



# Regulatory Review Webinar Series

## Lesson 2 Hydraulics, Part 1

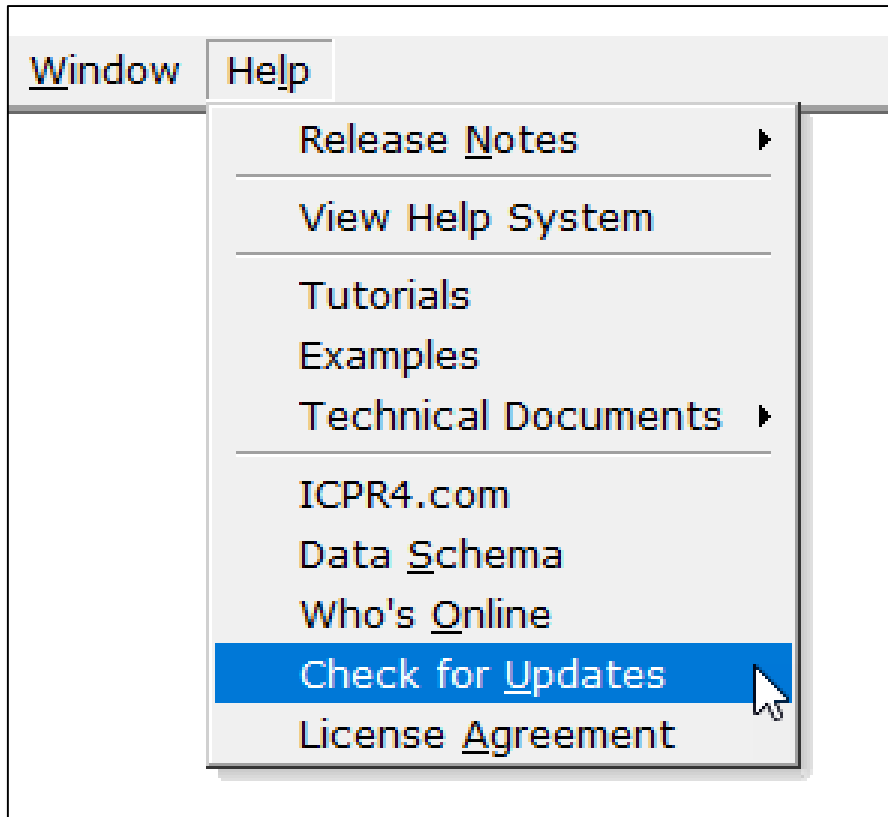
Peter J. Singhofen  
Streamline Technologies, Inc.

Wednesday – October 23, 2019

# Next Webinar – Lesson 3: Hydraulics, Part 2

Tuesday October 29, 2019

11:30 – 1:30 (EDT)



We will try to post a recording of this webinar and/or the presentation material as soon as we can.

To find them:

*“Check for Updates”*  
sometime tomorrow.

[support@icpr4.com](mailto:support@icpr4.com)

# Objectives of the Regulatory Review Webinar Series

- Learn details of ICPR4 computational methods
- Learn about input data requirements
- Learn about ICPR4's reporting system

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- Learn details of ICPR4 computational methods
- Learn about input data requirements
- Learn about ICPR4's reporting system

## What's not included:

- 2D overland flow
- 2D groundwater
- Details of the graphical user interface
- Importing/drawing background images, map layers and surfaces

# Lesson 2 Topics

- Nodes
  - Mass Balance Equation
  - Node Types
- Links
  - General
  - Pipes
  - Channels
- Examples
  - Highway Cross Drain & Channel
  - Integrated Storm Sewer Hydraulics and Pond Routing for a Commercial Site

# Nodes

## Mass Balance Equation

$$dz = dt (Q_{in} - Q_{out}) / A_{surface}$$

where,

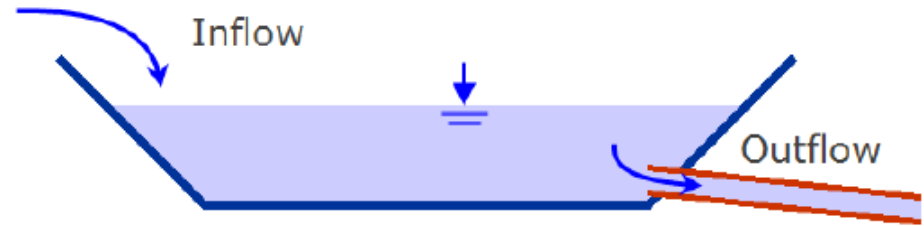
$dz$  change in stage

$dt$  change in time, or simply, the time increment

$Q_{in}$  combined or total inflow rate

$Q_{out}$  combined or total outflow rate

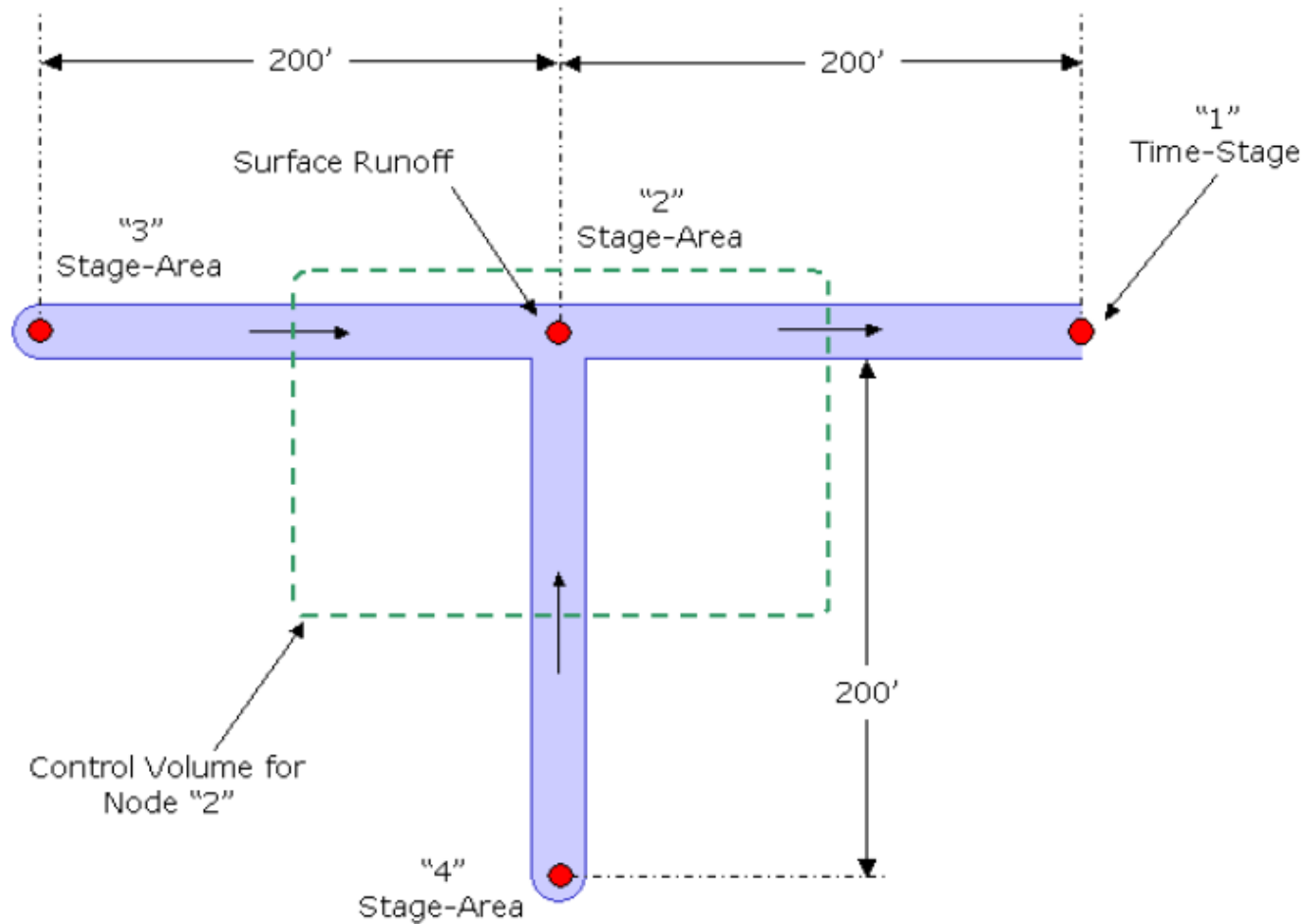
$A_{surface}$  surface area associated with the node



$$Z^1 = Z^0 + dz$$

# Nodes

## Mass Balance Equation



# Nodes

## Mass Balance Equation

$$dz = dt (Q_{in} - Q_{out}) / A_{surface}$$

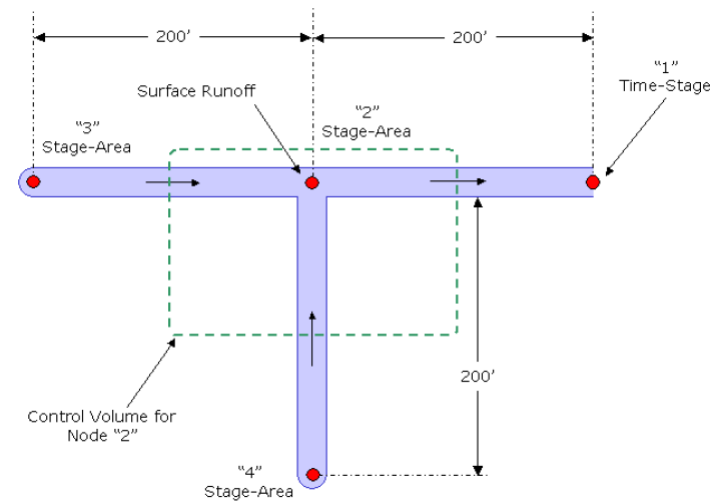
$$= dt (Q_{runoff} + Q_{3-2} + Q_{4-2} - Q_{2-1}) / A_{surface}$$

$$A_{3-2} = 0.5 \times (T^{ds}_{3-2} + T^{mid}_{3-2}) \times (200' / 2)$$

$$A_{4-2} = 0.5 \times (T^{ds}_{4-2} + T^{mid}_{4-2}) \times (200' / 2)$$

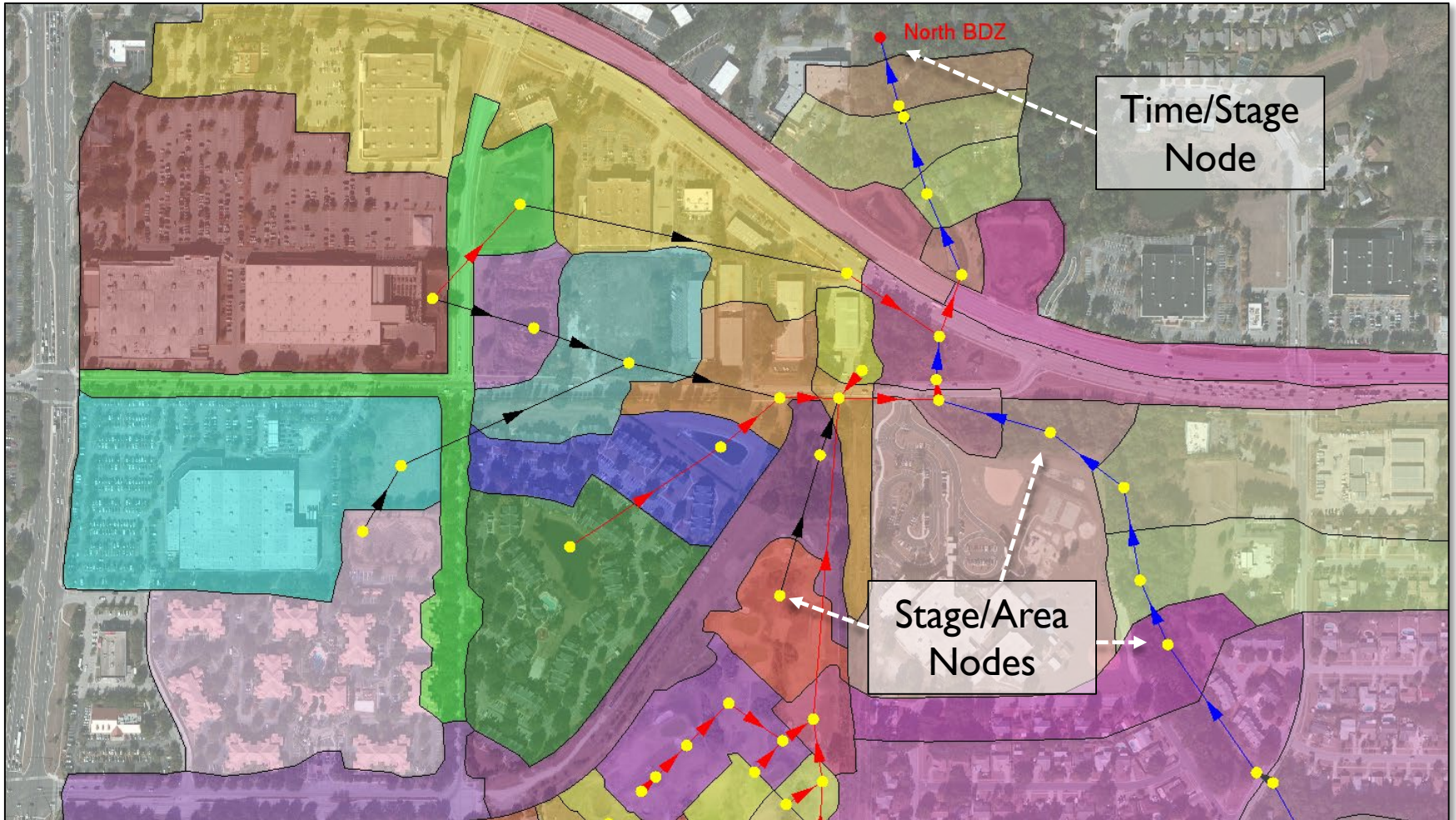
$$A_{2-1} = 0.5 \times (T^{us}_{2-1} + T^{mid}_{2-1}) \times (200' / 2)$$

$$A_{surface} = A_{3-2} + A_{4-2} + A_{2-1}$$





# Nodes



# Nodes

## Time/Stage Nodes

Time/Stage nodes serve as outlets for the surface water system. Instead of calculating stage from the mass balance equation, stage is forced from a time versus stage table.

The screenshot shows the 'Node Data Form' for a node named 'North BDZ'. The 'Type' is set to 'Time/Stage'. The 'Initial Stage' is 40, and the 'Boundary Stage' is 'North BDZ'. A table titled 'Node Point Edit' is shown, with columns for Year, Month, Day, Hour, and Stage. Red boxes highlight the 'Type' and 'Boundary Stage' fields. Red arrows point from the 'Initial Stage' and 'Boundary Stage' fields to explanatory text.

If time/stage table is left blank, the *Initial Stage* is used throughout the simulation ...

... unless a *Boundary Stage* table is specified.

## Node Data Form

# Nodes

## Boundary Stage Tables

Mapping Tables Scenarios Hydrology 1D Hydraulics

Boundary Stage Sets...  
External Hydrograph Sets...  
Roughness Sets...  
Rainfall Excess Methods  
Impervious...

CSV Imp...  
CSV Exp...

Boundary Stage Set Data

Menu ▾ [Icons]

Boundary Stage Set List

Name
010-24
025-24
050-24
▶ 100-24
010-03
MEAN_ANNUAL_24
Base Run

Name: 100-24

Comment: A boundary stage “set” is a collection of time/stage tables. A “set” is typically provided for each storm to be simulated.

“Set” Names

“Set” Tab

Create Clone Delete

Set Boundary Stage

Enter 'Name' 7 Boundary

# Nodes

## Boundary Stage Tables

Boundary Stage List

- Boundary Stage Set: 100-24
  - Lake Lotus
  - North BDZ

Boundary Stage Point Edit

Year	Month	Day	Hour	Stage
0	0	0	6.0002	54.3669
0	0	0	6.0834	54.3757
0	0	0	6.1668	54.3848
0	0	0	6.2504	54.3941
0	0	0	6.3334	54.4036
0	0	0	6.4167	54.4134
0	0	0	6.5001	54.4236
0	0	0	6.5834	54.434
0	0	0	6.6668	54.4448
0	0	0	6.7501	54.4558

7 Boundary Stage Set(s)

Boundary Stage Table Names

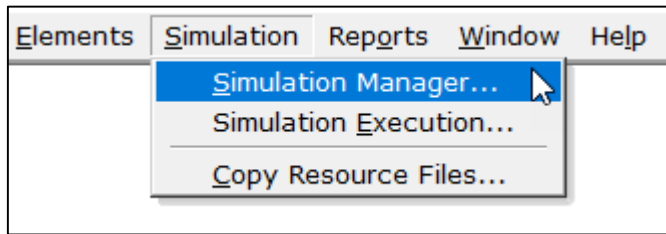
The table names are specified on the Time/Stage node data form

“Boundary Stage” Tab

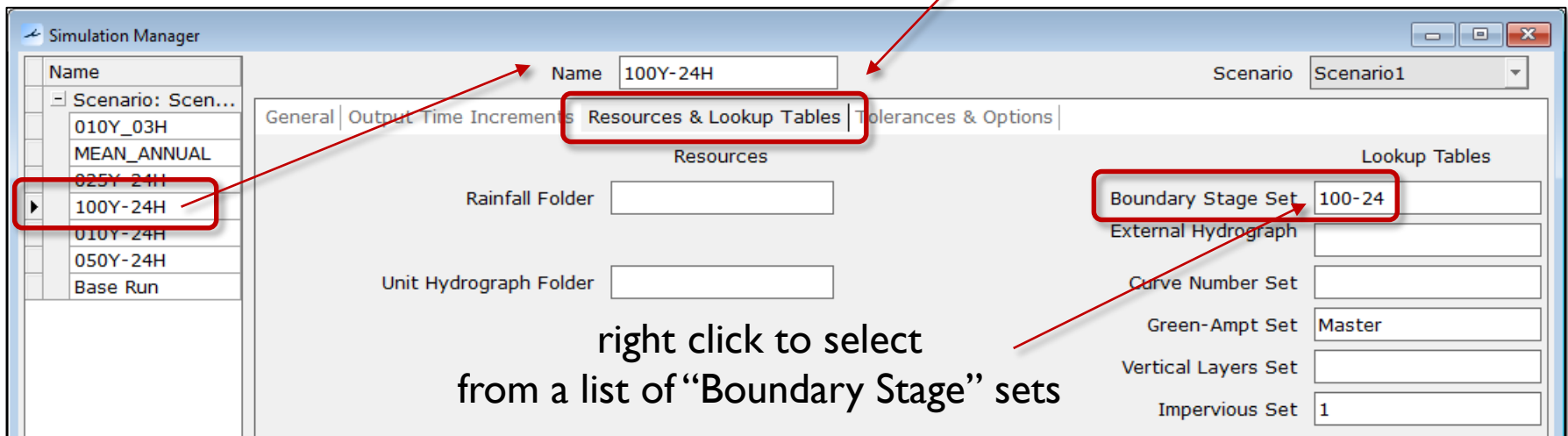
Time/Stage data obtained from a larger watershed model

# Nodes

## Boundary Stage Tables



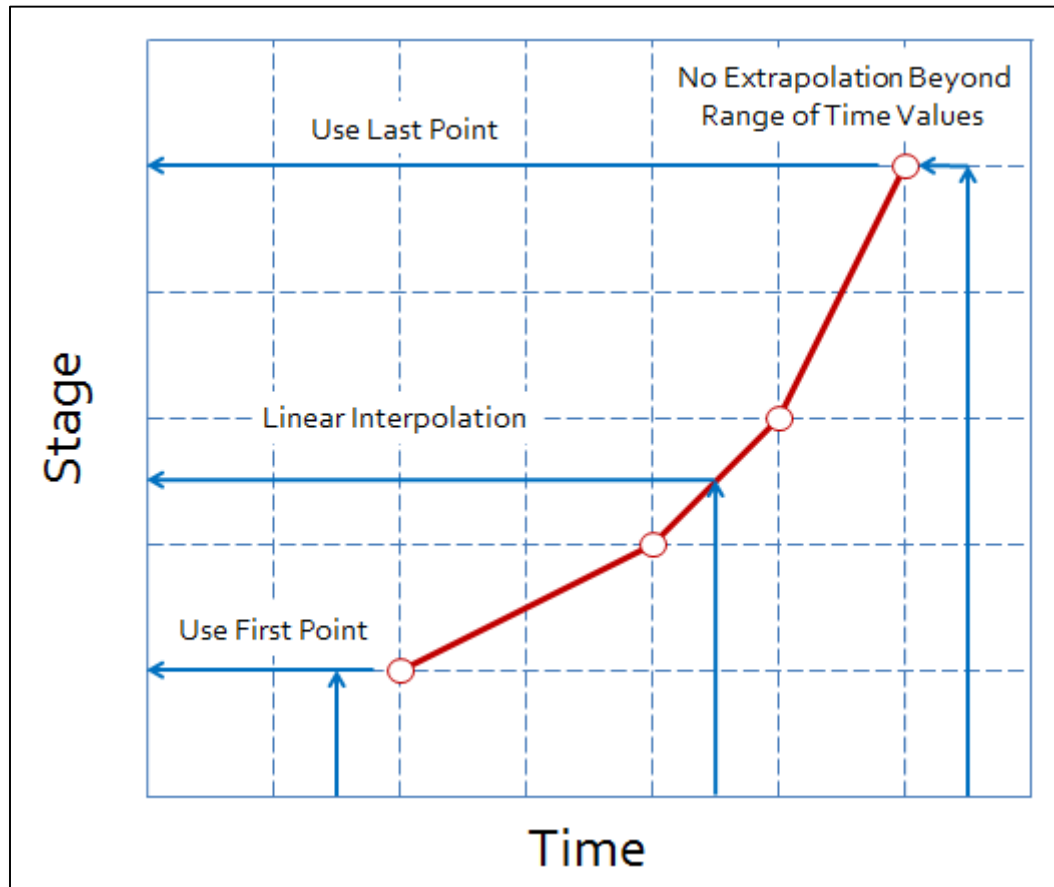
Simulation Manager  
“Resources & Lookup Tables” Tab



right click to select  
from a list of “Boundary Stage” sets

# Nodes

## Time/Stage Table Interpolation



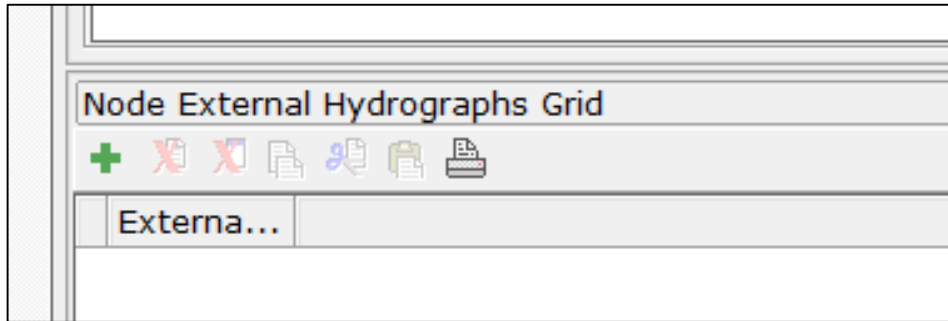
# Nodes

## Time/Stage Precedence

- The initial stage on the node data form is used for the entire simulation if a time/stage table is not provided.
- If a time/stage table is provided on the node data form, it overrides the initial stage.
- If a boundary stage table is specified for the node, it overrides the initial stage and the stage/area table on the node data form.

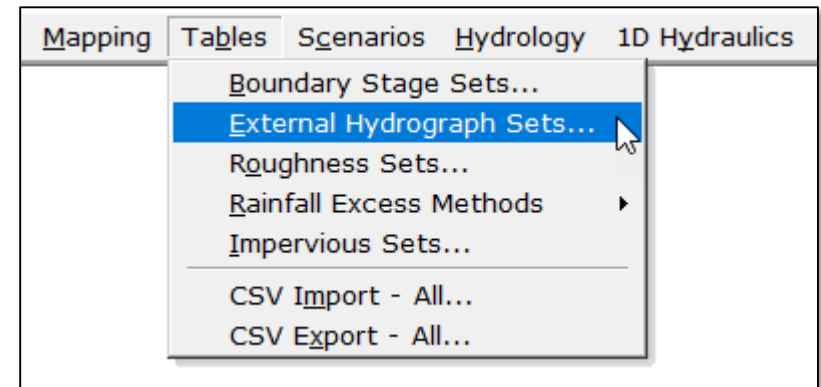
# Nodes

## External Hydrographs



← Node Data Form

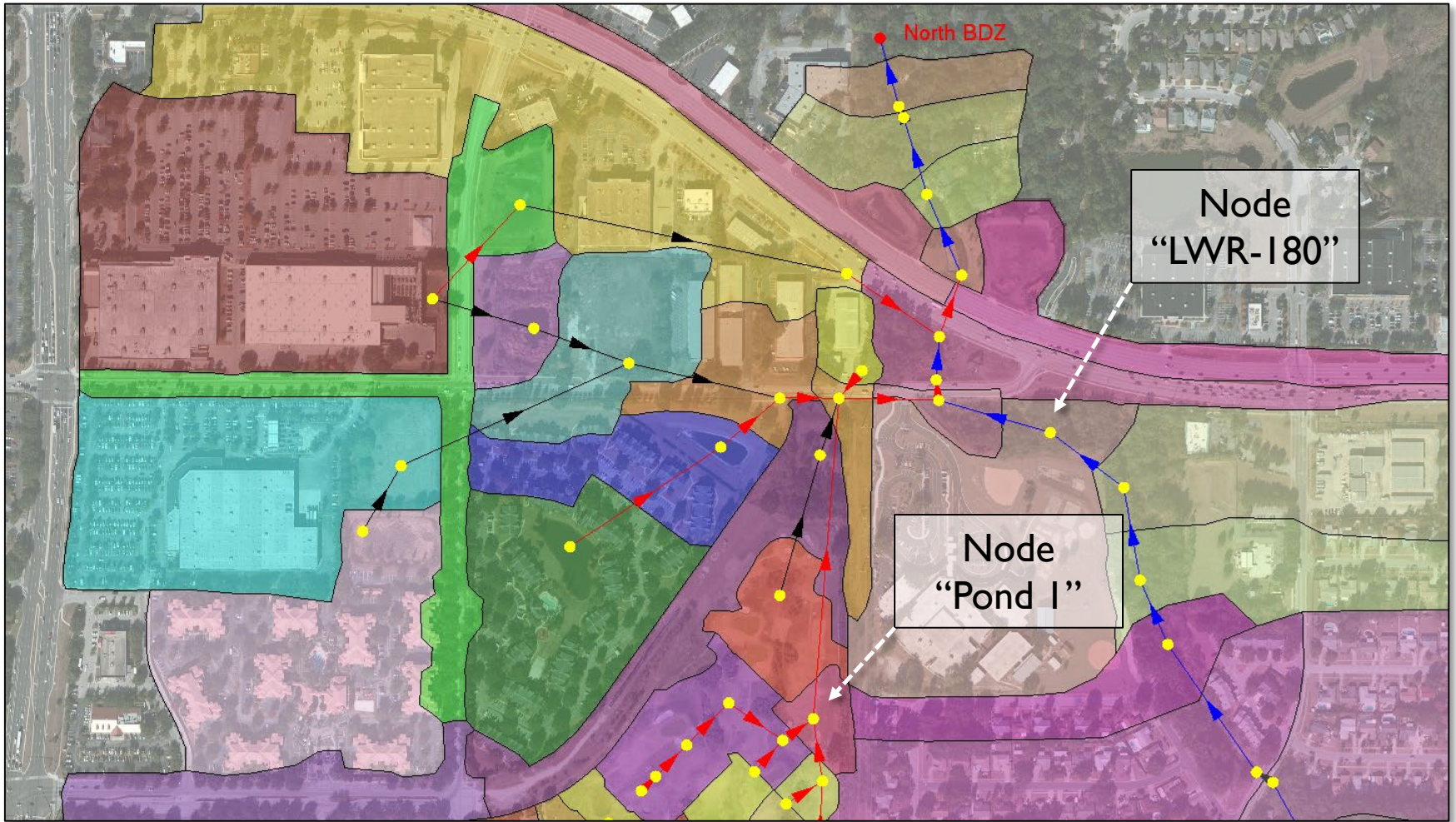
- “External Hydrographs” are similar to “Boundary Stage” tables, except instead of forcing stages, flows are added to the node.
- They can be assigned to any node type.
- External hydrographs are optional.
- There is no limit as to the number of external hydrographs that can be assigned to a given node.





# Nodes

## Stage/Area Nodes



# Nodes

Node "Pond 1"

## Stage/Area Nodes

The screenshot shows a software interface for editing a node. The left panel contains the following fields:

- Name: Pond 1
- Scenario: Scenario1
- Type: Stage/Area (highlighted with a red box)
- Base Flow: 0
- Initial Stage: 74
- Warning Stage: 82
- Comment: (empty text area)

The right panel, titled "Node Point Edit", contains a table with the following data:

Stage (ft)	Area (ac)
74	0.300643
74.25	0.318641
74.5	0.323324
74.75	0.343893
75	0.354362
75.25	0.369238
75.5	0.377376
75.75	0.399197
76	0.406244
76.25	0.425253
76.5	0.435231

Below the table is a section titled "Node External Hydrographs Grid" with a table containing one row labeled "Externa...".

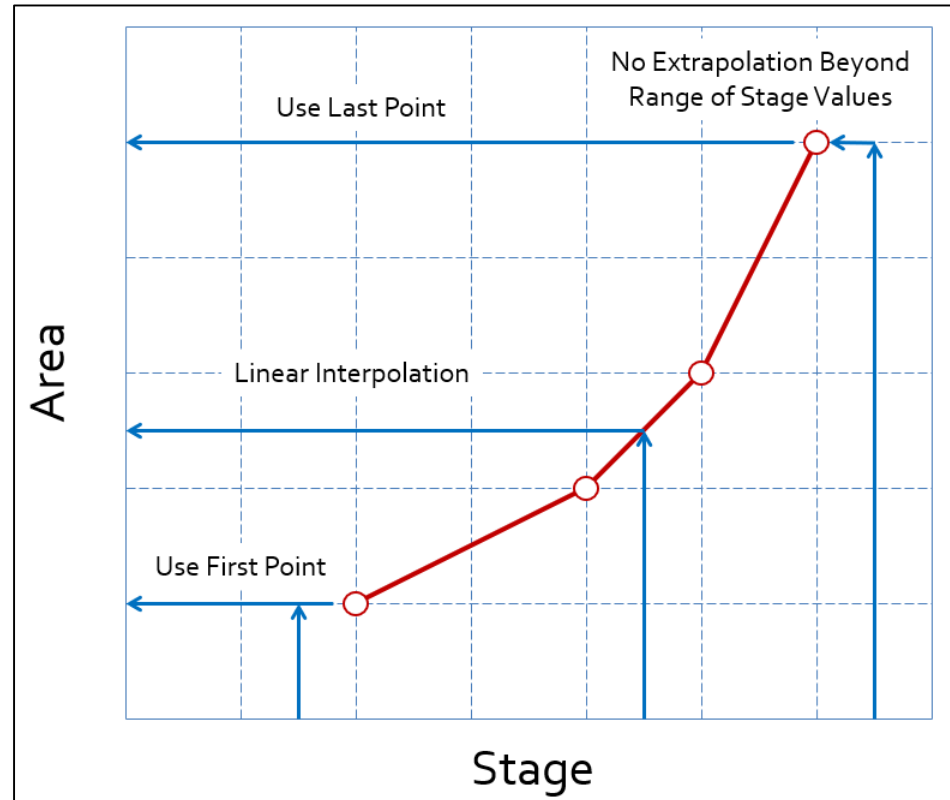
Stage versus area table usually provided for nodes that represent ponds, lakes and depressions

# Nodes

## Stage/Area Table Interpolation

If a channel link and/or a pipe link is attached to a node and the water level drops below the first data point in the stage/area table, the surface area for the node is derived completely from the links.

Otherwise, ICPR uses the area specified for the first data point.



# Nodes

Node "LWR-180"

## Stage/Area Nodes

The screenshot shows the 'Node Point Edit' window for node 'LWR-180'. The 'Type' is set to 'Stage/Area'. The 'Stage versus area table' is currently blank. A diagram below the table illustrates the concept of 'Effective Flow Area' and 'Overbank Storage Area'.

Stage	Area
-------	------

Stage versus area table usually left blank for nodes that represent locations along channels. However, stage-area data can be provided for overbank flooding beyond the channel cross section limits.

The diagram shows a channel cross-section with a red line representing the water surface. The area under the water surface within the channel is shaded with a blue cross-hatch pattern and labeled 'Effective Flow Area'. The area between the water surface and the ground level on either side of the channel is labeled 'Overbank Storage Area'.

# Nodes

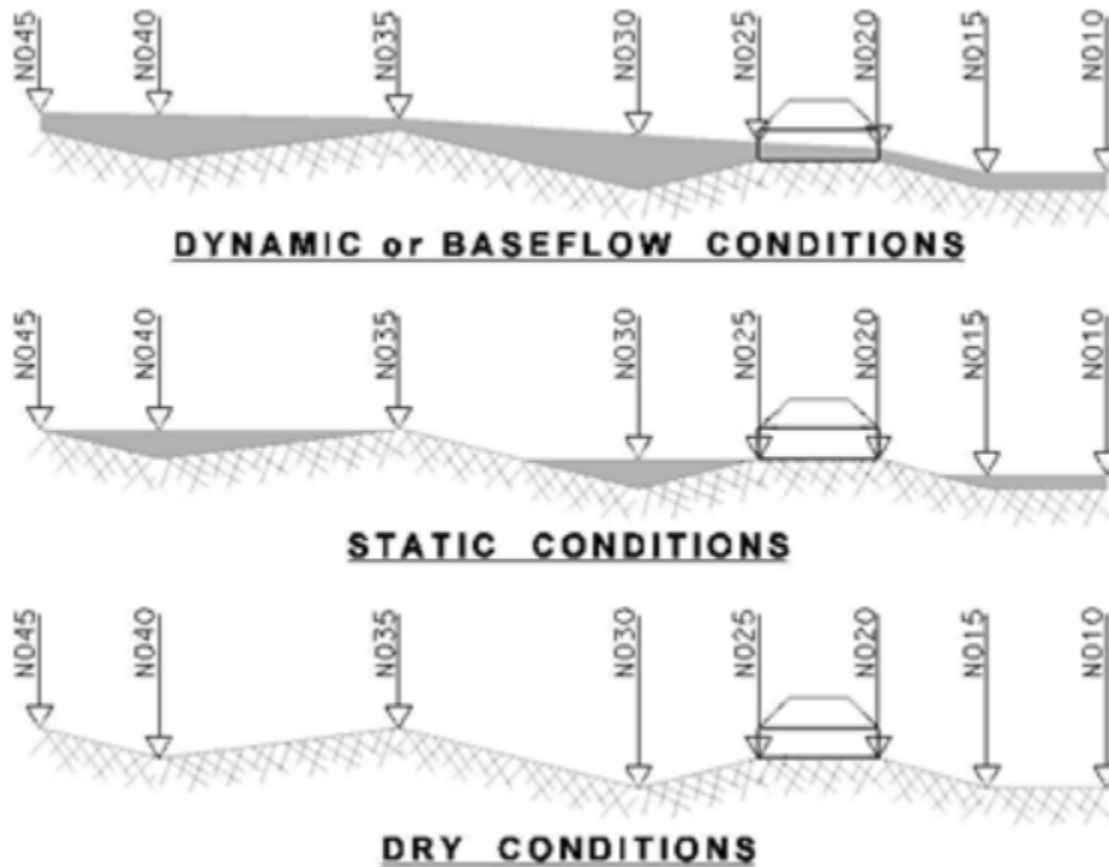
## Base Flow, Initial Stage, Warning Stage

Base Flow	0
Initial Stage	43.5
Warning Stage	58

- **Base Flow** – a constant (steady-state) flow rate. Positive value for inflow, negative value for outflow.
- **Initial Stage** – water surface elevations used at the start of a simulation. Initial link flows are calculated based on initial stages. Time-stage tables override the initial stage.
- **Warning Stage** – an optional parameter used to identify potential problems such as street flooding or out-of-bank flooding. Warning stages are not used for hydraulic computations but do appear in various reports and charts.

# Nodes

## Initial Stage



# Nodes

## Stage/Volume Nodes

- Stage/volume nodes are converted to stage/area nodes at runtime using a reverse average-end-area method.
- At least 3 points are needed for the conversion.
- The accuracy of the conversion from stage/volume to stage/area improves with more points.

# Nodes

## Storm Chambers

Name: STORM CHAMBER

Scenario: Scenario1

Type: Stage/Volume

Base Flow: 0

Initial Stage: 100

Warning Stage: 105.5

Comment: Used StromTech Calculator to develop Z-V table.  
100 MC-3500 chambers  
10 Endcaps  
9 inches of stone base  
12 inches stone cover  
stone porosity 0.40  
pit dimensions 75ft x 75ft  
stone base elev = 100.0 ft  
stone top elev = 105.5 ft

Stage	Volume
100	0
100.083333	0.004304
100.166667	0.008609
100.25	0.012913
100.333333	0.017218
100.416667	0.021522
100.5	0.025826
100.583333	0.030131
100.666667	0.034435
100.75	0.03874
100.833333	0.042954

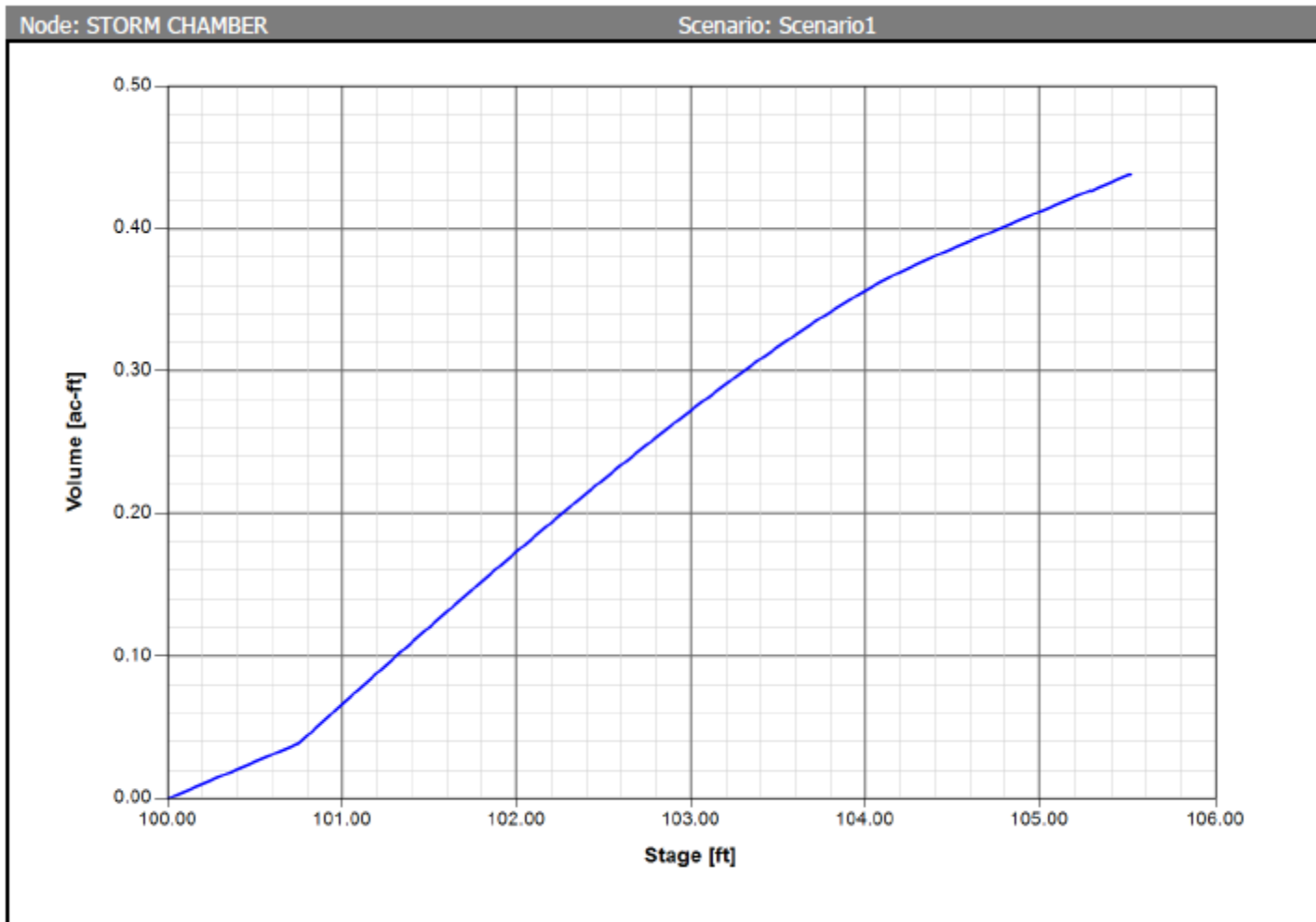
Node External Hydrographs Grid

Externa...


**Stage/Volume nodes are typically used for storm chambers**



# Nodes



# StormTech Calculator

1	C	D	E	F	G	H	I	J	K	L	
2	<b>Project:</b>										
3											
4	Chamber Model -			MC-3500							
5	Units -			Imperial	<a href="#">Click Here for Metric</a>						
6	Number of Chambers -			100							
7	Number of End Caps -			10							
8	Voids in the stone (porosity) -			40	%						
9	Base of STONE Elevation -			100.00	ft						
10	Amount of Stone Above Chambers -			12	in	<input checked="" type="checkbox"/> Include Perimeter Stone in Calculations					
11	Amount of Stone Below Chambers -			9	in						
12	Area of system -			5625	sf	Min. Area - 5305 sf min. area					
13											
14	<b>StormTech MC-3500 Cumulative Storage Volumes</b>										
15	Height of System	Incremental Single Chamber	Incremental Single End Cap	Incremental Chambers	Incremental End Cap	Incremental Stone	Incremental Ch, EC and Stone	Cumulative System	Elevation		
16	(inches)	(cubic feet)	(cubic feet)	(cubic feet)	(cubic feet)	(cubic feet)	(cubic feet)	(cubic feet)	(feet)		
17	66	0.00	0.00	0.00	0.00	187.50	187.50	19061.57	105.50		
18	65	0.00	0.00	0.00	0.00	187.50	187.50	18874.07	105.42		
19	64	0.00	0.00	0.00	0.00	187.50	187.50	18686.57	105.33		
20	63	0.00	0.00	0.00	0.00	187.50	187.50	18499.07	105.25		
21	62	0.00	0.00	0.00	0.00	187.50	187.50	18311.57	105.17		
22	61	0.00	0.00	0.00	0.00	187.50	187.50	18124.07	105.08		
23	60	0.00	0.00	0.00	0.00	187.50	187.50	17936.57	105.00		
24	59	0.00	0.00	0.00	0.00	187.50	187.50	17749.07	104.92		
25	58	0.00	0.00	0.00	0.00	187.50	187.50	17561.57	104.83		
		<b>Cumulative Volumes Imperial</b>			<b>Cumulative Volumes Metric</b>						

# CULTEC Calculator

**Project Information:**                      **Date:**

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

16 Chamber Model-	<b>Contactor 100HD</b>	
17 Number of Rows-	1	units
18 Total number of chambers -	1	units
19 HVLV SFCx2 Feed Connectors-	1	units
20 Stone Void -	40	%
21 Stone Base -	6	inches
22 Stone Above Units -	6	inches
23 Area -	49.97	ft <sup>2</sup>
24 Base of Stone Elevation-	100.00	ft

49.97 Min. Area Required  
 Note: Min. Area required is based on 12" around the system and typ. spacing

Contactor 100HD Incremental Storage Volumes								
Height of System	Chamber Volume	HVLV Feed Connector Volume	Stone Volume	Cumulative Storage Volume	Total Cumulative Storage Volume		Elevation	
in	ft <sup>3</sup>	ft <sup>3</sup>	ft <sup>3</sup>	ft <sup>3</sup>	ft <sup>3</sup>	Acre-ft	ft	
24.5	0.00	0.00	1.67	1.67	49.84	0.00114	102.04	
23.5	0.00	0.00	1.67	1.67	48.17	0.00111	101.96	

README    **Cumulative Volume- Imperial**

# Pipe & Channel Links

## Data Forms

Name	<input type="text"/>
Scenario	Scenario1
From Node	<input type="text"/>
To Node	<input type="text"/>
Link Count	1
Flow Direction	Both
Damping Threshold	0
Length	0

FHWA Culvert Code	0
-------------------	---

Entrance Loss Coefficient	0
Exit Loss Coefficient	0
Bend Loss Coefficient	0
Bend Location	0
Energy Switch	Energy

Pipe Link Data Form

Name	<input type="text"/>
Scenario	Scenario1
From Node	<input type="text"/>
To Node	<input type="text"/>
Link Count	1
Flow Direction	Both
Damping Threshold	0
Length	0

Contraction Coefficient	0
-------------------------	---

Expansion Coefficient	0
-----------------------	---

Entrance Loss Coefficient	0
Exit Loss Coefficient	0
Bend Loss Coefficient	0
Bend Location	0
Energy Switch	Energy

Channel Link Data Form

# Pipe & Channel Links

## General Considerations

- Connectivity
- Count
- Flow Direction
- Damping Threshold
- Energy Switch

# Pipe & Channel Links

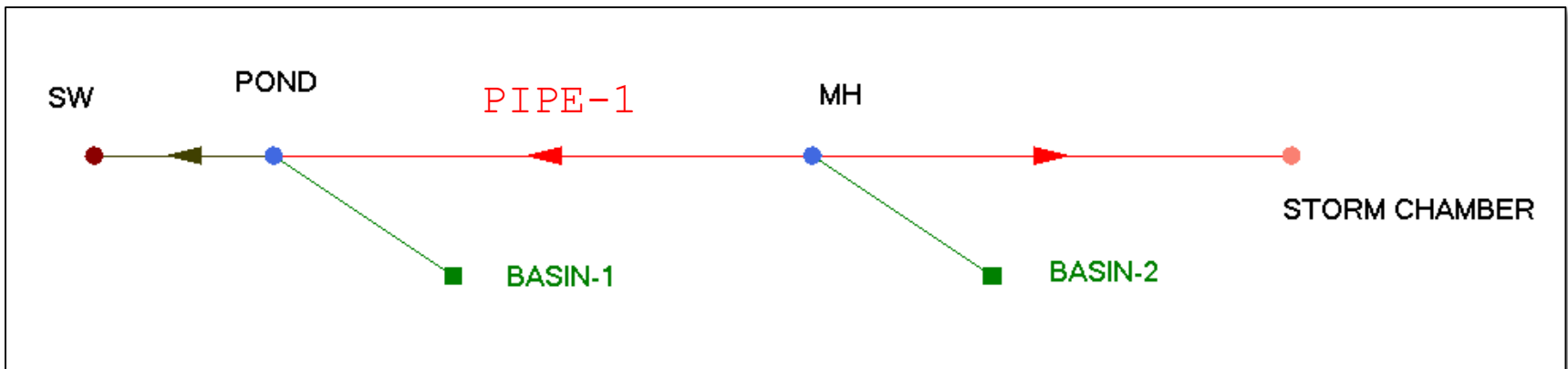
## General Considerations

### - Connectivity -

Name	PIPE-1
Scenario	Scenario1
From Node	MH
To Node	POND
Link Count	1
Flow Direction	Both
Damping Threshold	0

positive flow

- Links are used to move water “from” one node “to” another node
- Connectivity is established by setting a “from node” (upstream node) and a “to node” (downstream node)
- The positive flow direction is established with the connectivity



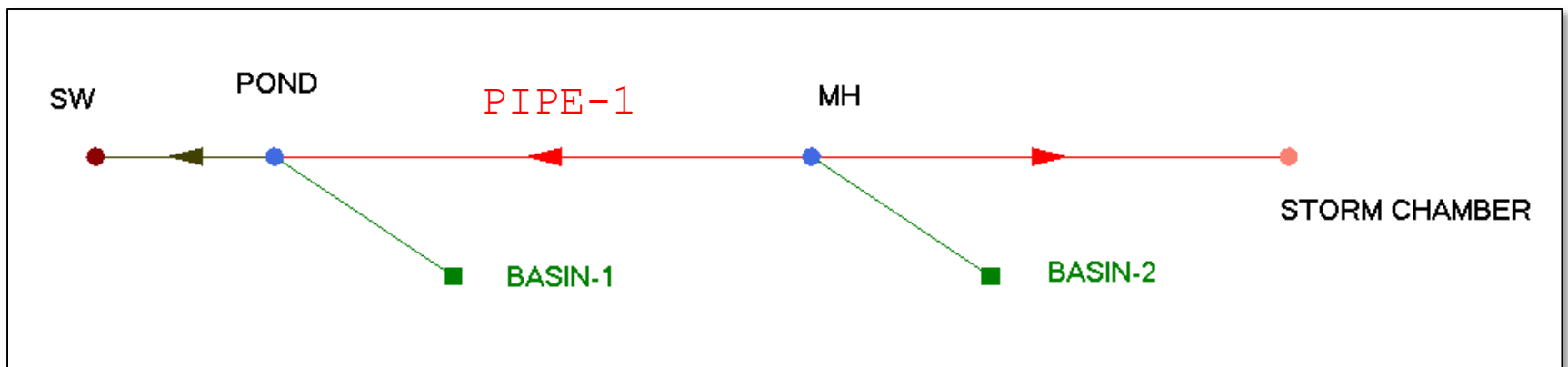
# Pipe & Channel Links

## General Considerations

### - Link Count -

Name	PIPE-1
Scenario	Scenario1
From Node	MH
To Node	POND
Link Count	1
Flow Direction	Both
Damping Threshold	0

- The link count is the number of identical links connecting the same two nodes
- It is always a positive integer
- Flow is calculated for one link and then that flow is multiplied by the “Link Count”



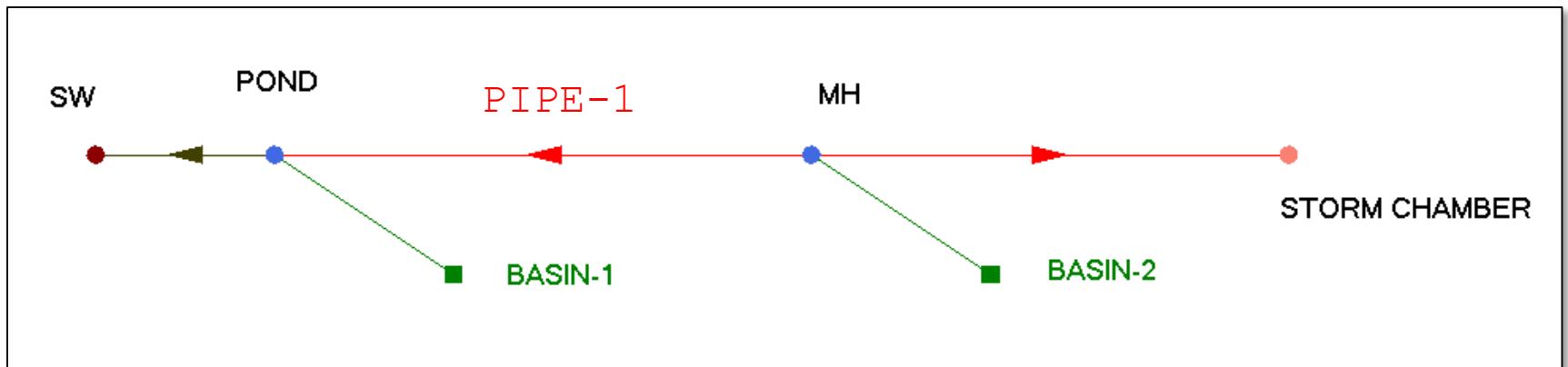
# Pipe & Channel Links

## General Considerations

### - Flow Direction -

Name	PIPE-1
Scenario	Scenario1
From Node	MH
To Node	POND
Link Count	1
Flow Direction	Both
Damping Threshold	0

- “Both” allows flow in the positive and negative directions
- “Positive” only allows flow in the direction of the defined connectivity
- “None” turns the link off, but retains the link data in the project





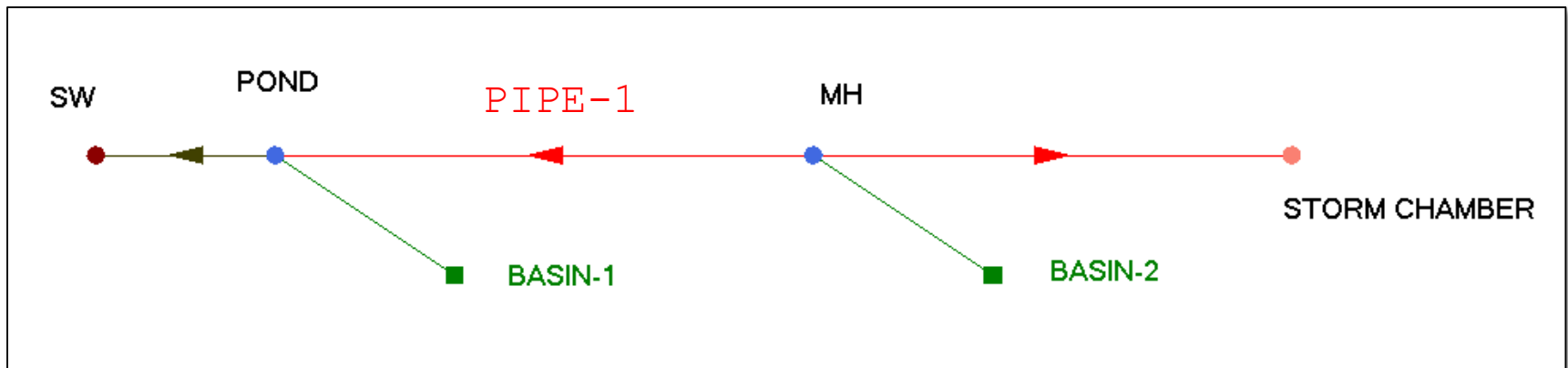
# Pipe & Channel Links

## General Considerations

### - Damping Threshold -

Name	PIPE-1
Scenario	Scenario1
From Node	MH
To Node	POND
Link Count	1
Flow Direction	Both
Damping Threshold	0

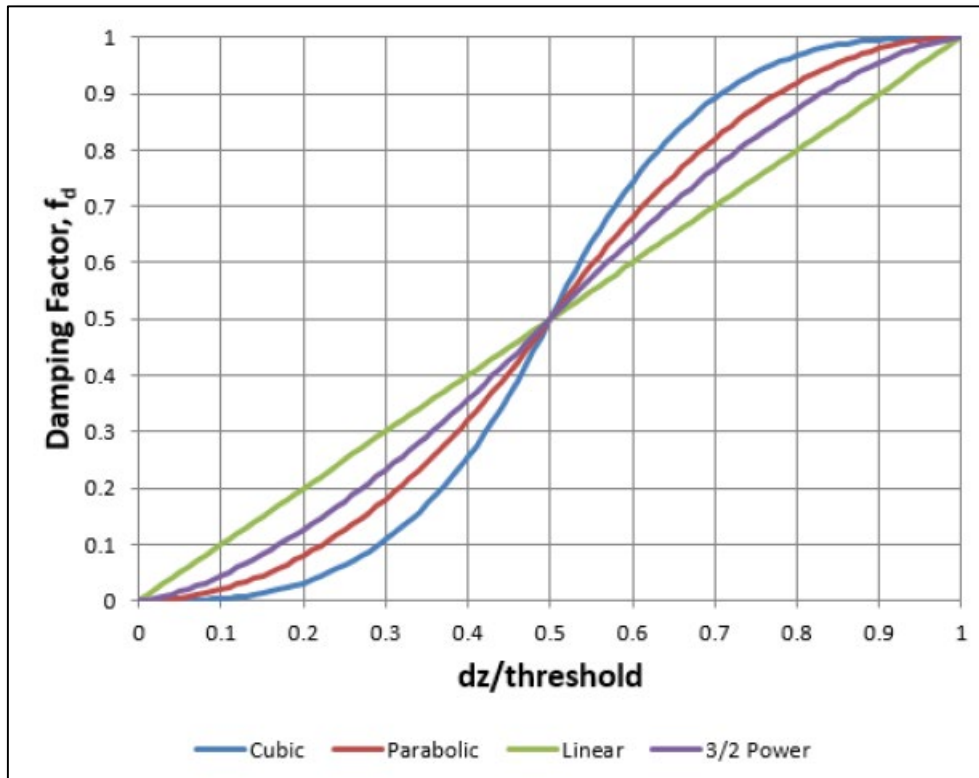
- This parameter can be used to help smooth out instabilities
- It is normally set to zero on the link data form unless there is a problematic link
- Typically, values range from 0.0001' to 0.01' when used, and should rarely exceed 0.1'



# Pipe & Channel Links

## General Considerations

### - Damping Threshold -



When the absolute value of the difference in water levels at both ends of a link fall within the specified “Damping Threshold”, the calculated flow is reduced in accordance with the equation below.

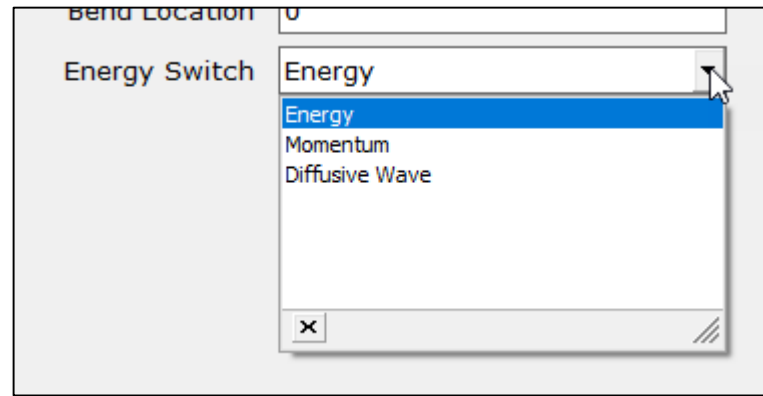
$$Q' = f_d Q$$

where,  $Q'$ , is the reduced flow.

The parabolic function is currently used in ICPR.

# Pipe & Channel Links

## Energy Switch



Momentum  
(St. Venant Eq)

$$\frac{\partial Q}{\partial t} + \frac{\partial(Q^2 / A)}{\partial x} + gA \frac{\partial Z}{\partial x} + gAS_f + gA(h_{eddy} + h_{entrance} + h_{exit} + h_{bend}) = 0$$

Energy

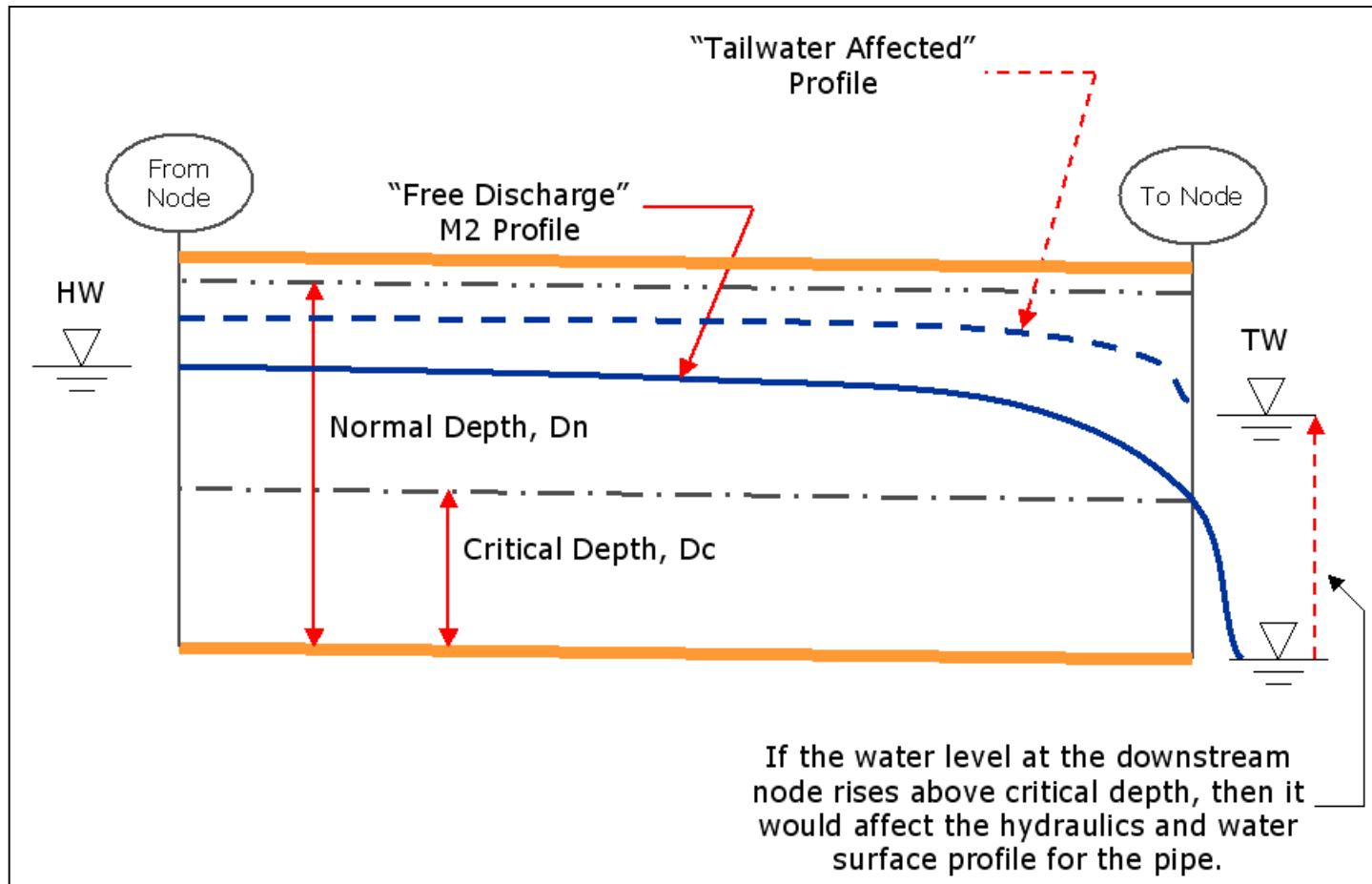
$$Z_1 + \frac{V_1^2}{2g} = Z_2 + \frac{V_2^2}{2g} + h_f + h_{eddy} + h_{entrance} + h_{exit} + h_{bend}$$

Diffusive Wave

$$Z_1 + = Z_2 + h_f + h_{eddy} + h_{entrance} + h_{exit} + h_{bend}$$

# Pipe & Channel Links

## Subcritical Flow (Outlet Control)



# Subcritical & Supercritical Pipe Transitions

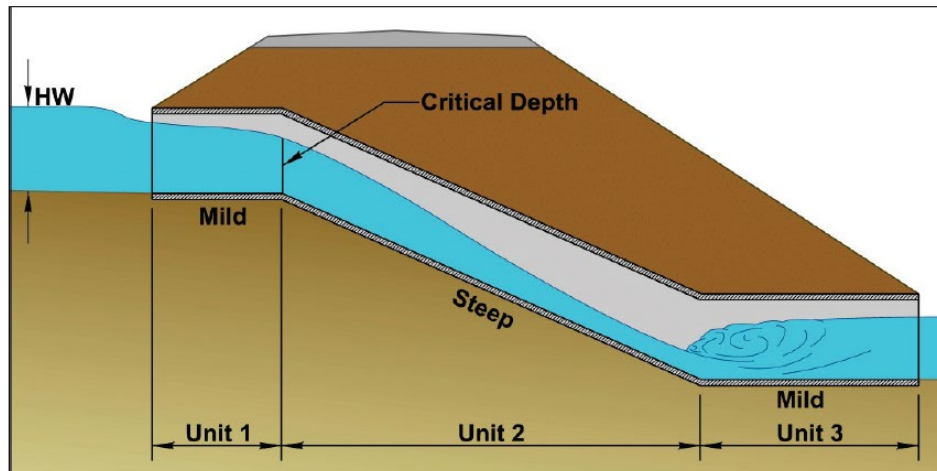
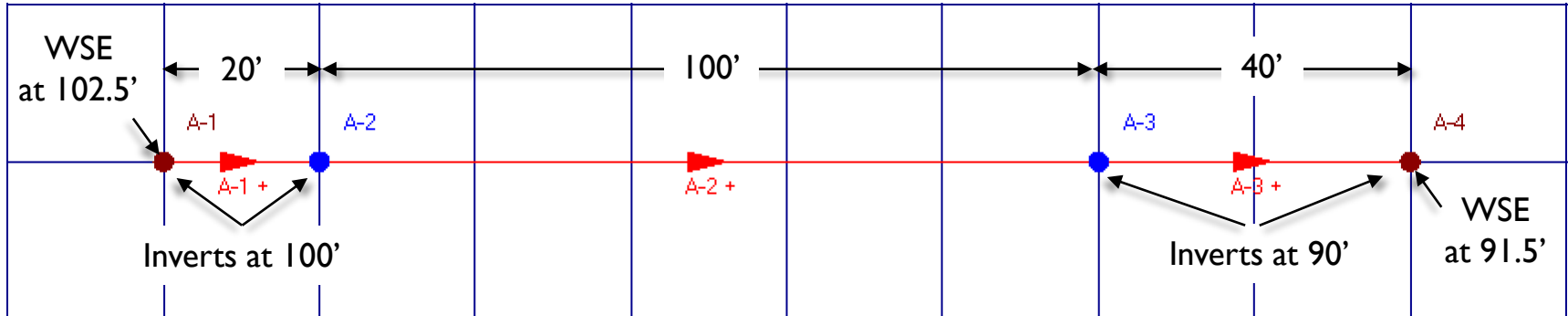
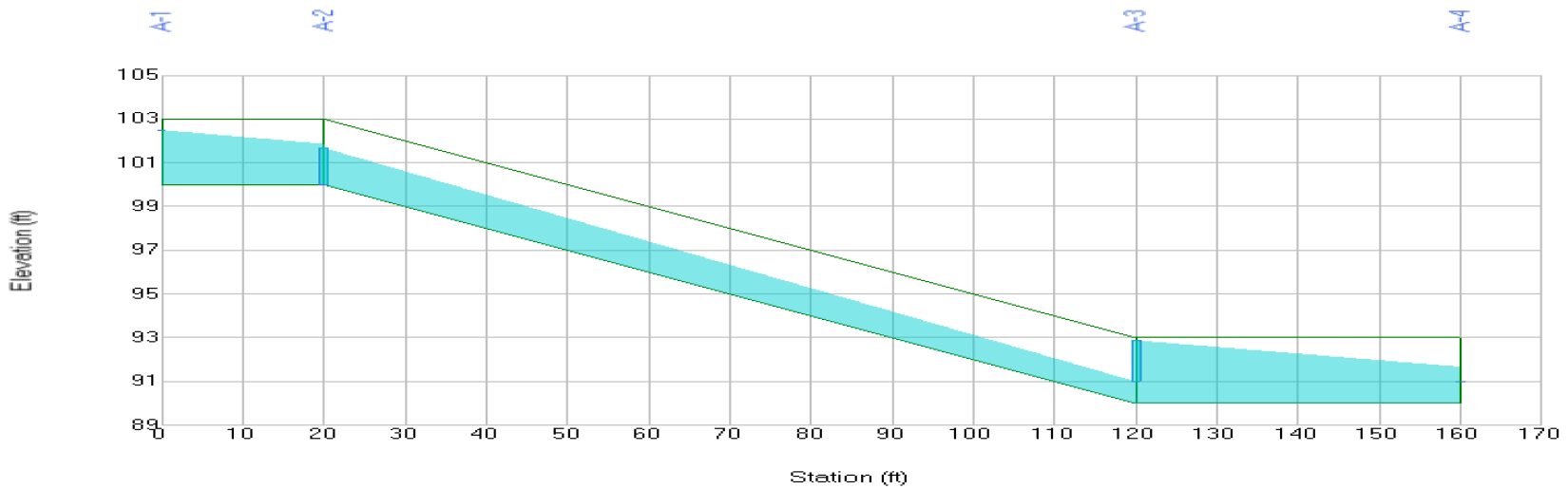
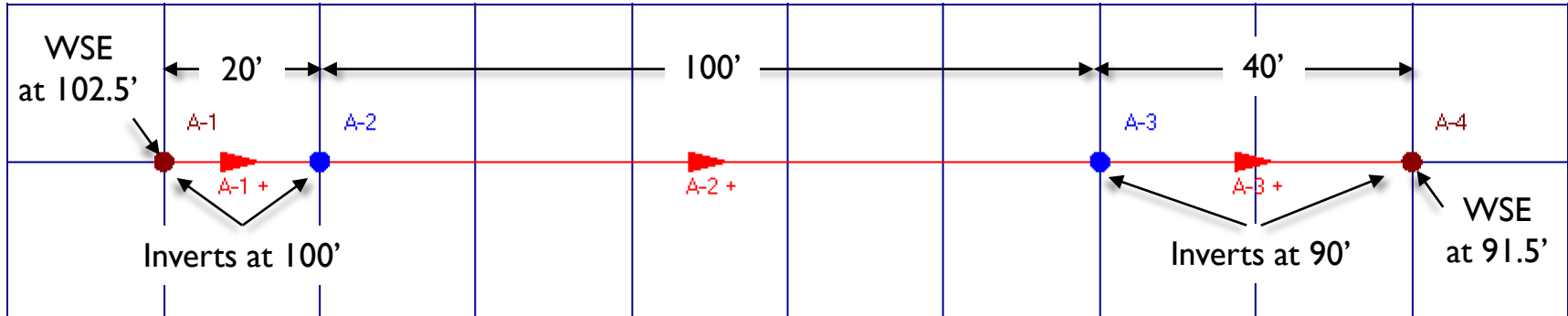


Figure 5.22. Three-unit broken-back culvert.

Source: FHWA 2012 "Hydraulic Design of Highway Culverts" 3<sup>rd</sup> Edition

# Subcritical & Supercritical Pipe Transitions

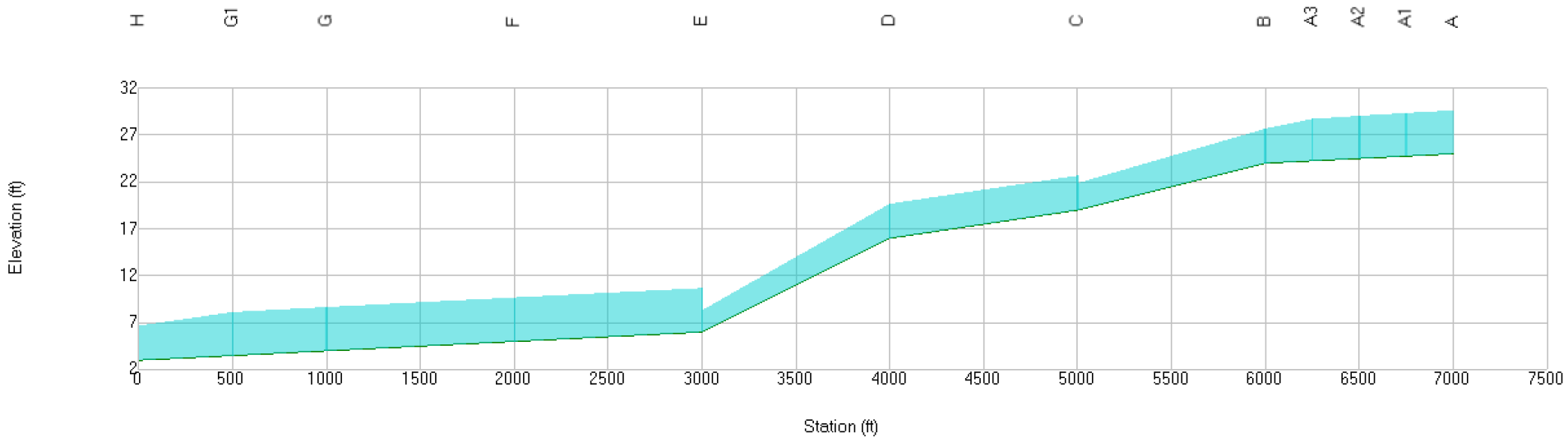
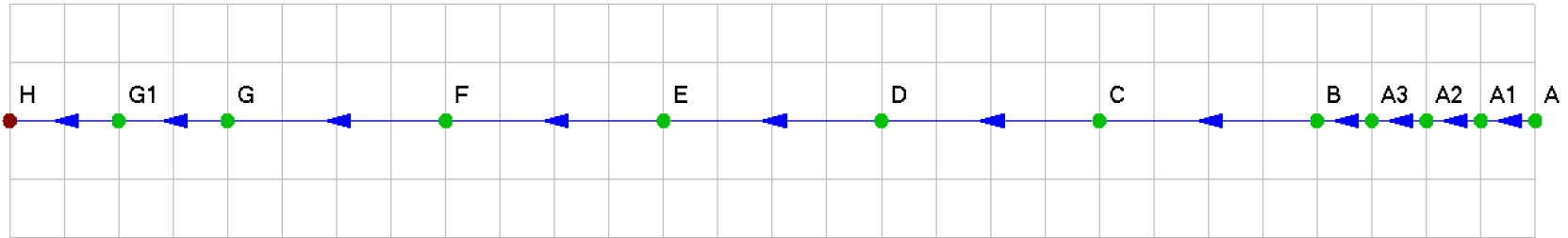


0.0000

# Subcritical & Supercritical Channel Transitions

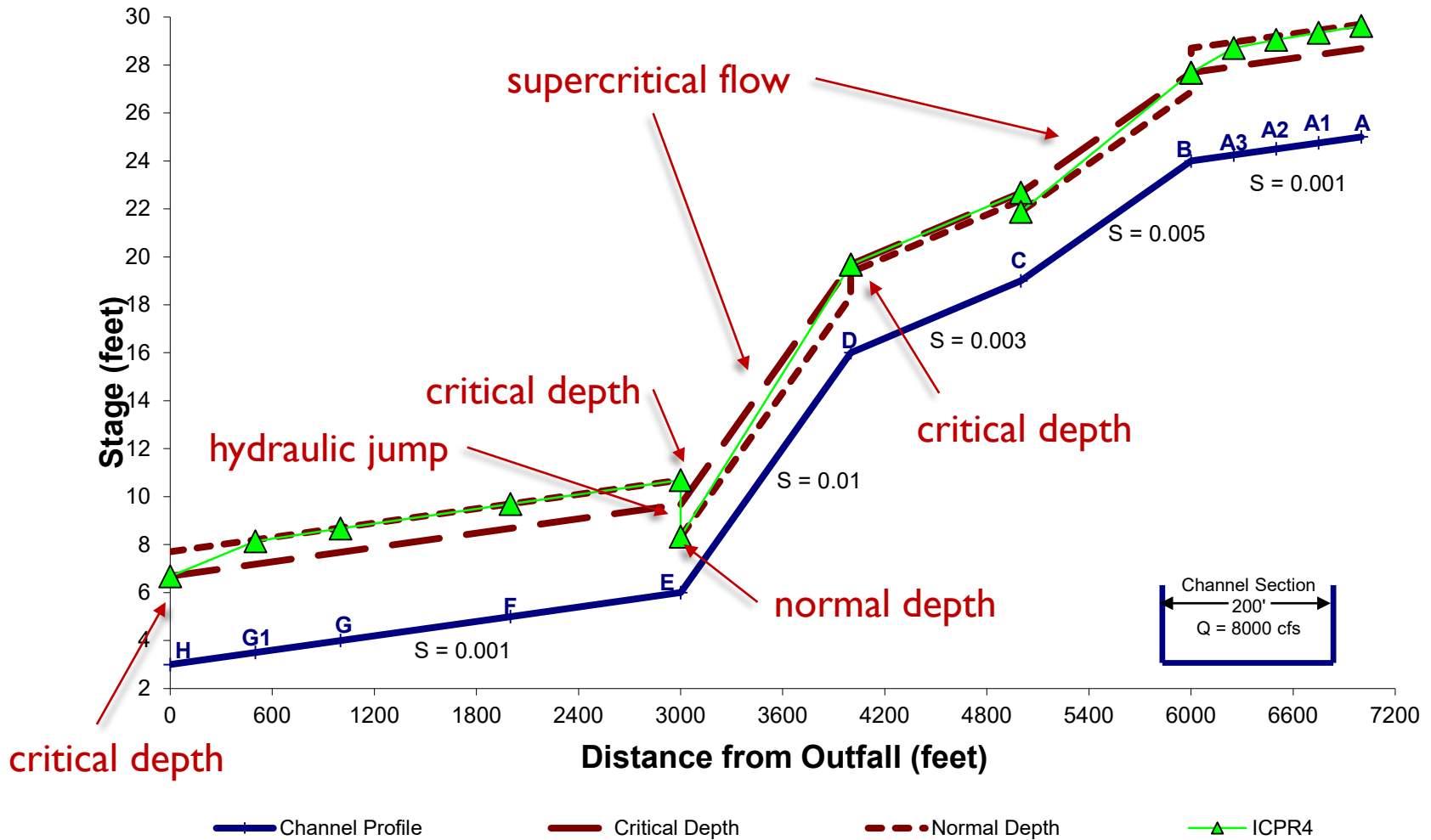
8,000 cfs

Rectangular cross section – 200' wide



# Subcritical & Supercritical Channel Transitions

Hromadka and Yen, 1986 - Open Channel with Varying Slope





# Pipe & Channel Links

## Friction Minor Losses

- Friction Loss
- Contraction/Expansion Loss  
(channels only)
- Entrance Loss
- Exit Loss
- Bend Loss

# Pipe & Channel Links

## Friction Loss

	Upstream	Downstream
Invert	<input type="text" value="0"/>	<input type="text" value="0"/>
Manning's N	<input type="text" value="0"/>	<input type="text" value="0"/>

$$h_f = L\bar{S}_f$$

The friction slope is derived from Manning's Equation as follows:

$$S_f = (Q / K)^2$$

$$K = \frac{1.486R^{2/3}A}{n}$$

# Pipe & Channel Links

## Friction Loss

Average Conveyance:

$$S_{f_{avg}} = \frac{4Q^2}{(K_1 + K_2)^2}$$

Average Friction Slope:

$$S_{f_{avg}} = \frac{Q^2 (1/K_1^2 + 1/K_2^2)}{2}$$

Geometric Mean Friction Slope:

$$S_{f_{avg}} = Q^2 \left( \frac{1}{K_1^2 K_2^2} \right)^{1/2}$$

Harmonic Mean Friction Slope:

$$S_{f_{avg}} = 2Q^2 \left[ \frac{1}{(K_1^2 K_2^2) (1/K_1^2 + 1/K_2^2)} \right]$$

ICPR includes several friction slope averaging techniques. These are automatically applied and depend on the flow regime.

# Channel Links

## Contraction/Expansion Loss Coefficients

Contraction Coefficient	0
Expansion Coefficient	0

$$h_{eddy} = C_{eddy} \left[ \frac{V_1^2}{2g} - \frac{V_2^2}{2g} \right]$$

Subcritical Flow Contraction and Expansion Coefficients		
	Contraction	Expansion
No transition loss computed	0.0	0.0
Gradual transitions	0.1	0.3
Typical bridge sections	0.3	0.5
Abrupt transitions	0.6	0.8

Source: HEC-RAS Reference Manual

- Eddy losses account for contracting or expanding flow from one end of a channel link to the other.
- They do not account for contractions or expansions beyond the extents of the channel link.
- The eddy loss for a channel link is a function of the velocity heads at its upstream and downstream ends.

# Pipe & Channel Links

## Entrance Loss Coefficient

Entrance Loss Coefficient	0.5
Exit Loss Coefficient	1
Bend Loss Coefficient	0
Bend Location	0

Press “F1” key for list of entrance loss coefficients

$$h_{entrance} = \frac{C_{entrance} V_1^2}{2g}$$

**Table C.2. Entrance Loss Coefficients.**

**Outlet Control, Full or Partly Full Entrance Head Loss**

$$H_e = K_e \left[ \frac{V^2}{2g} \right]$$

<u>Type of Structure and Design of Entrance</u>	<u>Coefficient <math>K_e</math></u>
• <u>Pipe, Concrete</u>	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove-end)	0.2
Square-edge	0.5
Rounded (radius = D/12)	0.2
Mitered to conform to fill slope	0.7
*End-Section conforming to fill slope	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2

Partial listing of entrance loss coefficients for pipes

# Pipe & Channel Links

## Exit Loss Coefficient

Entrance Loss Coefficient	0.5
Exit Loss Coefficient	1
Bend Loss Coefficient	0
Bend Location	0

$$h_{exit} = \frac{C_{exit} V_2^2}{2g}$$

The exit loss coefficient,  $C_{exit}$ , can vary from 0 to 1 and, in general, depends on the differences in velocities between the outlet of the pipe and immediately downstream of the outlet.

- If exit velocity is expected to drop to zero or near zero after leaving a pipe or channel outlet, then  $C_{exit} = 1.0$
- If exit velocity is expected to be unchanged, then  $C_{exit} = 0.0$

$$C_{ext} = (V_{pipe}^2 - V_{downstream}^2) / V_{pipe}^2$$

Or, from the following table:

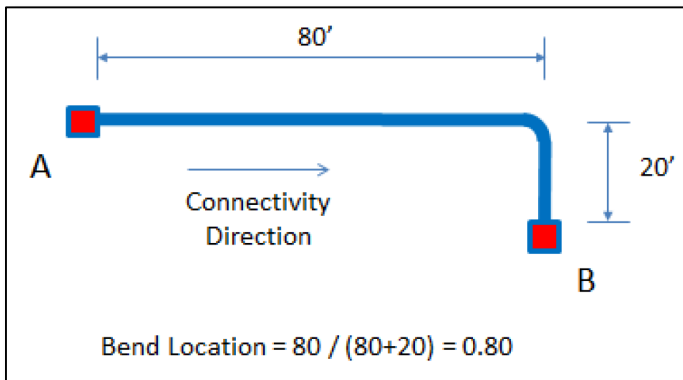
$(V_{pipe} / V_{downstream})$ or $(A_{downstream} / A_{pipe})$	$C_{ext}$
1.00	0.000
1.10	0.174
1.25	0.450
1.50	0.556
1.75	0.673
2.00	0.750
3.00	0.889
4.00	0.938
8.00	0.984
infinity	1.000

# Pipe & Channel Links

## Exit Loss Coefficient

Entrance Loss Coefficient	0.5
Exit Loss Coefficient	1
Bend Loss Coefficient	0
Bend Location	0

$$h_{bend} = \frac{C_{bend} V_{bend}^2}{2g}$$



Bend Loss Coefficients			
R = 31,500		r/b = 1.0	
r/b	$C_{bend}$	R	$C_{bend}$
2.5	0.02	10,000	0.59
2.0	0.07	30,000	0.27
1.5	0.12	50,000	0.25
1.0	0.25	70,000	0.35

Source: Brater and King, 1976, p. 8-31.

# Pipe Links

## FHWA Inlet Control Equations

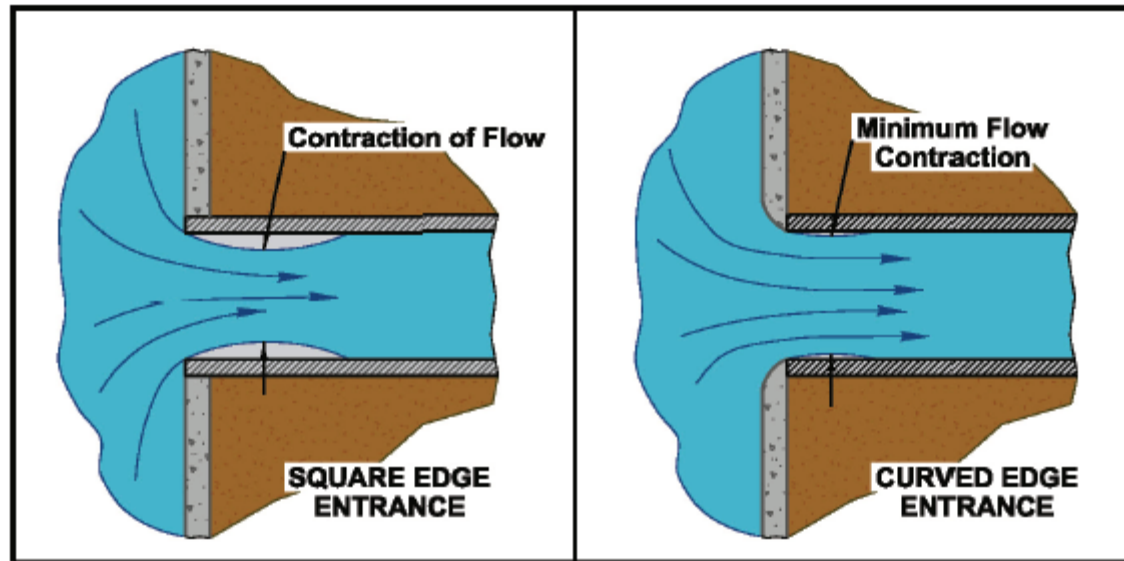


Figure 1.9. Entrance contraction.

Source: FHWA 2012 "Hydraulic Design of Highway Culverts" 3<sup>rd</sup> Edition



# Pipe Links

## FHWA Inlet Control Equations

Length	200
FHWA Culvert Code	1
Entrance Loss Coefficient	0.5

Press “F1” key for list of FHWA codes

### Unsubmerged:

$$\text{Form 1: } Q = AD^{1/2}[\{(z_1 - H_c)/D + 0.5S\} / K]^{1/M}$$

$$\text{Form 2: } Q = AD^{1/2}[z_1/(DK)]^{1/M}$$

### Submerged:

$$Q = AD^{1/2}[(z_1/D - Y + 0.5S) / c]^{1/2}$$

When a non-zero FHWA control code is specified for a pipe link, ICPR calculates *flows for both inlet and outlet control* and then *uses the most restrictive*. Normal depth at the pipe outlet is used for inlet control.

# Pipe Links

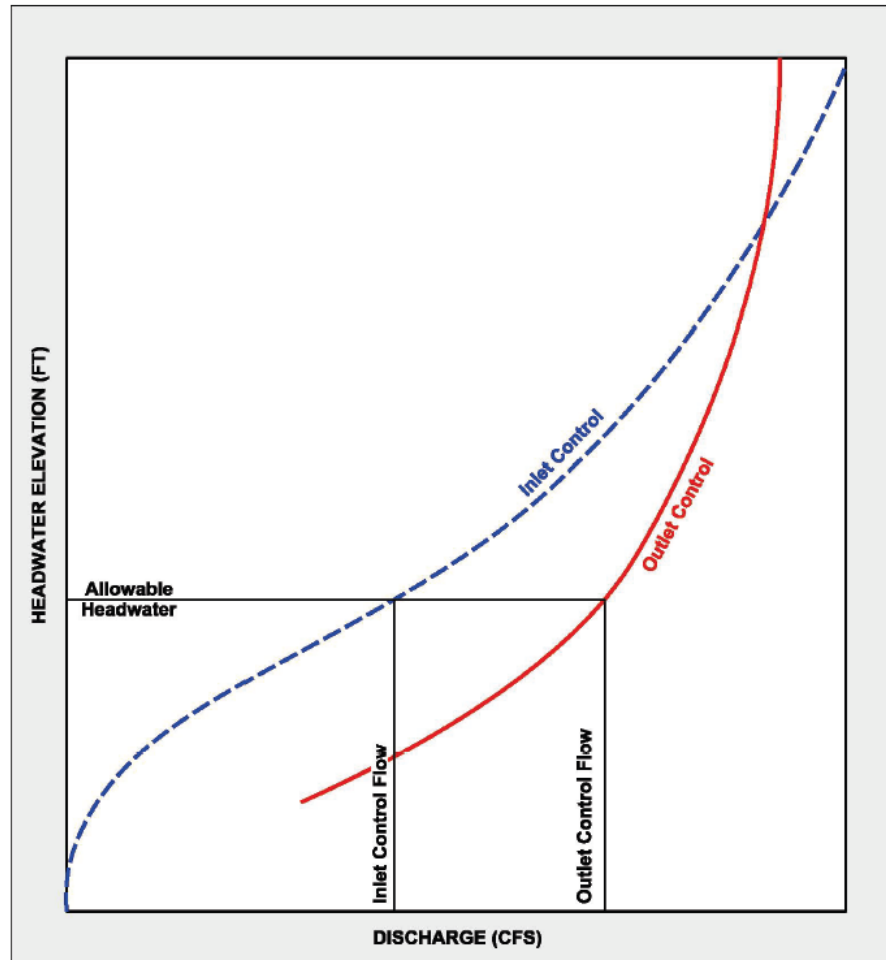


Figure 1.19. Culvert performance curve.

Source: FHWA 2012 “Hydraulic Design of Highway Culverts” 3<sup>rd</sup> Edition

# Pipe Links

## FHWA Culvert Code

Length	200
FHWA Culvert Code	1
Entrance Loss Coefficient	0.5

Press "F1" key for list of FHWA codes

- If FHWA code set to zero, critical depth at entrance used for supercritical flow
- Normal depth is used at the pipe outlet for inlet controlled pipes

FHWA Culvert Code	Shape and Material	Inlet Configuration
0	FHWA Inlet Control Option Not Used	
1	Circular Concrete	Square edge w/headwall
2	Circular Concrete	Groove end w/headwall
3	Circular Concrete	Groove end projecting
4	Circular CMP	Headwall
5	Circular CMP	Mitered to slope
6	Circular CMP	Projecting
7	Circular	Beveled ring, 45° bevels
8	Circular	Beveled ring, 22.5° bevels*



(A) Thin Edge Projecting – The culvert barrel projects out of the embankment.



(B) Mitered entrance – The culvert barrel is cut so it is flush with the embankment slope.



(C) Square edge in headwall – The end of the culvert barrel is flush with the headwall.



(D) Groove edge projecting – A concrete pipe culvert section extends beyond the fill or headwall.

Figure 3.2. Typical inlet configurations.

Source: FHWA 2012 “Hydraulic Design of Highway Culverts” 3<sup>rd</sup> Edition

# Pipe Links



Figure 1.8. Four standard inlet types.

Source: FHWA 2012 “Hydraulic Design of Highway Culverts” 3<sup>rd</sup> Edition

# Pipe Links

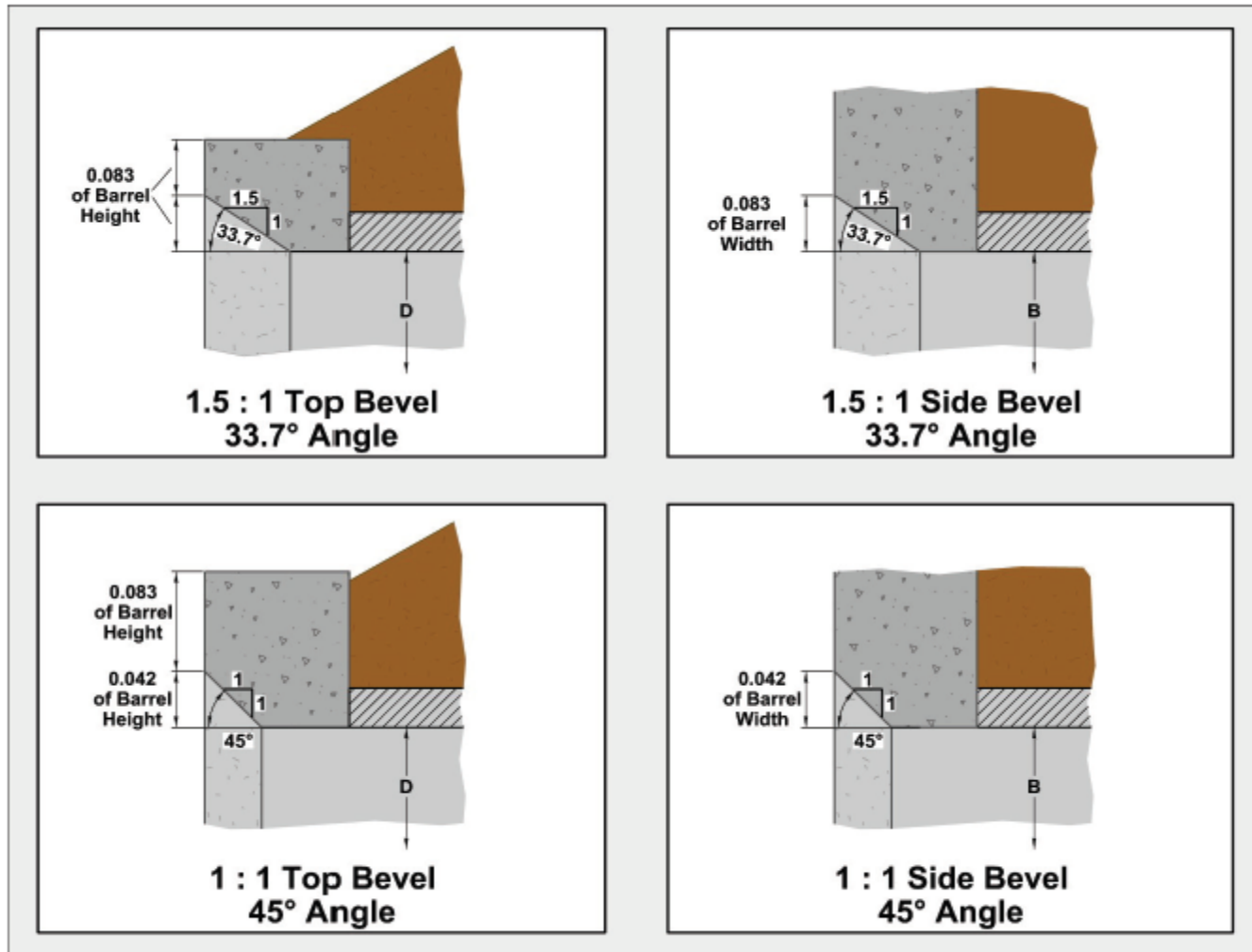
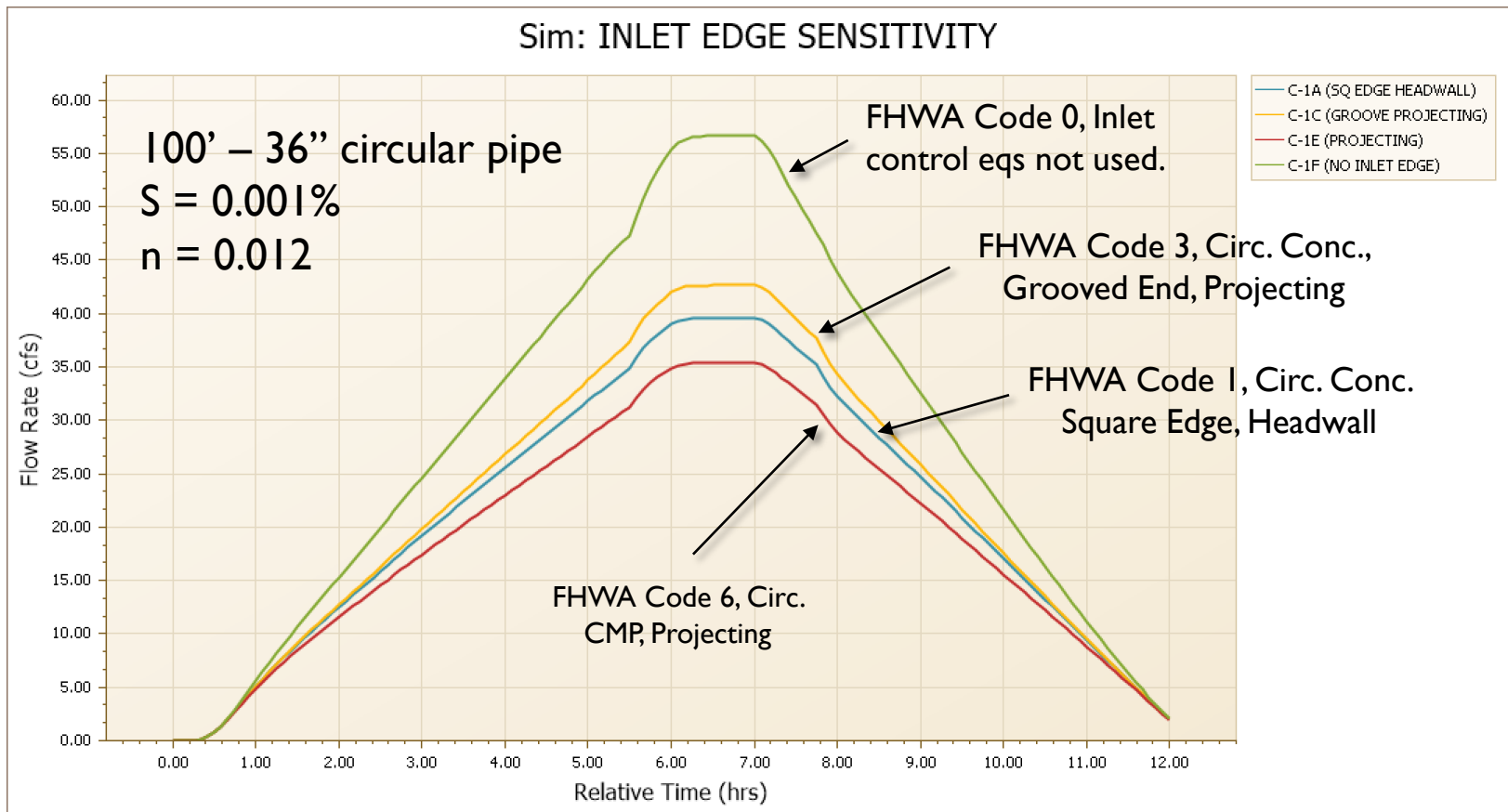


Figure 3.3. Beveled edges.

Source: FHWA 2012 "Hydraulic Design of Highway Culverts" 3<sup>rd</sup> Edition

# Pipe Links

## FHWA Inlet Control – Does it Matter?



# Pipe Links

## Geometric Considerations

	Upstream	Downstream
Invert	<input type="text" value="0"/>	<input type="text" value="0"/>
Manning's N	<input type="text" value="0"/>	<input type="text" value="0"/>
<b>Geometry</b>		
Type	<input type="text" value="Circular"/>	<input type="text" value="Circular"/>
Max Depth	<input type="text" value="0"/>	<input type="text" value="0"/>

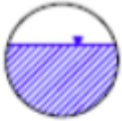
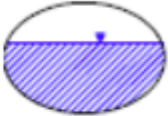



- Circular
- Horizontal Ellipse
- Vertical Ellipse
- Arch
- Arch Structural Plate
- Rectangular
- V-Notch Up
- V-Notch Down
- Egg Shaped
- Horseshoe
- Gothic
- Catenary
- Basket Handle
- Semi-Circular
- Semi-Elliptical
- Con Span

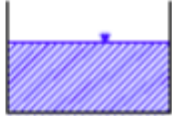

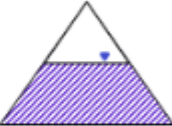


Drop Down List of Geometry Types








# Pipe Links

## Geometric Considerations

Geometry Type	
Circular	
H-Elliptical	
V-Elliptical	
Arch (2-2/3" x 1/2")	
Arch Structural Plate	

Geometry Type	
Rectangular	
V-notch Up	
V-notch Down	
Egg Shaped	
Horseshoe	

Geometry Type	
Gothic	
Catenary	
Basket handle	
Semi-Circular	
Semi-Elliptical	

# Pipe Links

## Geometric Considerations

**Upstream**

Invert

Manning's N

**Geometry**

Type

Max Depth

Max Width

Fillet

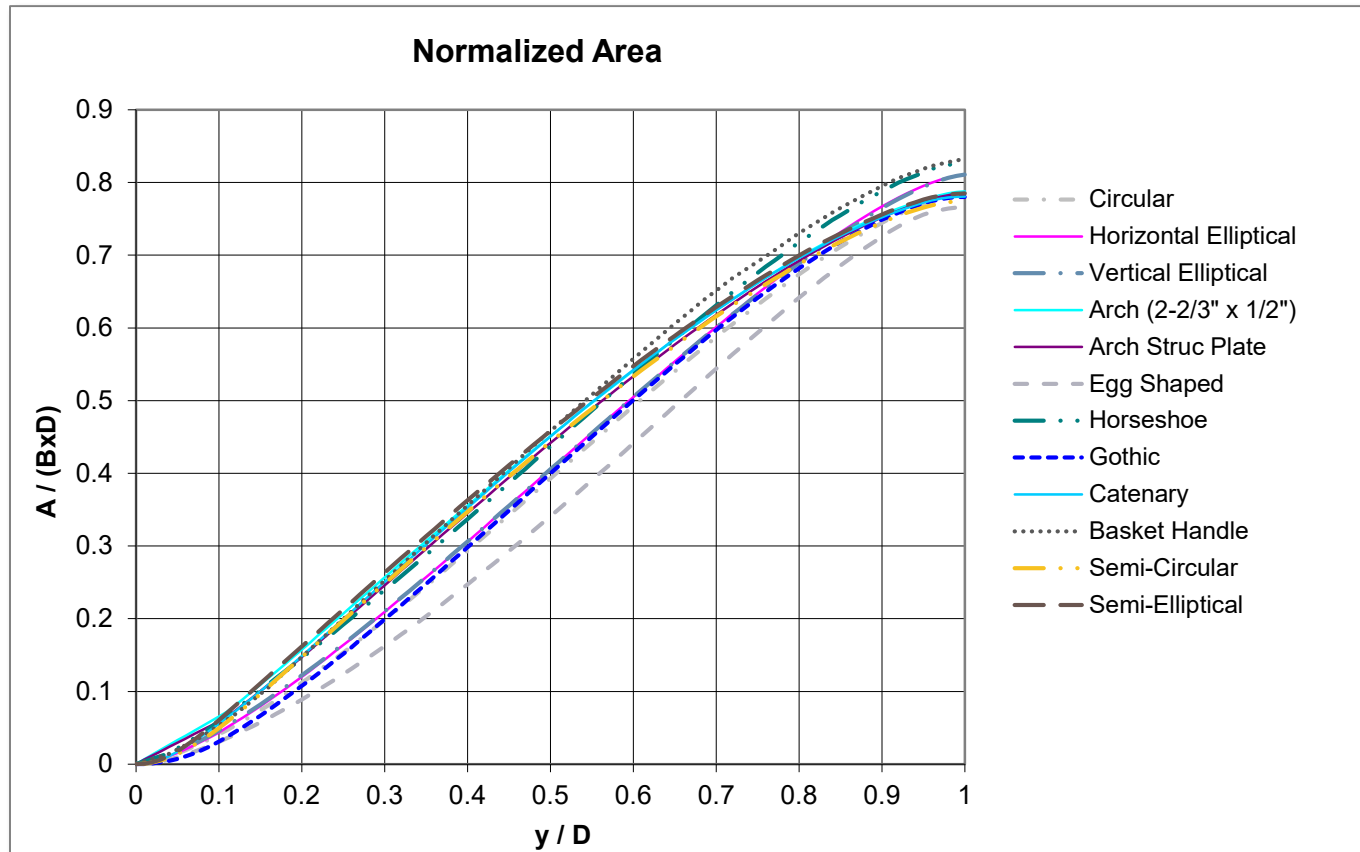
These Fields Depend on  
Geometry Type

Geometry Type	B/D	Input Requirements	CG/D
Circular	1.00	D	0.500
H-Elliptical	1.56	D	0.500
V-Elliptical	1.00/1.56	D	0.500
Arch (2-2/3" x 1/2")	1.607	D	0.446
Arch Structural Plate	variable	B, D	0.455
Rectangular	variable	B, D, F	0.500
V-notch Up	variable	B, D	0.677
V-notch Down	variable	B, D	0.333
Egg Shaped	2/3	D	0.529
Horseshoe	1.00	D	0.475
Gothic	0.84	D	0.492
Catenary	0.90	D	0.453
Basket handle	0.944	D	0.467
Semi-Circular	1.64	D	0.456
Semi-Elliptical	1.00	D	0.447
Con Span	variable	Xsec Name	Variable

B = maximum width, D = maximum depth, F = fillet length, CG = center of gravity

# Pipe Links

## Geometric Considerations



Normalized: Area, Hydraulic Radius & Wetted Perimeter

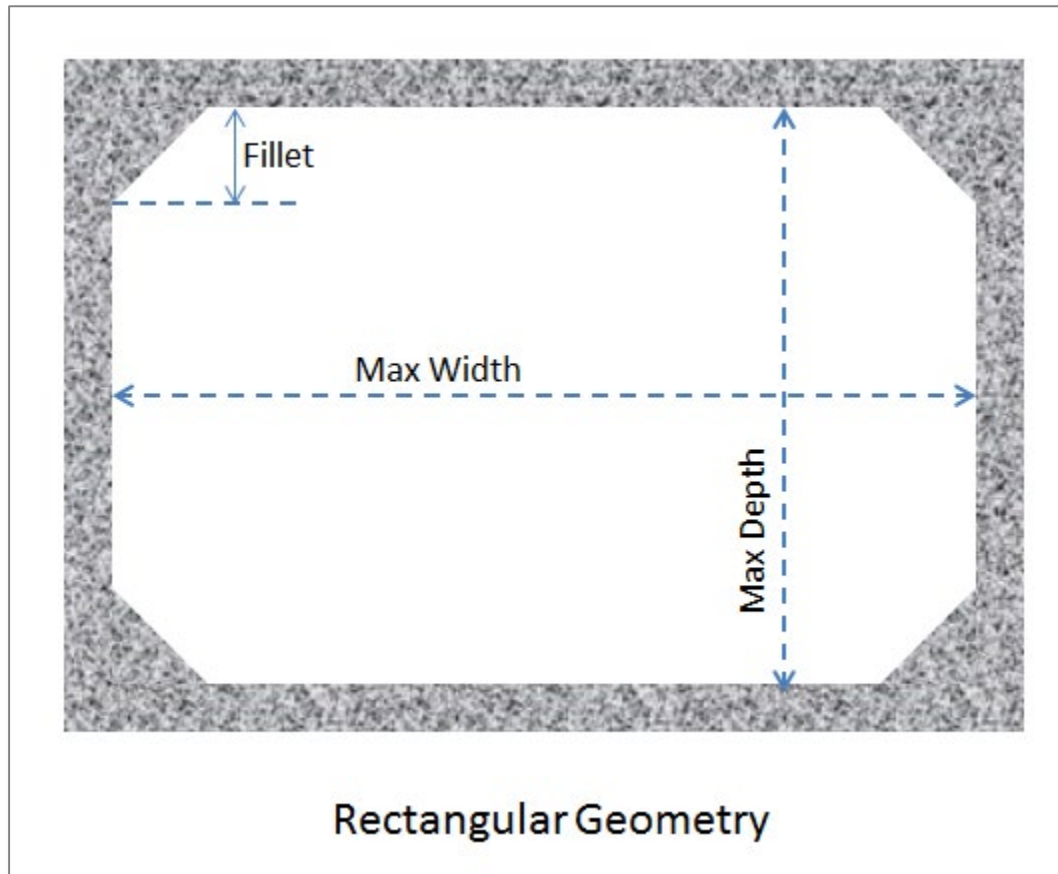
# Pipe Links

## Geometric Considerations



# Pipe Links

## Geometric Considerations



# Pipe Links

## Geometric Considerations

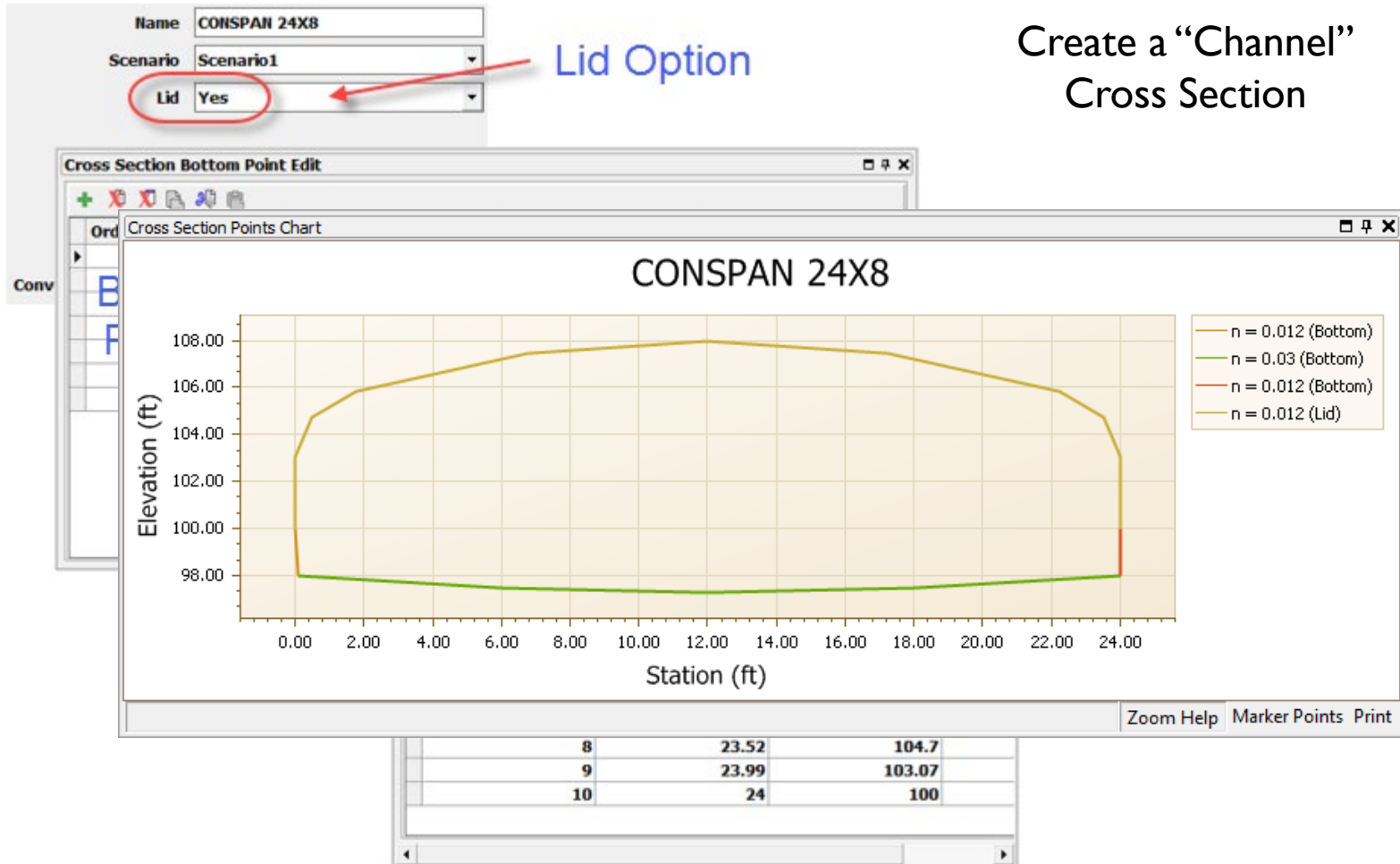


Source: CONTECH

## CONSPAN BRIDGE

# Pipe Links

## Geometric Considerations



# Pipe Links

## Geometric Considerations

Name	CONSPAN	Upstream		Downstream
Scenario	Scenario1	Invert	97.25	97.25
From Node	MH	Geometry		
To Node	POND	Type	Con Span	Con Span
Link Count	1	Cross Section		
Flow Direction	Both	CONSPAN 24X8	CONSPAN 24X8	
Damping Threshold	0	Right click to select from a list of cross sections		
Length	75			
FHWA Culvert Code	79			
Entrance Loss Coefficient	0.25			
Exit Loss Coefficient	0			
Bend Loss Coefficient	0			
Bend Location	0			
Energy Switch	Energy			



# Channel Links

## Geometric Considerations

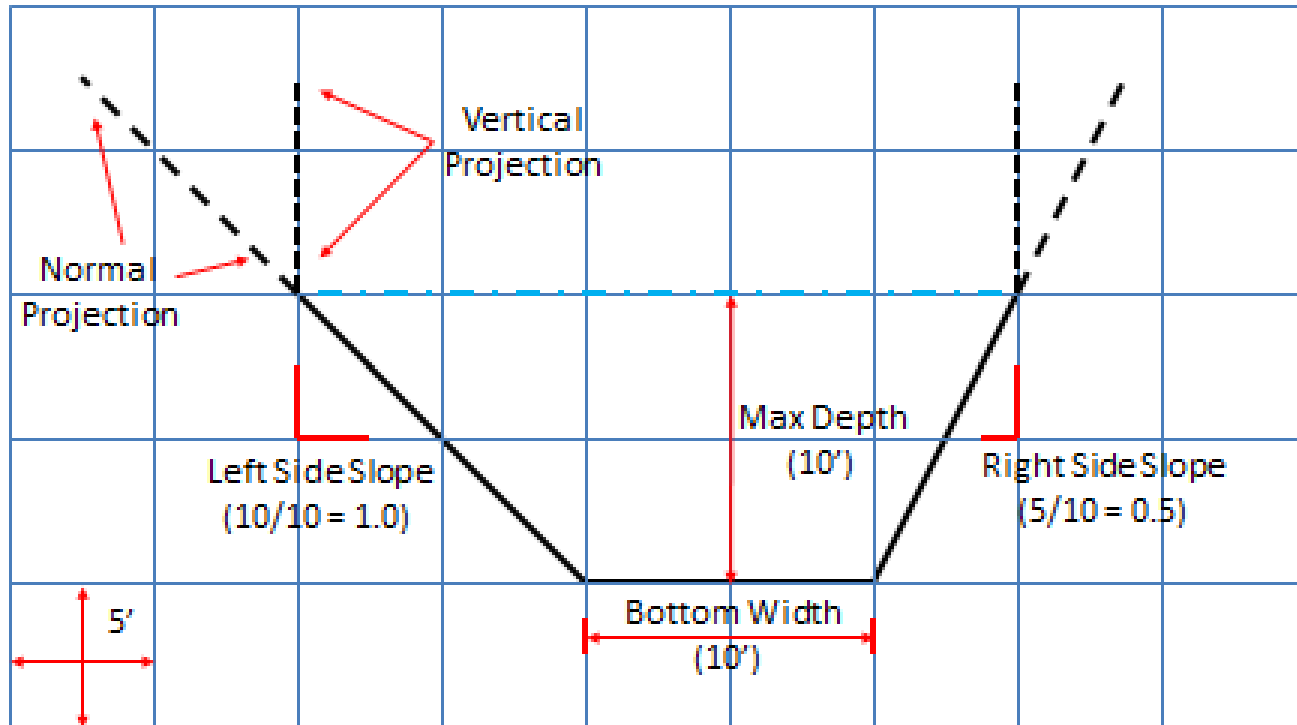
Drop Down List of  
Geometry Types

	Upstream	Downstream
Invert	<input type="text" value="0"/>	<input type="text" value="0"/>
Manning's N	<input type="text" value="0"/>	<input type="text" value="0"/>
	Geometry	
Type	<input type="text" value="Trapezoidal"/>	<input type="text" value="Parabolic"/>
Max Depth	<input type="text" value="0"/>	<input type="text" value="0"/>
Max Width		<input type="text" value="0"/>
Extrapolation Method	<input type="text" value="Normal Projection"/>	<input type="text" value="Normal Projection"/>
Bottom Width	<input type="text" value="0"/>	
Left Side Slope	<input type="text" value="0"/>	
Right Side Slope	<input type="text" value="0"/>	

# Channel Links

## Geometric Considerations

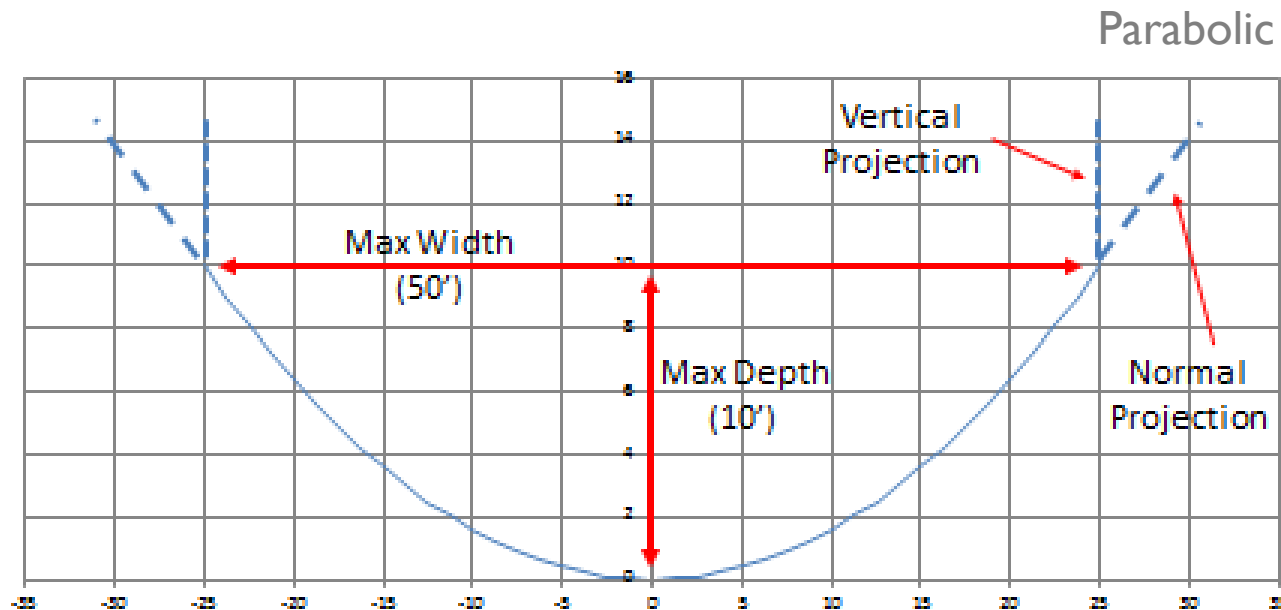
Trapezoidal



Wetted Perimeter Held Constant Above Max Depth

# Channel Links

## Geometric Considerations



Wetted Perimeter Held Constant Above Max Depth

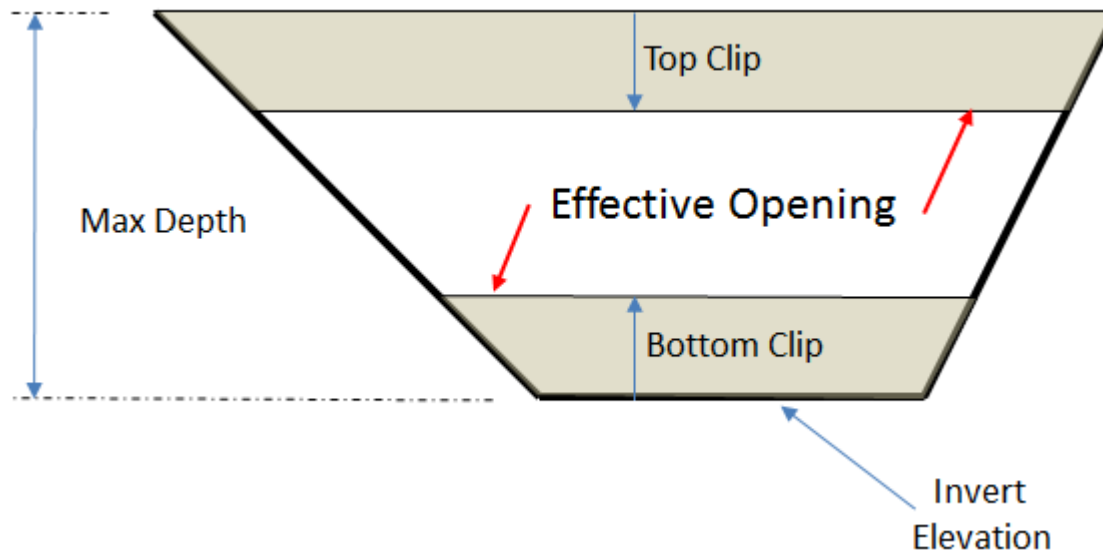
# Pipe & Channel Links

## Bottom and Top Clips

Bottom Clip		
Default Value	<input type="text" value="0"/>	<input type="text" value="0"/>
Operating Table	<input type="text"/>	<input type="text"/>
Reference Node	<input type="text"/>	<input type="text"/>
Manning's N	<input type="text" value="0"/>	<input type="text" value="0"/>
Top Clip		
Default Value	<input type="text" value="0"/>	<input type="text" value="0"/>
Operating Table	<input type="text"/>	<input type="text"/>
Reference Node	<input type="text"/>	<input type="text"/>
Manning's N	<input type="text" value="0"/>	<input type="text" value="0"/>

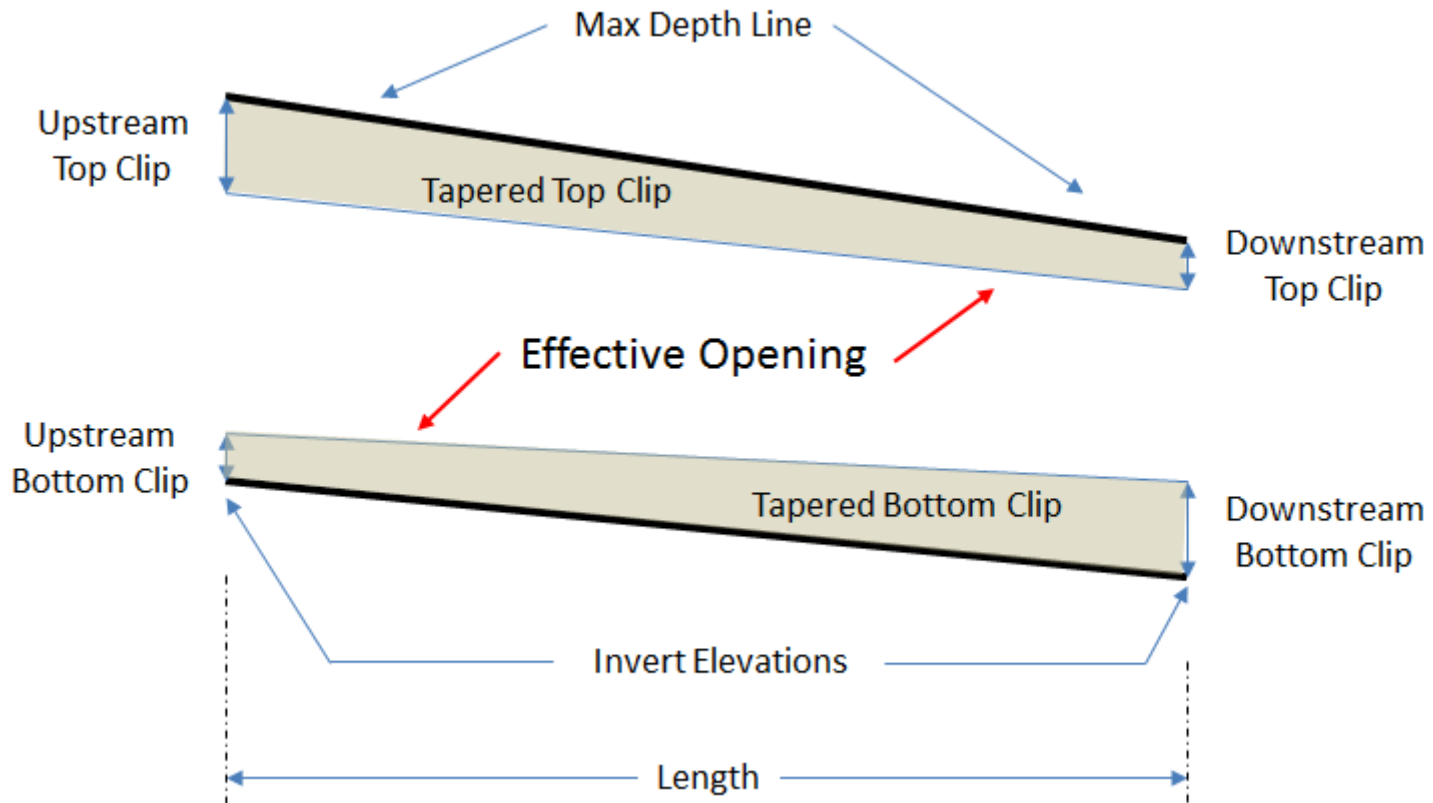
# Pipe & Channel Links

## Bottom and Top Clips



# Pipe & Channel Links

## Bottom and Top Clips



# Channel Links

## Placement of Irregular Cross Sections

Channel invert elevations are specified at each end of a channel link.

Upstream  
Node

Downstream  
Node

35.7'

Channel Link

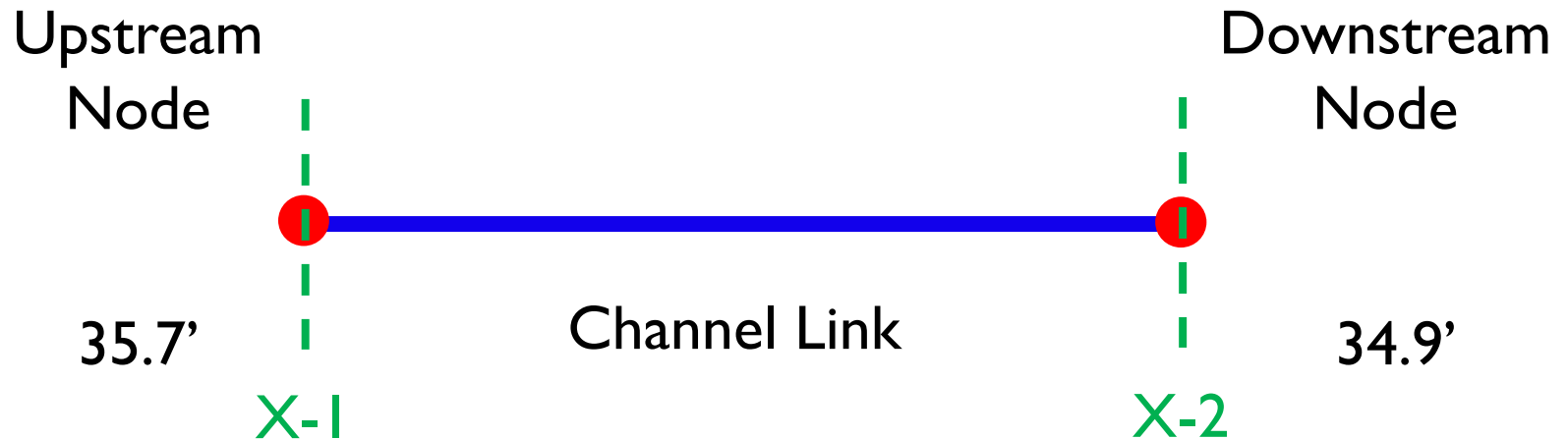
34.9'



# Channel Links

## Placement of Irregular Cross Sections

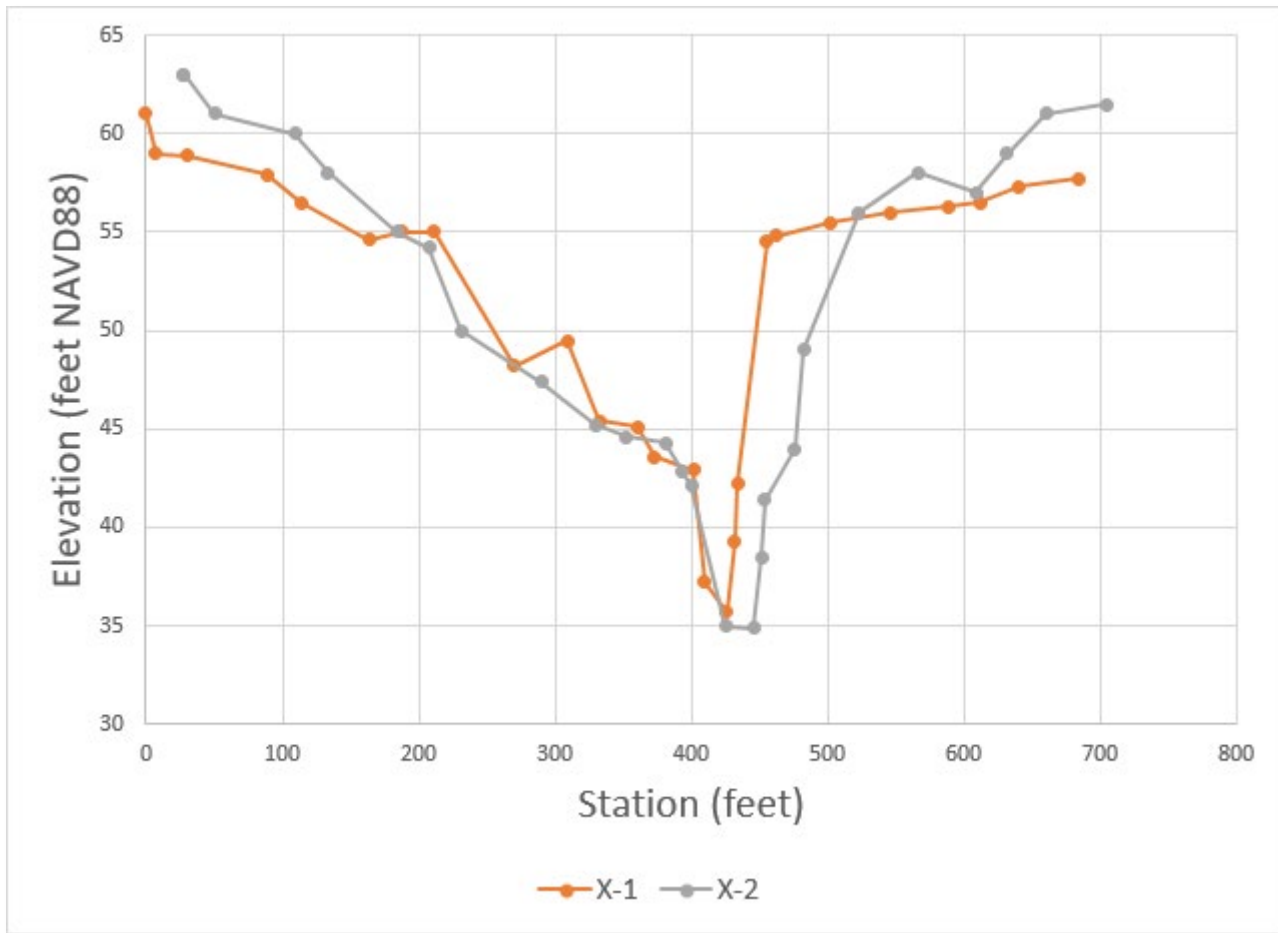
Typically, different cross sections are used at each end of the link for natural channels.





# Channel Links

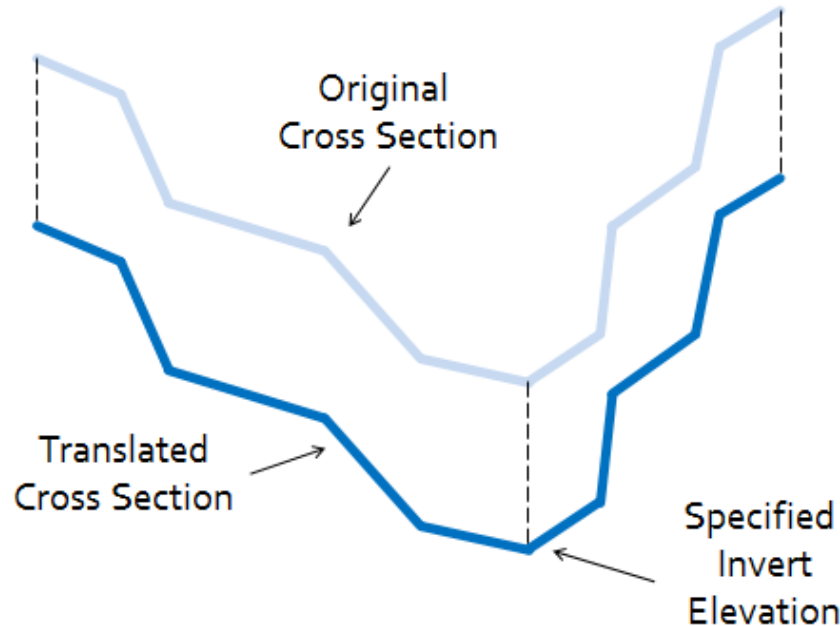
## Placement of Irregular Cross Sections



# Channel Links

## Placement of Irregular Cross Sections

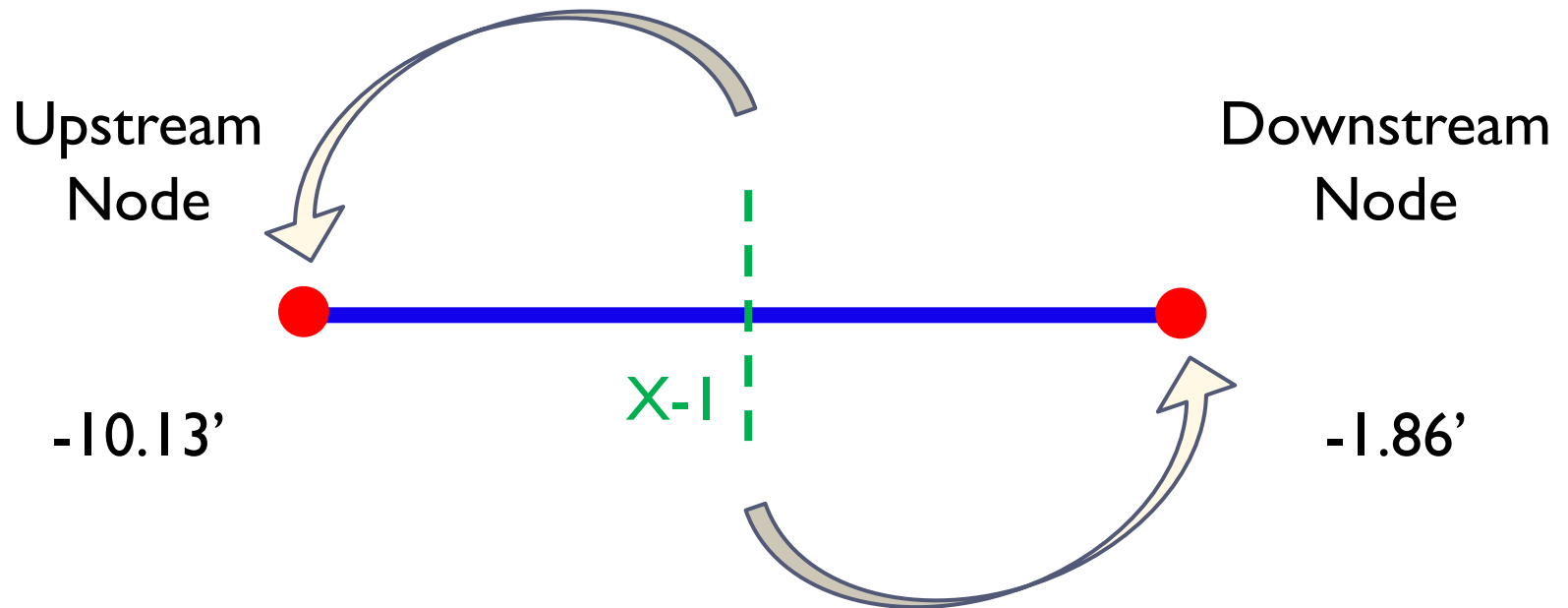
If a channel invert elevation is different than the low elevation of the corresponding channel cross section, then every data point in the cross section is translated vertically by a distance equal to the difference in elevation between the invert and the low spot on the cross section, including overbank areas.



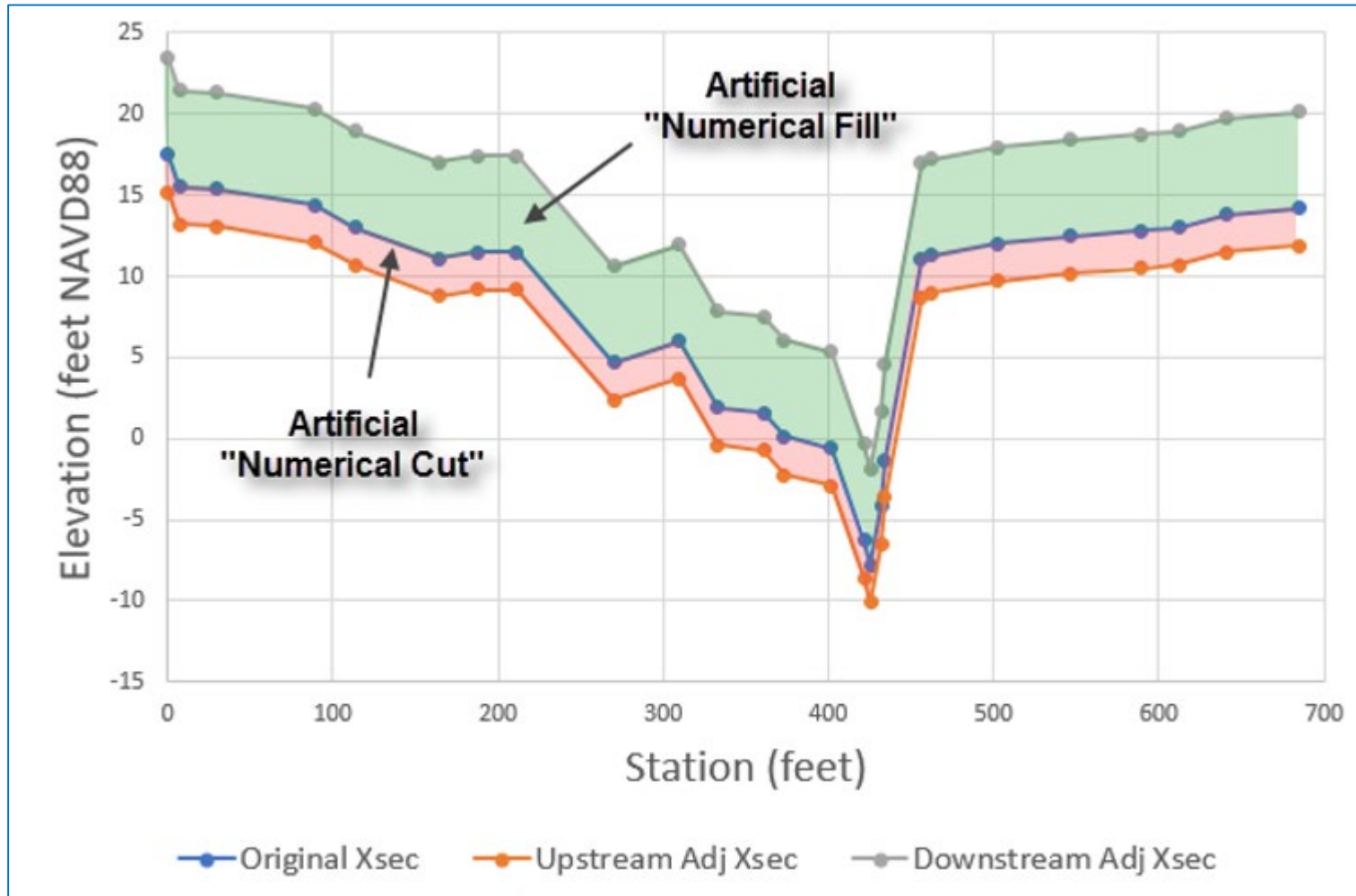
# Channel Links

## Placement of Irregular Cross Sections

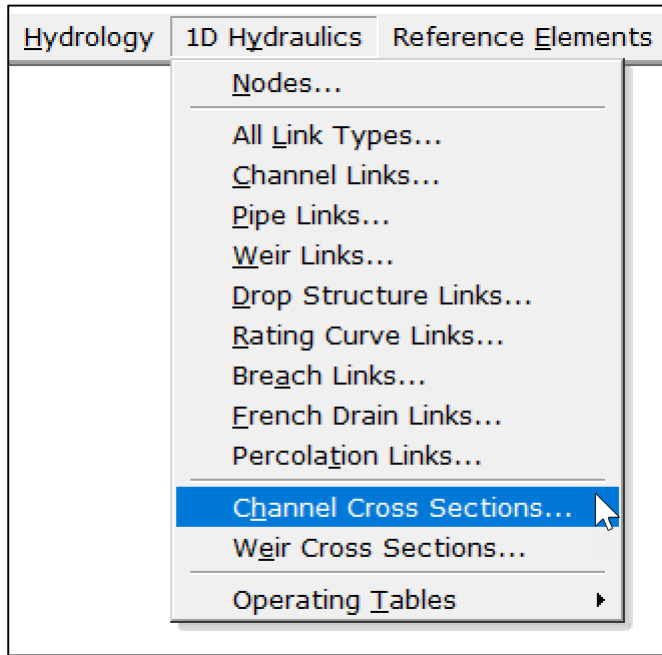
Be careful when applying the same cross section to both ends of a channel link!



If the terrain in the overbank areas does not follow the slope along the channel bottom, artificial cuts and fills can occur and potentially produce erroneous results.

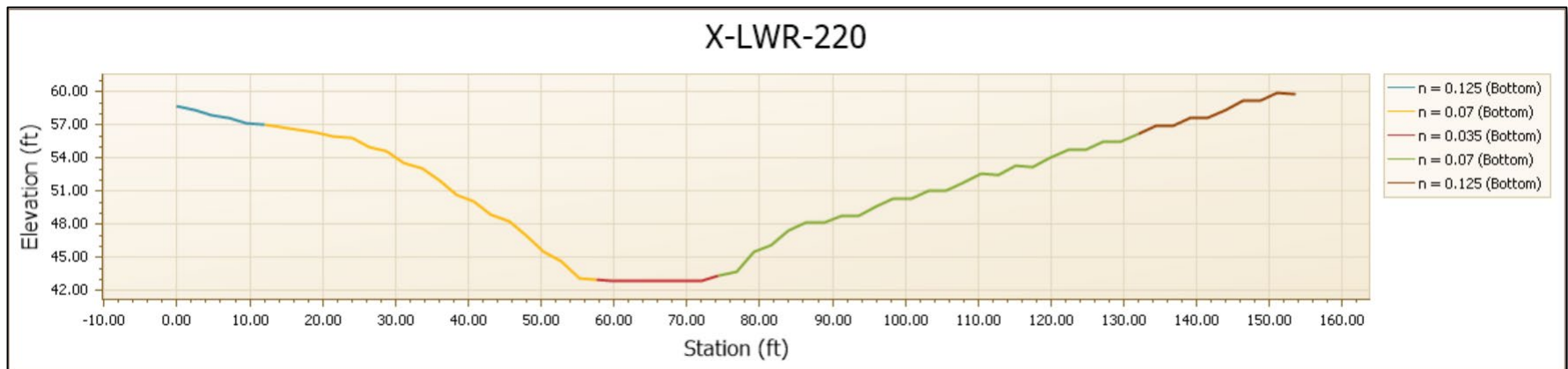


# Channel Cross Sections



Cross Section Bottom Point Edit

Order	Station	Elevation	Manning's N
0	0	58.666241	0.125
1	2.398465	58.337521	0.125
2	4.79693	57.895653	0.125
3	7.195395	57.579197	0.125
4	9.593861	57.14188	0.125
5	11.992326	57.026146	0.125
6	14.390791	56.832737	0.07
7	16.789256	56.523327	0.07
8	19.187721	56.328396	0.07
9	21.586186	56.005196	0.07
10	23.984652	55.806759	0.07
11	26.383117	54.958363	0.07
12	28.781582	54.635201	0.07



# Channel Cross Sections

## Conveyance Method “ICPR v3”

Name: X-LWR-220

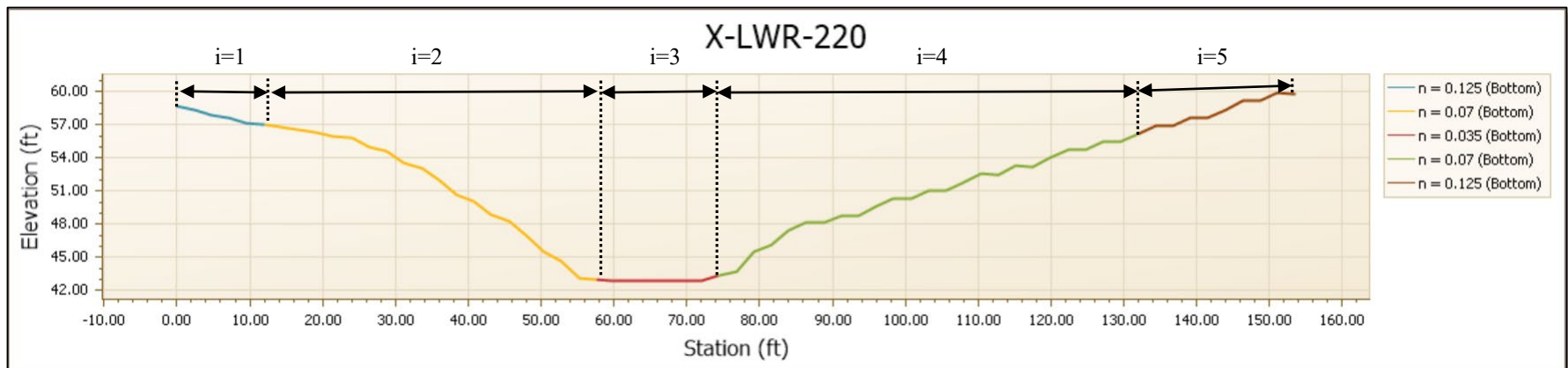
Scenario: Scenario1

Lid: No

Conveyance Method: ICPR v3

subdivides the conveyance calculation based on roughness

$$K = \sum_{i=1,S} \left[ \frac{1.486 R_i^{2/3} A_i}{n_i} \right]$$



# Channel Cross Sections

## Conveyance Method "HEC-RAS"

Conveyance Method:

Left Overbank Station:

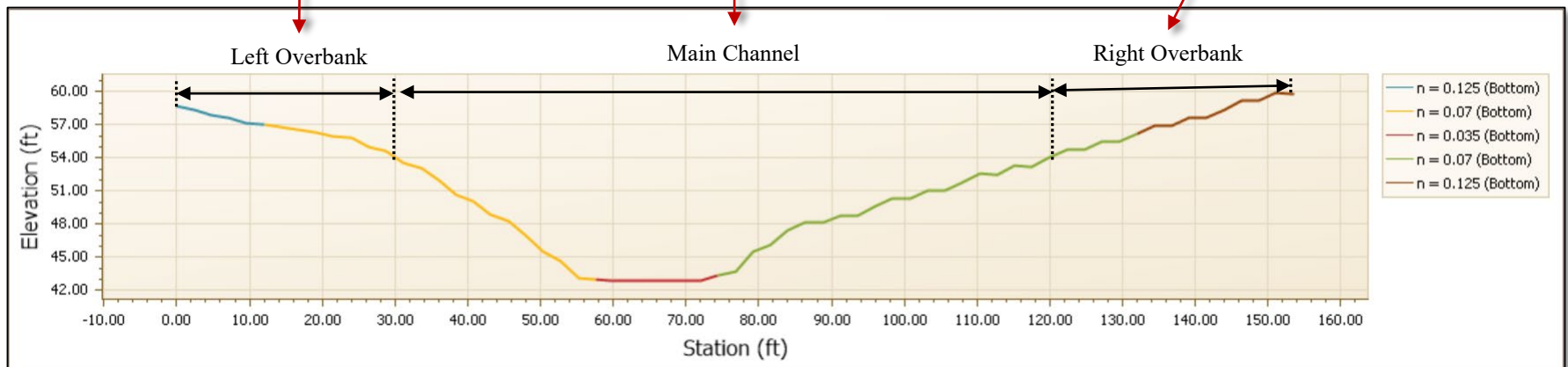
Right Overbank Station:

Composite n-value used for the main channel if side slopes steeper than 5H:1V

$$K = \sum_{i=1,S} \left[ \frac{1.486 R_i^{2/3} A_i}{n_i} \right]$$

$$n_c = \left[ \frac{\sum_{i=1,S} (P_i n_i^{1.5})}{P} \right]^{2/3}$$

$$K = \sum_{i=1,S} \left[ \frac{1.486 R_i^{2/3} A_i}{n_i} \right]$$



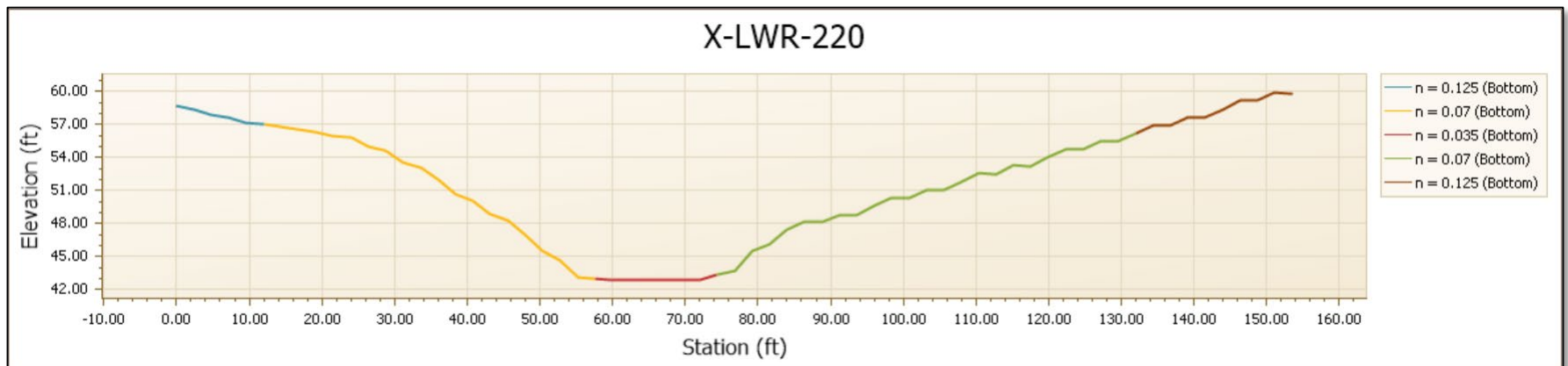
# Channel Cross Sections

## Conveyance Method “Composite Manning’s n”

Conveyance Method

$$n_c = \left[ \frac{\sum_{i=1,S} (P_i n_i^{1.5})}{P} \right]^{2/3}$$

The composite Manning’s n conveyance method calculates a composite n-value and conveyance at each unique elevation included in the data entered for the cross section by the user.



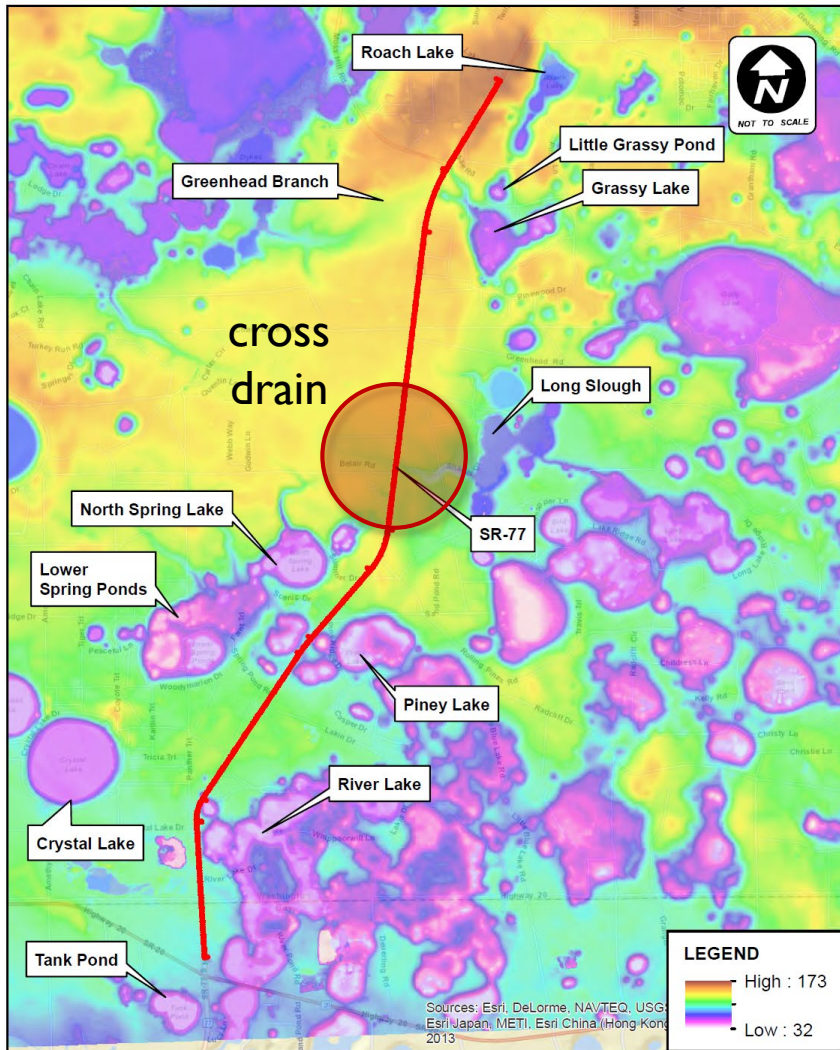


# Example #1

## Highway Cross Drain & Channel

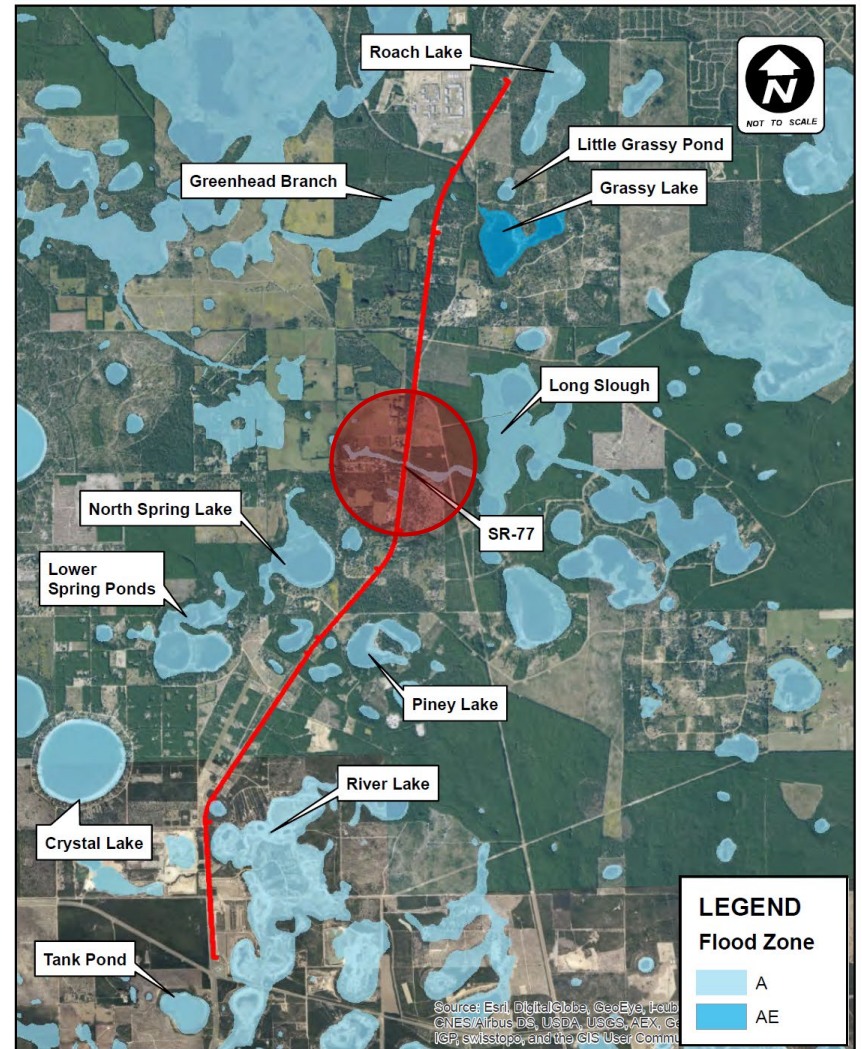
Acknowledgement:

ATKINS  
Drainage Report  
SR 77, from Bay County Line to North of CR 279  
Washington County, Florida



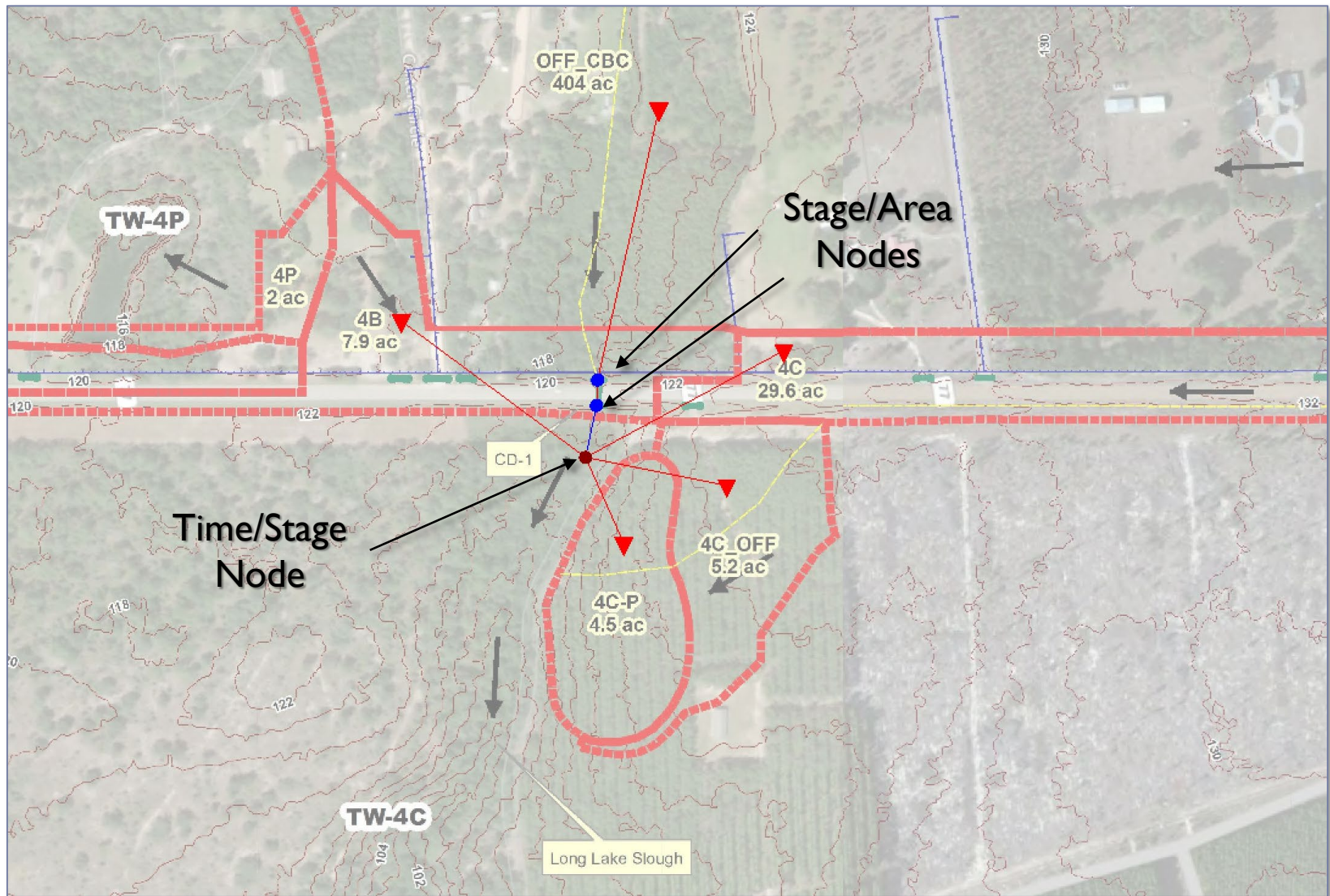
**SR-77  
 BAY CO. LINE TO CR 279  
 WASHINGTON COUNTY**

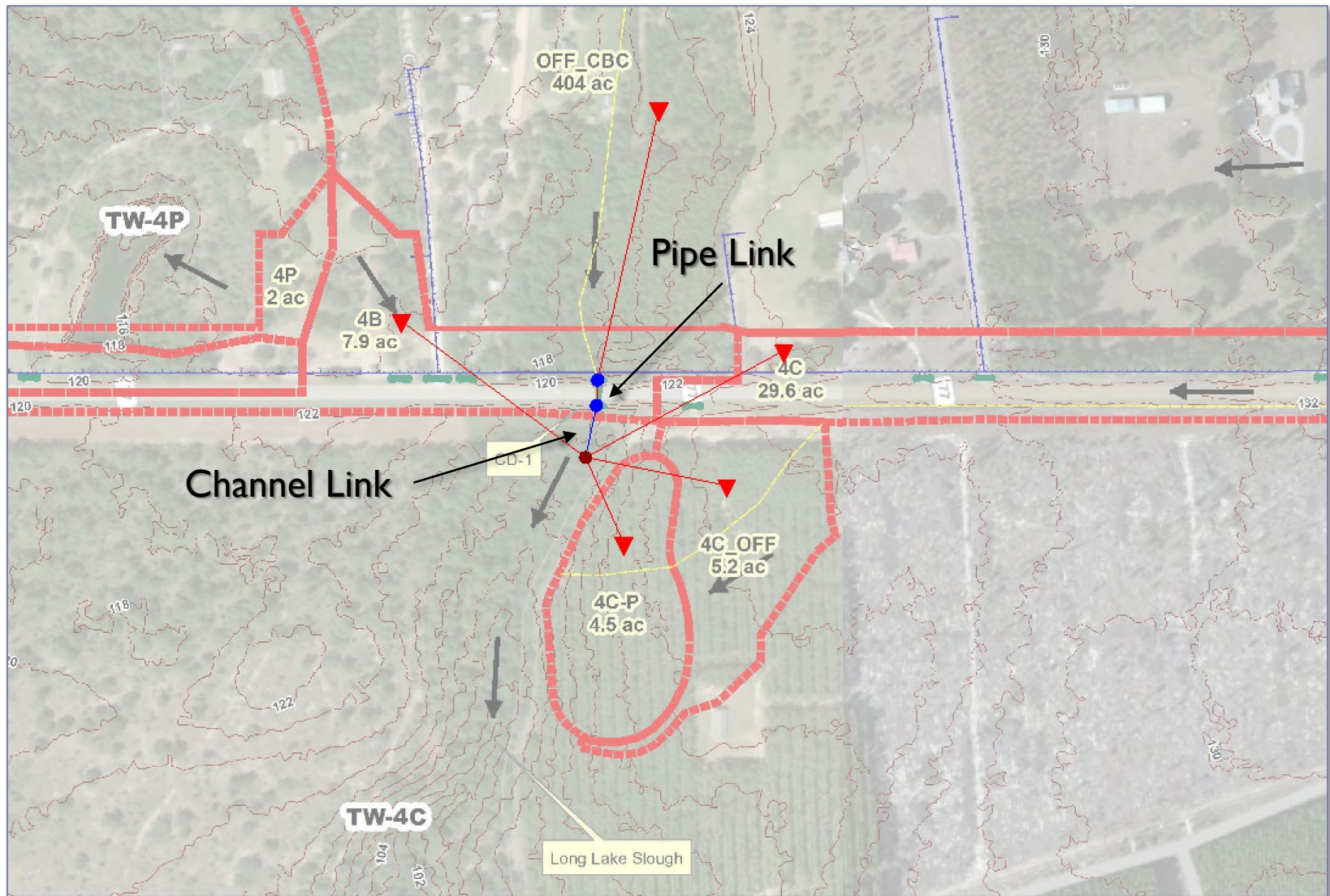
**FIGURE 4  
 TOPOGRAPHY MAP**

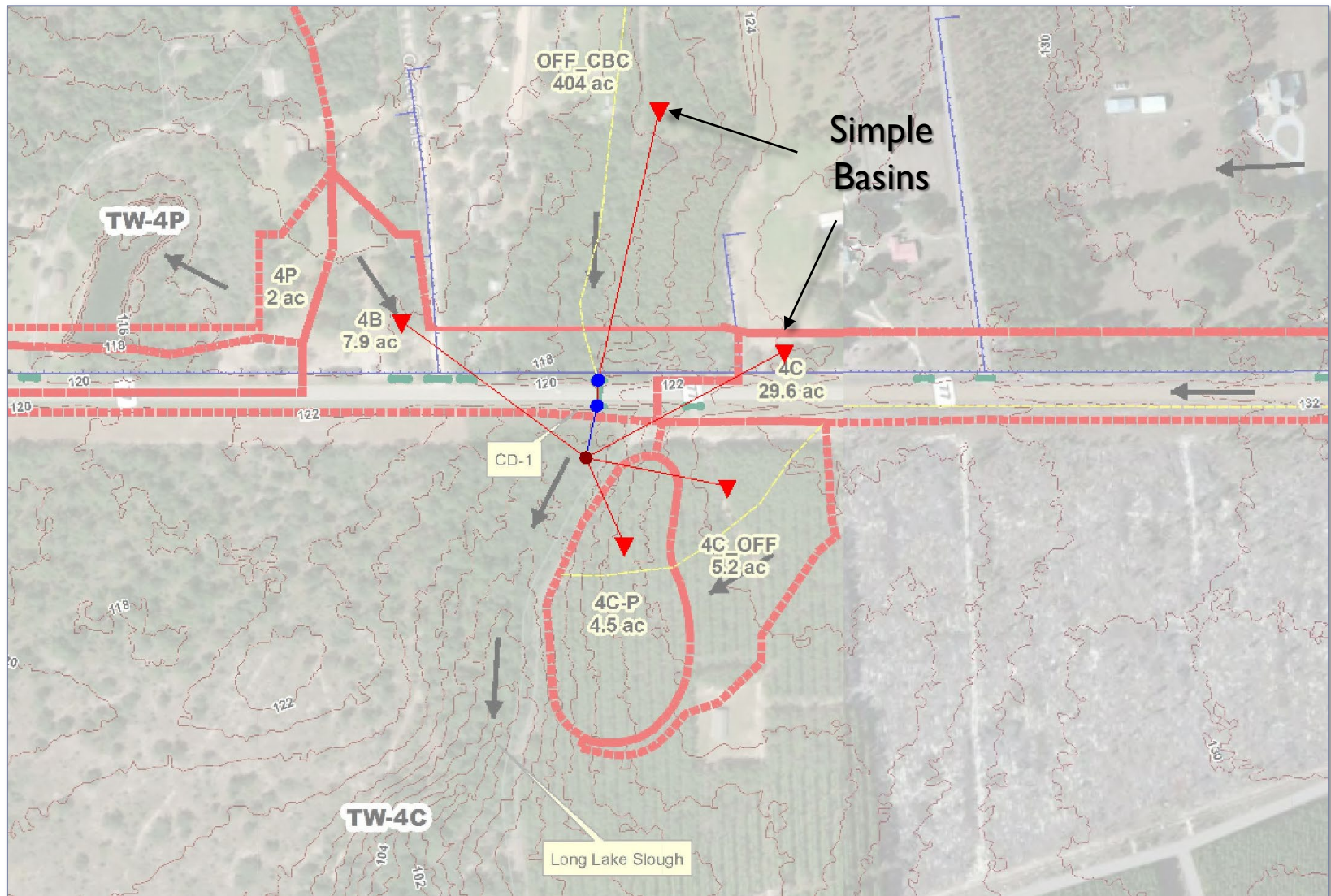


**SR-77  
 BAY CO. LINE TO CR 279  
 WASHINGTON COUNTY**

**FIGURE 6  
 FEMA FLOODPLAIN MAP**







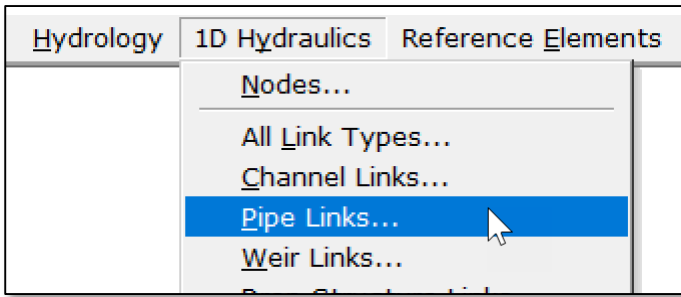
## Simple Basin Data Form

Name	OFF_CBC	Area	404
Scenario	Cross Drain	Curve Number	43
Node	US CROSSDRAIN	% Impervious	0
Hydrograph Method	NRCS Unit Hydrograph	% DCIA	0
Infiltration Method	Curve Number	% Direct	0
Time of Concentration	165	Rainfall Name	
Max Allowable Q	999999		
Time Shift	0		
Unit Hydrograph	Uh256		
Peaking Factor	256		

BASIN ID	LANDUSE TYPE	STATUS	Area (ac)	Impervious (ac)	Pervious (ac)	SOIL GROUP	CN	CN x A	CCN
OFF_CBC	Open-Space	ROW	0.29			A	39	11.43	
OFF_CBC	Roads-Dirt	ROW	0.02			A	72	1.38	
OFF_CBC	Woods	ROW	0.20			A	30	6.14	
OFF_CBC	Open-Space	ROW	1.99			A/D	80	158.91	
OFF_CBC	Impervious	ROW	0.14			A/D	98	13.47	
OFF_CBC	Woods	ROW	0.13			A/D	77	9.72	
		<b>ROW Total</b>	<b>2.77</b>	0.16	2.61				
OFF_CBC	Woods	OFFSITE	88.05			A	30	2641.51	
OFF_CBC	Woods-Tree Farm	OFFSITE	82.05			A	35	2871.90	
OFF_CBC	Woods-Grass	OFFSITE	9.82			A	45	442.01	
OFF_CBC	Roads-Dirt	OFFSITE	4.18			A	72	301.09	
OFF_CBC	Open-Space	OFFSITE	154.46			A	39	6023.94	
OFF_CBC	Impervious	OFFSITE	1.42			A	98	139.24	
OFF_CBC	Fallow	OFFSITE	43.87			A	77	3377.98	
OFF_CBC	Roads-Dirt	OFFSITE	0.27			A/D	89	24.12	
OFF_CBC	Woods	OFFSITE	5.04			A/D	77	387.83	
OFF_CBC	Impervious	OFFSITE	0.37			A/D	98	36.26	
OFF_CBC	Open-Space	OFFSITE	11.86			A/D	80	949.05	
		<b>OFFSITE Total</b>	<b>401.40</b>	5.97	395.43				
<b>OFF_CBC Total</b>			<b>404.17</b>	<b>6.13</b>	<b>398.04</b>			<b>17395.97</b>	<b>43.0</b>

CN  
Worksheet

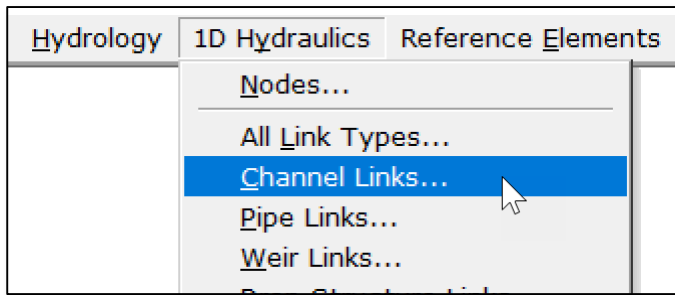
# Pipe Data Form



Name	CROSSDRAIN
Scenario	Cross Drain
From Node	US CROSSDRAIN
To Node	DS CROSSDRAIN
Link Count	1
Flow Direction	Both
Damping Threshold	0
Length	66
FHWA Culvert Code	9
Entrance Loss Coefficient	0.5
Exit Loss Coefficient	0.5
Bend Loss Coefficient	0
Bend Location	0
Energy Switch	Energy

	Upstream	Downstream
Invert	113.82	114.35
Manning's N	0.012	0.012
Geometry		
Type	Rectangular	Rectangular
Max Depth	4	4
Max Width	5	5
Fillet	0	0

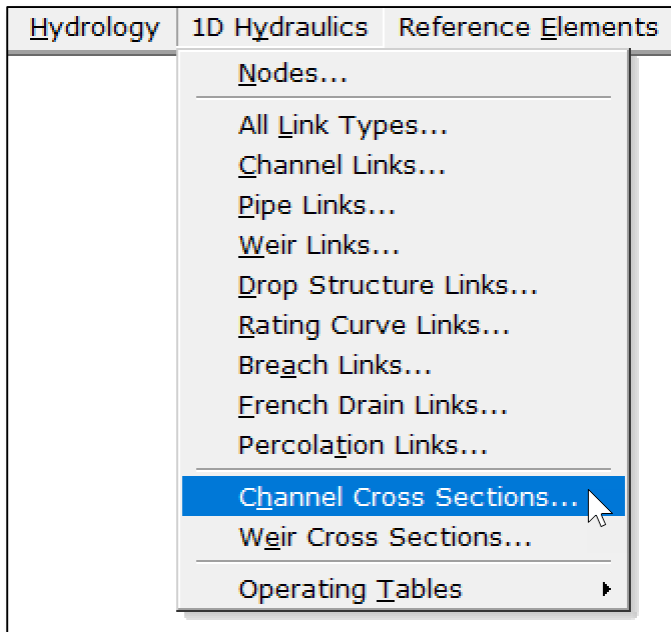
# Channel Data Form



Name	DITCH
Scenario	Cross Drain
From Node	DS CROSSDRAIN
To Node	TW-4C
Link Count	1
Flow Direction	Both
Damping Threshold	0
Length	170
Contraction Coefficient	0.1
Expansion Coefficient	0.3
Entrance Loss Coefficient	0
Exit Loss Coefficient	0
Bend Loss Coefficient	0
Bend Location	0
Energy Switch	Energy

	Upstream	Downstream
Invert	114.35	113.7
Geometry		
Type	Irregular	Irregular
Main Cross Section	CD CHANNEL	CD CHANNEL





# Channel Cross Section Data Form

Name: CD CHANNEL

Scenario: Cross Drain

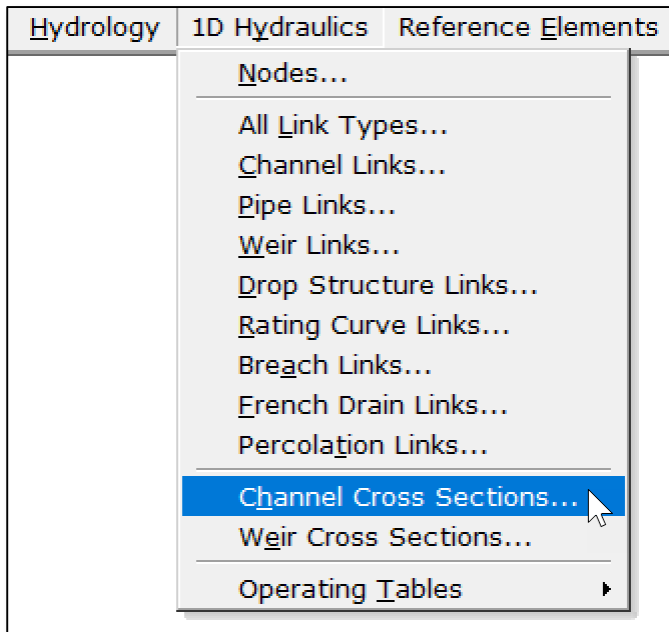
Lid: No

Conveyance Method: ICPR v3

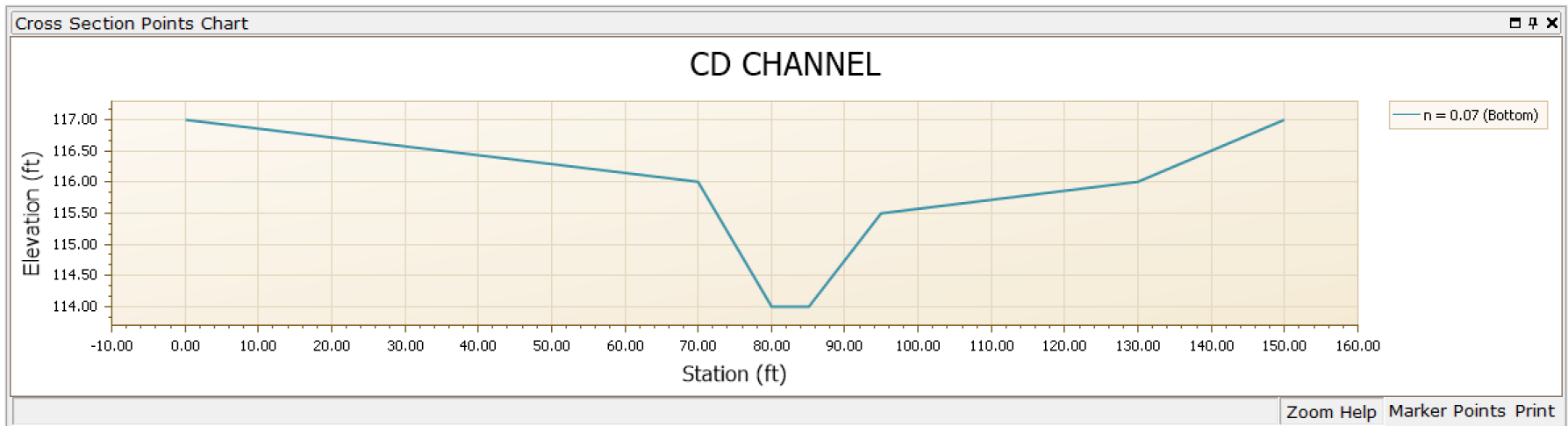
Cross Section Bottom Point Edit

Order	Station	Elevation	Manning's N
0	0	117	0.07
1	70	116	0.07
2	80	114	0.07
3	85	114	0.07
4	95	115.5	0.07
5	130	116	0.07
6	150	117	0.07

# Channel Cross Section Data Form



Name	CD CHANNEL
Scenario	Cross Drain
Lid	No
Conveyance Method	ICPR v3



# “Capture View” for Custom Report

Graphic View

Menu ▾ | Grid | Polyline | Simple Basin | Point | Exclusion | Exclusion

General

Graphic Elements On

- Display
- Scenarios
  - Cross Drain
  - Hydraulic Network
    - Node Types
    - Link Types
    - Simple Basin
      - Symbol
      - Text
    - Manual Basin
    - Mapped Basin
    - Cross Section Types
  - Reference Elements
  - Overland Flow Regions
  - Groundwater Regions
  - Map Layers
    - Background Images

#1 right click

- Import
- Pyramid
- Capture View
- Expand All Below
- Collapse All Below

#2 select “Capture View”

#3 name view & pull window

4B

US CROSSDRAIN

DS CROSSDRAIN

TW-4C

CROSSDRAIN

DITCH

4C

4C-P

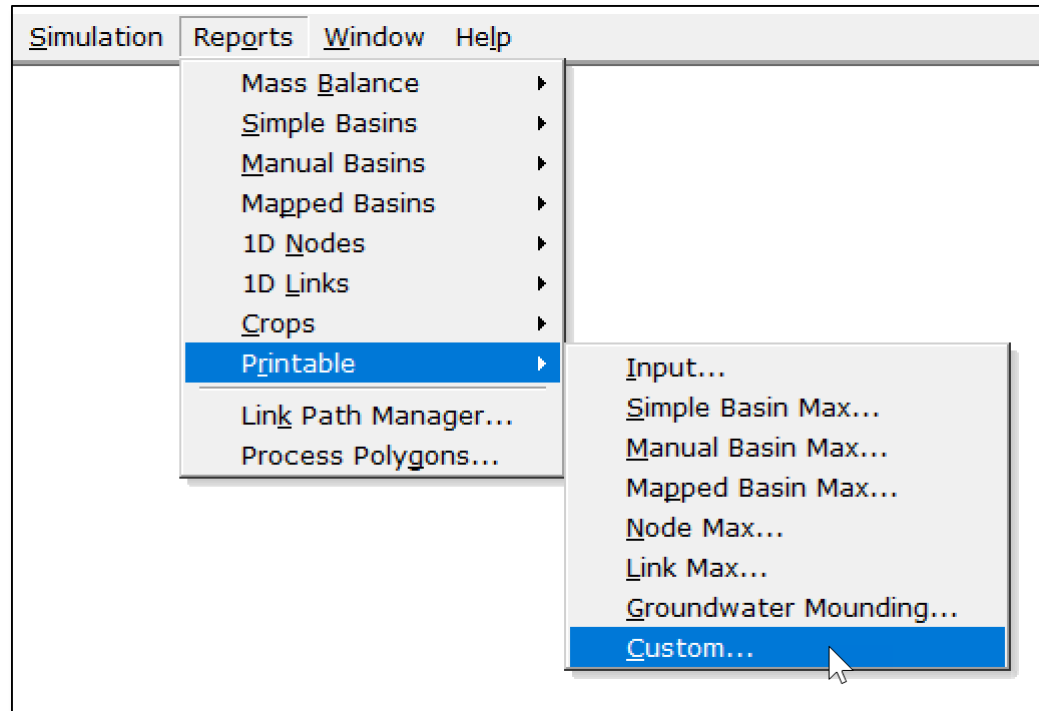
4C-OFF

OFF\_CBC

# “Capture View” for Custom Report

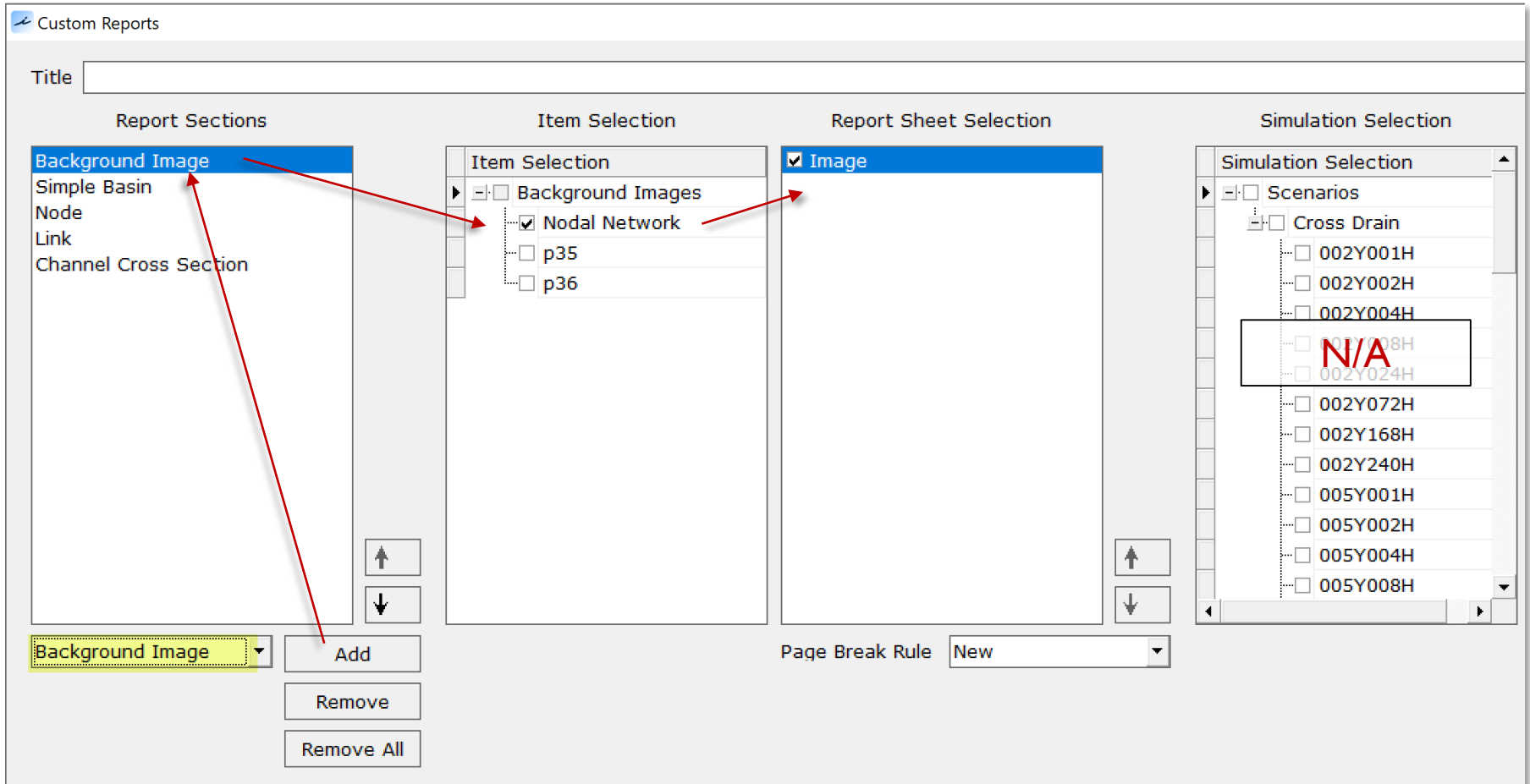
The screenshot displays the 'Graphic View' software interface. The top toolbar includes various drawing and editing tools, with 'Simple Basin' selected in the dropdown menu. The left sidebar, titled 'General', contains a tree view of 'Graphic Elements On'. Under the 'Display' section, 'Scenarios' is expanded, showing 'Cross Drain' (unchecked), 'Hydraulic Network' (checked), and 'Node Types' (checked). Under 'Map Layers', 'Background Images' is expanded, showing 'Nodal Network' (checked and highlighted in yellow), 'p35', and 'p36'. The main workspace shows a hydraulic network diagram with nodes and links. Nodes are labeled 'US CROSSDRAIN', 'DS CROSSDRAIN', 'TW-4C', 'CROSSDRAIN', and 'DITCH'. Links are labeled '4B', 'OFF\_CBC', '4C', '4C-OFF', and '4C-P'. Red arrows indicate flow direction from the nodes to the links.

# Preparing a Custom Report



# Preparing a Custom Report

## Background Image



# Preparing a Custom Report

## Simple Basin

The screenshot displays the 'Custom Reports' configuration window. It is divided into four main sections: Report Sections, Item Selection, Report Sheet Selection, and Simulation Selection.

- Report Sections:** A list of report sections including 'Background Image', 'Simple Basin' (highlighted in blue), 'Node', 'Link', and 'Channel Cross Section'. Below this list is a dropdown menu showing 'Simple Basin' and buttons for 'Add', 'Remove', and 'Remove All'.
- Item Selection:** A tree view showing a hierarchy of items. Under 'Scenarios', there is a sub-section 'Cross Drain' containing items '4B', '4C', '4C-OFF', '4C-P', and 'OFF\_CBC'. The 'OFF\_CBC' item is checked.
- Report Sheet Selection:** A list of report sheets with checkboxes. 'Input Report' and 'Runoff Summary Report' are checked. Other items include 'Mass Balance Summary Report', 'Runoff Rate Chart', and 'Runoff Volume Chart'.
- Simulation Selection:** A list of simulation IDs with checkboxes. A red rounded rectangle highlights a group of checked items: '025Y001H', '025Y002H', '025Y004H', '025Y008H', '025Y024H', '025Y072H', '025Y096H', '025Y168H', and '025Y240H'. Other items include '010Y072H', '010Y168H', '010Y240H', '050Y001H', and '050Y002H'.

At the bottom of the window, there is a 'Page Break Rule' dropdown menu set to 'New'.

# Preparing a Custom Report Node

The screenshot displays the 'Custom Reports' window with four main sections: Report Sections, Item Selection, Report Sheet Selection, and Simulation Selection. Red arrows indicate the workflow: selecting 'Node' in Report Sections, choosing 'US CROSSDRAIN' in Item Selection, selecting 'Input Report' and 'Max Conditions Report' in Report Sheet Selection, and finally selecting a group of simulation nodes (025Y001H through 025Y240H) in Simulation Selection.

**Report Sections**

- Background Image
- Simple Basin
- Node**
- Link
- Channel Cross Section

**Item Selection**

- Item Selection
  - Scenarios
    - Cross Drain
      - DS CROSSDRAIN
      - TW-4C
      - US CROSSDRAIN

**Report Sheet Selection**

- Input Report**
- Input Chart
- Max Conditions Report
- Max Conditions Report (with T)
- Mass Balance Condensed Repo
- Mass Balance Detailed Report
- Stage Chart
- Stage Chart (with Warning Sta
- Stage % Exceedance Chart
- Stage % Exceedance Chart (w
- Stage Raster Chart
- Surface Area % Exceedance C
- Depth Above Warning Raster C

**Simulation Selection**

- Simulation Selection
  - 010Y168H
  - 010Y240H
  - 025Y001H
  - 025Y002H
  - 025Y004H
  - 025Y008H
  - 025Y024H
  - 025Y072H
  - 025Y096H
  - 025Y168H
  - 025Y240H
  - 050Y001H
  - 050Y002H
  - 050Y004H

Page Break Rule: New



# Preparing a Custom Report Link

The screenshot displays the 'Custom Reports' window with four main sections: Report Sections, Item Selection, Report Sheet Selection, and Simulation Selection. Red arrows indicate the workflow: selecting 'Link' in Report Sections, adding it to the Item Selection list, selecting 'CROSSDRAIN' in Item Selection, adding it to the Report Sheet Selection list, and selecting 'Min/Max Conditions Report' in Report Sheet Selection. The Simulation Selection list is also visible, with a red box highlighting several simulation IDs.

**Report Sections**

- Background Image
- Simple Basin
- Node
- Link**
- Channel Cross Section

**Item Selection**

- Item Selection
  - Scenarios
    - Cross Drain
      - CROSSDRAIN
      - DITCH

**Report Sheet Selection**

- Input Report (Full)
- Input Report (Condensed)
- Min/Max Conditions Report
- Min/Max Conditions Report (with...)
- Flow Chart
- Average Velocity Chart
- Downstream Velocity Chart
- Upstream Velocity Chart
- Flow % Exceedance Chart
- Flow Raster Chart

**Simulation Selection**

- Simulation Selection
  - 010Y168H
  - 010Y240H
  - 025Y001H
  - 025Y002H
  - 025Y004H
  - 025Y008H
  - 025Y024H
  - 025Y072H
  - 025Y096H
  - 025Y168H
  - 025Y240H
  - 050Y001H
  - 050Y002H
  - 050Y004H

Page Break Rule: New

# Preparing a Custom Report

## Channel Cross Section

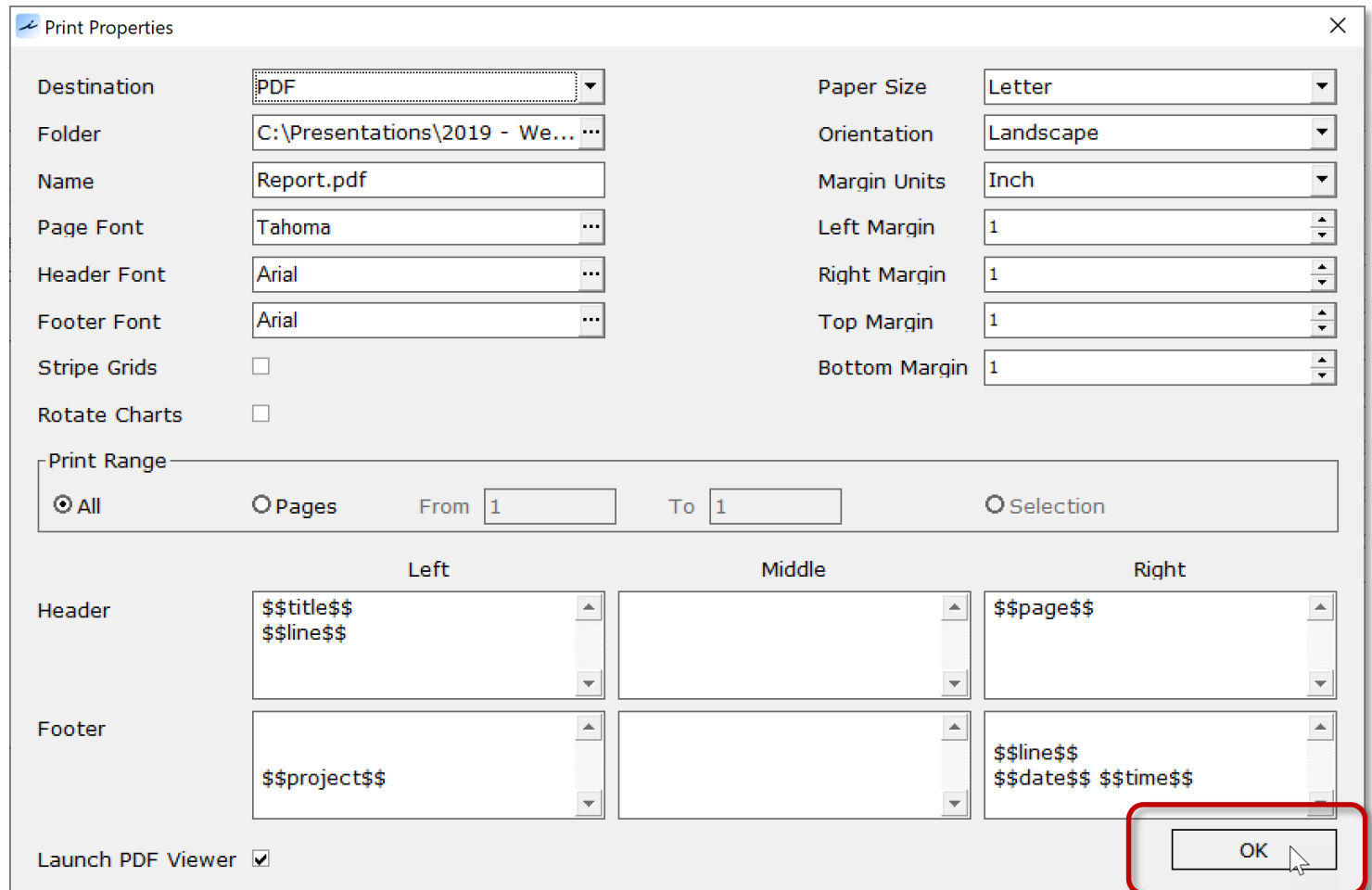
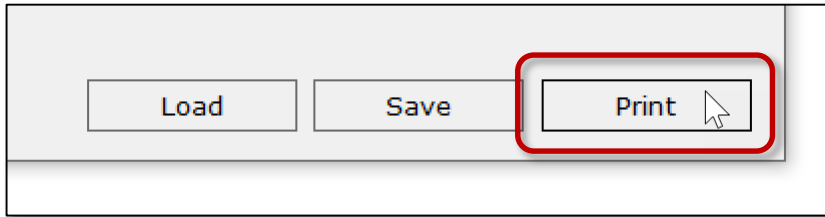
The screenshot displays the 'Custom Reports' configuration window. It is divided into four main sections: Report Sections, Item Selection, Report Sheet Selection, and Simulation Selection.

- Report Sections:** A list of report types including 'Background Image', 'Simple Basin', 'Node', 'Link', and 'Channel Cross Section'. The 'Channel Cross Section' option is selected and highlighted in blue. A red arrow points from this option to the 'Item Selection' panel.
- Item Selection:** A tree view showing selected items. Under 'Scenarios', 'Cross Drain' is expanded, and 'CD CHANNEL' is selected. A red arrow points from 'CD CHANNEL' to the 'Report Sheet Selection' panel.
- Report Sheet Selection:** A list of report sheets with checkboxes. 'Input Report' and 'Input Chart' are checked. A red arrow points from 'Input Report' to the 'Simulation Selection' panel.
- Simulation Selection:** A tree view showing simulation scenarios. Under 'Scenarios', 'Cross Drain' is expanded, and several scenarios are listed, including '002Y001H' through '005Y008H'. A red box highlights the 'N/A' text next to '002Y024H'.

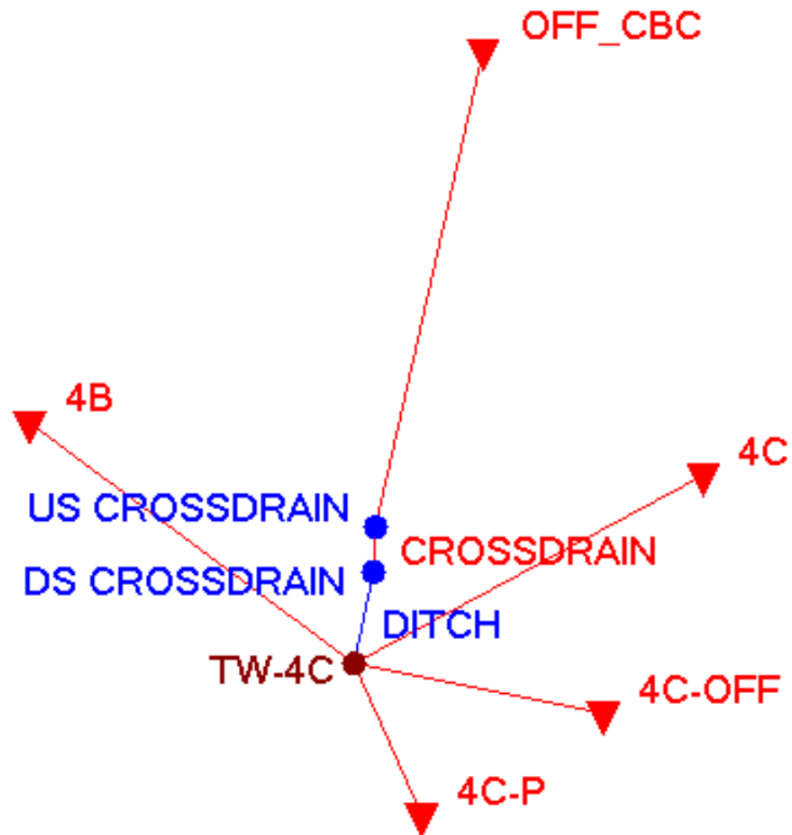
At the bottom of the 'Report Sections' panel, there is a dropdown menu showing 'Channel Cross Sect...', an 'Add' button, and 'Remove' and 'Remove All' buttons. The 'Page Break Rule' is set to 'Join'.

# Preparing a Custom Report

## Print Control



Background Image: Nodal Network



Simple Basin: OFF\_CBC

## Input Data

Scenario: Cross Drain  
 Node: US CROSSDRAIN  
 Hydrograph Method: NRCS Unit Hydrograph  
 Infiltration Method: Curve Number  
 Time of Concentration: 165.0000 min  
 Max Allowable Q: 999999.00 cfs  
 Time Shift: 0.0000 hr  
 Unit Hydrograph: Uh256  
 Peaking Factor: 256.0  
 Area: 404.0000 ac  
 Curve Number: 43.0  
 % Impervious: 0.00  
 % DCIA: 0.00  
 % Direct: 0.00  
 Rainfall Name:

Comment:

## Basin Runoff Summary

Simple Basin Runoff Summary [Cross Drain]

Basin Name	Sim Name	Max Flow [cfs]	Time to Max Flow [hrs]	Total Rainfall [in]	Total Runoff [in]	Area [ac]	Equivalent Curve Number	% Imperv	% DCIA
OFF_CBC	025Y001H	7.99	2.5667	3.80	0.06	404.0000	43.0	0.00	0.00
OFF_CBC	025Y002H	24.90	3.2667	4.80	0.24	404.0000	43.0	0.00	0.00
OFF_CBC	025Y004H	53.52	4.7500	6.00	0.55	404.0000	43.0	0.00	0.00
OFF_CBC	025Y008H	70.94	6.8000	7.30	1.13	404.0000	43.0	0.00	0.00
OFF_CBC	025Y024H	80.96	19.9667	10.00	2.62	404.0000	43.0	0.00	0.00
OFF_CBC	025Y072H	95.87	61.3833	12.20	3.98	404.0000	43.0	0.00	0.00
OFF_CBC	025Y096H	187.64	62.0000	13.00	4.54	404.0000	43.0	0.00	0.00
OFF_CBC	025Y168H	103.28	160.5167	14.50	5.59	404.0000	43.0	0.00	0.00
OFF_CBC	025Y240H	124.91	184.6000	16.00	6.70	404.0000	43.0	0.00	0.00

Node: US CROSSDRAIN

## Input Data

Scenario: Cross Drain  
 Type: Stage/Area  
 Base Flow: 0.00 cfs  
 Initial Stage: 113.82 ft  
 Warning Stage: 122.20 ft

Comment:

## Node Max Conditions

Node Max Conditions [Cross Drain]

Node Name	Sim Name	Warning Stage [ft]	Max Stage [ft]	Min/Max Delta Stage [ft]	Max Total Inflow [cfs]	Max Total Outflow [cfs]	Max Surface Area [ft2]
US CROSSDRAIN	025Y001H	122.20	115.33	0.0010	7.99	8.06	330
US CROSSDRAIN	025Y002H	122.20	116.10	0.0010	24.90	24.90	330
US CROSSDRAIN	025Y004H	122.20	117.02	0.0010	53.52	53.55	330
US CROSSDRAIN	025Y008H	122.20	117.48	0.0010	70.94	71.00	330
US CROSSDRAIN	025Y024H	122.20	117.74	0.0010	80.96	81.01	330
US CROSSDRAIN	025Y072H	122.20	118.16	0.0010	95.87	95.92	330
US CROSSDRAIN	025Y096H	122.20	120.14	0.0010	187.63	187.65	330
US CROSSDRAIN	025Y168H	122.20	118.36	0.0010	103.28	103.28	330
US CROSSDRAIN	025Y240H	122.20	118.93	0.0010	124.91	124.96	330

Pipe Link: CROSSDRAIN	Upstream	Downstream
Scenario: Cross Drain	Invert: 113.82 ft	Invert: 114.35 ft
From Node: US CROSSDRAIN	Manning's N: 0.0120	Manning's N: 0.0120
To Node: DS CROSSDRAIN	Geometry: Rectangular	Geometry: Rectangular
Link Count: 1	Max Depth: 4.00 ft	Max Depth: 4.00 ft
Flow Direction: Both	Max Width: 5.00 ft	Max Width: 5.00 ft
Damping: 0.0000 ft	Fillet: 0.00 ft	Fillet: 0.00 ft
Length: 66.00 ft	Bottom Clip	
FHWA Code: 9	Default: 0.00 ft	Default: 0.00 ft
Entr Loss Coef: 0.50	Op Table:	Op Table:
Exit Loss Coef: 0.50	Ref Node:	Ref Node:
Bend Loss Coef: 0.00	Manning's N: 0.0120	Manning's N: 0.0120
Bend Location: 0.00 ft	Top Clip	
Energy Switch: Energy	Default: 0.00 ft	Default: 0.00 ft
	Op Table:	Op Table:
	Ref Node:	Ref Node:
	Manning's N: 0.0120	Manning's N: 0.0120
Comment:		

## Input Data

Link Min/Max Conditions [Cross Drain]

Link Name	Sim Name	Max Flow [cfs]	Min Flow [cfs]	Min/Max Delta Flow [cfs]	Max Us Velocity [fps]	Max Ds Velocity [fps]	Max Avg Velocity [fps]
CROSSDRAIN	025Y001H	8.06	0.00	-0.17	1.07	1.78	1.42
CROSSDRAIN	025Y002H	24.90	0.00	-0.11	2.19	3.32	2.75
CROSSDRAIN	025Y004H	53.55	0.00	0.09	3.34	5.05	4.20
CROSSDRAIN	025Y008H	71.00	0.00	-0.13	3.88	6.16	5.02
CROSSDRAIN	025Y024H	81.01	0.00	0.20	4.13	6.77	5.45
CROSSDRAIN	025Y072H	95.92	0.00	-0.98	4.80	7.65	6.23
CROSSDRAIN	025Y096H	187.65	0.00	0.98	9.38	10.65	10.02
CROSSDRAIN	025Y168H	103.28	0.00	-0.98	5.16	8.07	6.62
CROSSDRAIN	025Y240H	124.96	0.00	0.98	6.25	9.28	7.76

## Link Min/Max Conditions



# Custom Report (Channel Cross Section)

Channel Cross Section: CD CHANNEL

Scenario: Cross Drain

Lid: No

Conveyance Method: ICPRv3

Bottom Point Table

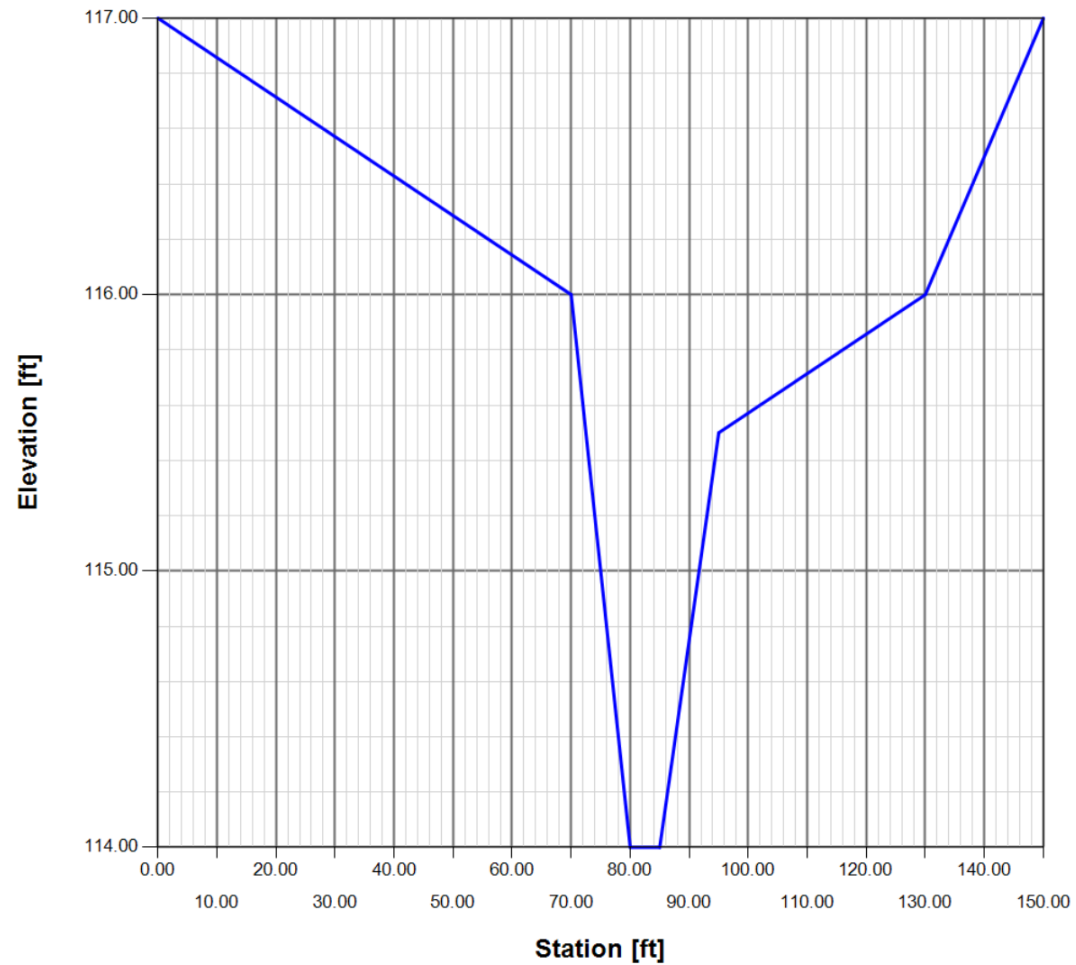
Order	Station [ft]	Elevation [ft]	Manning's N
0	0.00	117.00	0.0700
1	70.00	116.00	0.0700
2	80.00	114.00	0.0700
3	85.00	114.00	0.0700
4	95.00	115.50	0.0700
5	130.00	116.00	0.0700
6	150.00	117.00	0.0700

Comment:

## Input Data

Channel Cross Section: CD CHANNEL

Scenario: CD CHANNEL

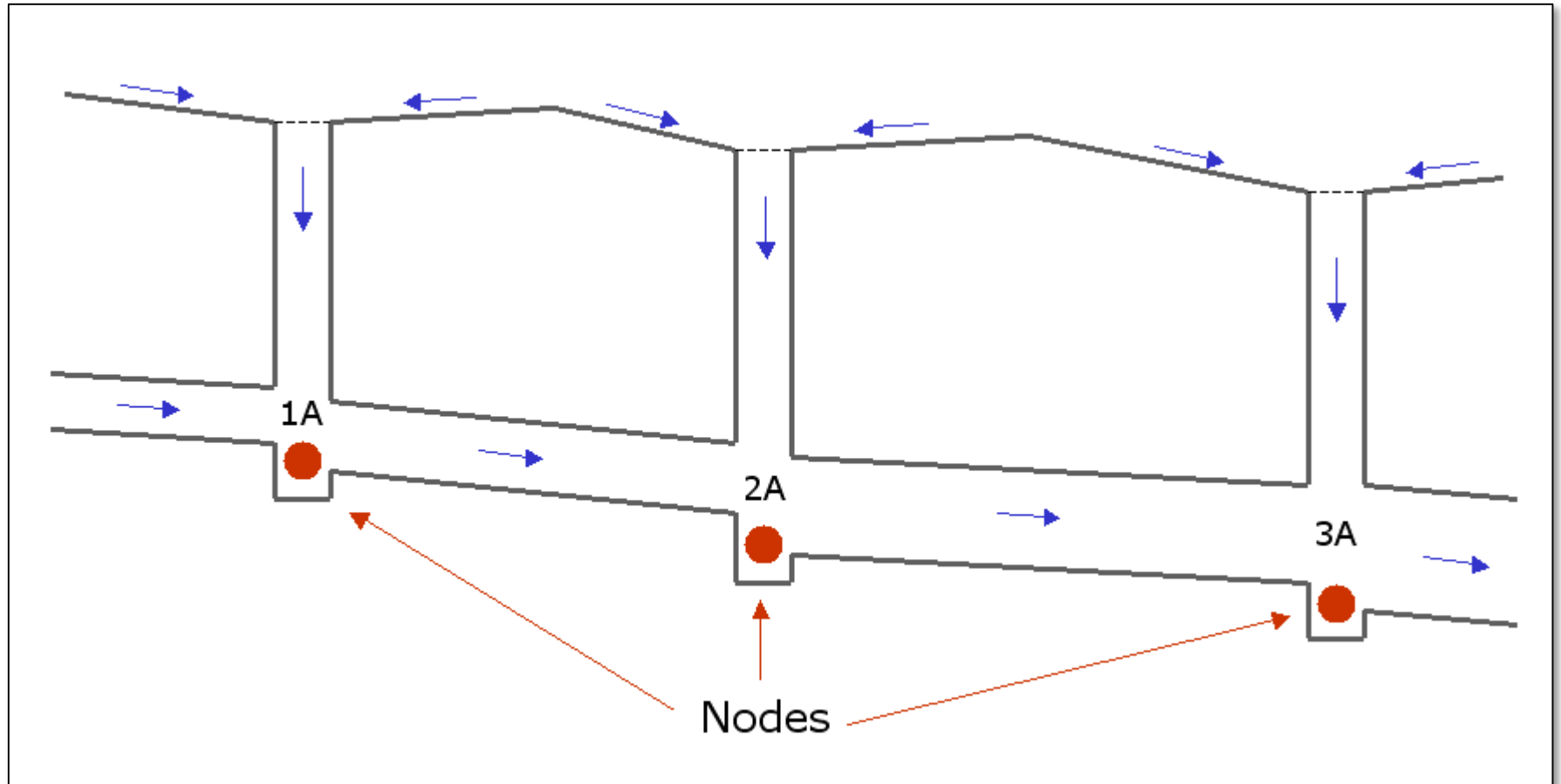


## Cross Section Chart

# Example #2

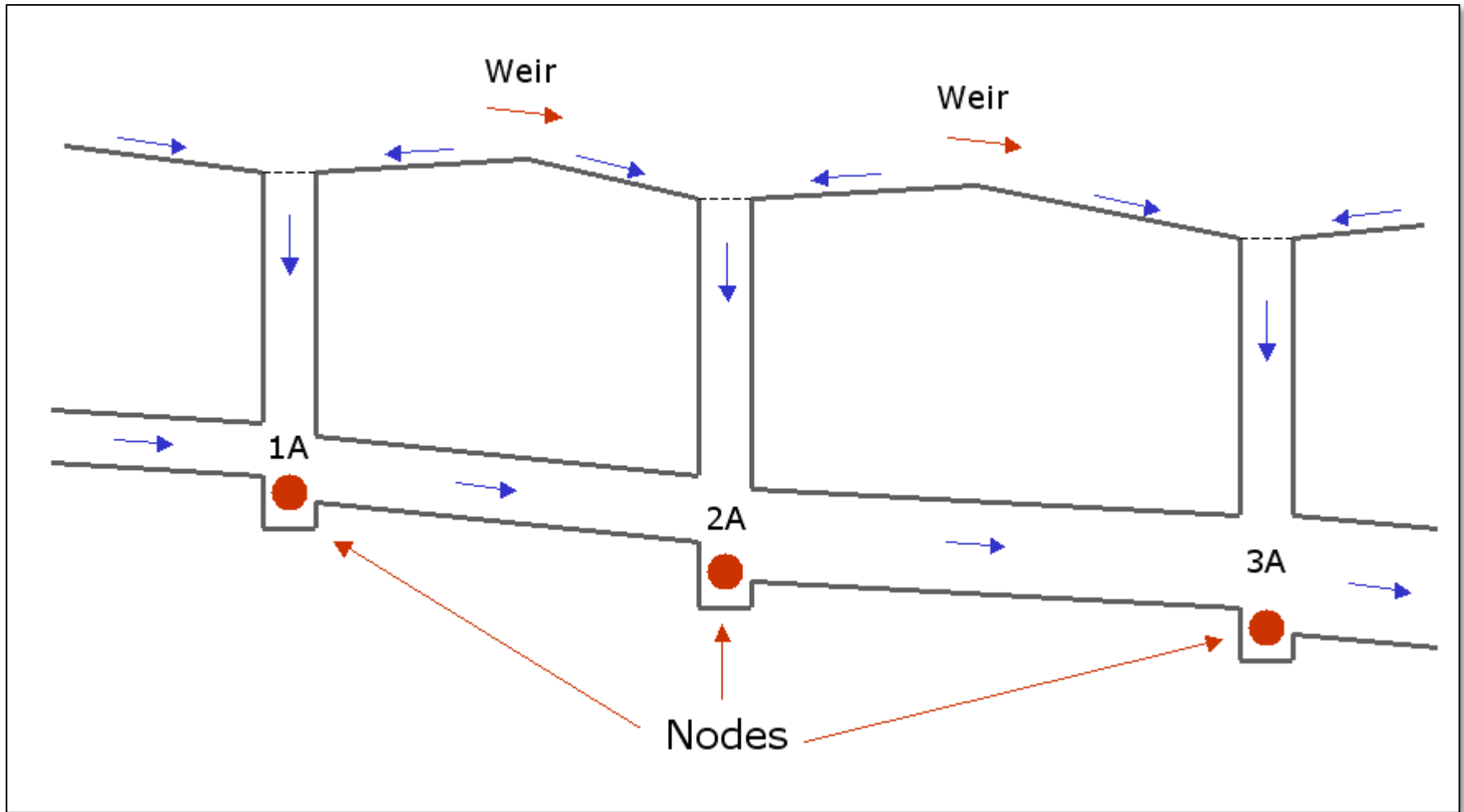
## Integrated Storm Sewer Hydraulics and Pond Routing for a Commercial Site

# Nodal Network Strategies for Storm Sewers



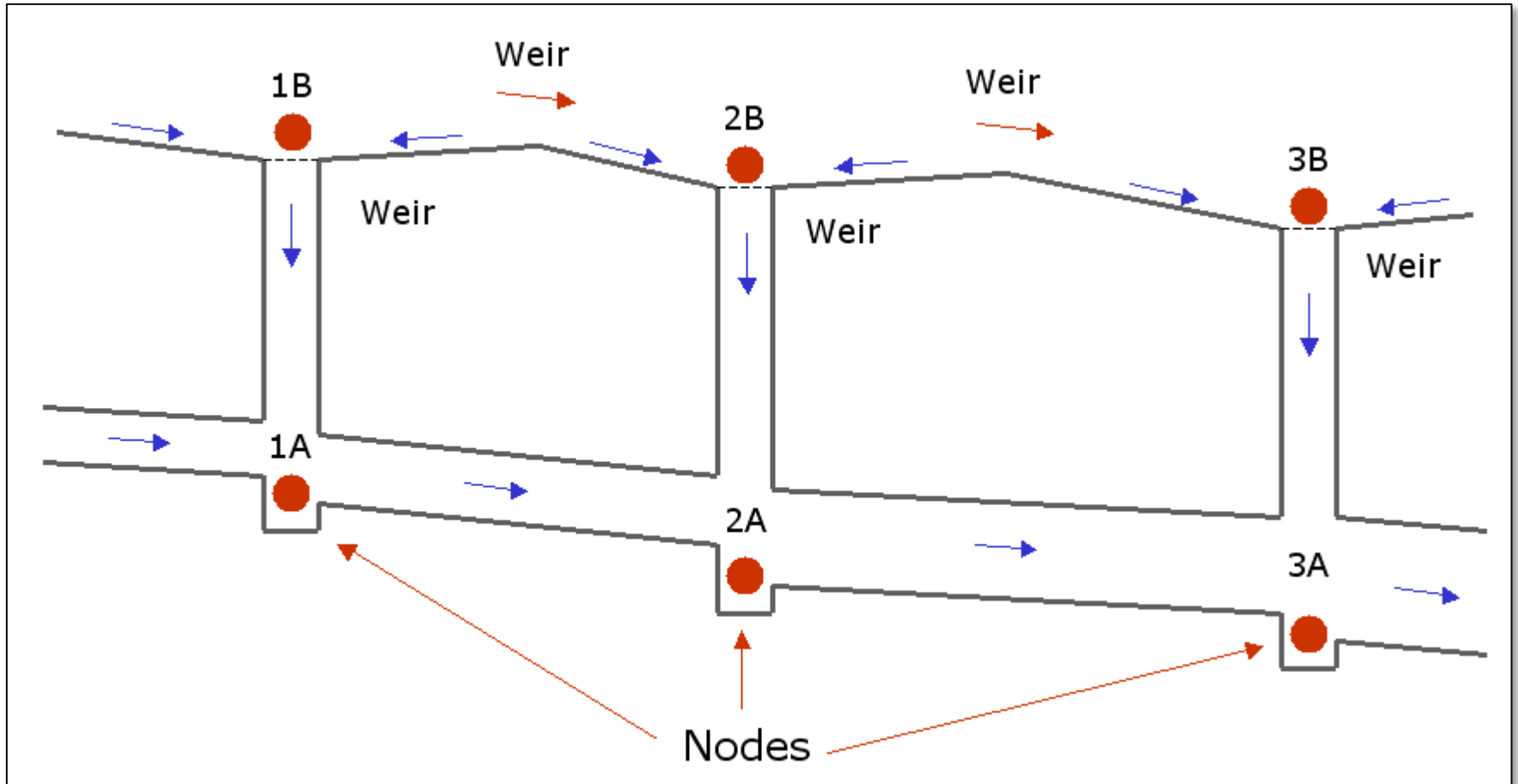
## Option I

# Nodal Network Strategies for Storm Sewers



Option 2

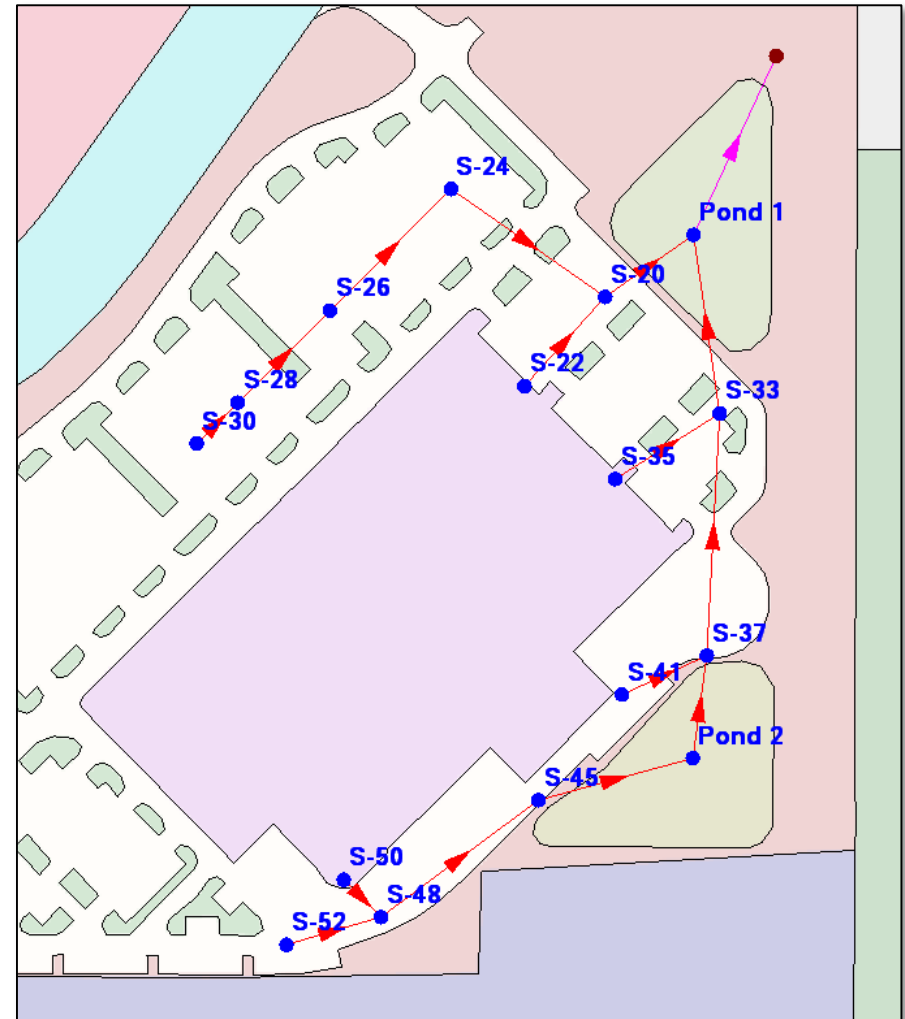
# Nodal Network Strategies for Storm Sewers



## Option 3

# Integrated Storm Sewer Hydraulics and Pond Routing

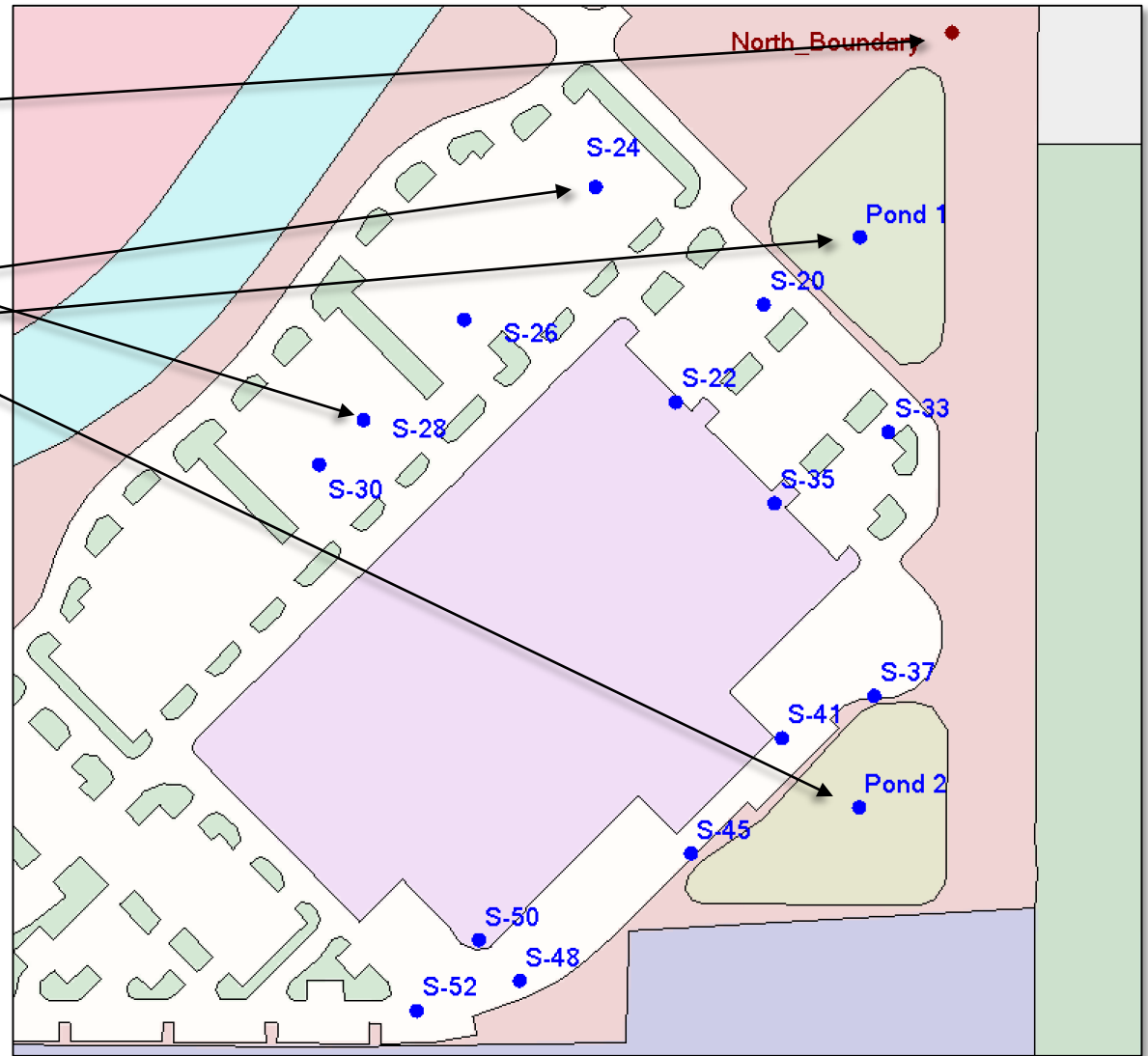
- This example includes a storm sewer system that drains part of a commercial site into 2 detention ponds
- A storm sewer is also used to connect the two ponds together
- “Option 1” from the previous slides is used for the nodal network strategy
- A control structure serves as the outfall for the system\*
- The storm sewer hydraulics are integrated with the pond routing computations (dynamic tailwater condition)



\* We will discuss control structures in Lesson 3

# Integrated Storm Sewer Hydraulics and Pond Routing

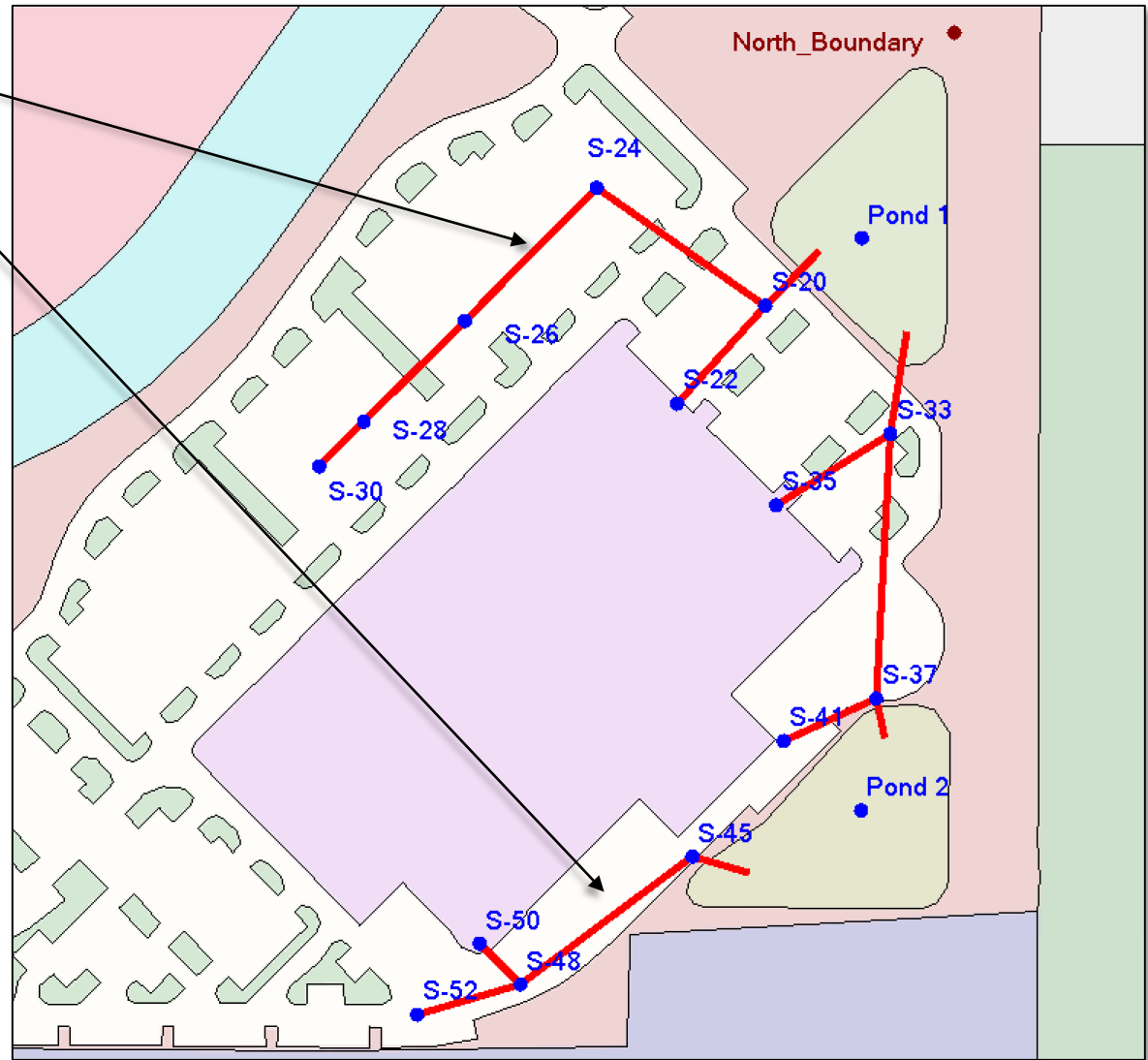
- a time/stage node is placed at the northern outlet
- stage/area nodes are placed at catch basins and at the ponds





# Integrated Storm Sewer Hydraulics and Pond Routing

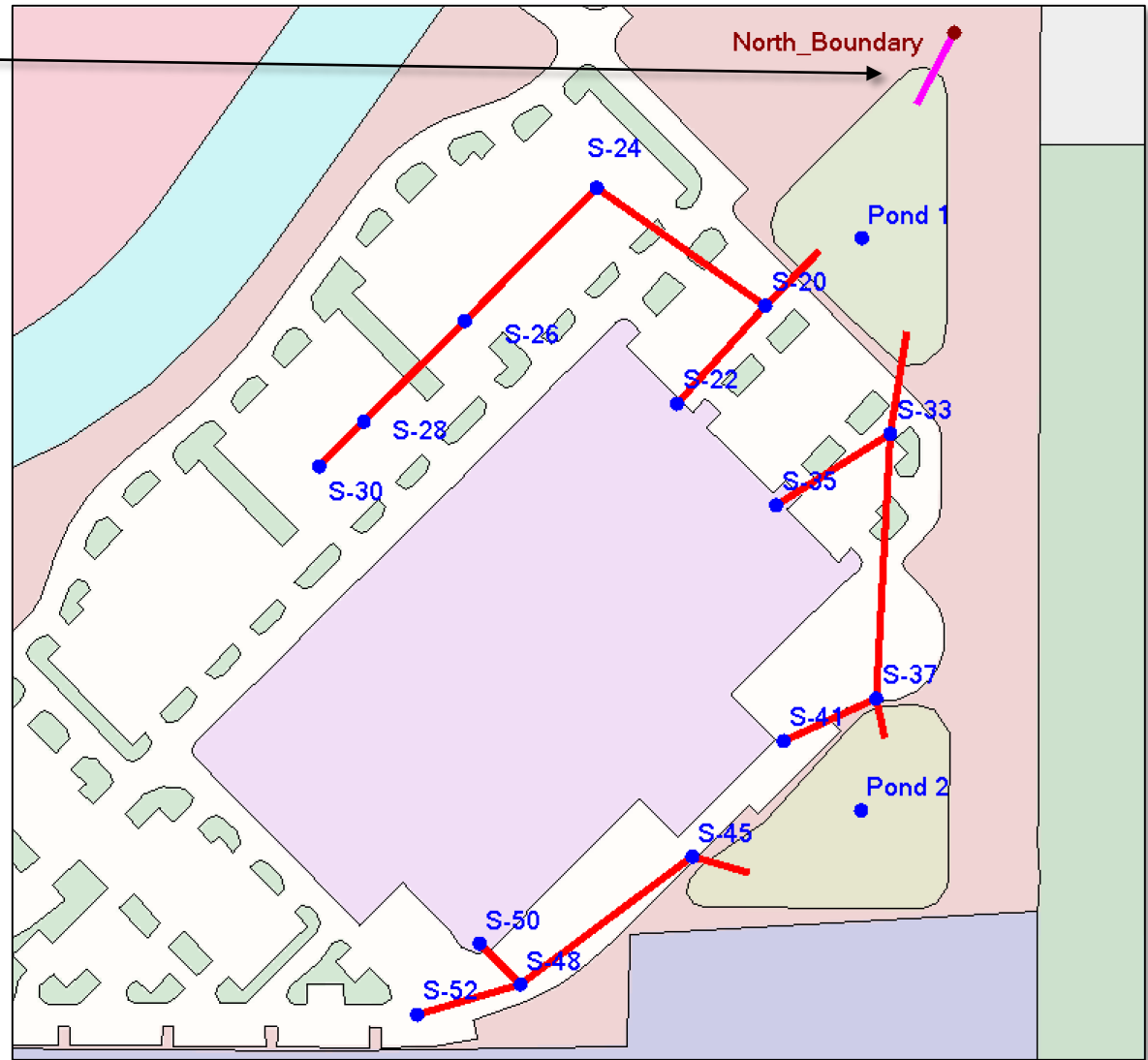
- add pipe links



# Integrated Storm Sewer Hydraulics and Pond Routing

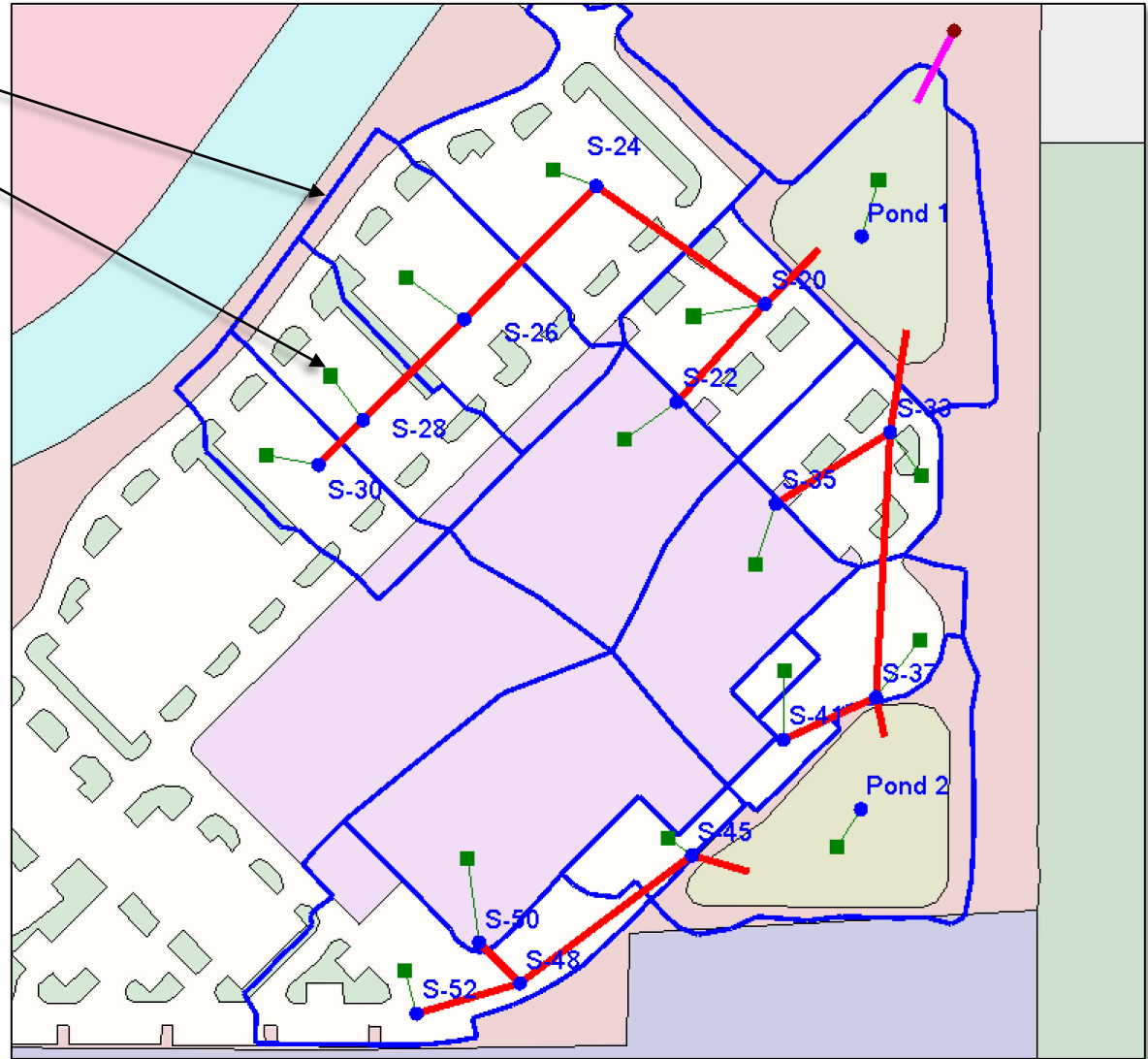
- add drop structure\*  
link (control structure)

\* to be discussed in Lesson 3



# Integrated Storm Sewer Hydraulics and Pond Routing

- delineate “manual” basins
- assign basins to nodes



# Integrated Storm Sewer Hydraulics and Pond Routing

right click

Name	Map Layer Type	Ed
Soils by HSG	Polygon Zone	
Post LU/LC	Polygon Zone	
Post-Basins	Polygon Zone	

Process Basin Polygons

Basin Map Layer: Post-Basins

Land Cover Zone Map Layer: Post LU/LC

Soil Zone Map Layer: Soils by HSG

Rainfall Zone Map Layer: (None)

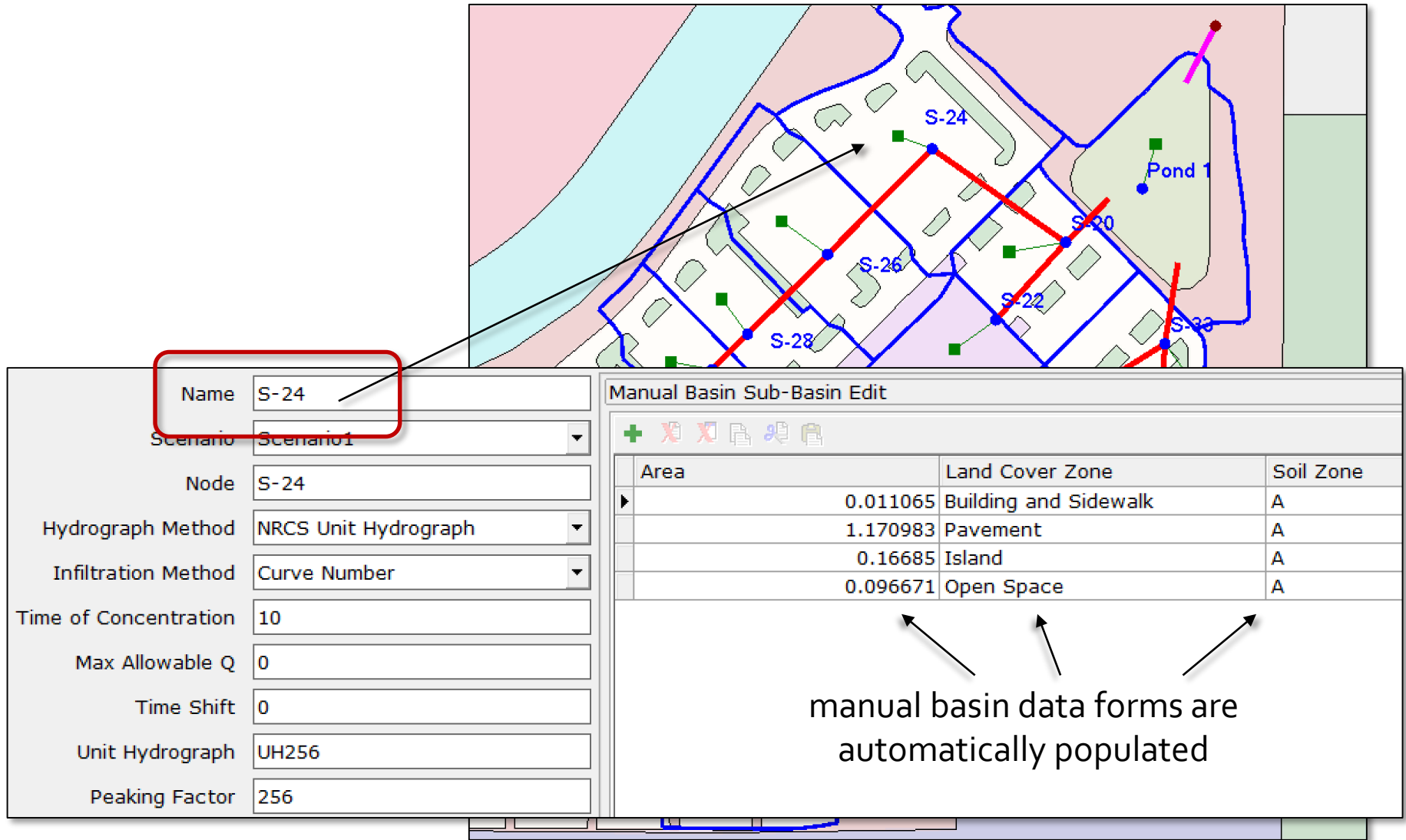
Create New Records

Update Existing Records

OK

use "Process Polygons" tool to automatically takeoff land cover and soil data for each basin

# Integrated Storm Sewer Hydraulics and Pond Routing



The screenshot displays a software interface for storm sewer hydraulics and pond routing. The top portion shows a map of a sub-basin with a network of pipes labeled S-24, S-26, S-28, S-22, S-20, and S-33, and a pond labeled Pond 1. A red box highlights the 'Name' field in the 'Manual Basin Sub-Basin Edit' dialog box, which is set to 'S-24'. The dialog box contains the following parameters:

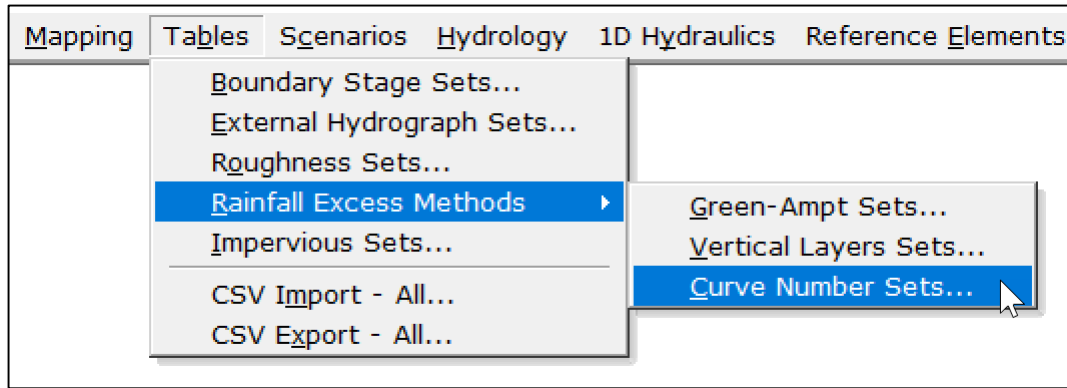
- Name: S-24
- Scenario: Scenario1
- Node: S-24
- Hydrograph Method: NRCS Unit Hydrograph
- Infiltration Method: Curve Number
- Time of Concentration: 10
- Max Allowable Q: 0
- Time Shift: 0
- Unit Hydrograph: UH256
- Peaking Factor: 256

The 'Manual Basin Sub-Basin Edit' dialog box also includes a table with the following data:

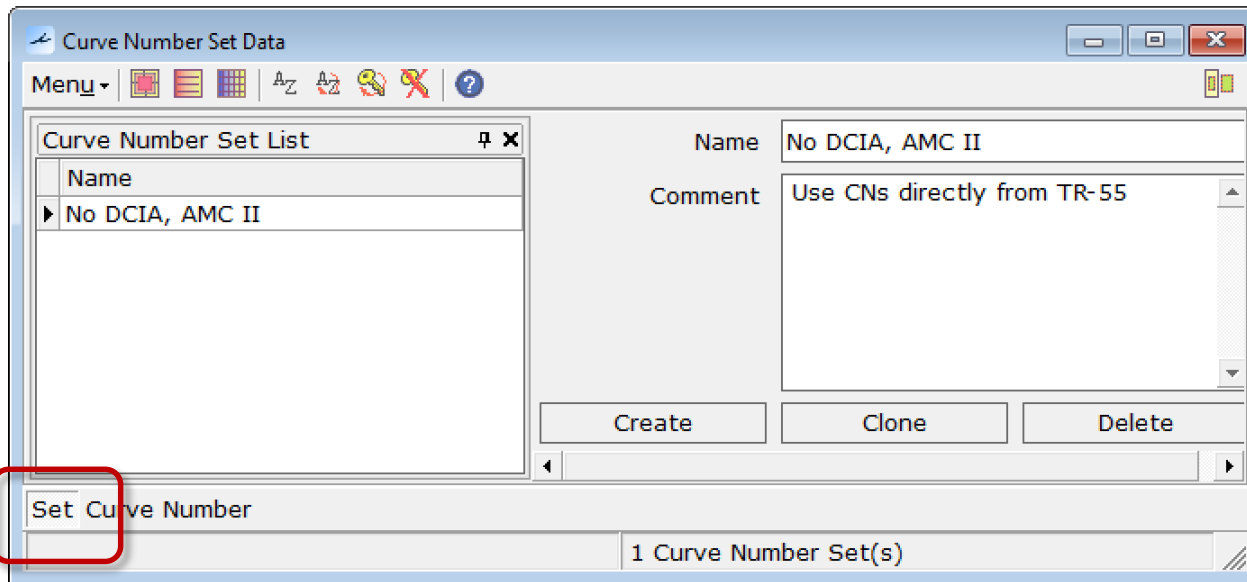
Area	Land Cover Zone	Soil Zone
0.011065	Building and Sidewalk	A
1.170983	Pavement	A
0.16685	Island	A
0.096671	Open Space	A

Arrows point from the text 'manual basin data forms are automatically populated' to the table data.

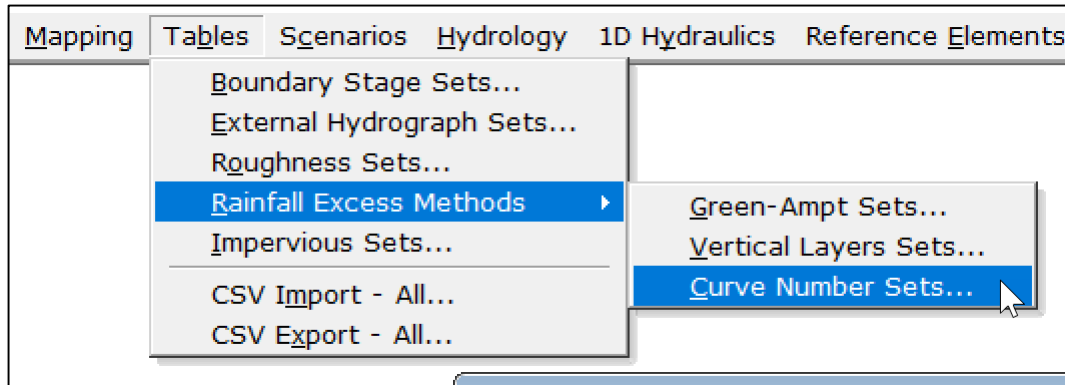
# Integrated Storm Sewer Hydraulics and Pond Routing



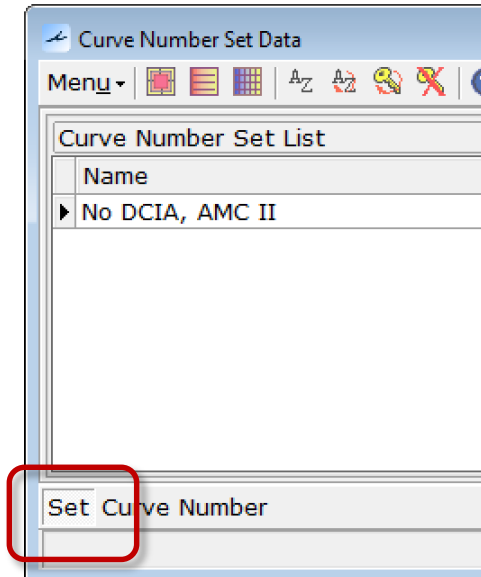
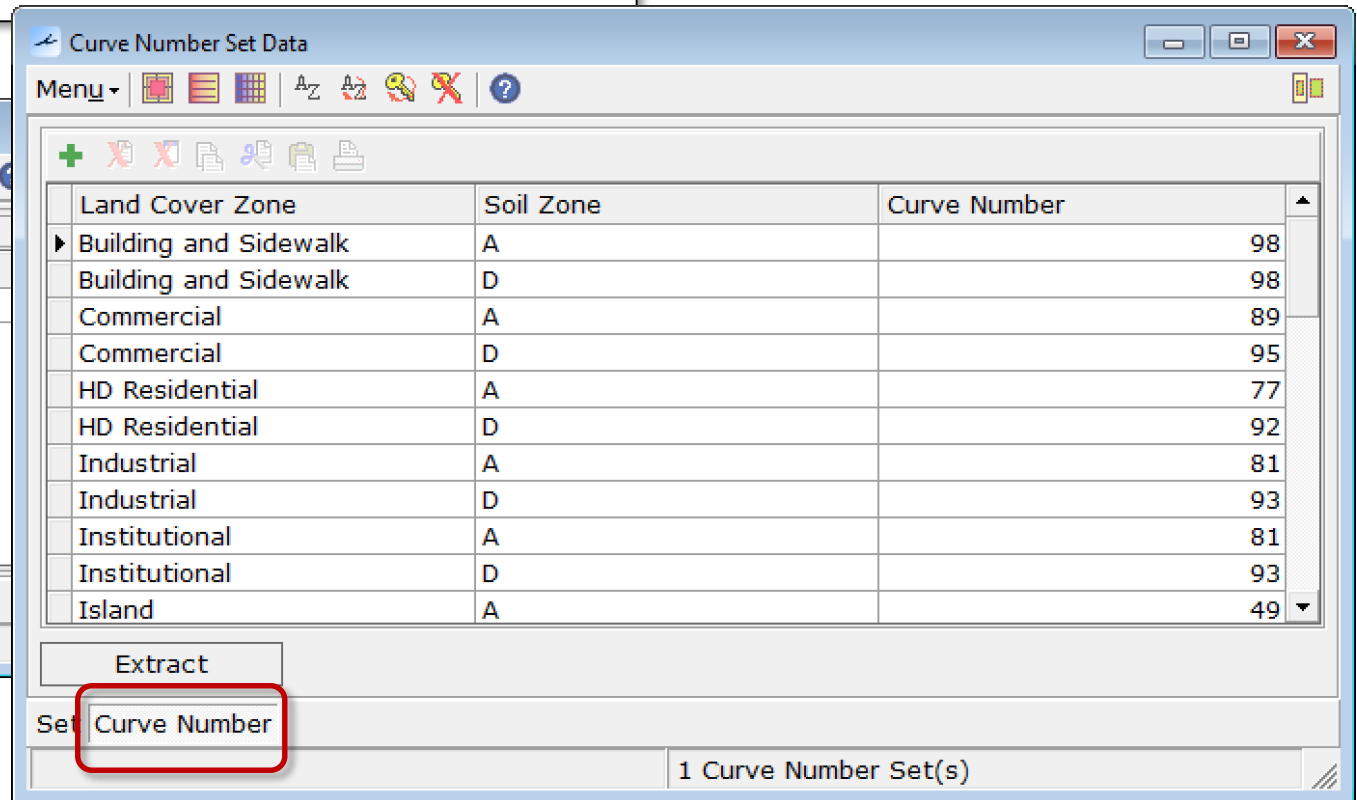
DCIA is not used in this example. The curve numbers include impervious areas.



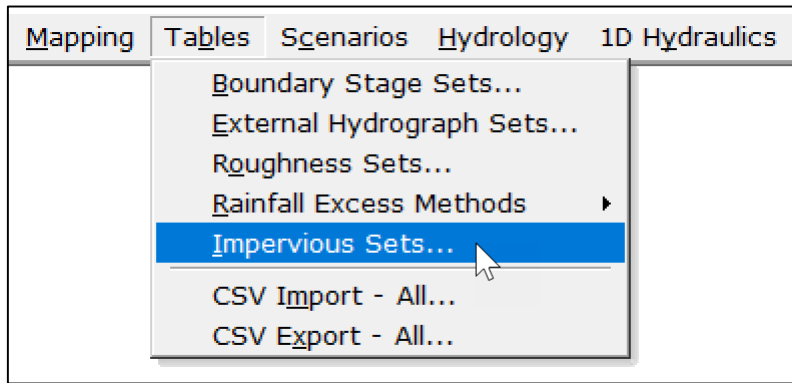
# Integrated Storm Sewer Hydraulics and Pond Routing



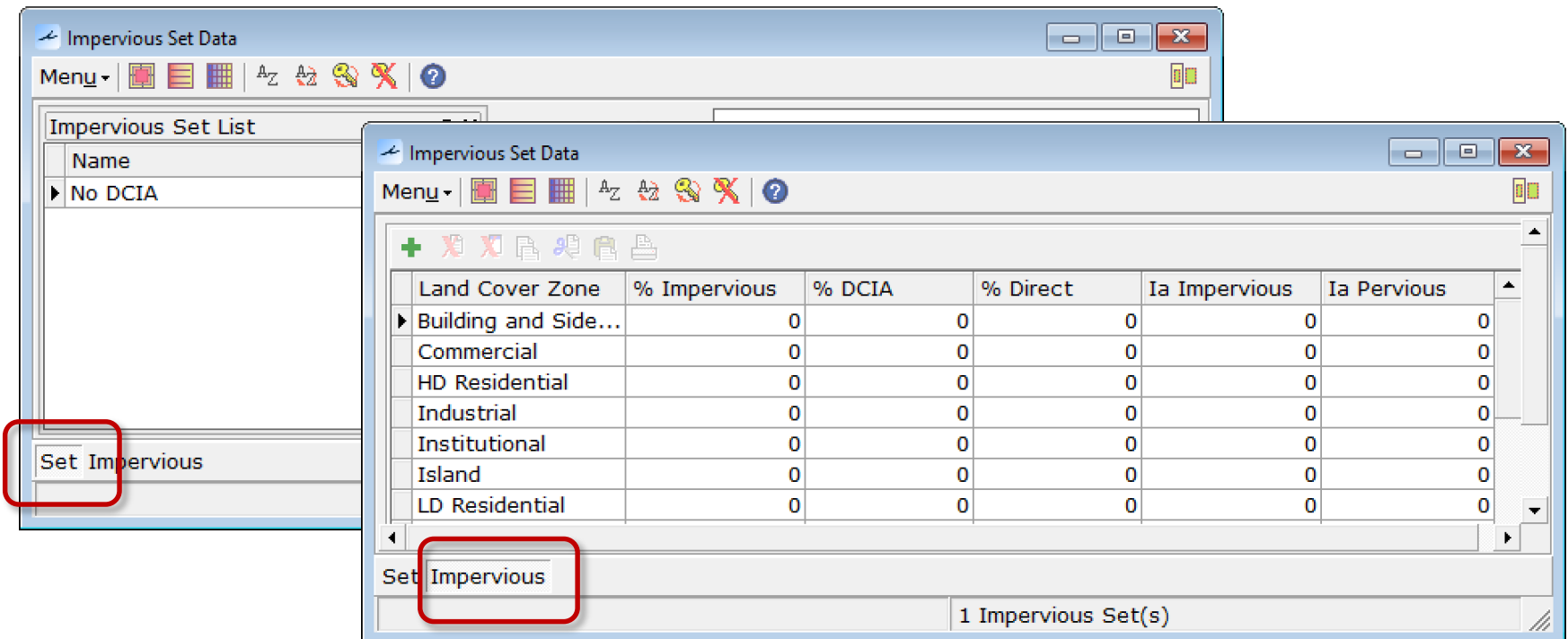
DCIA is not used in this example. The curve numbers include impervious areas.



# Integrated Storm Sewer Hydraulics and Pond Routing



“% Impervious” is set to zero for all land covers because impervious areas are incorporated into the curve numbers





# Integrated Storm Sewer Hydraulics and Pond Routing

Elements Simulation Reports Window Help

Simulation Manager...

Simulation Execution...

Copy Resource Files...

Simulation Manager

Name 010Y\_03H

Scenario: Scen...  
010Y\_03H  
025Y-24H  
100Y-24H

General | Output Time Increments | Resources & Lookup Tables | Tolerances & Options

Resources

Rainfall Folder

Unit Hydrograph Folder

Lookup Tables

Boundary Stage Set

External Hydrograph

Curve Number Set No DCIA, AMC II

Green-Ampt Set

Vertical Layers Set

Impervious Set No DCIA

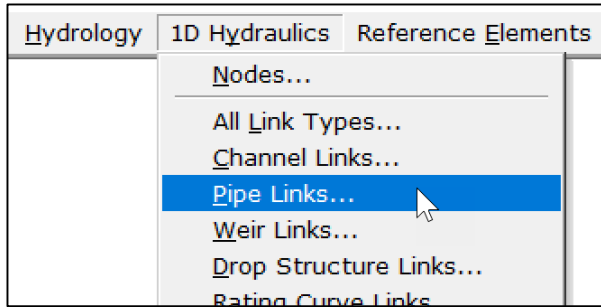
The lookup tables are specified in the simulation manager

Create Clone Print Status Errors Warnings Log Delete CSV Import CSV E

Help Toggle Float

410139be-7b54-4f87-bbcc-78654fcd7dab : 4 3 Simulations

# Integrated Storm Sewer Hydraulics and Pond Routing



- Pipe Data -  
Using the "grid" tab, columns can be moved and sorted for QC/QA purposes

Link Pipe Data

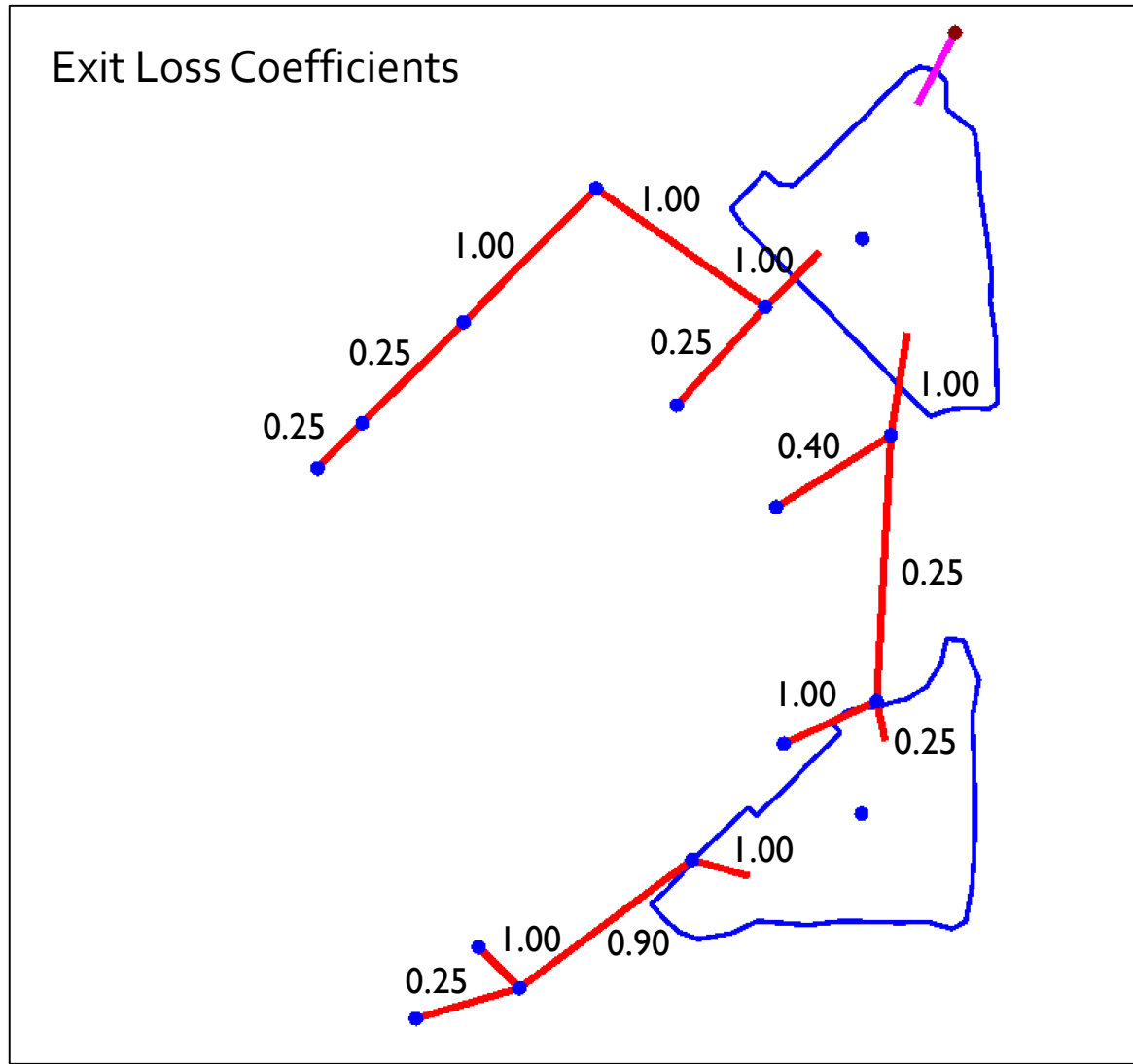
Menu ▾ [Icons]

Name	△	From N...	To Node	Upstream Invert	Downstream Invert	Length	FHWA Culvert Code	Entrance Loss Coefficient	Exit Loss Coefficient
S-19		S-20	Pond 1	76.25	76	68	1	0.5	1
S-21		S-22	S-20	79	77.8	128	1	0.5	0.25
S-23		S-24	S-20	76.65	76.25	205	1	0.5	1
S-25		S-26	S-24	77.15	76.65	189	1	0.5	1
S-27		S-28	S-26	77.75	77.15	142	1	0.5	0.25
S-29		S-30	S-28	78.25	77.75	61	1	0.5	0.25
S-32		S-33	Pond 1	76.1	76	91	1	0.5	1
S-34		S-35	S-33	79	77.8	130	1	0.5	0.4
S-36		S-37	S-33	76	76.1	268	1	0.5	0.25
S-38		Pond 2	S-37	76	76	27	5	0.7	0.25
S-40		S-41	S-37	78.35	77.95	100	1	0.5	1
S-44		S-45	Pond 2	76.15	76	50	1	0.5	1
S-47		S-48	S-45	77	76.35	215	1	0.5	0.9
S-49		S-50	S-48	79	78.6	54	1	0.5	1
S-51		S-52	S-48	77.5	77	105	1	0.5	0.25

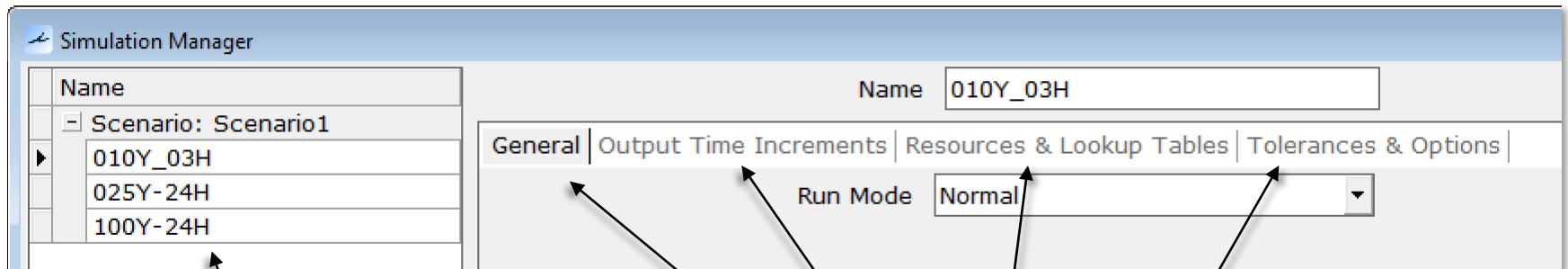
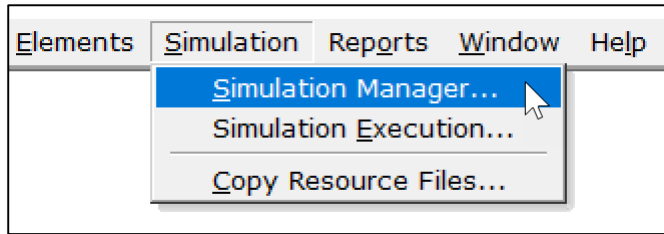
Main Grid

[ft] Enter Bend Location' 15 Pipe Link(s)

# Integrated Storm Sewer Hydraulics and Pond Routing



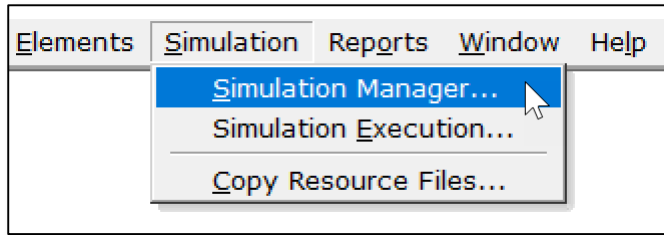
# Integrated Storm Sewer Hydraulics and Pond Routing



Three  
Simulations

Four Tabs

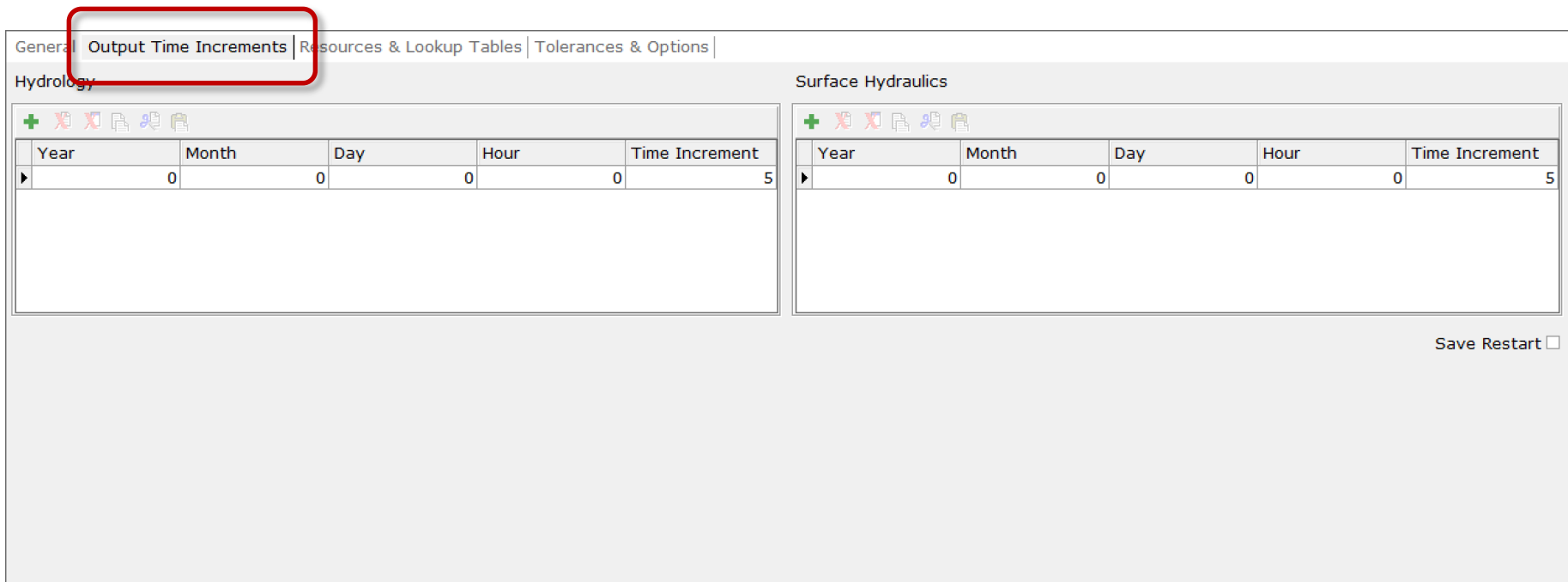
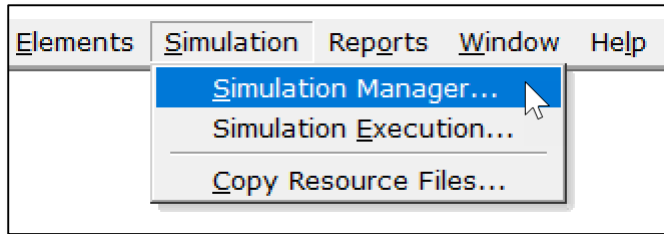
# Integrated Storm Sewer Hydraulics and Pond Routing



A screenshot of the 'General' tab in the software interface. The 'General' tab is highlighted with a red box. The interface includes a 'Run Mode' dropdown menu set to 'Normal'. Below this are input fields for 'Start Time' and 'End Time', each with columns for Year, Month, Day, and Hour. The 'Start Time' fields are all set to 0. The 'End Time' fields are set to 0, 0, 0, and 6. Below these are input fields for 'Minimum Calculation Time' and 'Maximum Calculation Time', with sub-sections for 'Hydrology' and 'Surface Hydraulics'. The 'Minimum Calculation Time' for Hydrology is 30, and for Surface Hydraulics is 0.1. The 'Maximum Calculation Time' for Surface Hydraulics is 30. At the bottom is a 'Comment' text area.

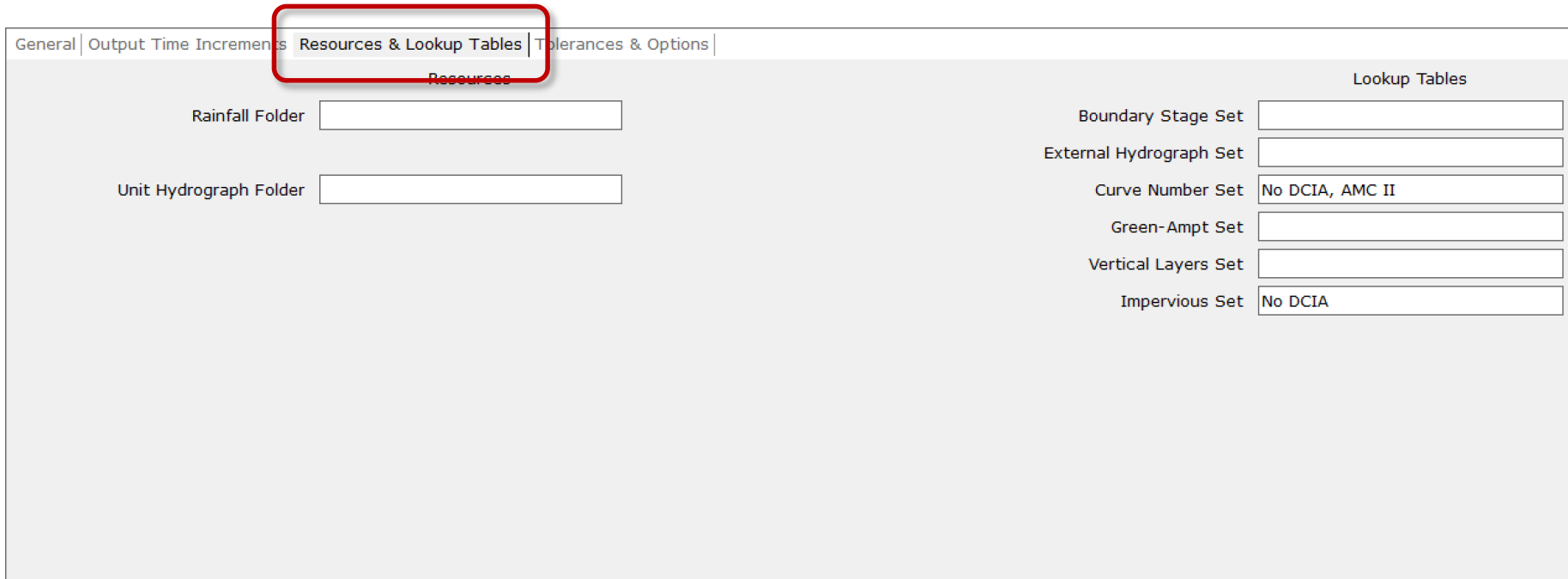
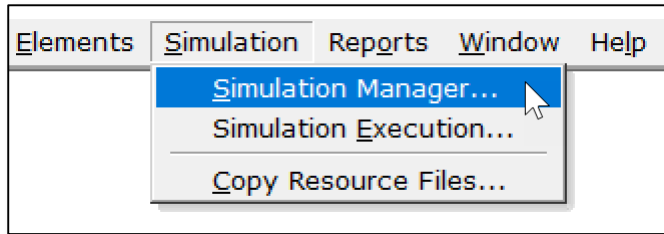
## The “General” Tab

# Integrated Storm Sewer Hydraulics and Pond Routing



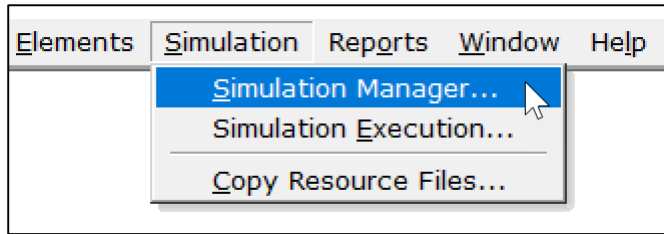
## The “Output Time Increments” Tab

# Integrated Storm Sewer Hydraulics and Pond Routing



## The “Resources & Lookup Tables” Tab

# Integrated Storm Sewer Hydraulics and Pond Routing



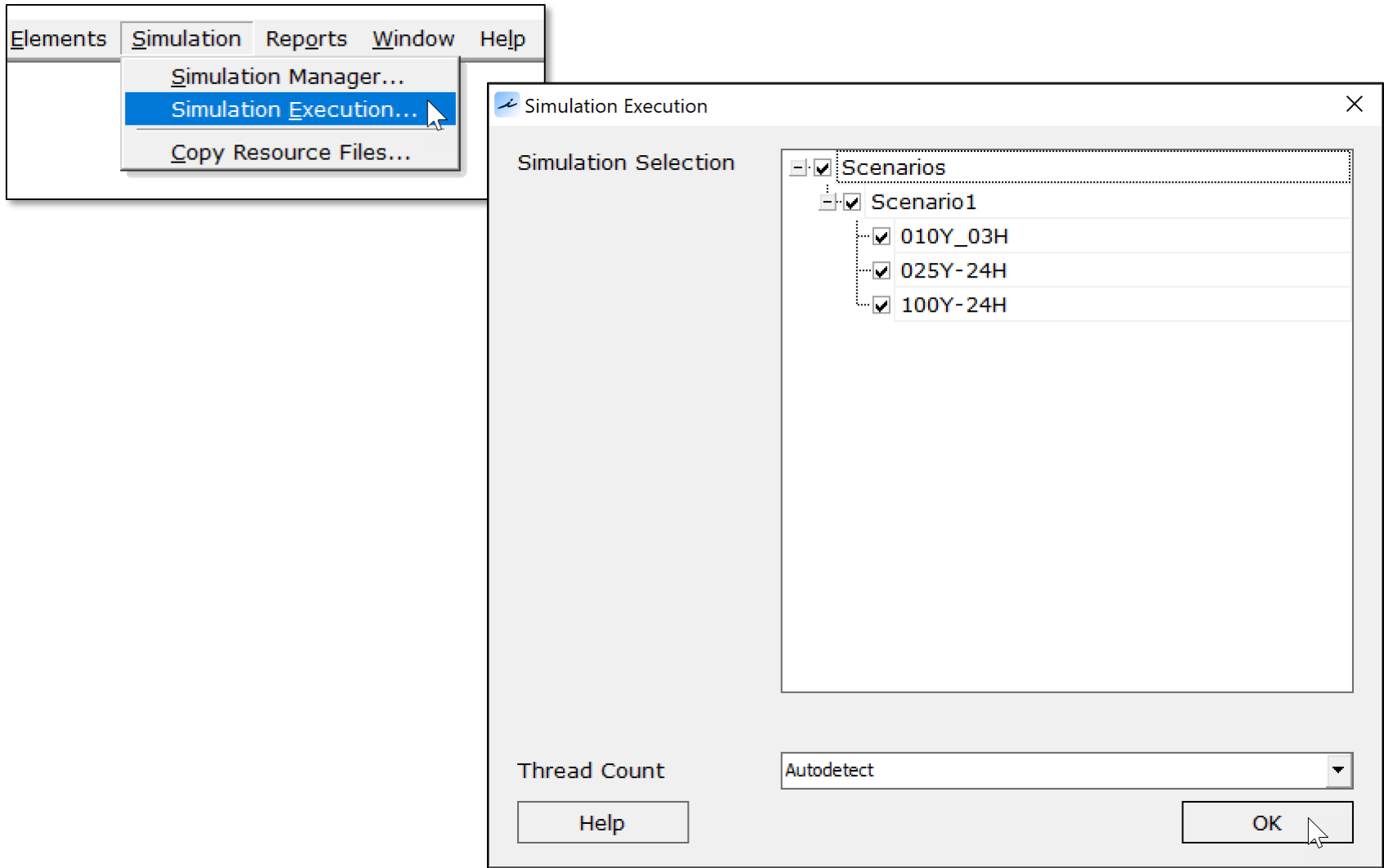
A screenshot of the 'Tolerances & Options' tab in the software interface. The tab is highlighted with a red box. The interface contains several input fields and dropdown menus for configuring simulation parameters.

Parameter	Value
Time Marching	SAOR
Maximum Iterations	6
Over-Relaxation Weighting Factor	0.5
dZ Tolerance	0.001
Maximum dZ	1
Link Optimizer Tolerance	0.0001
Initial Abstraction Recovery Time	24
Simple / Manual Basin Rainfall Opt.	Global
Rainfall Name	~FLMOD
Rainfall Amount	8.4
Storm Duration	24
Default Damping Threshold (1D)	0.005
Minimum Node Surface Area (1D)	12.5
Energy Switch (1D)	Energy

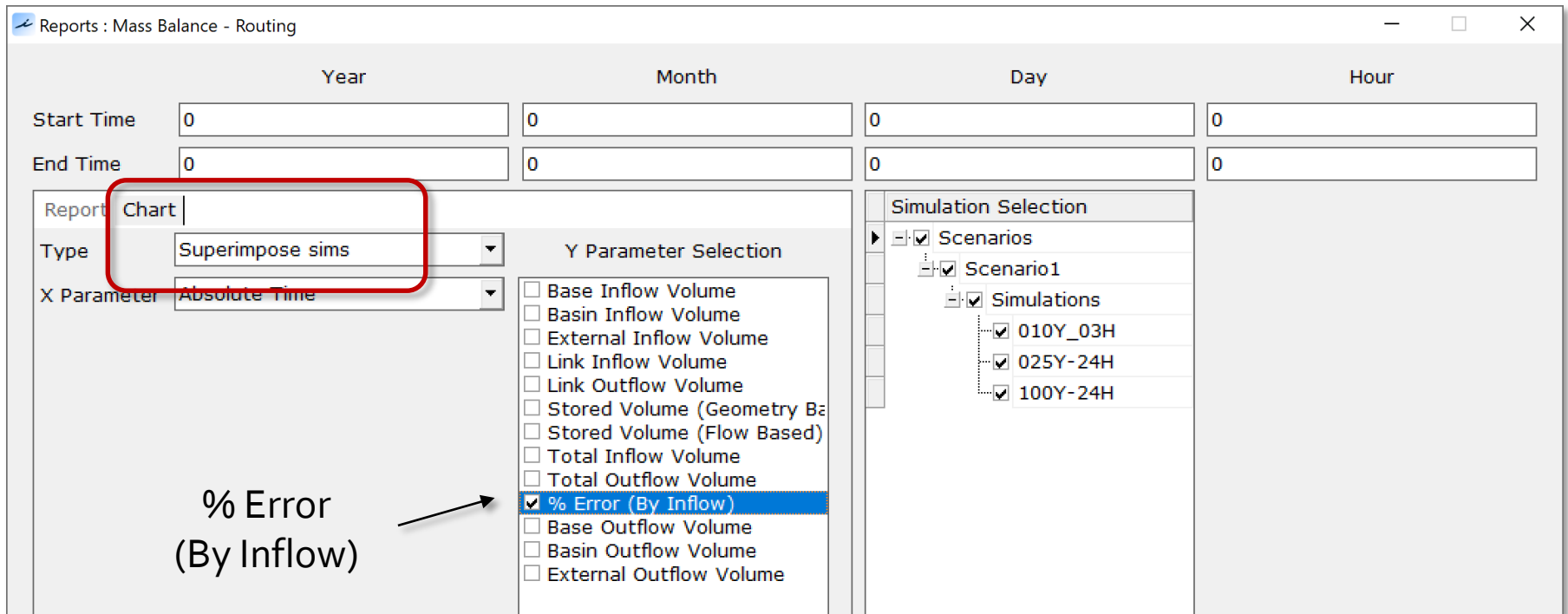
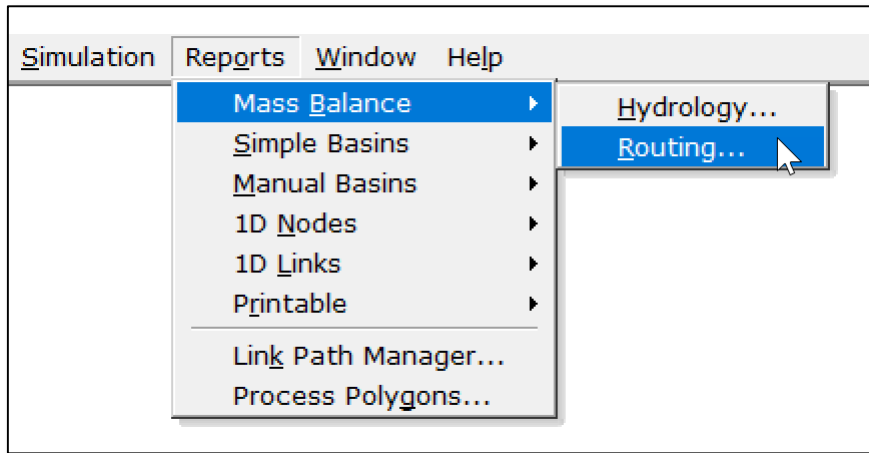
## The “Tolerances & Options” Tab



# Integrated Storm Sewer Hydraulics and Pond Routing

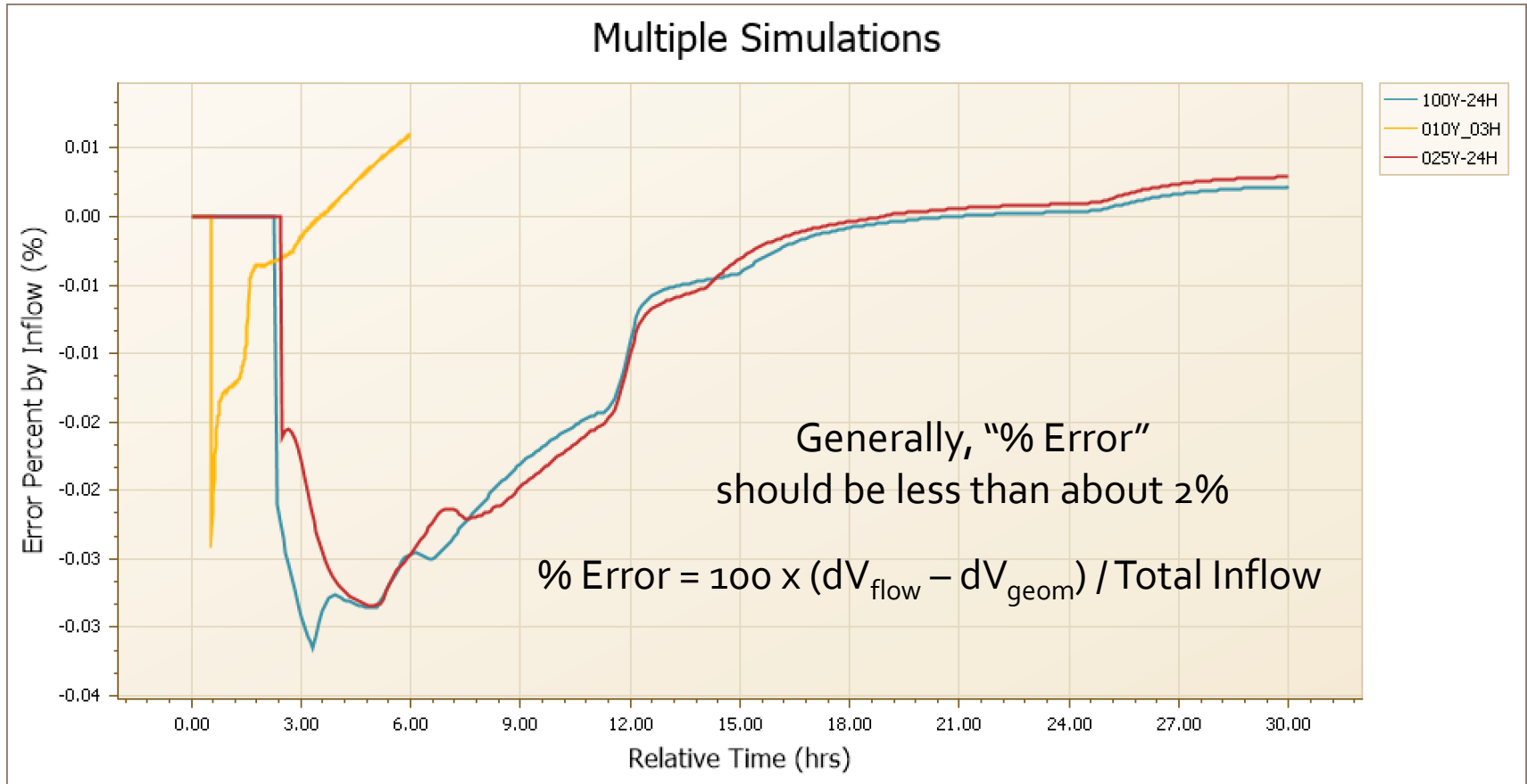


# Integrated Storm Sewer Hydraulics and Pond Routing



% Error  
(By Inflow)

# Integrated Storm Sewer Hydraulics and Pond Routing



# Integrated Storm Sewer Hydraulics and Pond Routing

Graphic View

Menu ▾ | Node Stag... | Point ▾ | ?

Soils by HSG ▾ | Polyline ▾ | [Tools]

Report

Multi-Item Report/Chart

Report Category: Manual Basins - Time Series

Item Count: 0

Add Item(s) | Remove Item(s) | Clear Item(s)

Reports Form

Quick Chart

Scenario: Scenario1

Simulation: 010Y\_03H

Item Type: Manual Basins

Chart Type: Flow

Absolute Time

Select / Display

Link Path

Report Elements On

- Scenarios
  - Scenario1
    - Link Paths
      - North Run
      - South Run

Create

Manager Form

General | Raster | Report | Search |

X: 524007.01 Y: 1571675.95

North Run

South Run

Right Click on Link Path Name

# Integrated Storm Sewer Hydraulics and Pond Routing

North Run

10-year 2-hr Storm

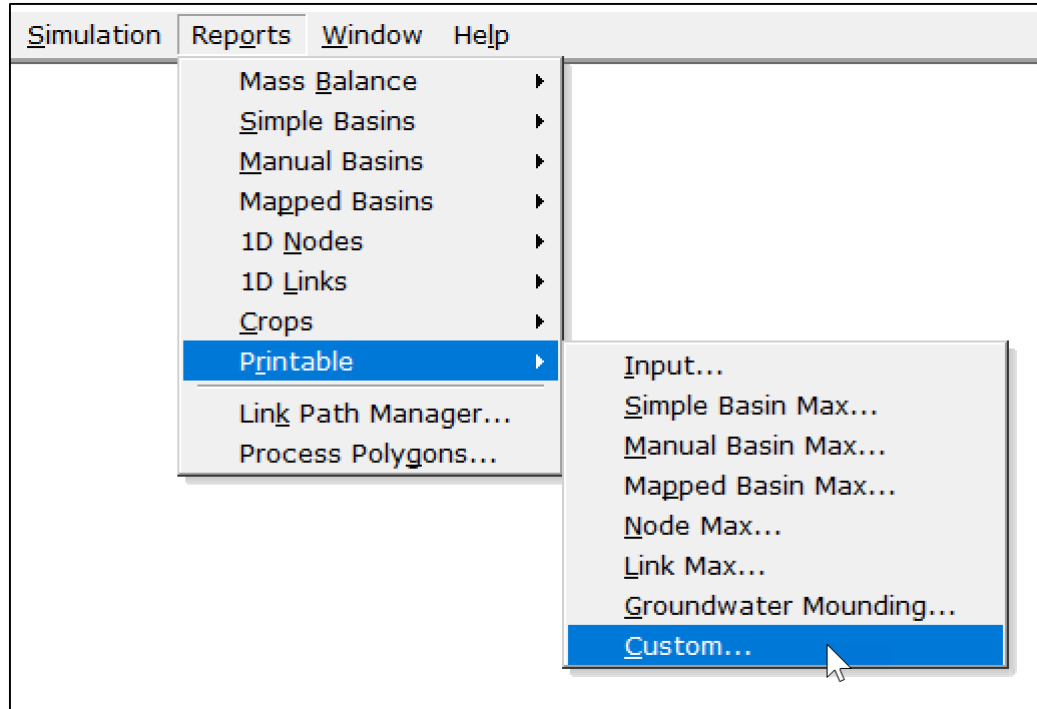


# Integrated Storm Sewer Hydraulics and Pond Routing

South Run



# Integrated Storm Sewer Hydraulics and Pond Routing



# Integrated Storm Sewer Hydraulics and Pond Routing

Custom Reports

Title

**Report Sections**

- Background Image
- Curve Number
- Impervious
- Manual Basin
- Node
- Link

**Item Selection**

- Item Selection
  - [-]  Background Images
  - [-]  Nodal Network

**Report Sheet Selection**

- Image

**Simulation Selection**

Simulation Selection

- [-]  Scenarios
  - [-]  Scenario1
    - 010Y\_03H
    - 025Y-24H
    - 100Y-24H

N/A

Background Image

Page Break Rule



# Integrated Storm Sewer Hydraulics and Pond Routing

Custom Reports

Title

Report Sections

- Background Image
- Curve Number**
- Impervious
- Manual Basin
- Node
- Link

Item Selection

- Item Selection
  - Curve Number Sets
    - No DCIA, AMC II
      - Building and Sidew
      - Building and Sidew
      - Commercial | A
      - Commercial | D
      - HD Residential | A
      - HD Residential | D
      - Industrial | A
      - Industrial | D
      - Institutional | A
      - Institutional | D
      - Island | A
      - Island | D

Report Sheet Selection

- Input Report

Simulation Selection

- Simulation Selection
  - Scenarios
    - Scenario1
      - 010Y\_03H
      - 025Y-24H
      - 100Y-24H

**N/A**

Curve Number  Add Remove Remove All

Page Break Rule

# Integrated Storm Sewer Hydraulics and Pond Routing

Custom Reports

Title

Report Sections

- Background Image
- Curve Number
- Impervious**
- Manual Basin
- Node
- Link

Item Selection

- Item Selection
  - Impervious Sets
    - No DCIA
      - Building and Sidew
      - Commercial
      - HD Residential
      - Industrial
      - Institutional
      - Island
      - LD Residential
      - MD Residential
      - Open Space
      - POND 1
      - POND 2
      - POND 3

Report Sheet Selection

- Input Report

Simulation Selection

- Simulation Selection
  - Scenarios
    - Scenario1
      - 010Y\_03H
      - 025Y-24H
      - 100Y-24H

**N/A**

Impervious

Page Break Rule

# Integrated Storm Sewer Hydraulics and Pond Routing

Custom Reports

Title:

**Report Sections**

- Background Image
- Curve Number
- Impervious
- Manual Basin**
- Node
- Link

**Item Selection**

- Scenarios
  - Scenario1
    - Pond 1
    - Pond 2
    - S-20
    - S-22
    - S-24
    - S-26
    - S-28
    - S-30
    - S-33
    - S-35
    - S-37
    - S-41

**Report Sheet Selection**

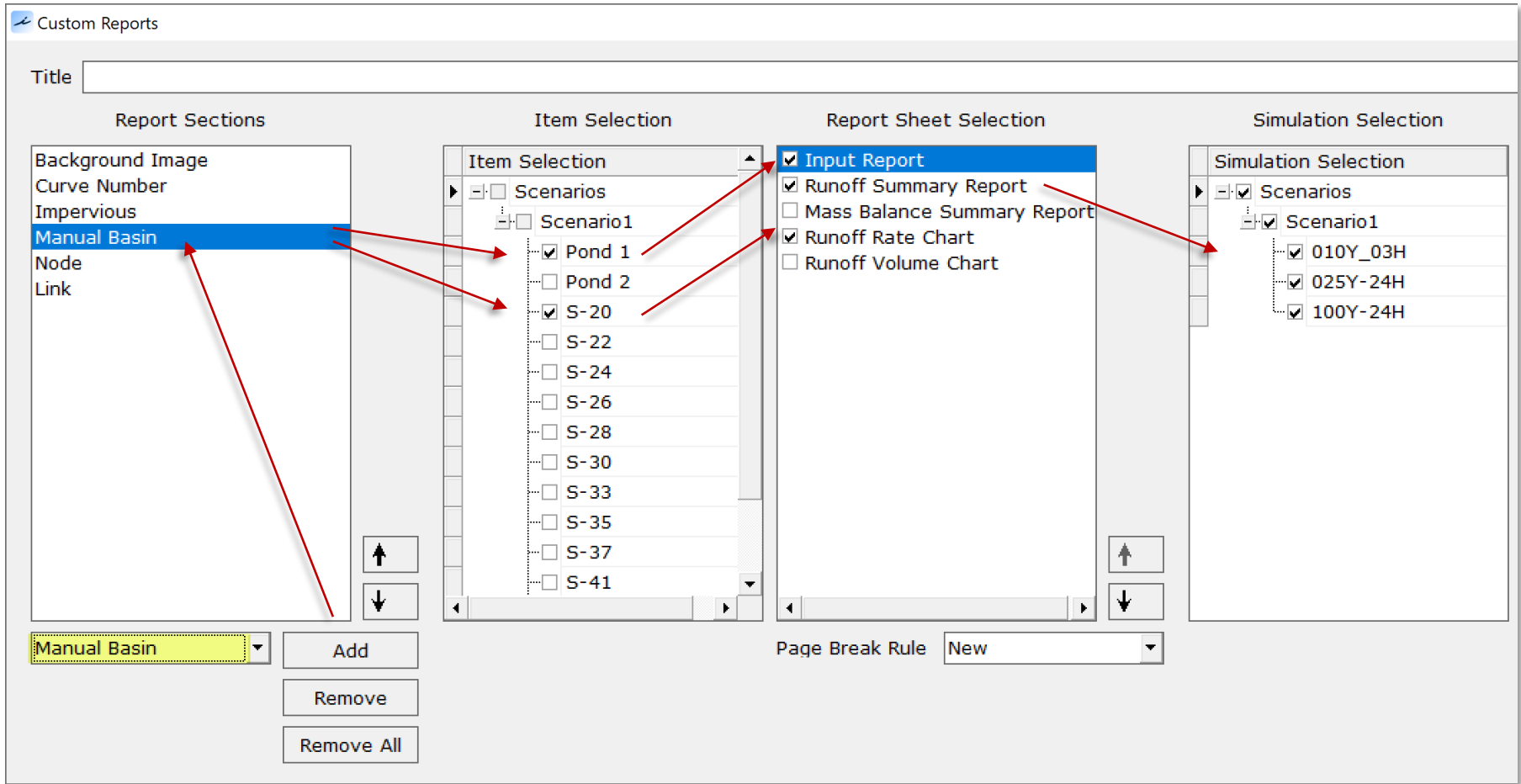
- Input Report
- Runoff Summary Report
- Mass Balance Summary Report
- Runoff Rate Chart
- Runoff Volume Chart

**Simulation Selection**

- Scenarios
  - Scenario1
    - 010Y\_03H
    - 025Y-24H
    - 100Y-24H

Manual Basin | Add | Remove | Remove All

Page Break Rule: New



# Integrated Storm Sewer Hydraulics and Pond Routing

Custom Reports

Title:

**Report Sections**

- Background Image
- Curve Number
- Impervious
- Manual Basin
- Node**
- Link

**Item Selection**

- Item Selection
  - Scenarios
    - Scenario1
      - North\_Boundary
      - Pond 1
      - Pond 2
      - S-20
      - S-22
      - S-24
      - S-26
      - S-28
      - S-30
      - S-33
      - S-35
      - S-37

**Report Sheet Selection**

- Input Report
- Input Chart
- Max Conditions Report
- Max Conditions Report (with T)
- Mass Balance Condensed Repo
- Mass Balance Detailed Report
- Stage Chart
- Stage Chart (with Warning Sta
- Stage % Exceedance Chart
- Stage % Exceedance Chart (w
- Stage Raster Chart
- Surface Area % Exceedance C
- Depth Above Warning Raster C

**Simulation Selection**

- Simulation Selection
  - Scenarios
    - Scenario1
      - 010Y\_03H
      - 025Y-24H
      - 100Y-24H

↑ ↓

Node Add Remove Remove All

Page Break Rule: New

# Integrated Storm Sewer Hydraulics and Pond Routing

Custom Reports

Title

**Report Sections**

- Background Image
- Curve Number
- Impervious
- Manual Basin
- Node
- Link**

**Item Selection**

- Scenarios
  - Scenario1
    - Pond 1
    - S-19
    - S-21
    - S-23
    - S-25
    - S-27
    - S-29
    - S-32
    - S-34
    - S-36
    - S-38
    - S-40

**Report Sheet Selection**

- Input Report (Full)**
- Input Report (Condensed)
- Min/Max Conditions Report
- Min/Max Conditions Report (with ...)
- Flow Chart
- Average Velocity Chart
- Downstream Velocity Chart
- Upstream Velocity Chart
- Flow % Exceedance Chart
- Flow Raster Chart

**Simulation Selection**

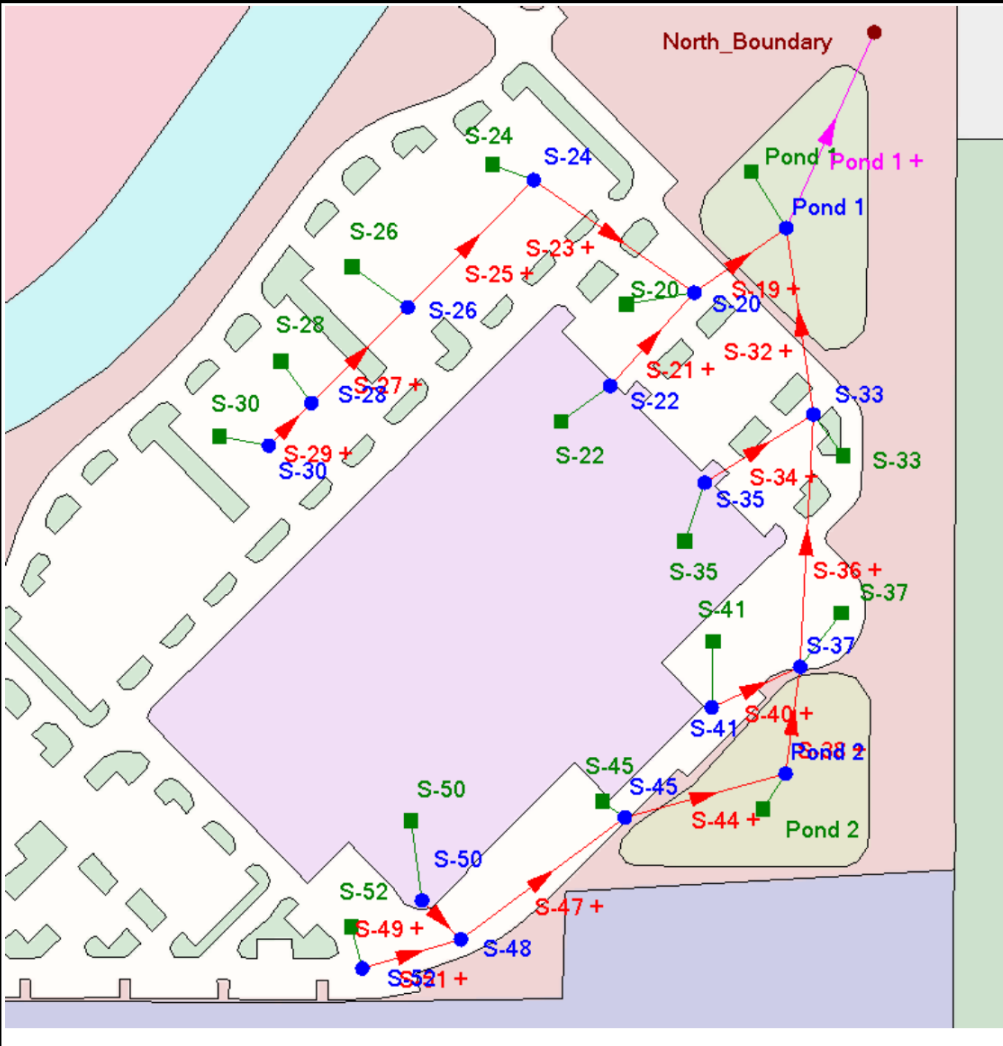
- Scenarios
  - Scenario1
    - 010Y\_03H
    - 025Y-24H
    - 100Y-24H

Link  Add Remove Remove All

Page Break Rule New

# Custom Report (Background Image)

Background Image: Nodal Network



Nodal Network “captured” as a background image and included in report

- Background Images
  - Nodal Network
  - Image
    - Import
    - Pyramid
    - Capture View
    - Expand All Below
    - Collapse All Below

# Custom Report (Curve Number Lookup Table)

Curve Number: No DCIA, AMC II [Set]

Land Cover Zone	Soil Zone	Curve Number [dec]
Building and Sidewalk	A	98.0
Building and Sidewalk	D	98.0
Commercial	A	89.0
Commercial	D	95.0
HD Residential	A	77.0
HD Residential	D	92.0
Industrial	A	81.0
Industrial	D	93.0
Institutional	A	81.0
Institutional	D	93.0
Island	A	49.0
Island	D	84.0
LD Residential	A	57.0
LD Residential	D	86.0
MD Residential	A	61.0
MD Residential	D	87.0
Open Space	A	49.0
Open Space	D	49.0
POND 1	A	49.0
POND 1	D	84.0
POND 2	A	49.0
POND 2	D	84.0
POND 3	A	49.0
POND 3	D	84.0
Pavement	A	98.0
Pavement	D	98.0
ROW	A	83.0
ROW	D	93.0
Recreation	A	49.0
Recreation	D	84.0
Stream	A	95.0
Stream	D	98.0

# Custom Report (Curve Number Lookup Table)

3

Land Cover Zone	Soil Zone	Curve Number [dec]
Trail	A	49.0
Trail	D	84.0
Wetland	A	95.0
Wetland	D	98.0



# Custom Report (Impervious Lookup Table)

Impervious: No DCIA [Set]

Land Cover Zone	% Impervious	% DCIA	% Direct	Ia Impervious [in]	Ia Pervious [in]
Building and Sidewalk	0.00	0.00	0.00	0.000	0.000
Commercial	0.00	0.00	0.00	0.000	0.000
HD Residential	0.00	0.00	0.00	0.000	0.000
Industrial	0.00	0.00	0.00	0.000	0.000
Institutional	0.00	0.00	0.00	0.000	0.000
Island	0.00	0.00	0.00	0.000	0.000
LD Residential	0.00	0.00	0.00	0.000	0.000
MD Residential	0.00	0.00	0.00	0.000	0.000
Open Space	0.00	0.00	0.00	0.000	0.000
POND 1	0.00	0.00	0.00	0.000	0.000
POND 2	0.00	0.00	0.00	0.000	0.000
POND 3	0.00	0.00	0.00	0.000	0.000
Pavement	0.00	0.00	0.00	0.000	0.000
ROW	0.00	0.00	0.00	0.000	0.000
Recreation	0.00	0.00	0.00	0.000	0.000
Stream	0.00	0.00	0.00	0.000	0.000
Trail	0.00	0.00	0.00	0.000	0.000
Wetland	0.00	0.00	0.00	0.000	0.000

# Custom Report (Manual Basin “Pond I”)

Manual Basin: Pond 1

## Input Data

Scenario: Scenario1  
 Node: Pond 1  
 Hydrograph Method: NRCS Unit Hydrograph  
 Infiltration Method: Curve Number  
 Time of Concentration: 10.0000 min  
 Max Allowable Q: 0.00 cfs  
 Time Shift: 0.0000 hr  
 Unit Hydrograph: UH256  
 Peaking Factor: 256.0  
 Area: 1.2373 ac

Area [ac]	Land Cover Zone	Soil Zone	Rainfall Name
0.0063	Pavement	A	
0.4262	Open Space	A	
0.8047	POND 1	A	

Comment:

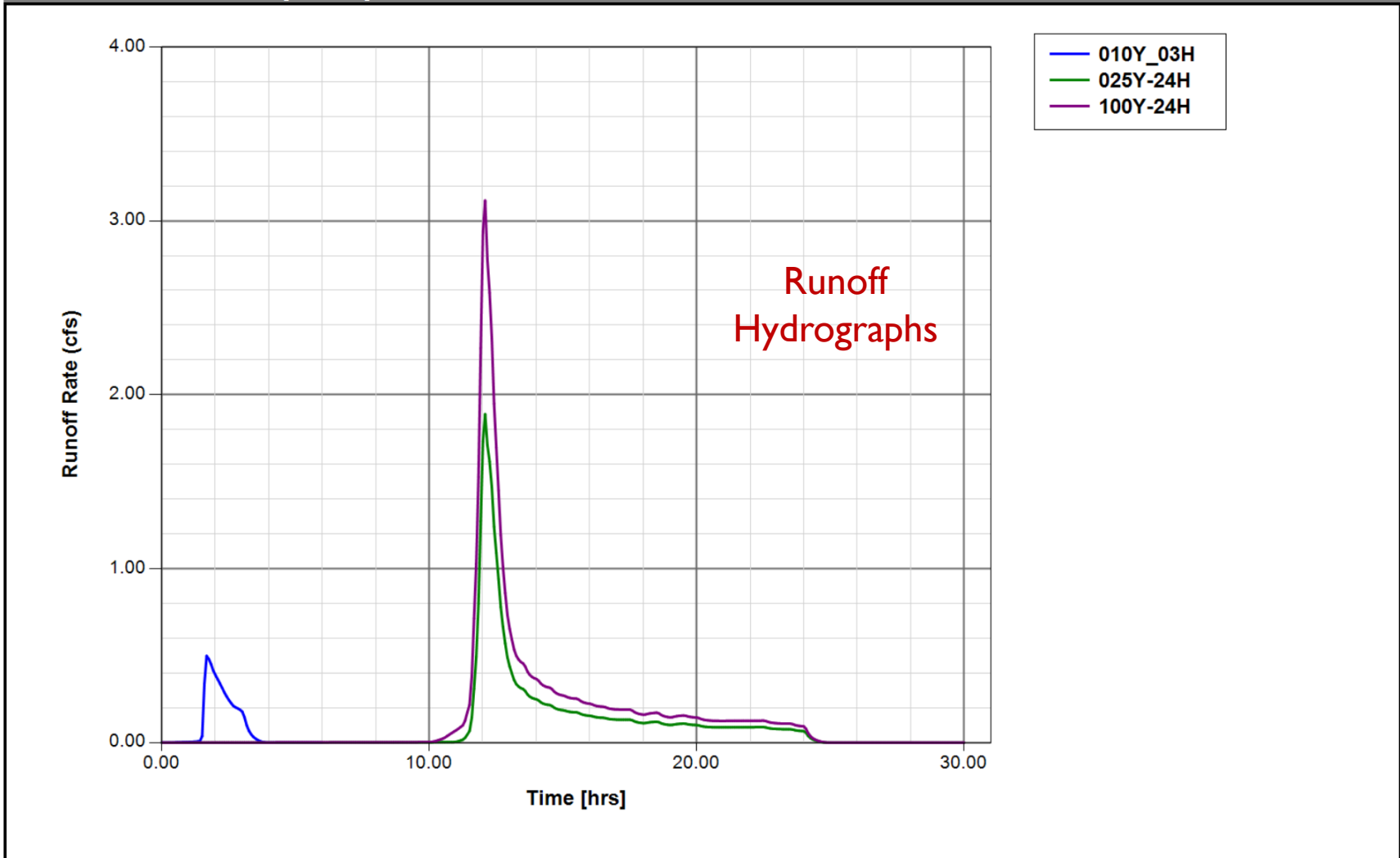
## Manual Basin Runoff Summary

Manual Basin Runoff Summary [Scenario1]

Basin Name	Sim Name	Max Flow [cfs]	Time to Max Flow [hrs]	Total Rainfall [in]	Total Runoff [in]	Area [ac]	Equivalent Curve Number	% Imperv	% DCIA
Pond 1	010Y_03H	0.50	1.6917	4.30	0.41	1.2373	49.5	0.00	0.00
Pond 1	025Y-24H	1.91	12.0750	8.40	2.42	1.2373	49.3	0.00	0.00
Pond 1	100Y-24H	3.17	12.0667	10.50	3.80	1.2373	49.2	0.00	0.00

# Custom Report (Manual Basin "Pond I")

Manual Basin Runoff Rate: Pond 1 [Scenario1]



# Custom Report (Manual Basin “S-20”)

Manual Basin: S-20

## Input Data

Scenario: Scenario1  
 Node: S-20  
 Hydrograph Method: NRCS Unit Hydrograph  
 Infiltration Method: Curve Number  
 Time of Concentration: 10.0000 min  
 Max Allowable Q: 0.00 cfs  
 Time Shift: 0.0000 hr  
 Unit Hydrograph: UH256  
 Peaking Factor: 256.0  
 Area: 0.7342 ac

Area [ac]	Land Cover Zone	Soil Zone	Rainfall Name
0.0176	Building and Sidewalk	A	
0.6341	Pavement	A	
0.0823	Island	A	
0.0002	Open Space	A	

Comment:

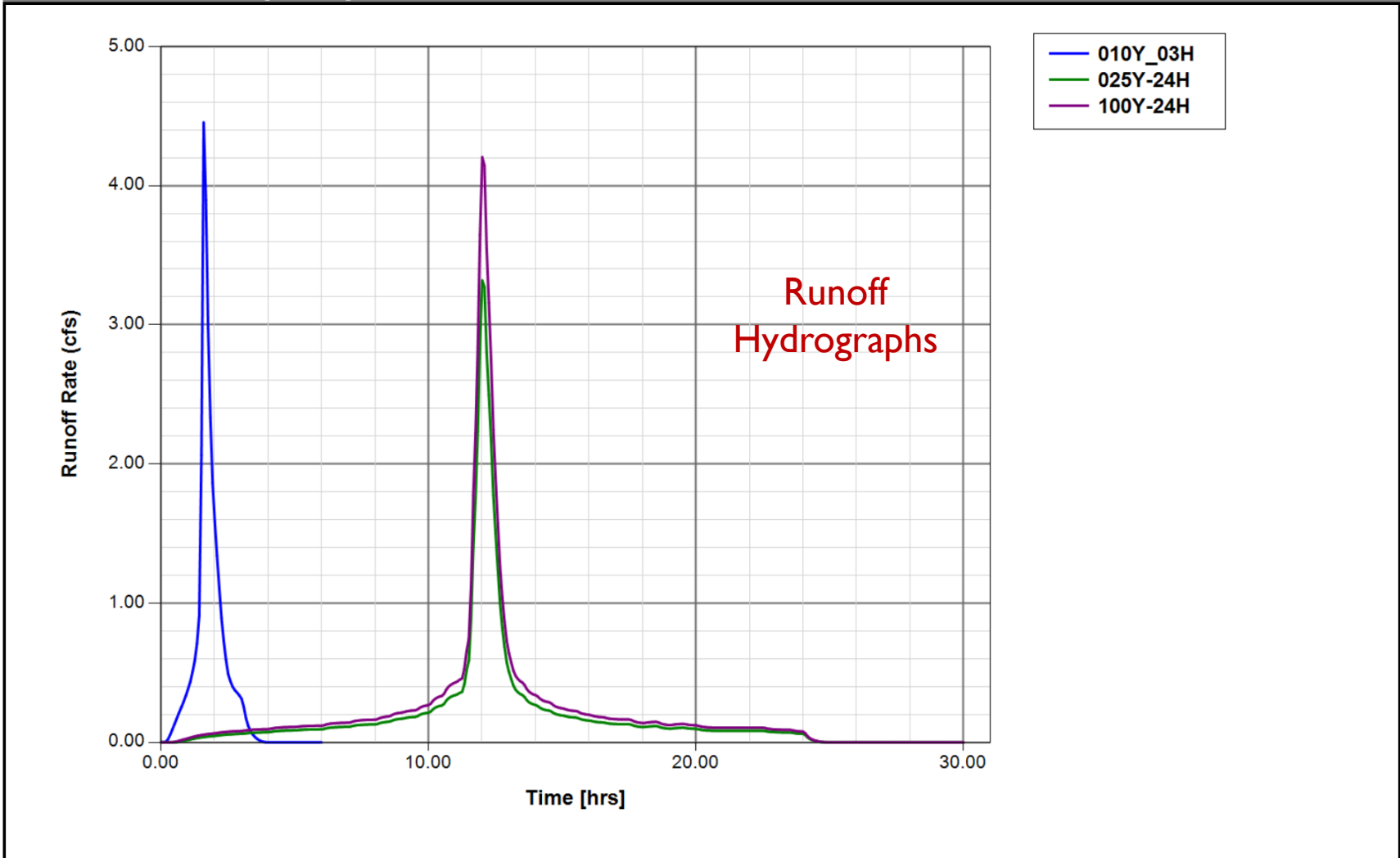
## Manual Basin Runoff Summary

Manual Basin Runoff Summary [Scenario1]

Basin Name	Sim Name	Max Flow [cfs]	Time to Max Flow [hrs]	Total Rainfall [in]	Total Runoff [in]	Area [ac]	Equivalent Curve Number	% Imperv	% DCIA
S-20	010Y_03H	4.52	1.6083	4.30	3.65	0.7342	94.3	0.00	0.00
S-20	025Y-24H	3.40	12.0500	8.40	7.51	0.7342	92.6	0.00	0.00
S-20	100Y-24H	4.31	12.0500	10.50	9.52	0.7342	92.0	0.00	0.00

# Custom Report (Manual Basin "S-20")

Manual Basin Runoff Rate: S-20 [Scenario1]



# Custom Report (Node "Pond I")

Node: Pond 1

## Input Data

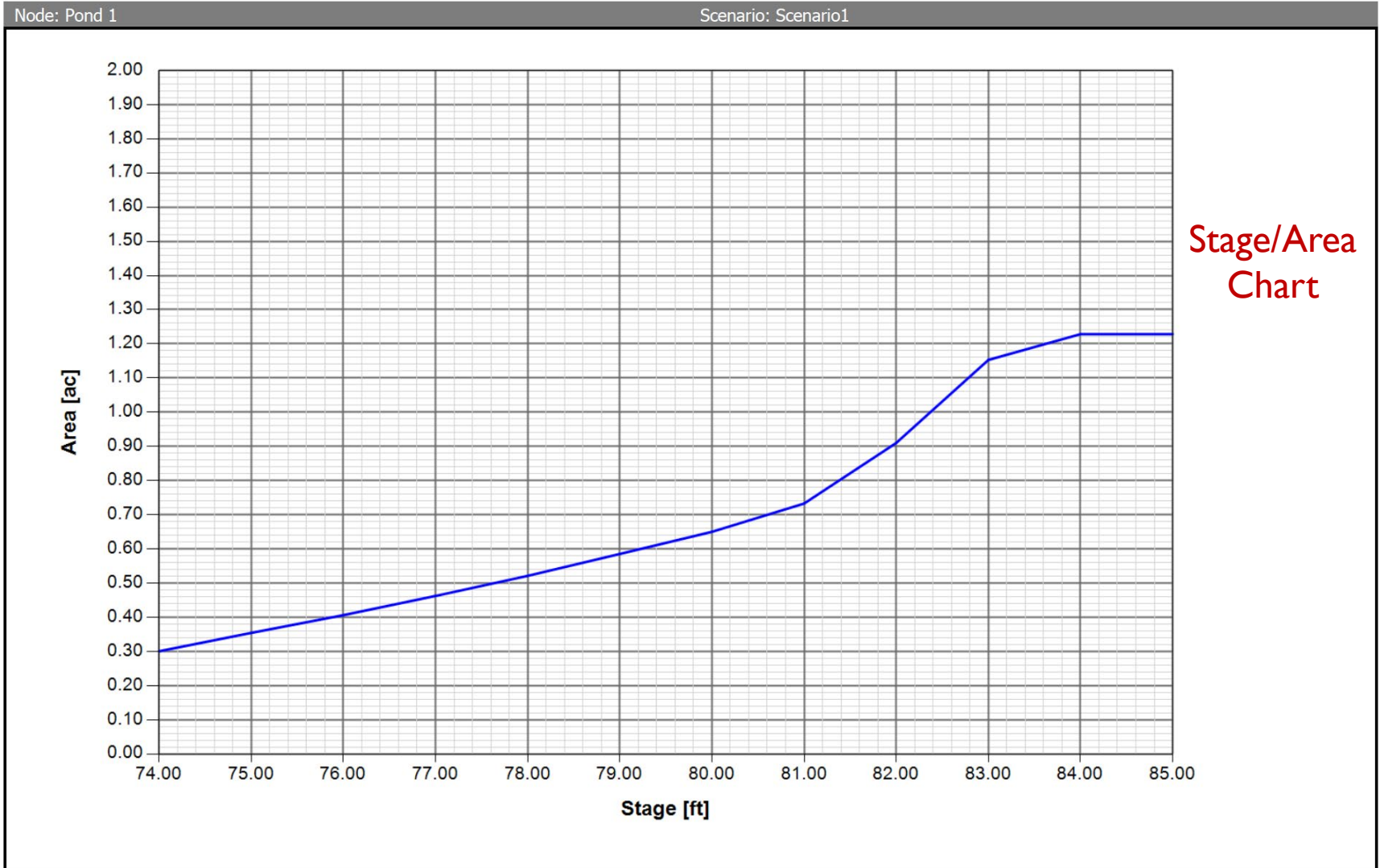
Scenario: Scenario1  
Type: Stage/Area  
Base Flow: 0.00 cfs  
Initial Stage: 74.00 ft  
Warning Stage: 80.50 ft

Stage [ft]	Area [ac]	Area [ft2]
74.00	0.3006	13096
75.00	0.3544	15436
76.00	0.4062	17696
77.00	0.4624	20140
78.00	0.5212	22703
79.00	0.5853	25494
80.00	0.6500	28316
81.00	0.7327	31916
82.00	0.9101	39644
83.00	1.1530	50224
84.00	1.2284	53511
85.00	1.2284	53511

Stage/Area  
Table

Comment:

# Custom Report (Node "Pond I")



# Custom Report (Node "Pond 1")

11

Node Max Conditions [Scenario1]

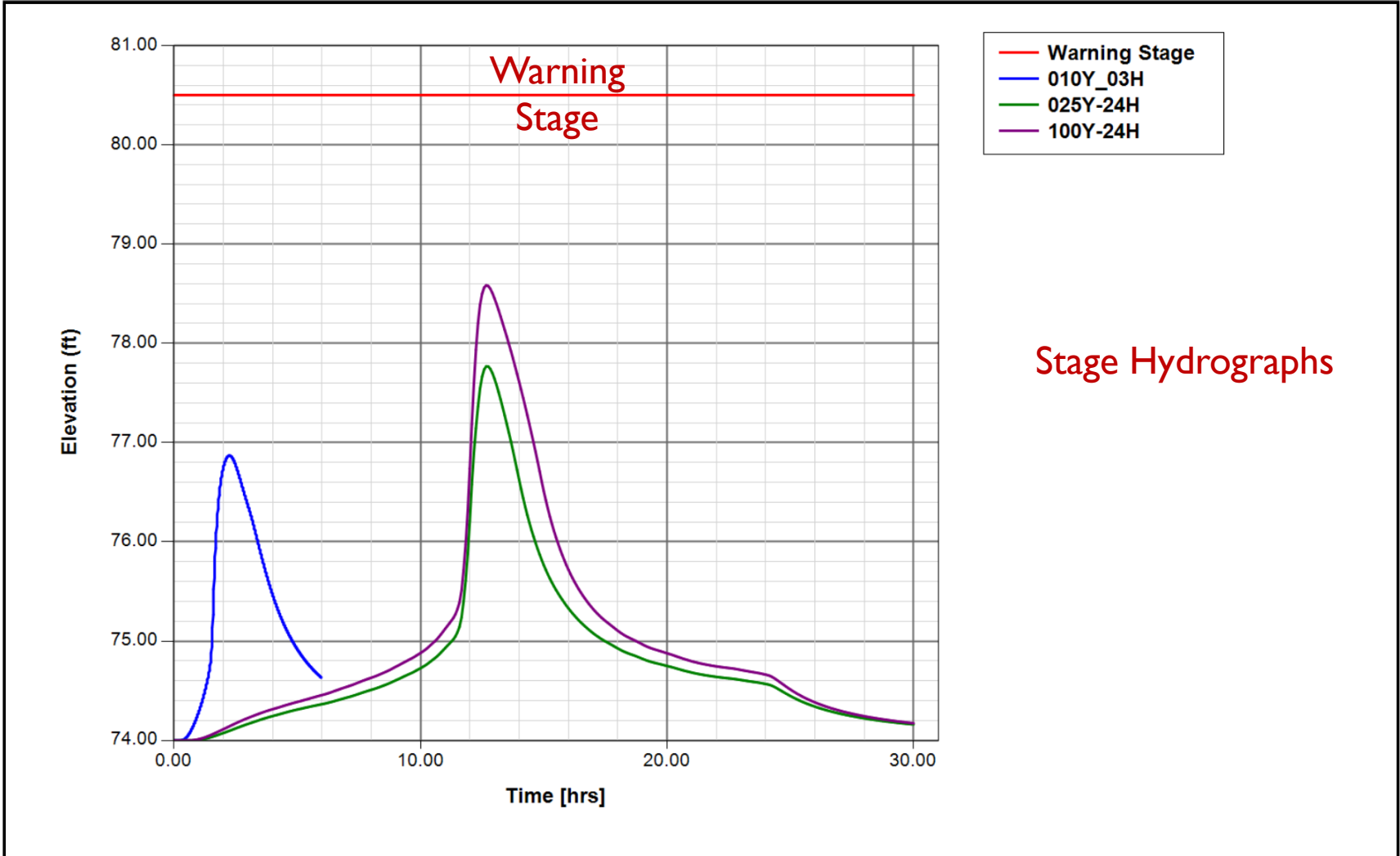
## Node Max Conditions

Node Name	Sim Name	Warning Stage [ft]	Max Stage [ft]	Min/Max Delta Stage [ft]	Max Total Inflow [cfs]	Max Total Outflow [cfs]	Max Surface Area [ft2]
Pond 1	010Y_03H	80.50	76.87	0.0010	40.53	14.79	20027
Pond 1	025Y-24H	80.50	77.77	0.0010	36.01	17.61	22319
Pond 1	100Y-24H	80.50	78.59	0.0010	47.27	19.44	24412



# Custom Report (Node "S-20")

Node Stage w/Warning Stage: Pond 1 [Scenario1]



Stage Hydrographs

# Custom Report (Node "S-20")

Node: S-20

## Input Data

Scenario: Scenario1  
Type: Stage/Area  
Base Flow: 0.00 cfs  
Initial Stage: 76.25 ft  
Warning Stage: 81.70 ft

Comment:

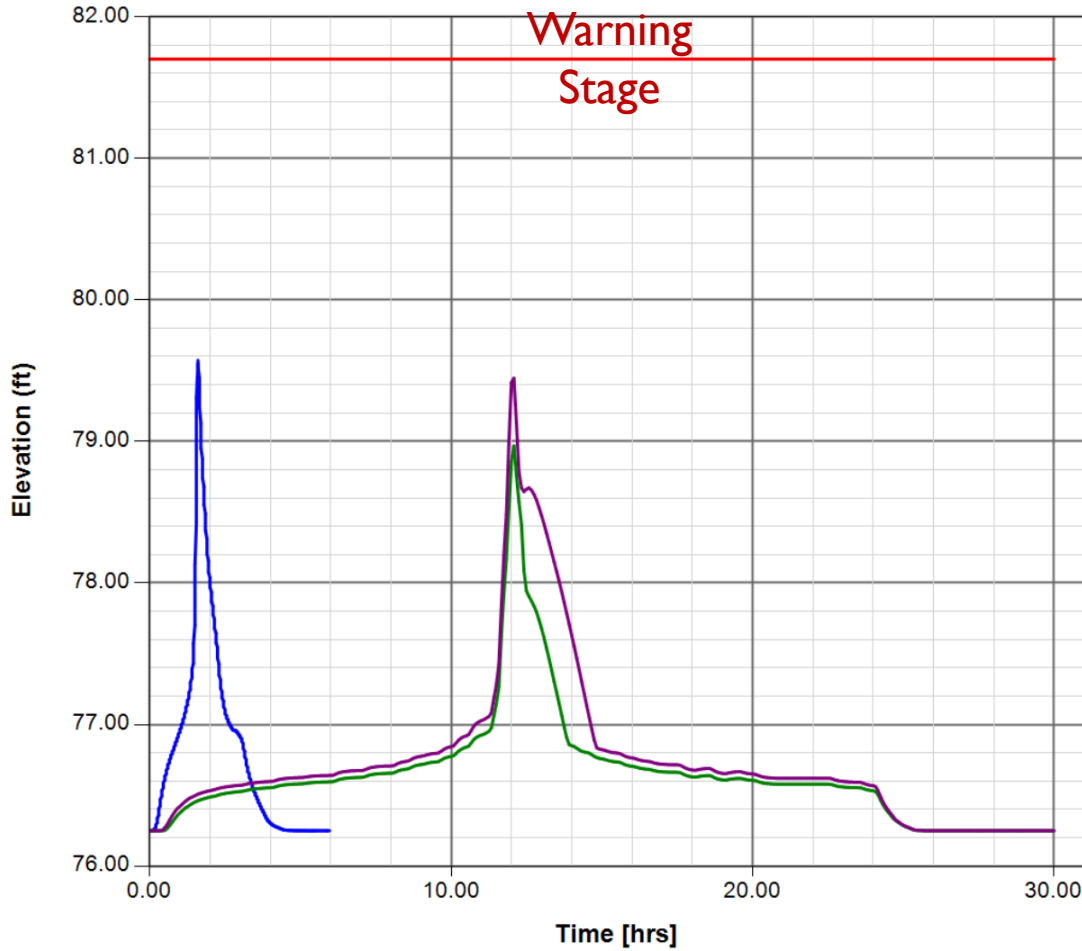
## Node Max Conditions

Node Max Conditions [Scenario1]

Node Name	Sim Name	Warning Stage [ft]	Max Stage [ft]	Min/Max Delta Stage [ft]	Max Total Inflow [cfs]	Max Total Outflow [cfs]	Max Surface Area [ft2]
S-20	010Y_03H	81.70	79.58	0.0019	34.07	34.05	603
S-20	025Y-24H	81.70	78.99	0.0010	25.85	25.84	601
S-20	100Y-24H	81.70	79.50	0.0010	32.93	32.96	602

# Custom Report (Node "S-20")

Node Stage w/Warning Stage: S-20 [Scenario1]



Stage Hydrographs

# Custom Report (Pipe Link "S-19")

## Pipe Input Data

15

Pipe Link: S-19	Upstream	Downstream
Scenario: Scenario1	Invert: 76.25 ft	Invert: 76.00 ft
From Node: S-20	Manning's N: 0.0130	Manning's N: 0.0130
To Node: Pond 1	Geometry: Circular	Geometry: Circular
Link Count: 1	Max Depth: 3.00 ft	Max Depth: 3.00 ft
Flow Direction: Both	Bottom Clip	
Damping: 0.0000 ft	Default: 0.00 ft	Default: 0.00 ft
Length: 68.00 ft	Op Table:	Op Table:
FHWA Code: 1	Ref Node:	Ref Node:
Entr Loss Coef: 0.50	Manning's N: 0.0000	Manning's N: 0.0000
Exit Loss Coef: 1.00	Top Clip	
Bend Loss Coef: 0.00	Default: 0.00 ft	Default: 0.00 ft
Bend Location: 0.00 ft	Op Table:	Op Table:
Energy Switch: Energy	Ref Node:	Ref Node:
	Manning's N: 0.0000	Manning's N: 0.0000
Comment:		

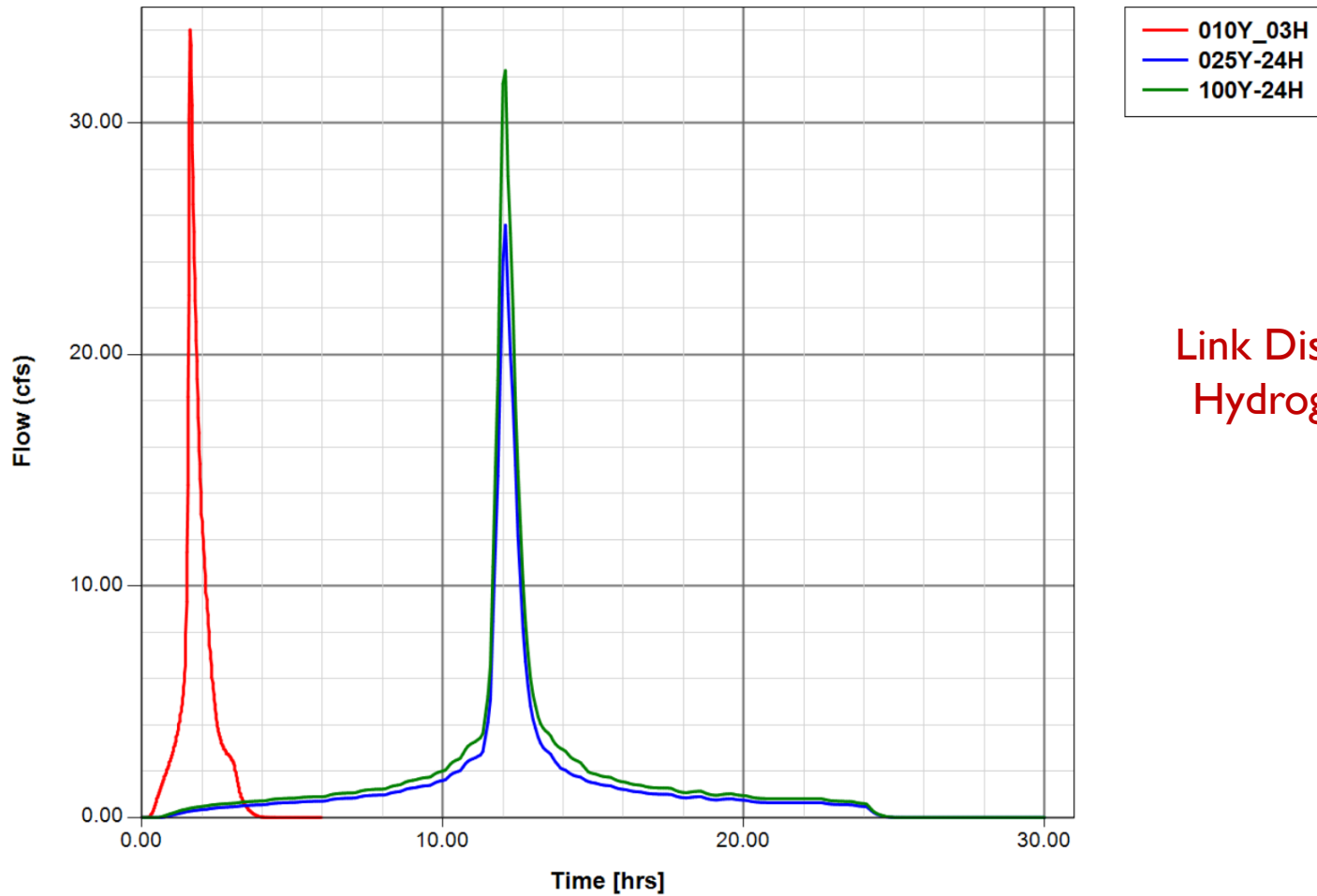
## Link Min/Max Conditions

Link Min/Max Conditions [Scenario1]

Link Name	Sim Name	Max Flow [cfs]	Min Flow [cfs]	Min/Max Delta Flow [cfs]	Max Us Velocity [fps]	Max Ds Velocity [fps]	Max Avg Velocity [fps]
S-19	010Y_03H	34.05	0.00	0.13	4.82	7.24	6.03
S-19	025Y-24H	25.84	0.00	-0.09	3.82	6.50	5.16
S-19	100Y-24H	32.96	0.00	0.13	4.66	7.20	5.93

# Custom Report (Pipe Link "S-19")

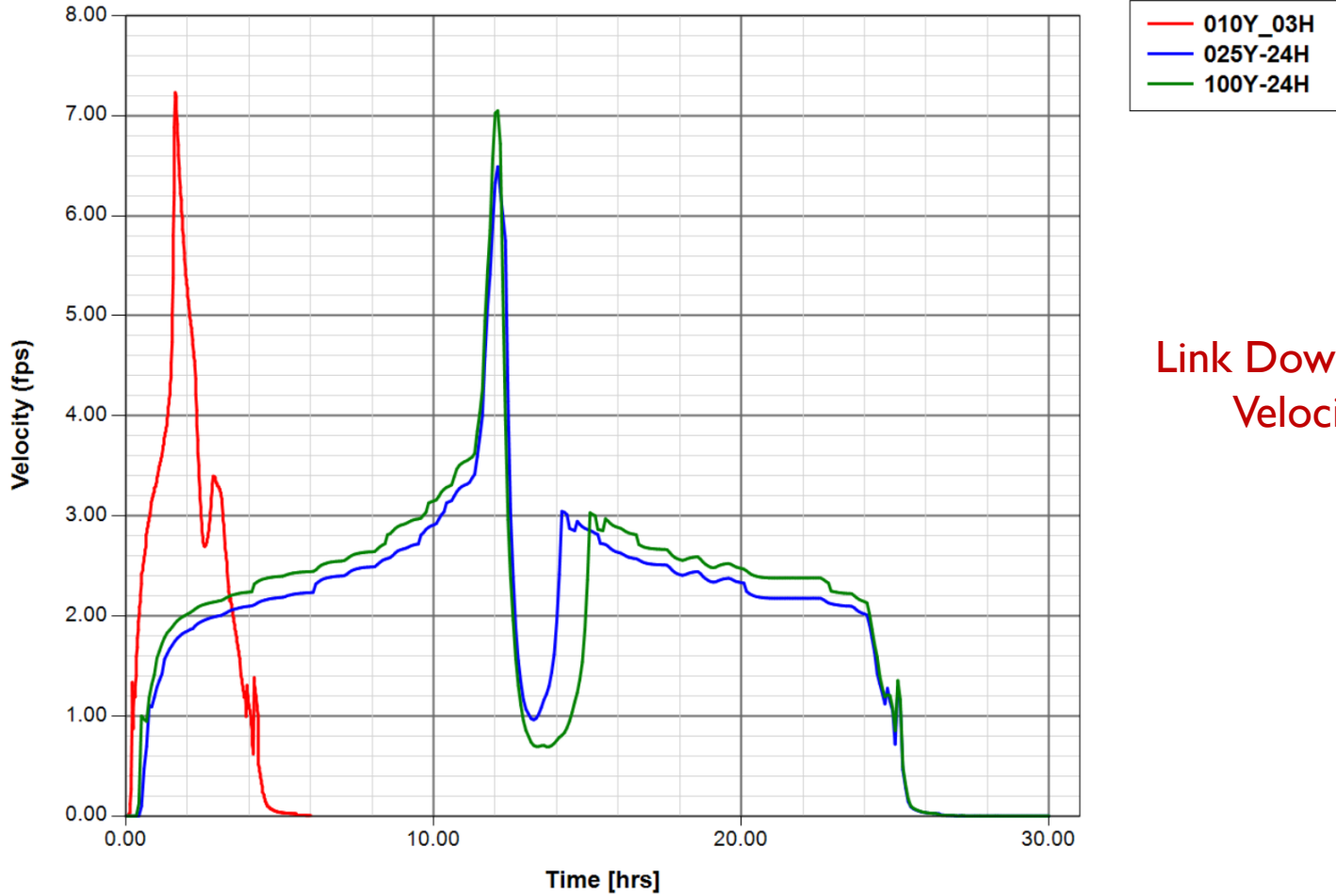
Link Flow: S-19 [Scenario1]



Link Discharge Hydrographs

# Custom Report (Pipe Link "S-19")

Link Downstream Velocity: S-19 [Scenario1]



Link Downstream Velocities

# Custom Report (Pipe Link "S-32")

## Pipe Input Data

18

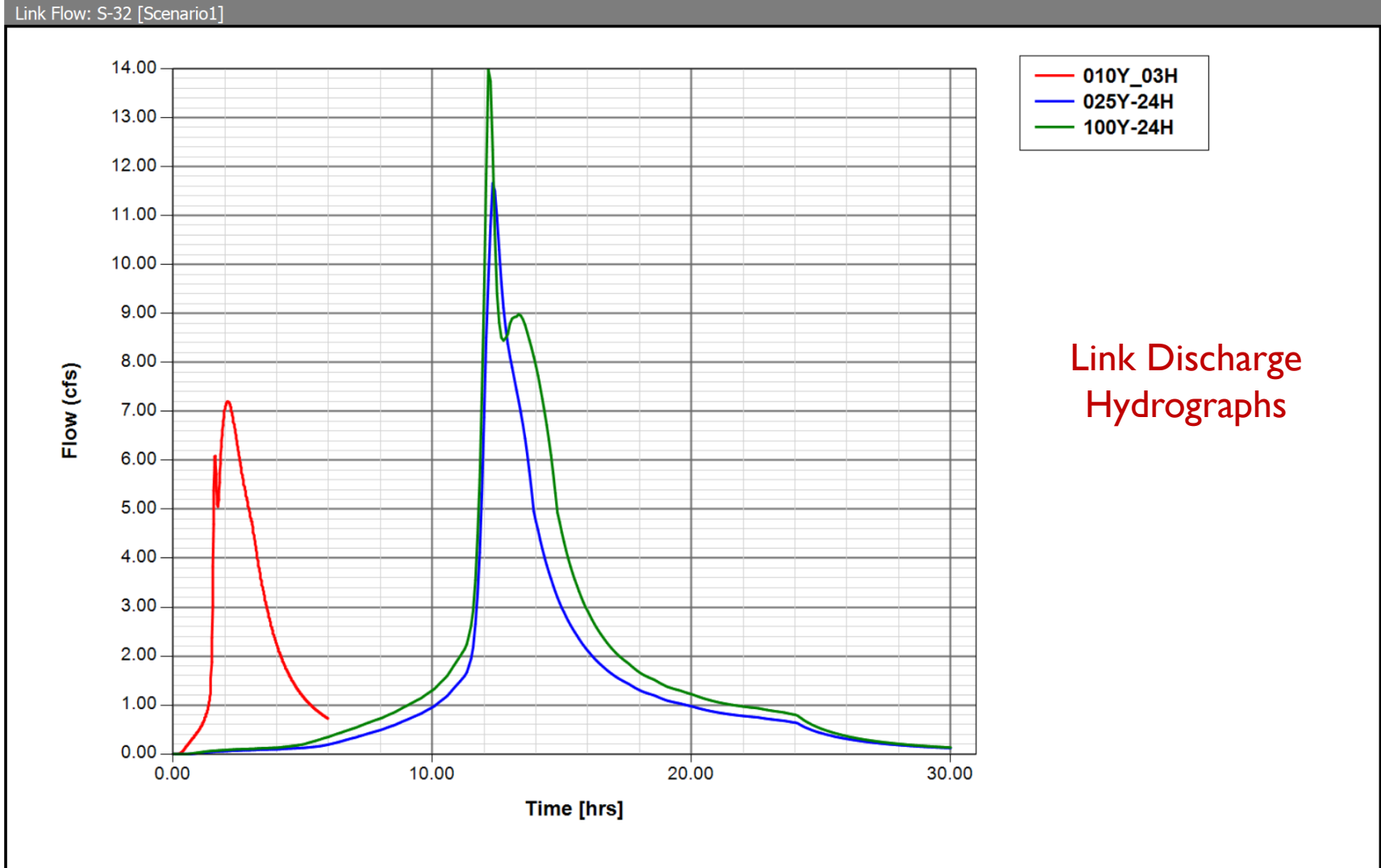
Pipe Link: S-32	Upstream	Downstream
Scenario: Scenario1	Invert: 76.10 ft	Invert: 76.00 ft
From Node: S-33	Manning's N: 0.0130	Manning's N: 0.0130
To Node: Pond 1	Geometry: Circular	Geometry: Circular
Link Count: 1	Max Depth: 2.50 ft	Max Depth: 2.50 ft
Flow Direction: Both	Bottom Clip	
Damping: 0.0000 ft	Default: 0.00 ft	Default: 0.00 ft
Length: 91.00 ft	Op Table:	Op Table:
FHWA Code: 1	Ref Node:	Ref Node:
Entr Loss Coef: 0.50	Manning's N: 0.0000	Manning's N: 0.0000
Exit Loss Coef: 1.00	Top Clip	
Bend Loss Coef: 0.00	Default: 0.00 ft	Default: 0.00 ft
Bend Location: 0.00 ft	Op Table:	Op Table:
Energy Switch: Energy	Ref Node:	Ref Node:
	Manning's N: 0.0000	Manning's N: 0.0000
Comment:		

## Link Min/Max Conditions

Link Min/Max Conditions [Scenario1]

Link Name	Sim Name	Max Flow [cfs]	Min Flow [cfs]	Min/Max Delta Flow [cfs]	Max Us Velocity [fps]	Max Ds Velocity [fps]	Max Avg Velocity [fps]
S-32	010Y_03H	7.20	0.00	-0.02	2.33	4.56	3.45
S-32	025Y-24H	11.70	0.00	-0.04	2.94	5.12	3.88
S-32	100Y-24H	14.09	0.00	-0.04	3.17	5.28	4.02

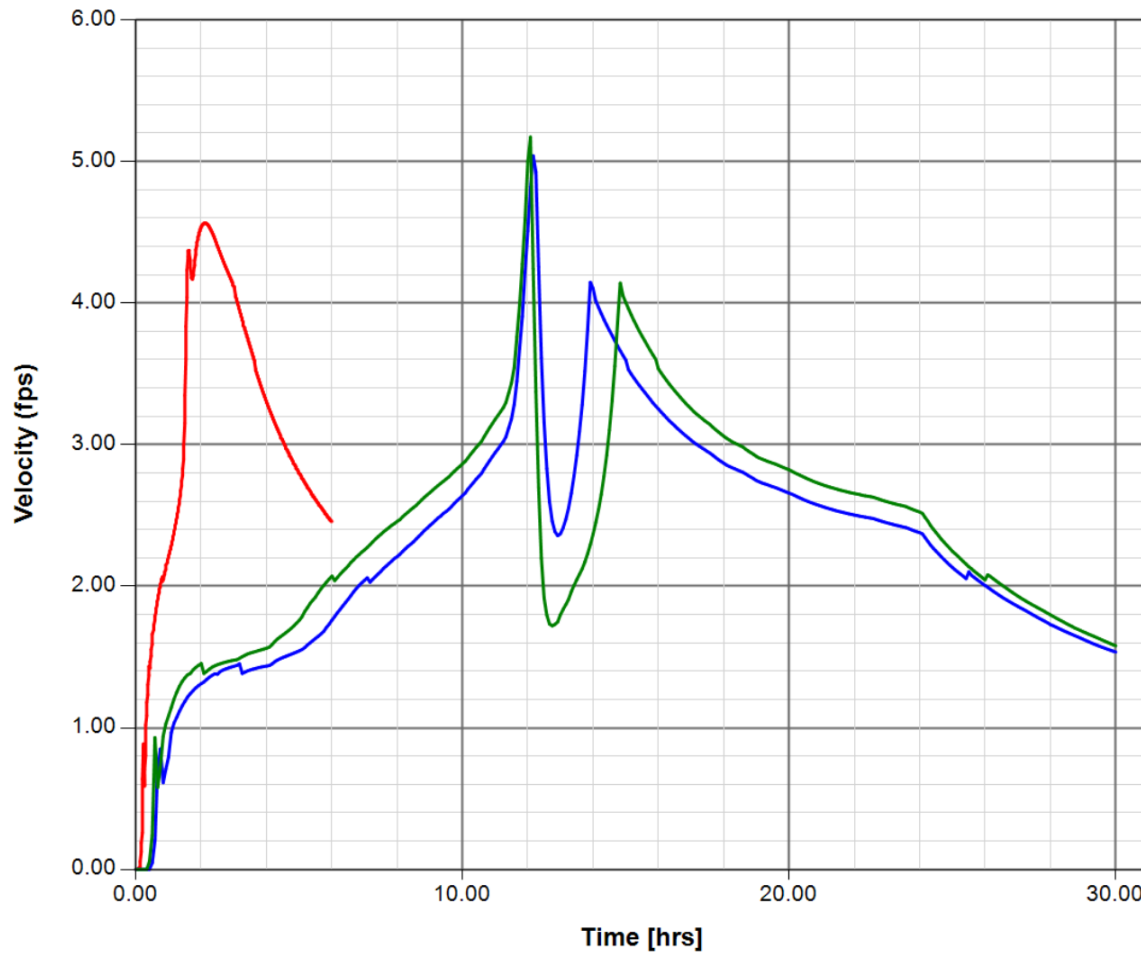
# Custom Report (Pipe Link "S-32")





# Custom Report (Pipe Link "S-32")

Link Downstream Velocity: S-32 [Scenario1]

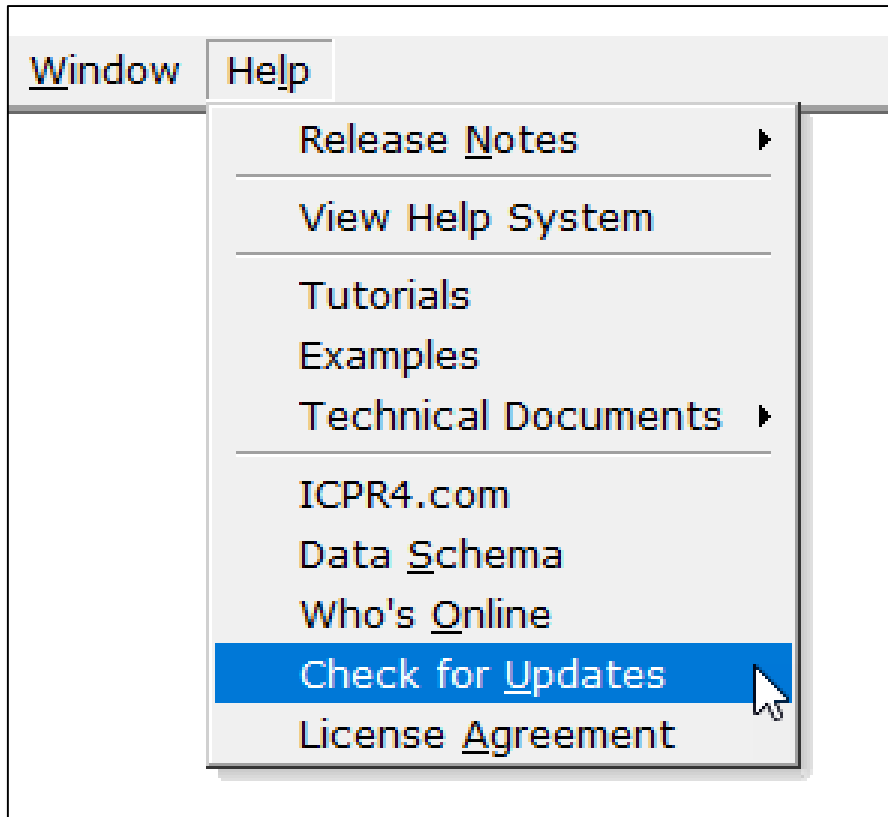


Link Downstream Velocities

# Next Webinar – Lesson 3: Hydraulics, Part 2

Tuesday October 29, 2019

11:30 – 1:30 (EDT)



We will try to post a recording of this webinar and/or the presentation material as soon as we can.

To find them:

*“Check for Updates”*  
sometime tomorrow.

[support@icpr4.com](mailto:support@icpr4.com)