DAY 1 Group Exercises

Exercises:

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

Inlet Spacing Exercise 1

Problem: Highway 2 (near Everett) is going to have a barrier installed along the edge of pavement for a 1000 foot long section. We need to capture all runoff from the eastbound (EB) lane + EB shoulder of Highway 2 and convey it to a location at the end of the 1000 foot long section of highway for stormwater treatment. Runoff is flowing east to west.

Assumptions:

Highway 2 = 2 lane highway; 12 foot lanes, 8 foot shoulders

normal crowned (2% cross slope, 2% longitudinal slope)

Highway 2 = principal arterial; >45 mph

Inlet Spacing Exercise 1

Question: What is the inlet spacing and how many inlets do I need to install to meet the spread width requirements and maximum bypass flow of 0.1 cfs at the end of the curb and gutter run?

What's next?

Inlet Spacing Exercise 1

Where to start?

1. Open up WSDOT inlet spacing spreadsheet and input project information
   a) Work in groups to figure out next steps!
   b) **Use the Hydraulics Manual!**

Assumptions:

Highway 2 = 2 lane highway; 12 foot lanes, 8 foot shoulders normal crowned (2% cross slope, 2% longitudinal slope)

Highway 2 = principal arterial; >45 mph

Maintenance office says the maximum pipe length they can maintain is 200 feet long (start with 5 inlets for the 1000 feet)

Inlet Spacing Exercise 1

STEPS TO SUCCESS!!!!

1) Input the starting station of curb/barrier and the inlet stations into the inlet spacing spreadsheet. Input corresponding roadway geometry that will flow into inlets
2) Use the 10-year storm coefficients
3) Pick inlet types.
4) If the inlet spacing has a small enough spread width and bypass flow at the last inlet, then the design is good.

Culvert Design Exercise 4

STEP BY STEP SOLUTION

Inlet Spacing Exercise 1

1. Input Tc, C, m and n values for “Everett” for SR 2 for 10-year, input allowable Zd based on assumptions for 10-year
2. Tc = 5 (minimum and typical for pavement)
3. C = 0.90 (pavement)
4. m = 6.31
5. n = 0.575
6. Zd allowable = shoulder = 8 feet based on HM Figure 5-4.1

Inlet Spacing Exercise 1

INLET SPACING - CURB AND GUTTER SPREADSHEET (ENGLISH UNITS)

Tc =	5.00
C =	0.90
I =	2.50 #NUM!
m=	6.31
n=	0.58
Allowable Zd=	8.00

Project Name SI
Project #:
S.R.:
Designed By:
Date:
Updated:

Station	Distance	Width	Δ Q	Σ Q	Slope L	Super T	G.W.	G.L.
	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------

Inlet Spacing Exercise 1

7. For stationing, start at Station 12+00. The next station = 14+00. Keep going until you get to Station 22+00 (1000 feet). You should end up with 5 structures (rows in the spreadsheet) to analyze.
8. Input roadway width = 12 feet + 8 feet = 20 feet for each row.

Inlet Spacing Exercise 1

INLET SPACING - CURB AND GUTTER SPREADSHEET (ENGLISH UNITS)

Tc =	5.00
C =	0.90
I =	2.50 #NUM!
m=	6.31
n=	0.58
Allowable Zd=	8.00

Project Name SI
Project #:
S.R.:
Designed By:
Date:
Updated:

Station	Distance	Width	Δ Q	Σ Q	Slope L	Super T	G.W.	G.L.
12+00.00	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------
14+00.00	200	20						
16+00.00	200	20						
18+00.00	200	20						
20+00.00	200	20						
22+00.00	200	20						

Inlet Spacing Exercise 1

9. Input longitudinal slope (0.02) and transverse slope (0.02) for 2% slopes for each.
10. For GW, see HM Figure 5-5.7. Let's try Vaned Grates for Catch Basins and Inlets; GW = 1.67 feet, GL = 2.0 feet
11. Look at Columns T, U, and V to see if the inlet spacing design looks ok.

Inlet Spacing Exercise 1

INLET SPACING - CURB AND GUTTER SPREADSHEET (ENGLISH UNITS)

Tc =	5.00
C =	0.90
I =	#NUM!
m=	6.31
n=	0.58
Allowable Zd=	8.00

Project Name SI
Project #:
S.R.:
Designed By:
Date:
Updated:

Station	Distance	Width	Δ Q	Σ Q	Slope L	Super T	G.W.	G.L.
12+00.00	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------
14+00.00	200	20			0.02	0.02	1.67	2.00
16+00.00	200	20			0.02	0.02	1.67	2.00
18+00.00	200	20			0.02	0.02	1.67	2.00
20+00.00	200	20			0.02	0.02	1.67	2.00
22+00.00	200	20			0.02	0.02	1.67	2.00

Inlet Spacing Exercise 1

Using 5 inlets is adequate to capture the runoff from the 1000 feet of roadway and meets the inlet spacing design criteria!
Can we use fewer inlets and still meet the inlet spacing design criteria? Let's try 3 inlets!

Q_i	Q_{bp}**	Z_d Check	Velocity Check	Q_{bp} Check
-----------	--------------	--------------	--------------	--------------
0.18	0.03	Zd ALLOWABLE > Zd DESIGN	VELOCITY < 5 FT/SEC	
0.21	0.03	Zd ALLOWABLE > Zd DESIGN	VELOCITY < 5 FT/SEC	
0.21	0.03	Zd ALLOWABLE > Zd DESIGN	VELOCITY < 5 FT/SEC	
0.21	0.04	Zd ALLOWABLE > Zd DESIGN	VELOCITY < 5 FT/SEC	
0.21	0.04	Zd ALLOWABLE > Zd DESIGN	VELOCITY < 5 FT/SEC	Qbp < 0.1 CFS

Looks ok! **Looks ok!** **Looks ok!**

Inlet Spacing Exercise 1

12. The spreadsheet says everything is good!
13. Can we eliminate inlets somewhere in the system and still meet the inlet spacing requirements?
14. Let's try to delete 2 inlets from the beginning and use only 3 inlets to see how that might affect our analysis.
15. Start the first inlet at Station 18+00 instead of 16+00.

Inlet Spacing Exercise 1

INLET SPACING - CURB AND GUTTER SPREADSHEET (ENGLISH UNITS)

Tc =	5.00
C =	0.90
I =	#NUM!
m=	6.31
n=	0.58
Allowable Zd=	8.00

Project Name	SI
Project #:	
S.R.:	
Designed By:	
Date:	
Updated:	

Station	Distance	Width	Δ Q	Σ Q	Slope L	Super T	G.W.	G.L.
12+00.00	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------
18+00.00	600	20			0.02	0.02	1.67	2.00
20+00.00	200	20			0.02	0.02	1.67	2.00
22+00.00	200	20			0.02	0.02	1.67	2.00

Inlet Spacing Exercise 1

Using 3 inlets is adequate to capture the runoff from the 1000 feet of roadway and meets the inlet spacing design criteria!
Can we use fewer inlets and still meet the inlet spacing design criteria? Let's try 2 inlets!

Q_i	Q_{bp}**	Z_d Check	Velocity Check	Q_{bp} Check
-------	--------------			-------------
0.44	0.18	Zd ALLOWABLE > Zd DESIGN	VELOCITY < 5 FT/SEC	
0.29	0.10	Zd ALLOWABLE > Zd DESIGN	VELOCITY < 5 FT/SEC	
0.25	0.06	Zd ALLOWABLE > Zd DESIGN	VELOCITY < 5 FT/SEC	Qbp < 0.1 CFS

Looks ok! Looks ok! Looks ok!

Inlet Spacing Exercise 1

16. That worked OK using only 3 inlets. How many inlets do we really need? Let's try using only 2 inlets! Remember maximum pipe spacing and bypass flow maximums.
17. Start the first inlet at Station 20+00.

Inlet Spacing Exercise 1

INLET SPACING - CURB AND GUTTER SPREADSHEET (ENGLISH UNITS)

Tc =	5.00
C =	0.90
I =	#NUM!
m=	6.31
n=	0.58
Allowable Zd=	8.00

Project Name	SI
Project #:	
S.R.:	
Designed By:	
Date:	
Updated:	

Station	Distance	Width	Δ Q	Σ Q	Slope L	Super T	G.W.	G.L.
12+00.00	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------
20+00.00	800	20			0.02	0.02	1.67	2.00
22+00.00	200	20			0.02	0.02	1.67	2.00

Inlet Spacing Exercise 1

Using 2 inlets allows too much bypass flow at the last inlet. The maximum bypass is 0.1 cfs. We will go back to using 3 inlets since that worked OK.

	Q_{bp}**	Z_d Check	Velocity Check	Q_{bp} Check
-	--------------	--------------	--------------	------
.52	0.31	Zd ALLOWABLE > Zd DESIGN	VELOCITY < 5 FT/SEC	
.37	0.15	Zd ALLOWABLE > Zd DESIGN	VELOCITY < 5 FT/SEC	NEED TO REDUCE Qbp

Too High; >0.1 cfs

Looks ok!

Looks ok!

Not good!!

Inlet Spacing Exercise 1

OPTIMIZED ANSWER = 3 inlets; start the first inlet at Station 18+00 and use 200 foot spacings; inlet at 18+00, 20+00, and 22+00.

Design meets spread width of 8 feet for the 10-year design event; meets the maximum of 0.1 cfs bypass on the last structure

DAY 1 Exercises

Exercises:

1) Inlet Spacing Design Exercise1
2) **Sag Design Exercise 2**
3) Pipe Network Exercise 3

Sag Analysis Exercise 2

Problem: Barrier will be installed on the EB side of SR 2 for 2200 feet (Station 12+00 to 34+00). SR 2 dips into a sump in the middle of this run of new barrier. The first 1000 feet of the barrier run was analyzed in the Inlet Spacing Exercise 1. The sump is 100 feet east of the last inlet (Station 22+00) from the inlet spacing Exercise. We want to do a sump analysis at the sump (Station 23+00) to see if the proposed design has enough capacity or if flanking inlets are needed.

Sag Analysis Exercise 2

Using information from the Inlet Spacing Exercise 1 and given some new information, analyze the sump to see if flanking inlets are needed. Please note the sump analysis is for the 50-year storm event, not the 10-year so the previous analysis needs to be re-run.

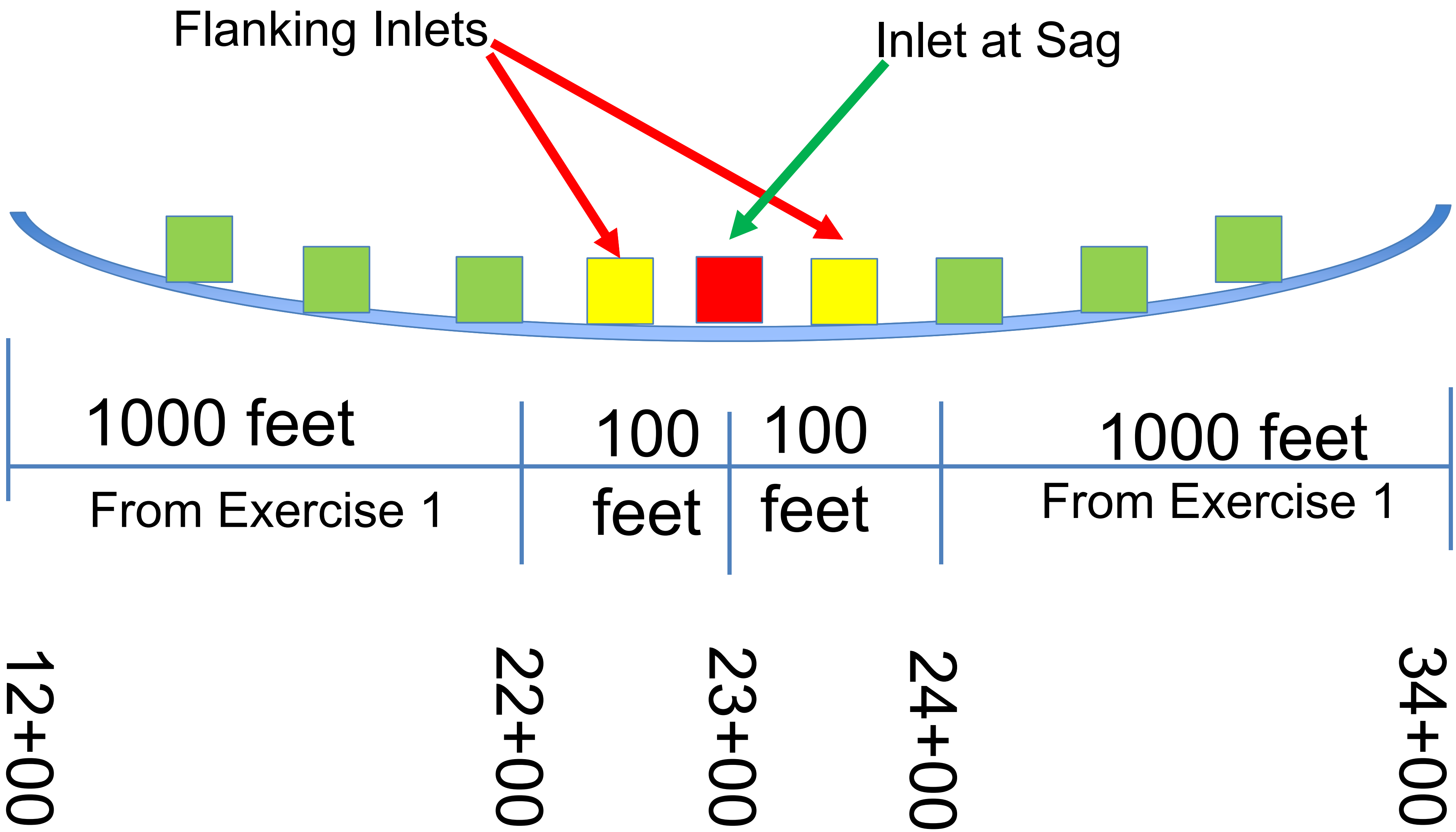
Assumptions:
2 lane highway; 12 foot lanes, 8 foot shoulders
normal crowned (2% cross slope, 2% longitudinal slope)

Sag Analysis Exercise 2

Assumptions (cont.):
The sump is at Station 23+00.
The same inlet spacing as designed in Exercise 1 exists west of the sump (1000 foot curb and gutter run + 100 feet from last inlet to the sump)
The bypass flow calculated for one inlet spacing run coming to the sump should equal the bypass flow from the other system coming to the sump
Highway 2 = principal arterial; >45 mph

Sag Analysis Exercise 2

Side view of SUMP



Sag Analysis Exercise 2

Question: Will a single vaned grate work at this sump location for the flows coming to it?

What's next?

Sag Analysis Exercise 2

STEPS TO SUCCESS!!!!

1) Re-run Exercise 1 for the 50-year event and determine the bypass flow at the end of the run
2) Input information into sag design spread sheet
3) Choose inlet type at sump
4) Determine if flanking inlets are needed
5) Run analysis to see if allowable depth is not exceeded at the sump and if there is adequate capacity to take away the ponded water

Culvert Design Exercise 4

STEP BY STEP SOLUTION

Sag Analysis Exercise 2

1. Open up previous WSDOT inlet spacing spreadsheet and input m and n values for "Everett" for SR 2 for 50-year, input allowable Zd based on assumptions for 50-year
2. Tc = 5 (minimum and typical for pavement)
3. C = 0.95 for pavement; for 50 year, C = (0.9 + 0.2*.9) = 1.38 but max = 0.95, see HM 2-5.2
4. m = 8.96
5. n = 0.585
6. Zd allowable = shoulder + 2 feet = 8 ft + 2 ft = 10 feet

Sag Analysis Exercise 2

INLET SPACING - CURB AND GUTTER SPREADSHEET (ENGLISH UNITS)

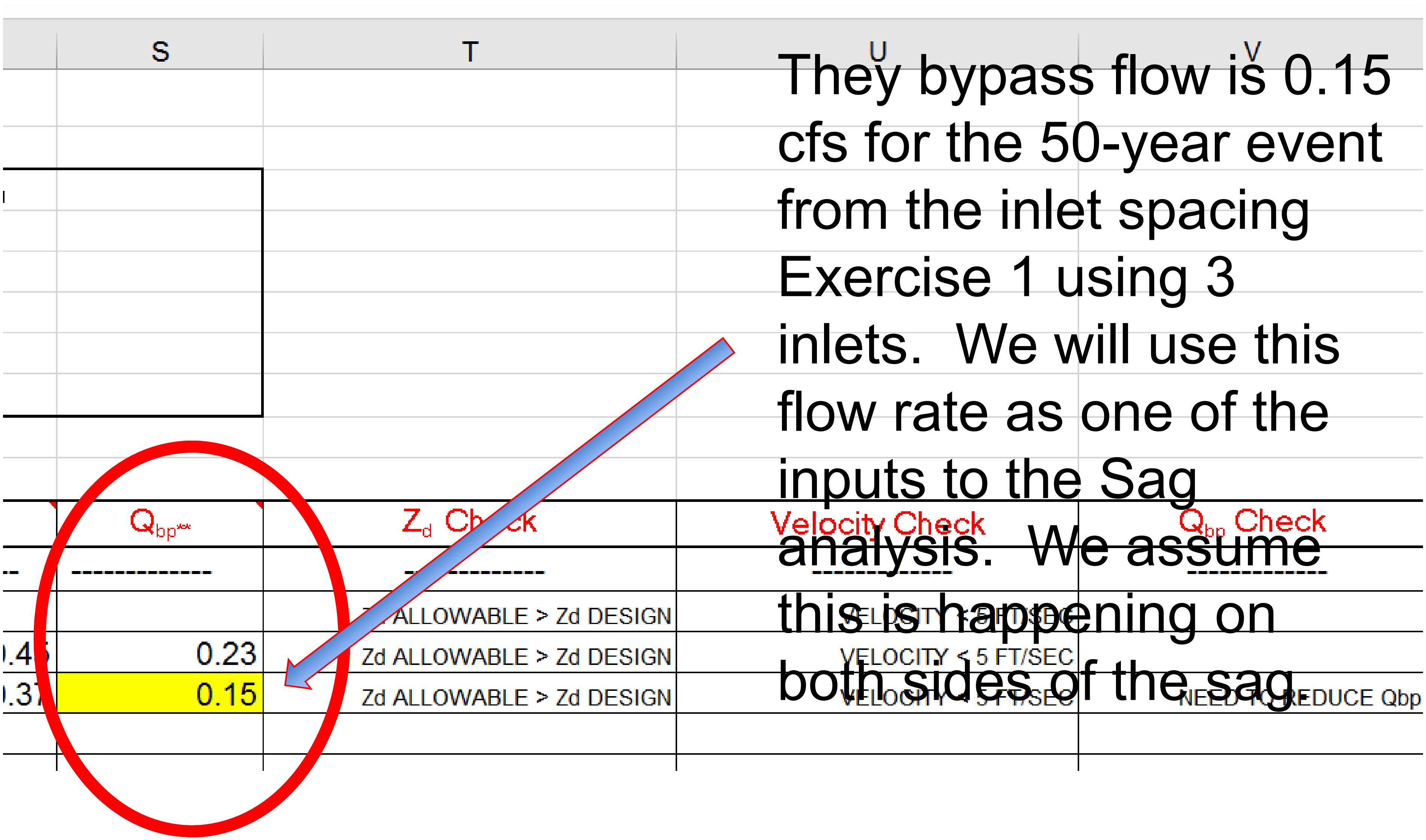
Tc =	5.00
C =	0.95
I =	#NUM!
m=	8.96
n=	0.59
Allowable Zd=	10.00

These are coefficient for a 50-year event

Project Name	SI
Project #:	
S.R.:	
Designed By:	
Date:	
Updated:	

Station	Distance	Width	Δ Q	Σ Q	Slope L	Super T	G.W.	G.L.
12+00.00	-------------	-------------	-------------	-------------	-------------	-------------	-------------	-------------
18+00.00	600	20			0.02	0.02	1.67	2.00
20+00.00	200	20			0.02	0.02	1.67	2.00
22+00.00	200	20			0.02	0.02	1.67	2.00

Sag Analysis Exercise 2



They bypass flow is 0.15 cfs for the 50-year event from the inlet spacing Exercise 1 using 3 inlets. We will use this flow rate as one of the inputs to the Sag analysis. We assume this is happening on both sides of the sag.

Sag Analysis Exercise 2

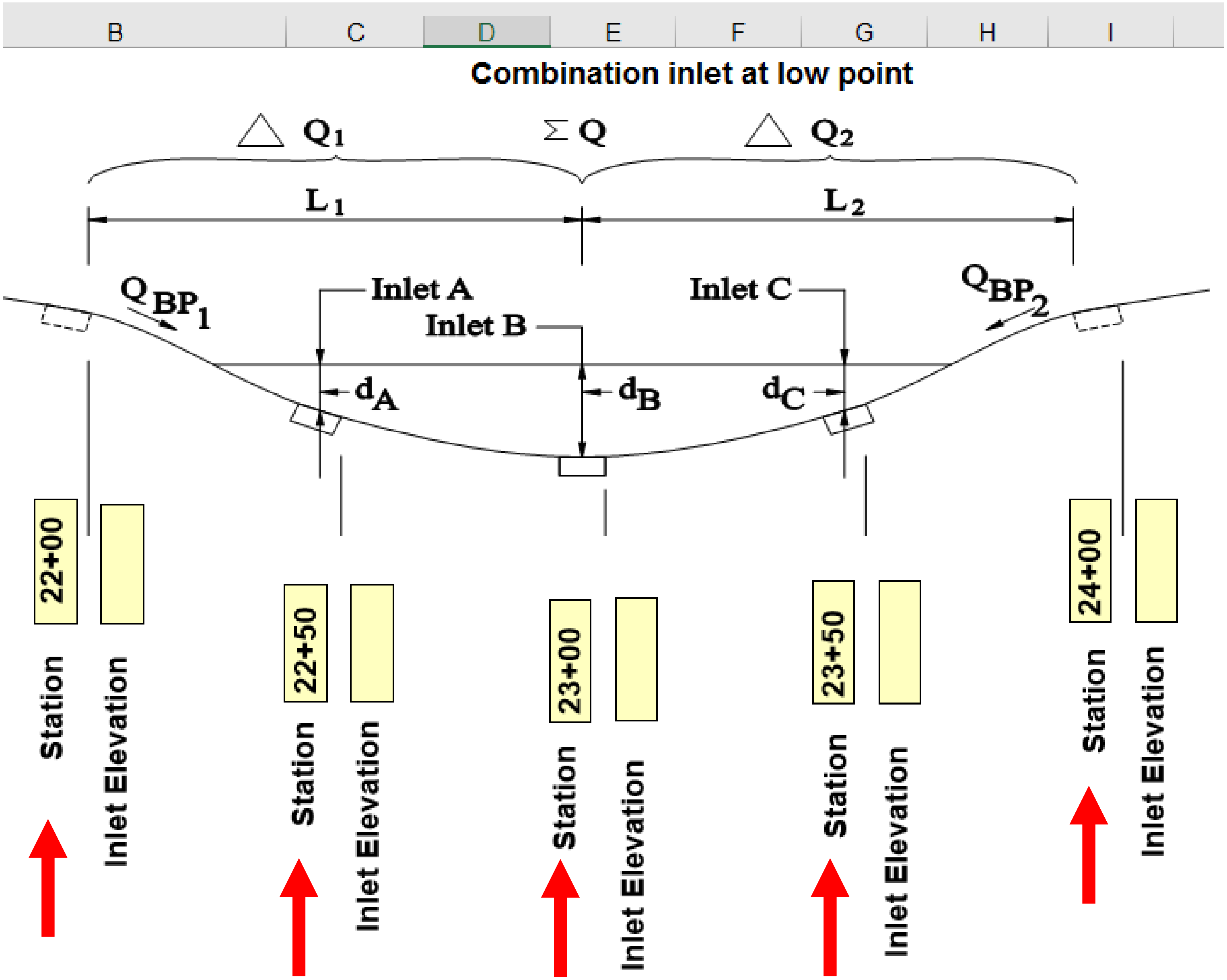
7. Based on new “m” and “n” values, we get a bypass flow of 0.15 cfs at Station 22+00.
8. Assume that the same conditions will be on the other side of the sump, same bypass flow of 0.15 cfs coming to the sump.
9. Take bypass flows and open up WSDOT Sag Inlet Design Spreadsheet

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

Sag Analysis Exercise 2

10. Input information into HORIZONTAL yellow boxes that are below the picture. The picture of the sump along with the vertical stationing and elevations boxes are there as FYI and do not affect the sump calculations.
11. Specify if a combination inlet or single grate inlet will be at the sump location.

Sag Analysis Exercise 2



Sag Analysis Exercise 2

12. Specify if a combination inlet or single grate inlet will be at the sump location.
13. Enter the grate length and width based on:
    - The type of grate per HM Figure 5-5.7
    - If the grate is rotated
    - Try a vaned grate per WSDOT Standard Plan B30-30
        - GW = 1.31; GL = 1.25
14. Input the same vaned grate information for the flanking inlets since they are required when using barrier per HM 5-5.4.

Sag Analysis Exercise 2

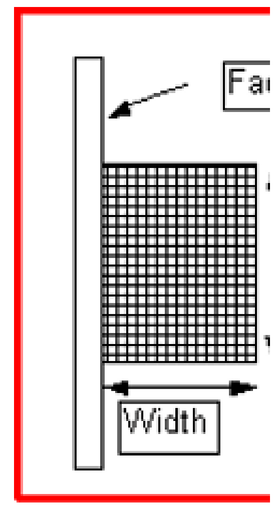
Enter values in the yellow colored cells

Transverse Slope	S_T	0.02	ft/ft	Shoulder Width	8.00	ft
Allowable	Z_d	10.00	ft	Lane Width	12.00	ft
Allowable	d_B	0.20	ft	($d_A = d_C =$ 0 ft allowable)		
Time of Concentration	T_c	5.00	min			
50 yr. rainfall coefficients	m	8.96				
	n	0.585				
Rainfall Intensity	$I_{50\text{-}yr}$	3.50 #NUM!	in/hr	(for 0 minute duration)		
Distance between last inlet and low point	L_1	100.00	ft	L_2	100.00	ft
Width of catchment area	W_1	20.00	ft	W_2	20.00	ft
Bypass from last inlet	Q_{BP1}[4]	0.15	cfs	Q_{BP2}[4]	0.15	cfs
Discharge of catchment area	Q_1	0.15 #NUM!	cfs	Q_2	0.15 #NUM!	cfs

$Q_{Total} = Q_{BP1} + Q_1 + Q_{BP2} + Q_2$

$Q_{Total} =$ #NUM! | 0.60 #NUM! cfs

Single Vaned Grate
Std. Plan B30-30



Combination[1] or Grate Inlet for sag P_B (C/G) → G

Effective Perimeter of Grate Inlets (reduced by 50% for plugging)								
P_A	Flank	1.94	ft	Width	1.31	Length	1.25
P_B		C/G 1.94	ft	Width	1.31	Length	1.25
P_C	Flank	1.94	ft	Width	1.31	Length	1.25

Sag Analysis Exercise 2

15. The sump design spreadsheet will calculate the flow capacity of the sump versus the flow coming to the sump
16. The sump design spreadsheet will calculate the allowable depth of flow and calculate the depth of flow at the sump but you have to compare the two
17. For this Exercise, the Sag Design spreadsheet will say the capacity is adequate since we have the flanking inlets so our design is complete!

Sag Analysis Exercise 2

Exercise2_SagWorksheetud_Complete_V2 [Compatibility Mode] - Excel

$$\Sigma Q = Q_A + Q_B + Q_C$$

0.60 cfs required

[2] $$\Sigma Q = C_{WA}P_A(0.5d_B)^{1.5} + C_{WB}P_Bd_B^{1.5} + C_{WC}P_C(0.5d_B)^{1.5}$$

0.89 cfs

Capacity is adequate, design is complete.

$$d_B = \left(\frac{\Sigma Q}{C_{WA}P_A0.3536 + C_{WB}P_B + C_{WB} + C_{WC}P_C0.3536}\right)^{2/3} =$$

0.16 ft

0.20 ft. max

Check calculated d_B against allowable d_B.

If d_B < allowable d_B, the design is complete.

If d_B > allowable d_B, additional inlets must be added[3] and the process repeated.

Notes:

[1] If using a combination inlet for the sag, the flank grate inlets are not required except in a depressed area (See Hydaulics Manual).

[2] Formulas based on weir flow. See Hydraulic Manual 5-5.2.

[3] To add more than one inlet in the sag or flanks just increase the width and length values to the sum of all values. Inlets can be different sizes. See Figure 5-5.7 in Hydraulics Manual for grate dimensions.

[4] Q_{bp1} and Q_{bp2} come from the inlet spreadsheet.

Sag Analysis Exercise 2

OPTIMIZED ANSWER = Specify a Vaned Grate per WSDOT Standard Plan B-30.30 at the sump with 2 flanking inlets. This will ensure the sump conditions meet the Hydraulics Manual requirements based on the Sag Design Spreadsheet.

Sag Analysis Exercise 2A

If we used curb instead of barrier in Exercise 2, how would that change the sag design?

We might not need flanking inlets since flows can go over the curb. We would have to make sure that flows going over the curb would not cause erosion.

Sag Analysis Exercise 2A

1. Let's rerun the Exercise 2 without flanking inlets.
2. Delete the flanking inlets but still use the vaned grate per WSDOT Standard Plan B30-30
   - GW = 1.31; GL = 1.25

Sag Analysis Exercise 2A

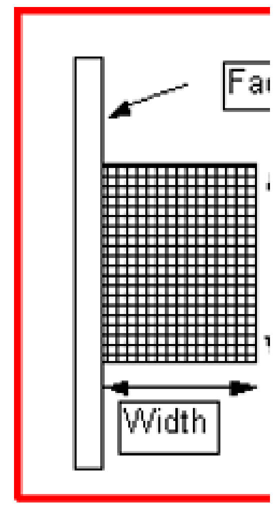
Enter values in the yellow colored cells

Transverse Slope	S_T	0.02	ft/ft	Shoulder Width		8.00	ft
Allowable	Z_d	10.00	ft	Lane Width		12.00	ft
Allowable	d_B	0.20	ft	(d_A = d_C = 0 ft allowable)			
Time of Concentration	T_c	5.00	min				
50 yr. rainfall coefficients	m	8.96					
	n	0.585					
Rainfall Intensity	$I_{50\text{-}yr}$	3.50 / #NUM!	in/hr	(for 0 minute duration)			
Distance between last inlet and low point	L_1	100.00	ft	L_2	100.00	ft	
Width of catchment area	W_1	20.00	ft	W_2	20.00	ft	
Bypass from last inlet	Q_{BP1}[4]	0.15	cfs	Q_{BP2}[4]	0.15	cfs	
Discharge of catchment area	Q_1	0.15 / #NUM!	cfs	Q_2	0.15 / #NUM!	cfs	

$Q_{Total} = Q_{BP1} + Q_1 + Q_{BP2} + Q_2$

Q_{Total} = #NUM! 0.60 / #NUM! cfs

Single Vaned Grate
Std. Plan B30-30



Combination[1] or Grate Inlet for sag P_B (C/G) → G

Effective Perimeter of Grate Inlets (reduced by 50% for plugging)							
P_A	Flank	0	ft	Width		Length	
P_B		1.94 / C/G	ft	Width	1.31	Length	1.25
P_C	Flank	0	ft	Width		Length	

Sag Analysis Exercise 2A

Exercise2_SagWorksheetud_Complete_V2 [Compatibility Mode] - Excel

Length1 | 100

$$\Sigma Q = Q_A + Q_B + Q_C$$

0.60 cfs required

[2] $$\Sigma Q = C_{WA}P_A(0.5d_B)^{1.5} + C_{WB}P_Bd_B^{1.5} + C_{WC}P_C(0.5d_B)^{1.5}$$

0.52 cfs

Capacity is inadequate, additional inlets required.

Capacity is adequate, design is complete.

$$d_B = \left(\frac{\Sigma Q}{C_{WA}P_A0.3536 + C_{WB}P_B + C_{WB} + C_{WC}P_C0.3536}\right)^{2/3} =$$

0.22 ft

0.20 ft. max

Check calculated d_B against allowable d_B.

If d_B < allowable d_B, the design is complete.

If d_B > allowable d_B, additional inlets must be added[3] and the process repeated.

Notes:

[1] If using a combination inlet for the sag, the flank grate inlets are not required except in a depressed area (See Hydaulics Manual).

[2] Formulas based on weir flow. See Hydraulic Manual 5-5.2.

[3] To add more than one inlet in the sag or flanks just increase the width and length values to the sum of all values. Inlets can be different sizes. See Figure 5-5.7 in Hydraulics Manual for grate dimensions.

[4] Q_{bp1} and Q_{bp2} come from the inlet spreadsheet.

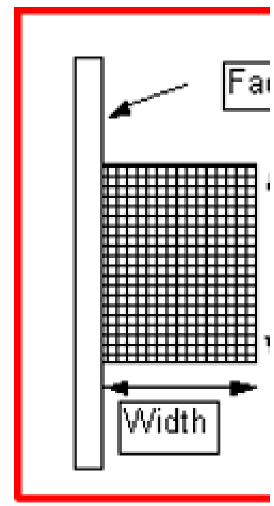
Sag Analysis Exercise 2A

3. There isn't enough capacity to take all of the water coming to the sump and the allowable depth is too high (>0.2 allowed)
4. Try using the rotated vaned grates for Grate Inlet Type 2 per WSDOT Std Plan B40-40
   - GW = 2.58; GL = 1.29

Sag Analysis Exercise 2A

	A	B	C	D	E	F	G	H	I
29									
30				**Enter values in the yellow colored cells**					
31		Transverse Slope	S_T	0.02	ft/ft	Shoulder Width		8.00	ft
32		Allowable	Z_d	10.00	ft	Lane Width		12.00	ft
33		Allowable	d_B	0.20	ft	(d_A = d_C = 0 ft allowable)			
34		Time of Concentration	T_c	5.00	min				
35		50 yr. rainfall coefficients	m	8.96					
36			n	0.585					
37		Rainfall Intensity	$I_{50\text{-}yr}$	3.50 #NUM!	in/hr	(for 0 minute duration)			
38		Distance between last inlet and low point							
39			L_1	100.00	ft	L_2	100.00	ft	
40		Width of catchment area	W_1	20.00	ft	W_2	20.00	ft	
41		Bypass from last inlet	Q_{BP1}[4]	0.15	cfs	Q_{BP2}[4]	0.15	cfs	
42		Discharge of catchment area	Q_1	0.15 #NUM!	cfs	Q_2	0.15 #NUM!	cfs	
43									
44		$Q_{Total} = Q_{BP1} + Q_1 + Q_{BP2} + Q_2$							
45									
46		Q_{Total} =	#NUM!	0.60 #NUM!	cfs				
47									
48									
49		Combination[1] or Grate Inlet for sag P_B (C/G) →		G					
50		Effective Perimeter of Grate Inlets (reduced by 50% for plugging)	P_A Flank	0	ft	Width		Length	
51			P_B	3.23 C/G	ft	Width	2.58	Length	1.29
52			P_C Flank	0	ft	Width		Length	

Single Vaned Grate
Std. Plan B40-40
Rotated



Sag Analysis Exercise 2A

Exercise2_SagWorksheetud_Complete_V2 [Compatibility Mode] - Excel

Length1 | 100

$$\Sigma Q = Q_A + Q_B + Q_C$$

0.60 cfs required

$$^{2}\ \Sigma Q = C_{WA}P_A(0.5d_B)^{1.5} + C_{WB}P_Bd_B^{1.5} + C_{WC}P_C(0.5d_B)^{1.5}$$

0.87 cfs

Capacity is adequate, design is complete.

$$d_B = \left(\frac{\Sigma Q}{C_{WA}P_A 0.3536 + C_{WB}P_B + C_{WB} + C_{WC}P_C 0.3536}\right)^{2/3} =$$

0.16 ft

Check calculated d_B against allowable d_B.

0.20 ft. max

If d_B < allowable d_B, the design is complete.

If d_B > allowable d_B, additional inlets must be added[3] and the process repeated.

Notes:

[1] If using a combination inlet for the sag, the flank grate inlets are not required except in a depressed area (See Hydaulics Manual).

[2] Formulas based on weir flow. See Hydraulic Manual 5-5.2.

[3] To add more than one inlet in the sag or flanks just increase the width and length values to the sum of all values. Inlets can be different sizes. See Figure 5-5.7 in Hydraulics Manual for grate dimensions.

[4] Q_{bp1} and Q_{bp2} come from the inlet spreadsheet.

Sag Analysis Exercise 2A

5. Using this configuration works for the sump design!
6. So if using a barrier, we would need 3 inlets Std. Plan B30-30 (the inlet at the sump + 2 flanking inlets)
7. If using a curb, we would only need one inlet Std. Plan B40-40 that is rotated

============END SAG PROBLEMS=====

DAY 1 Exercises

Exercises:

1) Inlet Spacing Design Exercise1
2) Sag Design Exercise 2
3) **Pipe Network Exercise 3**

Pipe Network Exercise 3

Problem: Since we already did the inlet spacing for the 1000 foot run of roadway, we need to size the conveyance system that carries the flow from the inlets. From Inlet Spacing Exercise 1, we ended up with 3 inlets but we will check to see how the pipe sizing works.

Pipe Network Exercise 3

Assumptions:

2 lane highway; 12 ft lanes, 8 ft shoulders

normal crown (2% cross & 2% longitudinal slope)

1000 foot long section of highway

Pipe material will be concrete

The invert elevation of the first pipe will start at 90.00 feet. We will put the pipe on 0.5% slope.

The ground elevation at Station 18+00 (CB1) = 105.00 feet, 20+00 (CB2) = 101.00 feet, and 22+00 (CB3) = 97.0.

Pipe Network Exercise 3

Assumptions (cont.):

Pavement thickness is 1 foot; pipe wall thickness is 2.0 inches

Start with a 12-inch pipe diameter for all pipes in the network

We need to input the last run of pipe which is the outlet pipe. So the last inlet is at 22+00. Let's assume a 20 foot long pipe from this catch basin empties the flow from our pipe network.

Pipe Network Exercise 3

Question: What are the final pipe sizes using the inlet spacing from Exercise 1?

What's next?

Pipe Network Exercise 3

STEPS TO SUCCESS!!!!

1) Input the inlet stations into the storm drain design spreadsheet.
2) Fill out the information in the spreadsheet using the 25-year storm coefficients
3) The storm drain spreadsheet will automatically calculate pipe capacities and velocities as well as pipe cover.
4) If the pipe network has adequate capacity, the velocity in the right range, and has adequate cover, then the design is good.

Culvert Design Exercise 4

STEP BY STEP SOLUTION

Pipe Network Exercise 3

1. Open up WSDOT Storm Drain Design spreadsheet and input project information
2. Input m = 7.83 and n= 0.582 values for "Everett" for SR 2 for 25-year event
3. Enter the design event as 25-year
4. Enter Stations of inlets at 18+00, 20+00, and 22+00. Also enter Station of pipe outlet.
5. Area for first run needs to take into account the area from start of the run Station 12+00 to Station 18+00 (600 feet). The pavement width = 20 feet. Area = 600 x 20 / 43560 = 0.28 acres

Pipe Network Exercise 3

6. C = 0.95 (pavement) – See HM 2-5.2 for C adjustment for 25-year event; C = 0.9 + (0.9x0.1) = 0.99; max = 0.95 so use 0.95
7. Tc = 5 (minimum and typical for pavement)
8. Contributing flow = 0 (only applicable if flow in from a lateral)
9. Pipe Diameter = 12 inches (12 inches diameter is the minimum unless it's a lateral that is less than 50 feet long, it can be 8 inches in diameter). See HM 6-2

Pipe Network Exercise 3

10. Pick a Manning's roughness coefficient for the pipe material; assume that a concrete pipe will be installed; n = 0.011 per HM Appendix 4-1.
11. Input pipe length = 200 feet
12. Upstream pipe invert elevation = 90.00
13. Downstream pipe invert elevation = 90.00 – 0.005*200 = 89.00 feet.
14. Upstream Ground Elevation (CB1) = 105.00
15. Downstream Ground Elevation (CB2) = 105 – 0.02*200 = 101.00

Pipe Network Exercise 3

16. The Storm Drain spreadsheet will calculate the grey cells and do a velocity check, pipe capacity check, and pipe cover check.
17. If everything shows the design is OK, move on to the next pipe run

Pipe Network Exercise 3

4	Project Name: SR 002 Storm Sewer System near Everett; Run for the 25 year storm										
5											
6											
7	m =	7.83	n =	0.582		Design Storm Event =		25			
8											
9	Location										
10	Drain Located On	From Sta.	To Sta.	Source of Drainage	Drainage Area A (acre)	Runoff Coeff. C	CA (acre)	Sum CA (acre)	T_c Across Area (minutes)	Total Tc = Col. 8a + Tc across pipe length (minutes)	Rainfall Intensity (in/hr)	Runoff (cfs)
11	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*8a*	*9*	*10*	*11*
12	EB	18+00	20+00	highway	0.28	0.95	0.27	0.27	5.00	5.00	3.07	0.82
13												
14												
15												

Pipe Network Exercise 3

Row											
7		Pavement thickness (ft) =			1.00			Pipe Thickness (inches) =		2.00	
8											
9			Discharge Drain Design								
10	Contrib. Inflow (cfs)	Total Flow (cfs)	Pipe Dia. (in)	Manning roughness coefficient "n"	Pipe Slope (ft/ft)	Velocity Of Flow (ft/s)	Pipe Capacity (cfs)	Pipe Velocity Check (Desirable Minimum 3 ft/sec; Desirable Maximum 10 ft/sec for Column 16)	Pipe Capacity Check (Column 13 vs. Column 17)	Pipe Length*** (ft)	Elevation Change (ft)
11	*12*	*13*	*14*	*14a*	*15*	*16*	*17*	*17a*	*17b*	*18*	*19*
12	0.00	0.82	12	0.011	0.005	3.79	2.97	VELOCITY OK	ADEQUATE PIPE CAPACITY	200.00	1.00
13											
14											
15											

Pipe Network Exercise 3

	Drain Profile			
10	Upstr. Invert Elev. (ft)	Downstr. Invert Elev. (ft)	Upstr. Ground Elev. (ft)	Downstr. Ground Elev. (ft)
11	*20*	*21*	*22*	*23*
12	90.00	89.00	105.00	101.00
13				
14				
15				

Pipe Network Exercise 3

9				
10	**Upstr. Pipe Cover (ft)**	**Downstr. Pipe Cover (ft)**	**Upstr. Pipe Cover Check (ft)**	**Downstr. Pipe Cover Check (ft)**
11	*24*	*25*	*26*	*27*
12	[illegible]	[illegible]	[illegible]	[illegible]
13	[illegible]		[illegible]	
14			[illegible]	
15				

Pipe Network Exercise 3

16. Input next run of pipe
17. Area for next run of pipe is from Station 20+00 to Station 22+00 (200 feet). The pavement width = 20 feet. Area = 200 x 20 / 43560 = 0.09 acres

Pipe Network Exercise 3

20. C = 0.95 (pavement)
21. Tc = 5 (minimum and typical for pavement)
22. Contributing flow = 0 (only applicable if flow in from a lateral)
23. Pipe Diameter = 12 inches
24. Pick a Manning's roughness coefficient n = 0.011
25. Input pipe length = 200 feet
26. Input pipe invert elevation. This is likely the same elevation as the downstream invert elevation from the previous pipe run = 89.00 feet

Pipe Network Exercise 3

27. Downstream invert elevation = 89.00 – 0.005*200 = 88.00 feet.
28. Upstream Ground Elevation (CB2) = 101.00
29. Downstream Ground Elevation (CB3) = 97.0
30. The Storm Drain spreadsheet will calculate the grey cells and do a velocity check, pipe capacity check, and pipe cover check.

Pipe Network Exercise 3

4	Project Name:	SR 002 Storm Sewer System near Everett; Run for the 25 year storm										
5												
6												
7	m =	7.83	n =	0.582		Design Storm Event =			25			
8												
9	Location											
10	Drain Located On	From Sta.	To Sta.	Source of Drainage	Drainage Area A (acre)	Runoff Coeff. C	CA (acre)	Sum CA (acre)	T_c Across Area (minutes)	Total Tc = Col. 8a + Tc across pipe length (minutes)	Rainfall Intensity (in/hr)	Runoff (cfs)
11	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*8a*	*9*	*10*	*11*
12	EB	18+00	20+00	highway	0.28	0.95	0.27	0.27	5.00	5.00	3.07	0.82
13	EB	20+00	22+00	highway	0.09	0.95	0.09	0.35	5.00	5.90	2.79	0.99
14												
15												

Pipe Network Exercise 3

Pavement thickness (ft) = 1.00

Pipe Thickness (inches) = 2.00

Row	Contrib. Inflow (cfs)	Total Flow (cfs)	Pipe Dia. (in)	Manning roughness coefficient "n"	Pipe Slope (ft/ft)	Velocity Of Flow (ft/s)	Pipe Capacity (cfs)	Pipe Velocity Check (Desirable Minimum 3 ft/sec; Desirable Maximum 10 ft/sec for Column 16)	Pipe Capacity Check (Column 13 vs. Column 17)	Pipe Length*** (ft)	Elevation Change (ft)
9			Discharge Drain Design								
10	Contrib. Inflow (cfs)	Total Flow (cfs)	Pipe Dia. (in)	Manning roughness coefficient "n"	Pipe Slope (ft/ft)	Velocity Of Flow (ft/s)	Pipe Capacity (cfs)	Pipe Velocity Check (Desirable Minimum 3 ft/sec; Desirable Maximum 10 ft/sec for Column 16)	Pipe Capacity Check (Column 13 vs. Column 17)	Pipe Length*** (ft)	Elevation Change (ft)
11	*12*	*13*	*14*	*14a*	*15*	*16*	*17*	*17a*	*17b*	*18*	*19*
12	0.00	0.82	12	0.011	0.005	3.79	2.97	VELOCITY OK	ADEQUATE PIPE CAPACITY	200.00	1.00
13	0.00	0.99	12	0.011	0.005	3.79	2.97	VELOCITY OK	ADEQUATE PIPE CAPACITY	200.00	1.00
14											
15											

Pipe Network Exercise 3

	Drain Profile			
10	Upstr. Invert Elev. (ft)	Downstr. Invert Elev. (ft)	Upstr. Ground Elev. (ft)	Downstr. Ground Elev. (ft)
11	*20*	*21*	*22*	*23*
12	90.00	89.00	105.00	101.00
13	89.00	88.00	101.00	97.00
14				
15				

Pipe Network Exercise 3

9				
10	**Upstr. Pipe Cover (ft)**	**Downstr. Pipe Cover (ft)**	**Upstr. Pipe Cover Check (ft)**	**Downstr. Pipe Cover Check (ft)**
11	*24*	*25*	*26*	*27*
12	12.83	9.83	More than 2 ft of cover	More than 2 ft of cover
13	[illegible]		[illegible]	
14			[illegible]	
15				

Pipe Network Exercise 3

31. We need to input the last run of pipe which is the outlet pipe. So the last inlet is at 22+00. Let's assume a 20 foot long pipe from this catch basin empties the flow from our pipe network.
32. Area for next run of pipe is from Station 22+00 to Station 22+20 (20 feet). The pavement width = 20 feet. Area = 200 x 20 / 43560 = 0.09 acres
33. C = 0.95 (pavement)
34. Tc = 5 (minimum and typical for pavement)

Pipe Network Exercise 3

35. Contributing flow = 0 (only applicable if flow in from a lateral)
36. Pipe Diameter = 12 inches
37. Pick a Manning's roughness coefficient n = 0.011
38. Input pipe length = 20 feet
39. Input pipe invert elevation. This is likely the same elevation as the downstream invert elevation from the previous pipe run = 88.00 feet
40. Downstream invert elevation = 88.00 – 0.005*20 = 87.90 feet.

Pipe Network Exercise 3

41. Upstream Ground Elevation (CB3) = 97.0
42. Downstream Ground Elevation (outlet) = 97 – (0.02*20) = 96.60
43. The Storm Drain spreadsheet will calculate the grey cells and do a velocity check, pipe capacity check, and pipe cover check.
44. If everything shows the design is OK, then we are done

Pipe Network Exercise 3

Project Name: SR 002 Storm Sewer System near Everett; Run for the 25 year storm

m =	7.83	**n =**	0.582	**Design Storm Event =**	25

Location											
Drain Located On	From Sta.	To Sta.	Source of Drainage	Drainage Area A (acre)	Runoff Coeff. C	CA (acre)	Sum CA (acre)	T_c Across Area (minutes)	Total Tc = Col. 8a + Tc across pipe length (minutes)	Rainfall Intensity (in/hr)	Runoff (cfs)
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*8a*	*9*	*10*	*11*
EB	18+00	20+00	highway	0.28	0.95	0.27	0.27	5.00	5.00	3.07	0.82
EB	20+00	22+00	highway	0.09	0.95	0.09	0.35	5.00	5.90	2.79	0.99
EB	22+00	outlet	highway	0.09	0.95	0.09	0.44	5.00	6.80	2.57	1.13

Pipe Network Exercise 3

7		Pavement thickness (ft) =			1.00		Pipe Thickness (inches) =			2.00	
8											
9			Discharge Drain Design								
10	Contrib. Inflow (cfs)	Total Flow (cfs)	Pipe Dia. (in)	Manning roughness coefficient "n"	Pipe Slope (ft/ft)	Velocity Of Flow (ft/s)	Pipe Capacity (cfs)	Pipe Velocity Check (Desirable Minimum 3 ft/sec; Desirable Maximum 10 ft/sec for Column 16)	Pipe Capacity Check (Column 13 vs. Column 17)	Pipe Length*** (ft)	Elevation Change (ft)
11	*12*	*13*	*14*	*14a*	*15*	*16*	*17*	*17a*	*17b*	*18*	*19*
12	0.00	0.82	12	0.011	0.005	3.79	2.97	VELOCITY OK	ADEQUATE PIPE CAPACITY	200.00	1.00
13	0.00	0.99	12	0.011	0.005	3.79	2.97	VELOCITY OK	ADEQUATE PIPE CAPACITY	200.00	1.00
14	0.00	1.13	12	0.011	0.005	3.79	2.97	VELOCITY OK	ADEQUATE PIPE CAPACITY	200.00	0.10
15											

Pipe Network Exercise 3

9	Drain Profile			
10	Upstr. Invert Elev. (ft)	Downstr. Invert Elev. (ft)	Upstr. Ground Elev. (ft)	Downstr. Ground Elev. (ft)
11	*20*	*21*	*22*	*23*
12	90.00	89.00	105.00	101.00
13	89.00	88.00	101.00	97.00
14	88.00	87.90	97.00	96.60
15				

Pipe Network Exercise 3

9				
10	**Upstr. Pipe Cover (ft)**	**Downstr. Pipe Cover (ft)**	**Upstr. Pipe Cover Check (ft)**	**Downstr. Pipe Cover Check (ft)**
11	*24*	*25*	*26*	*27*
12	12.83	9.83	More than 2 ft of cover	More than 2 ft of cover
13	9.83	6.83	More than 2 ft of cover	More than 2 ft of cover
14				
15				

Pipe Network Exercise 3

OPTIMIZED ANSWER = Three inlets (CBs) and two 12 inch diameter concrete pipes can handle the flows; start the first CB at Station 18+00 and use 200 foot spacings; CB1 = 18+00, CB2 = 20+00, and CB3 =22+00. There is a 20 foot outlet pipe from CB3 to that daylights to the side slope.

Design meets the capacity, velocity, and pipe cover checks for the 25 year event.

Next step would be to design outlet protection for flow velocity leaving the pipe network (3.8 ft/sec)