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## CHAPTER 22

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### DECK SLAB DRAINAGE

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* Indicates 11 x 17 sheet; all others are 8 ½ x 11.
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### INTEGRAL / JOINTLESS BRIDGE DRAINAGE

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INTRODUCTION

It is the intent of this chapter to establish the guidelines, procedures and practices of the Structure and Bridge Division for the design of bridge drainage systems. It also provides design aids and other sources of information along with cross references to other Manuals of the Structure and Bridge Division (Volume V - series) to assist in the design and preparation of plans.

The practices and specific requirements contained in this chapter have been established based on the Structure and Bridge Division’s experience, industry standards and recommendations.

The practices and requirements set forth herein are intended to supplement or clarify the requirements of the AASHTO Standard and LRFD specifications. In the event of conflict(s) between the practices and requirements set forth herein and those contained in the AASHTO Standard or LRFD specifications, the more stringent requirements shall govern.

This chapter in the manual contains specific requirements and/or guidelines for the detailing of various components of the bridge drainage system. It is not the intent of these requirements and guidelines to supersede the requirements contained in Chapter 1 of this manual but to convey necessary information to the designer for the detailing of various components of the bridge drainage system.

It is expected that the users of this chapter will adhere to the practices and requirements stated herein.

NOTE:

Due to various restrictions on placing files in this manual onto the Internet, portions of the drawings shown do not necessarily reflect the correct line weights, line types, fonts, arrowheads, etc. Wherever discrepancies occur, the written text shall take precedence over any of the drawn views.
GENERAL INFORMATION:

This section establishes the practices, procedures and guidelines for the design of bridge deck slab drainage systems.

The practices, procedures and guidelines contained in this section for the design of bridge drainage systems require routine maintenance to function properly.

Sources of information utilized in the development of this section are as follows:


The bridge drainage systems covered in this section includes the bridge deck gutter, drainage inlets, downspouts and longitudinal stormwater drain pipes suspended under the deck slab.

The primary goal in the design of the bridge deck slab drainage system is to limit the amount of stormwater runoff flowing on the travelway or ponding at sag (low) points in the roadway grade to quantities that will provide reasonable safety for the passage of vehicle traffic, as well as bicycle and pedestrian traffic. This shall be accomplished by:

- Placing drainage inlets at such points and at such intervals to intercept flows and control spread of water on travel lanes.
- Providing an adequately sized stormwater collection system, when required, to convey flow from drainage inlets to a suitable outfall location.

The bridge drainage system requirements shall be established and coordinated with the development of the bridge design during the Preliminary Engineering Phase I of the project in order to avoid conflict(s) with the structural components of the bridge.
HYDROLOGY / OPEN CHANNEL HYDRAULICS:

Hydrology:

There are many hydrologic methods available for estimating the peak stormwater runoff rate or discharge. The method recommended for the design of deck slab drainage system shall be the Rational Method.

The design peak stormwater runoff rate for the deck slab drainage system can be computed by using the following equation:

\[ Q = k \times C \times i \times A \]

where \( Q \) = design storm peak runoff rate (ft\(^3\)/sec)
\( k = 1.0 \) = unit conversion factor
\( C = 0.9 \) = a dimensionless runoff coefficient
\( i = \) average rainfall intensity (in/hr)
\( A = \) contributing drainage area (acres)

Open Channel Hydraulics:

A bridge deck gutter is defined as the section of deck slab next to a parapet or railing curb that conveys water during a storm runoff event.

Gutter cross sections are triangular in shape with the curb forming the near vertical leg of the triangle. See figure below.

The gutter flow rate in a triangular channel with a uniform cross slope can be computed by using the following modified Manning Equation:

\[ Q = \left[ \frac{k_g}{n} \right] \times S_x^{1.67} \times S^{0.5} \times T^{2.67} \]

where \( Q \) = gutter flow rate (ft\(^3\)/sec)
\( k_g = 0.56 \) = constant
\[ T = \text{width of flow/spread (ft)} \]
\[ S_x = \text{cross slope of deck slab (ft/ft)} \]
\[ S = \text{longitudinal gutter slope (ft/ft)} \]
\[ n = 0.016 = \text{Manning’s roughness coefficient for concrete} \]

Rearranging and/or substituting into the above equation the following equations may be used for computing the spread and depth of flow:

- The spread for a given gutter flow rate may be computed by using the following equation:

\[
T = \left[ \frac{1.786 \times Q \times n}{S_x^{1.67} \times S^{0.5}} \right]^{0.375} \leq T_{\text{allow}}
\]

where \( T_{\text{allow}} \) = maximum width of flow/spread allowed (ft)

- The depth of gutter flow at the curb for a given gutter flow rate may be computed by using the following equation:

\[
y = T \times S_x
\]

where \( y \) = depth of flow (ft)

The gutter flow velocity for a uniform cross slope may be computed by using the following equation:

\[
V = \left[ \frac{2k_g}{n} \right] \times S_x^{0.67} \times S^{0.5} \times T^{0.67}
\]

where \( V \) = gutter flow velocity (ft/sec)

**Hydraulic Discharge/Intercept Rate for Drainage Inlet Pipe:**

A drainage inlet pipe opening will operate as a weir discharge or orifice discharge depending on the depth (head) of water at the drainage inlet.

The discharge/intercept rate of a pipe opening operating as a weir can be computed by using the following equation:
\[ Q_w = C_w \times P \times h^{1.5} \]

where \( Q_w \) = weir flow discharge/intercept rate (ft\(^3\)/sec)

\( C_w = 3.33 \) = weir coefficient

\( P \) = inside perimeter of pipe (ft)

\( h \) = depth (head) of water above the top of pipe or grate (ft)

The discharge/intercept rate of a pipe opening operating as an orifice can be computed by using the following equation:

\[ Q_o = C_o \times A \times \sqrt{2 \times g \times h} \]

where \( Q_o \) = orifice flow discharge/intercept rate (ft\(^3\)/sec)

\( C_o = 0.608 \) = orifice coefficient

\( A \) = inside area of pipe (ft\(^2\))

\( g = 32.2 \) acceleration due to gravity (ft/sec\(^2\))

\( h \) = depth (head) of water above the top of pipe or grate (ft)
DECK SLAB DRAINAGE INLET HYDRAULICS:

General:

The two types of drainage inlets used by the Structure and Bridge Division for deck slab drainage are as follows:

- Downspout drainage inlets
- Grate drainage inlets

For drainage inlet details, see File No. 22.03.

The type of drainage inlet recommended for use when drainage inlets are required is the grate drainage inlet as it has a higher interception capacity and efficiency than the downspout drainage inlet. The downspout drainage inlet may be appropriate for use at sag (low) points and as flanking drainage inlets to discharge any water from the bridge deck slab.

When drainage inlets are required, grate and downspout inlets on grade shall be located outside travel lanes to minimize the shifting of vehicles attempting to avoid these areas.

All grate drainage inlets shall be bicycle safe when used at locations where bicycle travel is anticipated. For specific requirements for bicycle traffic, see File Nos. 06.04-1 thru -16.

Drainage Inlet Interception Capacity and Efficiency:

Frontal flow as referred to in this section is defined as the water flowing in the section of gutter (cross-hatched area) occupied by the drainage inlet as shown below.

GUTTER SECTION FOR DOWNSPOUT DRAINAGE INLET
The interception capacity of a drainage inlet is the amount of total approach frontal flow intercepted by the inlet. The interception capacity of an inlet changes with variations in cross slope, longitudinal slope and total gutter flow.

Gutter flow entering a drainage inlet will act in one of the following states:

- Channel frontal flow
- Weir flow
- Orifice flow

The amount of gutter flow discharged/intercepted by the drain inlet, \( Q_{\text{intercept}} \), is assumed to be the lesser of the above three calculated flow states.

For Channel frontal flow intercepted by inlet, the following equations are used:

\[
V = \frac{2K_g}{n} \times S_x^{0.67} \times S^{0.5} \times T^{0.67}
\]
Length of hydraulic jump (ft) = \( L_{\text{jump}} = \frac{V}{2} \times (y + d)^{0.5} \)

where \( V \) = gutter flow velocity (ft/sec)

\( y = T \times S_x \) = depth of flow at curb (ft)

\( d \) = depth of deck slab depression (ft)

\( T \) = width of flow/spread (ft)

\( S_x \) = cross slope of deck slab (ft/ft)

Intercept factor = I.F. = \( \frac{L_{\text{jump}} - w_d}{L_{\text{jump}}} \)

where \( L_{\text{jump}} \) = length of jump (ft)

\( w_d \) = inside width of grate drainage inlet or inside diameter of downspout drainage inlet (ft)

% channel frontal flow intercepted by drainage inlet = \( E_o \) = 1.0 \quad \text{for I.F.} \leq 0

= 1.0 − I.F. \quad \text{for I.F.} > 0

\( Q_{\text{channel}} = V \times \left[ L_d \times \left( y - (X \times S_x) \right) + (y - ((L_d + X) \times S_x)) \right] \times E_o \)

where \( Q_{\text{channel}} \) = channel frontal flow intercepted by drainage inlet (ft³/sec)

\( L_d \) = inside length of grate drainage inlet or inside diameter of downspout drainage inlet (ft)

\( X \) = drain inlet offset from face of curb (ft)

\( E_o \) = amount of channel frontal flow intercepted
For weir flow intercepted by drainage inlets, the following equation is used:

\[ Q_w = 3.33 \times [y - (X \times S_x)]^{1.5} \times \pi \times D \]

where
- \( Q_w \) = weir flow intercept rate (ft\(^3\)/sec)
- \( D \) = inside diameter of pipe (ft)
- \( y \) = depth of flow (ft)
- \( X \) = drain inlet offset from face of curb (ft)
  - \( = 0 \) (for drainage inlets on flat or nearly flat grades \( \leq 0.3\% \))
- \( S_x \) = cross slope of deck slab (ft/ft)

For orifice flow intercepted by drainage inlets, the following equation is used:

\[ Q_o = 0.608 \times \pi \times \left( \frac{D^2}{4} \right) \times [2 \times g \times (y - (X \times S_x))]^{0.5} \]

where
- \( Q_o \) = orifice flow intercept rate (ft\(^3\)/sec)
- \( D \) = inside diameter of pipe (ft)
- \( g = 32.2 \) = acceleration due to gravity (ft/sec\(^2\))
- \( y \) = depth of flow (ft)
- \( X \) = drain inlet offset from face of curb (ft)
  - \( = 0 \) (for drainage inlets on flat or nearly flat grades)
- \( S_x \) = cross slope of deck slab (ft/ft)

The efficiency of a drainage inlet is the percent of total gutter approach flow the inlet will intercept which can be expressed by the following equation:

\[ E = \frac{Q_{\text{intercept}}}{Q_{\text{Total}}} \]

where
- \( E \) = inlet interception efficiency (%)
- \( Q_{\text{intercept}} \) = amount of flow intercepted by the drainage inlet (ft\(^3\)/sec)
- \( Q_{\text{Total}} \) = total approach frontal flow to the drainage inlet (ft\(^3\)/sec)
DESIGN OF DECK SLAB DRAINAGE SYSTEM:

General:

All approach flow to and beyond the bridge is the responsibility of the road designer.

The designer shall coordinate with the road designer to ensure that any flow off the bridge is accounted for in the roadway drainage design.

General Design Procedure:

The general procedure for designing the bridge drainage system involves establishing the following:

- Allowable spread and rainfall intensity for the bridge
- Layout of design sections for bridge
- Drainage inlet requirements and locations (spacings) when required
- Stormwater discharge and collection requirements.

It is assumed that all drainage inlets will have by-pass flow. The by-pass flow, \( Q_{\text{By-pass}} \), is given by the following equation:

\[
Q_{\text{By-pass}} = Q_{i=1,2,...} - Q_{\text{Intercept}} = Q_{i=1,2,...} \times (1.0 - E)
\]

where

- \( Q_{\text{By-pass}} \) = by-pass flow at inlet \( (i=1,2,...) \) (ft\(^3\)/sec)
- \( Q_{i=1,2,...} \) = total approach flow to the inlet (ft\(^3\)/sec)
- \( Q_{\text{Intercept}} \) = amount of flow intercepted by inlet \( (i=1,2,...) \) (ft\(^3\)/sec)
- \( E \) = inlet interception efficiency (%) 

Maximum Design Spread Width and Rainfall Intensities:

The maximum design spread width (allowable), \( T_{\text{allow}} \), is the maximum width of water allowed to accumulate on the bridge deck slab gutter before any drainage inlets are required.

The rainfall intensity, \( i \), is the average rate of rainfall (in/hr) for a selected duration (time of concentration) and design storm frequency for the locality in which the bridge is designed.
The table below gives the design storm frequency, intensity and maximum design spread width (allowable) for different roadway classifications, vertical alignment and design speed.

### DESIGN STORM FREQUENCY, INTENSITY AND SPREAD

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<th>Design Speed (mph)</th>
<th>Design Storm Frequency (year)</th>
<th>Intensity (in/hr)</th>
<th>Maximum Design Spread Width (ft)</th>
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</thead>
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<tr>
<td>Freeways (Interstate):</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>On Grade</td>
<td>ALL</td>
<td>10</td>
<td>*Actual</td>
<td>Shoulder width w/ no encroachment in traffic lane</td>
</tr>
<tr>
<td>At Sag Point</td>
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<td>50</td>
<td>*Actual</td>
<td>Shoulder width w/ no encroachment in traffic lane</td>
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<tr>
<td>Principal Arterial:</td>
<td></td>
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<tr>
<td>On Grade</td>
<td>≤ 50</td>
<td>10</td>
<td>4.0</td>
<td>Shoulder/gutter width plus 1/2 traffic lane encroachment</td>
</tr>
<tr>
<td></td>
<td>&gt; 50</td>
<td>10</td>
<td>*Actual</td>
<td>Shoulder/gutter width plus 3'-0&quot; encroachment in traffic lane</td>
</tr>
<tr>
<td>At Sag Point</td>
<td>≤ 50</td>
<td>10</td>
<td>4.0</td>
<td>Shoulder/gutter width plus 1/2 traffic lane encroachment</td>
</tr>
<tr>
<td></td>
<td>&gt; 50</td>
<td>50</td>
<td>*Actual</td>
<td>Shoulder/gutter width plus 3'-0&quot; encroachment in traffic lane</td>
</tr>
<tr>
<td>Minor Arterial, Collector and Local:</td>
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<td>4.0</td>
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<td>At Sag Point</td>
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<tr>
<td></td>
<td>&gt; 50</td>
<td>50</td>
<td>4.0</td>
<td>Shoulder/gutter width plus 3'-0&quot; encroachment in traffic lane</td>
</tr>
</tbody>
</table>

For superelevated bridge deck slabs, the depth of water flow at edge of traffic lane shall be limited to 3" maximum.

The maximum design spread width for areas designated for use by pedestrian and/or bicycle traffic shall be one-half the “clear width of pedestrian and/or bicycle facility.”

* When the above table notes “Actual” for intensity, the designer shall contact L&D Hydraulics for the actual rainfall intensity at the bridge location. In no case shall the rainfall intensity be less than 4.0 in/hr.

### Layout of Bridge Design Sections:

Bridges with single vertical profile alignments have only one design section for bridges on a gradient (tangent) and two design sections for bridges on a vertical curve.

Bridges with multiple vertical profile alignments shall be broken down into design sections as shown below. The first step is locating the PVC and PVT for all vertical curves on the bridge and to identify any tangent sections. Tangent sections and vertical curve sections shall be separated for drainage design calculations.
BRIDGE VERTICAL ALIGNMENT

Locate the high end for bridges on a gradient (tangent). Locate high point and/or sag (low) point for bridges on vertical curve alignments. The location of high/sag (low) points on vertical curves can be determined by using the following equation:

\[
\text{Sta. High/Low Point} = \text{Sta. PVC} + \frac{g_1 \times LVC}{g_1 - g_2}
\]

where \( g_1 \) = slope of the tangent through the PVC (%)

\( g_2 \) = slope of the tangent through the PVT (%)

\( LVC \) = length of vertical curve (ft)

Number the design sections from the high point (starting point for calculation of spacings) to the left and then from the high point to the right.

General Drainage Inlet Requirements and Locations (Spacing):

Drainage inlets shall be provided and located to limit the spread of water on the travel lanes in accordance with the drainage design requirements specified in File No. 22.01-10.

A drainage inlet shall be provided at all sag (low) points regardless of the hydraulic requirements for the bridge and a minimum of one flanking drainage inlet at a 5'-0" maximum spacing shall be provided on each side. This is to limit the spread of water and to act in relief of the sag (low) point drainage inlet should it become clogged or the design storm is exceeded.

Transition areas, especially in areas from a crowned section to a superelevated section, require additional analysis beyond the scope of this manual. In general, elevations may need to be adjusted so that flat areas and irregularities can be adjusted to form a smooth grade. One method is to plot curb elevations on a reasonable vertical scale every two to five feet. The flat spots and irregularities can be adjusted by introducing a spline grade to achieve a smooth grade. A drainage inlet spacing of five feet (+/-) through these areas is recommended to prevent ponding of water especially in areas subject to icing.
The procedure for determining drainage inlet requirements and locations (spacing) for bridges on a gradient (tangent) starts at the high end of the bridge with the computation of the distance to the first required inlet. The spacing of remaining down grade inlets when required, continues until the end of the bridge.

The procedure for determining drainage inlet requirements and locations (spacing) for bridges on a vertical curve starts at the high point(s) on the bridge with the computation of the distance to the first required inlet. The spacing of remaining down grade inlets when required, continues until the end of bridge or the sag (low) point is reached.

The general procedure for determining drainage inlet requirements and locations (spacings) are as follows:

- Determine the location of the first required drainage inlet from the high end/point on the bridge or design section
- Determine drainage inlet efficiency and capacity (See File Nos. 22.01-5 thru -8)
- Compute spacing between down grade drainage inlets considering discharge requirements and span arrangement
- Adjust drainage inlet spacings as necessary to avoid conflicts with structural components of the bridge

**Drainage Inlet Locations (Spacing) for Bridges/Design Sections on a Gradient (Tangent):**

The distance, $L_{i=1}$, from the high end/point on the bridge/design section to the first required drainage inlet location can be computed by using the following equation:

$$L_{i=1} = \frac{43560 \frac{ft^2}{acre} \times Q_{\text{max}}}{C \times i \times W_p}$$

where $L_{i=1} =$ distance from high end or point on the bridge to first drainage inlet (ft)

$Q_{\text{max}} = Q_{i=1} =$ maximum gutter flow allowed (ft$^3$/sec)

$$Q_{\text{max}} = \left[ \frac{k_o}{n} \right] \times S_1^{1.67} \times S^{0.5} \times T_{\text{allow}}^{2.67}$$

The distance, $L_{i=1}$, computed by using the above equation is then compared with the length of bridge or the length of long/short end of the bridge or the length of the design section.

- If $L_{i=1} >$ length of bridge or long/short end of bridge or the length of the design section, then drainage inlets are not required.
- If $L_{i=1} <$ length of bridge or long/short end of bridge or the length of the design section, then drainage inlets are required.
When drainage inlets are required, the spacing between remaining down grade drainage inlets, \( L_i = 2,3,... \), can be computed using the following equation:

\[
L_i = \frac{43560 \frac{ft^2}{acre} \times (Q_{\text{max}} - Q_{\text{By-pass}})}{C \times i \times W_p} \]

where \( Q_{\text{max}} = \) maximum gutter flow allowed (ft\(^3\)/sec)

\[
= \left[ \frac{k_g}{n} \right] \times S_i^{1.67} \times S^{0.5} \times T_{\text{allow}}^{2.67}
\]

\( Q_{\text{By-pass}} = \) by-pass flow from up grade inlet (ft\(^3\)/sec)

The actual gutter flow, \( Q_{i=1,2,...} \), approaching a drainage inlet is computed using the following equation:

\[
Q_{i=1,2,...} = \frac{C \times i \times W_p \times L_{i=1,2,...} \times Q_{\text{By-pass}}}{43560 \frac{ft^2}{acre}} \leq Q_{\text{max}}
\]

where \( Q_{\text{By-pass}} = \) by-pass flow from up grade inlet (ft\(^3\)/sec)

\( = 0 \) (for Drain #1 - no by-pass from up grade drainage inlet)

Drainage Inlet Locations (Spacing) for Bridges/Design Sections on a Vertical Curve:

The methodology used for determining the drainage inlet locations (spacing) for bridges/design sections on vertical curves is similar to that for bridges/design sections on a gradient (tangent) except a trial and error approach is necessary to take into account changes in gutter slope from one inlet to another.

A trial distance \( L_i = 1,2,... \) to the inlet is selected and the gutter slope at this location is computed using the following equation:

\[
S_{i=1,2,...} = \left[ \frac{g_2 - g_1}{\text{LVC}} \right] \times X + g_1
\]

where \( S_{i=1,2,...} = \) longitudinal gutter slope at the (i th) drainage inlet (use absolute value) (ft/ft)

\( \text{LVC} = \) length of vertical curve (ft)

\( g_1 = \) slope of the tangent though the PVC (%)
\[ g_2 = \text{slope of the tangent though the PVT} \] %
\[ X = \text{distance from the PVC to the location of the (i th) drainage inlet (ft)} \]

The maximum allowed gutter flow is then computed using the gutter slope determined by the above equation. The maximum allowed gutter flow and by-pass flow (from up grade inlet) is used in the appropriate equations given for bridges/design sections on a gradient (tangent) to compute the distance to the inlet and the actual gutter flow for the trial distance. If the computed distance to the inlet is less than the trial distance and/or if the computed actual gutter flow is greater than the maximum gutter flow, then select another trial distance and repeat the computations. See Sample Deck Slab Drainage Design in File Nos. 22.02-1 thru -12.

**Drainage Inlet Requirements and Locations (Spacing) for Flat or Nearly Flat Bridges/Design Sections:**

Bridges/design sections on gradient (tangent) or vertical curves having sag (low) points or points along the vertical curve where the longitudinal gutter slope is less than or equal to 0.003 ft/ft shall be assumed flat or nearly flat for purposes of determining locations (spacing) of drainage inlets.

Gutter flow entering a drainage inlet will act in one of the following states:

- Weir flow
- Orifice flow

For determining the amount of flow intercepted by the drainage inlets, \( Q_{\text{intercept}} \) shall be the lesser of the above flows.

The number of drainage inlets required can be computed by using the following equation:

\[
N = \frac{Q_{\text{Total}}}{Q_{\text{intercept}}}
\]

where \( N \) = minimum number of drainage inlets required

\[
Q_{\text{Total}} = \text{total flow (ft}^3/\text{sec)}
\]
\[
= \frac{C \times i \times W_p \times L}{43560} + Q_{\text{By-pass}}
\]

\( L \) = distance between up grade inlet(s) (ft)

\( Q_{\text{intercept}} \) = amount of flow intercepted by the drainage inlet (ft\(^3\)/sec)

\( Q_{\text{By-pass}} \) = sum of the by-pass flows from up grade inlets (ft\(^3\)/sec)
SAMPLE DESIGN CALCULATIONS

Bridge on a Sag Vertical Curve and Gradient:

TRANSVERSE SECTION

VERTICAL PROFILE ALIGNMENT

Given:

Road Classification: Rural Freeway (DDHV for truck traffic ≤ 250) with 3 or more thru lanes in same direction

Required shoulder width = 12'-0"

\[ S_x = 2\% = 0.02 \text{ ft/ft} \]

\[ n = 0.016 \]

\[ C = 0.9 \]

\[ i = 7.3 \text{ in/hr} \text{ (from District L&D Hydraulic Engineer)} \]

Use VDOT Standard Grate Drainage Inlet. For details see File No. 22.03-15 and -27. For purposes of this design the inside diameter(d) for a 6" diameter schedule 40 steel pipe is equal to 6.065 inches.

Stormwater runoff intercepted by grate drainage inlets for the following design example shall be allowed to discharge into air (i.e. does not need to be piped).
Design Criteria:

The allowable spread for a Freeway (Interstate) is as follows:

\[ T_{\text{allow}} = \text{shoulder width with no encroachment} = 12"-0" \]

The width of deck slab contributing runoff is computed as follows:

\[ W_p = 2 \times \left[ \frac{2.25 \text{in} + 4.875 \text{in}}{12 \text{in/ft}} \right] + 60.0 \text{ft} = 61.19 \text{ ft} \]

Design Section 1:

Drain #1:

Determine the spacing, \( L_1 \), from the high point in Design Section 1 to the first required drainage inlet in Design Section 1:

Compute maximum gutter flow for an allowable spread, \( T_{\text{allow}} = 12 \text{ ft} \):

With a longitudinal gutter slope, \( S = 0.025 \text{ ft/ft} \)

\[
Q_{\text{max}} = Q_1 = \left[ \frac{k_b}{n} \right] \times S_x^{1.67} \times S^{0.5} \times T_{\text{allow}}^{2.67}
\]

\[
= \left[ \frac{0.56}{0.016} \right] \times \left( 0.025 \text{ ft/ft} \right)^{1.67} \times \left( 0.025 \text{ ft/ft} \right)^{0.5} \times (12.0 \text{ ft})^{2.67}
\]

\[ = 6.13 \text{ ft}^3/\text{sec} \]

From the high point in Design Section 1, the distance to the first required drainage inlet:

\[
L_1 = \frac{43560 \text{ ft}^2/\text{acre} \times Q_{\text{max}}}{C \times C \times W_p} = \frac{43560 \text{ ft}^2/\text{acre} \times 6.13 \text{ ft}^3/\text{sec}}{0.9 \times 7.3 \text{ in/hr} \times 61.19 \text{ ft}} = 664.2 \text{ ft}
\]

\[ > \text{length of Design Section 1} = 514.81 \text{ ft} \]

Therefore, drainage inlets not required in Design Section 1

Design Section 2:

Drain #1:

Determine the spacing, \( L_1 \), from the high point in Design Section 1 to the first required drainage inlet in Design Section 2:
Assume a trial distance of $L_1 = 700$ ft:

Therefore, the distance from the PVC of the curve to this location is as follows:

$$X = 800 \text{ ft} - (700 \text{ ft} - 514.81 \text{ ft}) = 614.81 \text{ ft}$$

and the slope at "X" is computed as follows:

$$S = \left[ \frac{g_2 - g_1}{LVC} \right] \times X + g_1 = \left[ \frac{0.025 \text{ ft}}{800 \text{ ft}} + \frac{0.025 \text{ ft}}{800 \text{ ft}} \right] \times 614.81 \text{ ft} - \frac{0.025 \text{ ft}}{800 \text{ ft}} = 0.0134 \text{ ft/ft}$$

Compute maximum gutter flow for an allowable spread, $T_{\text{allow}} = 12$ ft:

$$Q_{\text{max}} = Q_{i=1} = \left[ \frac{k_g}{n} \right] \times S_x^{1.67} \times S^{0.5} \times T_{\text{allow}}^{2.67}$$

$$Q_{\text{max}} = Q_{i=1} \left[ \frac{0.56}{0.016} \right] \times \left( \frac{0.02 \text{ ft}}{800 \text{ ft}} \right)^{1.67} \times \left( 0.0134 \text{ ft/ft} \right)^{0.5} \times (12.0 \text{ ft})^{2.67} = 4.48 \text{ ft}^3/\text{sec}$$

The distance from high point in Design Section 1 to the first drainage inlet, $L_1$, in Design Section 2 is computed as follows:

$$L_1 = \frac{43560 \frac{\text{ft}^2}{\text{acre}} \times Q_{\text{max}}}{C \times 1 \times W_p} = \frac{43560 \frac{\text{ft}^2}{\text{acre}} \times 4.48 \frac{\text{ft}^3}{\text{sec}}}{0.9 \times 7.3 \frac{\text{in}}{\text{hr}} \times 61.19 \text{ ft}} = 485 \text{ ft} \neq \text{trial } L_1 = 700 \text{ ft}$$

Therefore, select a new trial value for $L_1$ and repeat the above steps

Assume a second trial distance of $L_1 = 590$ ft:

Therefore, the distance from the PVC of the curve to this location is as follows:

$$X = 800 \text{ ft} - (590 \text{ ft} - 514.81 \text{ ft}) = 724.81 \text{ ft}$$

and the slope at "X" is computed as follows:

$$S = \left[ \frac{g_2 - g_1}{LVC} \right] \times X + g_1 = \left[ \frac{0.025 \text{ ft}}{800 \text{ ft}} + \frac{0.025 \text{ ft}}{800 \text{ ft}} \right] \times 724.81 \text{ ft} - \frac{0.025 \text{ ft}}{800 \text{ ft}} = 0.0203 \text{ ft/ft}$$

Compute maximum gutter flow for an allowable spread, $T_{\text{allow}} = 12$ ft:

$$Q_{\text{max}} = Q_{i=1} = \left[ \frac{k_g}{n} \right] \times S_x^{1.67} \times S^{0.5} \times T_{\text{allow}}^{2.67}$$

$$Q_{\text{max}} = Q_{i=1} \left[ \frac{0.56}{0.016} \right] \times \left( \frac{0.02 \text{ ft}}{800 \text{ ft}} \right)^{1.67} \times \left( 0.0203 \text{ ft/ft} \right)^{0.5} \times (12.0 \text{ ft})^{2.67} = 5.52 \text{ ft}^3/\text{sec}$$
The distance from high point in Design Section 1 to the first drainage inlet, \( L_1 \), in Design Section 2 is computed as follows:

\[
L_1 = \frac{\frac{ft^2}{acre} \times Q_1}{C \times i \times W_p} = \frac{43560 \times \frac{ft^2}{acre} \times 5.52 \times \frac{ft^3}{sec}}{0.9 \times 7.3 \frac{in}{hr} \times 61.19 ft} = 598 ft \approx \text{trial } L_1 = 590 ft \quad \text{OK}
\]

The actual gutter flow, \( Q_1 \text{(act)} \), approaching Drain #1 is computed as follows:

\[
Q_1 \text{(act)} = \frac{C \times i \times W_p \times L_1}{\frac{ft^2}{acre}} = \frac{43560 \times \frac{ft^2}{acre}}{43560 \times \frac{ft^2}{acre}} = 5.45 ft^3/sec
\]

\(< Q_{max} = 5.52 ft^3/sec \quad \text{OK}\)

Therefore, use \( L_1 = 590 ft \) from the high point in Design Section 1

Determine inlet interception efficiency and by-pass flow for Drain #1:

- **Channel Flow:**

  Actual spread = \( T_{act} = \left[ \frac{1.786 \times Q_1 \times S_x}{S_x^{0.67} \times S_x^{0.5}} \right]^{0.375} = \left[ \frac{1.786 \times 5.45 \frac{ft^3}{sec} \times 0.016}{0.02 \frac{ft}{ft}^{1.67} \times (0.0203 \frac{ft}{ft})^{0.5}} \right]^{0.375}
  
  = 11.98 ft

  Gutter flow velocity = \( V = \left[ \frac{2k_g}{n} \right] \times S_x^{0.67} \times S_x^{0.5} \times T_{act}^{0.67}
  
  = \left[ \frac{2 \times 0.56}{0.016} \right] \times \left( 0.02 \frac{ft}{ft} \right)^{0.67} \times \left( 0.0203 \frac{ft}{ft} \right)^{0.5} \times (11.98 ft)^{0.67}
  
  = 3.83 ft/sec

  Depth of flow at curb = \( y = T_{act} \times S_x = 11.98 ft \times 0.02 \frac{ft}{ft} = 0.24 ft\)

  Length of hydraulic jump = \( L_{jump} = \frac{V}{2} \times (y + d)^{0.5} = \frac{3.83 \frac{ft}{sec}}{2} \times \left( 0.24 + \frac{0.5 \text{in}}{12 \text{in/ft}} \right)^{0.5} = 1.02 ft\)

  with a width of drain = \( w_d = \frac{8.13 \text{in} - (2 \times 0.75 \text{in})}{12 \frac{\text{in}}{\text{ft}}} = 0.55 \text{ ft}\)
Channel flow intercept factor, I.F. = \( \frac{L_{\text{jump}} - W_d}{L_{\text{jump}}} = \frac{1.02\text{ft} - 0.55\text{ft}}{1.02\text{ft}} = 0.46 > 0 \)

Therefore \( E_0 = 1.0 - 0.46 = 0.54 \)

\[ Q_{\text{channel}} = V \times \left[ \frac{L_d \times \left[ (y - (X \times S_x)) + (y - (L_d + X) \times S_x) \right]}{2} \right] \times E_0 = \]

\[ \frac{3.83 \text{ ft}}{\text{sec}} \times \left[ \frac{1.5\text{ft} \times \left[ 0.24\text{ft} - \left(0.0625\text{ft} \times 0.02\text{ft} \right) \right] + 0.24\text{ft} - \left(1.5\text{ft} + 0.0625\text{ft} \times 0.02\text{ft} \right) \right]}{2} \times 0.54 \]

\[ Q_{\text{channel}} = 0.69 \text{ ft}^3/\text{sec} \]

- Orifice Flow:
  \[ Q_o = 0.608 \times \pi \times \left(\frac{D^2}{4} \right) \times 2 \times g \times (y - (X \times S_x))^{0.5} \]
  \[ = 0.608 \times \pi \times \left(\frac{(0.5\text{ft})^2}{4} \right) \times 2 \times 32.2 \frac{\text{ft}}{\text{sec}^2} \times \left(0.24\text{ft} - \left(0.0625\text{ft} \times 0.02\text{ft} \right) \right)^{0.5} \]
  \[ = 0.47 \text{ ft}^3/\text{sec} \text{ controls} \]

- Weir Flow:
  \[ Q_w = 3.33 \times [y - (X \times S_x)]^{1.5} \times \pi \times D = 3.33 \times \left[ 0.24\text{ft} - \left(0.0625\text{ft} \times 0.02\text{ft} \right) \right]^{1.5} \times \pi \times 0.5\text{ft} \]
  \[ = 0.61 \text{ ft}^3/\text{sec} \]

Therefore, \( Q_{\text{intercept}} \) for Drain #1 = 0.47 \( \text{ft}^3/\text{sec} \)

Inlet interception efficiency = \( E = \frac{Q_{\text{intercept}}}{Q_1(\text{act})} = \frac{0.47 \text{ ft}^3/\text{sec}}{5.45 \text{ ft}^3/\text{sec}} = 0.09 \)

\( Q_{\text{By-pass}} \) (at Drain #1) = \( Q_1(\text{act}) - Q_{\text{intercept}} = 5.45 \text{ ft}^3/\text{sec} - 0.47 \text{ ft}^3/\text{sec} = 4.98 \text{ ft}^3/\text{sec} \)

Drain #2:
Determine the spacing, \( L_2 \), to Drain #2:
Assume a trial distance of \( L_2 = 50 \) ft:

Therefore, the distance from the PVC of the curve to this location is as follows:

\[
X = 800 \text{ ft} - [(590 \text{ ft} + 50 \text{ ft}) - 514.81 \text{ ft}] = 674.81 \text{ ft from the PVC}
\]

and the slope at “X” is computed as follows:

\[
S = \left[ \frac{g_2 - g_1}{LVC} \right] \times X + g_1 = \left[ \frac{0.025 \text{ ft}}{\text{ft}} + \frac{0.025 \text{ ft}}{\text{ft}} \right] \times 800 \text{ ft} - 0.025 \text{ ft} = 0.0172 \text{ ft/ft}
\]

Compute maximum gutter flow for an allowable spread, \( T_{\text{allow}} = 12 \text{ ft} \):

\[
Q_{\text{max}} = \frac{k_g}{n} \times S_x^{1.67} \times S^{0.5} \times T_{\text{allow}}^{2.67}
\]

\[
Q_{\text{max}} = \left( \frac{0.56}{0.016} \right) \left( \frac{0.02 \text{ ft}}{\text{ft}} \right)^{1.67} \times (0.0172)^{0.5} \times (12.0 \text{ ft})^{2.67} = 5.08 \text{ ft}^3/\text{sec}
\]

The distance from Drain #1 to Drain #2, \( L_2 \), is computed as follows:

\[
L_2 = \frac{43560 \text{ ft}^2}{\text{acre}} \times \left( \frac{Q_{\text{max}} - Q_{\text{By-pass}}}{C \times i \times W_p} \right) = \frac{43560 \text{ ft}^2}{\text{acre}} \times \left( \frac{5.08 \text{ ft}^3}{\text{sec}} - 4.98 \text{ ft}^3/\text{sec} \right)
\]

\[
= 10.84 \text{ ft} \neq \text{ trial } L_2 = 50 \text{ ft} \quad \text{N.G.}
\]

Therefore, select a new trial value for \( L_2 \) and repeat the above steps.

Assume a second trial distance of \( L_2 = 30 \) ft:

Therefore, the distance from the PVC of the curve to this location is as follows:

\[
X = 800 \text{ ft} - [(590 \text{ ft} + 30 \text{ ft}) - 514.81 \text{ ft}] = 694.81 \text{ ft from the PVC}
\]

and the slope at “X” is computed as follows:

\[
S = \left[ \frac{g_2 - g_1}{LVC} \right] \times X + g_1 = \left[ \frac{0.025 \text{ ft}}{\text{ft}} + \frac{0.025 \text{ ft}}{\text{ft}} \right] \times 800 \text{ ft} - 0.025 \text{ ft} = 0.0184 \text{ ft/ft}
\]

Compute maximum gutter flow for an allowable spread, \( T_{\text{allow}} = 12 \text{ ft} \):

\[
Q_{\text{max}} = \frac{k_g}{n} \times S_x^{1.67} \times S^{0.5} \times T_{\text{allow}}^{2.67}
\]
\[ Q_{\text{max}} = \left[ \frac{0.56}{0.016} \right] \times \left( \frac{0.02 \text{ ft}}{\text{ft}} \right)^{1.67} \times (0.0184)^{0.5} \times (12.0 \text{ ft})^{2.67} = 5.26 \text{ ft}^3/\text{sec} \]

The distance from Drain #1 to Drain #2, \( L_2 \), is computed as follows:

\[
L_2 = \frac{43560 \text{ ft}^2/\text{acre} \times (Q_{\text{max}} - Q_{\text{Bypass}})}{C \times i \times W_p} = \frac{43560 \text{ ft}^2/\text{acre} \times \left( 5.26 \text{ ft}^3/\text{sec} - 4.98 \text{ ft}^3/\text{sec} \right)}{0.9 \times 7.3 \text{ in/hr} \times 61.19 \text{ ft}}
\]

= 30.34 ft = trial \( L_2 = 30 \text{ ft} \) OK

The actual gutter flow, \( Q_2 \) (act), approaching Drain #2 is computed as follows:

\[
Q_2 \text{ (act)} = \frac{C \times i \times W_p \times L_2}{43560 \text{ ft}^2/\text{acre}} + Q_{\text{Bypass}} = \frac{0.9 \times 7.3 \text{ in/hr} \times 61.19 \text{ ft} \times 30 \text{ ft}}{43560 \text{ ft}^2/\text{acre}} + 4.98 \text{ ft}^3/\text{sec}
\]

= 5.26 \text{ ft}^3/\text{sec} = Q_{\text{max}} = 5.26 \text{ ft}^3/\text{sec} OK

Therefore, use \( L_2 = 30 \text{ ft} \) from Drain #1

Determine inlet interception efficiency and by-pass flow for Drain #2

- Channel Flow:

Actual spread = \( T_{\text{act}} = \left[ \frac{1.786 \times Q_2 \text{ (act)} \times n}{S_x^{1.67} \times S^{0.5}} \right]^{0.375} = \left[ \frac{1.786 \times 5.26 \text{ ft}^3/\text{sec} \times 0.016}{(0.02 \text{ ft})^{1.67} \times (0.0184 \text{ ft})^{0.5}} \right]^{0.375} \]

= 12.04 ft

Gutter flow velocity = \( V = \left[ \frac{2k_a}{n} \right] \times S_x^{0.67} \times S^{0.5} \times T_{\text{act}}^{0.67} \)

= \left[ \frac{2 \times 0.56}{0.016} \right] \times \left( \frac{0.02 \text{ ft}}{\text{ft}} \right)^{0.67} \times \left( \frac{0.0184 \text{ ft}}{\text{ft}} \right)^{0.5} \times (12.04 \text{ ft})^{0.67}

= 3.66 \text{ ft/sec}

Depth of flow at curb = \( y = T_{\text{act}} \times S_x = 12.04 \text{ ft} \times 0.02 \text{ ft} = 0.24 \text{ ft} \)

Length of hydraulic jump = \( L_{\text{jump}} = \frac{V}{2} \times (y + d)^{0.5} = \frac{3.66 \text{ ft/sec}}{2} \times \left( \frac{0.24 \text{ ft} + 0.5 \text{ in}}{12 \text{ in/ft}} \right)^{0.5} \)

= 0.97 ft
width of drain = \( w_d = \frac{8.13 \text{in} - (2 \times 0.75 \text{in})}{12 \text{in}} = 0.55 \text{ft} \)

Channel flow intercept factor, I.F. = \( \frac{L_{\text{jump}} - w_d}{L_{\text{jump}}} = \frac{0.97 \text{ft} - 0.55 \text{ft}}{0.97 \text{ft}} = 0.43 > 0 \)

Therefore \( E_o = 1.0 - 0.43 = 0.57 \)

\[ Q_{\text{channel}} = \frac{v \times \left( \frac{L_d \times \left[ (y - (X \times S_x)) + (y - (L_d + X) \times S_x) \right]}{2} \right)}{3.66 \text{ft}^3/\sec} \times E_o = \left( \frac{0.24 \text{ft} - \left( 0.0625 \text{ft} \times 0.02 \text{ft} \right)}{2} \right) \times \left( \frac{0.24 \text{ft} - \left( (1.5 \text{ft} + 0.0625 \text{ft}) \times 0.02 \text{ft} \right)}{2} \right) \times 0.57 \]

\[ = 0.70 \text{ft}^3/\sec \]

- Orifice Flow:
  \[ Q_o = 0.608 \times \pi \times \left( \frac{D^2}{4} \right) \times \left[ 2 \times g \times (y - (X \times S_x)) \right]^{0.5} \]

\[ = 0.608 \times \pi \times \left( \frac{0.5 \text{ft}^2}{4} \right) \times \left[ 2 \times 32.2 \text{ft}^3/\sec \times \left( 0.24 \text{ft} - \left( 0.0625 \text{ft} \times 0.02 \text{ft} \right) \right) \right]^{0.5} \]

\[ = 0.47 \text{ft}^3/\sec \text{ controls} \]

- Weir Flow:
  \[ Q_w = 3.33 \times \left[ (y - (X \times S_x)) \right]^{1.5} \times \pi \times D = 3.33 \times \left[ 0.24 \text{ft} - \left( 0.0625 \text{ft} \times 0.02 \text{ft} \right) \right]^{1.5} \times \pi \times 0.5 \text{ft} \]

\[ = 0.61 \text{ft}^3/\sec \]

Therefore, \( Q_{\text{Intercept}} \) for Drain #2 = 0.47 ft\(^3\)/sec

Inlet interception efficiency = \( E = \frac{Q_{\text{Intercept}}}{Q_2(\text{act})} = \frac{0.47 \text{ft}^3/\sec}{5.26 \text{ft}^3/\sec} = 0.09 \)

\( Q_{\text{By-pass}} \) (at Drain #2) = \( Q_2(\text{act}) - Q_{\text{Intercept}} = 5.26 \text{ft}^3/\sec - 0.47 \text{ft}^3/\sec = 4.79 \text{ft}^3/\sec \)

**Spacing of Remaining Drains in Design Section #2:**

Similarly, the computation of the spacing, slope, gutter flow and by-pass flow for Drains #3 through #13 are made and the results are summarized in the table on the next sheet.
The longitudinal gutter slope at Drain #13 indicates that at this location the slope is nearly flat so the design process moves to the high point in Design Section 3 to locate the first required drain.

**Design Section 3:**

**Drain #14:**

Determine the spacing, \( L_{14} \), from the high point in Design Section 3 to the first required drainage inlet:

Assume a trial distance of \( L_{14} = 39 \) ft:

Therefore, the distance from the PVC of the curve to this location is as follows:

\[
X = 312.81 \text{ ft} + 39 \text{ ft} = 351.81 \text{ ft from the PVC}
\]

and the slope at "X" is computed as follows:

\[
S = \left[ \frac{g_2 - g_1}{\text{LVC}} \right] \times X + g_1 = \left[ \frac{0.025 \frac{\text{ft}}{\text{ft}} + 0.025 \frac{\text{ft}}{\text{ft}}}{800 \text{ft}} \right] \times 351.81 \text{ ft} - 0.025 \frac{\text{ft}}{\text{ft}} = 0.003 \frac{\text{ft}}{\text{ft}}
\]

Compute maximum gutter flow for an allowable spread, \( T_{\text{allow}} = 12 \) ft:

\[
Q_{\text{max}} = \left[ \frac{k_g}{n} \right] \times S_x^{1.67} \times S^{0.5} \times T_{\text{allow}}^{2.67}
\]

\[
Q_{\text{max}} = \left[ \frac{0.56}{0.016} \right] \times \left( \frac{0.02}{\text{ft}} \right)^{1.67} \times (0.0030)^{0.5} \times (12.0 \text{ft})^{2.67} = 2.12 \text{ ft}^3/\text{sec}
\]
The actual gutter flow, $Q_{14} \text{ (act)}$, approaching Drain #14 is computed as follows:

$$Q_{14} \text{ (act)} = \frac{C \times i \times W_p \times L_{14}}{43560 \text{ ft}^2 \text{ / acre}} = \frac{0.9 \times 7.3 \text{ in/hr} \times 61.19 \text{ ft} \times 39 \text{ ft}}{43560 \text{ ft}^2 \text{ / acre}} = 0.36 \text{ ft}^3/\text{sec} < Q_{\text{max}}$$

OK

Since the slope at $L_{14}$ is nearly flat ($S \leq 0.003 \text{ ft/ft}$), locate Drain #14 at a distance of $L_{14} = 39 \text{ ft}$ from the high point in Design Section 3.

Determine inlet interception efficiency and by-pass flow for Drain #14:

- **Channel Flow:**

  Actual spread $= T_{act} = \left[ \frac{1.786 \times Q_{14} \text{ (act)} \times n}{S_x^{1.67} \times S^{0.5}} \right]^{0.375} = \left[ \frac{1.786 \times 0.36 \text{ ft}^3 \times 0.016}{(0.02 \text{ ft} / \text{ ft})^{1.67} \times (0.003 \text{ ft} / \text{ ft})^{0.5}} \right]^{0.375} = 6.19 \text{ ft}$

  Gutter flow velocity $= V = \frac{2k_g \times n}{f} \times S_x^{0.67} \times S^{0.5} \times T_{act}^{0.67}$

  $= \left[ \frac{2 \times 0.56}{0.016} \right] \times \left[ \frac{0.02 \text{ ft} / \text{ ft}}{T_{act}^{0.67}} \times \left( \frac{0.0030 \text{ ft} / \text{ ft}}{\text{ ft}} \right)^{0.5} \times (6.19 \text{ ft})^{0.67} \right]$

  $= 0.95 \text{ ft/sec}$

  Depth of flow at curb $= y = T_{act} \times S_x = 6.19 \times 0.02 \frac{\text{ ft}}{\text{ ft}} = 0.12 \text{ ft}$

  Length of hydraulic jump $= L_{\text{jump}} = \frac{V}{2} \times (y + d)^{0.5} = \frac{0.95 \text{ ft/sec}}{2} \times \left( \frac{0.12 \text{ ft} + 0.5 \text{ in}}{12 \text{ in / ft}} \right)^{0.5} = 0.20 \text{ ft}$

  with a width of drain $= w_d = \frac{8.13 \text{ in} - (2 \times 0.75 \text{ in})}{12 \text{ in / ft}} = 0.55 \text{ ft}$

  Channel flow intercept factor, $I.F. = \frac{L_{\text{jump}} - w_d}{L_{\text{jump}}} = \frac{0.20 \text{ ft} - 0.55 \text{ ft}}{0.20 \text{ ft}} = -1.75 < 0$

  Therefore, $E_d = 1.0$
\[ Q_{\text{channel}} = V \times \left[ L_d \times \left( y - (X \times S_x) \right) + \left( y - (L_d + X) \times S_x \right) \right] \times E_0 = \]

\[ = 0.95 \text{ ft/sec} \times \frac{1.5 \text{ ft} \times \left( 0.12 \text{ ft} - 0.0625 \text{ ft} \times 0.02 \text{ ft} \right)}{2} + \left( 0.12 \text{ ft} - \left( 1.5 \text{ ft} + 0.0625 \text{ ft} \right) \times 0.02 \text{ ft} \right) \times 1.0 \]

\[ = 0.15 \text{ ft}^3/\text{sec} \quad \text{controls} \]

- Orifice Flow:
  \[ Q_o = 0.608 \times \pi \times \left( \frac{D^2}{4} \right) \times 2 \times g \times (y - (X \times S_x))^0.5 \]
  \[ = 0.608 \times \pi \times \left( \frac{(0.5 \text{ ft})^2}{4} \right) \times 2 \times 32.2 \frac{\text{ft}}{\text{sec}} \times \left( 0.12 \text{ ft} - \left( 0.0625 \text{ ft} \times 0.02 \frac{\text{ft}}{\text{ft}} \right) \right)^0.5 \]
  \[ = 0.33 \text{ ft}^3/\text{sec} \]

- Weir Flow:
  \[ Q_w = 3.33 \times [y - (X \times S_x)]^{1.5} \times \pi \times D = 3.33 \times \left( 0.12 \text{ ft} - \left( 0.0625 \text{ ft} \times 0.02 \frac{\text{ft}}{\text{ft}} \right) \right)^{1.5} \times \pi \times 0.5 \text{ ft} \]
  \[ = 0.21 \text{ ft}^3/\text{sec} \]

Therefore, \( Q_{\text{intercept}} \) for Drain #14 = 0.15 ft\(^3\)/sec

Inlet interception efficiency = \( E = \frac{Q_{\text{intercept}}}{Q_1(\text{act})} = \frac{0.15 \text{ ft}^3/\text{sec}}{0.36 \text{ ft}^3/\text{sec}} = 0.42 \)

\( Q_{\text{By-pass}} \) (at Drain #14) = \( Q_{14} - Q_{\text{intercept}} = 0.36 \text{ ft}^3/\text{sec} - 0.15 \text{ ft}^3/\text{sec} = 0.21 \text{ ft}^3/\text{sec} \)

**Spacing of Drains in Sag (Low) Point Section:**

The sag (low) point section of bridge between Drain #13 in Design Section 2 and Drain #14 in Design Section 3 will be treated as a flat / nearly flat bridge section.

The length of the sag (low) point section:

\[ L = X_{13} - X_{14} = 451.81 \text{ ft} - 351.81 \text{ ft} = 100 \text{ ft} \]
Sum of the by-pass flow from Drain #13 (Design Section #2) and Drain #14 (Design Section #3):

\[ Q_{\text{By-pass (Total)}} = Q_{\text{By-pass (Drain #13)}} + Q_{\text{By-pass (Drain #14)}} = 1.72 \text{ ft}^3/\text{sec} + 0.21 \text{ ft}^3/\text{sec} \]

\[ = 1.93 \text{ ft}^3/\text{sec} \]

Total flow for this section of the bridge:

\[ Q_{\text{Total}} = \frac{C \times i \times W_p \times L}{43560 \text{ ft}^2/\text{acre}} + \frac{Q_{\text{By-pass (Total)}}}{43560 \text{ ft}^2/\text{acre}} + 1.93 \text{ ft}^3/\text{sec} \]

\[ = 2.85 \text{ ft}^3/\text{sec} \]

Interception capacity per drainage inlet:

with \( T_{\text{allow}} = 12 \text{ ft} \), the maximum depth of flow at curb is computed as follows:

\[ y_{\text{max}} = T_{\text{allow}} \times S_x = 12.0 \text{ ft} \times 0.02 \frac{\text{ft}}{\text{ft}} = 0.24 \text{ ft} \]

The intercept capacity per drain is the lesser of the following flow interception capacities:

- Weir flow interception capacity:
  \[ Q_w = 3.33 \times y_{\text{max}}^{1.5} \times \pi \times D = 3.33 \times 0.24 \text{ ft}^{1.5} \times \pi \times 0.5 \text{ ft} = 0.62 \text{ ft}^3/\text{sec} \]

- Orifice flow interception capacity:
  \[ Q_o = 0.608 \times \pi \times \left[ \frac{D^2}{4} \right] \times \left[ 2 \times g \times y_{\text{max}} \right]^{0.5} \]
  \[ = 0.608 \times \pi \times \left[ \frac{(0.5 \text{ ft})^2}{4} \right] \times \left[ 2 \times 32 \frac{\text{ft}}{\text{sec}} \times 0.24 \text{ ft} \right]^{0.5} = 0.47 \text{ ft}^3/\text{sec} \]

Therefore, \( Q_{\text{intercept}} \) capacity per drain = 0.47 ft\(^3\)/sec

The total number of drainage inlets required in this section is computed as follows:

\[ N = \frac{Q_{\text{Total}}}{Q_{\text{intercept}}} = \frac{2.85 \text{ ft}^3/\text{sec}}{0.47 \text{ ft}^3/\text{sec}} = 6.06 \text{ drains} \quad \text{Therefore, use 7 drains} \]
DRAIN SPACING FOR SAG POINT SECTION
GENERAL INFORMATION:

The deck slab drainage inlet details used by the Structure and Bridge Division are shown in this section of the chapter.

The details shown are for the designer’s information only. See Introduction File No. 22.00-1.

The minimum and maximum deck slab cantilever width requirements shown in this section for a drainage inlet detail are only intended to assist the designer in determining where the particular drainage inlet detail may be used. They are not intended to supersede the requirements for deck slab cantilevers contained in Chapter 10 of this manual.

The deck slab drainage inlet details shown may not work for all locations as it is dependent on the location of face of curb/rail. The designer may need to adjust the deck slab cantilever width and or beam/girder spacings.

When deck slab drainage inlets are required in locations designated for use by pedestrian and/or bicycle traffic, all downspout and grate openings shall be pedestrian and bicycle friendly and conform to the requirements of File No. 6.04 of this manual.

The location(s) of deck slab drainage inlets shall be shown on the deck slab plan sheet of the bridge plans.

Reinforcing steel in deck slab may be shifted or cut as directed by the Engineer to clear the downspout pipe or grate drainage assembly.

Costs for furnishing and installing all components of the deck slab drainage system shall be included as a lump sum bid item as shown on the plans.

MATERIALS:

Steel pipe downspouts shall be ASTM A53 Schedule 40 black seamless steel pipe.

Steel plates, bars and rods shall be ASTM A36.

All bolts shall be ASTM A325.

All threaded inserts shall be flared thin slab ferrule 1/2"- 9 NC threaded insert. See File No. 12.09-3.

CORROSION PROTECTION:

Welded frame, grate and downspout pipe assemblies and attachments to include all steel pipes, plates, bars, rods, studs, bolts and nuts shall be hot dipped galvanized after fabrication.

When pipe support straps are attached to weathering steel, a neoprene or vinyl washer shall be placed between the contact surfaces of the support strap and the hex nut with the weathering steel to isolate the contact between the two surfaces.
1. For Sections A-A, see File Nos. 22.03-3 thru -13.

2. The arrows shown above show direction of slope of deck slab around the downspout drainage inlet.

3. For location(s) of downspout drainage inlet assemblies, see the deck slab plan sheet of the bridge plans.

4. For detail of downspout drainage inlet opening, see File No. 22.03-27.
1. The above downspout drainage inlet detail is intended for use with AASHTO prestressed concrete Type II thru IV I-beam superstructures having the minimum cantilever widths shown below for the parapet/railing series used.

### DOWNSPOUT DRAINAGE INLETS

<table>
<thead>
<tr>
<th>PARAPET/RAILING</th>
<th>AASHTO TYPE II</th>
<th>AASHTO TYPE III</th>
<th>AASHTO TYPE IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPB - Series</td>
<td>3'-3 1/8&quot;</td>
<td>3'-5 1/8&quot;</td>
<td>3'-7 1/8&quot;</td>
</tr>
<tr>
<td>BR27 - Series</td>
<td>2'-5 1/8&quot;</td>
<td>2'-7 1/8&quot;</td>
<td>2'-9 1/8&quot;</td>
</tr>
<tr>
<td>BIR - Series</td>
<td>3'-1 1/8&quot;</td>
<td>3'-3 1/8&quot;</td>
<td>3'-5 1/8&quot;</td>
</tr>
<tr>
<td>BCR - Series</td>
<td>2'-10 1/8&quot;</td>
<td>3'-0 1/8&quot;</td>
<td>3'-2 1/8&quot;</td>
</tr>
</tbody>
</table>

2. For deck slab cantilevers with widths less than the required minimum width shown above, see details in File Nos. 22.03-5, -10 and -11.

3. For location of section cut, see File No. 22.03-2.

4. For location of Section B-B, see File No. 22.03-26.

5. Designer shall detail section with appropriate beam and parapet/railing, median, median barrier, etc.
DRAINAGE
DECK SLAB DRAINAGE INLET DETAILS
DOWNSPOUT DRAINAGE INLETS

SECTION A-A

<table>
<thead>
<tr>
<th>PARAPET/RAILING</th>
<th>AASHTO TYPE V and VI and BULB-T</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPB - Series</td>
<td>This detail not recommended since minimum cantilever required exceeds 0.3 beam/girder spacing.</td>
</tr>
<tr>
<td>BR27 - Series</td>
<td></td>
</tr>
<tr>
<td>BIR - Series</td>
<td></td>
</tr>
<tr>
<td>BCR - Series</td>
<td></td>
</tr>
</tbody>
</table>

1. For Bulb-T’s, see details in File Nos. 22.03-6 thru -9 and for AASHTO Types V and VI beams, see detail in File No. 22.03-9.

2. For location of section cut, see File No. 22.03-2.

3. For location of Section B-B, see File No. 22.03-26.
1. The above downspout drainage inlet detail is intended for use with AASHTO prestressed concrete Type II thru IV I-beam superstructures having the minimum cantilever widths shown below for the parapet/railing series used.

<table>
<thead>
<tr>
<th>PARAPET/RAILING</th>
<th>AASHTO TYPE II</th>
<th>AASHTO TYPE III</th>
<th>AASHTO TYPE IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPB - Series</td>
<td>3'-0&quot;</td>
<td>3'-2 1/8&quot;</td>
<td>3'-4 1/8&quot;</td>
</tr>
<tr>
<td>BR27 - Series</td>
<td>2'-2 1/8&quot;</td>
<td>2'-4 1/8&quot;</td>
<td>2'-6 1/8&quot;</td>
</tr>
<tr>
<td>BIR - Series</td>
<td>2'-10 1/8&quot;</td>
<td>3'-0 1/8&quot;</td>
<td>3'-2 1/8&quot;</td>
</tr>
<tr>
<td>BCR - Series</td>
<td>2'-7 1/8&quot;</td>
<td>2'-9 1/8&quot;</td>
<td>2'-11 1/8&quot;</td>
</tr>
</tbody>
</table>

2. For deck slab cantilevers with widths less than the required minimum width shown above, see details in File Nos. 22.03-10 and -11.

3. For location of section cut, see File No. 22.03-2.

4. For location of Section B-B, see File No. 22.03-26.

5. Designer shall detail section with appropriate beam and railing, median, median barrier, etc.
1. The above downspout drainage inlet detail is intended for use with prestressed concrete Bulb-T superstructures having a cantilever width within the ranges shown below for the parapet/railing series used.

<table>
<thead>
<tr>
<th>PARAPET/RAILING</th>
<th>CANTILEVER WIDTH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MINIMUM</td>
</tr>
<tr>
<td>BPB - Series</td>
<td>2'-11\text{1/2}&quot;</td>
</tr>
<tr>
<td>BR27 - Series</td>
<td>2'-1\text{1/2}&quot;</td>
</tr>
<tr>
<td>BIR - Series</td>
<td>2'-9\text{1/2}&quot;</td>
</tr>
<tr>
<td>BCR - Series</td>
<td>2'-5\text{1/2}&quot;</td>
</tr>
</tbody>
</table>

2. For deck slab cantilevers having widths less than the required minimum width shown above, see details in File Nos. 22.03-8 and -9.

3. For location of section cut, see File No. 22.03-2.
4. For location of Section B-B, see File No. 22.03-26.

5. Designer shall detail section with appropriate beam and railing, median, median barrier, etc.

6. For details of Bulb-T top flange pipe sleeve, see File Nos. 12.03-4 and -5.
1. The above downspout drainage inlet detail is intended for use with prestressed concrete Bulb-T superstructures having face of curbs for sidewalks, medians, median barriers located between beams or parapets/railings where the width of deck slab cantilever requires that the pipe downspout drainage inlet to be located between beams.

2. The required minimum distance from C of beam to face of curb/rail is 2\(\frac{7}{8}\)" with a required maximum distance of 7\(\frac{1}{2}\)". For locations of face of curb/rail less than the required minimum, see details in File Nos. 22.03-6. For locations of face of curb/rail greater than the required maximum, see detail File No. 22.03-9.

3. For location of section cut, see File No. 22.03-2.

4. For location of Section B-B, see File No. 22.03-26.

5. Designer shall detail section with appropriate beam and railing, median, median barrier, etc.

6. For details of Bulb-T top flange pipe sleeve, see File Nos. 12.03-4 and -5.
1. The above downspout drainage inlet detail is intended for use with prestressed concrete Bulb-T and AASHTO Type V and VI superstructures with face of curbs for sidewalks, medians, median barriers or parapets/railings requiring that the pipe downspout be located between beams.

2. The required minimum distance from $\ell$ of prestressed concrete Bulb-T to face of curb/rail is 1'-9" and 1'-6\(\frac{1}{2}\)" for an AASHTO Type V and VI beam. For prestressed concrete Bulb-T’s when the locations of face of curb/rail are less than the required minimum, see details in File Nos. 22.03-6 thru -8.

3. For location of section cut, see File No. 22.03-2.

4. For location of Section B-B, see File No. 22.03-26.

5. The section shown above is for superstructures with a Bulb-T section. For AASHTO Type V or VI beam sections and/or other locations of pipe downspouts, modify as required. Provide $\frac{1}{2}$" minimum clearance between pipe downspout and the beam’s widest flange.

6. Designer shall detail section with appropriate beam and railing, median, median barrier, etc.
1. The above downspout drainage inlet detail is intended for use with AASHTO prestressed concrete Type II thru IV I-beam superstructures with face of curbs for sidewalks, medians, median barriers located between beams or parapets/railings requires that the pipe downspout be located between beams.

2. The required minimum distance from L of AASHTO prestressed concrete I-beam to face of curb/rail is as shown below for the beam type used.

<table>
<thead>
<tr>
<th>AASHTO I-BEAM TYPE</th>
<th>MINIMUM DISTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>3 1/2&quot;</td>
</tr>
<tr>
<td>III</td>
<td>5 1/2&quot;</td>
</tr>
<tr>
<td>IV</td>
<td>7 1/2&quot;</td>
</tr>
</tbody>
</table>

3. When the locations of face of curb/rail are less than the required minimum distances shown above, see details in File Nos. 22.03-3, and -5.

4. For location of section cut, see File No. 22.03-2.

5. For location of Section B-B, see File No. 22.03-26.

6. Designer shall detail section with appropriate beam and railing, median, median barrier, etc.
1. The above downspout drainage inlet detail is intended for use with AASHTO prestressed concrete Type II thru IV I-beam superstructures with face of curbs for sidewalks, medians, median barriers or parapets/railings requiring that the pipe downspout be located between beams.

2. The required minimum distance from \( \ell \) of AASHTO prestressed concrete I-beam to face of curb/rail is as shown below for the beam type used.

### DOWNSPOUT DRAINAGE INLETS

<table>
<thead>
<tr>
<th>AASHTO I-BEAM TYPE</th>
<th>MINIMUM DISTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>6( \frac{1}{2} )&quot;</td>
</tr>
<tr>
<td>III</td>
<td>8( \frac{1}{2} )&quot;</td>
</tr>
<tr>
<td>IV</td>
<td>10( \frac{1}{2} )&quot;</td>
</tr>
</tbody>
</table>

3. When the locations of face of curb/rail are less than the required minimum distances shown above, see details in File Nos. 22.03-3, -5 and -10.

4. For location of section cut, see File No. 22.03-2.

5. For location of Section B-B, see File No. 22.03-26.

6. Designer shall detail section with appropriate beam and railing, median, median barrier, etc.
1. The above downspout drainage inlet detail is intended for use with steel plate girder/rolled beam superstructures.

2. For location of section cut, see File No. 22.03-2.

3. For location of Section C-C, see File No. 22.03-26.

4. The section shown above is for superstructures with a steel plate girder having a 16" top flange and a 18" bottom flange. For other plate girder sections, rolled beams and/or other locations of pipe downspouts, modify as required. Provide 1/2" minimum clearance between pipe downspout and the girder/beam's widest flange.

5. Designer shall detail section with appropriate beam and railing, median, median barrier, etc.

6. When pipe support straps are attached to weathering steel, a neoprene or vinyl washer shall be placed between the contact surfaces of the support strap and the hex nut with the weathering steel to isolate the contact between the two surfaces.
1. The above downspout drainage inlet detail is intended for use with steel plate girder/rolled beam superstructures with face of curbs for sidewalks, medians, median barriers or parapets/railings requiring that the pipe downspout be located between girders/beams.

2. For location of section cut, see File No. 22.03-2.

3. For location of Section C-C, see File No. 22.03-26.

4. The section shown above is for superstructures with a steel plate girder having a 16" top flange and a 18" bottom flange. For other plate girder sections, rolled beams and/or other locations of pipe downspouts, modify as required. Provide 1/2" minimum clearance between pipe downspout and the girder/beams widest flange.

5. Designer shall detail section with appropriate beam and railing, median, median barrier, etc.

6. When pipe support straps are attached to weathering steel, a neoprene or vinyl washer shall be placed between the contact surfaces of the support strap and the hex nut with the weathering steel to isolate the contact between the two surfaces.
1. For Sections A-A, see File Nos. 22.03-15 thru -25.

2. The arrows shown above show direction of slope of deck slab around the grate drainage inlet.

3. For location(s) of grate drain inlet assemblies, see the Deck Plan sheet of the bridge plans.

4. For detail of grate drainage inlet opening, see File No. 22.03-27.
1. The above grate drainage inlet detail is intended for use with AASHTO prestressed concrete Type II thru IV I-beam superstructures having the minimum cantilever widths shown below for the parapet/railing series used.

<table>
<thead>
<tr>
<th>PARAPET/RAILING</th>
<th>AASHTO TYPE II</th>
<th>AASHTO TYPE III</th>
<th>AASHTO TYPE IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPB - Series</td>
<td>3'-0'/8&quot;</td>
<td>3'-2'/8&quot;</td>
<td>3'-4'/8&quot;</td>
</tr>
<tr>
<td>BR27 - Series</td>
<td>2'-2'/8&quot;</td>
<td>2'-4'/8&quot;</td>
<td>2'-6'/8&quot;</td>
</tr>
<tr>
<td>BIR - Series</td>
<td>2'-10'/8&quot;</td>
<td>3'-0'/8&quot;</td>
<td>3'-2'/8&quot;</td>
</tr>
<tr>
<td>BCR - Series</td>
<td>2'-7'/8&quot;</td>
<td>2'-9'/8&quot;</td>
<td>2'-11'/8&quot;</td>
</tr>
</tbody>
</table>

2. For deck slab cantilevers with widths less than the required minimum width shown above, see details in File Nos. 22.03-17, -22 and -23.

3. For location of section cut, see File No. 22.03-14.

4. For location of Section B-B, see File No. 22.03-26.

5. Designer shall detail section with appropriate beam and railing, median, median barrier, etc.
SECTION A-A

### DOWNSPOUT DRAINAGE INLETS

<table>
<thead>
<tr>
<th>PARAPET/RAILING</th>
<th>AASHTO TYPE V and VI and BULB-T</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPB - Series</td>
<td></td>
</tr>
<tr>
<td>BR27 - Series</td>
<td></td>
</tr>
<tr>
<td>BIR - Series</td>
<td></td>
</tr>
<tr>
<td>BCR - Series</td>
<td></td>
</tr>
</tbody>
</table>

This detail not recommended since minimum cantilever required exceeds 0.3 beam/girder spacing.

1. For Bulb-T’s, see details in File Nos. 22.03-18 thru -21 and for AASHTO Types V and VI beams, see detail in File No. 22.03-21.

2. For location of section cut, see File No. 22.03-14.

3. For location of Section B-B, see File No. 22.03-26.
1. The above grate drainage inlet detail is intended for use with AASHTO prestressed concrete Type II thru IV I-beam superstructures having the minimum cantilever widths shown for the parapet/railing series used:

<table>
<thead>
<tr>
<th>PARAPET/RAILING</th>
<th>MINIMUM CANTILEVER WIDTH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AASHTO TYPE II</td>
</tr>
<tr>
<td>BPB - Series</td>
<td>2'-9/8&quot;</td>
</tr>
<tr>
<td>BR27 - Series</td>
<td>1'-11/8&quot;</td>
</tr>
<tr>
<td>BIR - Series</td>
<td>2'-7/8&quot;</td>
</tr>
<tr>
<td>BCR - Series</td>
<td>2'-4/8&quot;</td>
</tr>
</tbody>
</table>

2. For deck slab cantilevers with widths less than the required minimum width shown above, see details in File Nos. 22.03-22 and -23.

3. For location of section cut, see File No. 22.03-14.

4. For location of Section B-B, see File No. 22.03-26.

5. Designer shall detail section with appropriate beam and railing, median, median barrier, etc.
1. The above grate drainage inlet detail is intended for use with prestressed concrete Bulb-T superstructures having a cantilever width within the ranges shown below for the parapet/railing series used:

<table>
<thead>
<tr>
<th>PARAPET/RAILING</th>
<th>CANTILEVER WIDTH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MINIMUM</td>
</tr>
<tr>
<td>BPB - Series</td>
<td>2'9 1/4&quot;</td>
</tr>
<tr>
<td>BR27 - Series</td>
<td>1'11 1/4&quot;</td>
</tr>
<tr>
<td>BIR - Series</td>
<td>2'7 3/4&quot;</td>
</tr>
<tr>
<td>BCR - Series</td>
<td>2'3 3/4&quot;</td>
</tr>
</tbody>
</table>

2. For deck slab cantilevers having widths less than the required minimum width shown above, see details in File Nos. 22.03-20 and -21.

3. For location of section cut, see File No. 22.03-14.

4. For location of Section B-B, see File No. 22.03-26.
5. Designer shall detail section with appropriate beam and railing, median, median barrier, etc.

6. For details of Bulb-T top flange pipe sleeve, see File Nos. 12.03-4 and -5.
1. The above grate drainage inlet detail is intended for use with prestressed concrete Bulb-T superstructures with face of curbs for sidewalks, medians, median barriers located between beams or parapets/railings requiring that the pipe downspout of the grate drainage inlet to be located between beams.

2. The required minimum distance from $C$ of beam to face of curb/rail is $5\frac{1}{8}''$ with a maximum distance of $9\frac{3}{4}''$. For locations of face of curb/rail less than the required minimum, see details in File Nos. 22.03-18. For locations of face of curb/rail greater than the required maximum, see detail File No. 22.03-21.

3. For location of section cut, see File No. 22.03-14.

4. For location of Section B-B, see File No. 22.03-26.

5. Designer shall detail section with appropriate beam and railing, median, median barrier, etc.

6. For details of Bulb-T top flange pipe sleeve, see File Nos. 12.03-4 and -5.

*Note: Designer shall account for this when calculating minimum vertical clearance.*
1. The above grate drainage inlet detail is intended for use with prestressed concrete Bulb-T and AASHTO Type V and VI superstructures with face of curbs for sidewalks, medians, median barriers or parapets/railings requiring that the pipe downspout of the grate drainage inlet be located between beams.

2. The required minimum distance from  $L$ of prestressed concrete Bulb-T to face of curb/rail is 1'-11 $\frac{3}{4}$" and 1'-8 $\frac{3}{4}$" for an AASHTO Type V and VI beam. For prestressed concrete Bulb-T’s when the locations of face of curb/rail are less than the required minimum, see details in File Nos. 22.03-18 thru -20.

3. For location of section cut, see File No. 22.03-14.

4. For location of Section B-B, see File No. 22.03-26.

5. The section shown above is for superstructures with a Bulb-T section. For AASHTO Type V or VI beam sections and/or other locations of pipe downspouts, modify as required. Provide $\frac{1}{2}$" minimum clearance between pipe downspout and the beam’s widest flange.

6. Designer shall detail section with appropriate beam and railing, median, median barrier, etc.

*Note: Designer shall account for this when calculating minimum vertical clearance.

SECTION A-A

DRAINAGE
DECK SLAB DRAINAGE INLET DETAILS
GRATE DRAINAGE INLETS
1. The above grate drainage inlet detail is intended for use with AASHTO prestressed concrete Type II thru IV I-beam superstructures with face of curbs for sidewalks, medians, median barriers or parapets/railings requiring that the pipe downspout of the grate drainage inlet be located between beams.

2. The required minimum distance from \( C \) of AASHTO prestressed concrete I-beam to face of curb/rail is as shown below for the beam type used.

<table>
<thead>
<tr>
<th>AASHTO I-BEAM TYPE</th>
<th>MINIMUM DISTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>5 3/4&quot;</td>
</tr>
<tr>
<td>III</td>
<td>7 3/4&quot;</td>
</tr>
<tr>
<td>IV</td>
<td>9 3/4&quot;</td>
</tr>
</tbody>
</table>

3. When the locations of face of curb/rail are less than the required minimum distances shown above, see details in File Nos. 22.03-15 and -17.

4. For location of section cut, see File No. 22.03-14.

5. For location of Section B-B, see File No. 22.03-26.

6. Designer shall detail section with appropriate beam and railing, median, median barrier, etc.
1. The above grate drainage inlet detail is intended for use with AASHTO prestressed concrete Type II thru IV I-beam superstructures with face of curbs for sidewalks, medians, median barriers or parapets/railings requiring that the pipe downspout of the grate drainage inlet be located between beams.

2. The required minimum distance from $C$ of AASHTO prestressed concrete I-beam to face of curb/rail is as shown below for the beam type used.

<table>
<thead>
<tr>
<th>AASHTO I-BEAM TYPE</th>
<th>MINIMUM DISTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>8 7/8&quot;</td>
</tr>
<tr>
<td>III</td>
<td>10 3/4&quot;</td>
</tr>
<tr>
<td>IV</td>
<td>1-0 3/4&quot;</td>
</tr>
</tbody>
</table>

3. When the locations of face of curb/rail are less than the required minimum distances shown above, see details in File Nos. 22.03-15, -17 and -22.

4. For location of section cut, see File No. 22.03-14.

5. For location of Section B-B, see File No. 22.03-26.

6. Designer shall detail section with appropriate beam and railing, median, median barrier, etc.
1. The above grate drainage inlet detail is intended for use with steel plate girder/rolled beam superstructures.

2. For location of section cut, see File No. 22.03-14.

3. For location of Section C-C, see File No. 22.03-26.

4. The section shown above is for superstructures with a steel plate girder having a 16” top flange and a 18” bottom flange. For other plate girder sections, rolled beams and/or other locations of pipe downspouts, modify as required. Provide 1/2” minimum clearance between pipe downspout and the girder/beam’s widest flange.

5. Designer shall detail section with appropriate beam and railing, median, median barrier, etc.

6. When pipe support straps are attached to weathering steel, a neoprene or vinyl washer shall be placed between the contact surfaces of the support strap and the hex nut with the weathering steel to isolate the contact between the two surfaces.
1. The above grate drainage inlet detail is intended for use with steel plate girder/rolled beam superstructures with face of curbs for sidewalks, medians, median barriers or parapets/railings requiring that the pipe downspout of the grate drainage inlet be located between girders/beams.

2. For location of section cut, see File No. 22.03-14.

3. For location of Section C-C, see File No. 22.03-26.

4. The section shown above is for superstructures with a steel plate girder having a 16" top flange and a 18" bottom flange. For other plate girder sections, rolled beams and/or other locations of pipe downspouts, modify as required. Provide 1/2" minimum clearance between pipe downspout and the girder/beam's widest flange.

5. Designer shall detail section with appropriate beam and railing, median, median barrier, etc.

6. When pipe support straps are attached to weathering steel, a neoprene or vinyl washer shall be placed between the contact surfaces of the support strap and the hex nut with the weathering steel to isolate the contact between the two surfaces.
**DOWNSPOUT PIPE ATTACHMENT DETAILS:**

**SECTION B-B – PRESTRESSED CONCRETE BEAMS**

1. H.S. bolts installed in threaded inserts shall be tightened to a snug tight condition as defined in Section 407 of the VDOT Road and Bridge Specifications. Rotational capacity test will not be required.

2. When pipe support straps are attached to weathering steel, a neoprene or vinyl washer shall be placed between the contact surfaces of the support strap and the hex nut with the weathering steel to isolate the contact between the two surfaces.

**SECTION C-C – STEEL BEAMS/GIRDERS**

1. H.S. bolts installed in threaded inserts shall be tightened to a snug tight condition as defined in Section 407 of the VDOT Road and Bridge Specifications. Rotational capacity test will not be required.

2. When pipe support straps are attached to weathering steel, a neoprene or vinyl washer shall be placed between the contact surfaces of the support strap and the hex nut with the weathering steel to isolate the contact between the two surfaces.
DRAINAGE INLET OPENING DETAILS:

GRATE DRAINAGE INLET OPENING DETAIL

DOWNSPOUT DRAINAGE INLET OPENING DETAIL
GENERAL INFORMATION:

Stormwater runoff intercepted by drainage inlets shall be discharged from the deck slab by either falling directly to surfaces beneath the bridge (discharge to air), or is collected and conveyed to another location on or off the bridge.

Collected stormwater runoff is conveyed either to a vertical surface on the bridge by means of a collector pipe suspended beneath the bridge superstructure to downspouts attached to piers or other vertical surfaces of the bridge or to a specified location away from the bridge.

Stormwater shall not be discharged openly over any traveled way (either vehicular or pedestrian), unprotected embankments or other ground surfaces where it might cause erosion or undermine structural integrity of the bridge. In such cases, riprap or other means such as energy dissipators, paved slab or splash blocks shall be provided.

For bridges over railroads, all stormwater runoff intercepted by deck slab drainage inlets shall be collected and conveyed by longitudinal storm drain collector pipe(s) to a specified location off the railroad property.

Discharge to Air:

Stormwater runoff intercepted by deck slab drainage inlets shall normally be allowed to fall freely from drainage inlets to surfaces beneath the bridge unless structural and/or environmental constraints preclude doing so.

When short vertical downspouts are used to discharge water into the air, they shall be 6 inch minimum diameter steel pipe and shall extend 6” below the bottom of adjacent beam/girder flange.

Short vertical downspout pipes shall be located a minimum of 5’-0” away from piers to avoid wind driven spray on bridge components.

Stormwater Collection Systems:

When project constraints/requirements preclude the discharging of stormwater intercepted by drainage inlets from being discharged into the air, collected stormwater runoff shall normally be conveyed by collector pipes to downspouts attached to piers or other vertical surfaces on the bridge.

When project requirements preclude the discharging of stormwater runoff directly into a waterway or other areas such as in environmentally sensitive locations, it shall be necessary to provide a longitudinal storm drain collector pipe to carry the stormwater runoff to a specified location away from the bridge.

Collector and downspout pipes shall be 6 inch minimum diameter pipe. Pipes shall be sloped at least 2% (1/4” per foot) or more where conditions allow to provide sufficient velocities at low flow to move silt and small debris to avoid clogging.

If collector pipes are exposed, they shall run parallel to the existing lines of the structure and painted to match the general color of the bridge.
Collector/downspout pipes shall not be concealed (embedded) within pier caps, columns, abutment walls or installed through steel box girders.

Cleanouts both upward and downward shall be provided at all key points within the system to facilitate removal of debris and other obstructions. They shall be located so that they are accessible and easily reached by maintenance crews.

Costs for furnishing and installing all components of the stormwater collection and discharge system shall be included as a lump sum bid item as shown on the plans.

**Materials:**

Steel collector and downspout pipes shall be ASTM A53 Schedule 40 black seamless steel pipe.

Steel plates, bars and rods shall be ASTM A36.

All bolts shall be ASTM A325.

All threaded inserts shall be flared thin slab ferrule 1/2”- 9 NC threaded insert. See File No. 12.09-3.

**Corrosion Protection:**

Collector and downspout assemblies and attachments to include all steel plates, pipe, bars, bolts and nuts shall be hot dipped galvanized after fabrication.

When pipe support straps are attached to weathering steel, a neoprene or vinyl washer shall be placed between the contact surfaces of the support strap and the hex nut with the weathering steel to isolate the contact between the two surfaces.
DRAINAGE COLLECTOR PIPE DETAILS:

1. The details shown above and in File Nos. 22.04-4 thru -7 are for the designer's information only. See Introduction File No. 22.00-1.

2. For Sections A-A, see File No. 22.04-4. For Sections B-B, see File Nos. 22.04-5 thru -7.

3. For details of pipe support straps, see File Nos. 22.04-9 and -10.

4. For collector downspout pipe reducer details, see File No. 22.04-8.

5. For pipe hanger details, see File No. 22.04-11.
SECTION A-A – SHARED USE PATH

For location of section cuts and notes, see File No. 22.04-3.
SECTION B-B

For location of section cuts and notes, see File No. 22.04-3.
SECTION B-B - SIDEWALK

For location of section cuts and notes, see File No. 22.04-3.
SECTION B-B – SHARED USE PATH

For location of section cuts and notes, see File No. 22.04-3.
COLLECTOR DOWNSPOUT PIPE REDUCER DETAILS:

![Diagram of collector downsout pipe reducer details]

- PLAN
- ELEVATION

COLLECTOR DOWNSPOUT PIPE REDUCER DETAILS
PIPE SUPPORT STRAP DETAILS:

1. The pipe support strap detail shown above is intended to be used for attachment of collector and downspout pipe to flat faces of beams/girders, abutment walls, pier caps and pier columns.

2. Provide dimension on plan detail.
1. The pipe support strap detail shown above is intended to be used for attachment of collector and downspout pipe to faces of circular pier columns.

2. Provide dimension on plan detail.

3. Provide circular pier column radius on plan detail.
PIPE HANGER DETAILS:

![Diagram of a pipe hanger detail with annotations]

ALTERNATE PIPE HANGER DETAIL

![Diagram of an alternate pipe hanger detail with annotations]
ALTERNATE PIPE HANGER ROD DETAIL

Bottom of deck slab

1/2" rebar with threaded end and two hex nuts

7"
GENERAL INFORMATION:

This section of the chapter shows typical drainage details that may be used in a plan assembly. Included is a check list for completing this sheet.

It is not the intent of the sample deck slab drainage detail sheet and check list to show the practices and requirements for the design and layout of the deck slab drainage system. The sample deck slab drainage detail sheet shown is intended only to provide the designer with the type of details that may be used for a complete deck slab drainage detail sheet. There may be details shown that may not be necessary for some bridge drainage systems.

Information placed in blocks is for designer's information only and is not to be placed on the deck slab drainage detail sheet.

The practices for the completion of interior sheets contained in Chapter 4 shall be adhered to.
CHECK LIST FOR SAMPLE DECK SLAB DRAINAGE DETAIL SHEET:

1. The location of drainage inlets is typically shown on the DECK SLAB PLAN of the DECK PLAN sheet.

2. Show and label C of drainage inlet(s) along face of curb/rail. Dimension locations from C of piers.

3. Show TYPICAL DOWNSPOUT/GRATE DRAINAGE INLET DETAILS as required. Include the appropriate SECTION A-A details.

4. Show DRAINAGE COLLECTOR PIPE DETAIL showing the drainage collector pipes conveying the stormwater runoff from the drainage inlets to the piers or other vertical surfaces of the bridge. Minimum slope of longitudinal collector pipe shall be 2%. Maximum spacing of steel attachment bars shall be 10'-0" on centers. Detail not required when stormwater is discharged directly into the air from the drainage inlet downspout.

5. Show PIER PLAN - COLLECTOR/DOWNSPOUT PIPE DETAIL showing the collector downspout configuration for conveying the stormwater from the drainage collector pipes to the pier cap and down the pier column(s). Detail not required when stormwater is discharged directly into the air from the drainage inlet downspout.

6. Show PIER ELEVATION - DRAINAGE COLLECTOR DOWNSPOUT PIPE DETAIL showing the routing of downspout pipes to the pier columns. Show all cleanouts, reducers and support brackets. Maximum spacing of support brackets shall be 10'-0" on centers. Detail not required when stormwater is discharged directly into the air from the drainage inlet downspout.

7. Show DOWNSPOUT REDUCER DETAILS.

8. Show TYPICAL PIPE SUPPORT STRAP DETAILS. Provide dimension(s) from face of beam/girder web and pier cap/column to C of downspout pipe. Provide minimum 1/2" clearance between pipe downspout and beam/girder flanges and webs.

9. Show Notes as required. Add appropriate sheet number(s). For instructions on completing the notes, see File No. 04.03.

10. For instructions on completing the title block, see File No. 04.04-2.

11. For instructions on completing the project block, see File No. 04.01.

12. For instructions on completing this portion of the sheet, see File No. 04.04-3.

13. For instructions on completing the block for sealing, signing and dating this sheet, see File Nos. 01.16-1 thru -7.

14. Show appropriate drainage inlet opening detail.
GENERAL INFORMATION:

For practices and requirements regarding the detailing of abutment drainage systems, refer to the appropriate section(s) of Chapter 17: Abutments.
GENERAL INFORMATION:

For practices and requirements regarding the detailing of full integral, semi-full integral and deck slab extension drainage systems, refer to the appropriate section(s) of Chapter 17: Abutments.