City of Springfield

Drainage Criteria Manual

Streets, Inlets and Storm Drains

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Overview

- Street Drainage
- Inlets
- Storm Drains
- Examples

1.2 Design Storms

- System begins where 2-year exceeds 5 cfs
  - Approximately 2.0 acres ¼ acre residential
  - Approximately 1.2 acres commercial (80%) impervious
- 2-year assuming fully developed conditions

1.2 Cont'd

- 25-year HGL cannot exceed the gutter elevation for enclosed systems
- 25-year requires 0.5 ft. freeboard above HGL for open channel systems
- 100-year must meet street inundation requirements
- All runoff must be directed to the detention facilities or to the drainage system

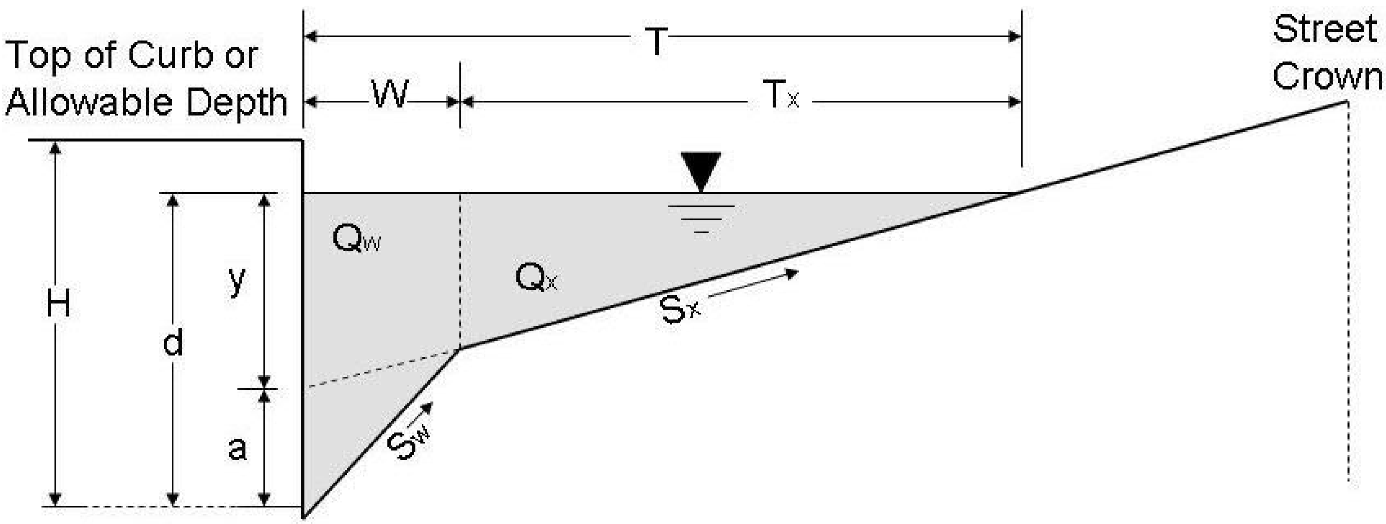
1.2 Cont'd

- The effects of detention basins on adjacent properties may be accounted for if assurances that detention will be provided for perpetuity are provided and maintenance is assured.
- Assurances must typically be provided through recorded documents with land use restrictions and maintenance responsibilities properly noted

Table ST-1
City of Springfield Street Inundation Criteria

Street Classification	Minor Storm (2-year)	Major Storm (100-year)
Local	• No flow from one side of street to another • No curb overtopping • Inlets spaced for a maximum spread of 8 feet from curb face with one clear 10-foot travel lane	• No curb overtopping
Collector	• No flow from one side of street to another • No curb overtopping • Inlets spaced for a maximum spread of 8 feet from curb face with one 12-foot travel lane clear for non-residential collectors, and two 10-foot travel lanes clear for non-residential collectors	• No curb overtopping
Arterial	• No flow from one side of street to another • No curb overtopping • For secondary arterials, inlets spaced for a maximum 12-foot spread with two 12-foot travel lanes open. • For other arterials, inlets spaced for a maximum 6-foot spread with one full lane and one 8-foot lane clear in both directions	• No curb overtopping

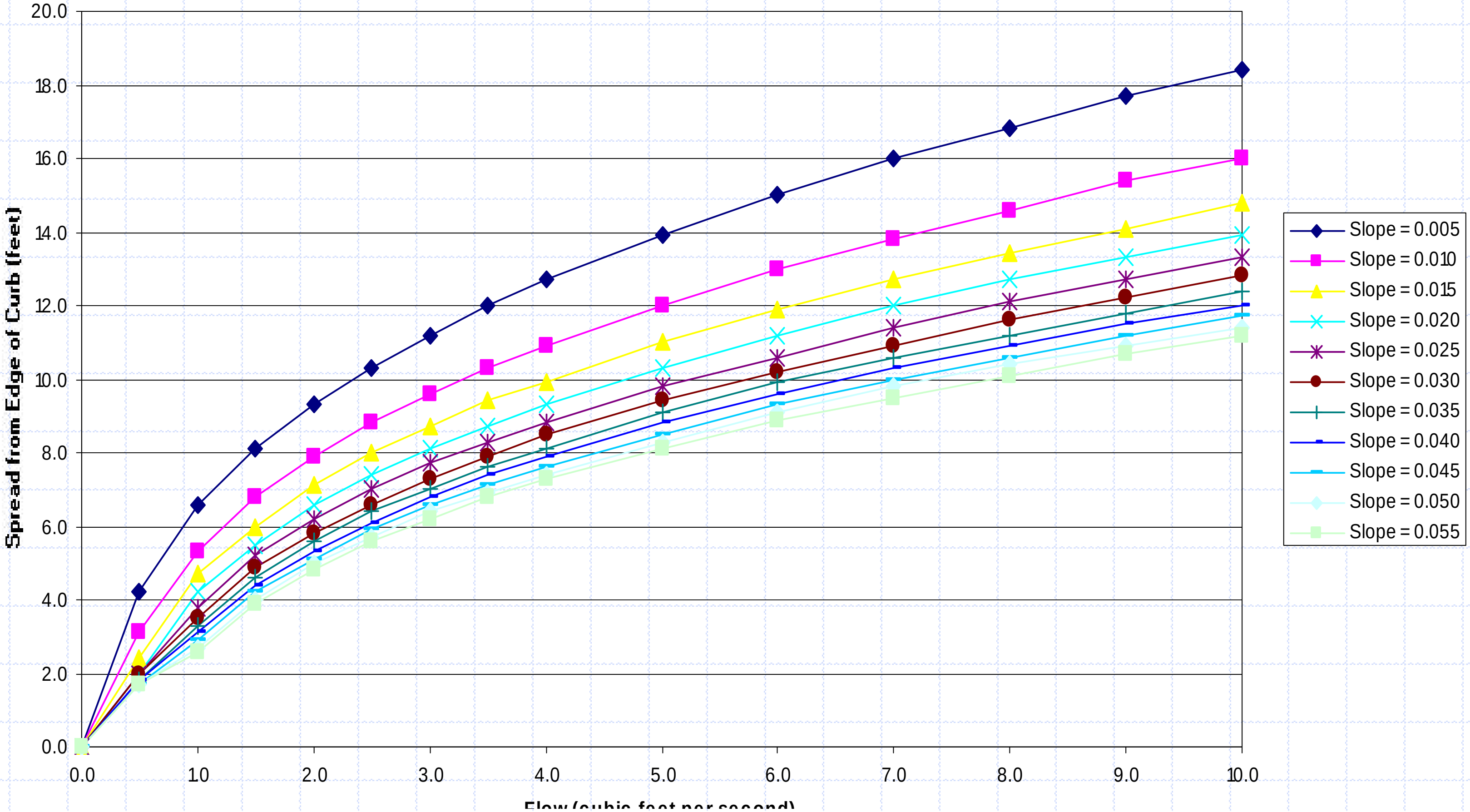
2.2 Curb & Gutter Hydraulics



For Springfield:

S_w = 0.0833 ft/ft, S_x = 0.021 ft/ft, a = 1.5 in

2.2 Spread for Standard Street Section



2.3 Roadside Swales

- Roadside swale sections or other Low Impact Development (LID) designs, will be considered on a case-by-case basis
- A subdivision variance will be required and generally, the developer or property owners' association will be required to maintain all street rights-of-way and LID components
- Alternative designs must adhere to the principles of containing the 100-year flow within the right-of-way or drainage easement and preventing erosion

3.1 Inlets

- Inlets are placed at all low points.
- On grade.
- !! On the upstream side of intersections, median breaks, pedestrian ramps, and crosswalks !!
- Spacing of inlets placed in addition to those required by geometric controls is governed by the allowable inundation criteria

3.1 Inlets cont'd

- SS-5, standard curb opening inlet for 24" or larger storm pipes
- SS-6, standard curb opening inlet for 18" storm pipes
- SS-6-R, recessed curb inlet, opening height > 6", must have horizontal ¾" bar

3.1 Area Inlets

- Open side area inlet may be used off street
- Grated area inlets may be used in parking lots
- Grated area inlets may be used in grass areas with drainage areas less than ¼ acre

3.3.1 Curb Opening Inlets on Grade

- Curb inlets on grade function as a lateral weir and typically only intercept a fraction of the total gutter flow.
- Efficiency drops dramatically on grades greater than 4 percent.
- Bypass flow must be accounted for at downstream structures.
- A clogging factor of 10 percent is to be applied to inlets on grade.

3.3.2 Inlets in Sumps

- Grated inlets clogging factor of 50 percent.
- Curb opening inlets clogging factor of 10 percent.
- Function as a weir for depths less than 1.4 times the opening height.
- Function as an orifice for depths greater than 1.4 times the opening height.

4.0 Storm Drain Systems

- Horizontal alignment
  - Behind the curb, street crossing minimized.
  - Bends at junction boxes only.
  - Storm sewers outside of right-of-way must be located in a drainage easement.
  - Minimum clearance between storm sewers and sanitary sewers or water lines is 10 ft.

Easement Requirements

Table ST-3
Minimum Easement Widths Required for Storm Drains

Inside Horizontal Dimension (inches)	Minimum Easement Width (ft)
12 – 18	10
21 – 36	15
42 – 72	20
Larger	To be determined

Additional width may be required based on depth or other site specific conditions.

4.1.2 Vertical Alignment

- Minimum velocity = 2 ft/sec
- Maximum velocity = 15 ft/sec
  - Check velocities reported by programs.
  - Some report velocity based on the design flow assuming pipe full flow.
  - Some report average velocities.
  - May need to generate custom report for submittal.

Velocity Issues

- Example:
  - Pipe diameter 30 inches
  - Discharge 37 cfs
  - Slope 10.44 %
    - Program reported average velocity = 7.5 ft/s
    - Velocity based on normal depth = 20.8 ft/s

4.1.2 Cont’d

- Minimum vertical clearance between storm sewers and sanitary sewers or water lines is 18”.
- Minimum cover 12” or manufacturer’s recommendations (Whichever is greater).
- Pipe must support HS-20 loading.
- Drops greater than six ft. require design for structure protection and energy dissipation.

4.1.3 Pipes

- Allowable materials
  - Reinforced concrete
  - Corrugated steel
  - High Density Polyethylene
- Reinforced concrete required under the street or within 2 ft. of the curb.
- Minimum diameter 15".
- Minimum slope 0.5 percent.
- Maximum slope 15 percent (slope anchors required).

4.1.4 Junction Boxes

- Required at all bends, changes in grade, pipe materials or shape.
- Exceptions may be made for diameters greater than 36 inches.
- Bends within 3 ft of a junction box may be used to improve the junction.
- Bend angles may not exceed 60 degrees for pipes 24 inches or less in diameter or 30 degrees for pipes larger than 24 inches.
- Distance between access points shall not exceed 300 ft.

4.1.5 Bends and Transitions

- Where bends or transitions outside of a junction box are acceptable, bends at joints may not exceed 2 degrees.
- Special structures for transitions may be required.

4.1.6 Outlets

- Primary function to minimize erosion.
- Generally pipe outlets are required to have a riprap pad extending a minimum of five times the pipe diameter beyond the end of the flared end section and with a minimum width of three times the pipe diameter.
- 6” rock is not riprap.

4.1.7 Other Appurtenances

- Flow splitters, deflectors or flap gates require individual consideration and must have prior approval.

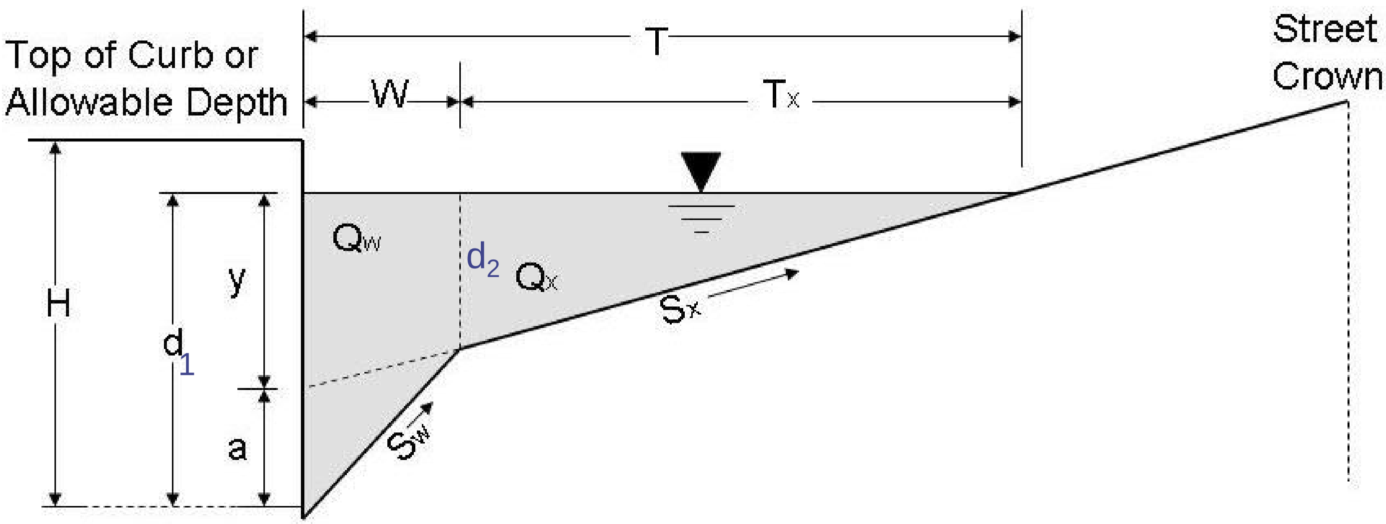
4.1.8 General Safety

- Handrails are required on all headwalls or wingwalls with a drop of 30 inches or more.
- Trash racks shall be provided at all entrances to storm drains.
  - Net open area of trash rack should be five times the open area of the pipe/culvert.
  - Slope trash racks at 3:1 to 5:1 to allow debris to ride up as depth of flow increases.

4.2 Storm Drain Hydraulics

- HGL computations are required for all storm drain designs.
- Head losses must be accounted for in HGL computations:
  - Entrance losses
  - Friction losses
  - Inlet, manhole and junction losses
  - Transition losses
  - Bend losses
  - Exit losses

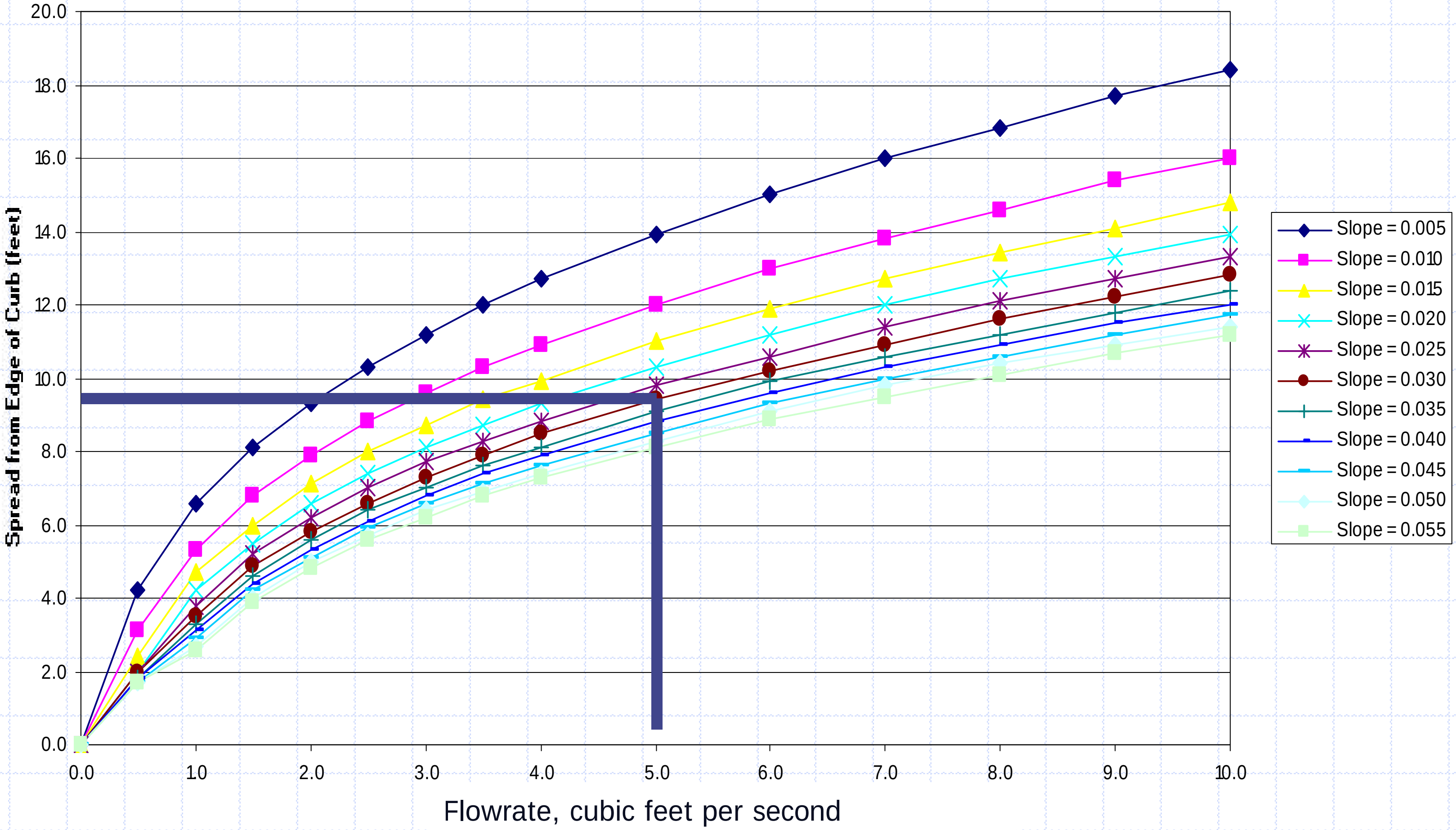
2.2 Curb & Gutter Hydraulics



For Springfield:

$S_w = 0.0833$ ft/ft, $S_x = 0.021$ ft/ft, $a = 1.5$ in

2.2 Spread for Standard Street Section



Example Problem, 7' curb inlet on 27' standard cross section street on a longitudinal grade of 3%.
Find the top width, intercepted flow and bypass flow for a discharge of 5 cfs

Knowns

$n := .016$ $S_L := .03$ $a := 1.5$ $L := 7$

$S_x := 0.021$ $S_w := 0.0833$ $w := 2$

$$d_1 := .32170 \qquad d_2 := d_1 - \frac{a}{12} - w \cdot S_x \qquad d_2 = 0.155$$

Target flow rate $Q_t := 5$

Street Flow $$Q_s := 0.56 \cdot \frac{S_L^{\,0.5}}{n} \cdot \frac{\left(d_2^{\,2.67}\right)}{\left(S_x\right)} \qquad Q_s = 1.979$$

Gutter Flow $$Q_w := 0.56 \cdot \frac{S_L^{\,0.5}}{n} \cdot \frac{\left[\left(d_1\right)^{2.67} - d_2^{\,2.67}\right]}{\left(S_w\right)} \qquad Q_w = 3.024$$

Total Flow $$Q := Q_s + Q_w \qquad Q = 5.00$$

Top Width $$T := \frac{\left(d_1 - \frac{a}{12}\right)}{S_x} \qquad T = 9.367$$

Equivalent cross slope

$$E_o := 1 - \left(\frac{Q_s}{Q}\right)$$

$$E_o = 0.604$$

$$S_e := S_x + \frac{a}{24} \cdot E_o$$

$$S_e = 0.059$$

Length required for total interception

$$L_t := 0.6 \cdot Q^{0.42} \cdot S_L^{0.3} \cdot \left(\frac{1}{n \cdot S_e} \right)^{0.6}$$

$$L_t = 26.973$$

Inlet Efficiency

$$E := 1 - \left(1 - \frac{L}{L_t}\right)^{1.8} \qquad E = 0.418$$

$$clog := .1 \qquad E := E - clog \qquad E = 0.318$$

Intercepted and bypass flow

$$Q_i := Q \cdot E \qquad Q_i = 1.589$$

$$Q_b := Q - Q_i \qquad Q_b = 3.413$$

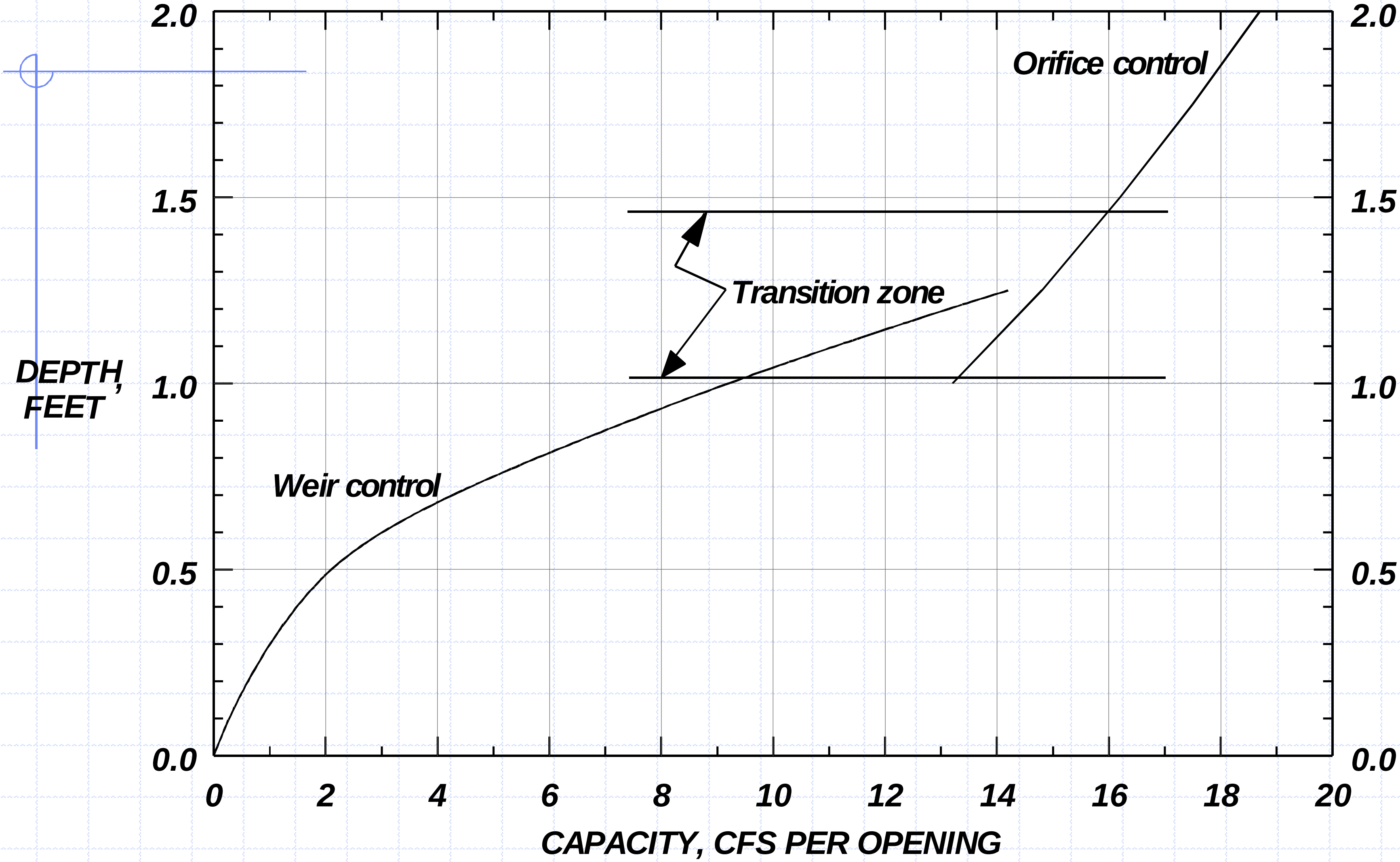
Length,ft	Intercepted	Bypass	Efficiency*	Distance between inlets
7	1.6	3.4	31.2	95
14	3.2	1.8	63.2	190
21	4.2	0.8	83.4	250

*Interception reduced by 10% for clogging

Table ST-2
Sump Inlet Discharge Variables and Coefficients
(Modified from Akan and Houghtalen 2002)

Weir Inlet Types	C_w	L_w [1]	Weir Equation Valid For	Definition of Terms
Curb opening inlet (SS-5, SS-6)	3.00	L	$d < h$	L = Length of curb opening h = Height of curb opening $h = d_i - (h/2)$ d_i = Depth of water at curb opening
Recessed curb opening inlet (SS-6-R)[2]	2.30	$L + 1.8W$	$d < h + a$	W = Lateral width of recessed section a = Depth of curb depression
Vane Grate Inlet	3.00	$L + 2W$	$d < 1.79(A_o/L_w)$	A_o = Clear opening area W = Width of grate
Orifice Inlet Types	C_o	A_o [3]	**Orifice Equation Valid For**	**Definition of Terms**
Curb opening inlet (SS-5, SS-6) or recessed curb opening inlet (SS-6-R)[2]	0.67	hL	$d_i > 1.4h$	d_i = Depth of water at curb opening $d = d_i - (h/2)$ h = Height of curb opening
Vane Grate Inlet	0.67	Clear opening area	$d > 1.79(A_o/L_w)$	d = Depth of water over grate A_o = Clear opening area

[1] The weir length (L_w) should be reduced where clogging is expected.
[2] If L > 12 feet, use the expressions for curb opening inlets that are not recessed.
[3] The orifice area (A_o) should be reduced where clogging is expected.



2.0
1.5
1.0
0.5
0.0
DEPTH, FEET
Orifice control
Transition zone
Weir control
0
2
4
6
8
10
12
14
16
18
20
CAPACITY, CFS PER OPENING

HGL and EGL

For open channel flow:

$$z_1 + d_1 + \frac{V_1^2}{2g} = z_2 + d_2 + \frac{V_2^2}{2g} + h_L$$

For pressure flow:

$$z_1 + \frac{p_1}{\gamma} + \frac{V_1^2}{2g} = z_2 + \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + h_L$$

HGL and EGL

For open channel flow:

$$z_1 + d_1 + \frac{V_1^2}{2g} = z_2 + d_2 + \frac{V_2^2}{2g} + h_L$$

For pressure flow:

$$z_1 + \frac{p_1}{\gamma} + \frac{V_1^2}{2g} = z_2 + \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + h_L$$

Headloss Components

- Entrance losses
- Friction losses
- Junction losses
- Bend Contraction/Expansion losses
- Exit losses

Losses are computed as:

Entrance Loss

$$H_e = K_e\left(\frac{V^2}{2g}\right)$$

Friction Loss

$$H_f = S_f L$$

Where:

$$S_f = \frac{V^2 n^2}{2.22 R_h^{\frac{4}{3}}}$$

Exit Loss

$$H_x = K_x\left(\frac{V^2 - V_2^2}{2g}\right)$$

Losses, cont'd

Junction Losses

$$H_j = K\left(\frac{V_0^2}{2g}\right)$$

$$K = K_o C_D C_d C_Q C_p C_B$$

Where:

K = adjusted loss coefficient

K_o = initial head loss coefficient based on relative size

C_D = correction factor for pipe diameter

C_d = correction factor for flow depth

C_Q = correction factor for relative flow

C_p = correction factor for plunging flow

C_B = correction factor for benching

V_o = velocity of exit pipe

Contraction/Expansion Losses

Contraction Loss $$H_c = K_c\left(\frac{V_2^2 - V_1^2}{2g}\right)$$

Expansion Loss $$H_e = K_e\left(\frac{V_1^2 - V_2^2}{2g}\right)$$

Where:

- K_e = expansion coefficient
- K_c = contraction coefficient
- V_1 = upstream velocity
- V_2 = downstream velocity
- g = acceleration due to gravity

Bend losses

$$H_b = 0.0033\Delta\left(\frac{V^2}{2g}\right)$$

Where: Δ = deflection in degrees

Profile: 18th Street

2 yr event

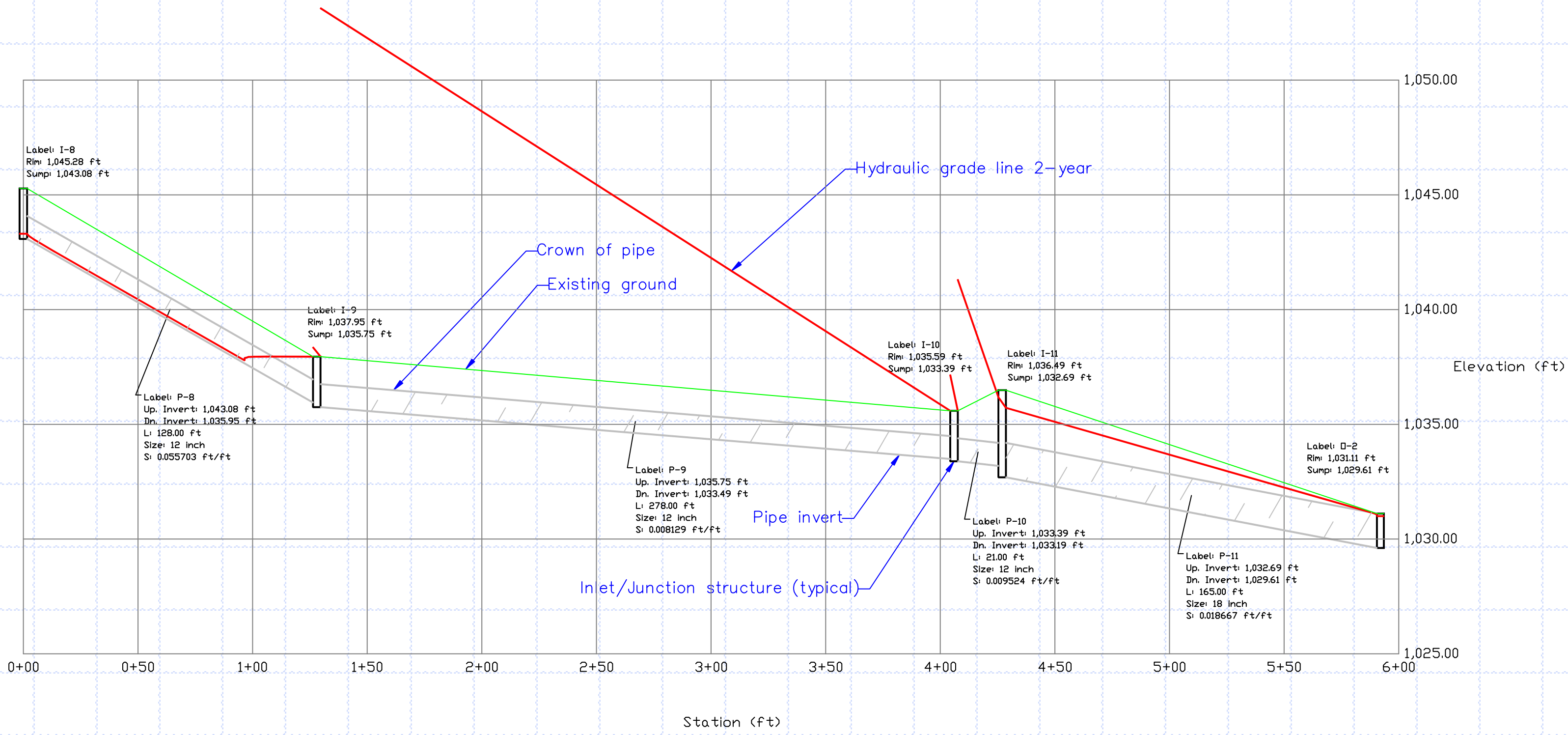
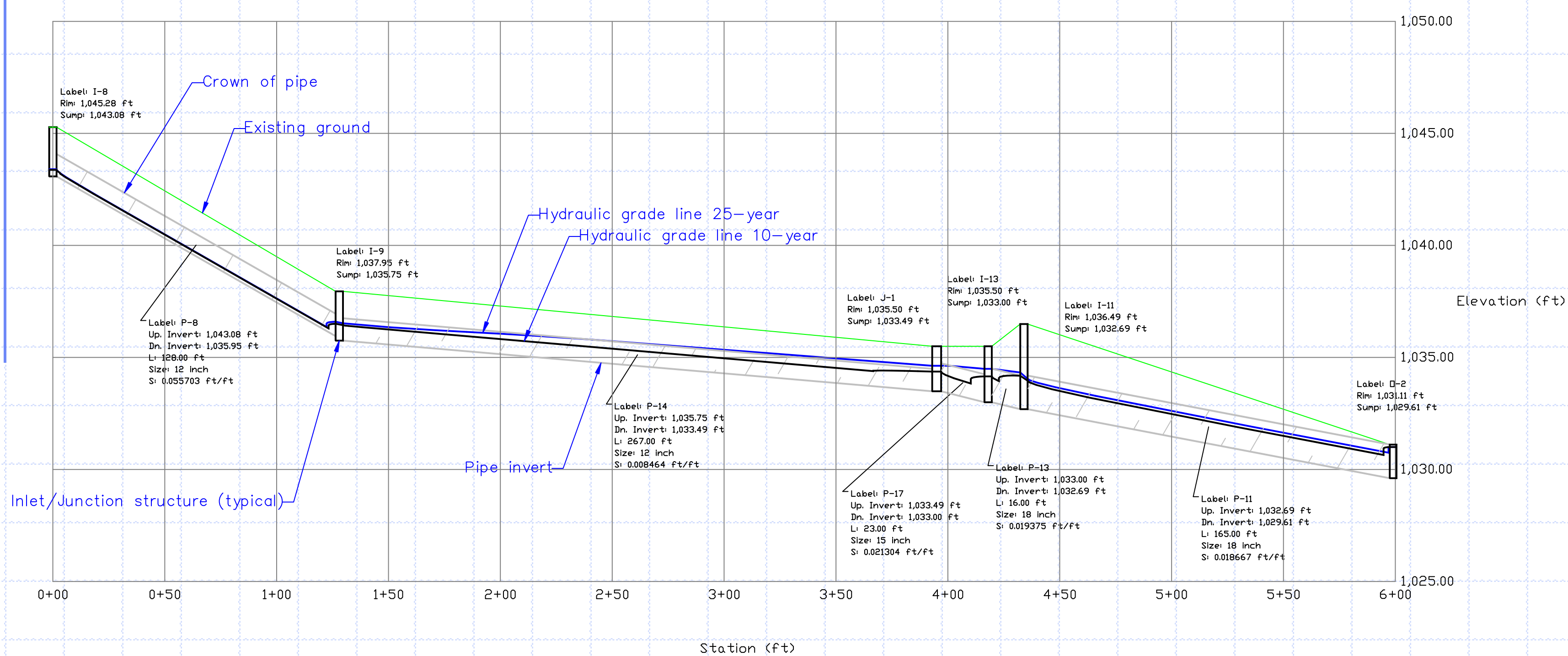


Table of Results

Profile: 18th Street

Scenario: Proposed



[Table of Results](#)

Questions?