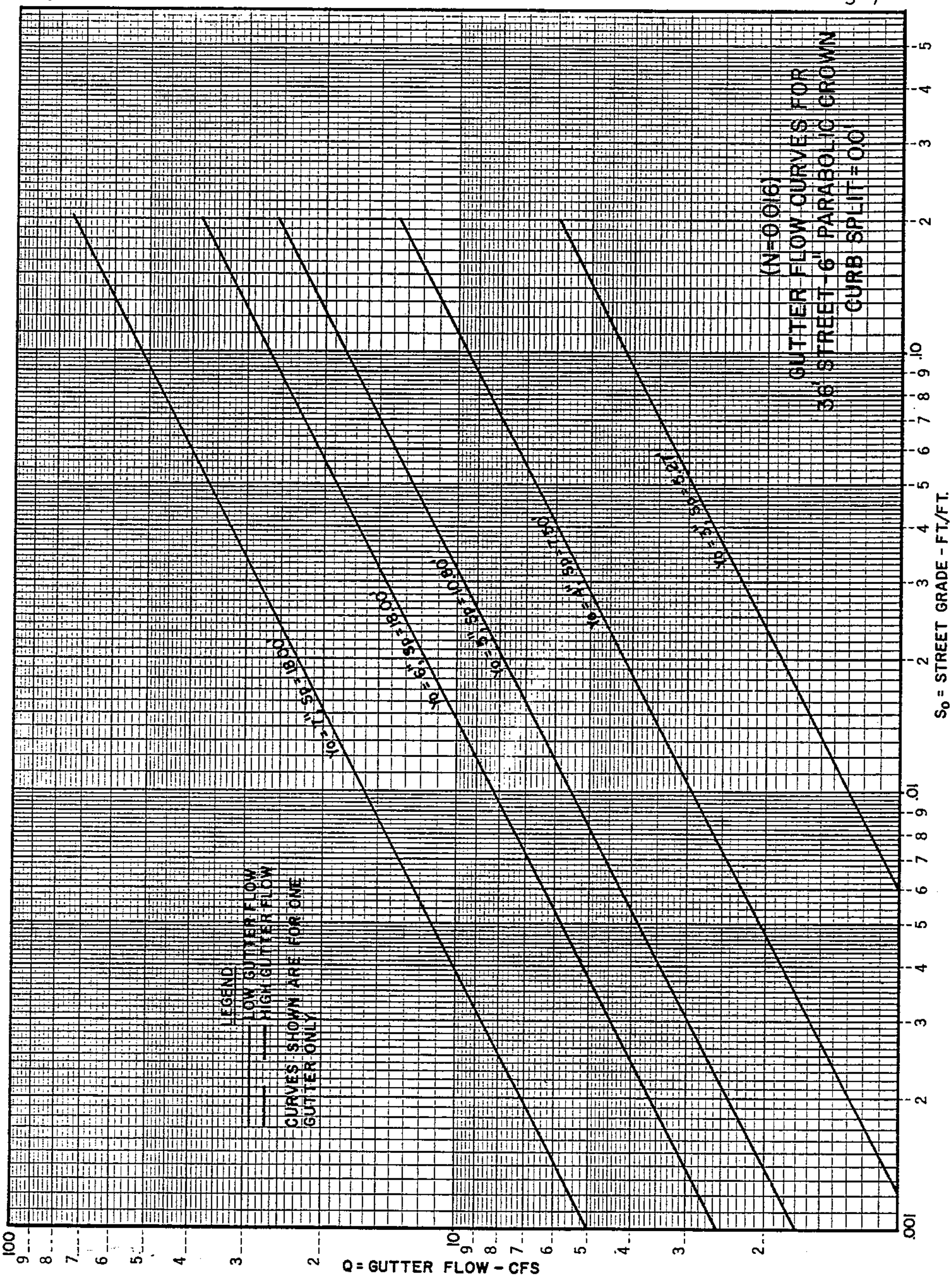

(N=0.016)
GUTTER FLOW CURVES FOR
36' STREET-6" PARABOLIC CROWN
CURB SPLIT=00'
LEGEND
LOW GUTTER FLOW
HIGH GUTTER FLOW
CURVES SHOWN ARE FOR ONE
GUTTER ONLY
Yo=7", Sd=18.00'
Yo=6", Sd=18.00'
Yo=5", Sd=10.80'
Yo=4", Sd=7.50'
Yo=3", Sd=5.21'
So = STREET GRADE - FT./FT.
Q = GUTTER FLOW - CFS

Figure 3-3

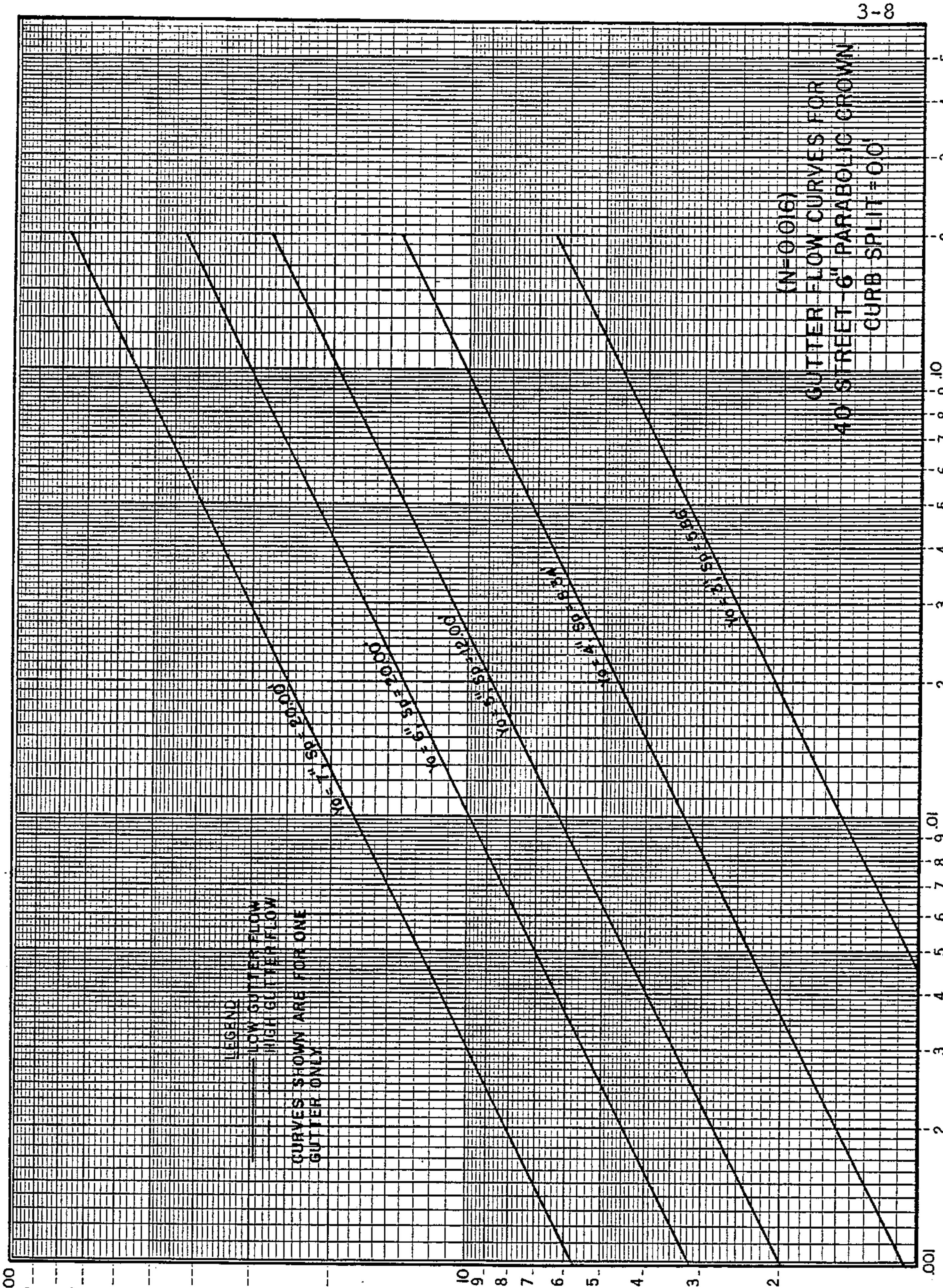

(N=0.016)
GUTTER FLOW CURVES FOR
40' STREET-6" PARABOLIC CROWN
CURB SPLIT = 0.0'
LEGEND
LOW GUTTER FLOW
HIGH GUTTER FLOW
CURVES SHOWN ARE FOR ONE GUTTER ONLY
$S_o$ = STREET GRADE - FT./FT.
Q = GUTTER FLOW - CFS

Figure 3-4

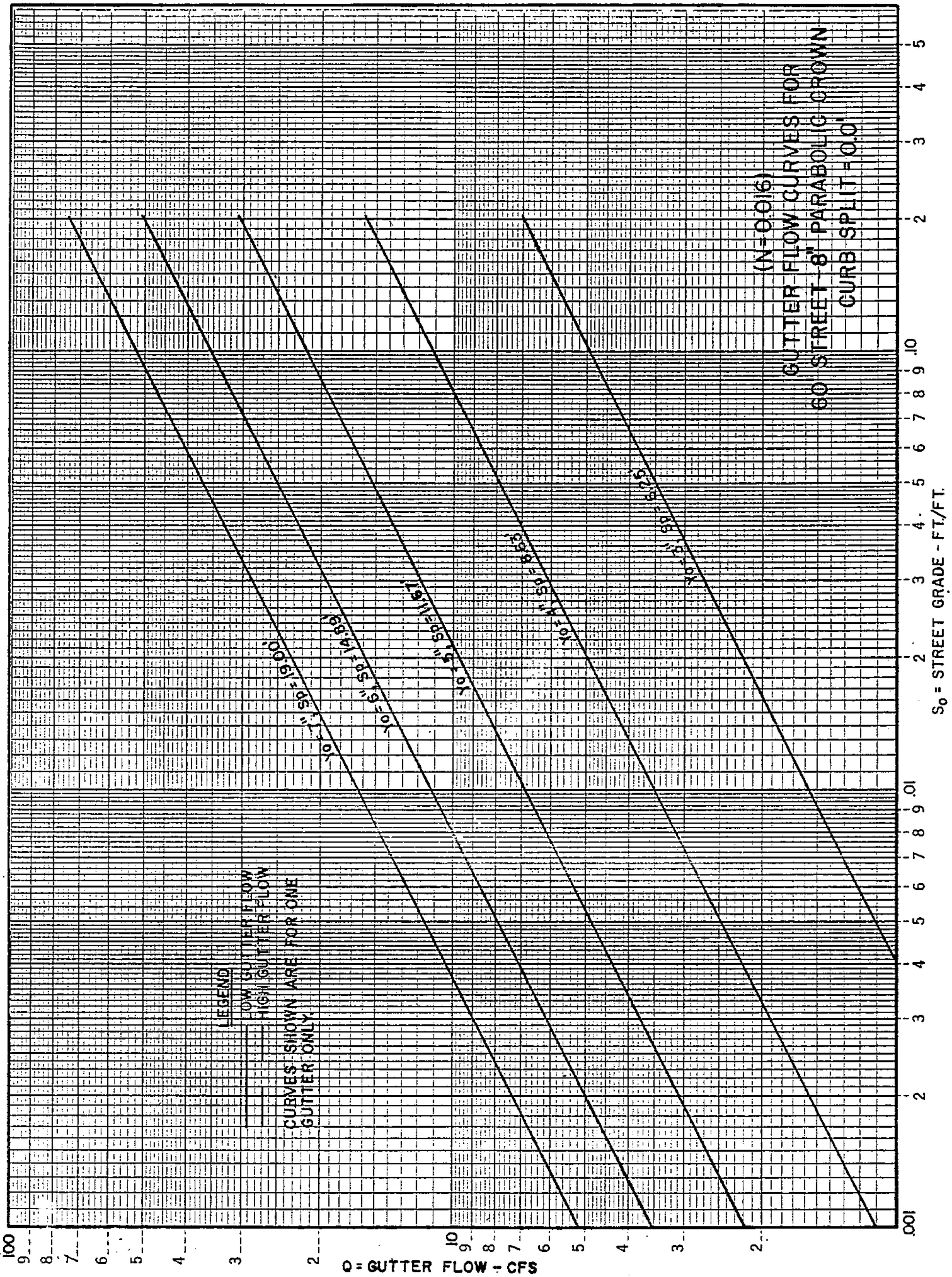

(N=0.016)
GUTTER FLOW CURVES FOR
60' STREET 8" PARABOLIC CROWN
CURB SPLIT = 0.0'
LEGEND
LOW GUTTER FLOW
HIGH GUTTER FLOW
CURVES SHOWN ARE FOR ONE GUTTER ONLY.
Yo = 7" Sp = 19.00'
Yo = 6" Sp = 14.83'
Yo = 5" Sp = 11.67'
Yo = 4" Sp = 8.63'
Yo = 3" Sp = 6.25'
Q = GUTTER FLOW - CFS
So = STREET GRADE - FT./FT.

Figure 3-5

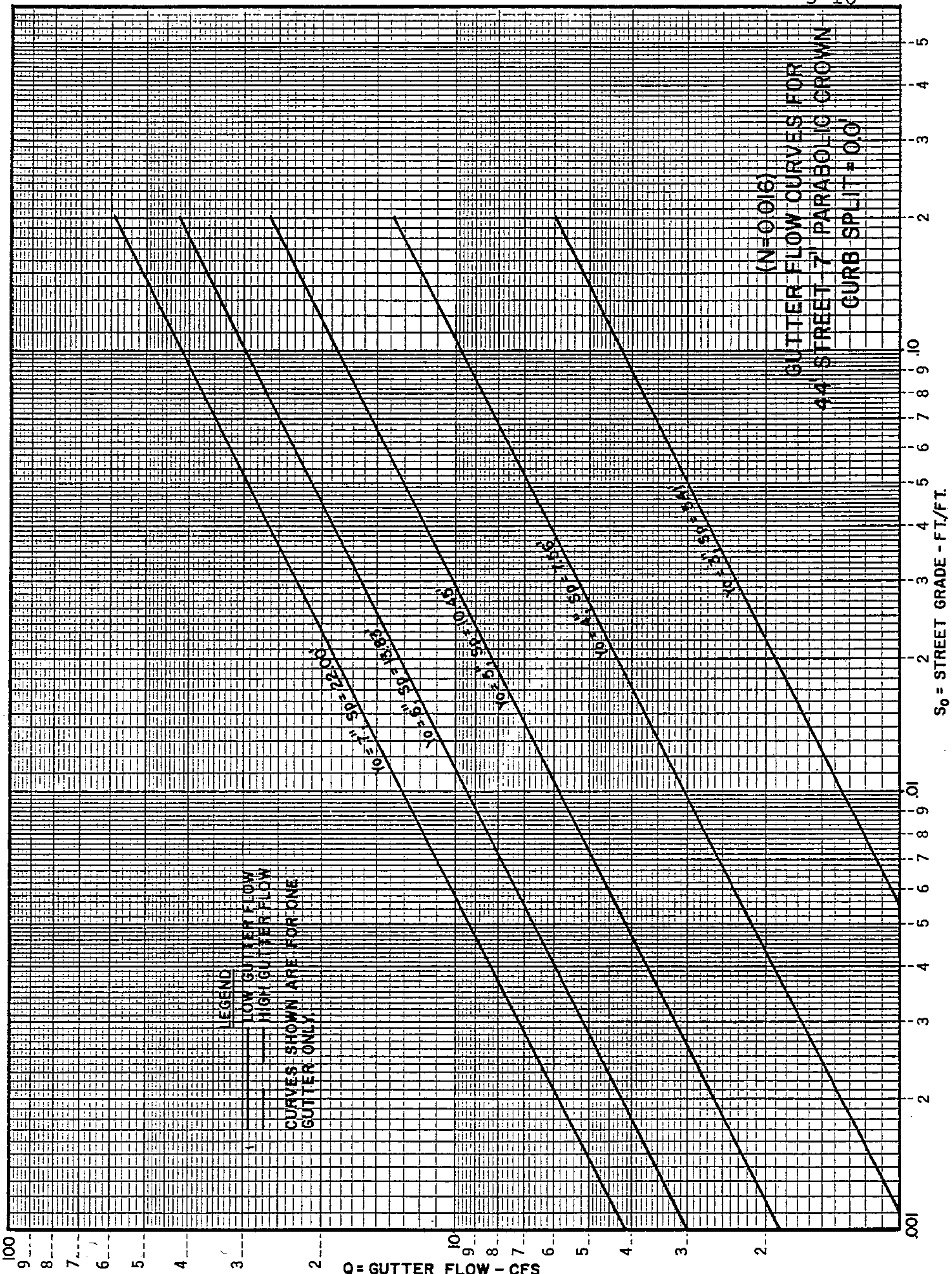

(N=0.016)
GUTTER FLOW CURVES FOR
44' STREET 7" PARABOLIC CROWN
CURB SPLIT = 0.0'
LEGEND
LOW GUTTER FLOW
HIGH GUTTER FLOW
CURVES SHOWN ARE FOR ONE GUTTER ONLY.
Q = GUTTER FLOW - CFS
S0 = STREET GRADE - FT./FT.

Figure 3-6