

SECTION 9
STORM SEWER INLETS

CITY OF WESTMINSTER
STORM DRAINAGE DESIGN AND TECHNICAL CRITERIA

SECTION 9 STORM SEWER INLETS

9.1 INTRODUCTION

There are three types of inlets: curb opening, grated, and combination inlets. Inlets are further classified as being "continuous grade" or "sump". The term "continuous grade" refers to an inlet located such that the grade of the street has a continuous slope past the inlet and, therefore, ponding does not occur at the inlet. The "sump" condition exists whenever the inlet is located at a low point. A "sump" condition can occur at a change in grade of the street from positive to negative or at an intersection due to the crown slope of a cross street.

The criteria and methodology for the design and evaluation of storm sewer inlets in the CITY are presented in this section. Except as modified herein, all storm sewer inlet criteria shall be in accordance with the MANUAL.

9.2 STANDARD INLETS

The standard inlets permitted for use in the CITY are:

INLET TYPE	PERMITTED USE
Curb Opening Inlet Type R	All street types. Minimum inlet length is 5 feet
Grated Inlet Type C	All streets with a roadside median ditch. Private areas where pedestrian use is limited.
Grated Inlet Type 13	Private areas with a valley gutter only. Must use a "Bicycle Safe" grate.
Combination Inlet Type 13	Private areas only. Must use a "Bicycle Safe" grate.

9.3 INLET HYDRAULICS

The procedures and basic data used to define the capacities of the standard inlets under various flow conditions were obtained from the MANUAL and Reference 11 for curb opening inlets. The procedure consists of defining the amount and depth of flow in the street gutter and determining the theoretical flow interception by the inlet. To account for the effects which decrease the capacity of the inlets such as debris plugging, pavement overlaying, and variations in design assumptions, the theoretical capacity calculated is reduced to the allowable capacity.

Allowable inlet capacities for the standard inlets have been developed and are presented in Figures 901, 902, and 903 for the "continuous grade" condition and Figure 904 for the "sump" condition. These nomographs already include the capacity reduction factors. The allowable inlet capacity is compatible with the allowable street capacity discussed in Section 10. The values shown on the figures were calculated based on the maximum flow allowed in the street gutter or roadside ditch. For gutter flow amounts less than the maximum allowable street flow, the allowable inlet capacity must be proportionately reduced. Table 901 shall be included in the Phase II and Phase III drainage reports. The table is provided to assist in calculating the required inlet type, sizing, and carry-over flow.

9.3.1 Continuous Grade Condition

For the "continuous grade" condition, the capacity of the inlet is dependent upon many factors including gutter slope, depth of flow in the gutter, height and length of the curb opening, street cross-slope, and the amount of depression at the inlet. In the "continuous grade" condition, not all of the gutter flow will be intercepted by the inlet. A portion of the gutter flow will continue past the inlet area and is referred to as carryover flow. The amount of carryover flow must be included in the drainage facility evaluation as well as in the design of the inlet.

The use of Figures 902 and 904 is illustrated by the following example:

EXAMPLE 1: DESIGN OF TYPE R CURB OPENING INLETS

<u>Given:</u>	Arterial street	Type C
	Longitudinal slope	1.0 percent
	Maximum flow depth	0.5 feet (refer to Section 10)
	Maximum allowable gutter capacity	11.0 cfs (refer to Section 10)
	Starting gutter flow (Q_L)	8.0 cfs
	Minor storm design event	

Find: Interception and carryover amounts for the inlets #1 and #2 illustrated on Figure 905.

Procedure:

As shown on Figure 905, inlets #1 and #2 are in a "continuous grade" condition and inlet #3 is in a "sump" condition. The size of the inlet required for the sump condition is discussed in Example 2.

Step 1:

From Figure 902 for an allowable flow depth of 0.50 feet and a 15-foot Type R inlet, the allowable inlet capacity is 8.6 cfs. Note that even though the actual gutter flow is less than maximum allowable gutter flow, the maximum allowable flow depth is used for Figure 902.

The effect of the lower gutter flow depth on the inlet capacity will be accounted for in the following steps.

Step 2:

Compute the interception ratio R:

$$R = \frac{\text{Allowable Inlet Capacity}}{\text{Allowable Street Capacity}} = \frac{8.6 \text{ cfs}}{11 \text{ cfs}} = 0.78$$

Step 3:

Compute the interception amount Q_I :

$$Q_I = R \times Q_{\text{street}} = 0.78 \times 8.0 \text{ cfs}$$
$$Q_I = 6.2 \text{ cfs amount intercepted by inlet}$$

Step 4:

Compute the carryover amount Q_{CO} :

$$Q_{CO} = Q_{\text{street}} - Q_I = 8.0 \text{ cfs} - 6.2 \text{ cfs}$$
$$Q_{CO} = 1.8 \text{ cfs}$$

Step 5:

Compute the total flow at inlet #2, which is the sum of the carryover flow (Q_{CO}) from inlet #1 plus the local runoff to inlet #2:

$$Q_T (\text{inlet \#2}) = Q_{CO} (\text{inlet \#1}) + Q_L (\text{inlet \#2}) = 1.8 \text{ cfs} + 4 \text{ cfs}$$
$$Q_T (\text{inlet \#2}) = 5.8 \text{ cfs}$$

Step 6:

Compute the interception ratio, intercepted amount, and carryover flow for inlet #2 (10-foot Type R) using the procedure described in Steps 1 through 4:

$$\text{Allowable inlet capacity} = 7.2 \text{ cfs from Figure 902}$$
$$R = (7.2 \text{ cfs}) / (11.0 \text{ cfs}) = 0.65$$
$$Q_I (\text{inlet \#2}) = (0.65)(5.8 \text{ cfs}) = 3.8 \text{ cfs}$$
$$Q_{CO} (\text{inlet \#2}) = 5.8 \text{ cfs} - 3.8 \text{ cfs} = 2.0 \text{ cfs}$$

Step 7:

Compute the flow to inlet #3 using the procedure described in Step 5:

$$Q_T (\text{inlet \#3}) = 8 \text{ cfs} + 2.0 \text{ cfs} = 10.0 \text{ cfs}$$

Step 8:

Size inlet #3, which is in a “sump” condition using the procedures described in the following example.

9.3.2 Sump Condition

The capacity of an inlet in a “sump” condition is dependent on the depth of ponding at the inlet. Typically, the inlet design consists of estimating the number of inlets or depth of flow required to intercept a given flow amount. The use of Figure 904 is illustrated by the following example:

EXAMPLE 2: ALLOWABLE CAPACITY FOR TYPE R INLET IN A SUMP

<u>Given:</u>	Total street flow at inlet #3	10.0 cfs	from Example 1
	Arterial street	Type C	
	Longitudinal slope	1.0 %	
	Maximum allowable street depth	0.50 feet	
	Type R inlet	double	

Find: Depth of ponding at inlet #3

Procedure:

Step 1:

From Figure 904, the depth of ponding (D) for a double Type R inlet at a gutter flow of 10.0 cfs is 0.49 feet.

Step 2:

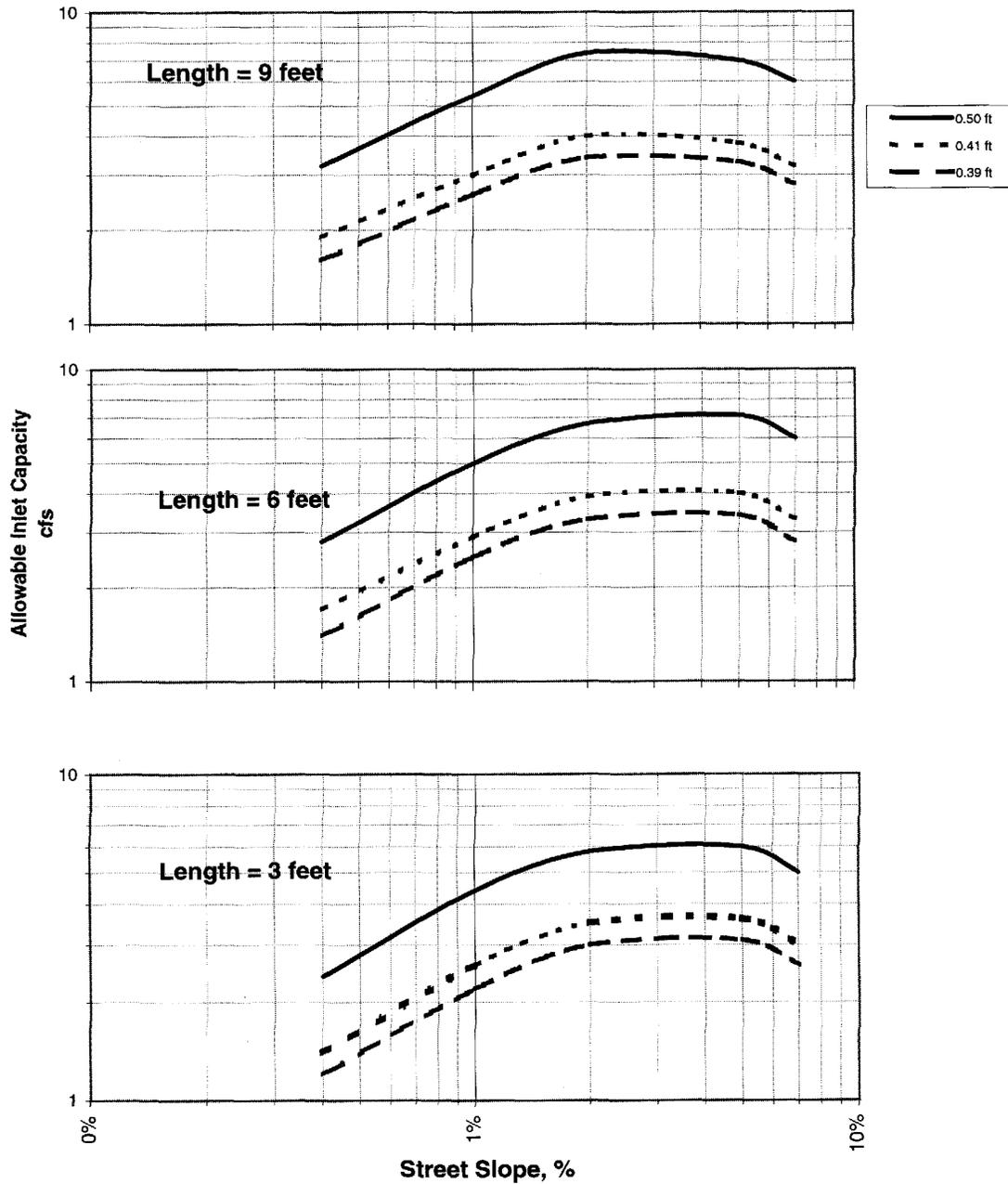
Compare the computed depth to the allowable flow depth. Since the computed depth is less than the allowable depth, the inlet is acceptable. Otherwise, the width of the inlet or the type of inlet would need to be changed and the depth of ponding procedure repeated.

9.4 INLET SPACING

The optimum spacing of storm inlets is dependent upon several factors including traffic requirements, contributing land use, street slope and capacity, amount of flow bypassed at the upstream inlet, and distance to the nearest outfall system. The suggested sizing and spacing of the inlets is based upon the interception rate of 70% to 80%. This spacing has been found to be more efficient than a spacing using a 100% interception rate. Using the suggested spacing, only the most downstream inlet in a development would be designed to intercept 100% of the flow. Also, considerable improvements in the overall inlet system

1. Place the inlets on the flattest street grades or in sump conditions to increase inlet interception capacity.
2. Space inlets based upon the interception rate of 70% to 80% of the actual gutter flow to optimize inlet capacity.
3. Reduce the inlet interception capacity due to the actual depth of flow in the gutter.
4. Check the actual inlet capacity to determine the carryover flow. Account for the carryover flow plus the local runoff in the sizing of the next downstream inlet.
5. Verify the storm inlets behavior during both the major and minor storm events.
6. Include Table 901 in the drainage report for both the major and minor storm.

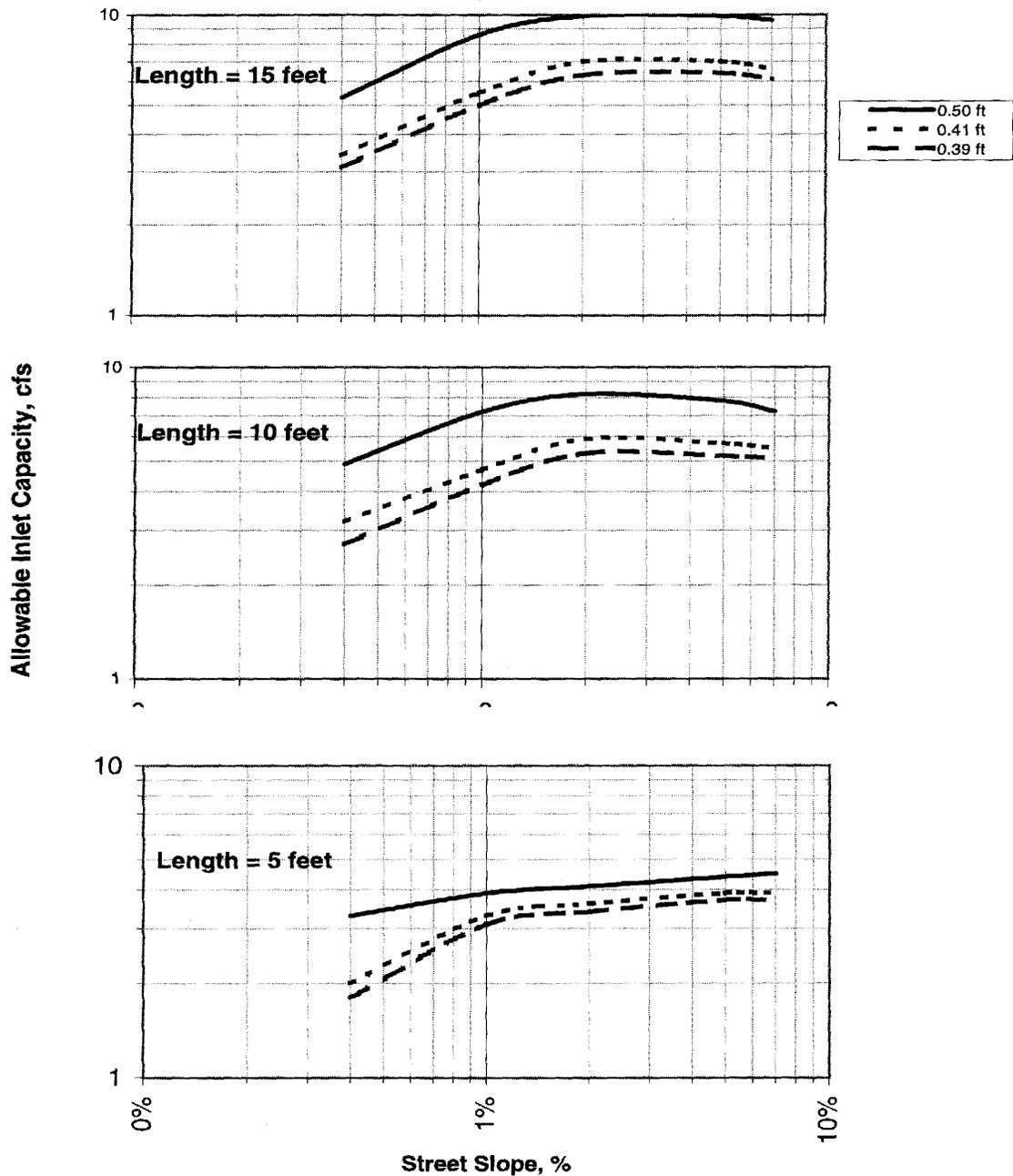
Figure 901
Allowable Inlet Capacity
Type 13 Combination on Continuous Grade



1. Allowable capacity = 66% of theoretical capacity.
2. Maximum inlet capacity at maximum allowable street flow depth. Proportionally reduce capacity for other depths.
3. Residential, Major Collector, Major Arterial (6 lanes) – 0.50 ft; Major Arterial (4 lanes), Minor Arterial – 0.41 ft; Minor Collector – 0.37 ft

Reference: WRC Engineering, Inc., TM-1, February 1989

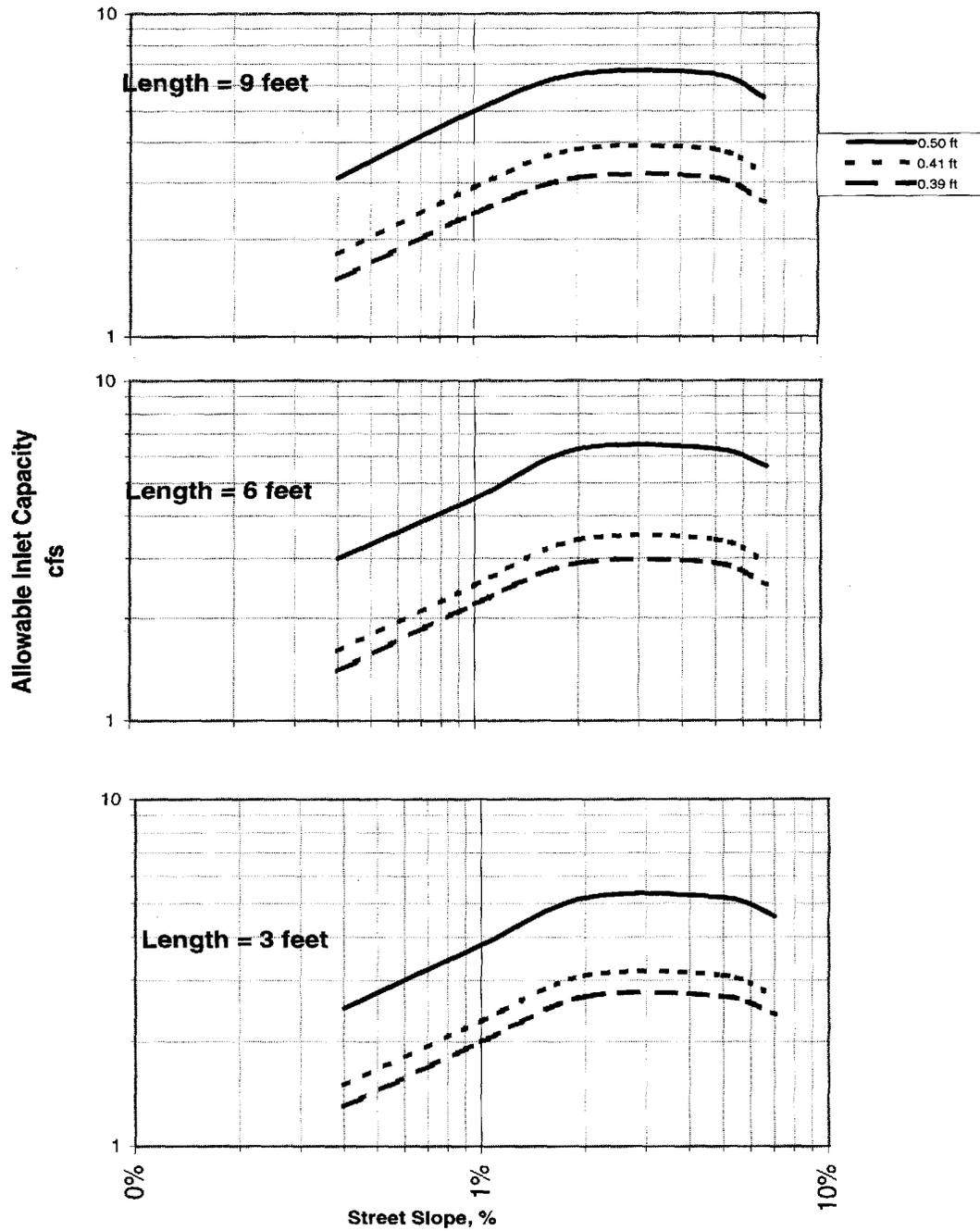
Figure 902
Allowable Inlet Capacity
Type R on a Continuous Grade



1. Maximum inlet capacity at maximum allowable flow depth in street. Proportionally reduce for other depths.
2. Allowable Capacity = 88% of theoretical capacity for L = 5 feet, 92% for L = 10 feet, and 95% for L = 15 feet
3. Interpolate for other inlet lengths
4. Residential, Major Collector, Major Arterial (6 lanes) – 0.50 ft; Major Arterial (4 lanes), Minor Arterial – 0.41 ft; Minor Collector – 0.37 ft

Reference: WRC Engineering, Inc., TM-1, February 1989

Figure 903
 Allowable Inlet Capacity
 Type 13 Grated on a Continuous Grade



1. Allowable capacity = 60% of theoretical capacity
2. Maximum inlet capacity at maximum allowable street flow depth. Proportionally reduce capacity for other flow depths.
3. Residential, Major Collector, Major Arterial (6 lanes) – 0.50 ft; Major Arterial (4 lanes), Minor Arterial – 0.41 ft; Minor Collector – 0.37 ft

Reference: WRC Engineering, Inc., TM-1, February 1989

Figure 904
 Allowable Inlet Capacity
 All Inlets - Sump Condition

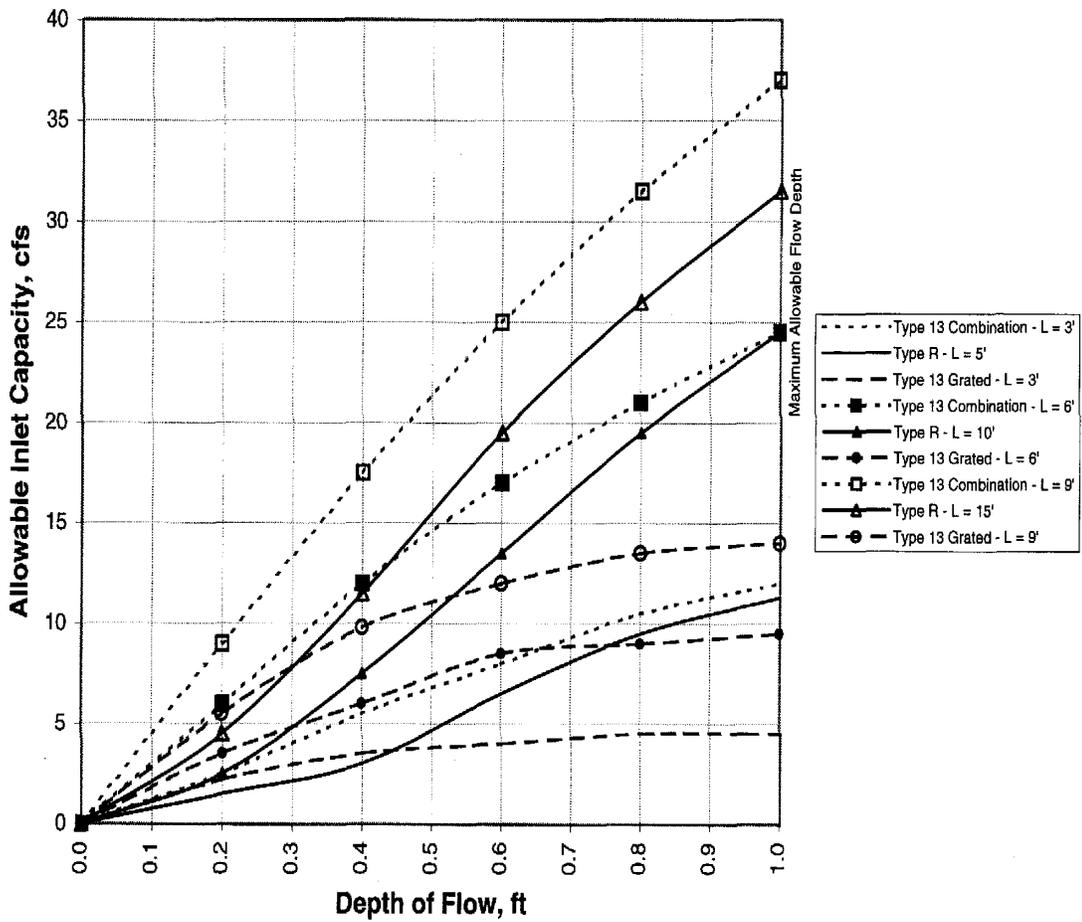
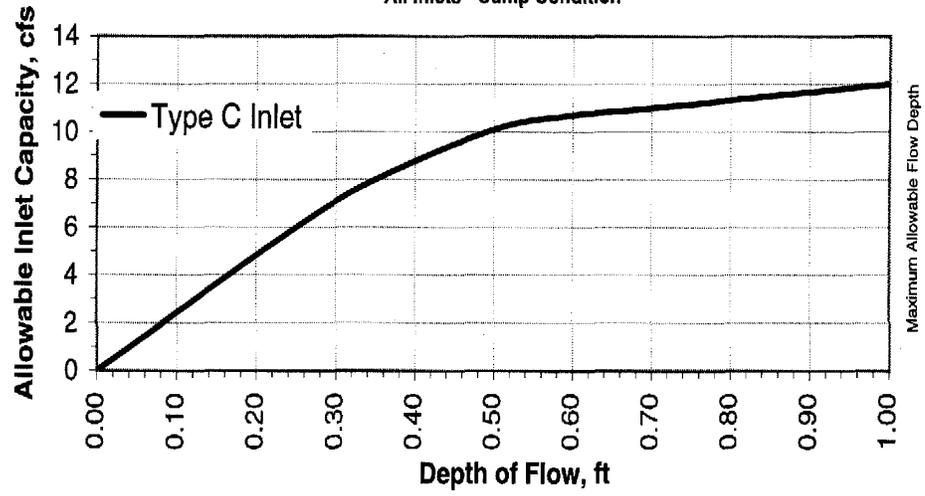
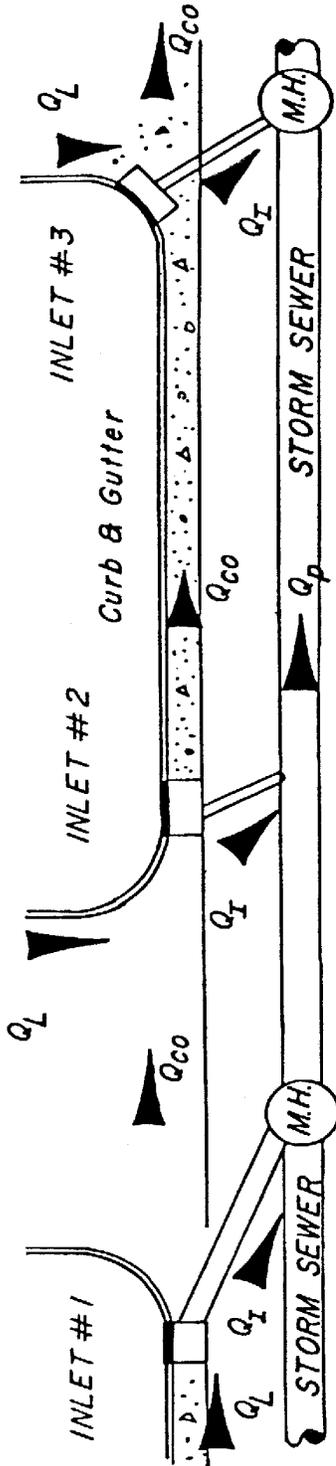


Figure 905
Design Example for Inlet



LEGEND Q_L = Local runoff for design storm tributary to designated inlet (cfs)

Q_I = Runoff intercepted by inlet (cfs)

Q_{CO} = Carry over runoff past inlet (cfs)

Q_T = Total runoff at inlet = $Q_L + Q_{CO}$

Q_P = Runoff in Pipe

SUMMARY OF FLOWS
FOR DESIGN EXAMPLE

INLET	Q	Q_L	Q_{CO}	Q_T	Q_I	Q_{CO}	Q_P	SEWER	COMMENTS
NO. 1, 15' TYPE R	8.6	8	0	8	6.2	1.8	6.2		Inlet on Grade
NO. 2, 10' TYPE R	7.2	4	1.8	5.8	3.8	2.0	10.0		Inlet on Grade
NO. 3, 10' TYPE R	10.4	8	2.0	10.0	10.0	0	20.0		Inlet in Sump Condition