# Lesson 3: Pavement Drainage - Pipe Network Sizing (HM Chpt 5 & 6)

# Objectives

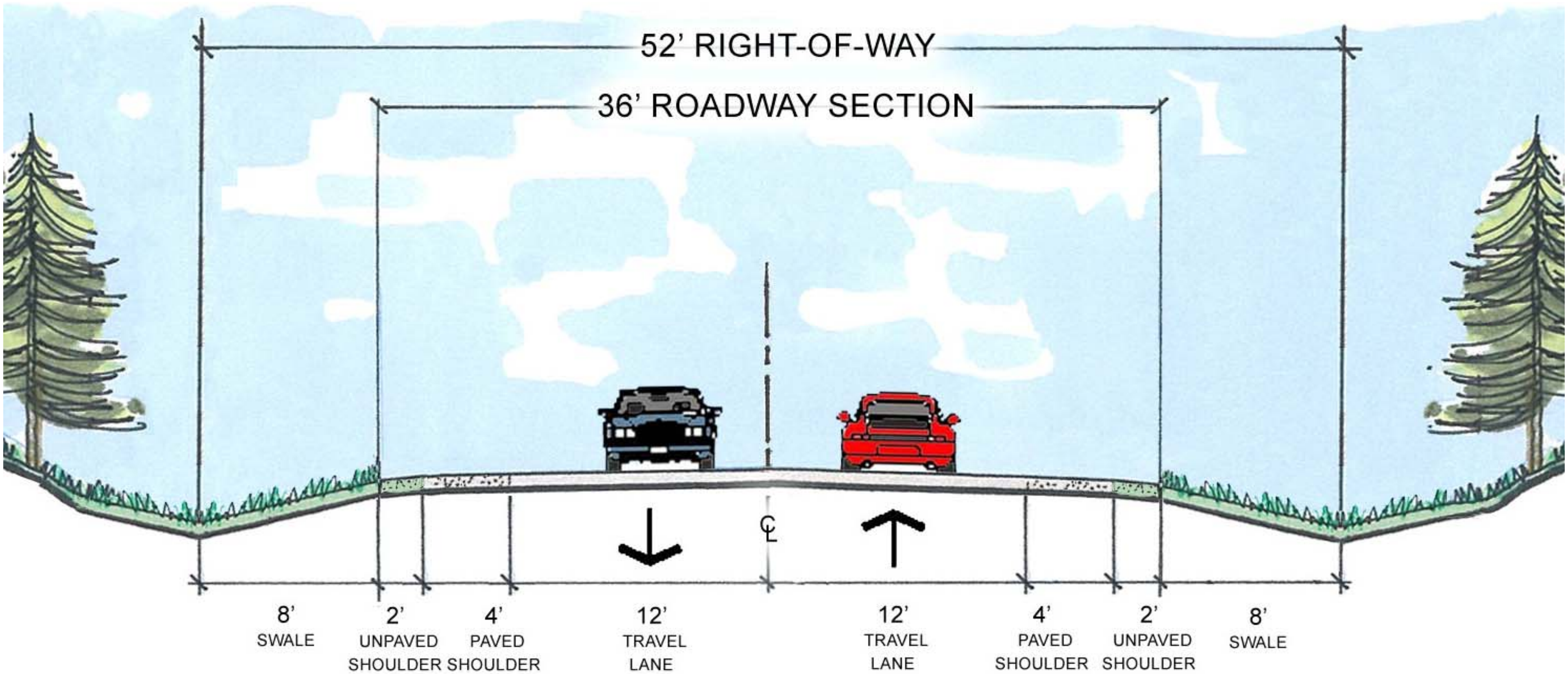
- Understand roadway geometrics
- Develop basin hydrology flowing to the structure(s) you are designing
- Know the different types of grate inlets, catch basins, and manholes
- Complete Inlet Spacing Calculations using the WSDOT spreadsheet
- Complete a pipe networks design using the WSDOT spreadsheet

# Roadway Geometrics

**Roadway Cross Sections**

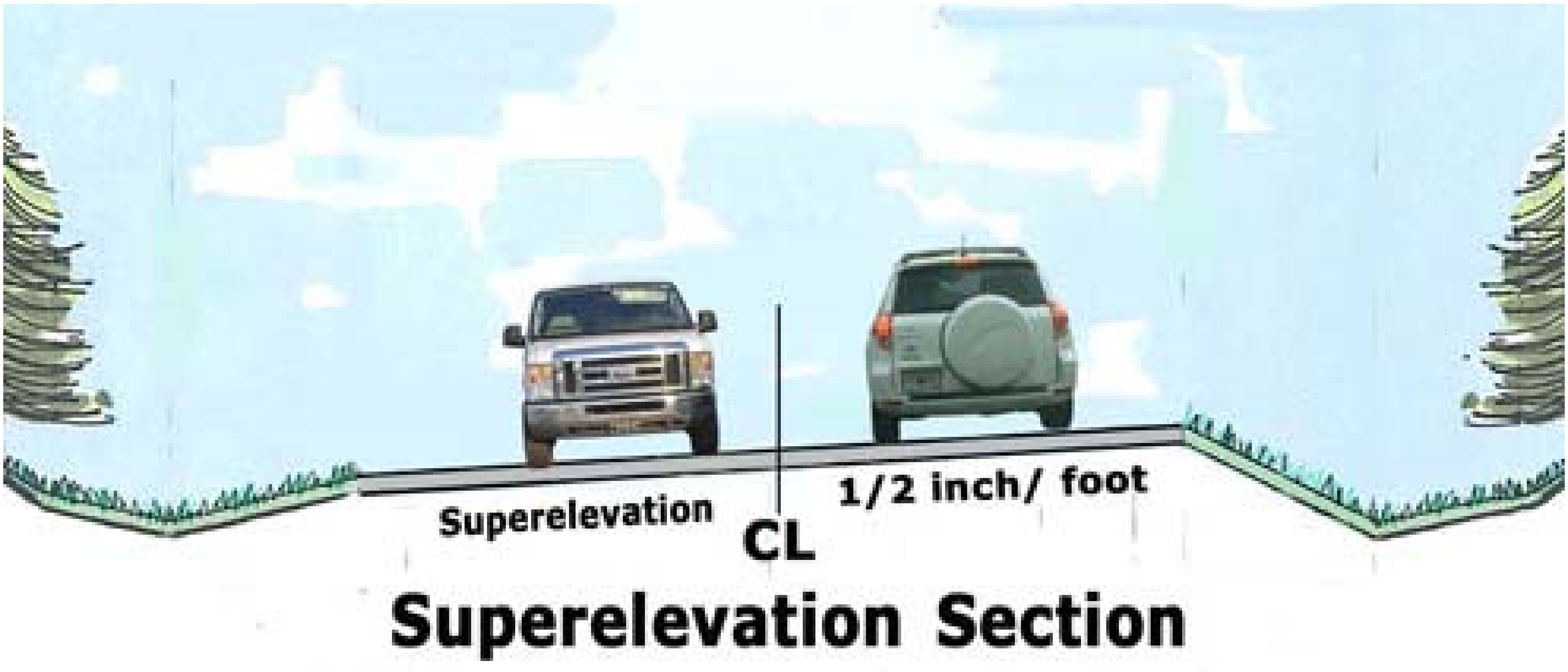
- Tangent Sections or Crown Sections (High point is in the middle of the roadway)
- Full Super elevation or Curve Sections (High point is on one side of the roadway)

# Normal Crown Section



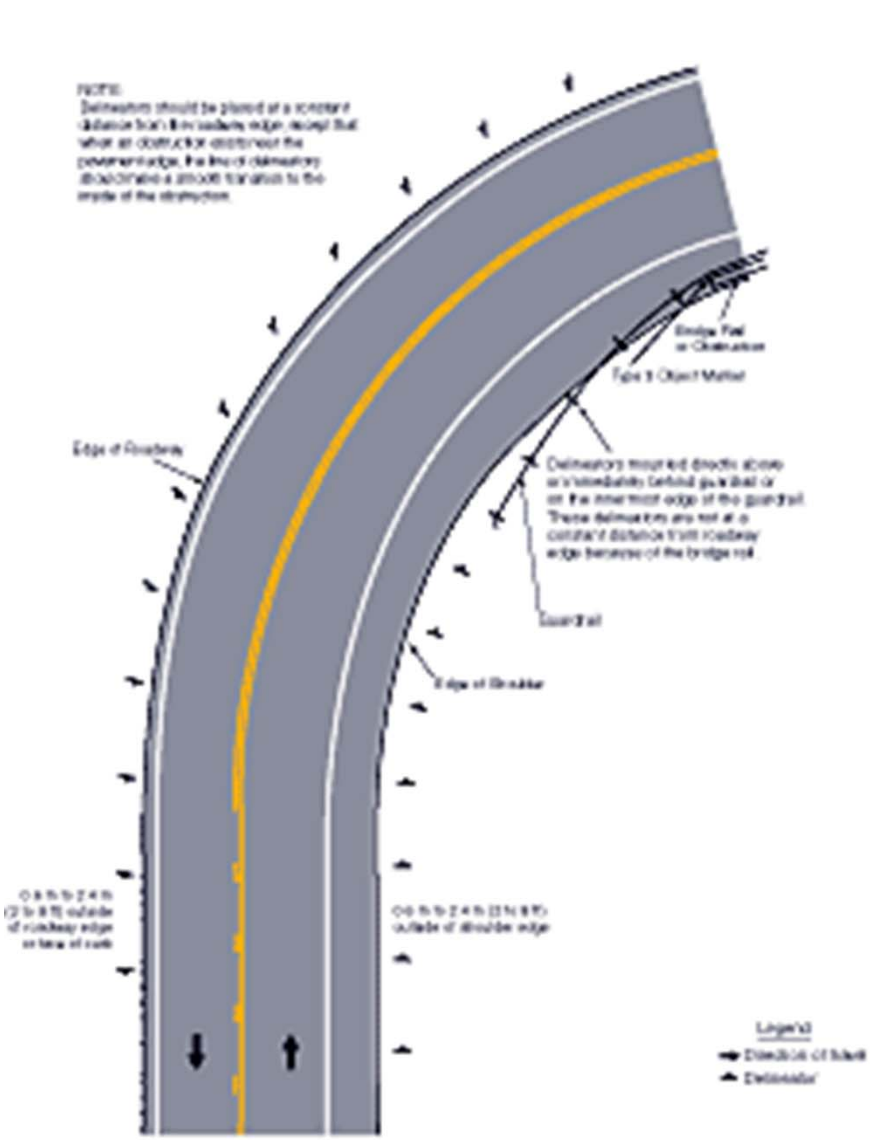
# Normal Crown Section

# Super elevation Section



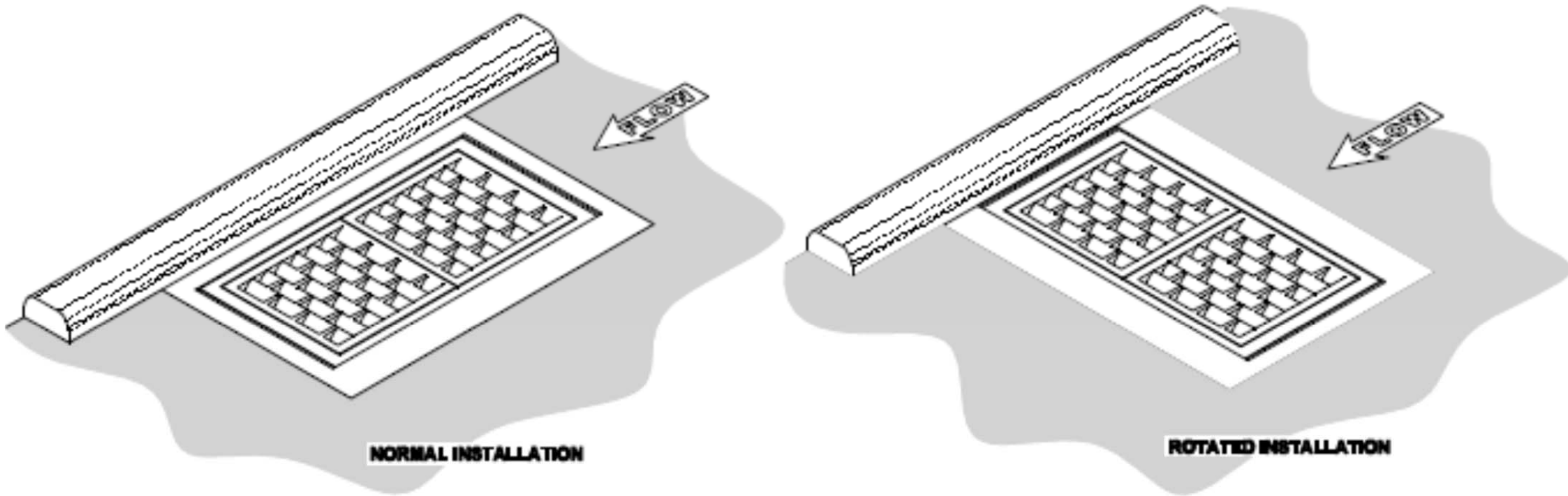
# Superelevation Section

*Figure 3D-1. Examples of Delineator Placement*




- Put catch basins on the lower side of the road.
- Flow bypass must be equal or less than 0.1 cfs flowing across the travel lanes.
- Pay attention to locations where the roadway superelevation goes to zero when a tangent section goes to a curve; the $Z_d$ gets very wide!

# Catch Basin Installation




**Frame and Vaned Grates for Installation on Grate Inlet**
***Figure 5-5.5***

There should be no gap between the opening and the curb face to minimize the flow bypass.

# Hydrology

$$I = \frac{m}{(T_c)^n}$$

Where:

$I$ = rainfall intensity in inches per hour (millimeters per hour)

$T_c$ = time of concentration in minutes

m & n = coefficients in dimensionless units (Figures 2-5.4A and 2-5.4B)

Tc: use 5 minutes

Rational Method

Q= CIA

Q: Flow in cfs

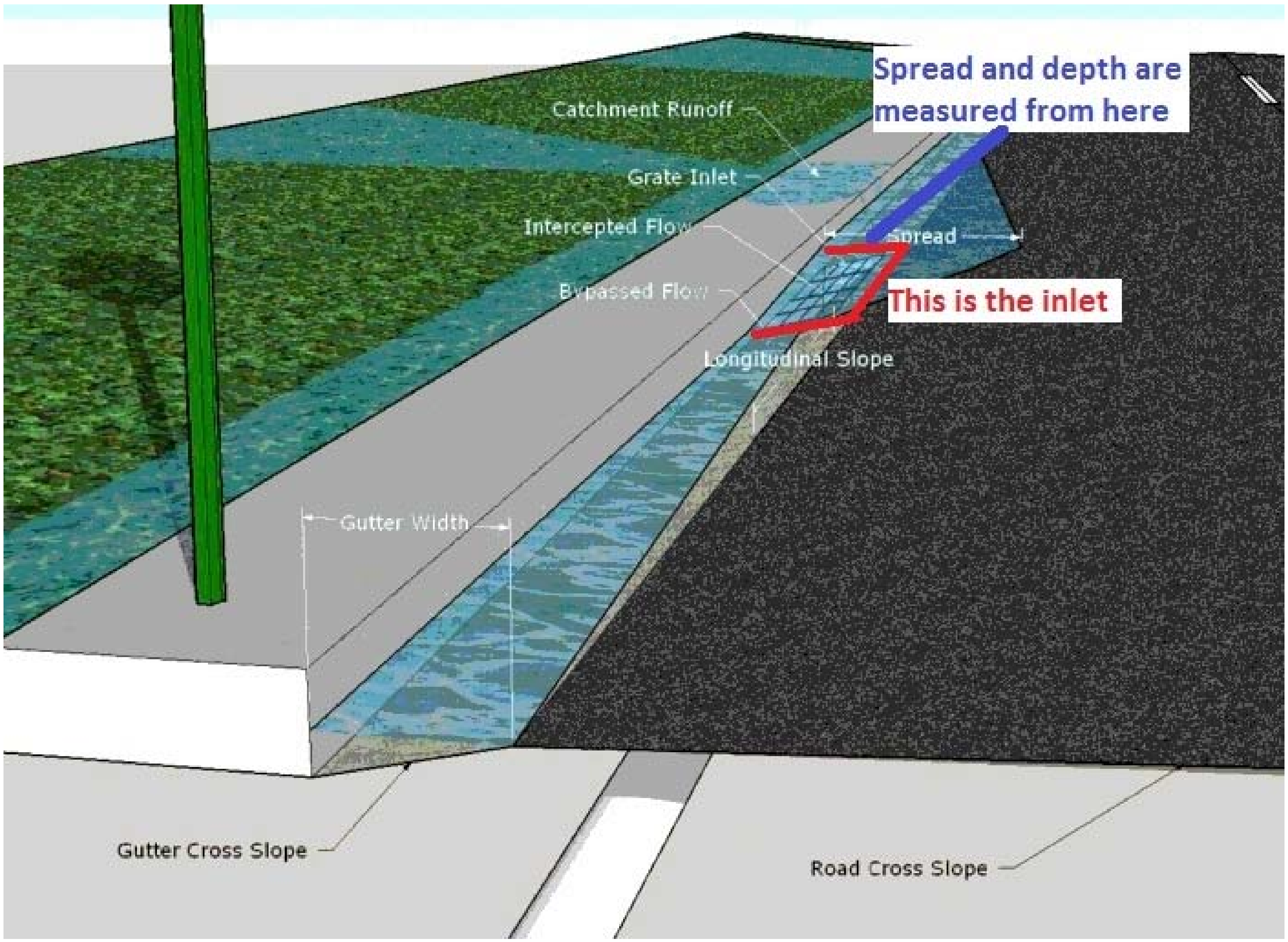
C: coefficient (0.9 for pavement)

I: rainfall intensities vary from one location to another

A: catchment area in acres (tributary area flowing to the catch basin)

# Gutter Flow

Flow running along the curb face or the face of a cement concrete barrier.



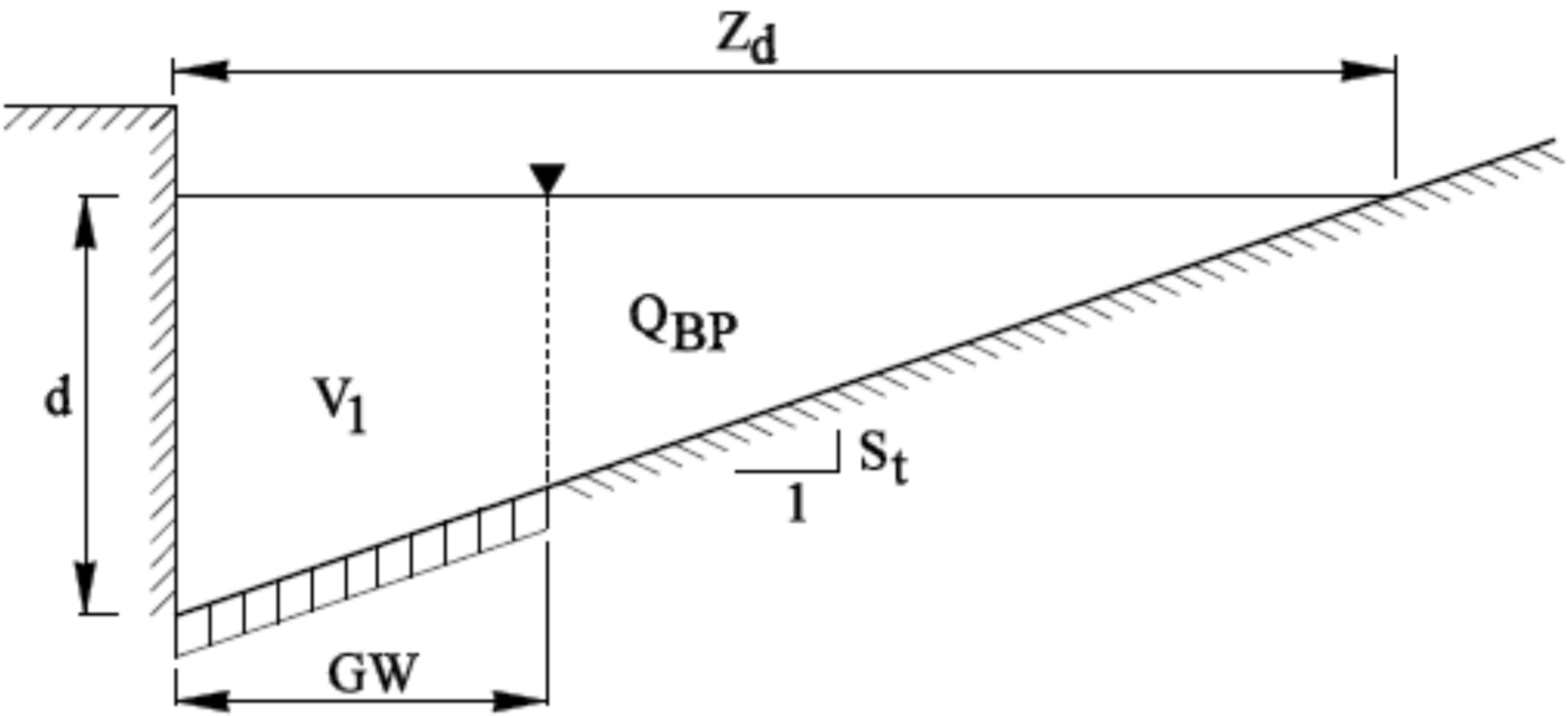
# Grate Inlets and Catch Basins

Standard Plans

http://www.wsdot.wa.gov/Design/Standards/#SectionB

| | | Continuous Grade[1] | | Sump Condition[2] Perimeter Flows as Weir | |
|---|---|---|---|---|---|
| **Standard Plan** | **Description** | **Grate Width** | Grate Length | **Width** | **Length** |
| B-30.50[3] | Rectangular Herringbone Grate | 1.67 ft (0.50 m) | 2.0 ft (0.61 m) | 0.69 ft (0.21 m) | 0.78 ft (0.24 m) |
| B-30.30 or 30.40[8] | Vaned Grate for Catch Basin and Inlet | 1.67 ft (0.50 m | 2.0 ft (0.61 m) | 1.31 ft (0.40 m) | 1.25 ft (0.38 m) |
| B-25.20[2] | Combination Inlet | 1.67 ft (0.50 m | 2.0 ft (0.61 m) | 1.31 ft (0.40 m) | 1.25 ft (0.38 m) |
| B-40.20 | Grate Inlet Type 1 (Grate A or B[4]) | 2.01 ft (0.62 m) 3.89 ft[7] (1.20 m) | 3.89 ft (0.62 m) 2.01 ft[7] (1.20 m) | 1.67 ft (0.50 m) 3.52 ft (1.07 m) | 3.52 ft (1.07 m) 1.67 ft (0.50 m) |
| B-30.80 | Circular Grate[9] | 1.52 ft (0.47 m) | | 2.55 ft[10] (0.79 m) | |
| B-40.40 | Frame and Vaned Grates for Grate Inlet Type 2 | 1.75 ft[5] (0.52 m) 3.52 ft[6] (1.05 m) | 3.52 ft[5] (1.05 m) 1.75 ft[6] (0.52 m) | 1.29 ft (0.40 m) 2.58 ft[6] (0.80 m) | 2.58 ft (0.50 m) 1.29 ft[6] (0.26 m) |

# Gutter Flow and Flow Bypass




$Z_d$: flow spread width from curb/barrier face into the travel lane

$Q_{BP}$: flow bypass

GW: grate width in feet

d: flow depth at the curb face in feet

$V_1$: velocity of flow in feet per second

# Gutter Analysis/Inlet Spacing

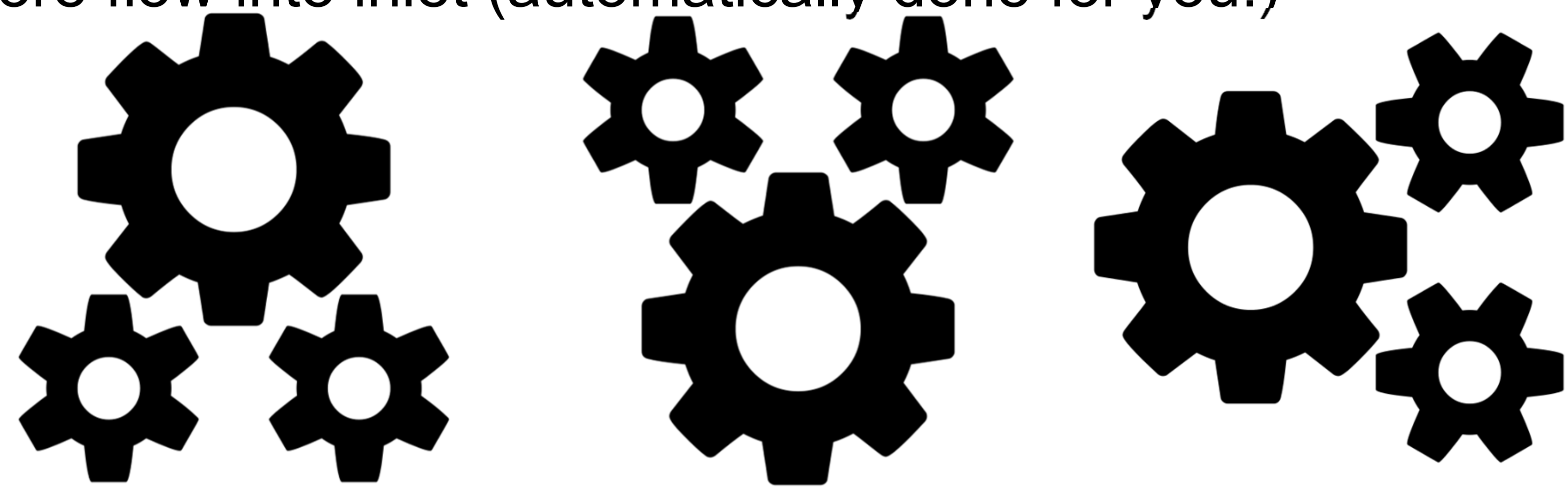
Use the WSDOT Inlet Spacing Spreadsheet

http://wsdot.wa.gov/Design/Hydraulics/ProgramDownloads.htm

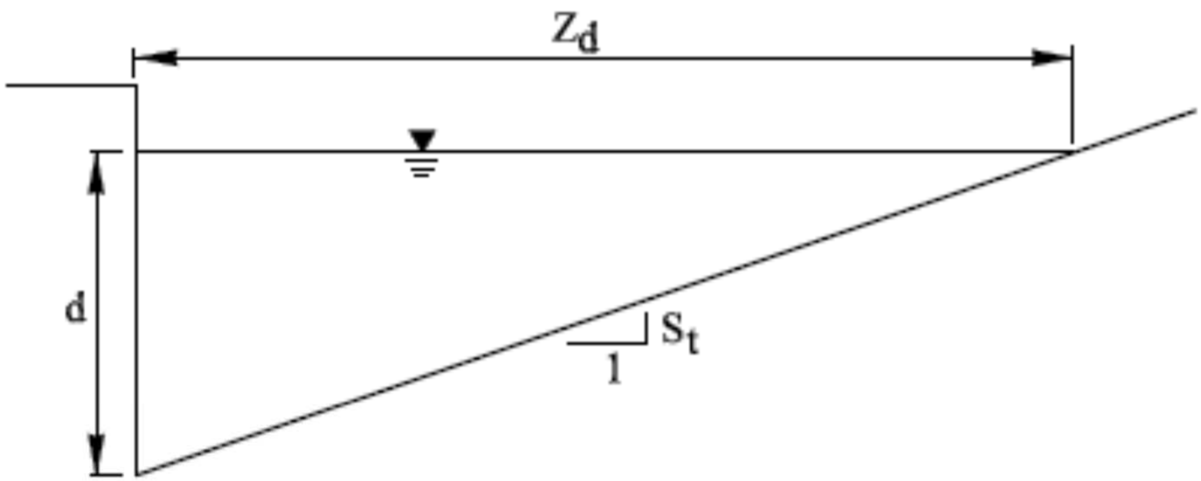
Goal: to determine the space between catch basins or inlets.

# Inlet Spacing Design

- Uses Rational Method $Q = CIA$
- Catchment area or pavement draining to inlet being designed is defined by begin/end station and roadway width
- Roadway longitudinal slope and transverse (cross) slope
- Allowable width of flow (flow spread or $Z_d$ allowable)
- 0.1 cfs maximum flow allowed to bypass last inlet ($Q_{bp}$)
- If flow is slow enough and gutter is flat, spreadsheet allows more flow into inlet (automatically done for you!)



# Flow Spreads




**Typical Gutter Section**
*Figure 5-4.2*

**ations show**
**of flow as a**
**gutter**
**flow rate**

$$d = \left[ \frac{\Delta O S_t}{37(S_L)^{0.5}} \right]^{3/8} \quad (5\text{-}1)$$

$$Z_d = \frac{d}{S_t} \quad (5\text{-}2)$$

Where:

- $d$ = depth of flow at the face of the curb (ft)
- $\Delta O$ = gutter discharge (cfs)
- $S_L$ = longitudinal slope of the gutter (ft/ft)
- $S_t$ = transverse slope or superelevation (ft/ft)
- $Z_d$ = top width of the flow prism (ft)

# Allowable Flow Spreads

| Road Classification | | Design Frequency | Design Spread (Zd) |
|---|---|---|---|
| Interstate, Principal, Minor Arterial, or Divided | < 45 mph (70 km/hr)<br>≥ 45 mph (70 km/hr)<br>Sag Pt. | 10-year<br>10-year<br>50-year | Shoulder+2 ft (0.67 m)[1]<br>Shoulder<br>Shoulder+2 ft (0.67 m)[1] |
| Collector and Local Streets | < 45 mph (70 km/hr)<br>≥ 45 mph (70 km/hr)<br>Sag Pt. | 10-year<br>10-year<br>50-year | Shoulder+½ Driving Lane[2]<br>Shoulder<br>½ Driving Lane[2] |

[1]The travel way shall have at least 10 ft that is free of water.

[2]In addition to the design spread requirement, the depth of flow shall not exceed 0.12 ft at the edge of shoulder.

**Design Frequency and Spread**
*Figure 5-4.1*

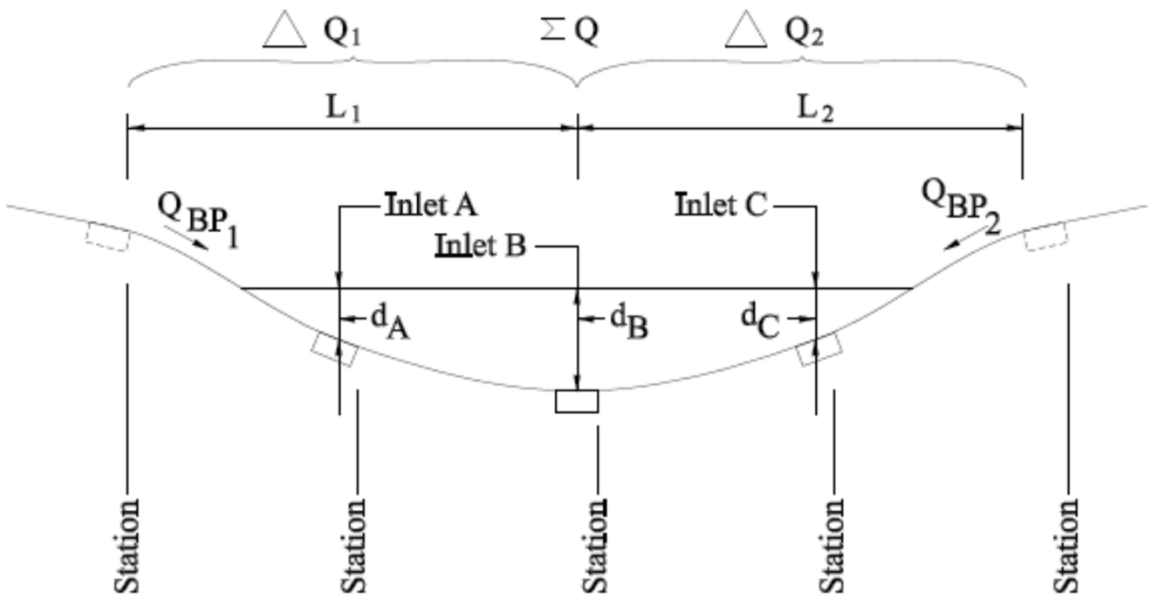
Roadway classification + Design Speeds = Design Spread ($Z_d$)

Also lists criteria for Sag Analysis

# Sag Design

# Sag Design

Sag: lowest elevation in the roadway. Higher elevations on both ends.




**Sag Analysis**
***Figure 5-5.8***

Once an inlet has been placed in a sag location, the total actual flow to the inlet can be determined as shown below. $Q_{Total}$ must be less than $Q_{allowable}$ as described in Equation 5-13.

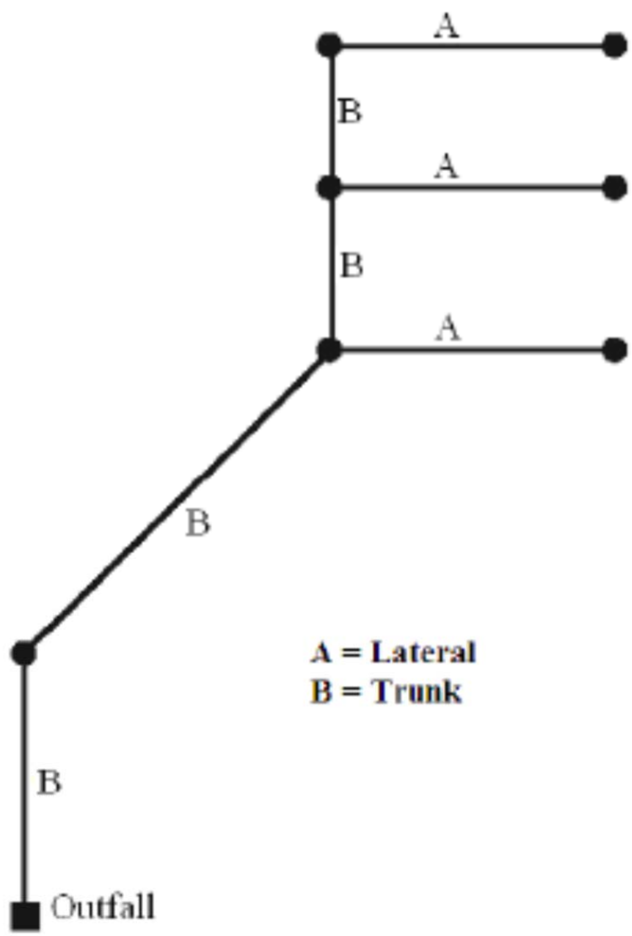
$$Q_{Total} = Q_{BP1} + Q_{BP2} + \Delta Q_1 + \Delta Q_2 \qquad (5\text{-}11)$$

# Sag Design

- 50 years storm event
- Flow spread: shoulder + 2 feet or ½ of the driving lane.
- Flanking inlets on both sides
- Sag Design Spreadsheet http://wsdot.wa.gov/Design/Hydraulics/ProgramDownloads.htm

# Storm Drains

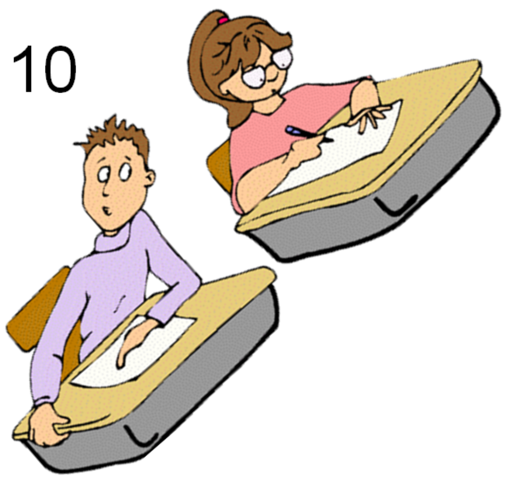
# Pipe Networks




**Storm Drain Structure**
*Figure 6-1.1*

# Storm Drain Cheat Sheet

- Minimum pipe diameter is 12 inches except 8 inches for laterals less than 50 feet long
- Inlet spacing and storm drain design compliment each other
- Maximum storm drain length = 300 feet but may be less depending on maintenance input
- Velocity in storm drain should be > 3 fps but < 10 fps
- Match pipe crowns (tops), not pipe inverts
- Pipe angles coming into a CB, MH, or Inlet should be constructible (see pipe angle calculator spreadsheet on WSDOT website)
- Consider maintenance when designing storm drain pipe network for structure depths and pipe lengths



# Flow Velocities

$$V = \frac{1.486}{n} R^{2/3}\sqrt{S} = \frac{1.486}{n}\left[\frac{D}{4}\right]^{2/3}\sqrt{S} \quad \text{(English Units)} \qquad (6\text{-}1)$$

$$V = \frac{1}{n} R^{2/3}\sqrt{S} = \frac{1}{n}\left[\frac{D}{4}\right]^{2/3}\sqrt{S} \quad \text{(Metric Units)}$$

Where:

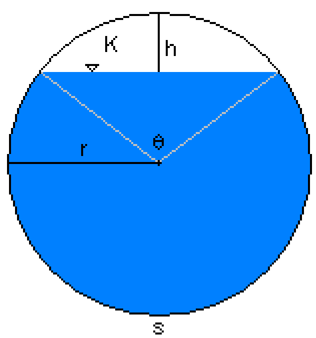
- V = velocity in ft/s (m/s)
- D = pipe diameter in feet (meters)
- S = pipe slope in feet/foot (meters/meter)
- n = Manning's roughness coefficient (see Appendix 4-1)

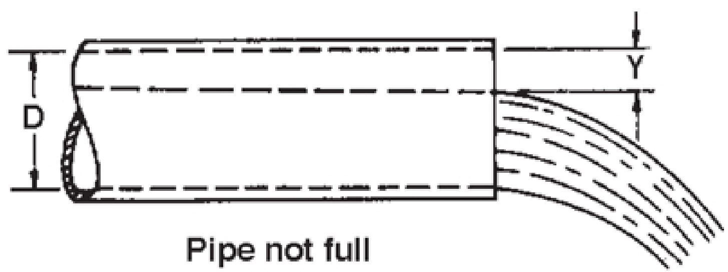
R = cross area / wetted perimeter of the pipe

# Pipe Capacities

Q = VA

Q = flow capacity in cfs
V = flow velocity in fps
A = cross area of the flow section



# Group Designs

Exercises:

1) Inlet Spacing Design Exercise 1
2) Sag Design Exercise 2
3) Pipe Network Exercise 3

# Inlet Spacing Exercise 1

Open up Day1 Exercises PPT file