

**5-1 Introduction**

Roadway and structure pavement drainage should be considered early in a project design, while the roadway geometry is still being developed since the hydraulic capacity of gutters and inlets is determined by the longitudinal slope and superelevation of the pavement. The imperviousness of the roadway pavement will result in significant runoff from any rainfall event. To ensure safety to the traveling public, careful consideration must be given to removing the runoff from the roadway through structure pavement drainage facilities.

This chapter provides specific guidance on designing the drainage of highway pavements, including assessing site hydrology ([Section 5-2](#)), methods for draining highways ([Section 5-3](#)), gutter flow and determining inlet spacing ([Section 5-4](#)), and drainage structures and grate types and considerations ([Section 5-5](#)). It concludes with a brief discussion of hydroplaning and hydrodynamic drag ([Section 5-6](#)).

The flatter the longitudinal profile, the wider the shoulders need to be to accommodate increased spread width. However, for narrow shoulders, superelevation and/or widening transitions can create a gutter profile far different from the centerline profile. The PEO must carefully examine the geometric profile of the gutter to eliminate standing water created by these transitions. These areas should be identified and eliminated. This generally requires geometric changes stressing the need for early consideration of drainage.

Improperly placed superelevation transitions can cause serious problems, especially on bridges. Inlets or other means must pick up gutter flow before the flow crosses to the other side of the pavement. The collection of crossover flow on bridges is complex as effective drain inlets are difficult to place within structure reinforcement. Bridges over waterways and wetlands pose water quality issues and downspouts are not allowed. Also, bridge drain downspouts have a history of plugging problems and are an objectionable aesthetic impact on the structure.

Eliminating inlets on bridges can usually be accomplished by considering drainage early in the design phase. Superelevation transitions, zero gradients, and sag vertical curves should be avoided on bridges. Modern bridges generally use watertight expansion joints so that all surface water can drain off the structure and collect in inlets placed at the bridge ends. Drainage design at bridge ends requires a great deal of coordination between the RHE, PEO, and the HQ Hydraulics Section.

Multilane highways create unique drainage situations. The number of lanes draining in one direction should be considered during the design phase. Contact the RHE for additional design guidance.

**5-2 Hydrology**

The Rational Method is required for determining peak flow rates for pavement drainage. This method is easy to use for pavement drainage design because the time of concentration is generally taken as five minutes. For more discussion on the Rational Method, see [Chapter 2](#). The design frequency and spread width are also significant variables in the design of pavement drainage.

## 5-3 Highway Drainage

When highways are built on fill, roadway drainage is usually allowed to flow uncollected to the sides of the roadway and over the side of the fill slope. Where erosion potential is low, this sheet flow of highway drainage does not present any problem to adjacent property owners nor is it a threat to the highway fill.

Curbs are often used before vegetation is established to prevent erosion. Once sufficient vegetation is present to resist erosion and treat runoff, consideration should be given to eliminating the curb in future overlay contracts. However, since most approach slabs include curbs, consideration must be given to dispersing the concentrated flow at the bridge ends before removing the curb. Possible solutions include discharging runoff to an inlet, maintaining curbing until runoff can be properly dispersed, or utilizing a fabric or filter blanket.

A ditch running parallel to the roadway generally drains highways in a cut section. These ditches are designed and sized in accordance with the criteria shown in [Chapter 4](#).

### 5-3.1 Downstream End of Bridge Drainage

The downstream end of bridges need special attention. If a storm sewer inlet system is not provided, a channel should be provided at the end of any significant barrier, which collects and concentrates stormwater away from the bridge.

Bridges with approach slabs generally have an extruded curb beginning at the bridge end and terminating just past the approach slab. The concentrated flow shall be directed into a low-risk erosion area. Inlets shall be located a minimum of 10 feet downstream from an approach slab to avoid approach slab settlement, see Standard Plan B-95.41-00 for typical inlet.

Bridges without approach slabs and curbing pose yet another set of problems. The concentrated flow runs off the bridge slab and flows off the fill slope or drains behind the wing walls and can compromise the integrity of the structure's geotechnical design. To mitigate this effect, all runoff shall be directed away from wing walls, fill slopes, and embankments, so that no material is susceptible to erosion. Bridge drains are designed to reduce the amount of concentrated flows off a structure; however, bridge drains tend to get blocked or clogged from roadside debris during normal use. This clogging creates an excess of concentrated flow off the structure, which must be mitigated to prevent subgrade erosion.

### 5-3.2 Slotted Drains and Trench Systems

Slotted drains and trench systems shall not be used for highway drainage.

### 5-3.3 Drop Inlets

Drop inlets shall not be used for pavement drainage.

## 5-4 Gutter Flow and Inlet Spacing

When stormwater is collected and carried along the roadside in a gutter, or next to a curb or barrier, the allowable top width of the flow prism ( $Z_d$ ) is dependent on the road classification, as noted in [Figure 5-1](#).

For Design-Bid-Build projects, the PEO shall perform a gutter flow analysis for each construction staging plan of the project using the same allowable spread design criteria in [Figure 5-1](#). Not meeting the criteria in [Figure 5-1](#) is not considered a HM deviation. The

purpose of the required analysis is to identify areas of ponding water for the Contractor to be aware of during the construction portion of the project. The gutter spread analysis shall be placed in the TESC Plan, Abbreviated TESC Plan, or Region equivalent document and shall have concurrence from the region hydraulics engineer.

For Design-Build projects, the Design-Builder shall perform a gutter flow analysis for each construction staging plan of the project using the same allowable spread design criteria in Figure 5-1. Not meeting the criteria in Figure 5-1 is not considered a HM deviation. The purpose of the required analysis is to identify areas of ponding water for the Design-Builder to be aware of during the construction of the project and for the Design-Builder to manage the risk accordingly. The gutter spread analysis shall be placed in the TESC Plan, Abbreviated TESC Plan, or Region equivalent document and shall have concurrence from the region hydraulics engineer.

WSDOT uses gutter flow capacity and inlet spacing (on continuous grades and at sumps) equations from the FHWA’s HEC-22. WSDOT gutter flow calculations generally assume a uniform gutter section per HEC-22. The following specific sections of HEC-22 are used for gutter flow capacity and inlet spacing:

- 4.3.4 Flow in Sag Vertical Curves
- 4-4 Drainage Inlet Design
- 4-4.4 Interception Capacity of Inlets on Grade
- 4-4.5 Interception Capacity of Inlets in Sag Locations
- 4-4.6.2 Inlet Spacing on Continuous Grades
- 4-4.6.3 Flanking Inlets

**Figure 5-1** Design Frequency and Allowable Spread

Road Classification		Design Frequency (years)	Allowable Spread ( $Z_d$ )
Interstate, Principal, Minor Arterial, or Divided	<45 mph	10	Shoulder + 2 feet <sup>(1)</sup>
	≥45 mph	10	Shoulder
	Sag Point	50	Shoulder + 2 feet <sup>(1)</sup>
Collector and Local Streets	<45 mph	10	Shoulder + one-half/driving lane <sup>(2)</sup>
	≥45 mph	10	Shoulder
	Sag Point	50	One-half driving lane <sup>(2)</sup>
Roundabouts	All design speeds	10	Maintain at least 10 feet of driving lane that is free of water
Restricted Turning Lanes	With STOP sign or signalized intersections	10	Shoulder + one-half driving lane
	All other	10	Shoulder
Ferry Terminals	All	10	Driving lane

**Notes:**

mph = miles per hour

<sup>(1)</sup>When the lane adjacent to the shoulder is less than 12 feet, there shall be a minimum of 10 feet that is free of water.

<sup>(2)</sup>In addition to the allowable spread requirement, the depth of flow shall not exceed 0.12 feet at the fog line.

### 5-4.1 Capacity of Inlets on a Continuous Grade

The flow that is not intercepted by an inlet on a continuous grade and continuous run of curb and gutter is considered bypass flow and should be added to the flow traveling toward the next inlet located downstream. The last inlet on a continuous run of curb (that is not a sag or flanking inlet) is permitted to bypass a maximum of 0.10 cfs for the 10-year MRI storm. The bypass flow rate of 0.1 cfs will not usually cause erosion or hydroplaning problems. The PEO shall analyze the spread width of flow after the last inlet on a continuous run of curb until the curb ends or the curb enters into a sump. The spread width analysis shall end at the 50-year water surface elevation determined in the sag analysis. The spread width shall be compliant with [Figure 5-1](#).

In urban situations, with much lower speeds than noted in [Figure 5-1](#), it may not be feasible to use the allowable spread recommended in the *Hydraulics Manual*. In this situation, the PEO should first consider innovative solutions such as increasing the slope of the gutter (from 2 to 5 percent, for example), depressing the inlet, or using a combination curb opening and grate inlet. If it is still not possible to meet the allowable spread in [Figure 5-1](#), the PEO should consider the safety of the intersection, how icing and hydroplaning could affect a driver at this location, and how quickly ponding from the rainfall event will shed off the roadway. The PEO should work with the RHE and Traffic Engineer to develop a solution that best suits the project location and keeps the roadway safe. If, after considering all possible scenarios, it is determined that the spread of runoff is not safe at this location then more drastic measures such as revising the project scope or seeking more funding may be necessary.

In addition to the requirements above, in areas where a superelevation transition causes a crossover of gutter flow, the amount of flow calculated at the point of zero superelevation shall be limited to 0.10 cfs. The PEO will find, by the time the roadway approaches the zero point, the calculated spread ( $Z_d$ ) will become very wide; because of this, the new inlet shall be placed upstream of the zero point. The flow width criteria will be exceeded at the crossover point, even when the flow is less than 0.10 cfs.

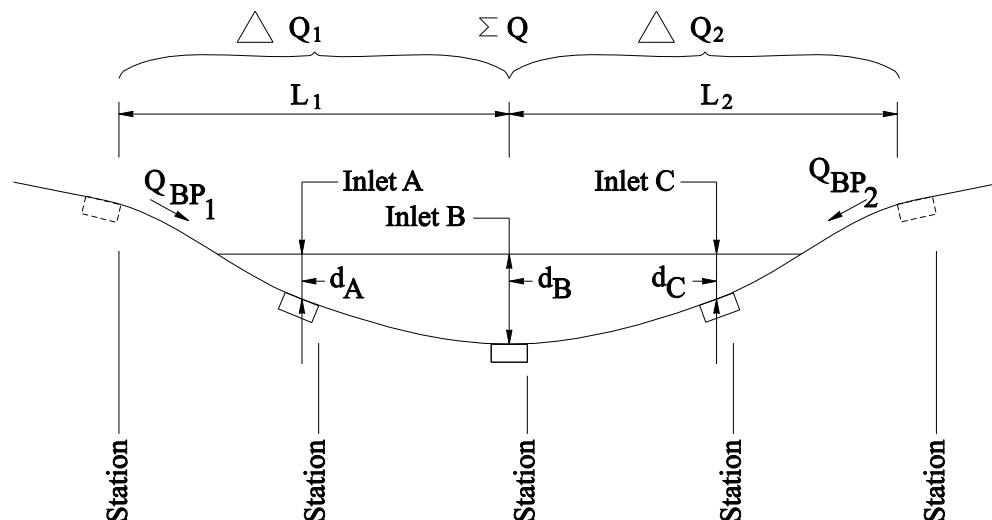
Roundabouts are typically designed to accommodate speed limits of 35 miles per hour or less, generally, the posted advisory speed limits are between 15 to 25 miles per hour. Potentially, runoff from a roundabout is diverted to multiple different directions and, if it is possible, runoff from the upstream roadway should be captured so that flow bypass should be 0.1 cfs or less flowing through the roundabout area. If runoff within a roundabout area is less than 0.1 cfs, no inlets would be necessary. If inlets are placed within a roundabout area, when maintenance is necessary, the roundabout may need to be closed. Curb openings could be used to alleviate ponding water at roundabouts. The inlet spacing spreadsheet may not be fully accurate to calculate the flow spread at roundabouts since runoff at a roundabout could flow off in multiple directions. The PEO should consult the RHE for help with analyzing spread widths inside of roundabouts.

### 5-4.2 Capacity of Inlets at Sag Locations

By definition, a sag is any portion of the roadway where the profile changes from a negative grade to a positive grade. Inlets at sag locations perform differently than inlets on a continuous grade and therefore require a different design criterion. Theoretically, inlets at sag locations may operate in one of two ways: <sup>(1)</sup> at low ponding depths, the inlet will operate as a weir or <sup>(2)</sup> high ponding depths (5-inch depth above the grated inlet and 1.4 times the grate opening height for combination inlets), the inlet will operate as an orifice. It is very rare that ponding on a roadway will become deep enough to force the inlet to operate as an orifice. As

a result, this section will focus on inlets operating as a weir with flow spilling in from the three sides of the inlet that are exposed to the ponding.

Figure 5-2 Sag Analysis



Where:

Inlet B = sag inlet

Inlet A and Inlet C = flanking inlets

$$d_A = d_C = 0.5d_B$$

Inlets at sag locations can easily become plugged with debris; therefore, it is good engineering practice to provide some type of relief. This relief can be accomplished by locating flanking inlets, on either side of the sag inlet, so they will operate before water exceeds the allowable spread into the travel lane at the sag. Flanking inlets shall be located so the depth of water at the flanking inlets pond to half the allowable depth at the sag (or  $0.5d_{B \text{ allowable}}$ ); see Figure 5-2. Flanking inlets are only required when the sag is located in a depressed area and water has no outlet except through the system. A tall curb, traffic barrier, retaining wall, or other obstruction that prevents the runoff from flowing off of the traveled roadway, generally represents this condition since it contains this ponded area. However, if runoff is capable of overtopping the curb and flowing away from the roadway before exceeding the allowable sag limits noted in Figure 5-1, flanking inlets are not required. With this situation, there is a low potential for danger to the drivers of the roadway if the inlets do not function as designed. Before flanking inlets are removed in this situation, the PEO should consider the potential damage of water going over the curb. The PEO shall use the guidelines provided in this section for locating flanking inlets. If the PEO suspects flanking inlet are unnecessary, consult the RHE earlier in the design.

Any section of roadway located in a sag should be designed according to the criteria described below and further detailed in the WSDOT Sag Worksheet located on the HQ Hydraulics Section web page ([www.wsdot.wa.gov/publications/fulltext/hydraulics/programs/sagworksheetud.xls](http://www.wsdot.wa.gov/publications/fulltext/hydraulics/programs/sagworksheetud.xls)).

Once an inlet has been placed in a sag location, the total actual flow to the inlet can be determined as shown below.  $Q_{\text{Total}}$  must be less than  $Q_{\text{allowable}}$ , as described in Equation 5-1.

$$Q_{\text{TOTAL}} = Q_{\text{BP1}} + Q_{\text{BP2}} + \Delta Q_1 + \Delta Q_2 \quad (5-1)$$

Where:

$Q_{\text{BP1\&2}}$  = Bypass flow from the last inlet on either side of a continuous grade

$\Delta Q_{1\&2}$  = Runoff that is generated from last inlet on either side of the continuous grades; see [Figure 5-2](#)

The effective perimeter of the flanking and sag inlets can be determined using the length and widths for various grates provided in [Figure 5-11](#). This would be the sum of the three sides of the inlet where flow spills in and where ponding would occur. Only the sides that receive gutter flow (see [Figure 5-8](#)) would be assumed to be 50 percent plugged (except for the Combination Inlet, Standard Plan [B-25.20-02](#), which should be considered 0 percent plugged). This typically will be the grate widths (and not grate length) that are reduced by 50 percent. The total available perimeter that would receive flow is represented by Equation 5-2. This adjustment is in addition to reducing the perimeter to account for the obstruction caused by the bars in the grate. [Figure 5-11](#) lists perimeters for various grates with reductions already made for bars.

$$P_n = L + 2*W/2 \quad (5-2)$$

Where:

$P_n$  = Effective perimeter of the inlet "n" (sag or flanking inlet)

$L$  = Length of the inlet "n" from [Figure 5-2](#)

$W$  = Width of the inlet "n" from [Figure 5-2](#)

The allowable capacity of an inlet operating as a weir, that is the maximum  $Q_{\text{allowable}}$ , can be found depending on the inlet layout as described below:

When there is only a single inlet at the sag (no flanking inlets), Equation 5-3 should be used:

$$Q_{\text{allowable}} = C_w \times P \times d_{\text{B allowable}}^{1.5} \quad (5-3)$$

Where:

$C_w$  = Weir coefficient, 3.0 for English Units

$P$  = effective perimeter of the grate in feet

$d_{\text{B allowable}}$  = maximum depth of water at the sag inlet in feet

Flanking inlets shall be located laterally from the sag inlet at a distance equal to that required to produce a depth of  $0.5d_{\text{B allowable}}$ .  $Q_{\text{allowable}}$  can be simplified to Equation 5-4 below. Equation 5-4 assumes all grates are the same size and are oriented the same (all rotated or not rotated):

$$\Sigma Q = C_w \times P \times \left[ 2(0.5d_B)^{1.5} + (d_B)^{1.5} \right] \quad (5-4)$$

Where:

$d_B$  = depth of water at the sag inlet (ft)

In some applications, locating inlets so water ponds to  $0.5d_{B \text{ allowable}}$  is too long of a distance (generally in cases with long flat slopes). The PEO should instead calculate  $Q_{\text{allowable}}$  using Equation 5-5 and check that the spread width of surface water does not exceed those noted in Figure 5-1.

$$Q_{\text{allowable}} = C_w P \left[ d_A^{1.5} + d_B^{1.5} + d_C^{1.5} \right] \quad (5-5)$$

Where:

$d_N$  = depth of water at the flanking inlets and the sag (ft)

The actual depth of water over the sag inlet can be found with Equation 5-6 and must be less than  $d_{B \text{ allowable}}$ . If, however, the inlets are not located at  $0.5d_{B \text{ allowable}}$ , Equation 5-6 will need to be modified to reflect this.

$$d_B = \left[ \frac{Q_{\text{TOTAL}}}{(C_{WA} P_A 0.3536 + C_{WB} P_B + C_{WC} P_C 0.3536)} \right]^{\frac{2}{3}} \quad (5-6)$$

Where:

$Q_{\text{Total}}$  = Actual flow into the inlet in cfs

$C_w$  = Weir coefficient, 3.0

$P_N$  = Effective grate perimeter, in feet; see Figure 5-11

$d_B$  = Actual depth of ponded water at the inlet in feet

After the analysis is completed, the PEO shall verify the allowable depth and allowable flow have not been exceeded ( $Q_{\text{allowable}} > Q_{\text{TOTAL}}$  and  $d_{B \text{ allowable}} > d_B$ ). If both the allowable depth and allowable flow are greater than the actual, then the maximum allowable spread will not be exceeded and the design is acceptable. If the actual depth or flow is greater than the allowable, then the runoff will spread beyond the maximum limits and the design is not acceptable. In this case, the PEO shall add flanking inlets or use different inlets that have larger openings. Additional flanking inlets should be placed close to the sag inlet to increase the flow interception and reduce the flow into the sag.

## 5-5 Drainage Structures

There are many variables involved in determining the hydraulic capacity of an inlet structure including depth of flow, grade, superelevation, and placement. The depth of flow next to the curb is a major factor in the interception capacity of an inlet structure. Slight variations in grade or superelevation of the roadway can also have a large effect on flow patterns, and placement of an inlet can result in dramatic changes in its hydraulic capacity. These variables can be found by collecting the following information prior to starting an inlet design: plan sheets, road profiles, curb/barrier profiles, cross sections, superelevations, and contour maps.

Drainage structures should never be placed directly in the wheel path. While many are traffic rated and have lockdown grates, the constant pounding of traffic causes unnecessary stress and wear on the structure, frame, and grate. Inlets shall be installed at the curb/barrier face and at the proper elevation relative to the pavement. The structure offset shown in the plans shall be to the center of grate, not to the center of the structure, to ensure the grate is located along the curb face. There shall be no gap between the structure and the curb/barrier face as this would lead to other issues.

Scuppers in median barriers shall not be used in the following situations:

- Passing runoff from one side of a median barrier to a drainage structure or curb and gutter section on the other side (downstream) of the median barrier.
- Passing runoff through the median barrier so that the runoff continues to flow across highway lanes on the other side (downstream) of the median barrier.

For the above scenarios, flows shall be captured by placing inlets on each side of the median barrier as shown in Standard Plan B-95.20-01, allowing runoff to pass between the structures in a pipe.

Debris floating in the gutter tends to collect at the inlets, plugging part or all of the grate opening. Inlet locations on a continuous grade are calculated using the full width of the grate with no allowance needed for debris. Inlets located in a sag are analyzed with an allowance for debris blocking half of the grate. Areas with deciduous trees and large pedestrian populations are more prone to debris plugging. Bark from logging operations and agricultural areas are also known to cause debris problems. These areas may require additional maintenance.

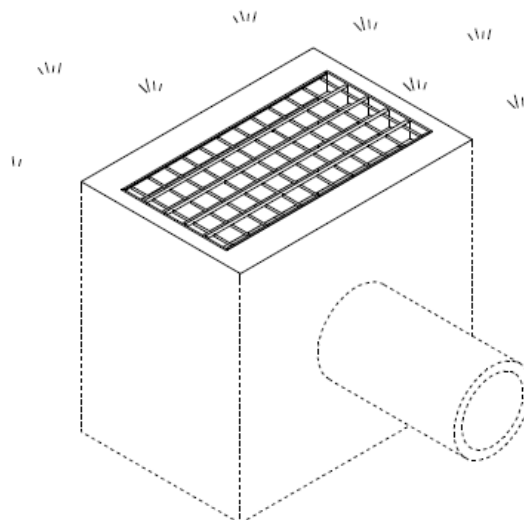
### 5-5.1 Inlet Structure Types

WSDOT uses grate inlets, catch basins, and manholes to capture runoff for WSDOT projects. Each inlet structure type has different variations and advantages for use in certain situations. On top of each inlet structure type is a grate that allows water to flow into the structure. This section will briefly describe each structure type.

#### 5-5.1.1 Grate Inlet Type 1 Structure - Standard Plan B-35.20-00

Grate inlet Type 1 structures are cast-in-place and utilizes a sump by placing the outlet pipe's invert elevation higher than the bottom of the structure (Figure 5-3). This allows suspended sediment within the water to settle and reduce turbidity prior to entering the downstream stormwater system. Type 1 inlet structures require more construction because they are cast-in-place; however, this allows the PEO to tie into existing stormwater infrastructure without modifying the hydraulic gradient.

Figure 5-3 Grate Inlet Type 1 Structure

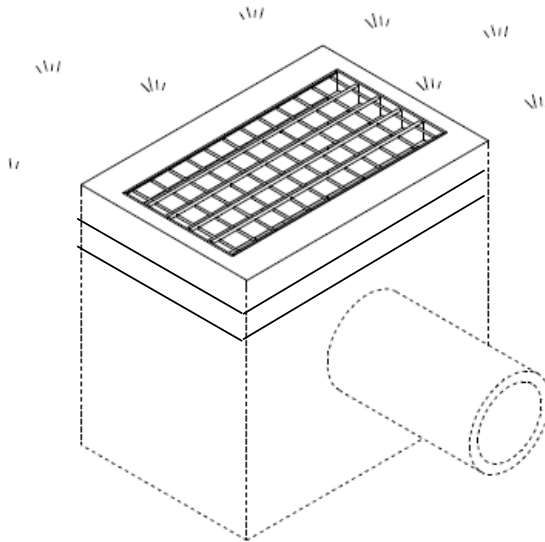




### 5-5.1.2 Grate Inlet Type 2 Inlet Structure - Standard Plan B-35.40-00

Grate inlet Type 2 structures are constructed using sections of pre-cast reinforced concrete (Figure 5-4). These pre-cast sections can be stacked to meet the required height, thus reducing the construction time and cost. This inlet structure is similar to the grate inlet Type 1 in that they both have an invert elevation higher than the structure bottom. This creates a sump that allows suspended sediment to settle prior to entering the downstream stormwater system. The grate inlet Type 2 should be used in areas where existing infrastructure is easy to tie into.

Figure 5-4 Grate Inlet Type 2 Structure



### 5-5.1.3 Catch Basins

Catch basins are designed to retain sediment and debris transported by stormwater into a storm sewer system. Catch basins include a sump for the collection of sediment and debris. Catch basin sumps require periodic cleaning to be effective and may become an odor and mosquito nuisance if not properly maintained. Catch basins are used to link long runs of storm sewer pipes and to help change directions of the storm sewer system. See the following:

- Standard Plan [B-5.20-02](#) Catch Basin Type 1
- Standard Plan [B-5.40-02](#) Catch Basin Type 1L
- Standard Plan [B-5.60-02](#) Catch Basin Type 1P (for Parking Lot)
- Standard Plan [B-10.20-02](#) Catch Basin Type 2
- Standard Plan [B-10.40-01](#) Catch Basin Type 2 with Flow Restrictor
- Standard Plan [B-10.70-00](#) Catch Basin T - PVC

### 5-5.1.4 Manholes

Similar to catch basins, manholes are to convey stormwater as a part of a storm sewer system. They are used to also change the direction of a storm sewer system. Manholes do not have a sump. They can have solid locking lids that block water from entering the manhole. They can also be configured to have a grate to allow water to flow into the manhole. See the following:

- Standard Plan [B-15.20-01](#) Manhole Type 1
- Standard Plan [B-15.40-01](#) Manhole Type 2
- Standard Plan [B-15.60-02](#) Manhole Type 3

### 5-5.1.5 Concrete Inlet - Standard Plan B-25.60-02

A concrete inlet is used when a sump to catch sediments is not desired and the maximum inside pipe diameter is less than or equal to 15 inches.

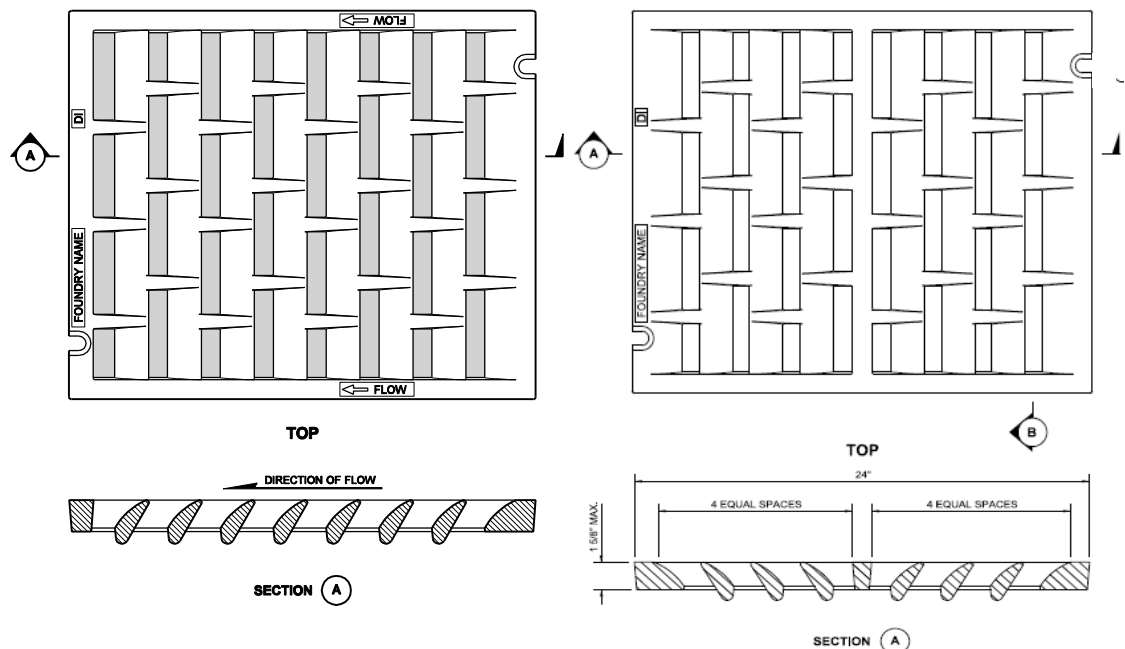
## 5-5.2 Grate Types

Grates are an essential component in ensuring the efficiency of a drainage system. The following grates (except the Rectangular Herringbone Grate) shall be used for new construction, where applicable.

### 5-5.2.1 Rectangular Bi-Directional Vaned Grate – Standard Plan B-30.40-03

At low velocities, the vaned grate ([Figure 5-5](#)) and the herringbone Rectangular Vaned Grate - Standard Plan [B-30.30-03](#) and grate are equally efficient. At higher velocities—greater than 5 ft/s—a portion of the flow tends to skip over the herringbone grate whereas the vaned grate will capture a greater portion of this flow. The vaned grate also has a higher capacity for passing debris and shall be used in place of the herringbone grate in all new installations. Installation of the vaned grate is critical as the grate is directional. If installed backwards the interception capacity is severely limited.

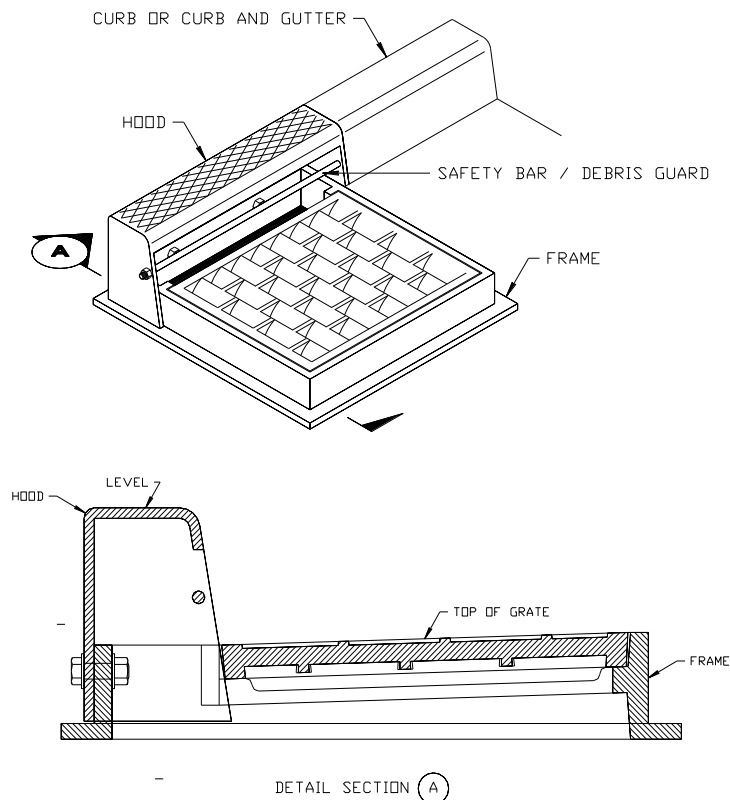
Figure 5-5 Rectangular Vaned Grate and Rectangular Bi-Directional Vaned Grate



### 5-5.2.2 Combinations Inlet - Standard Plan B-25.20-02

The combination inlet is a vaned grate on a catch basin with a hooded curb cut area (Figure 5-6). The vaned grate is debris efficient, and, if the grate does become clogged, the overflow goes into the hooded opening. These inlets are useful for sag condition installations, although they can also be effective on continuous grades. The interception capacity of a combination inlet is only slightly greater than with a grate alone. Therefore, the capacity is computed neglecting the curb opening and the PEO should follow the same analysis as for a vaned grate alone (see Standard Plan B-30.30-03).

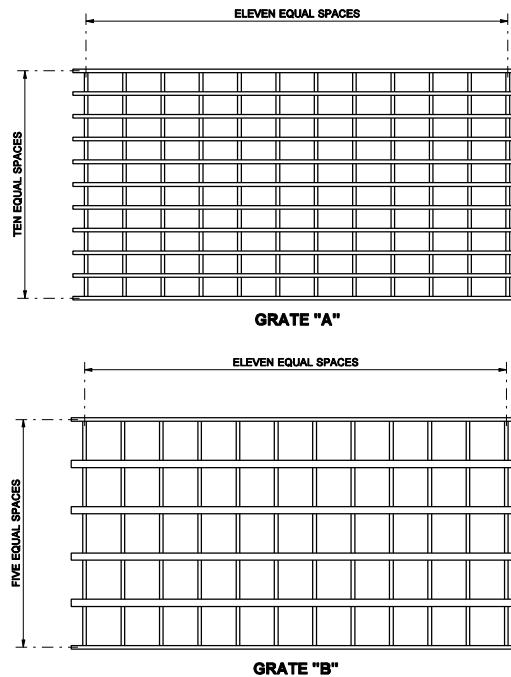
Figure 5-6 Section and Isometric View Combination Inlet Frame, Hood, and Vaned Grate



### 5-5.2.3 Welded Grates for Grate Inlet, Grate A and Grate B - Standard Plan B-40.20.00

Both welded grates (types A and B) have large openings that can compensate for debris problems (Figure 5-7); however, there are limitations in their usage. Due to structural failure of Grates A and B, neither of these grates can be installed in heavy traffic areas where wheel loads will pass directly over. Grate B has large openings and is useful in ditches or non-paved median locations, in areas where there is no pedestrian or bicycle traffic. Grate A can be used anywhere Grate B is used as well as at the curb line of a wide interstate shoulder. Grate A may occasionally be subject to low-speed traffic or parked on, but it cannot withstand repeated interstate loading or turning vehicles.

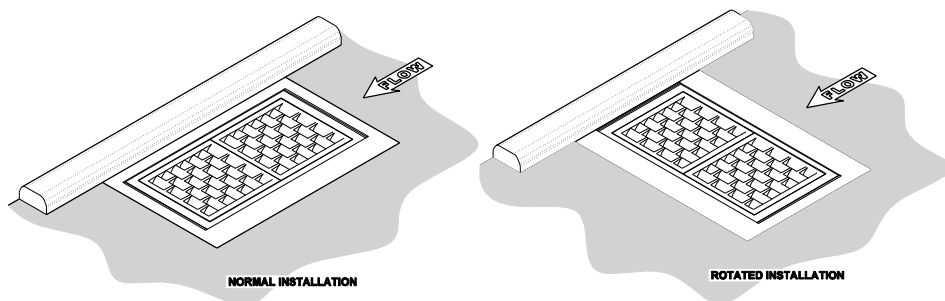
Figure 5-7 Grates A and B



#### 5-5.2.4 Frame and Dual Vaned Grates for Grate Inlet - Standard Plan B-40.40-02

Standard Plan [B-40.40-02](#) has been tested in H-25 loading and was determined compatible with heavy traffic installations. This frame and double-vaned grate should be installed in a Unit H on top of a Grate Inlet Type 2 ([Figure 5-8](#)). The frame and vaned grates may be used in either new construction or retrofit situations. When used in areas of highway speeds, lockdown grates shall be specified. This grate can also be rotated 90 degrees to increase the flow interception capacity.

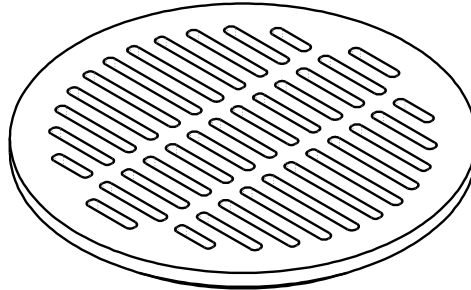
Figure 5-8 Frame and Vaned Grates for Installation on Grate Inlet



### 5-5.2.5 Circular Grate or Standard Plan B-30.80-01

Circular grates are intended for use with dry wells, see Standard Plan [B-20.20-02](#) and [B-20.60-03](#) for details ([Figure 5-9](#)). Install with circular frames (rings) as detailed in Standard Plan [B-30.70-04](#).

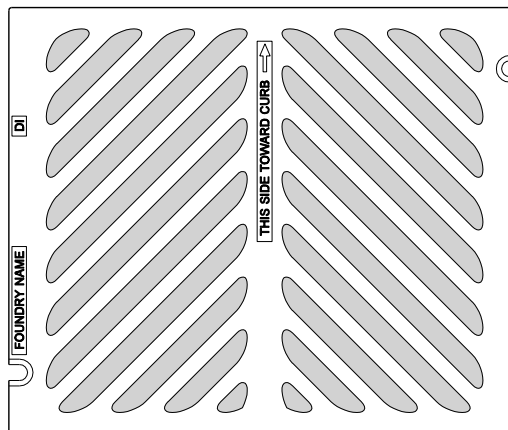
Figure 5-9 Circular Grate



### 5-5.2.6 Rectangular Herringbone Grate - Standard Plan B-30.50-03

The HQ Hydraulics Section no longer allows herringbone grates ([Figure 5-10](#)) to be used on WSDOT projects. Historically, use of the vaned grate was limited due to cost considerations. The cost difference now is minimal, the vaned grate is bicycle safe and is hydraulically superior under most conditions. Herringbone grates shall not be used for new construction.

Figure 5-10 Herringbone Pattern



Grate inlet properties are summarized in [Figure 5-11](#).

**Figure 5-11** Properties of Grate Inlets

Standard Plan	Description	Continuous Grade <sup>(1)</sup>		Sag Location <sup>(2)</sup> Perimeter Flows as Weir	
		Grate Width (feet)	Grate Length (feet)	Width (feet)	Length (feet)
B-30.50-03 <sup>(3)</sup>	Rectangular Herringbone Grate	1.67	2.0	0.69	0.78
B-30.30-03 or B-30.40-03 <sup>(4)</sup>	Vaned Grate for Catch Basin and Inlet	1.67	2.0	1.31	1.25
B-25.20-02 <sup>(2)</sup>	Combination Inlet	1.67	2.0	1.31	1.25
B-40.20-00	Grate Inlet Type 1 (Grate A or B <sup>(5)</sup> )	2.01	3.89	1.67	3.52
		3.89 <sup>(6)</sup>	2.01 <sup>(6)</sup>	3.52	1.67
B-30.80-01	Circular Grate	1.52		2.55 <sup>(7)</sup>	
B-40.40-02	Frame and Vaned (Single or Dual)	1.75 <sup>(8)</sup>	3.52 <sup>(8)</sup>	1.29	2.58
	Grates for Grate Inlet Type 2	3.52 <sup>(6)</sup>	1.75 <sup>(6)</sup>	2.58 <sup>(6)</sup>	1.29 <sup>(6)</sup>

**Notes:**

<sup>(1)</sup>Inlet widths on a continuous grade are not reduced for bar area or for debris accumulation.

<sup>(2)</sup>The perimeters and areas in this portion of the table have already been reduced for bar area. These values shall be cut in half when used in a sag location as described in [Section 5-5.2](#), except for the Combination Inlet, Standard Plan.

<sup>(3)</sup>Shown for informational purposes only (see [Section 5-5](#)).

<sup>(4)</sup>For sag conditions, combination inlets shall use a bidirectional vaned grate (as shown in Standard Plan).

<sup>(5)</sup>Type B grate shall not to be used in areas of pedestrian or vehicular traffic (see [Section 5-5](#) for further discussion).

<sup>(6)</sup>Rotated installation (see [Standard Plans](#)).

<sup>(7)</sup>Only the perimeter value has been provided for use with weir equations.

<sup>(8)</sup>Normal Installation (see [Standard Plans](#)).

## 5-6 Hydroplaning and Hydrodynamic Drag

FHWA's [HEC-22](#) provides an in-depth discussion on the factors that contribute to hydroplaning on roadways and offers rules of thumb to help reduce hydroplaning.