Regulatory Review Webinar Series

Lesson 4
Hydraulics, Part 3

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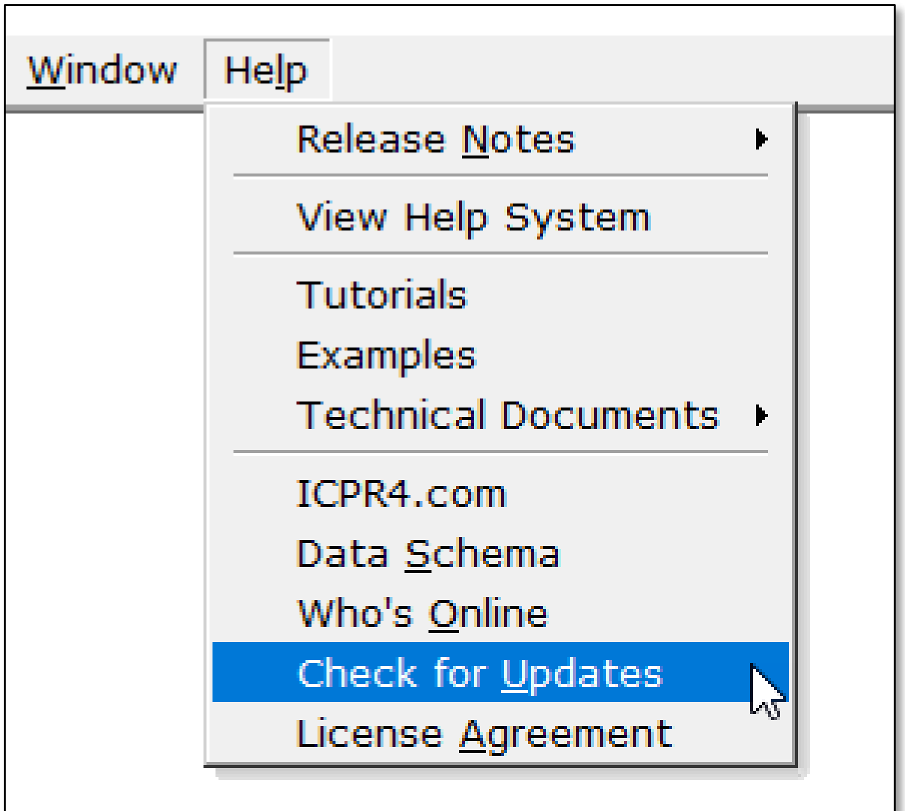
Streamline Technologies, Inc.

Thursday – October 31, 2019

Next Webinar – Lesson 5: Typical Pre/Post Examples

Tuesday November 5, 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.

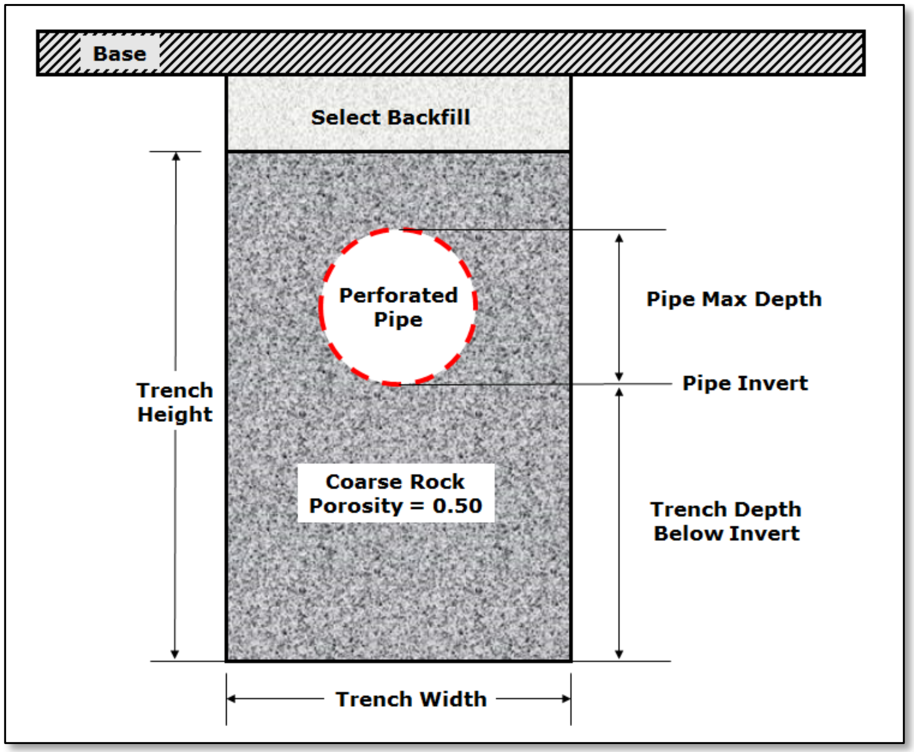
To find them:
"Check for Updates"
sometime tomorrow.

support@icpr4.com

Lesson 4 Topics

- French Drain Links
- Percolation Links
- Examples

French Drain Links



Source: *An Overview of Urban Stormwater Management Practices in Miami-Dade County, Florida*, 2004

French Drain Links

Includes:

- Storage in Trench & Pipe
- Pipe Hydraulics

Does Not Include:

- Percolation

French Drain Links

Provide treatment volume for 1" of runoff from a 1-ac site

$V_{treatment} = 43{,}560\ ft^2 \times (1in) \times (1ft/12in) = 3{,}630\ ft^3$
$A_{pipe} = \pi r^2 = \pi$
$A_{trench} = [(W_{trench} \times D_{treatment}) - A_{pipe}] \times Porosity$

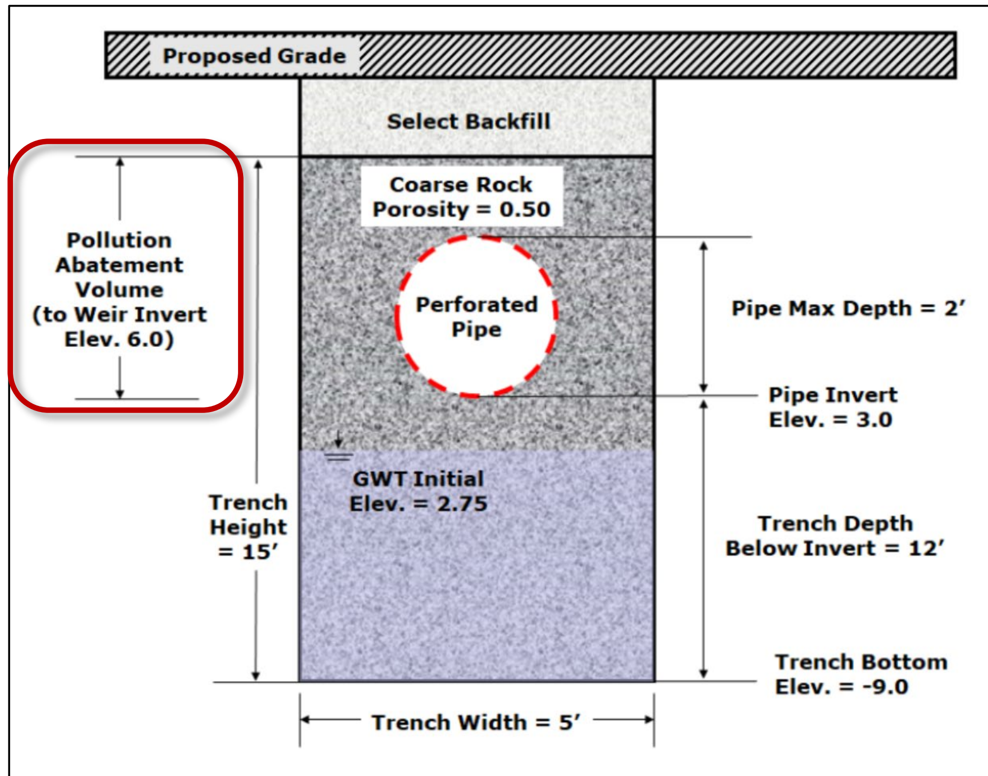
$V_{treatment}$ / LF

$= (1ft)A_{pipe} + (1ft)A_{trench}$

$= \pi + [(5' \times (6'-3')) - \pi] \times 0.5$

$= 9.071\ ft^3$ per ft

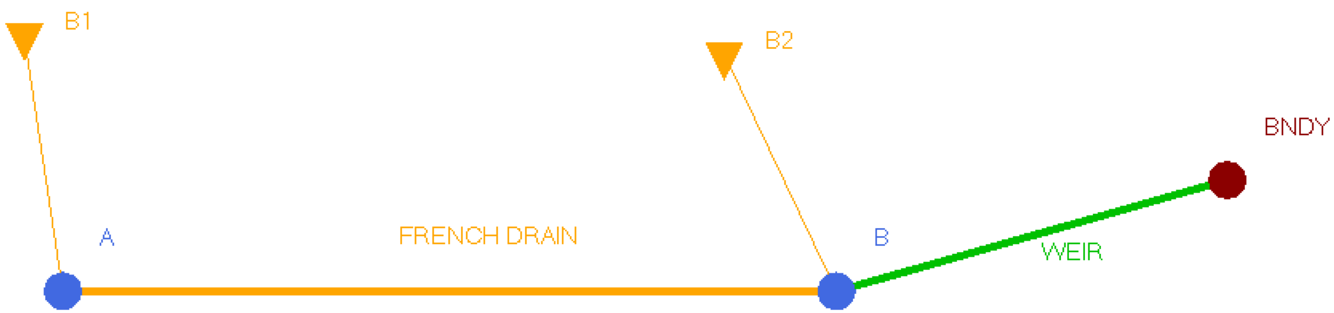
$L_{FD} = 3{,}630 / 9.071 =$ 400 ft



French Drain Links

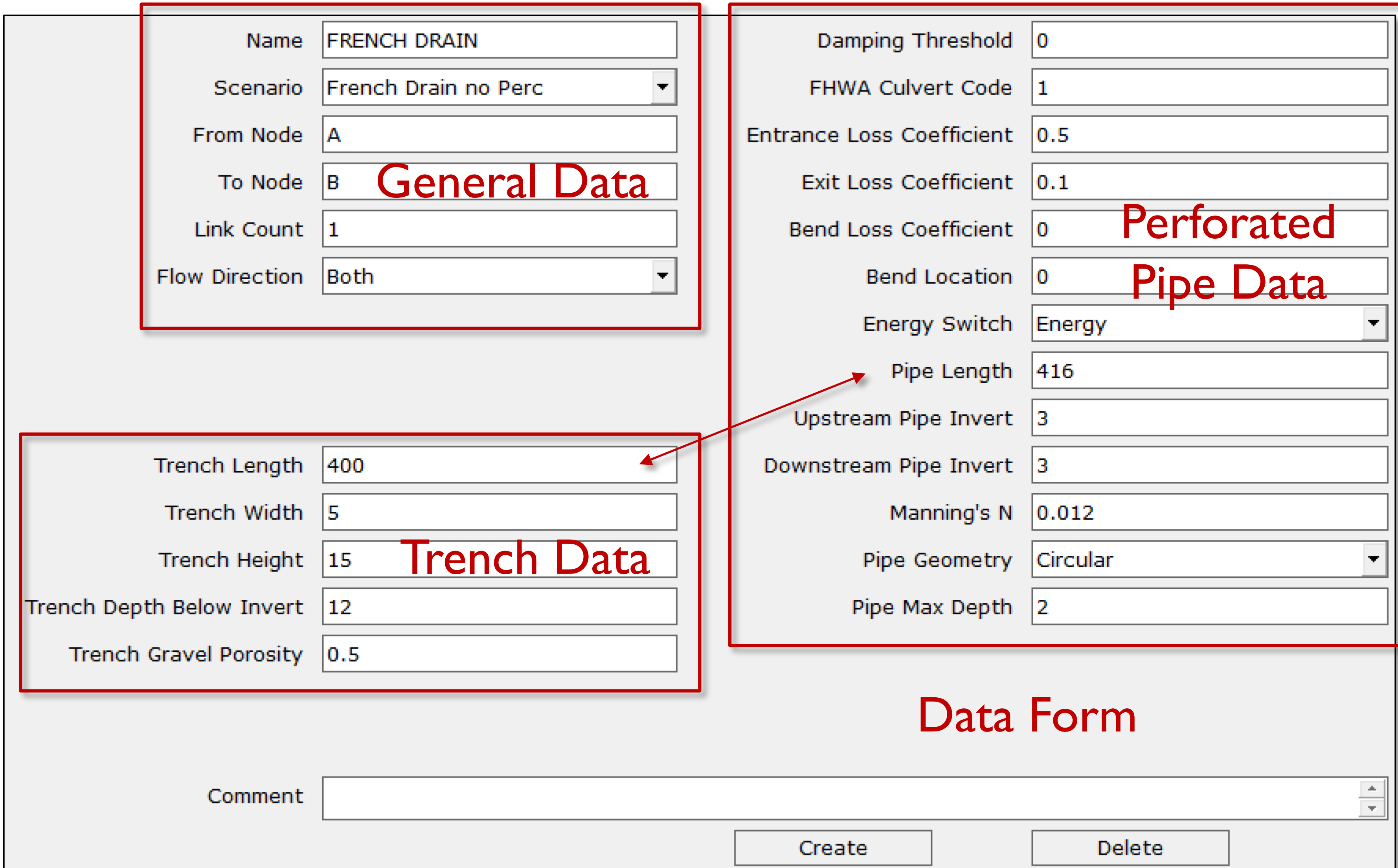
Model Data

A	= 0.5 ac	A	= 0.5 ac
CN	= 100	CN	= 100
TC	= 10 min	TC	= 10 min



Trench		Pipe		Vertical Sharp Crested Weir	
Length	= 400'	Length	= 416'	Geometry	= Rect
Width	= 5'	Geometry	= Circ	Max Depth	= 1'
Height	= 15'	Max Depth	= 2'	Max Width	= 4'
Depth Below Inv	= 12'	Invert Elev	= 3'	Invert Elev	= 6'
Gravel Porosity	= 0.5				

French Drain Links

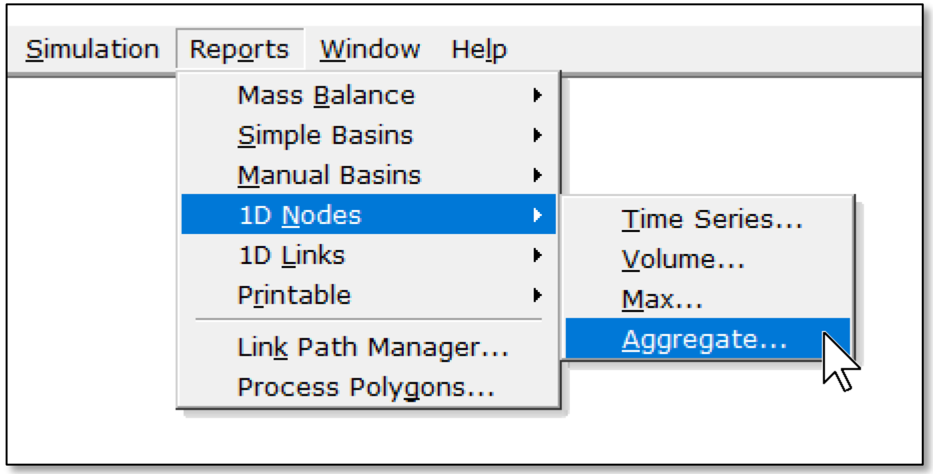


French Drain Links

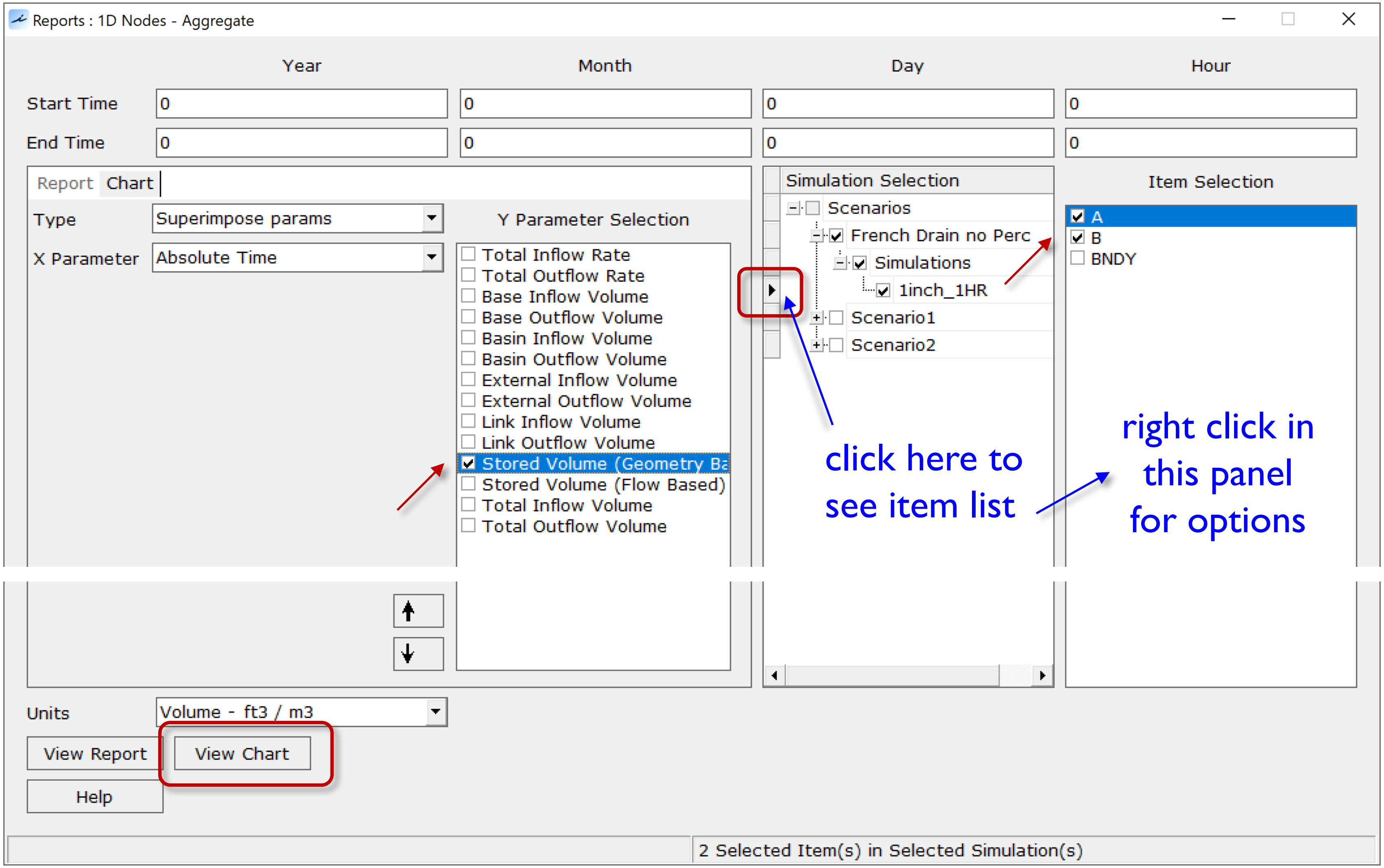
French Drain Link: FRENCH DRAIN		Pipe Data	
Scenario:	French Drain no Perc	Damping:	0.0000 ft
From Node:	A	FHWA Code:	1
To Node:	B	Entr Loss Coef:	0.50
Link Count:	1	Exit Loss Coef:	0.10
Flow Direction:	Both	Bend Loss Coef:	0.00
		Bend Location:	0.00 ft
		Energy Switch:	Energy
		Pipe Length:	416.00 ft
Trench Length:	400.00 ft	Pipe Invert:	3.00 ft
Trench Width:	5.00 ft	Pipe Invert:	3.00 ft
Trench Height:	15.00 ft	Manning's N:	0.0120
Trench Depth Below Invert:	12.00 ft	Geometry Type:	Circular
Trench Gravel Porosity:	0.500	Pipe Max Depth:	2.00 ft
Comment:			

Input Report

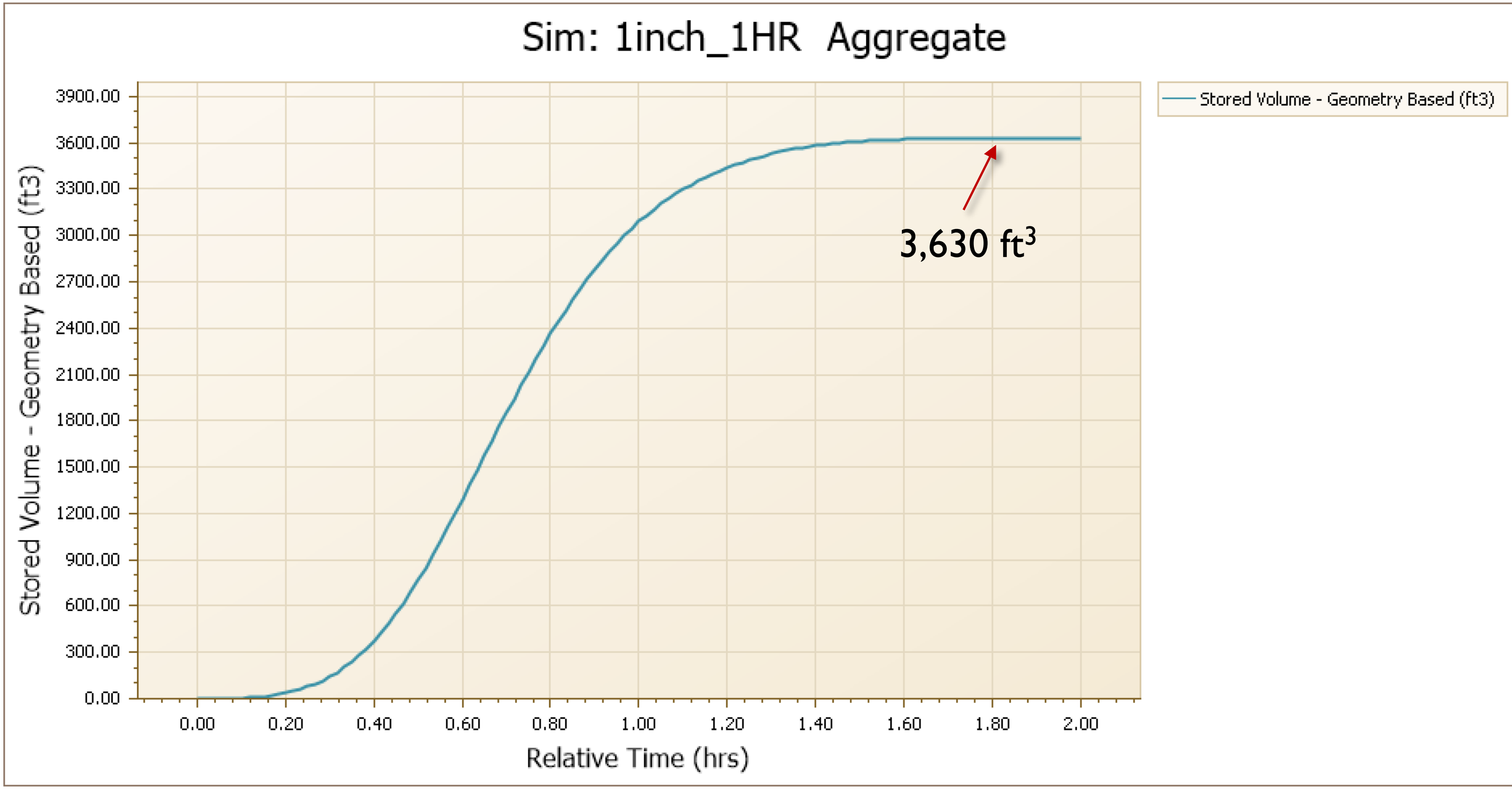
French Drain Links



French Drain Links

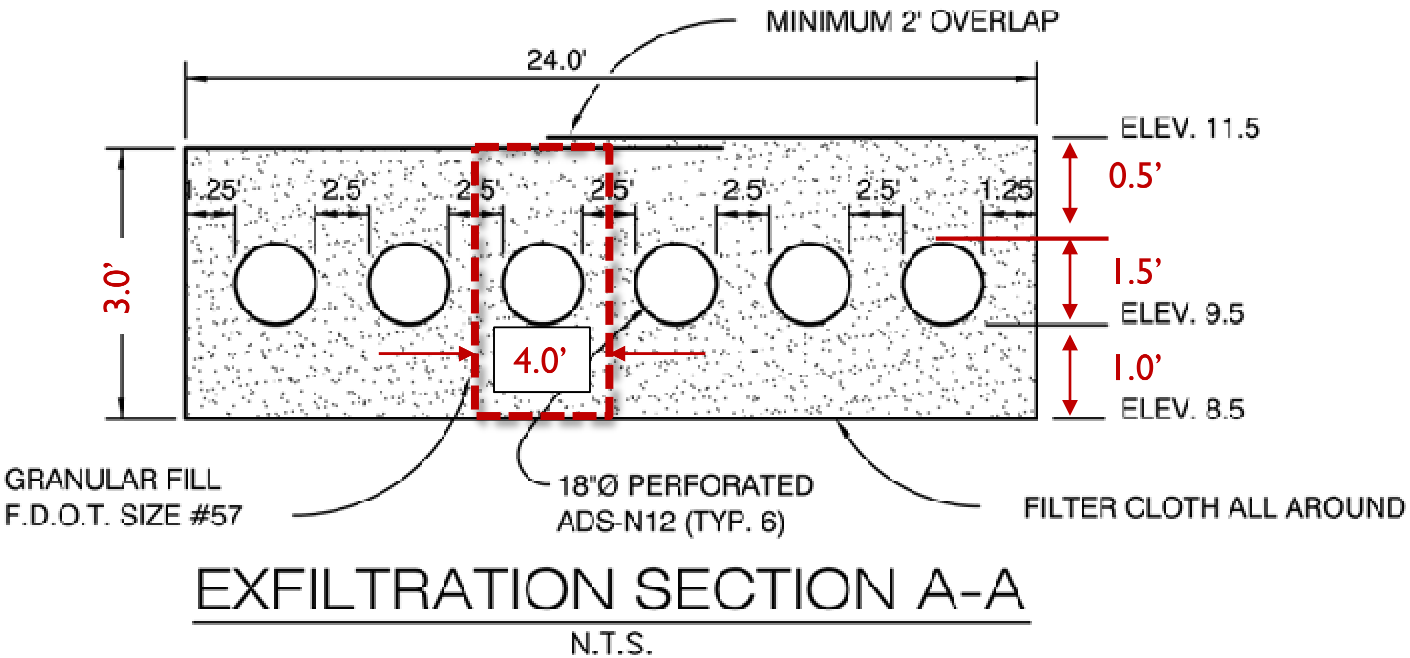


French Drain Links



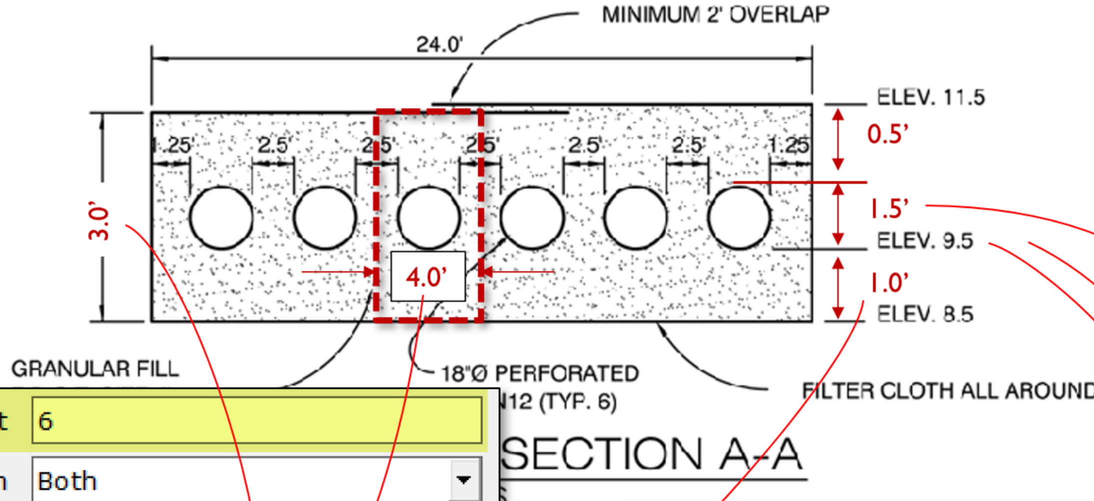
French Drain Links

Infiltration Gallery



French Drain Links

Infiltration Gallery

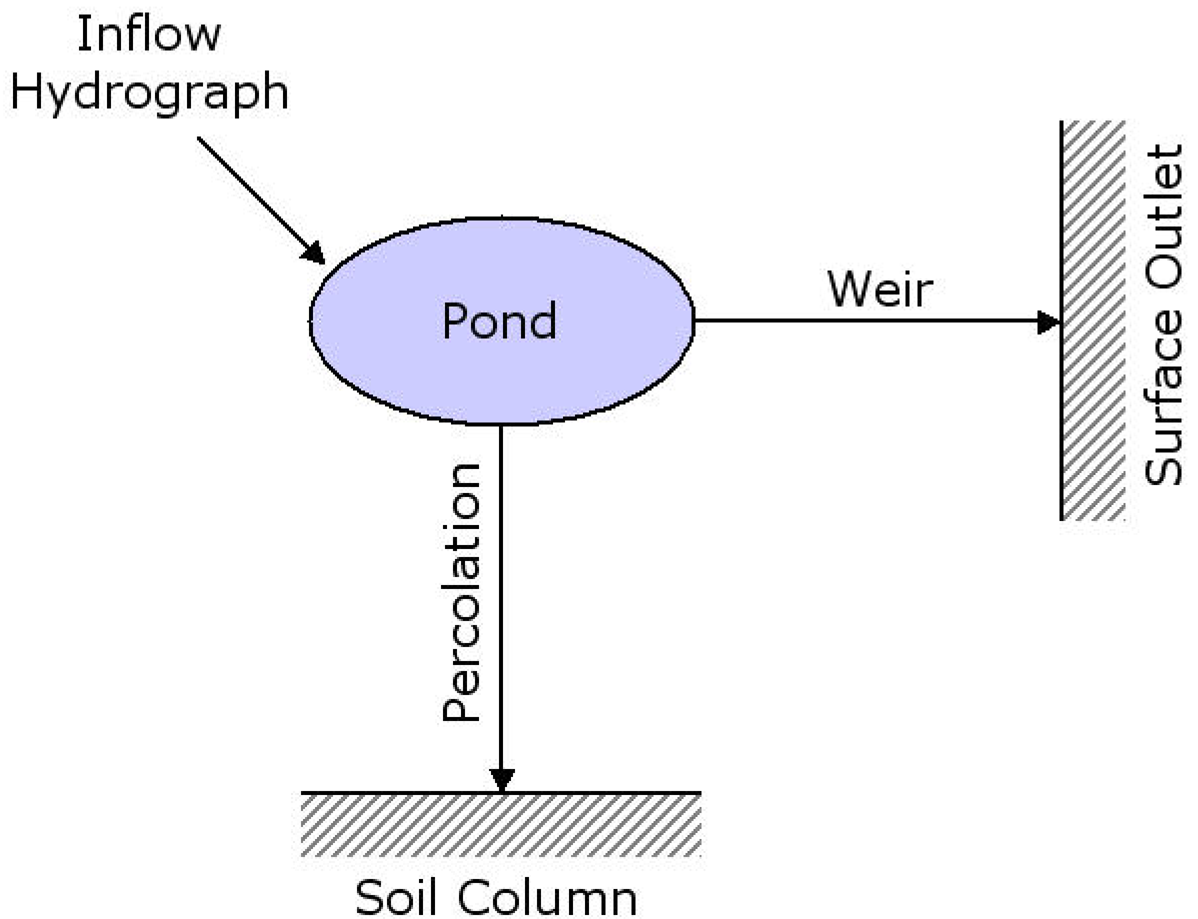


Link Count	6
Flow Direction	Both
Trench Length	0 TBD
Trench Width	4
Trench Height	3
Trench Depth Below Invert	1
Trench Gravel Porosity	0.5

Upstream Pipe Invert	9.5
Downstream Pipe Invert	9.5
Manning's N	0.024
Pipe Geometry	Circular
Pipe Max Depth	1.5

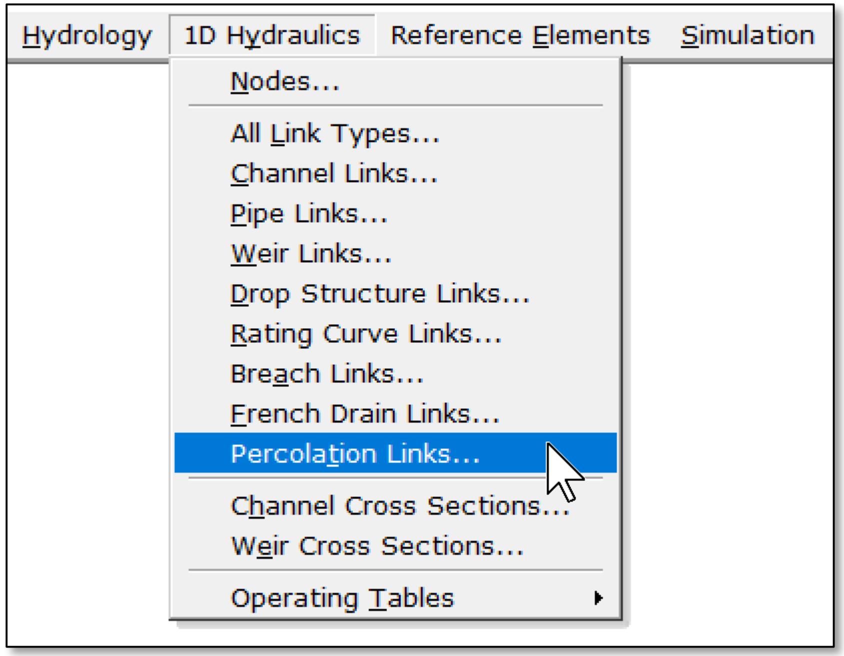
Percolation Links

Concepts



Percolation Links

Data Form



Percolation Links

Data Form

Field	Value	Field	Value
Name	PERC	Surface Area Option	Vary Based on Stage/Area T...
Scenario	French Drain with Perc		
From Node	POND		
To Node	GWT	Vertical Flow Termination	Horizontal Flow Algorithm
Link Count	1	Perimeter 1	600
Flow Direction	Both	Perimeter 2	1228
Aquifer Base Elevation	76	Perimeter 3	3142
Water Table Elevation	96	Distance P1 to P2	100
Annual Recharge Rate	0	Distance P2 to P3	400
Horizontal Conductivity	16	# of Cells P1 to P2	20
Vertical Conductivity	8	# of Cells P2 to P3	40
Fillable Porosity	0.3		
Layer Thickness	99		
Comment			

Create | Delete

Percolation Links

Data Form

Field	Value
Name	PERC
Scenario	French Drain with Perc
From Node	POND
To Node	GWT
Link Count	1
Flow Direction	Both
Aquifer Base Elevation	76
Water Table Elevation	96
Annual Recharge Rate	0
Horizontal Conductivity	16
Vertical Conductivity	8
Fillable Porosity	0.3
Layer Thickness	99
Comment	

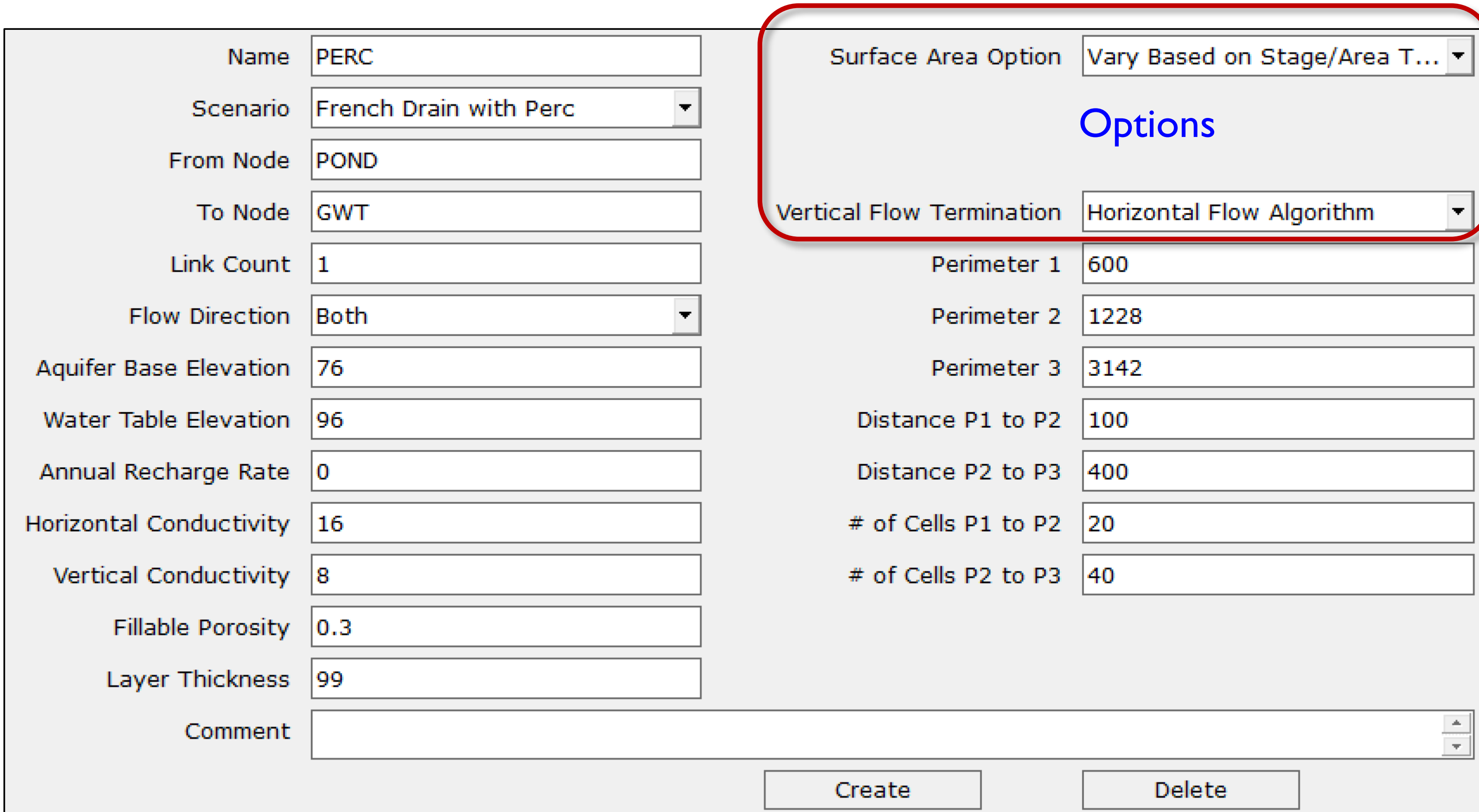
Field	Value
Surface Area Option	Vary Based on Stage/Area T...
Vertical Flow Termination	Horizontal Flow Algorithm
Perimeter 1	600
Perimeter 2	1228
Perimeter 3	3142
Distance P1 to P2	100
Distance P2 to P3	400
# of Cells P1 to P2	20
# of Cells P2 to P3	40

Connectivity

Create | Delete

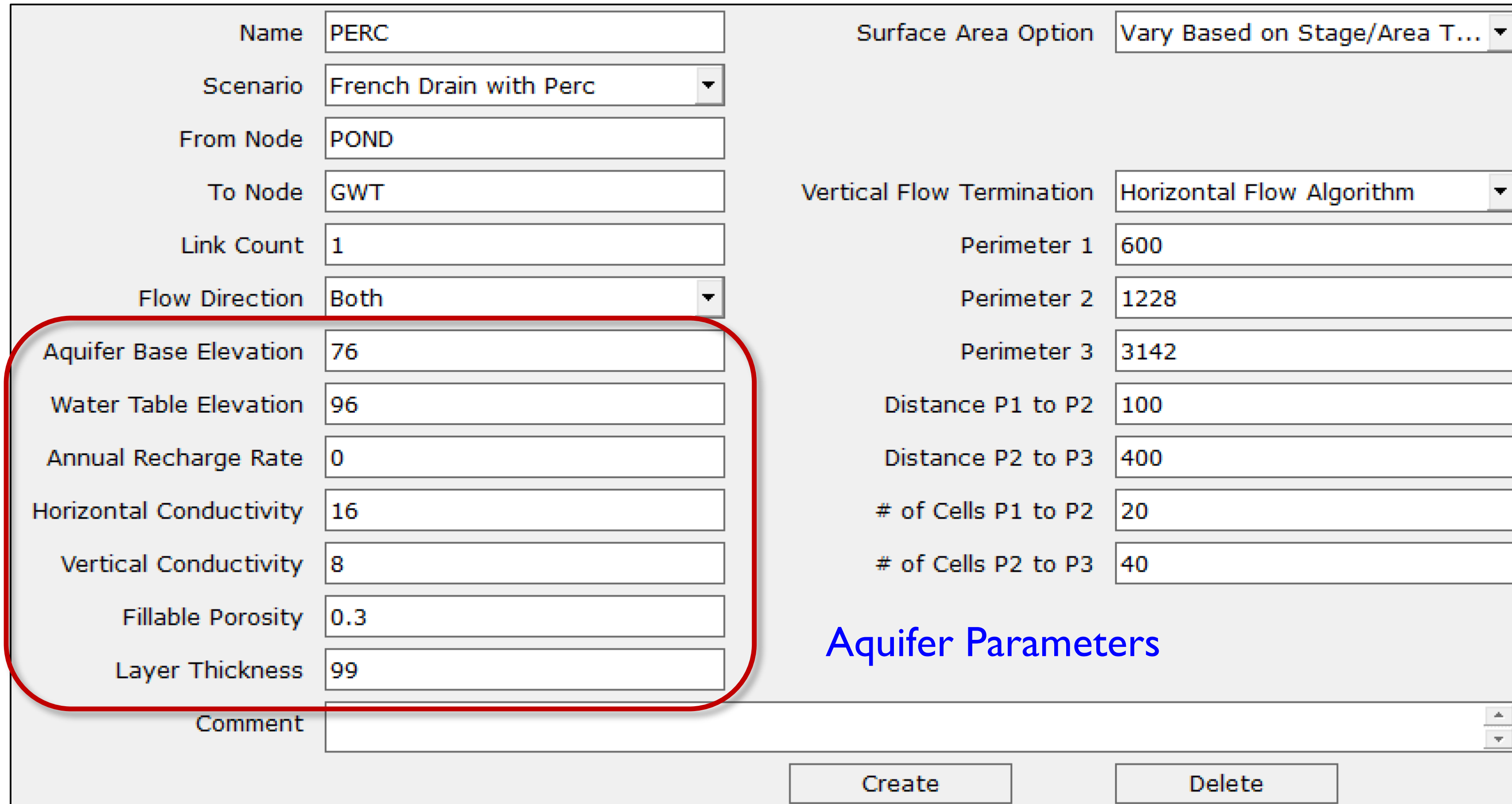
Percolation Links

Data Form



Percolation Links

Data Form



Name	PERC	Surface Area Option	Vary Based on Stage/Area T...
Scenario	French Drain with Perc		
From Node	POND		
To Node	GWT	Vertical Flow Termination	Horizontal Flow Algorithm
Link Count	1	Perimeter 1	600
Flow Direction	Both	Perimeter 2	1228
Aquifer Base Elevation	76	Perimeter 3	3142
Water Table Elevation	96	Distance P1 to P2	100
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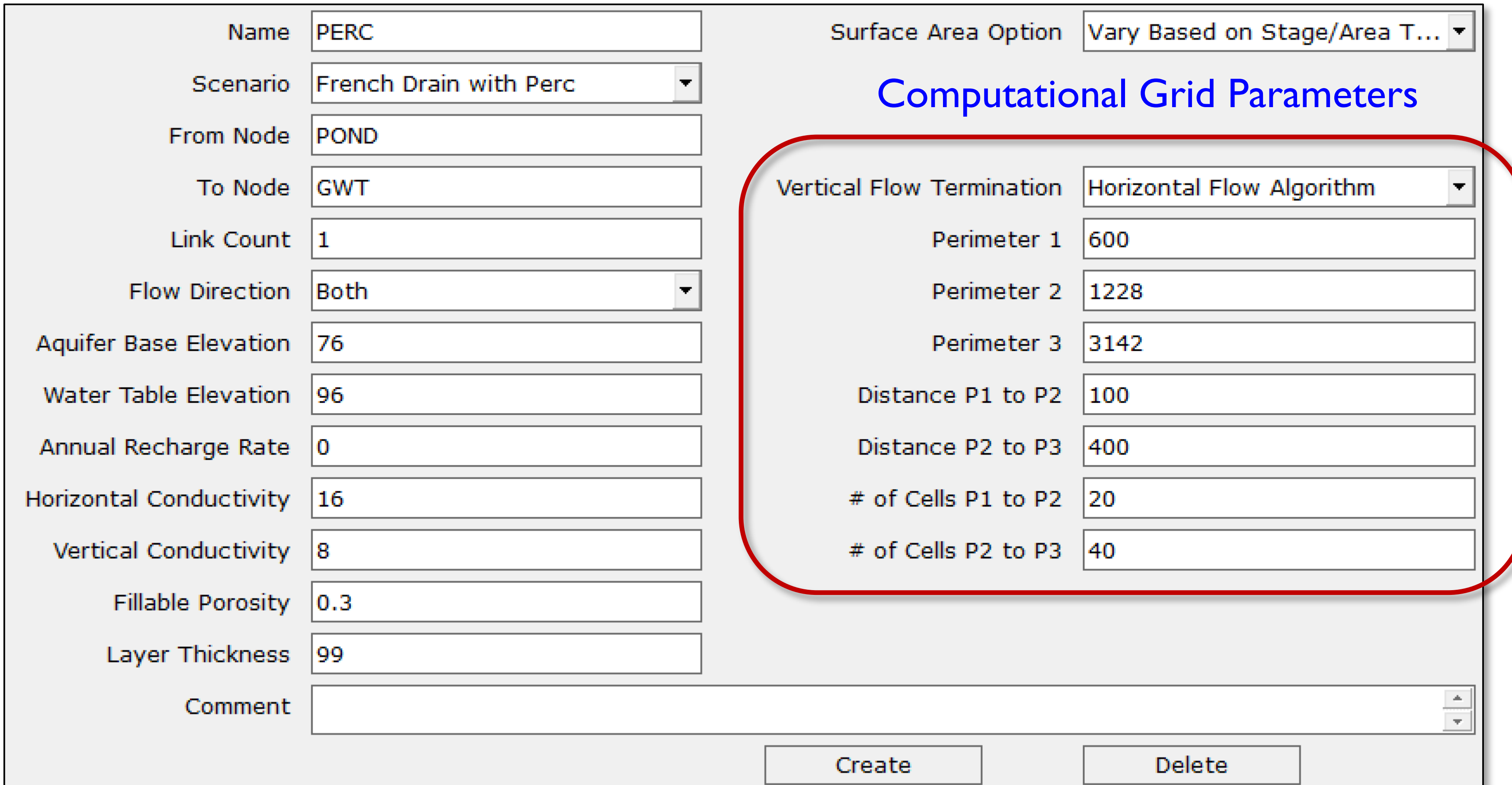
Horizontal Conductivity	16	# of Cells P1 to P2	20
Vertical Conductivity	8	# of Cells P2 to P3	40
Fillable Porosity	0.3		
Layer Thickness	99		
Comment			

Create Delete

Aquifer Parameters

Percolation Links

Data Form



Field	Value	Field	Value
Name	PERC	Surface Area Option	Vary Based on Stage/Area T...
Scenario	French Drain with Perc		
From Node	POND		
To Node	GWT	Vertical Flow Termination	Horizontal Flow Algorithm
Link Count	1	Perimeter 1	600
Flow Direction	Both	Perimeter 2	1228
Aquifer Base Elevation	76	Perimeter 3	3142
Water Table Elevation	96	Distance P1 to P2	100
Annual Recharge Rate	0	Distance P2 to P3	400
Horizontal Conductivity	16	# of Cells P1 to P2	20
Vertical Conductivity	8	# of Cells P2 to P3	40
Fillable Porosity	0.3		
Layer Thickness	99		
Comment			

Computational Grid Parameters

Create | Delete

Percolation Links

Input Report

1

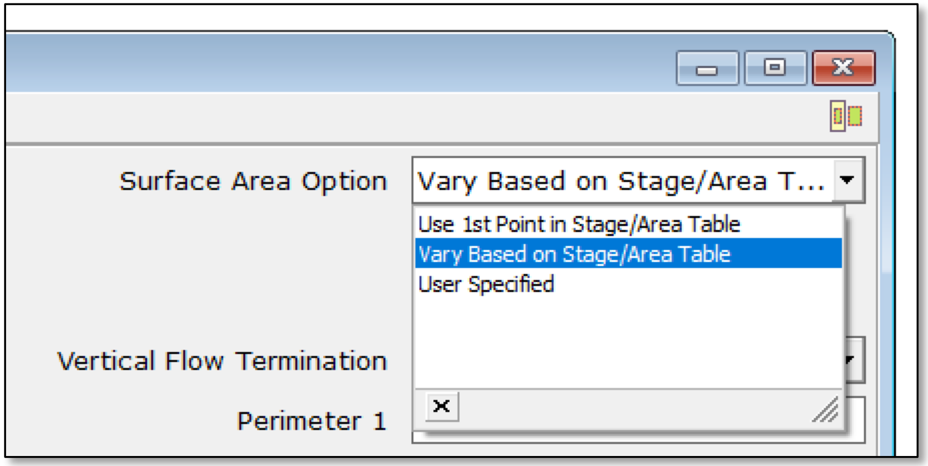
Percolation Link: PERC			
Scenario:	French Drain with Perc	Surface Area Option:	Vary Based on Stage/Area Table
From Node:	POND	Vertical Flow Termination:	Horizontal Flow Algorithm
To Node:	GWT	Perimeter 1:	600.00 ft
Link Count:	1	Perimeter 2:	1228.00 ft
Flow Direction:	Both	Perimeter 3:	3142.00 ft
Aquifer Base Elevation:	76.00 ft	Distance P1 to P2:	100.00 ft
Water Table Elevation:	96.00 ft	Distance P2 to P3:	400.00 ft
Annual Recharge Rate:	0 ipy	# of Cells P1 to P2:	20
Horizontal Conductivity:	16.000 fpd	# of Cells P2 to P3:	40
Vertical Conductivity:	8.000 fpd		
Fillable Porosity:	0.300		
Layer Thickness:	99.00 ft		
Comment:			

Percolation Links

Unsaturated Vertical Flow

Surface Area Option

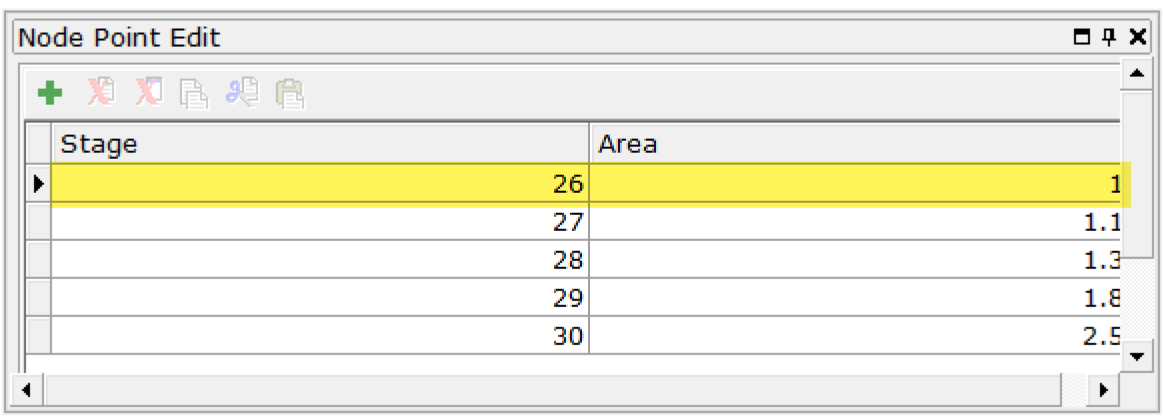
1. Use 1st Point in Stage/Area Table
2. Vary based on Stage/Area Table
3. User Specified



Percolation Links
Unsaturated Vertical Flow

Surface Area Option

1. Use 1st Point in Stage/Area Table
2. Vary based on Stage/Area Table
3. User Specified



Stage	Area
26	1
27	1.1
28	1.3
29	1.8
30	2.5

Constant Surface Area Used

Percolation Links

Unsaturated Vertical Flow

Surface Area Option

1. Use 1st Point in Stage/Area Table
2. Vary based on Stage/Area Table
3. User Specified

Node Point Edit

Stage	Area
26	1
27	1.1
28	1.3
29	1.8
30	2.5

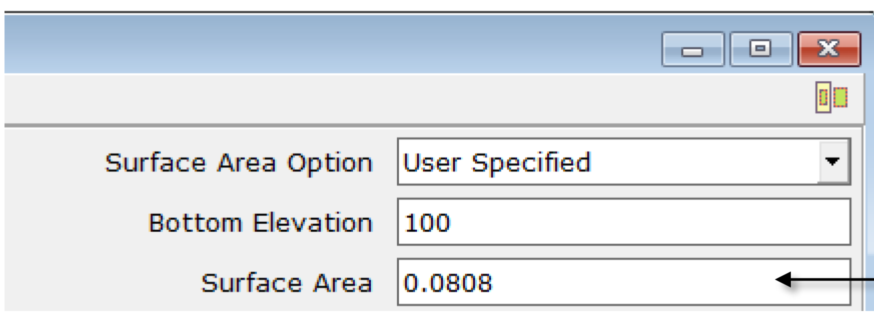
Variable Surface Area Used

Percolation Links

Unsaturated Vertical Flow

Surface Area Option

1. Use 1st Point in Stage/Area Table
2. Vary based on Stage/Area Table
3. User Specified



Constant Surface Area Used

Percolation Links

Unsaturated Vertical Flow

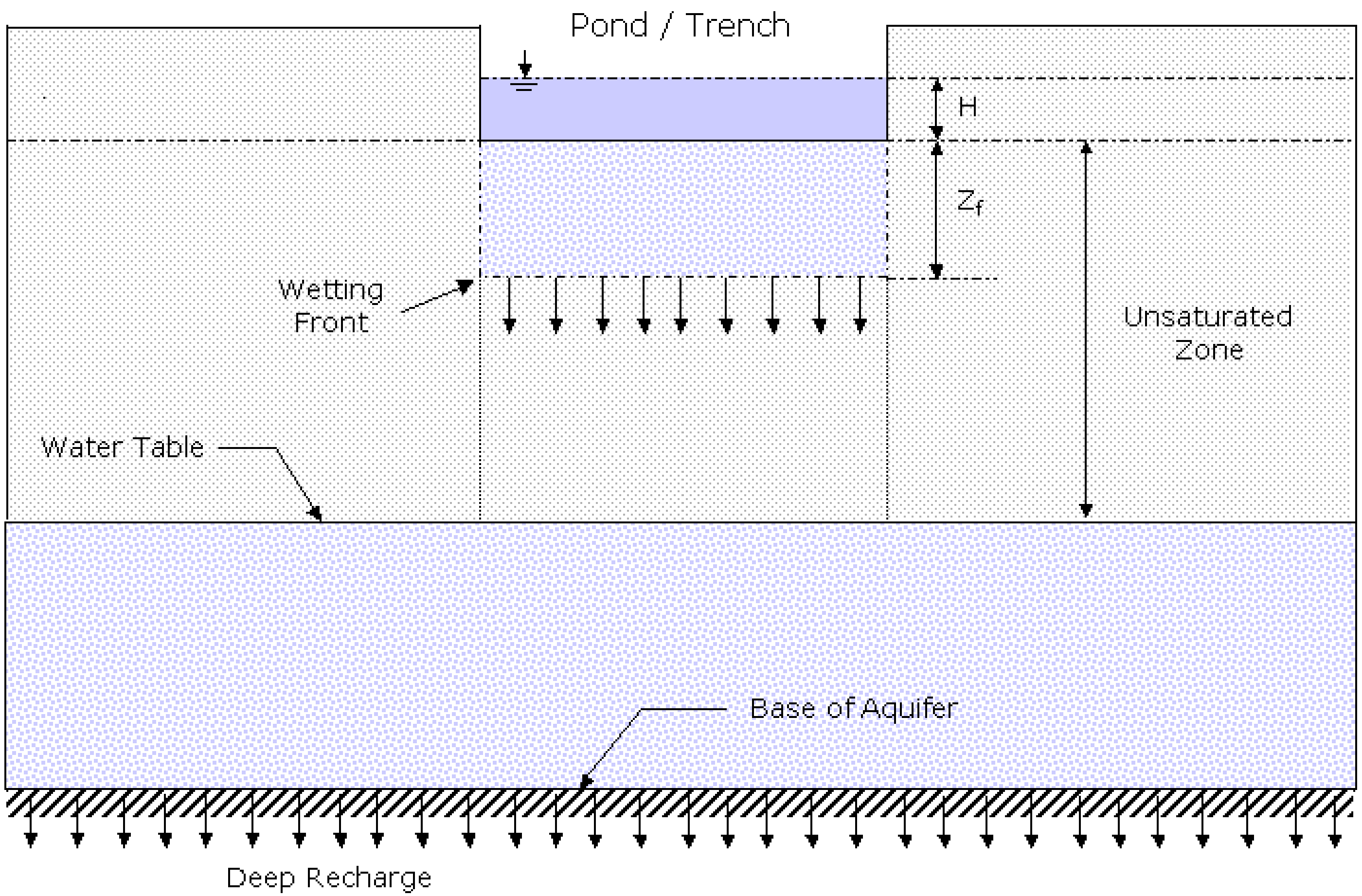
- Constant Surface Area
- Variable Surface Area

Percolation Based on Modified Green-Ampt Equation
(driving head is considered)

Percolation Links

Unsaturated Vertical Flow

- constant surface area -



Percolation Links

Unsaturated Vertical Flow

- constant surface area -

$q = K_v \, I$ (Darcy's Equation)

$I = (H + Z_f) / Z_f$ (Gradient)

Modified Form of the Green-Ampt Equation

$t_0 = (F\,H / K_y)\,[\,(Z_0 / H) - \ln(1 + Z_0 / H)\,]$

Percolation Links

Unsaturated Vertical Flow

- constant surface area -

$q = K_v I$ (Darcy's Equation)

$I = (H + Z_f + \Psi) / Z_f$ (Gradient)

Modified Form of the Green-Ampt Equation

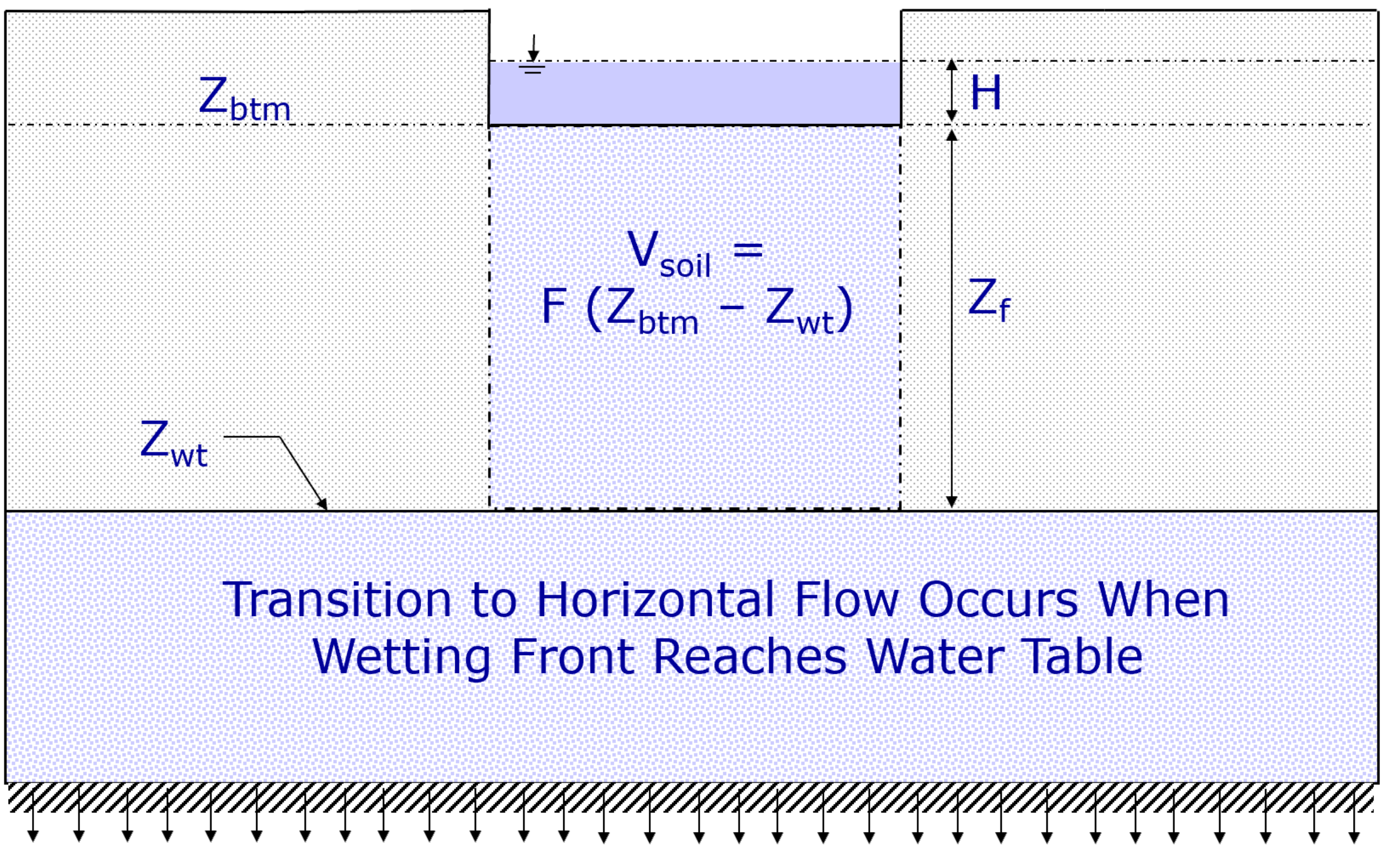
$$t_0 = (F H / K_v) [(Z_0 / H) - \ln(1 + Z_0 / H)]$$

Percolation Links

Unsaturated Vertical Flow

- constant surface area -

Pond / Trench



Percolation Links

Unsaturated Vertical Flow

- variable surface area -

- Constant Surface Area
- Variable Surface Area

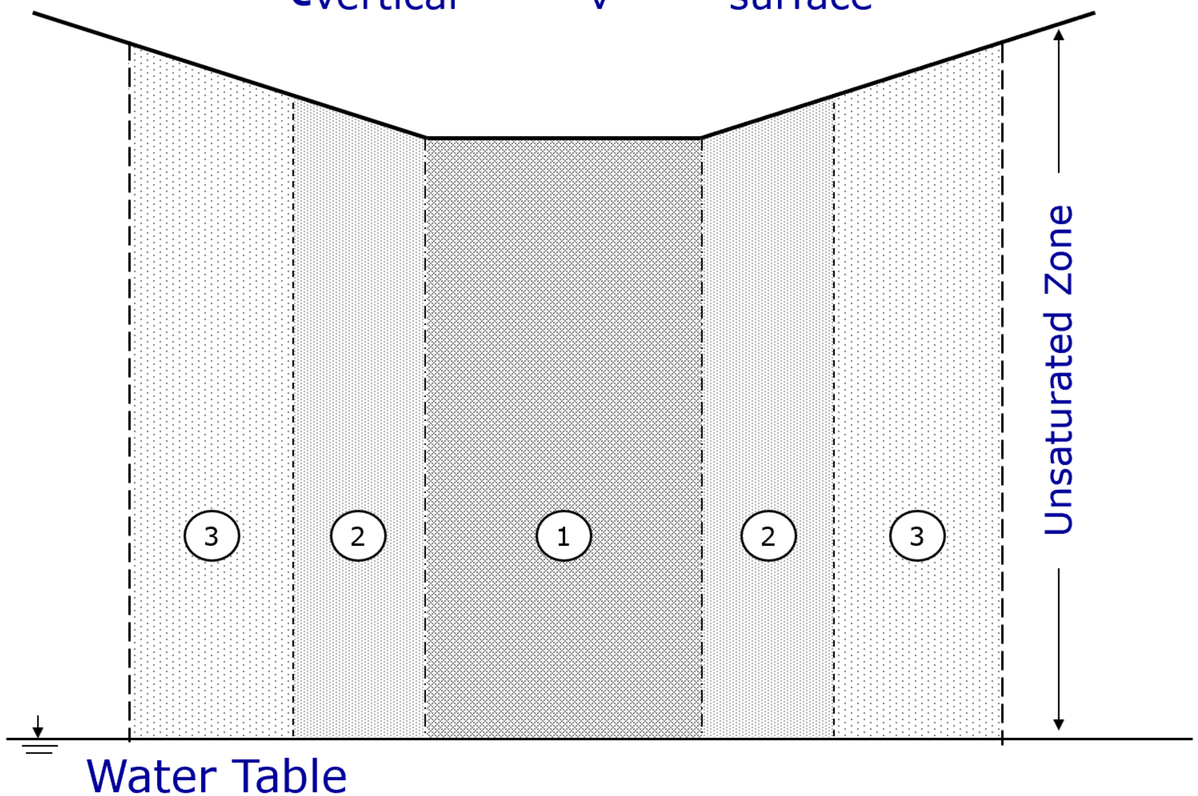
Percolation Based on Vertical Conductivity Multiplied by Wetted Surface Area
(driving head not considered)

Percolation Links

Unsaturated Vertical Flow

- variable surface area -

$$Q_{vertical} = K_v \times A_{surface}$$

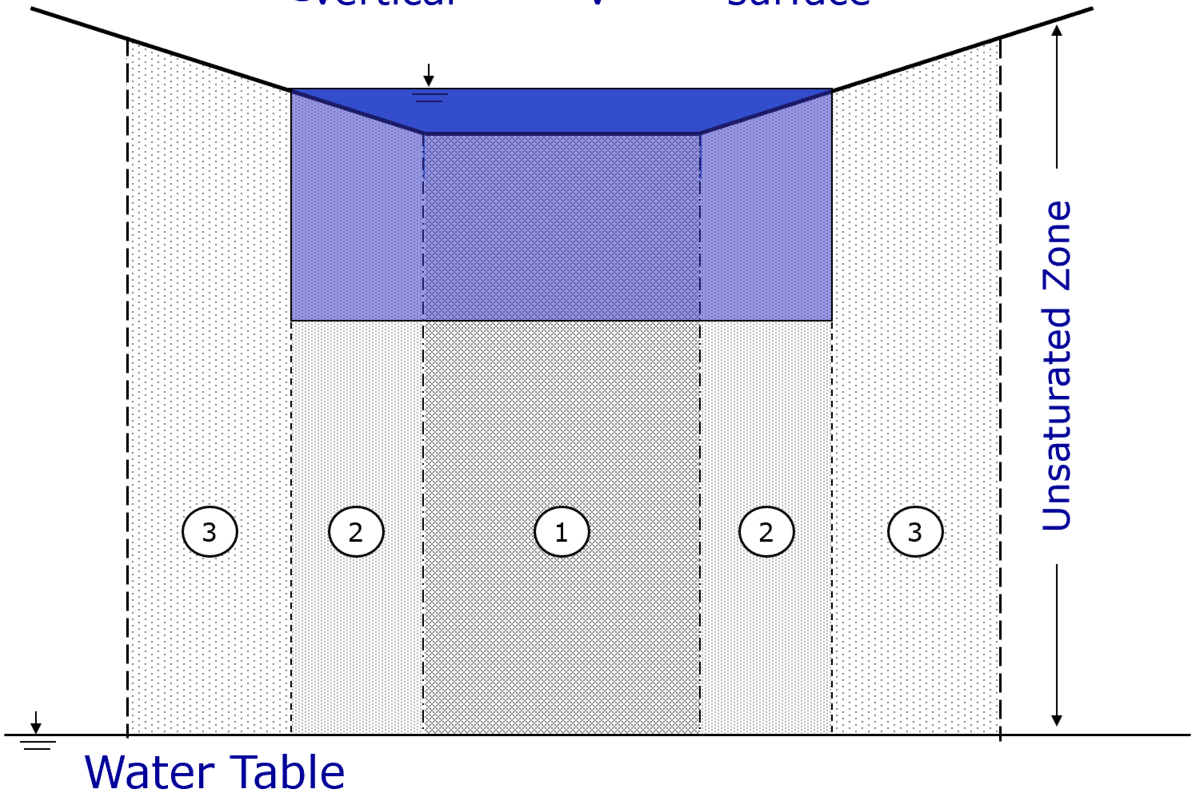


Percolation Links

Unsaturated Vertical Flow

- variable surface area -

$$Q_{vertical} = K_v \times A_{surface}$$

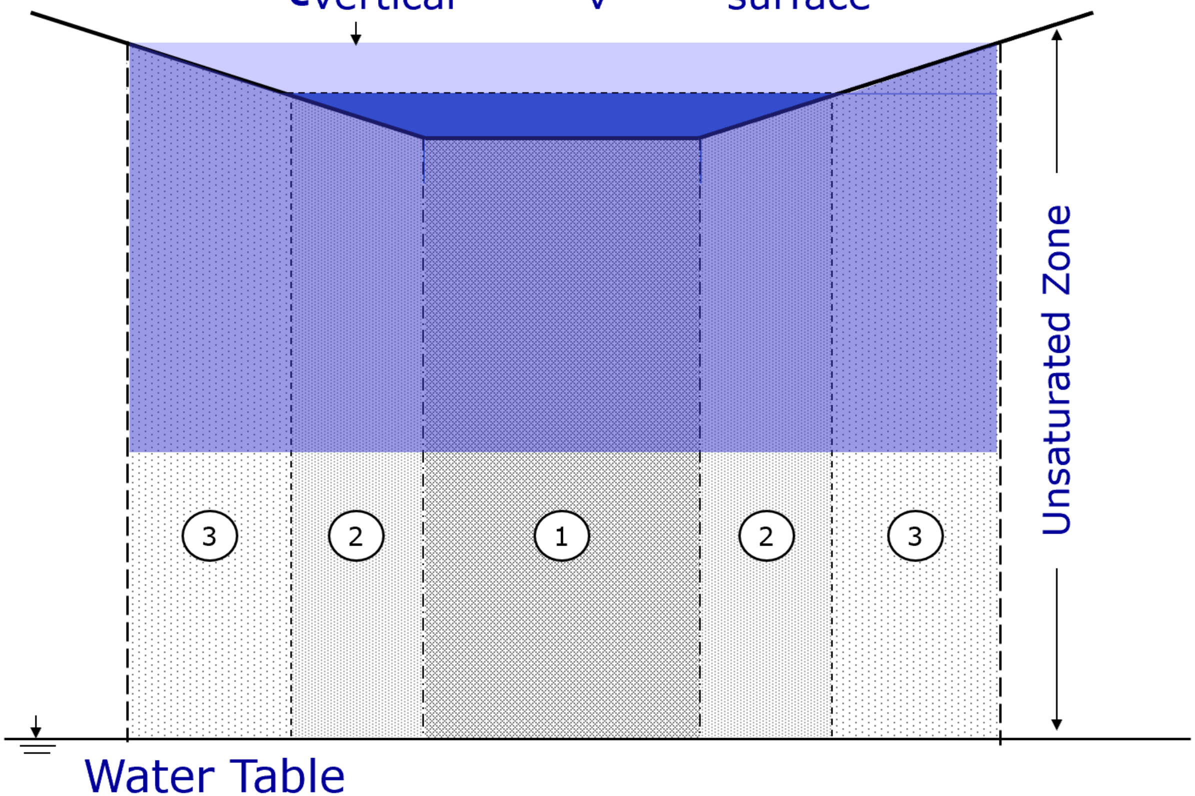


Percolation Links

Unsaturated Vertical Flow

- variable surface area -

$$Q_{vertical} = K_v \times A_{surface}$$

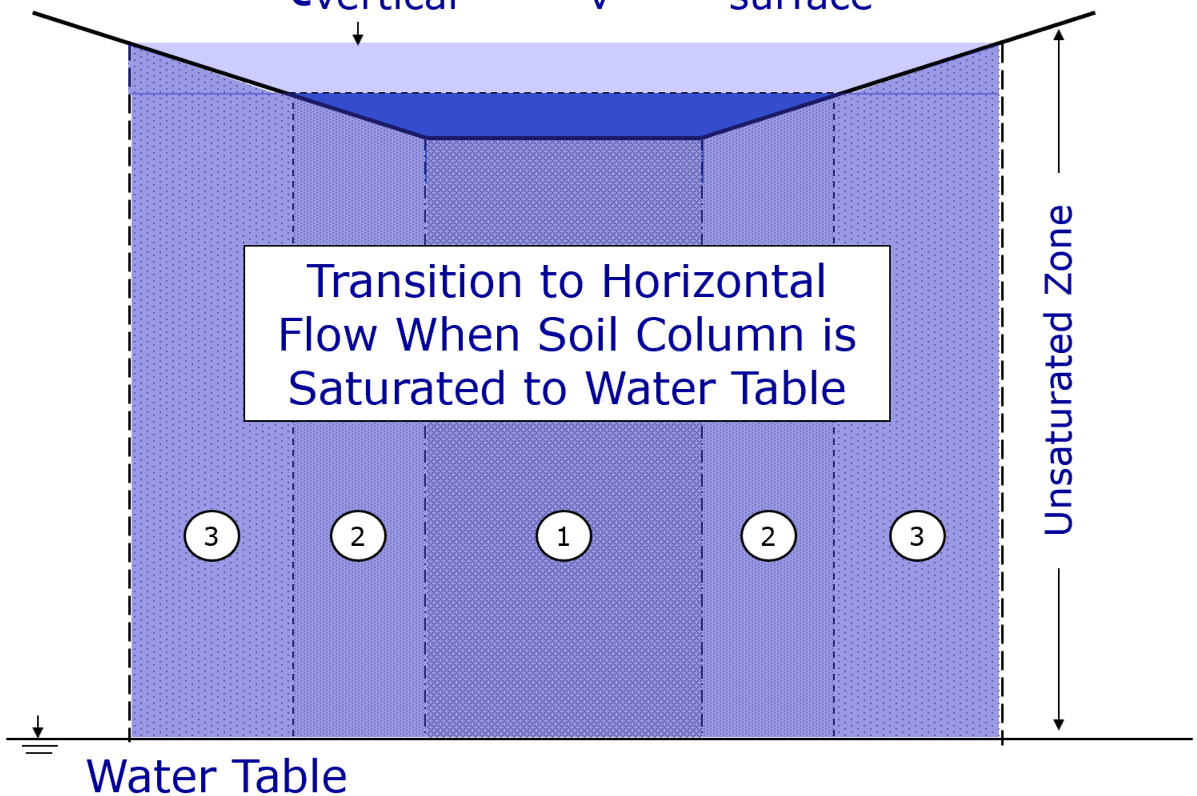


Percolation Links

Unsaturated Vertical Flow

- variable surface area -

$$Q_{vertical} = K_v \times A_{surface}$$



Percolation Links

Unsaturated Vertical Flow

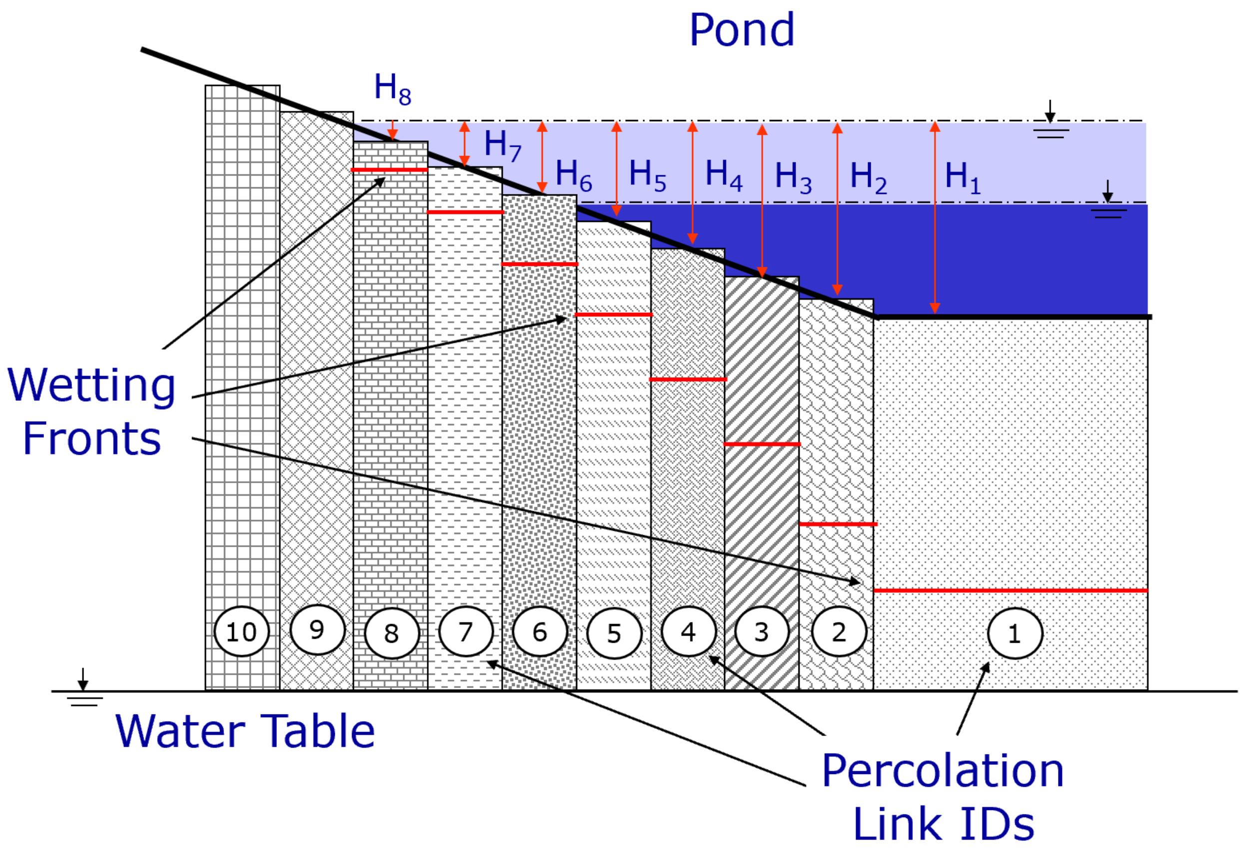
- stair stepping approach -

The advantages of the modified Green-Ampt equation can be combined with a variable surface area by "stair stepping" up the slope of the pond with multiple perc links.

Percolation Links

Unsaturated Vertical Flow

- stair stepping approach -

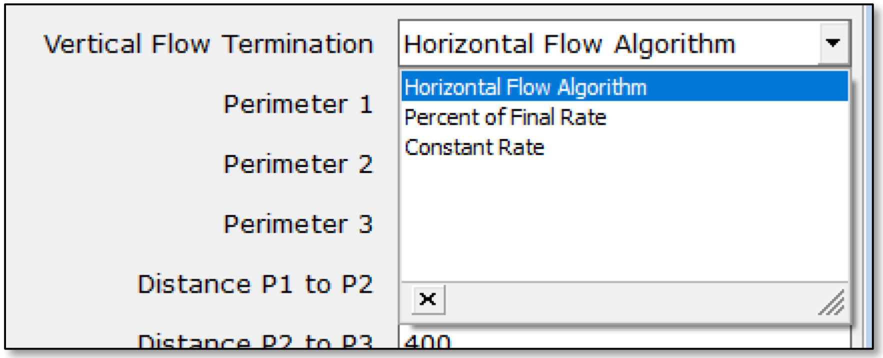


Percolation Links

Transition to Saturated Horizontal Flow

- vertical flow termination option -

1. Horizontal Flow Algorithm
2. Percent of Final Rate
3. Constant Rate



Percolation Links

Transition to Saturated Horizontal Flow
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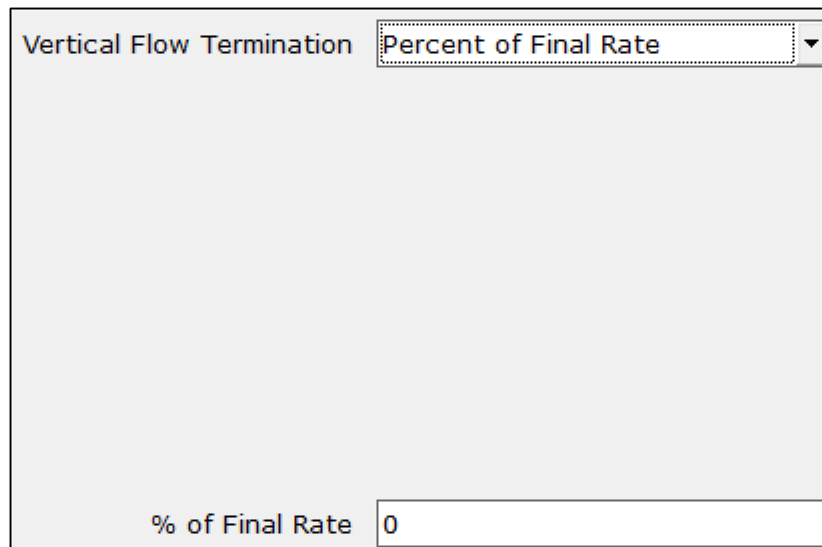

Percolation Links

Transition to Saturated Horizontal Flow

- vertical flow termination option -

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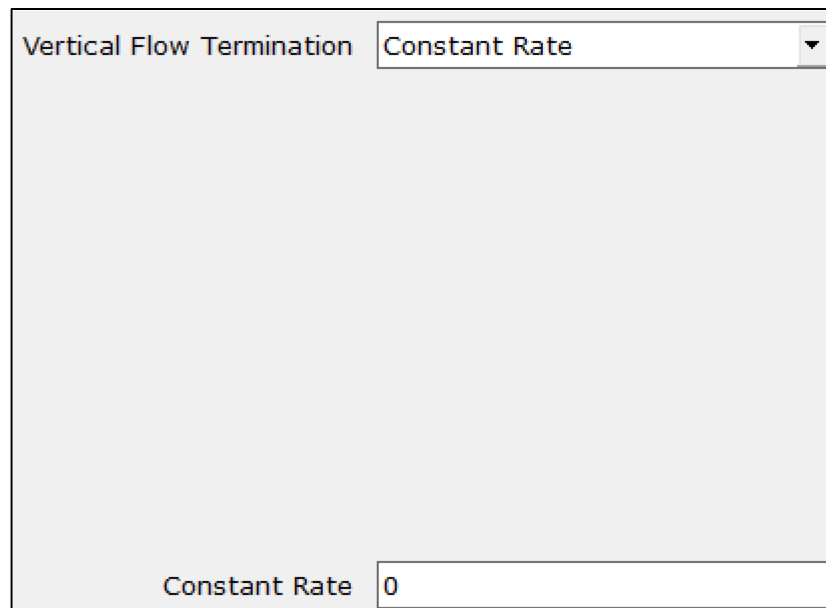
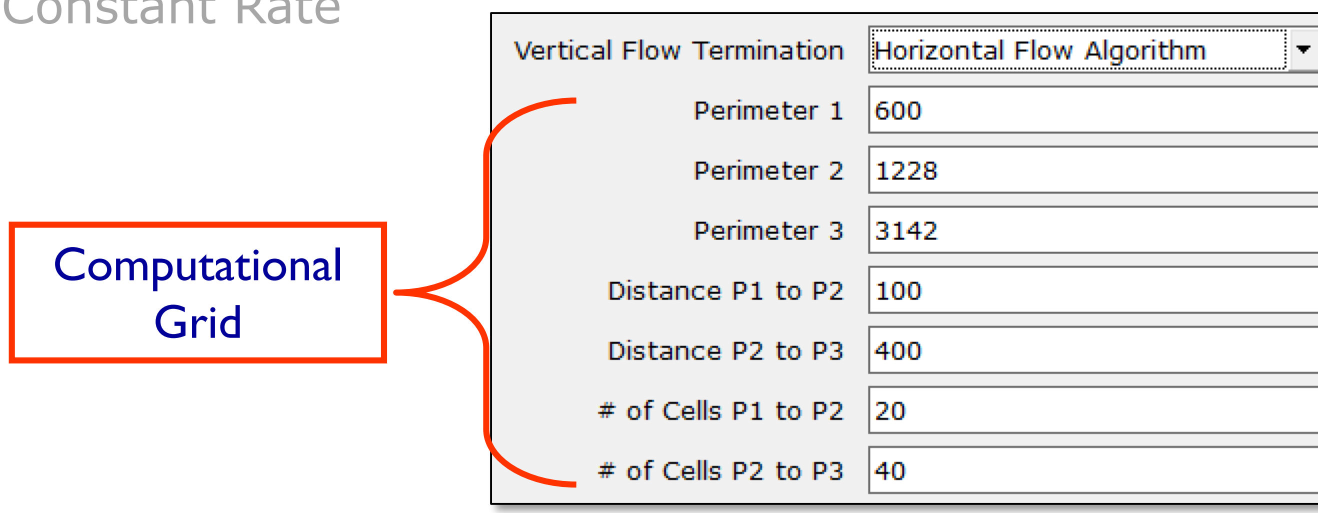


Percolation Links

Transition to Saturated Horizontal Flow

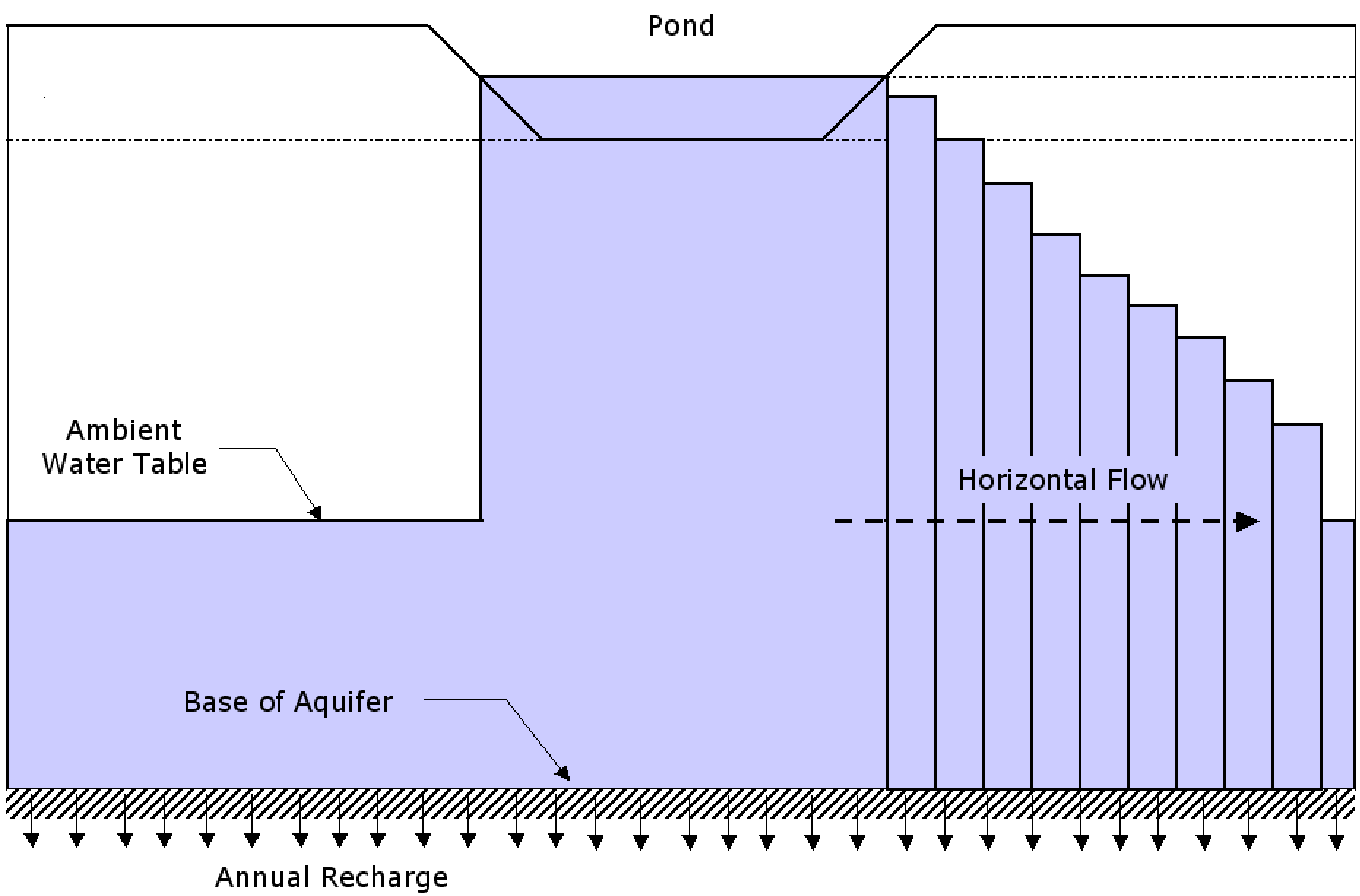
- vertical flow termination option -

1. Horizontal Flow Algorithm
2. Percent of Final Rate
3. Constant Rate



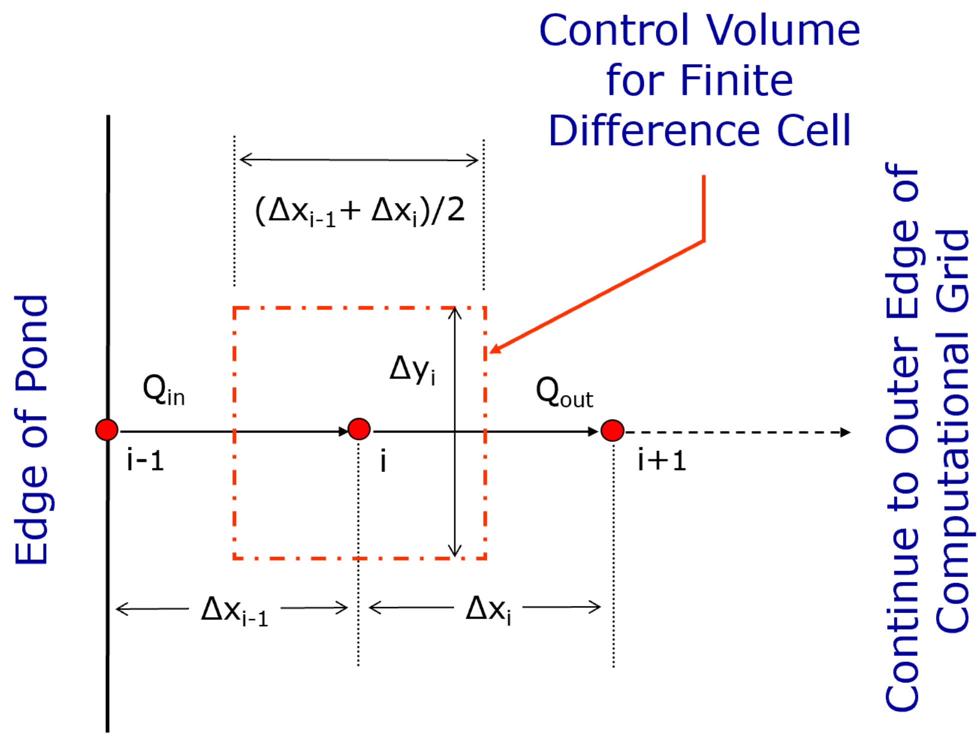
Percolation Links

Saturated Horizontal Flow



Percolation Links

Saturated Horizontal Flow



$$Q = (K_h) \bullet (I) \bullet (A)$$

$$= (K_h) \bullet (\Delta h/\Delta x) \bullet (h\Delta y)$$ (Darcy's Eq.)

Percolation Links

Assumptions and Limitations of Perc Links

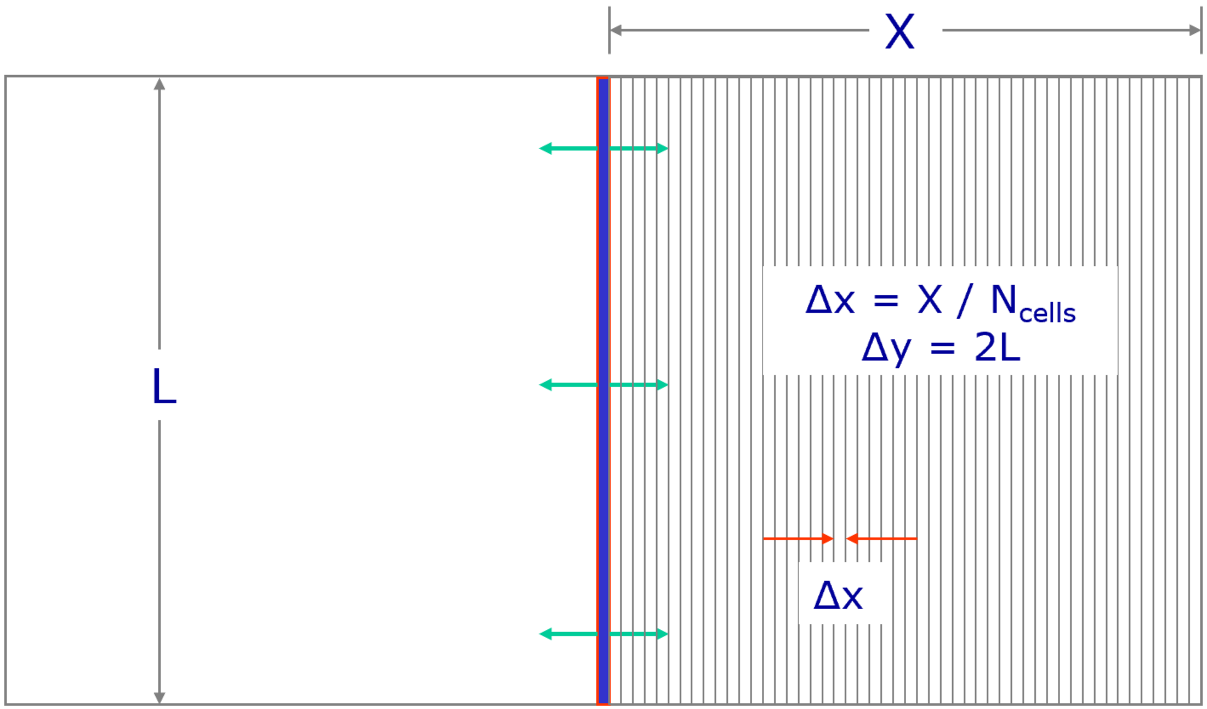
1. The aquifer base is assumed to be flat.
2. The ambient water table is assumed to be flat. Sloping water tables are not permitted.
3. Soil properties are homogeneous.
4. A physically-based rainfall-recharge mechanism is not included with percolation links.
5. Each percolation link is independent of other percolation links. Consequently, modeling ponds that are near one another or near other surface water bodies may require adjustments to the computational perimeters.

Percolation Links

Saturated Horizontal Flow

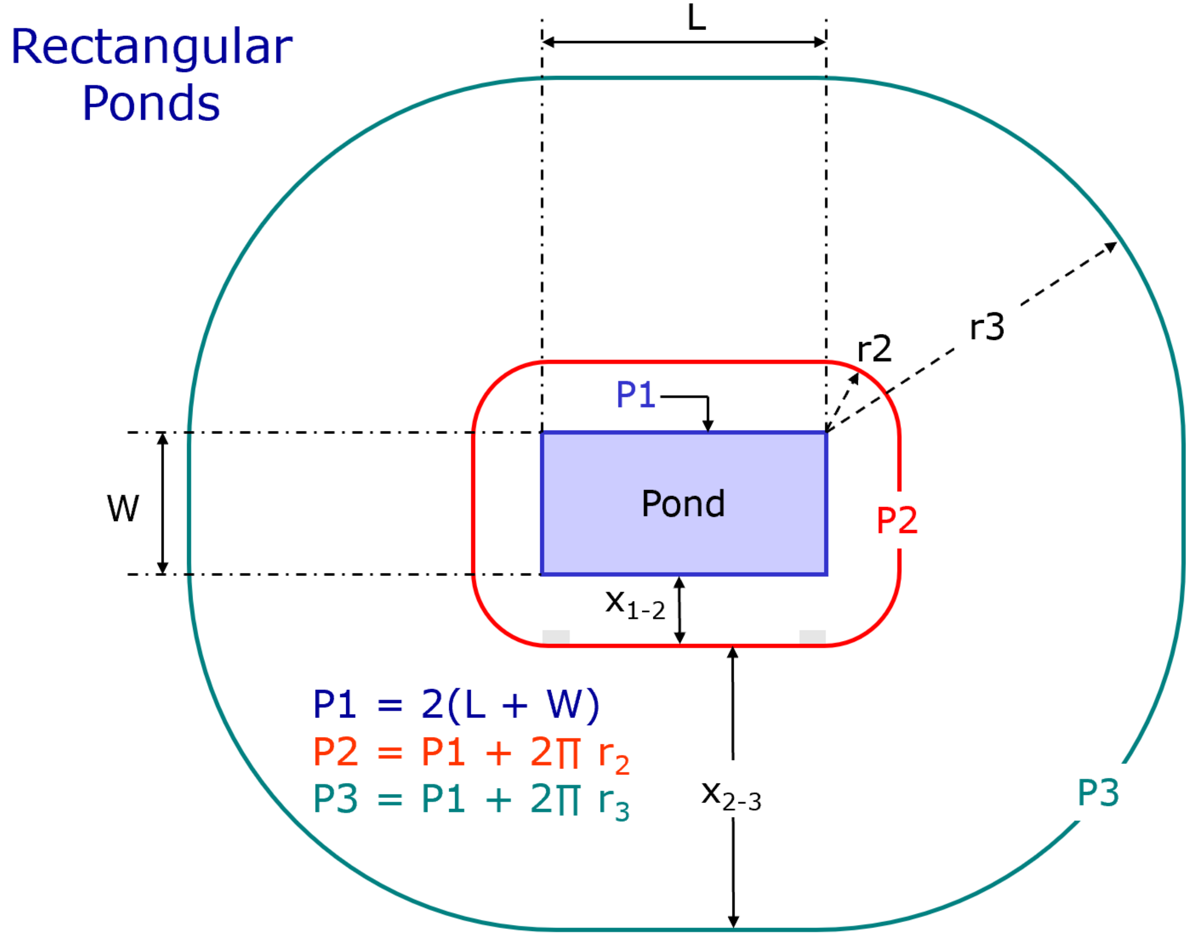
French Drain or Narrow Ditch

(groundwater flow occurs from both sides and is perpendicular to surface flow)



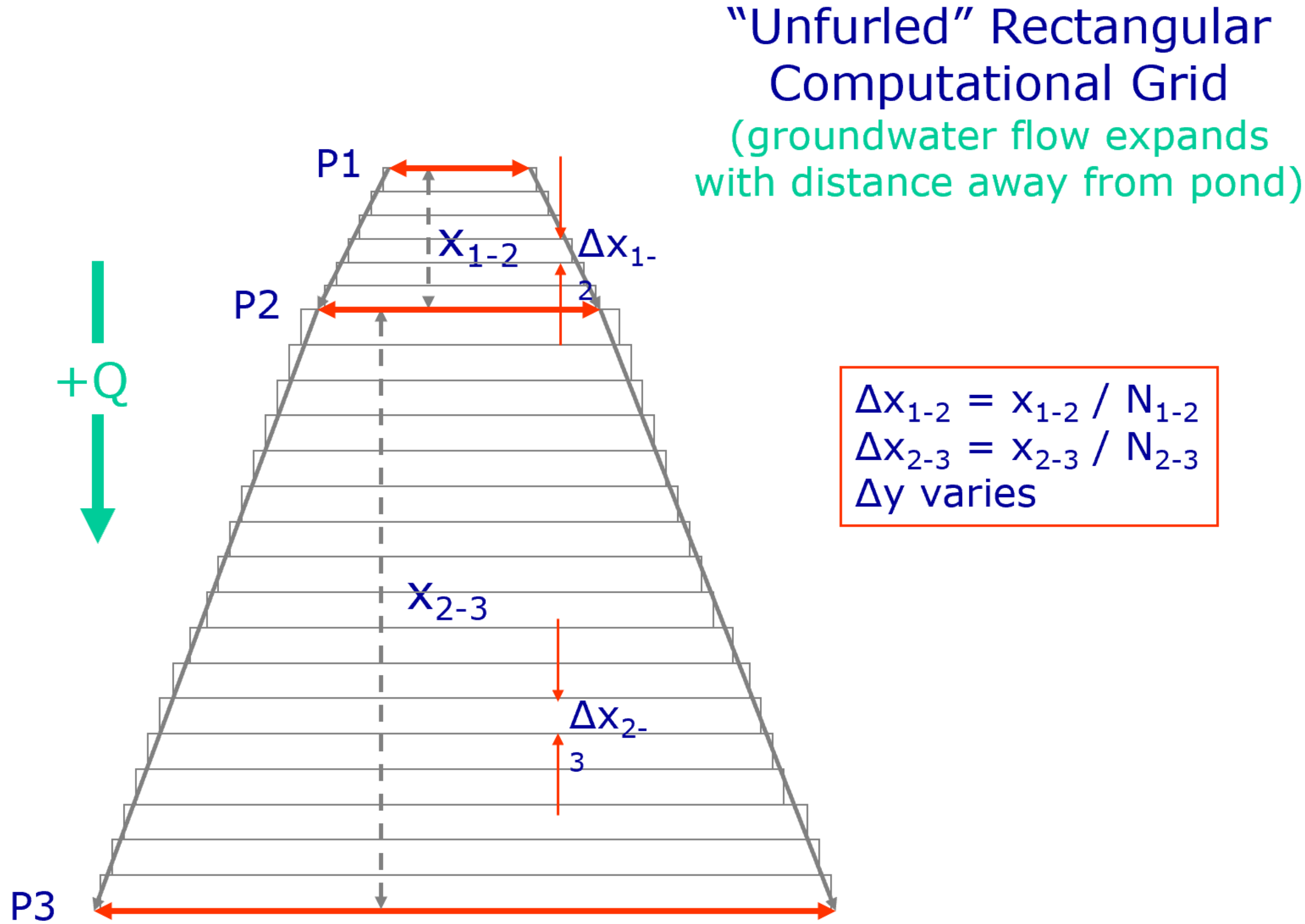
Percolation Links

Saturated Horizontal Flow



Percolation Links

Saturated Horizontal Flow



$\Delta x_{1-2} = x_{1-2} / N_{1-2}$
$\Delta x_{2-3} = x_{2-3} / N_{2-3}$
Δy varies

Percolation Links

Saturated Horizontal Flow

Circular Ponds

(groundwater flow expands radially outward from center)

$P1 = 2\pi r_1$

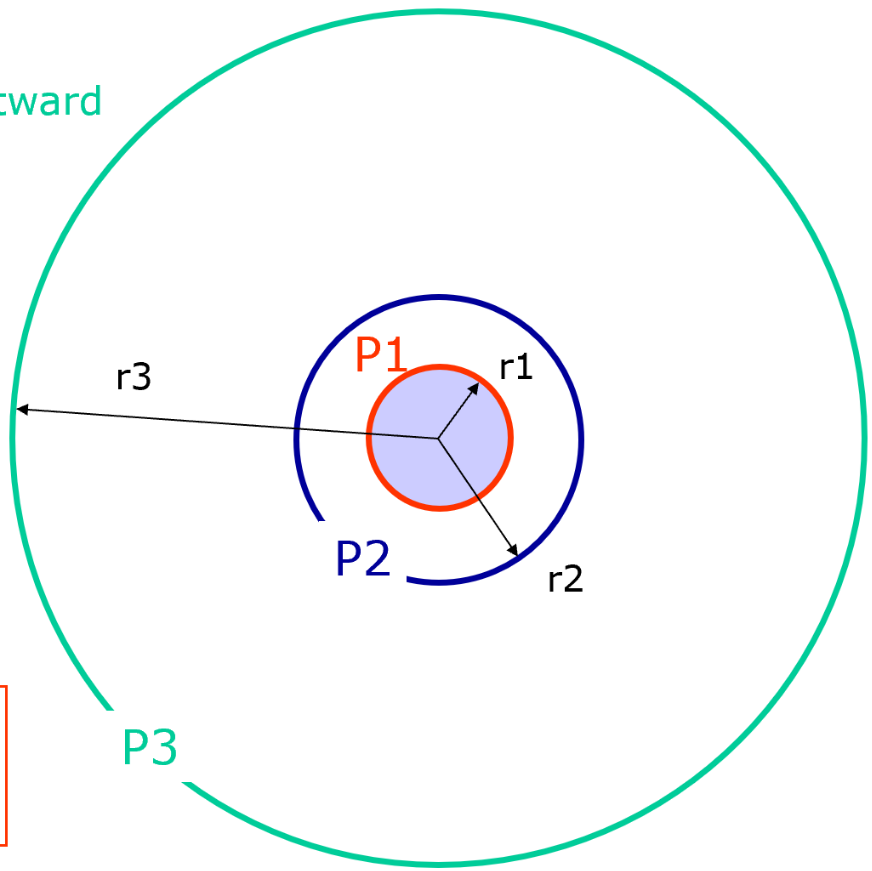
$P2 = 2\pi r_2$

$x_{1-2} = r_2 - r_1$

$P3 = 2\pi r_3$

$x_{2-3} = r_3 - r_2$

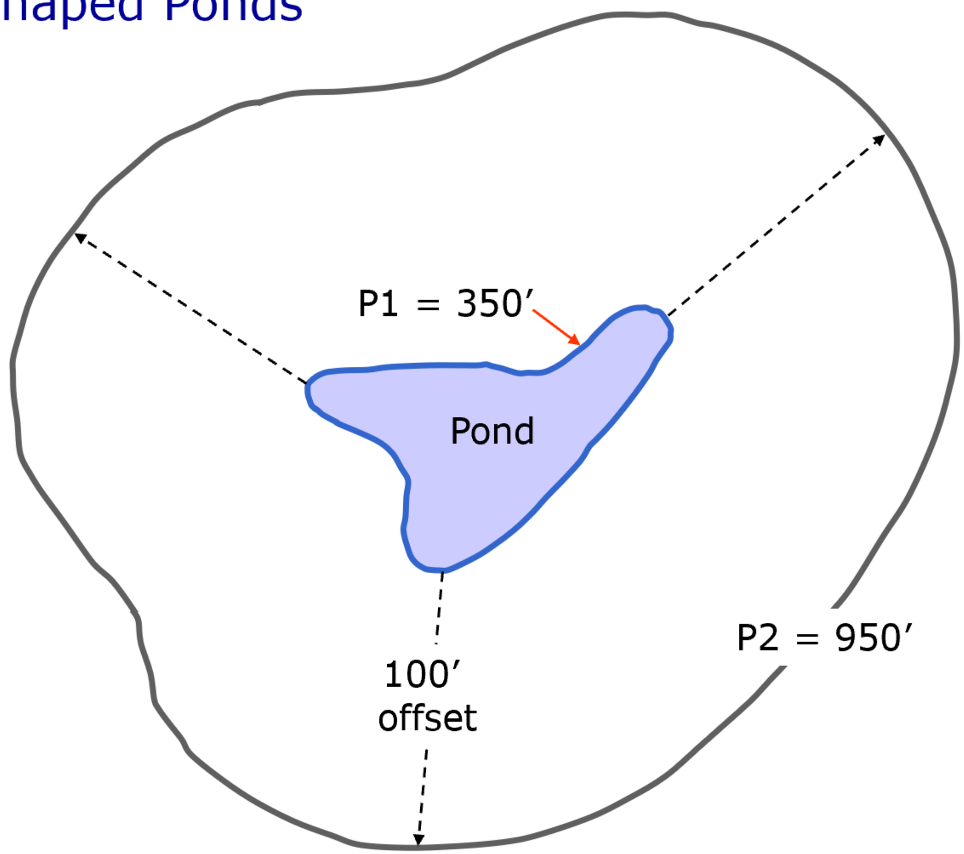
$\Delta x_{1-2} = x_{1-2} / N_{1-2}$
$\Delta x_{2-3} = x_{2-3} / N_{2-3}$
Δy varies



Percolation Links

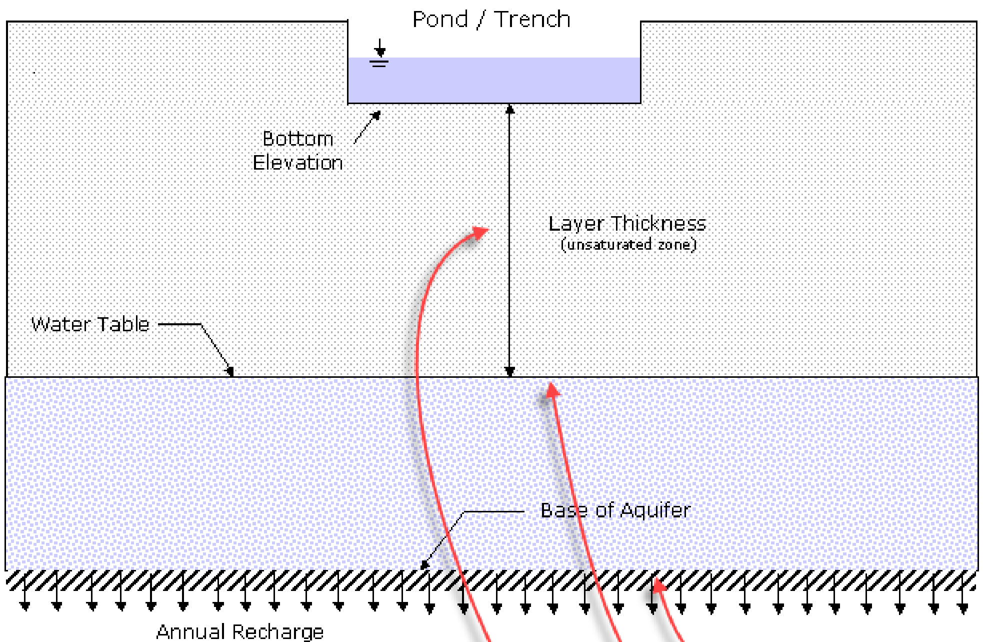
Saturated Horizontal Flow

Irregular Shaped Ponds



Percolation Links

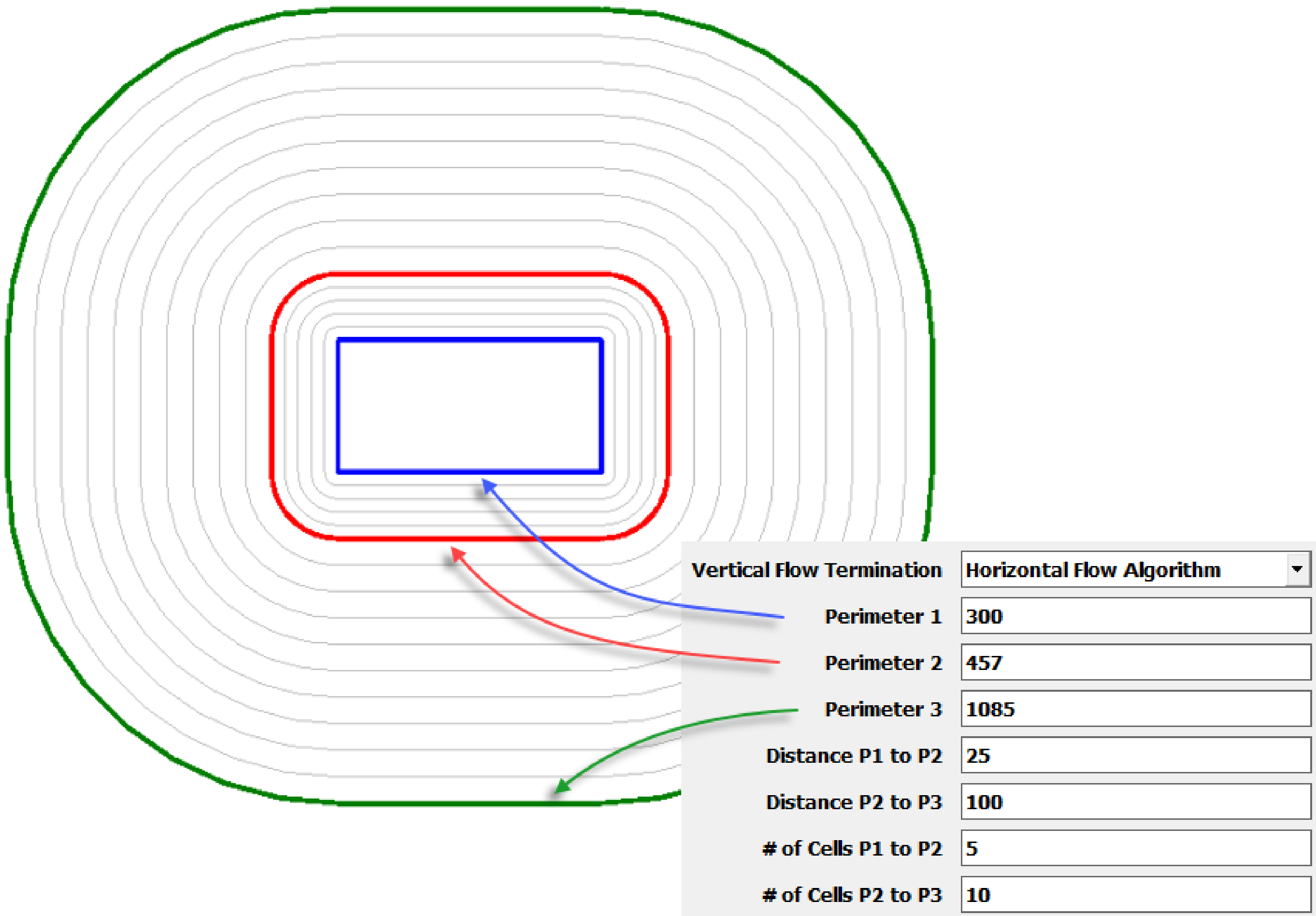
Input Parameters: Aquifer



Aquifer Base Elevation	90
Water Table Elevation	94
Annual Recharge Rate	0
Horizontal Conductivity	20
Vertical Conductivity	10
Fillable Porosity	0.25
Layer Thickness	6

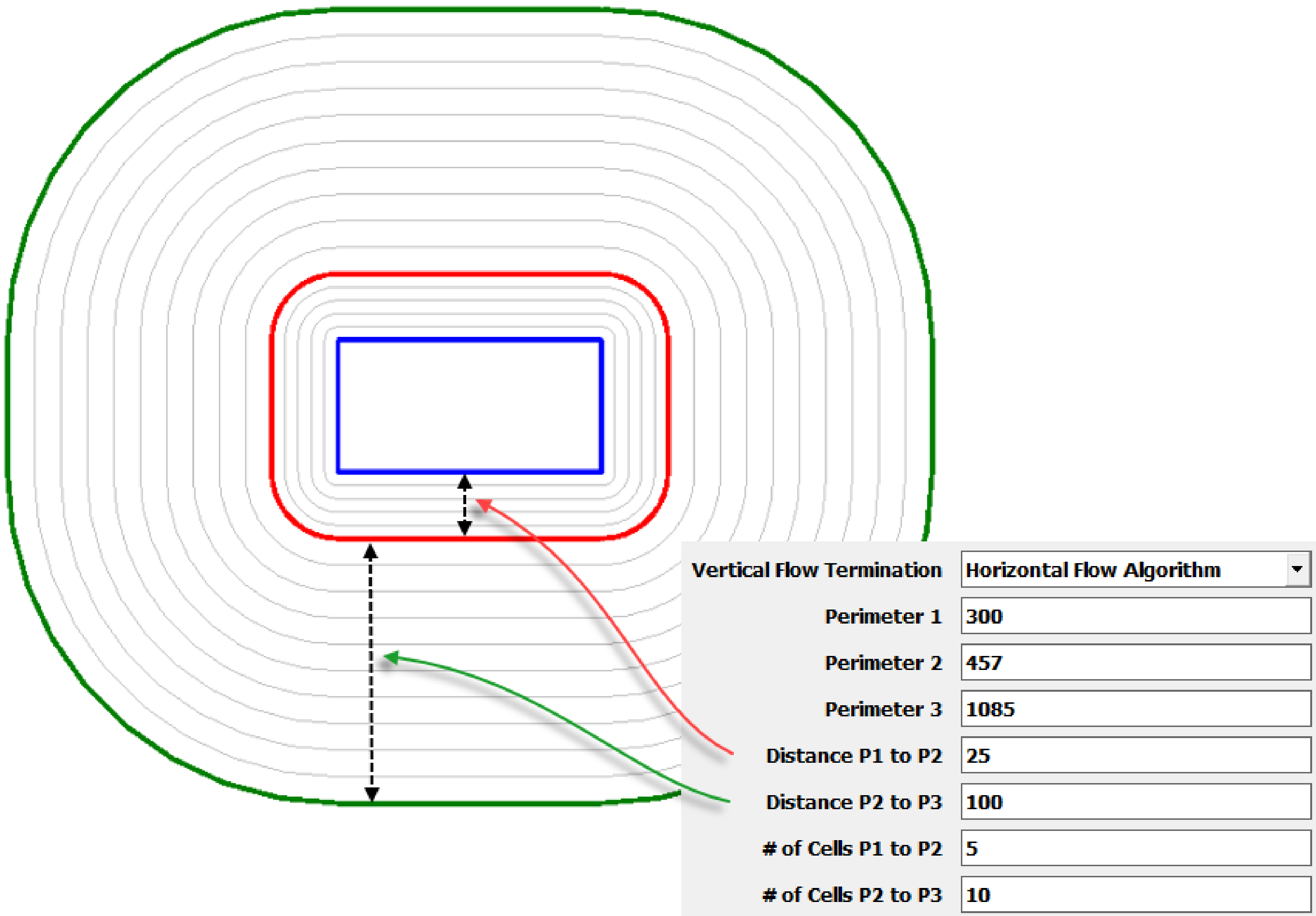
Percolation Links

Input Parameters: Computation Grid



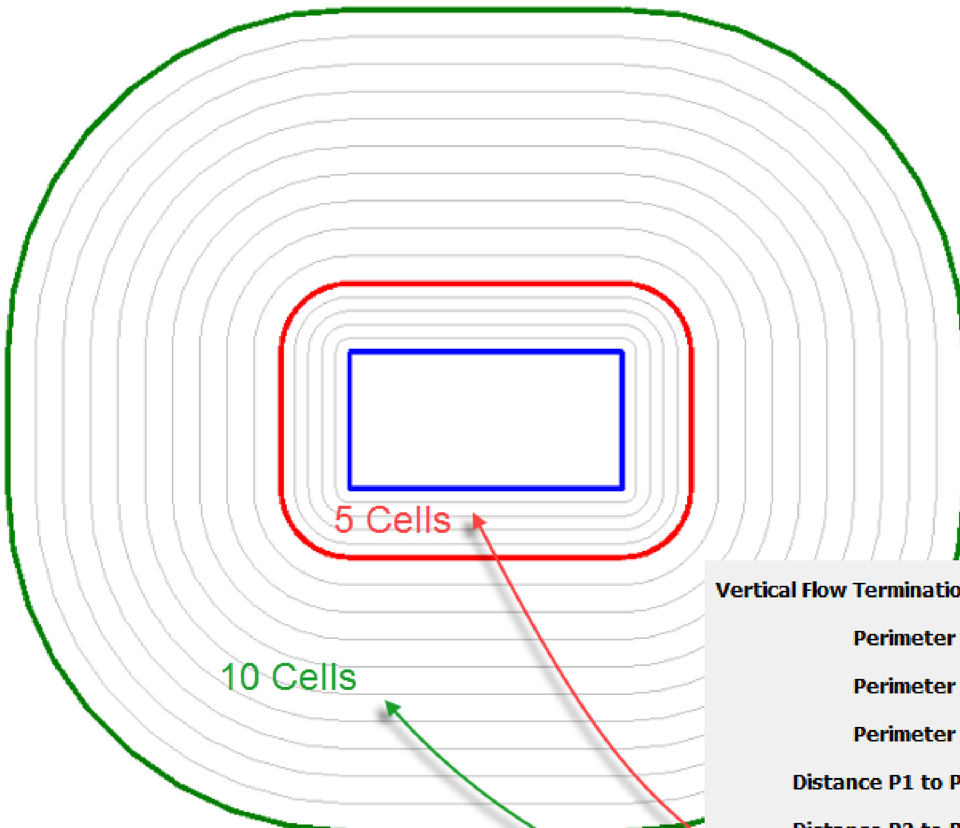
Percolation Links

Input Parameters: Computational Grid



Percolation Links

Input Parameters: Computational Grid



Vertical Flow Termination	Horizontal Flow Algorithm
Perimeter 1	300
Perimeter 2	457
Perimeter 3	1085
Distance P1 to P2	25
Distance P2 to P3	100
# of Cells P1 to P2	5
# of Cells P2 to P3	10

Percolation Links

Input Parameters: Initial Conditions

The water table (an input parameter)
is used to initialize heads.

Aquifer Base Elevation	76
Water Table Elevation	96
Annual Recharge Rate	0
Horizontal Conductivity	16
Vertical Conductivity	8
Fillable Porosity	0.3
Layer Thickness	99

Percolation Links

Input Parameters: Boundary Condition at Outer Edge (P3)

- For "Annual Recharge" = Zero, use "Fixed Head" = Water Table
- Otherwise, use "Zero Flow" and let Head fluctuate as needed

Aquifer Base Elevation	76
Water Table Elevation	96
Annual Recharge Rate	0
Horizontal Conductivity	16
Vertical Conductivity	8
Fillable Porosity	0.3
Layer Thickness	99

Aquifer Base Elevation	76
Water Table Elevation	96
Annual Recharge Rate	0.0001
Horizontal Conductivity	16
Vertical Conductivity	8
Fillable Porosity	0.3
Layer Thickness	99

Percolation Links

Input Parameters: Boundary Condition at Pond (P1)

Use "Variable Head" = Pond Elevation

unless, $Q_{vertical} < Q_{horizontal}$

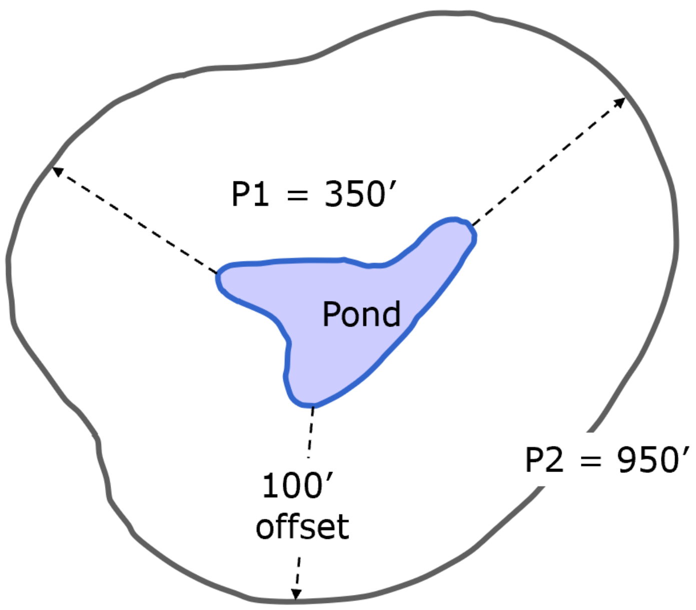
in which case,

set $Q_{horizontal} = Q_{vertical}$

Percolation Links

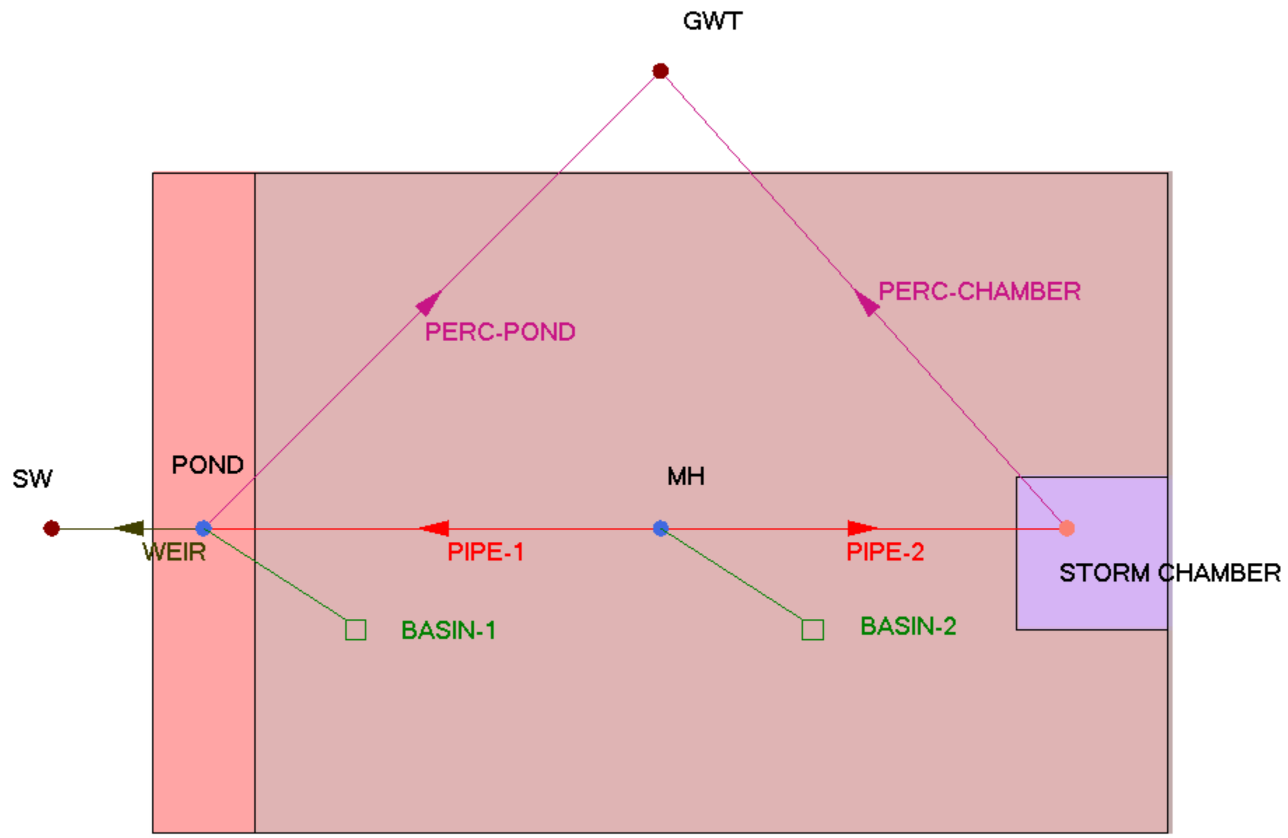
Input Parameters: Final Perc Rate for Pond

The flux (horizontal flow) across the innermost computational ring becomes the percolation rate for the pond or trench.



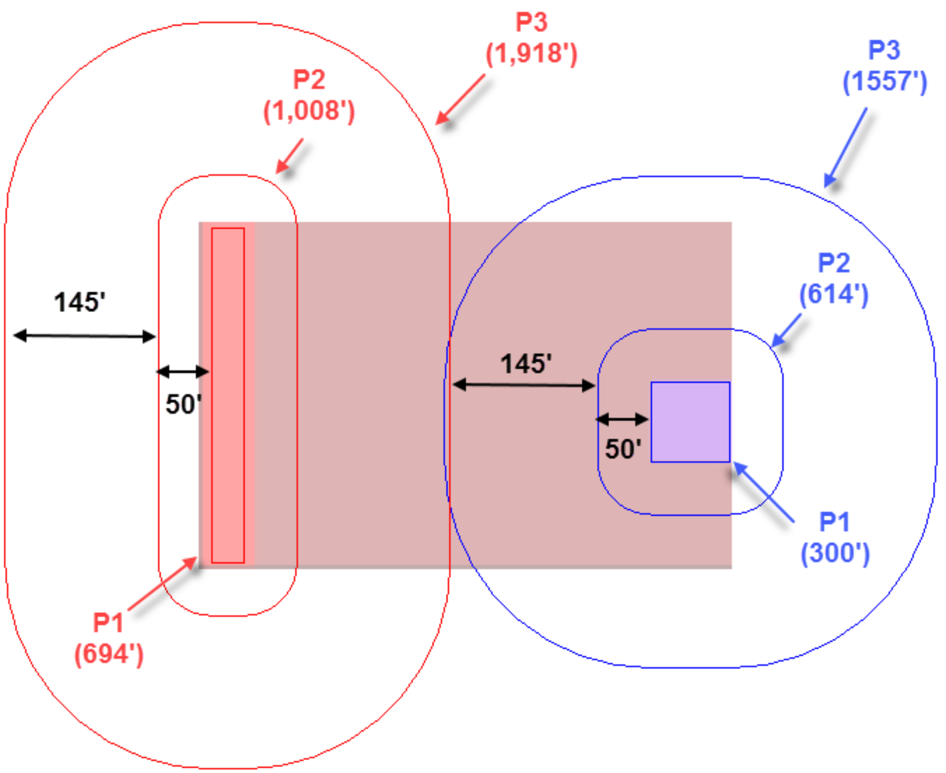
Percolation Links

Setup Example: Storm Chamber & Pond



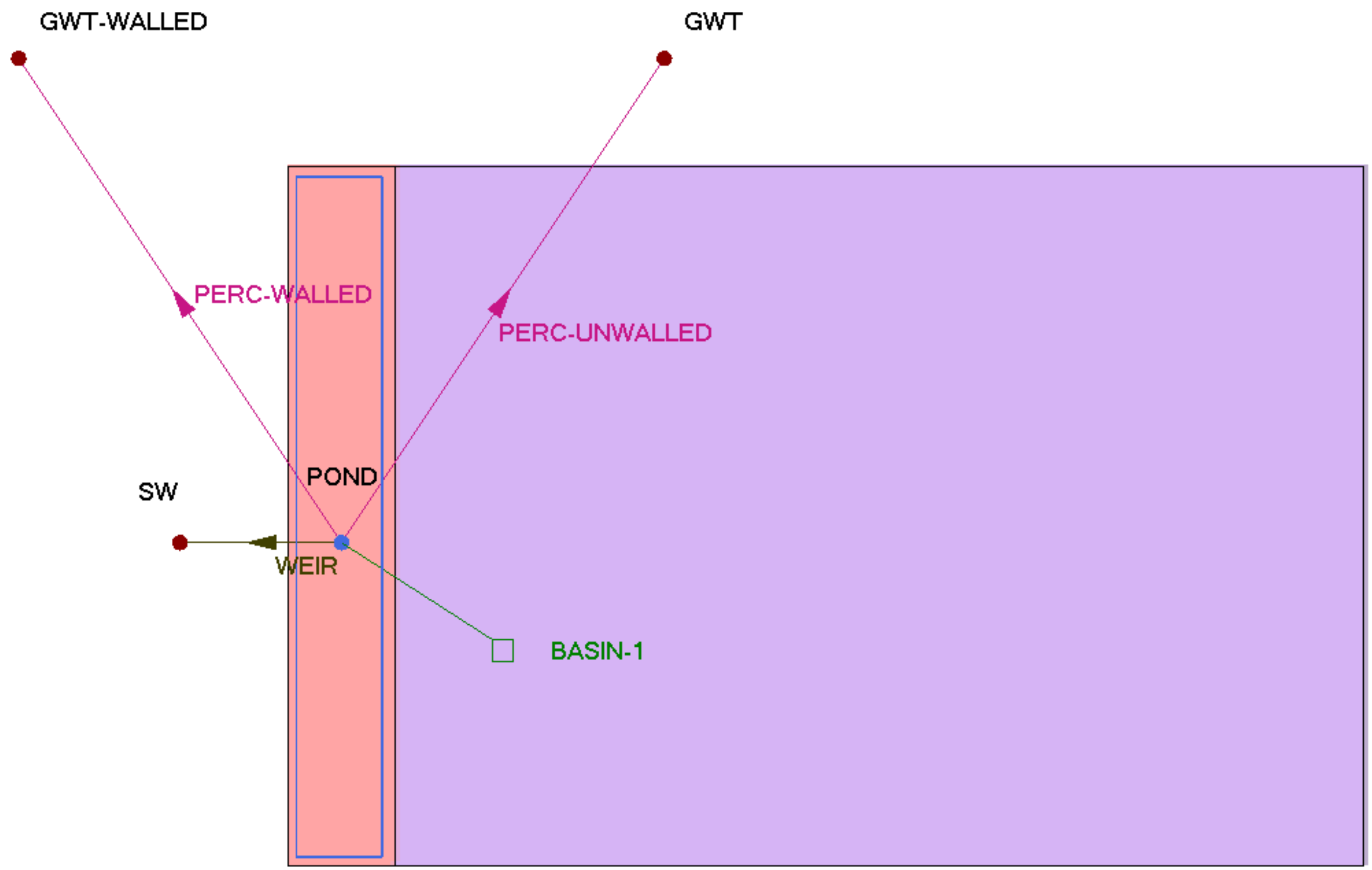
Percolation Links

Setup Example: Storm Chamber & Pond



Percolation Links

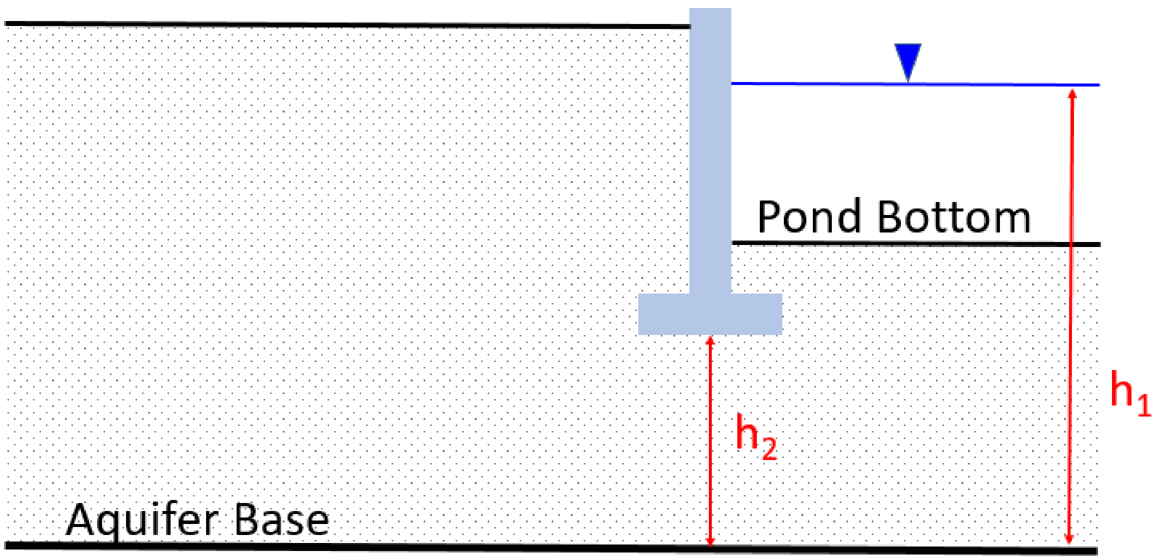
Setup Example: Pond with Retaining Wall



Percolation Links

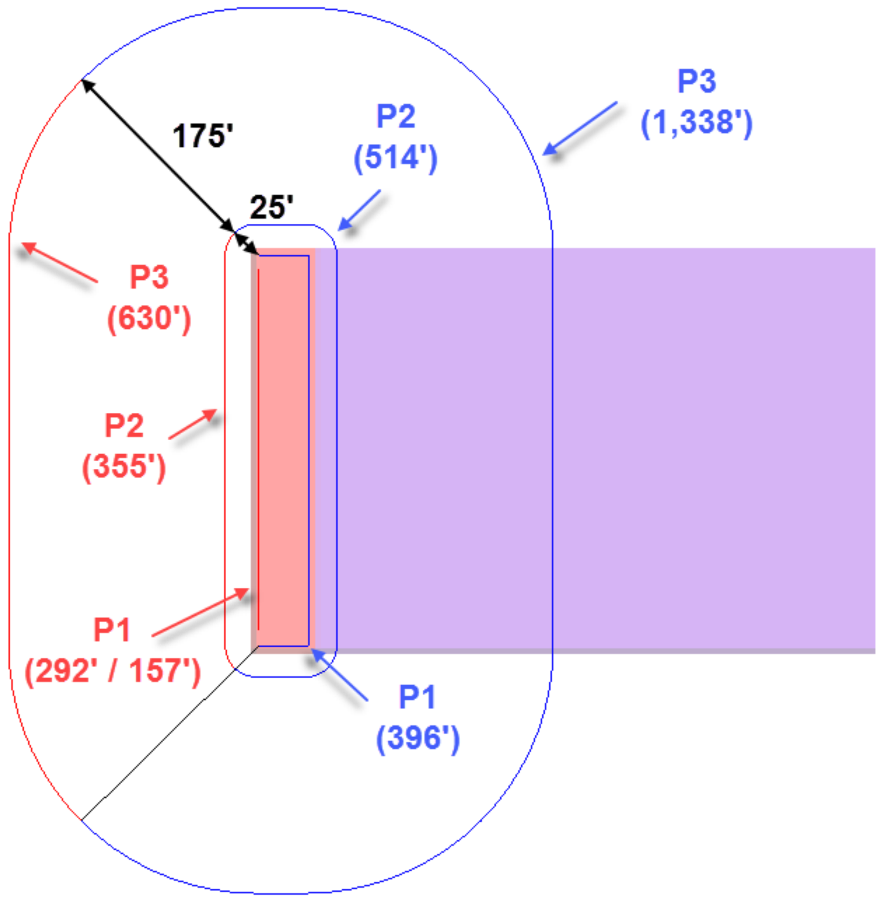
Setup Example: Pond with Retaining Wall

$$P1^* = P1 \times (h_2 / h_1)$$



Percolation Links

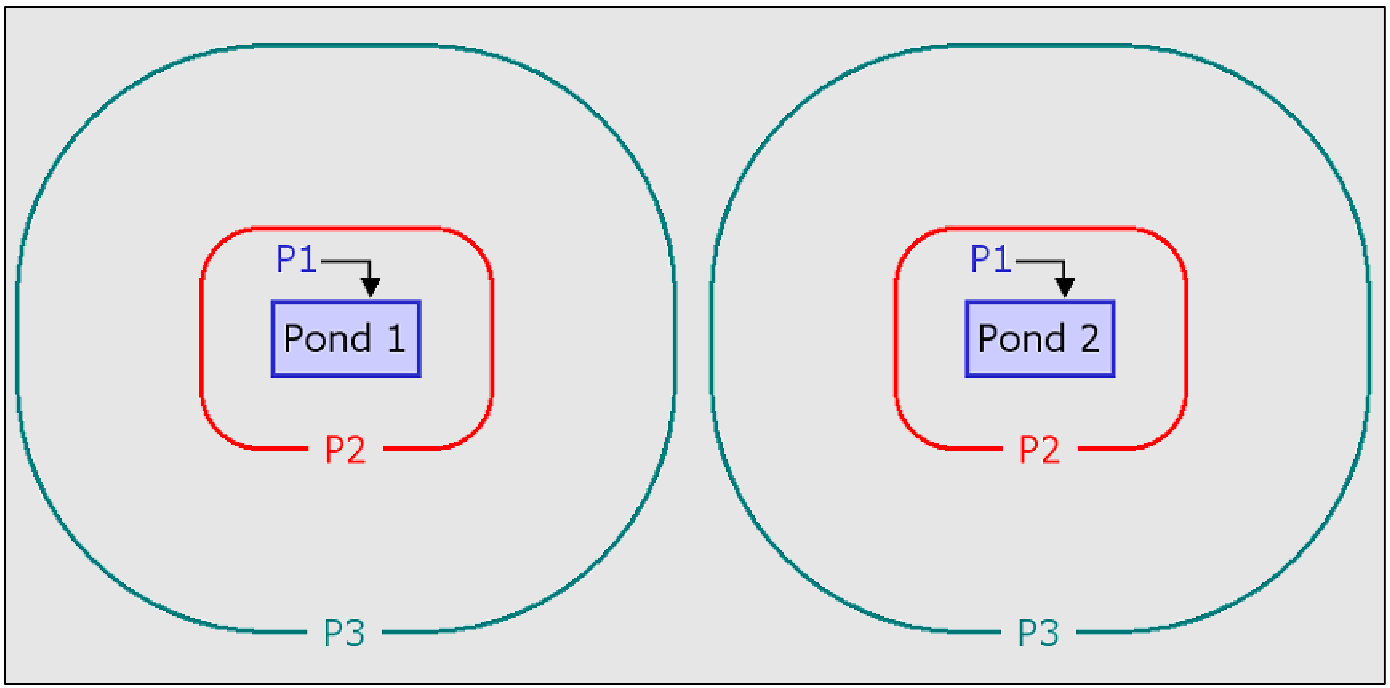
Setup Example: Pond with Retaining Wall



Percolation Links

Setup Example: Dual Ponds in Close Proximity

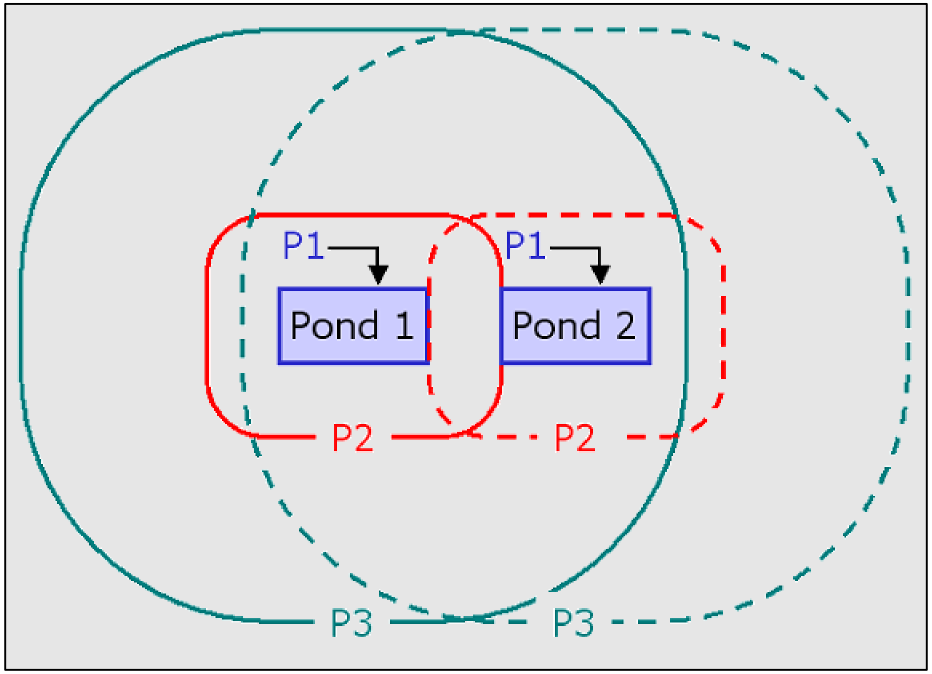
If the computational rings for adjacent ponds do not intersect, then the ponds are independent and no adjustments to the perimeters are required.



Percolation Links

Setup Example: Dual Ponds in Close Proximity

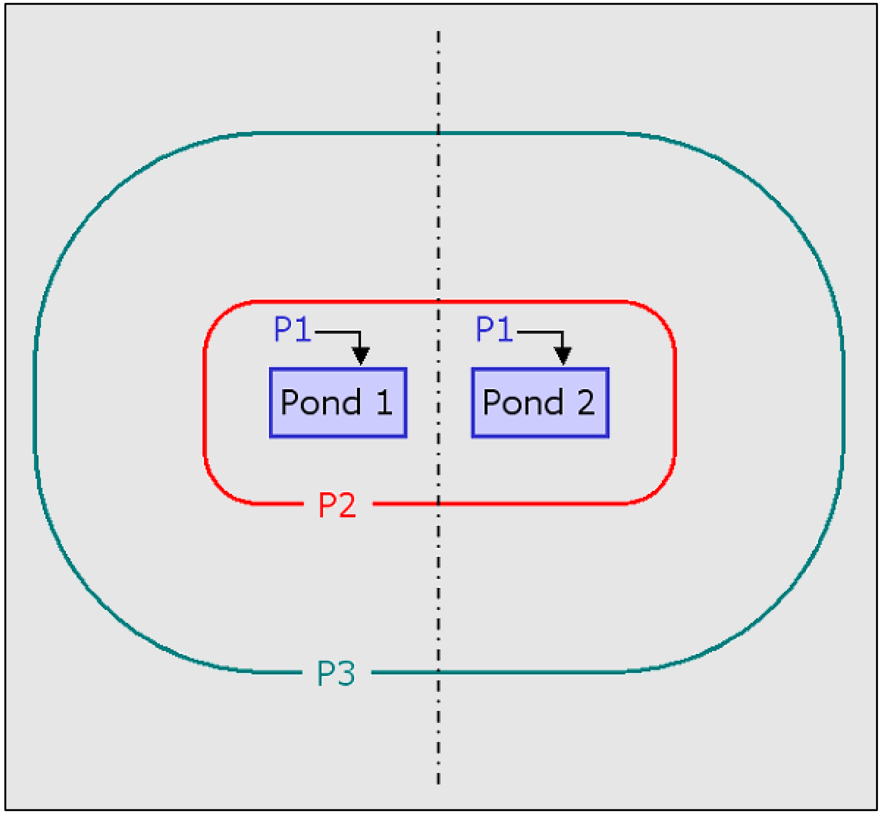
If the computational rings do intersect, then
an adjustment to the perimeters is required.



Percolation Links

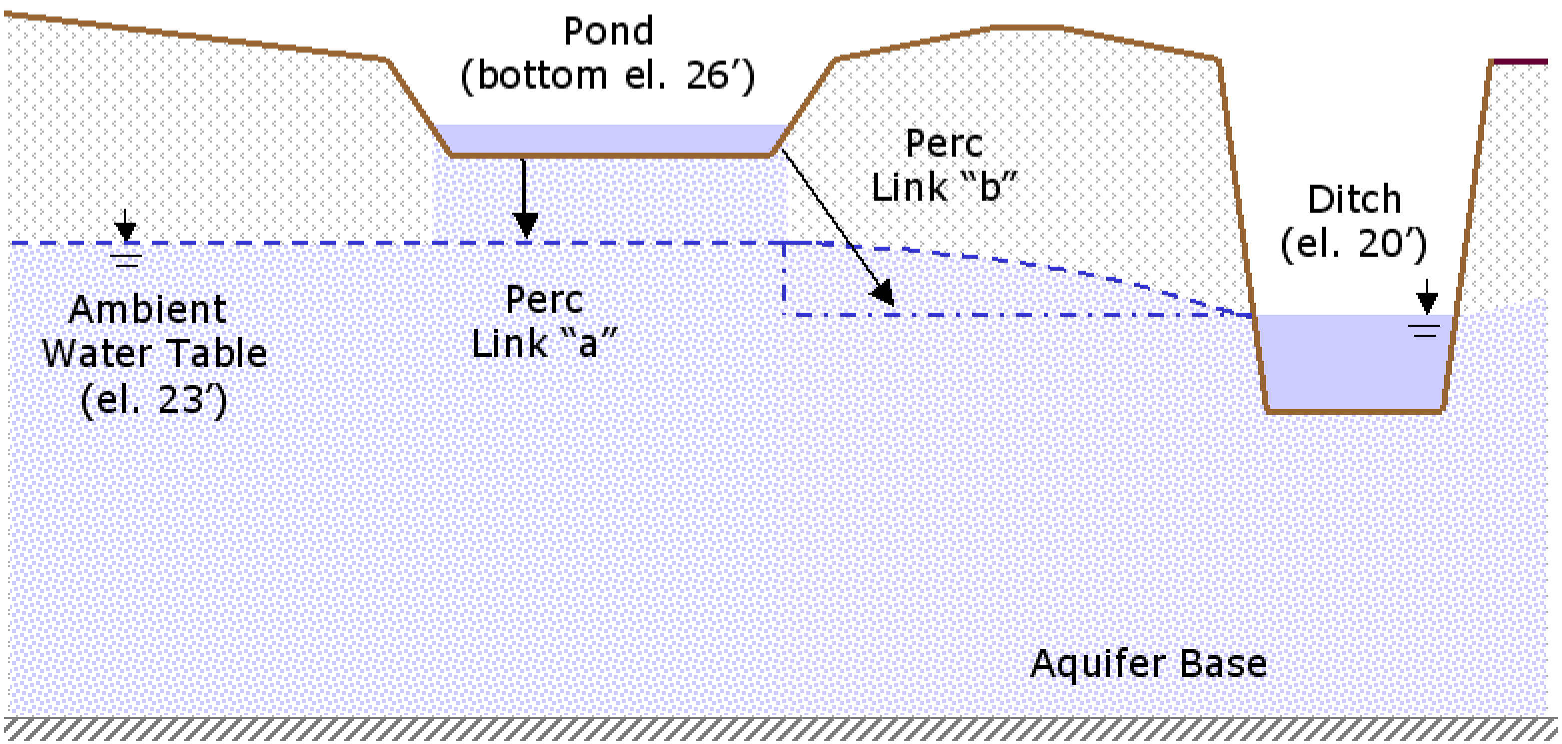
Setup Example: Dual Ponds in Close Proximity

The computational rings must be blended together
and then proportioned between the two ponds.



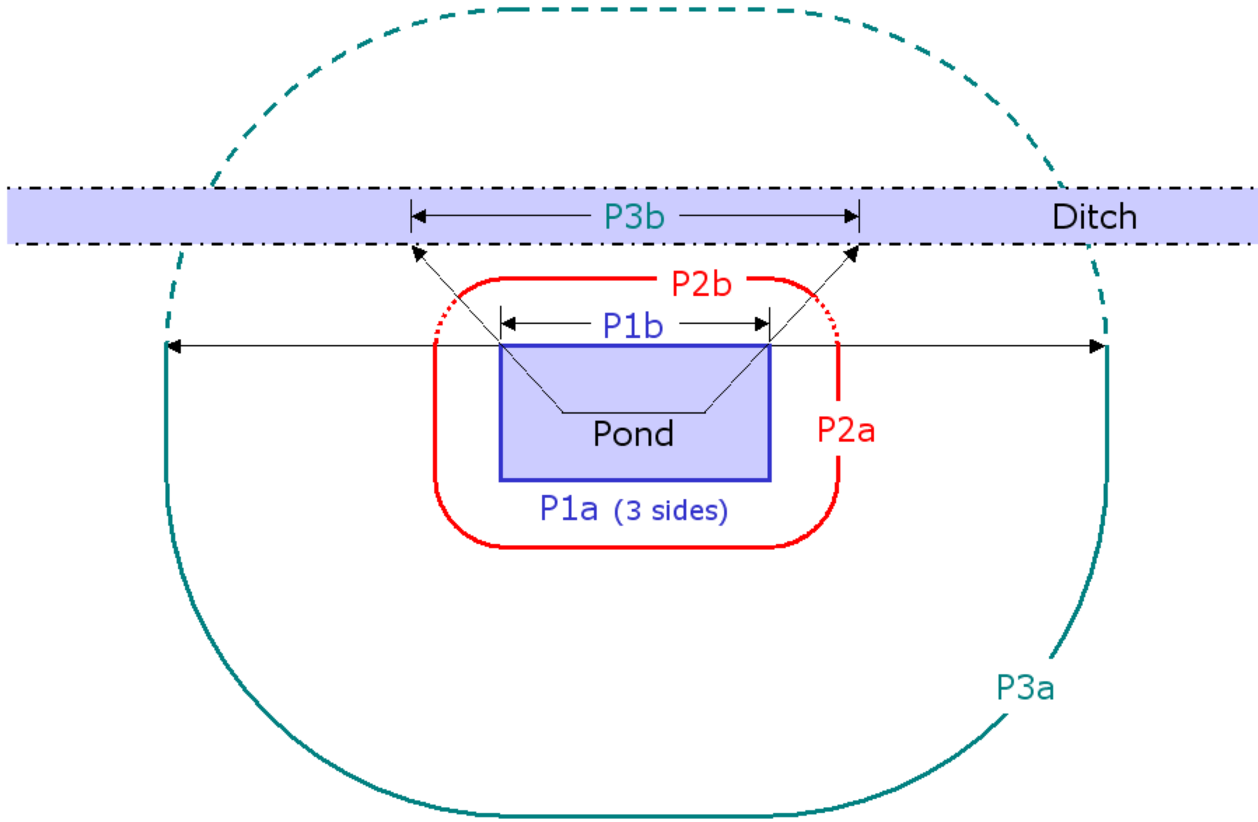
Percolation Links

Setup Example: Ponds in Close Proximity to Canal



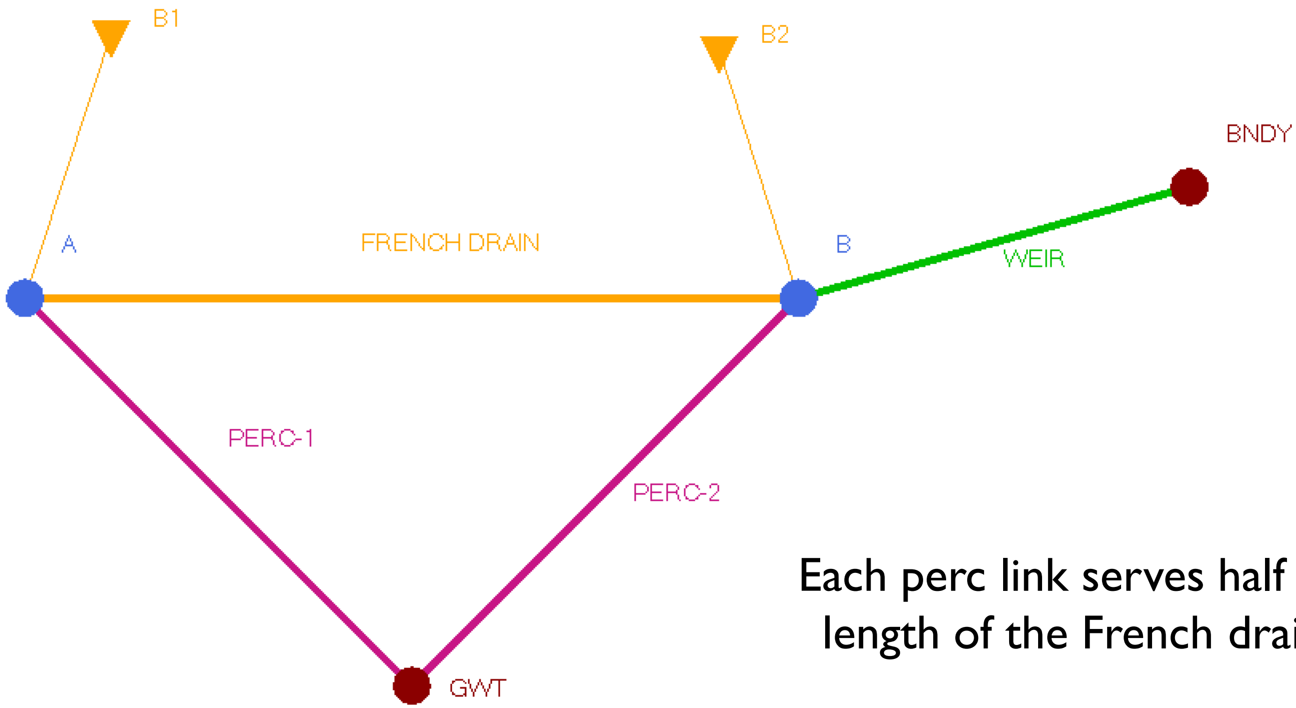
Percolation Links

Setup Example: Ponds in Close Proximity to Canal



Example #1 – French Drain with Percolation

Nodal Network



Each perc link serves half the length of the French drain.

Example #1 – French Drain with Percolation

Name	FRENCH DRAIN
Scenario	French Drain with Perc
From Node	A
To Node	B
Link Count	1
Flow Direction	Both
Trench Length	400
Trench Width	5
Trench Height	15
Trench Depth Below Invert	12
Trench Gravel Porosity	0.5

Damping Threshold	0
FHWA Culvert Code	1
Entrance Loss Coefficient	0.5
Exit Loss Coefficient	0.1
Bend Loss Coefficient	0
Bend Location	0
Energy Switch	Energy
Pipe Length	416
Upstream Pipe Invert	3
Downstream Pipe Invert	3
Manning's N	0.012
Pipe Geometry	Circular
Pipe Max Depth	2

Comment

Create Delete

Example #1 – French Drain with Percolation

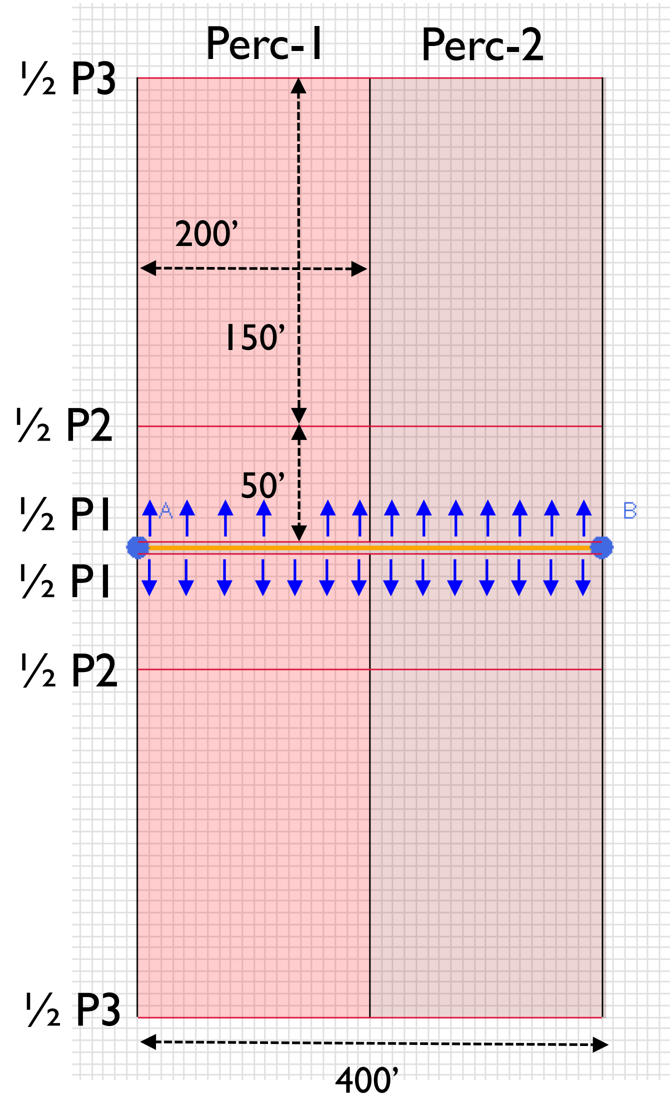
- Water will percolate from both sides of the trench.
- Each perc link serves ½ of the French drain.

Therefore:

P1 = 2 x ½ L = 2 x (½ x 400’) = 400’

P1 = P2 = P3

Distance P1 to P2 = 50’
Distance P2 to P3 = 150’



Example #1 – French Drain with Percolation

Nodal Network

Soil Conductivity: Saturated horizontal conductivity for projects in South Florida are calculated from field tests at 10-foot and 15-foot depths (and sometimes to 20-feet). A weighted average conductivity is needed for ICPR4.

K_{10} = 3.7 x 10^{-4} cfs per sqft per foot of head (fps per foot of head)
(from 0-ft to 10-ft depth)
K_{15} = 6.1 x 10^{-4} cfs per sqft per foot of head (fps per foot of head)
(from 10-ft to 15-ft depth)

Weighted average:
K = 4.5 x 10^{-4} cfs per sqft per foot of head (fps per foot of head)

Assuming 1-ft of head*:
K_{icpr4} = (4.5 x 10-4) x (24 x 3600) = 38.9 fpd (19.45 fpd, F.O.S. = 2.0)

* Perc links in ICPR4 automatically include head and hydraulic gradient components.

Example #1 – French Drain with Percolation

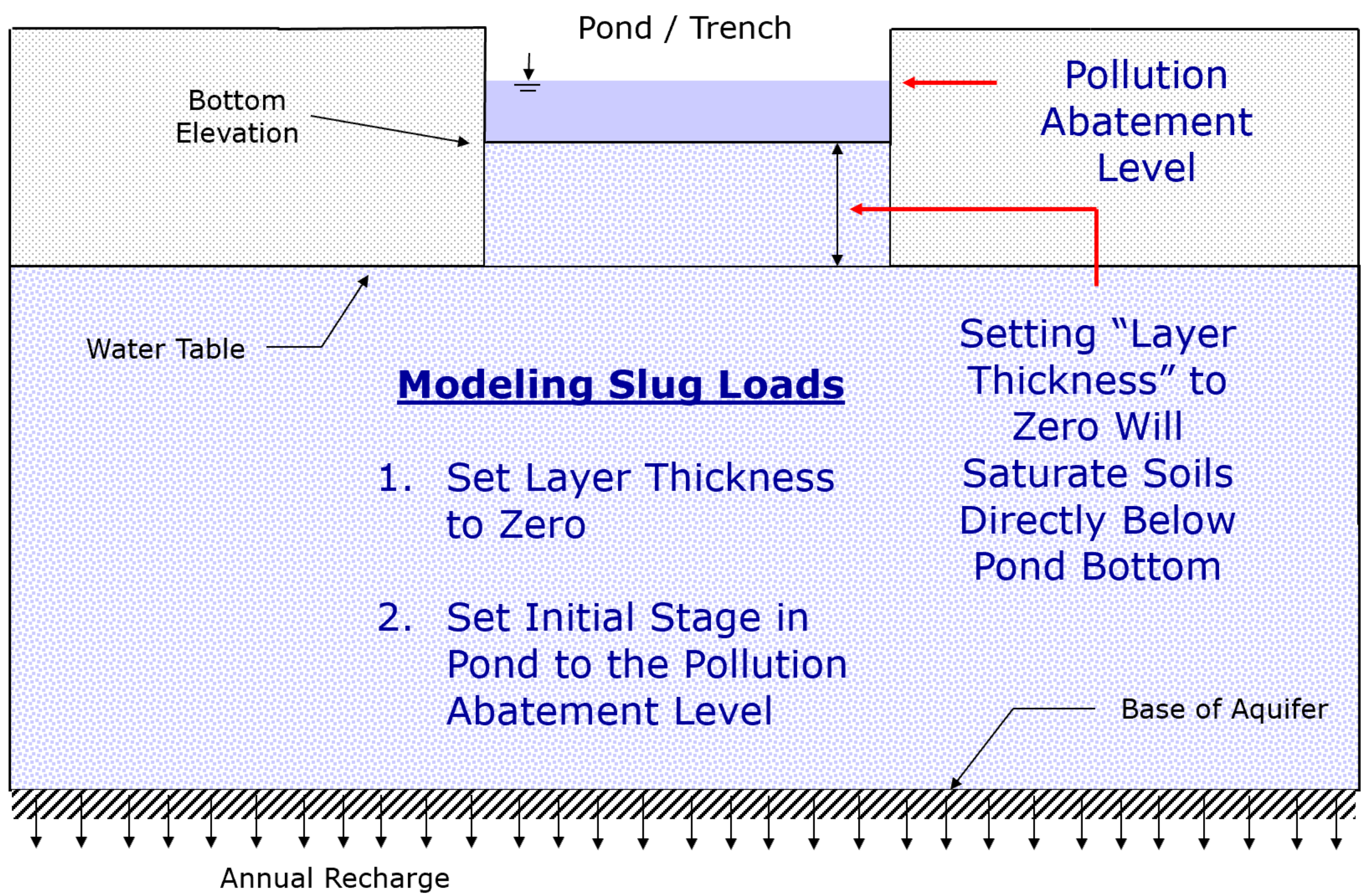
Perc Link Data Form

Flow Direction	Both
Aquifer Base Elevation	-9.1
Water Table Elevation	2.75
Annual Recharge Rate	0
Horizontal Conductivity	19.45
Vertical Conductivity	9.73 $K_v = ½ K_h$
Fillable Porosity	0.25
Layer Thickness	0 GWT > BTM of Trench

Surface Area Option	User Specified
Bottom Elevation	-9 bottom of trench
Surface Area	0.02296 = (5x200)/43560
Vertical Flow Termination	Horizontal Flow Algorithm
Perimeter 1	400
Perimeter 2	400 P1 = P2 = P3 = 2(1/2)L
Perimeter 3	400
Distance P1 to P2	50
Distance P2 to P3	150
# of Cells P1 to P2	10
# of Cells P2 to P3	15

Example #1 – French Drain with Percolation

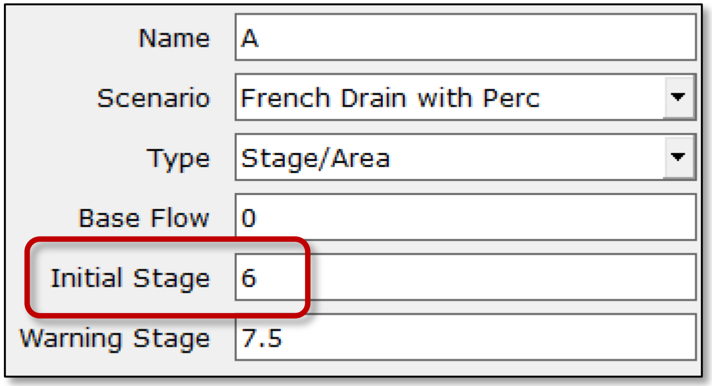
Slug Load

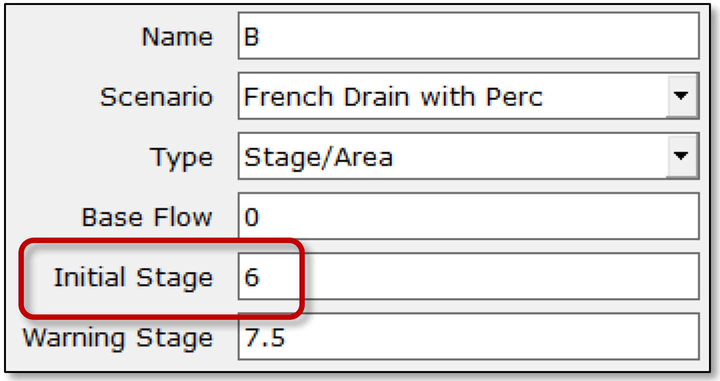


Example #1 – French Drain with Percolation

Slug Load

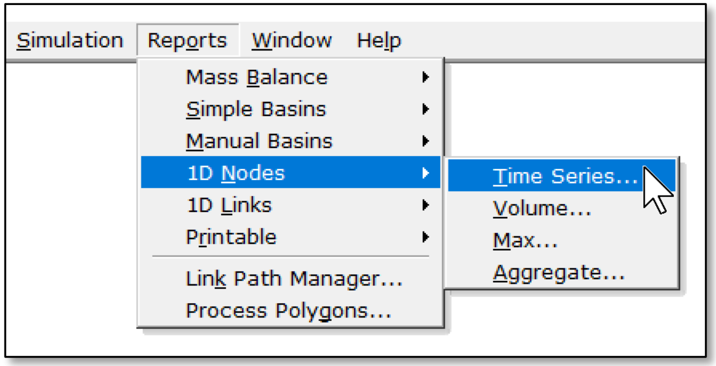
- Initial stage at the weir overflow elevation of 6' (pollution abatement volume)
- No rainfall
- Recovery to elevation 3' must occur by hour 72

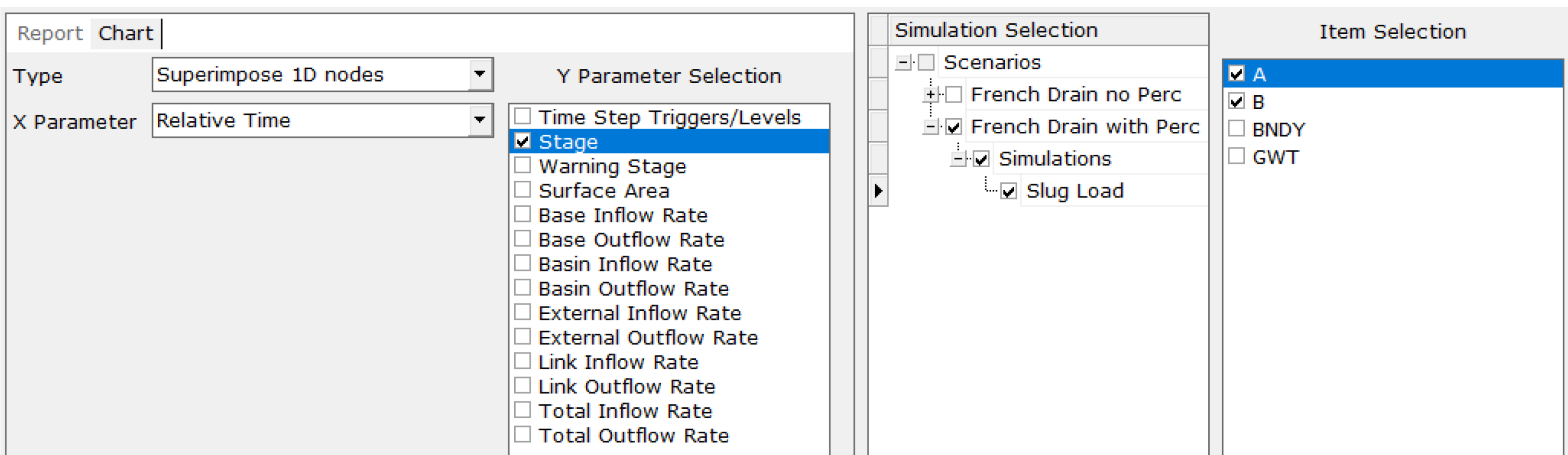




Example #1 – French Drain with Percolation

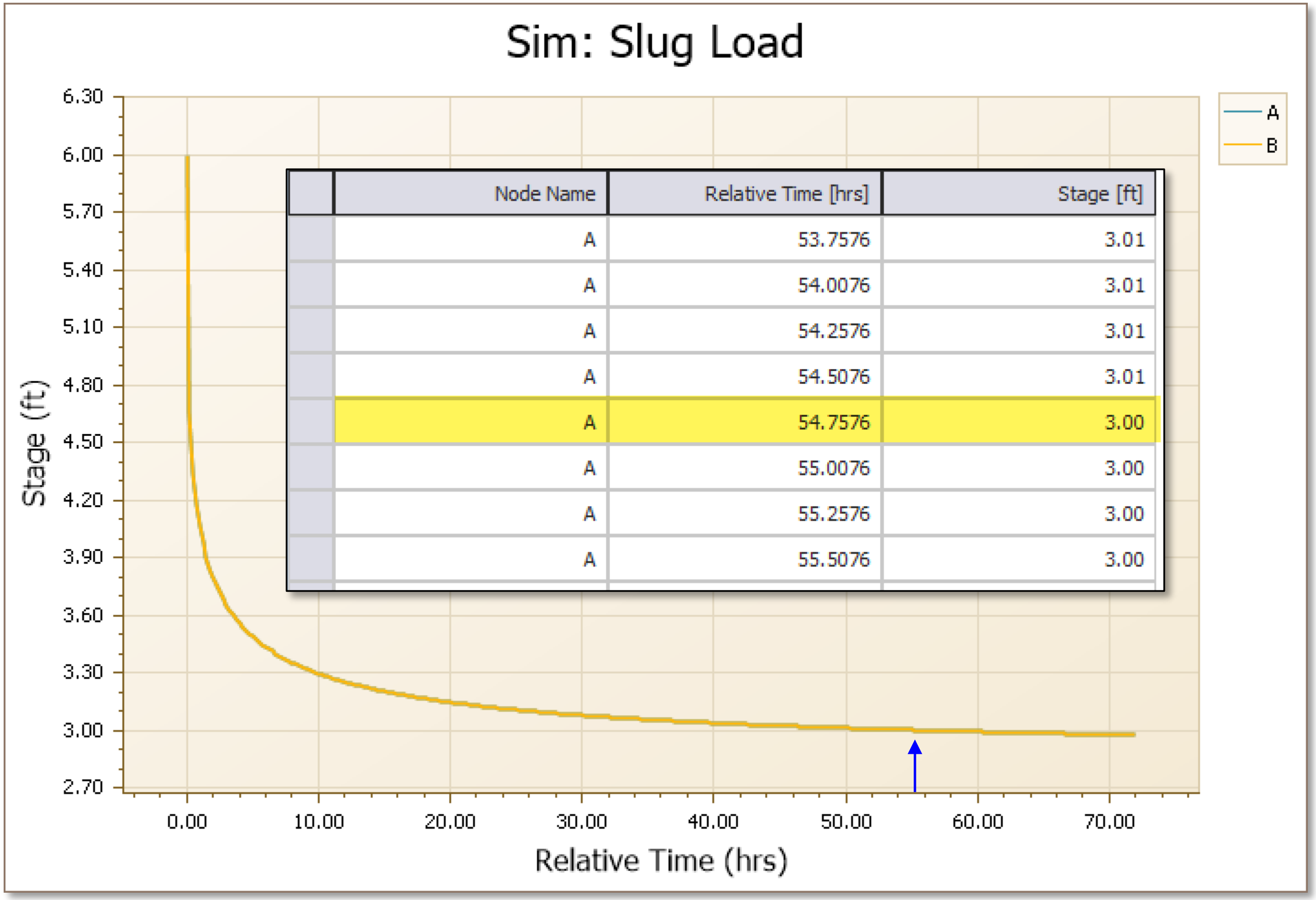
Slug Load





Example #1 – French Drain with Percolation

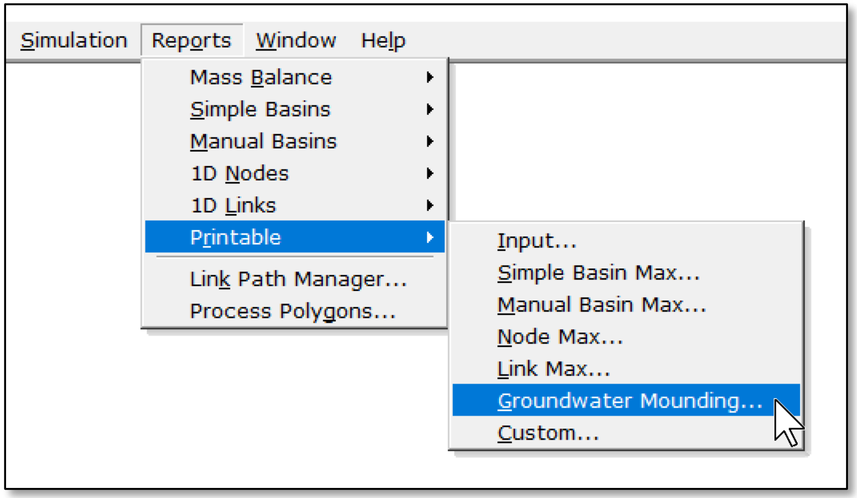
Slug Load

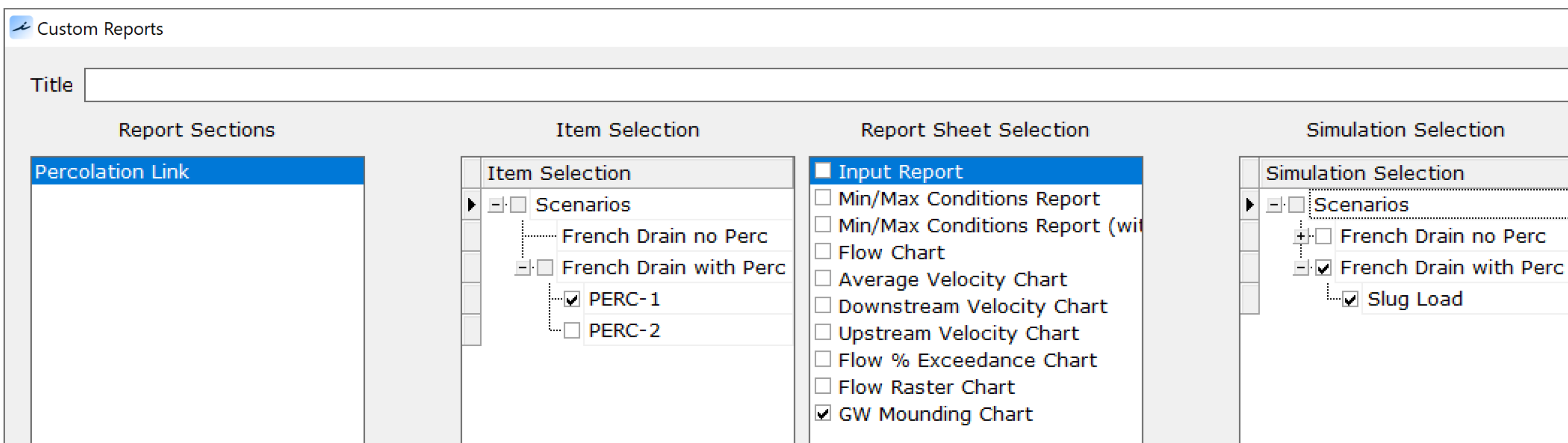


Node Name	Relative Time [hrs]	Stage [ft]
A	53.7576	3.01
A	54.0076	3.01
A	54.2576	3.01
A	54.5076	3.01
A	54.7576	3.00
A	55.0076	3.00
A	55.2576	3.00
A	55.5076	3.00

Example #1 – French Drain with Percolation

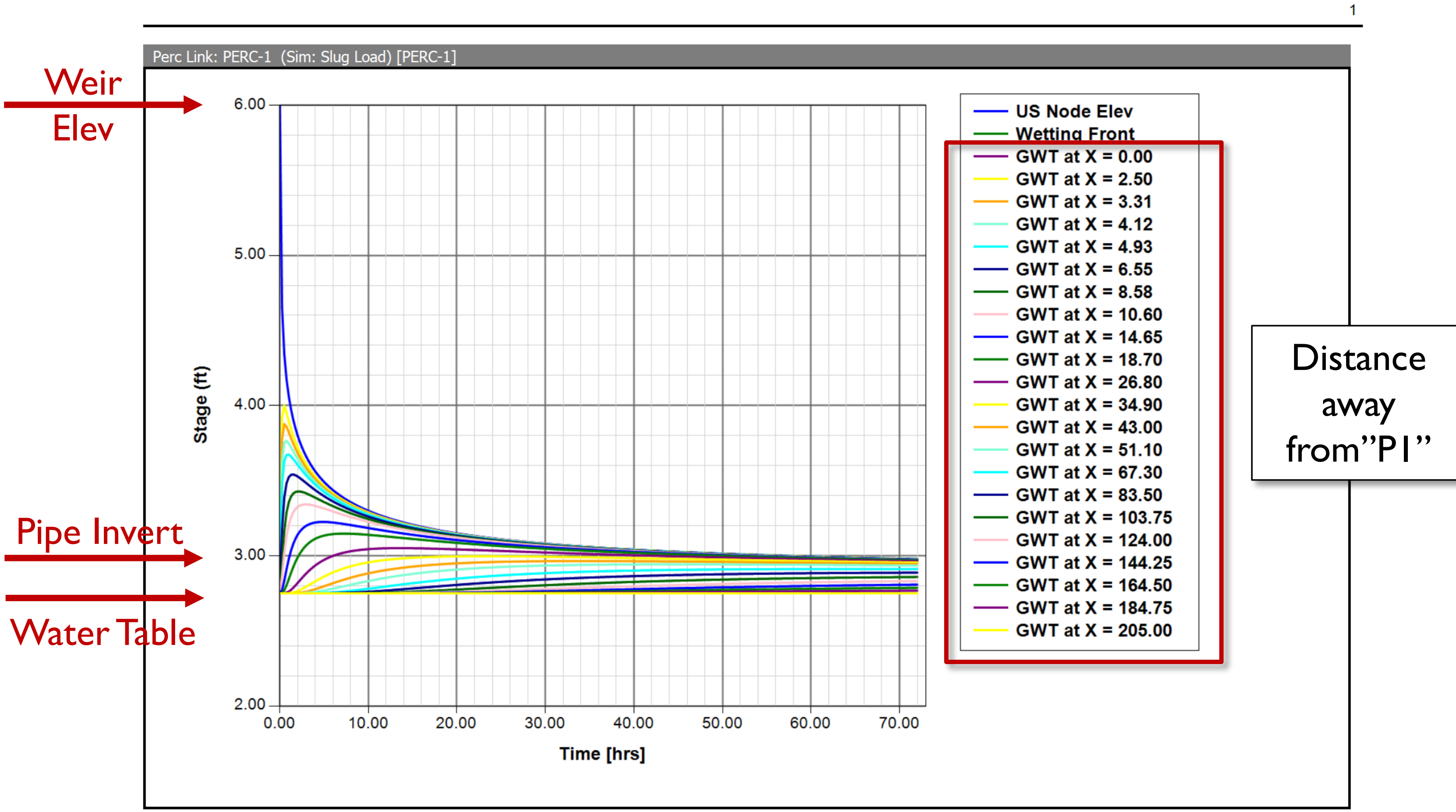
Slug Load





Example #1 – French Drain with Percolation

Slug Load



Example #1 – French Drain with Percolation

8.5" Storm

- Initial stage at the pipe invert elevation of 3'
- 8.5" rainfall in 24 hours (FLMOD distribution)

Name	A
Scenario	French Drain with Perc
Type	Stage/Area
Base Flow	0
Initial Stage	3
Warning Stage	7.5

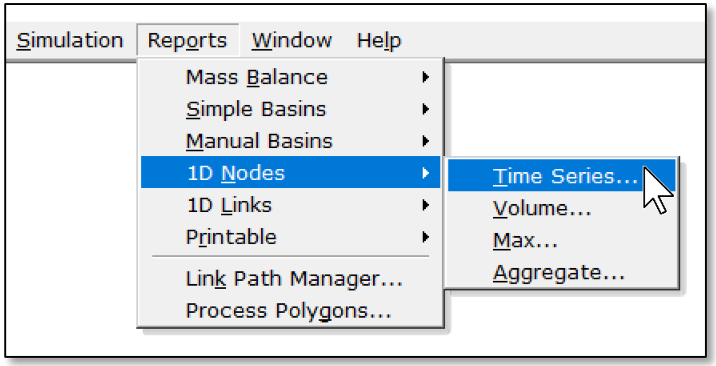
Node Data Form

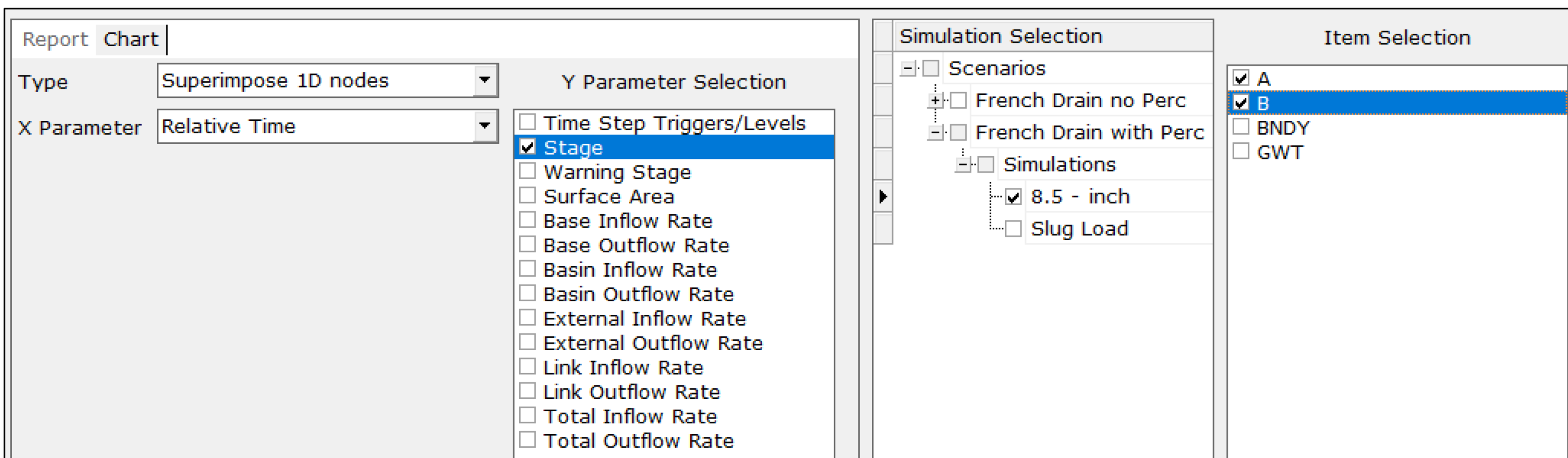
Simple / Manual Basin Rainfall Opt.	Global
Rainfall Name	~FLMOD
Rainfall Amount	8.5
Storm Duration	24

Simulation Manager

Example #1 – French Drain with Percolation

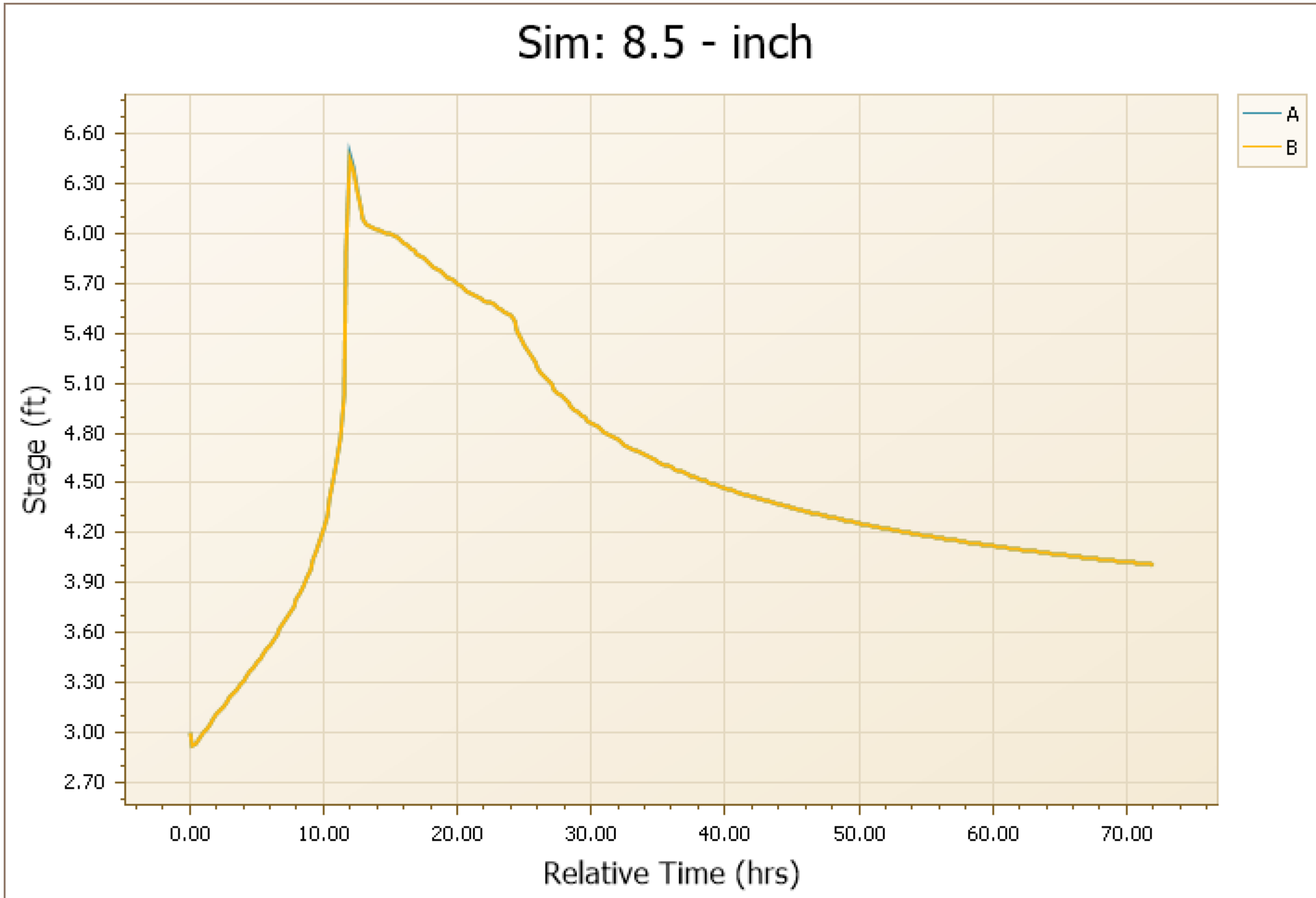
8.5" Storm





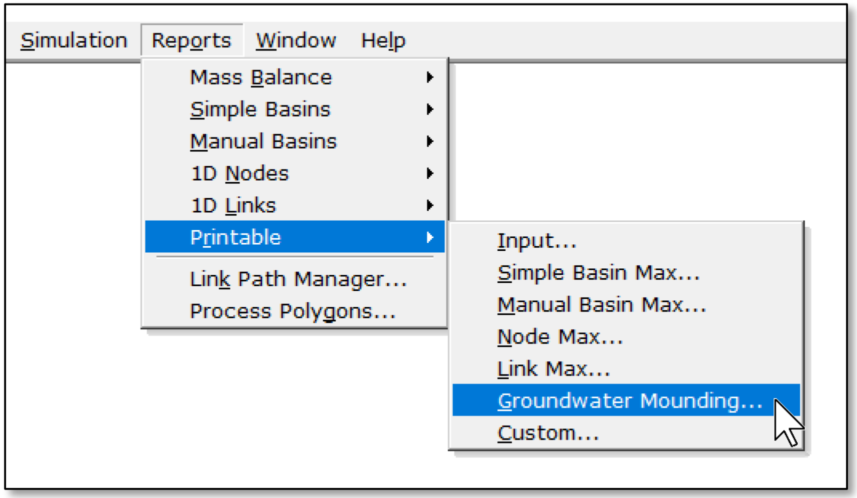
Example #1 – French Drain with Percolation

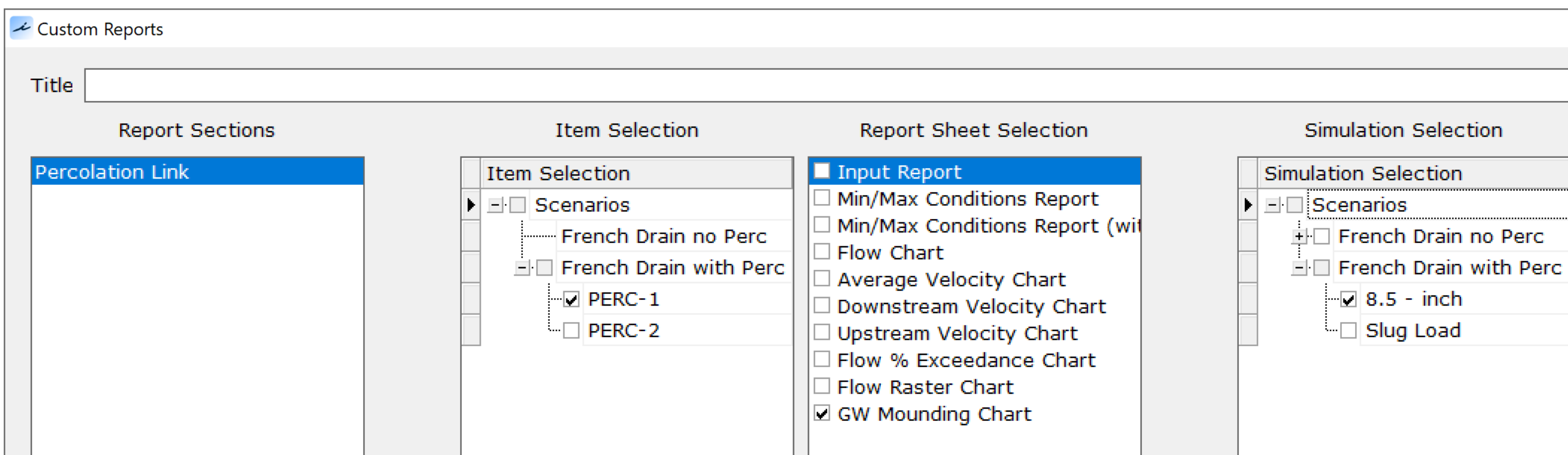
8.5" Storm



Example #1 – French Drain with Percolation

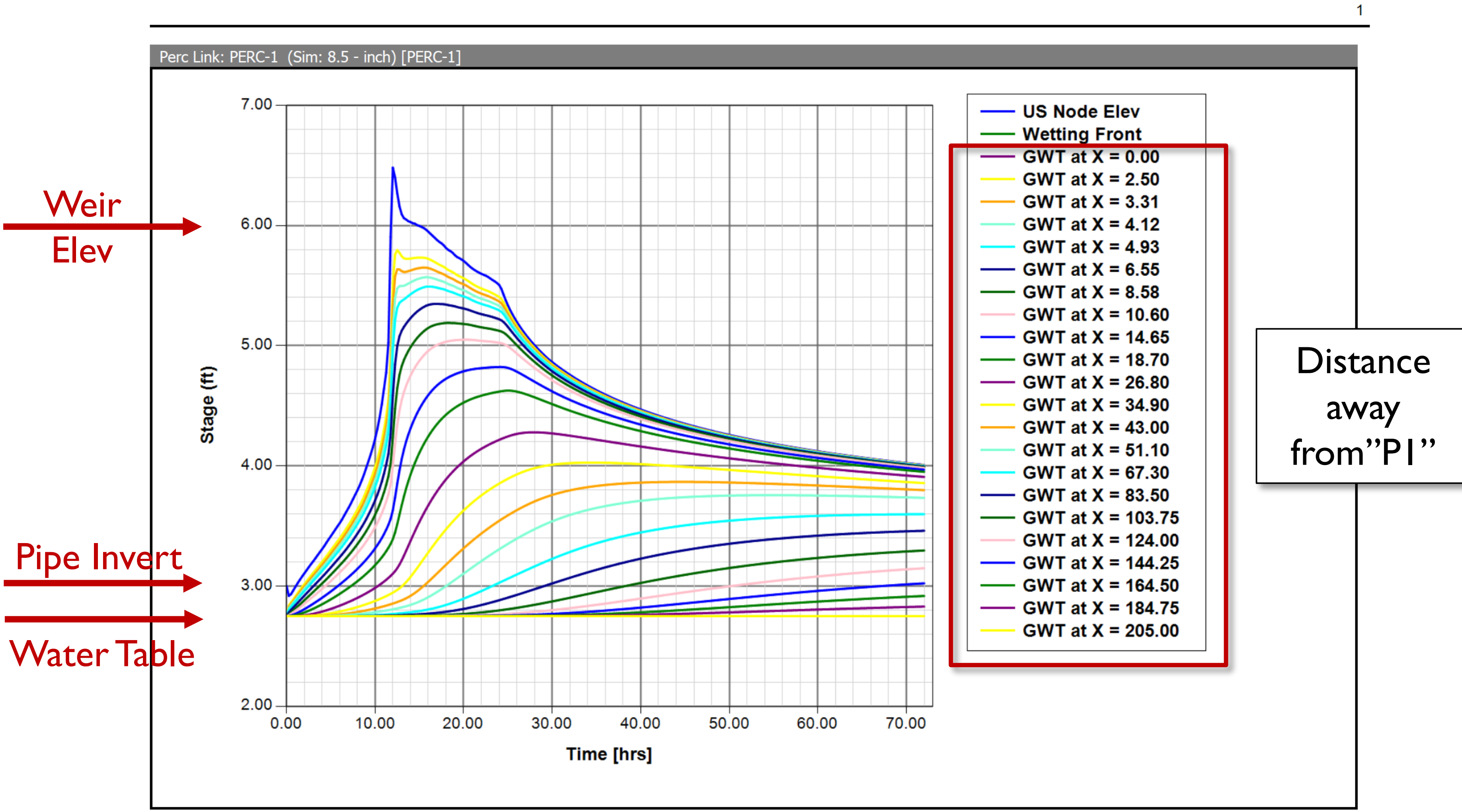
8.5" Storm





Example #1 – French Drain with Percolation

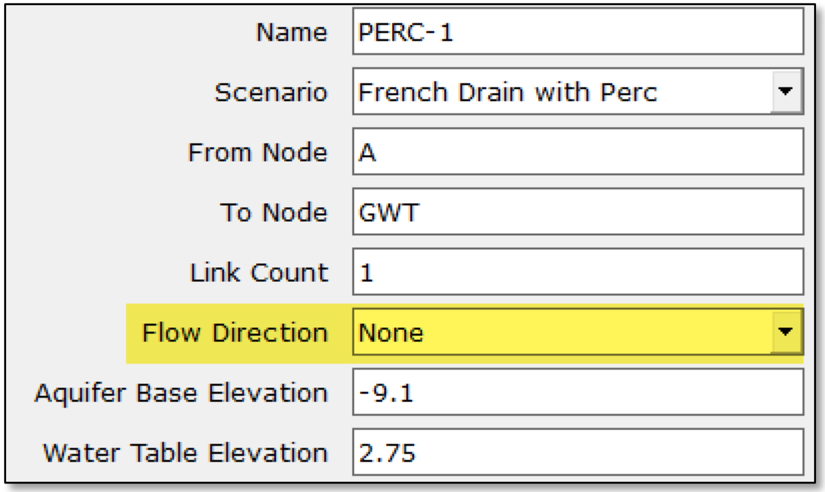
8.5” Storm



Example #1 – French Drain with Percolation

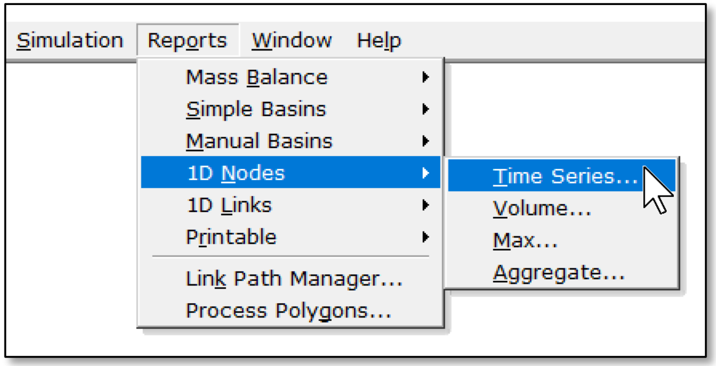
8.5" Storm

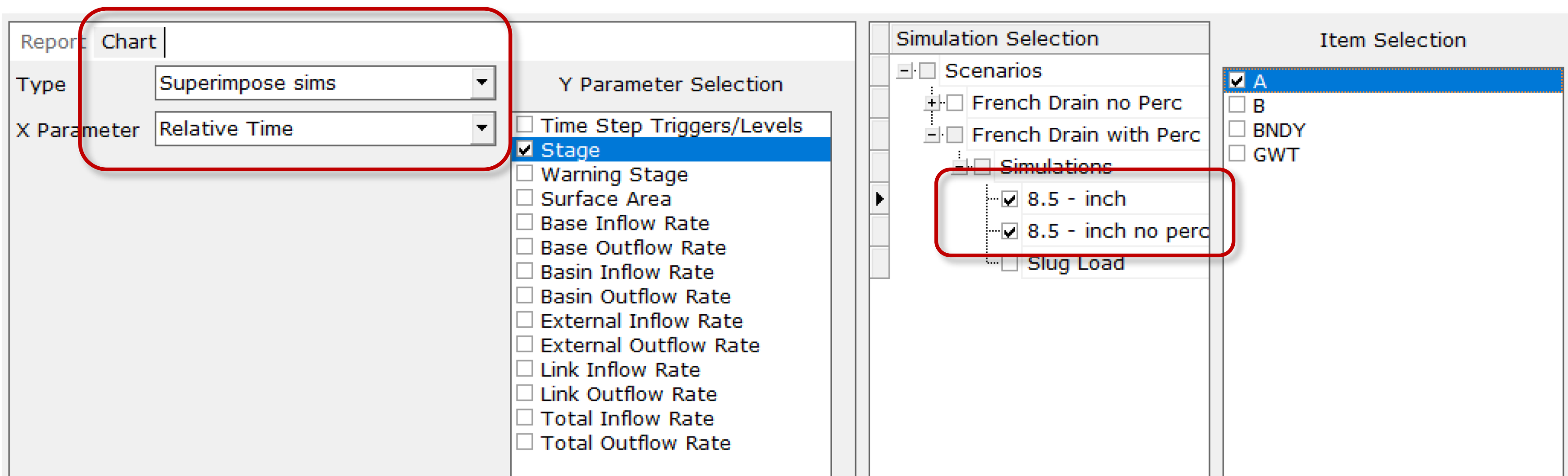
- Turn perc links off and rerun the 8.5" storm



Example #1 – French Drain with Percolation

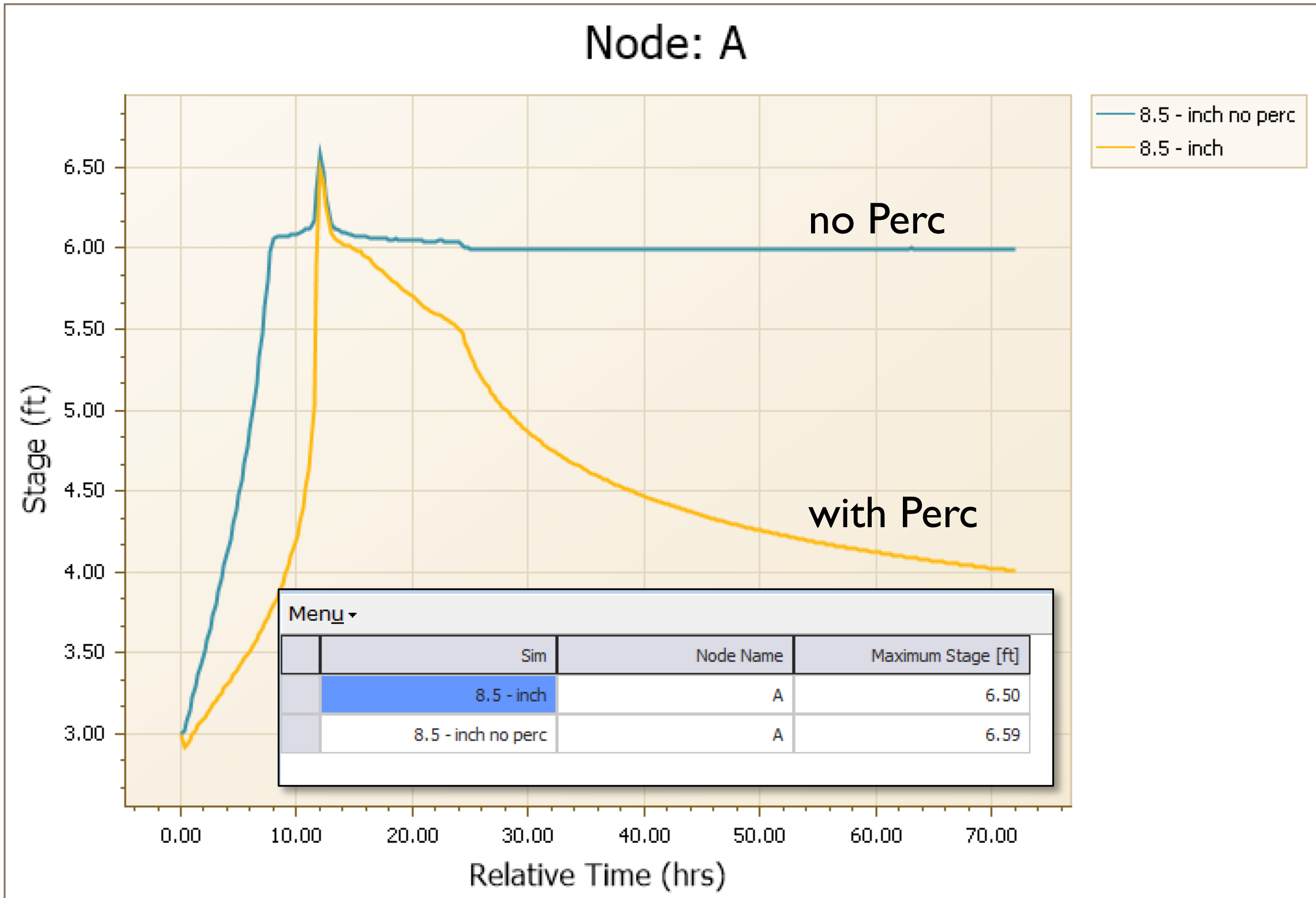
8.5" Storm





Example #1 – French Drain with Percolation

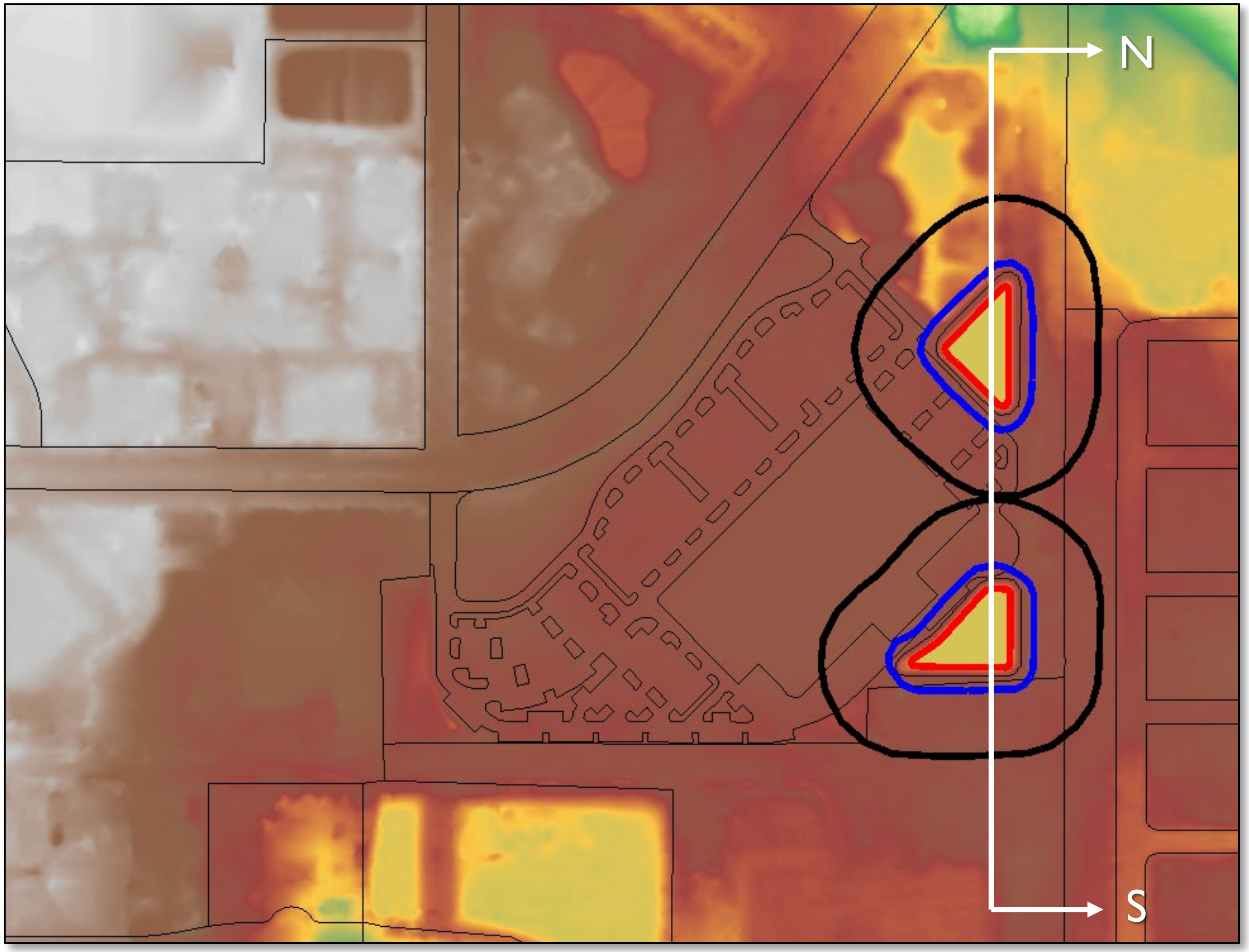
8.5" Storm



Sim	Node Name	Maximum Stage [ft]
8.5 - inch	A	6.50
8.5 - inch no perc	A	6.59

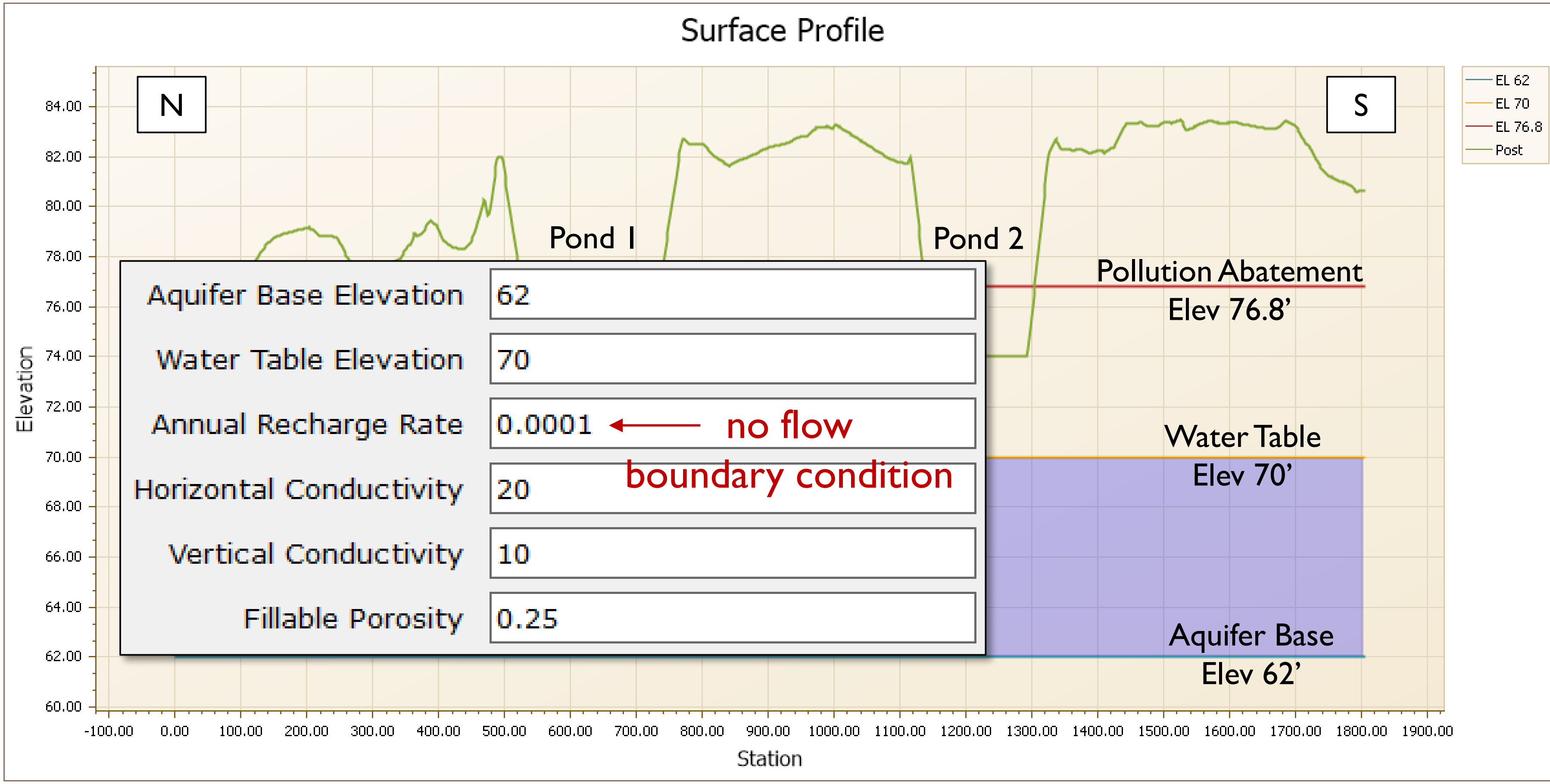
Example #2 – Dual Ponds in Close Proximity

Layout 1 (P3@190')



Example #2 – Dual Ponds in Close Proximity

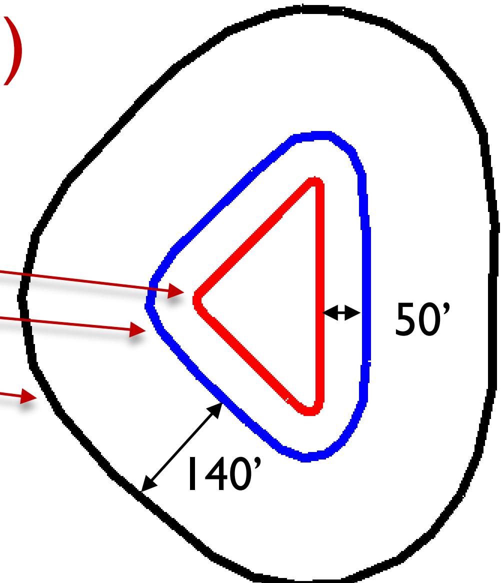
Layout 1 (P3@190') No Flow at P3



Example #2 – Dual Ponds in Close Proximity

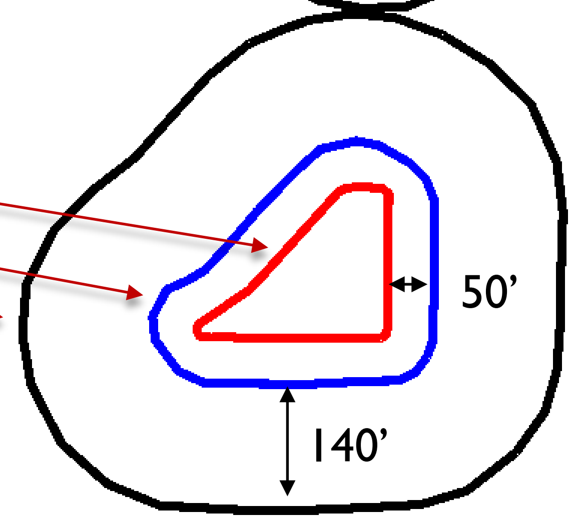
Layout 1 (P3@190’)

Vertical Flow Termination	Horizontal Flow Algorithm
Perimeter 1	623.4
Perimeter 2	931.9
Perimeter 3	1807.7
Distance P1 to P2	50
Distance P2 to P3	140
# of Cells P1 to P2	10
# of Cells P2 to P3	28



5’ cell size

Vertical Flow Termination	Horizontal Flow Algorithm
Perimeter 1	645.6
Perimeter 2	944.9
Perimeter 3	1828.1
Distance P1 to P2	50
Distance P2 to P3	140
# of Cells P1 to P2	10
# of Cells P2 to P3	28



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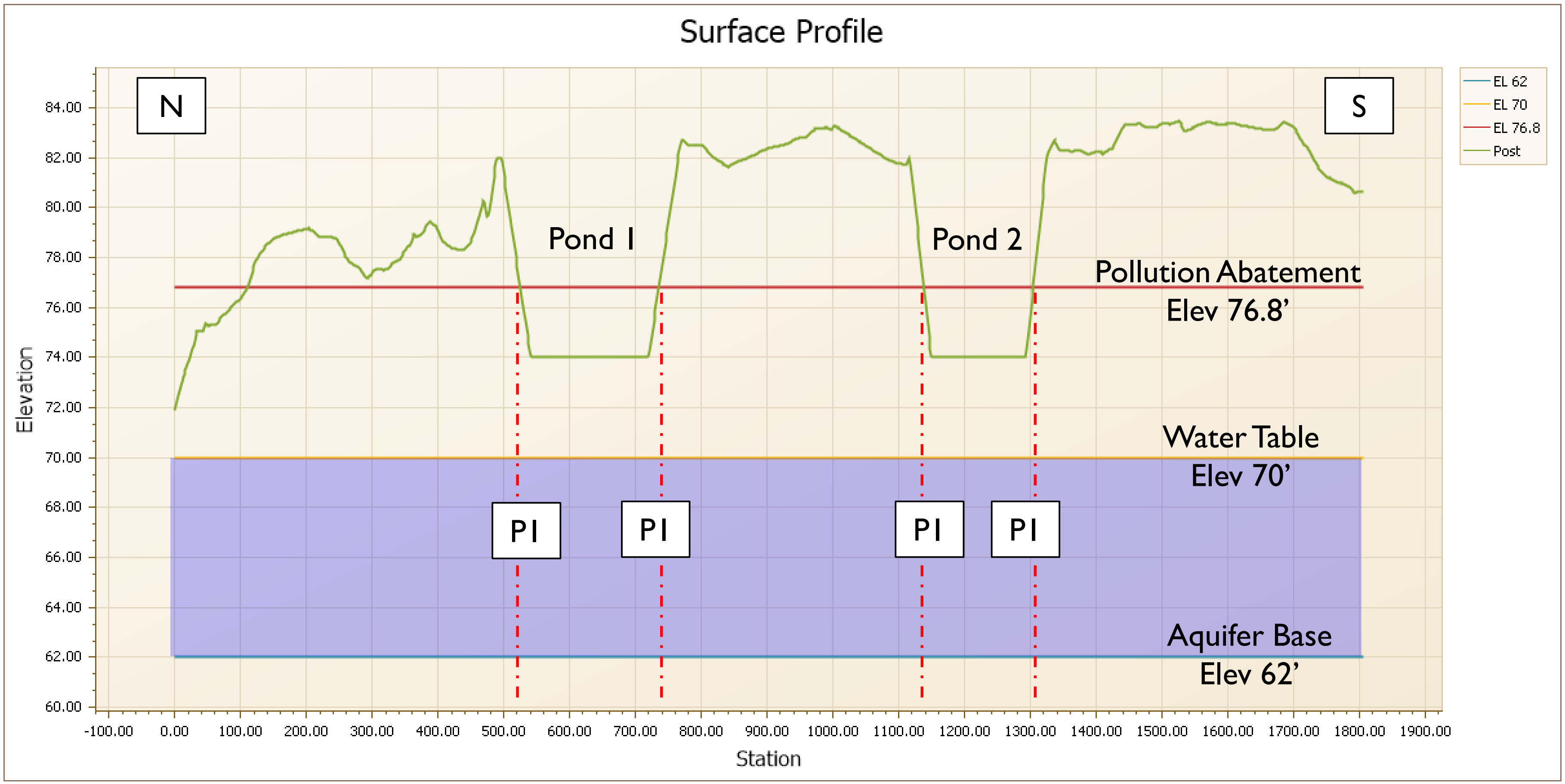
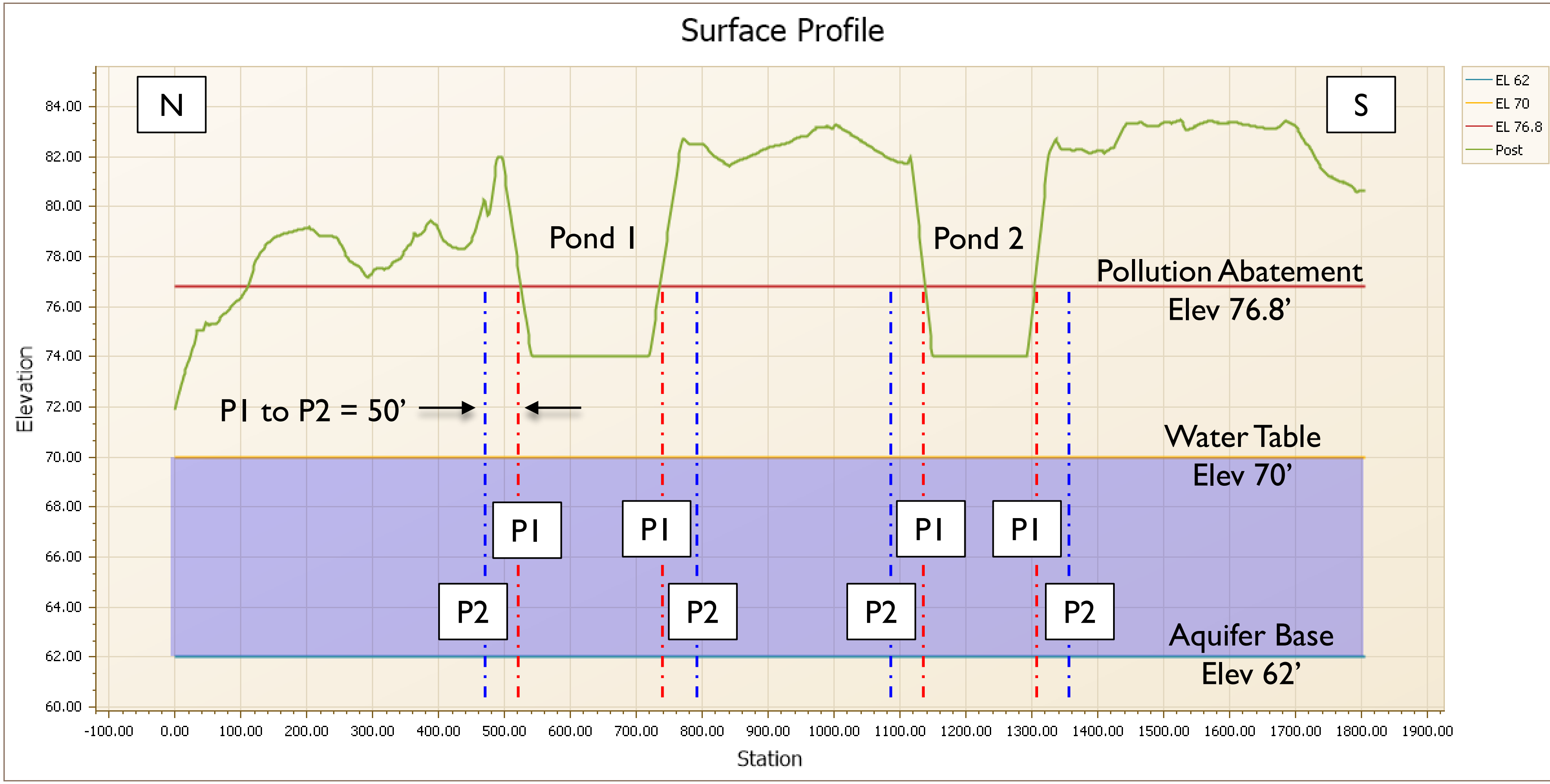
Layout 1 (P3@190')



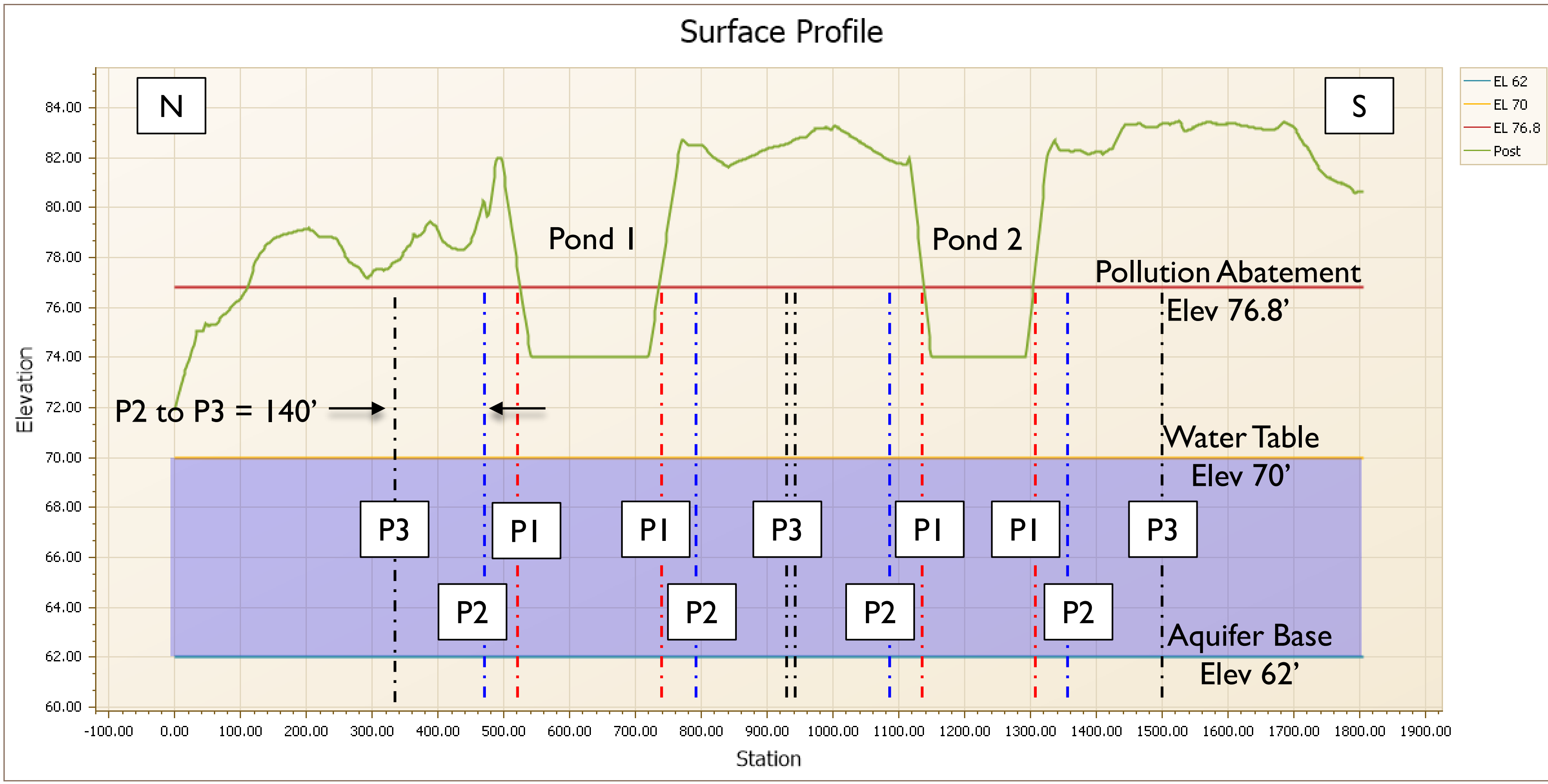
Example #2 – Dual Ponds in Close Proximity

Layout 1 (P3@190')



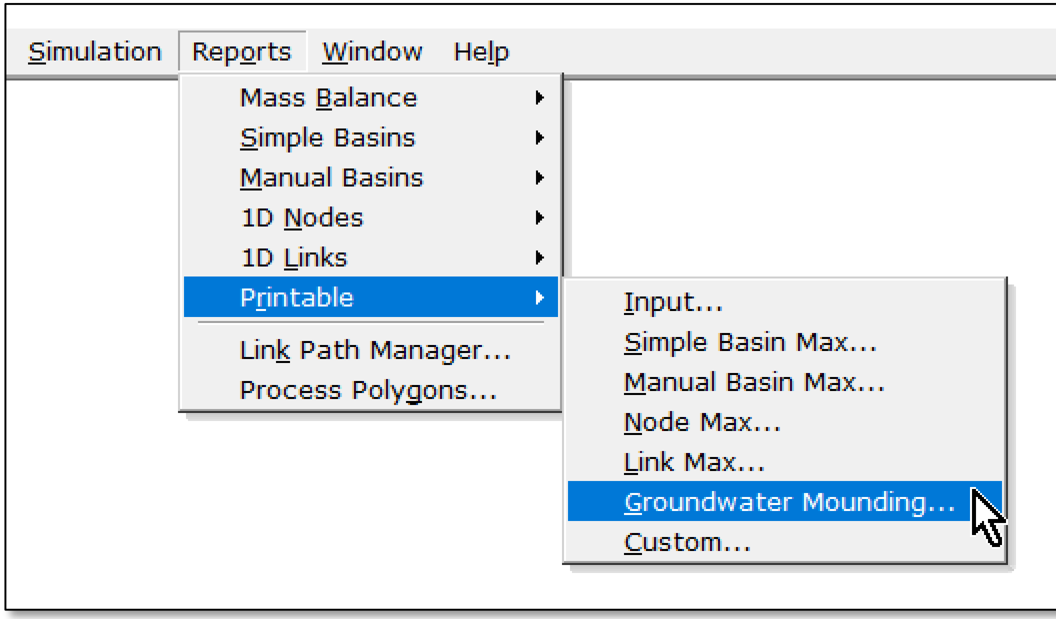
Example #2 – Dual Ponds in Close Proximity

Layout 1 (P3@190')



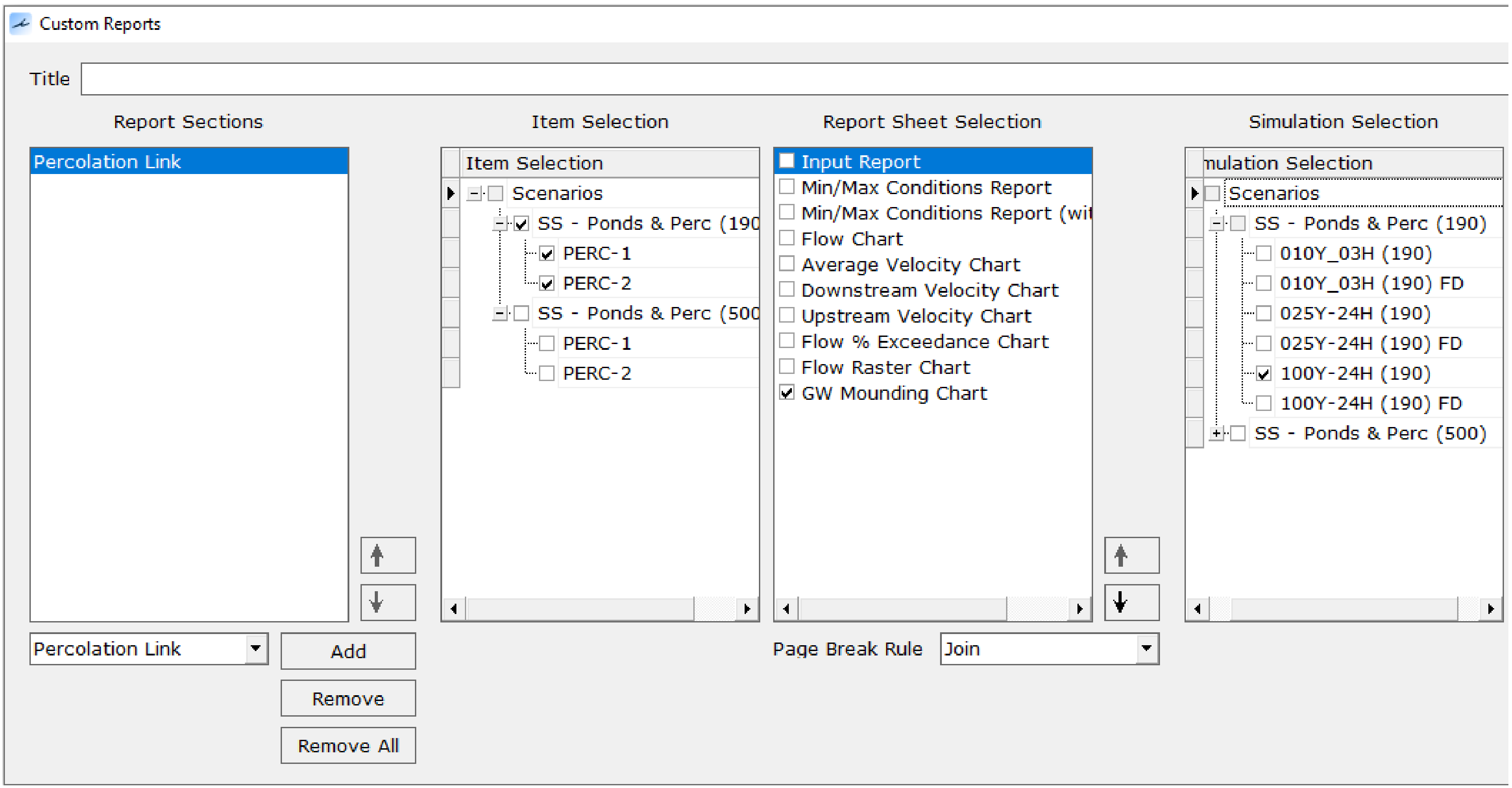
Example #2 – Dual Ponds in Close Proximity

Layout 1 (P3@190') No Flow at P3



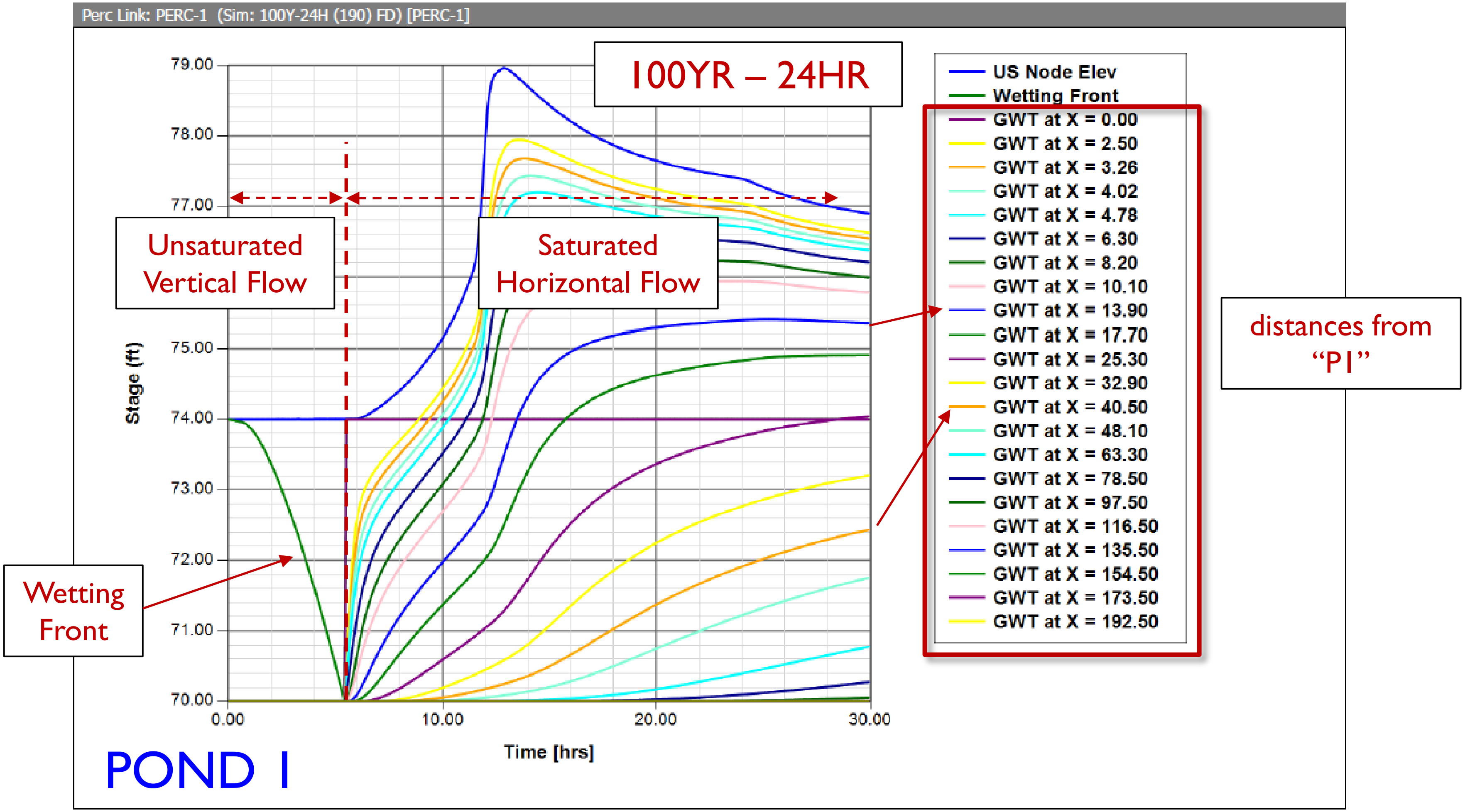
Example #2 – Dual Ponds in Close Proximity

Layout 1 (P3@190') No Flow at P3



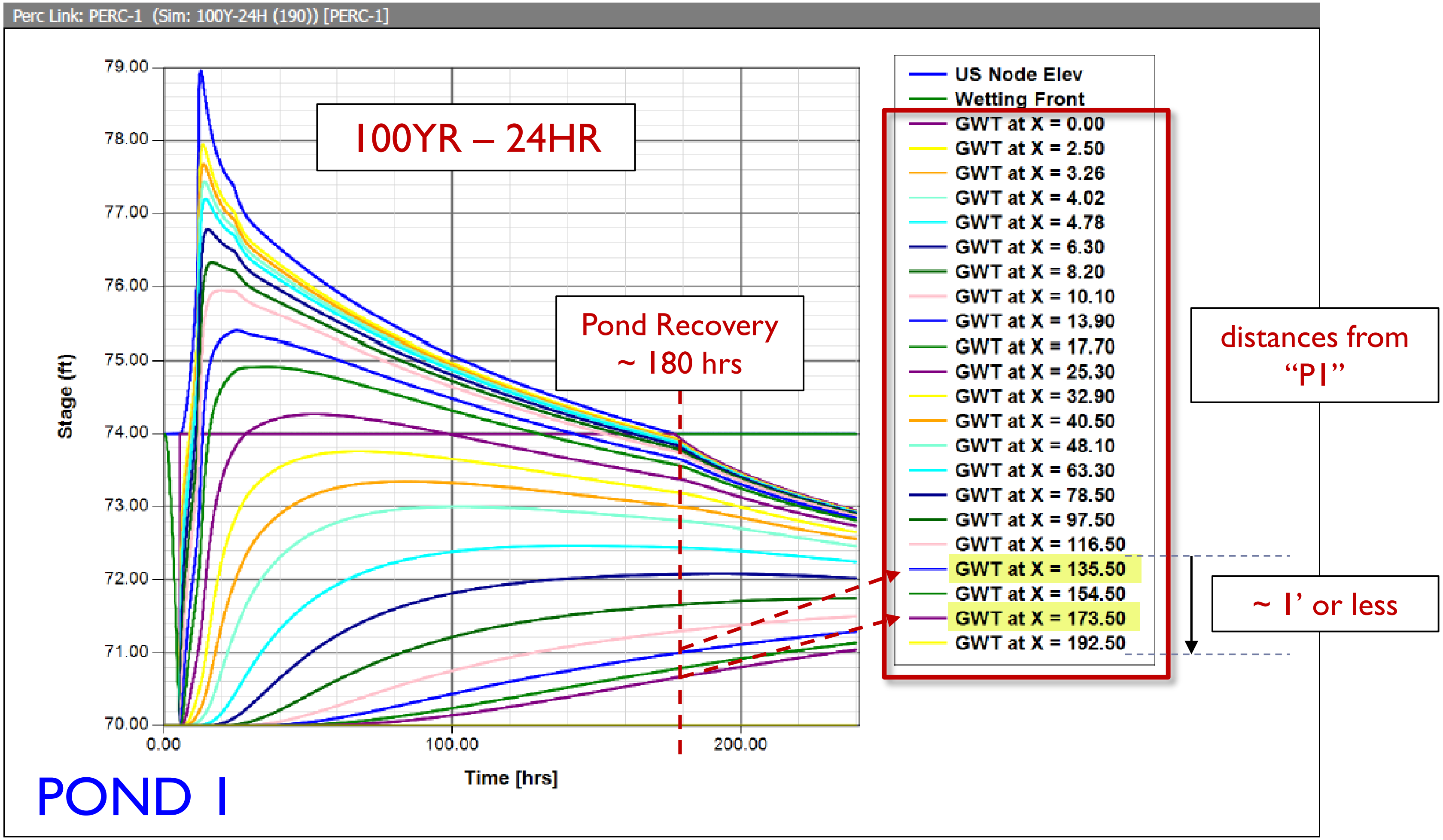
Example #2 – Dual Ponds in Close Proximity

Layout 1 (P3@190') No Flow at P3



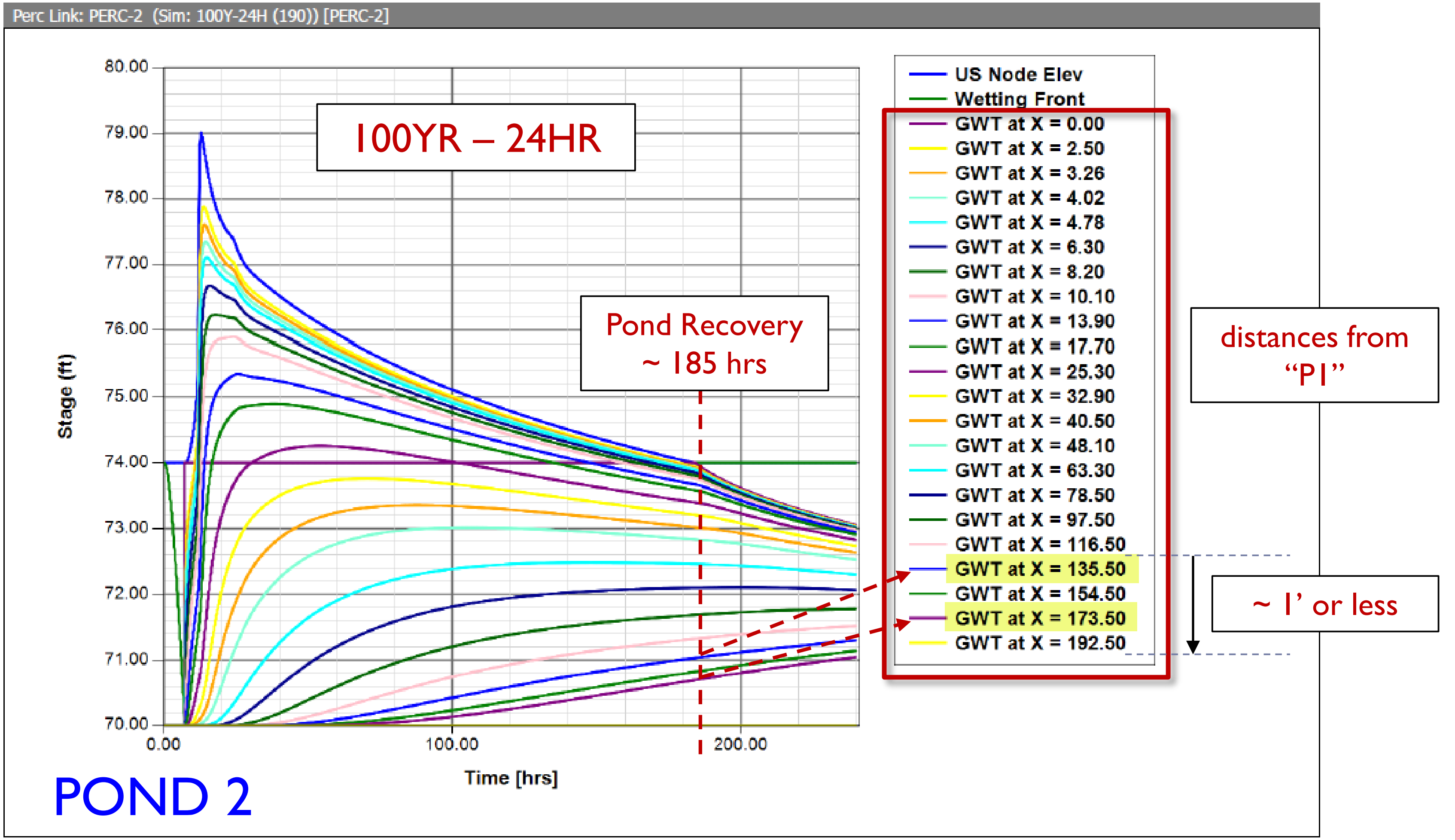
Example #2 – Dual Ponds in Close Proximity

Layout 1 (P3@190') No Flow at P3



Example #2 – Dual Ponds in Close Proximity

Layout 1 (P3@190') No Flow at P3



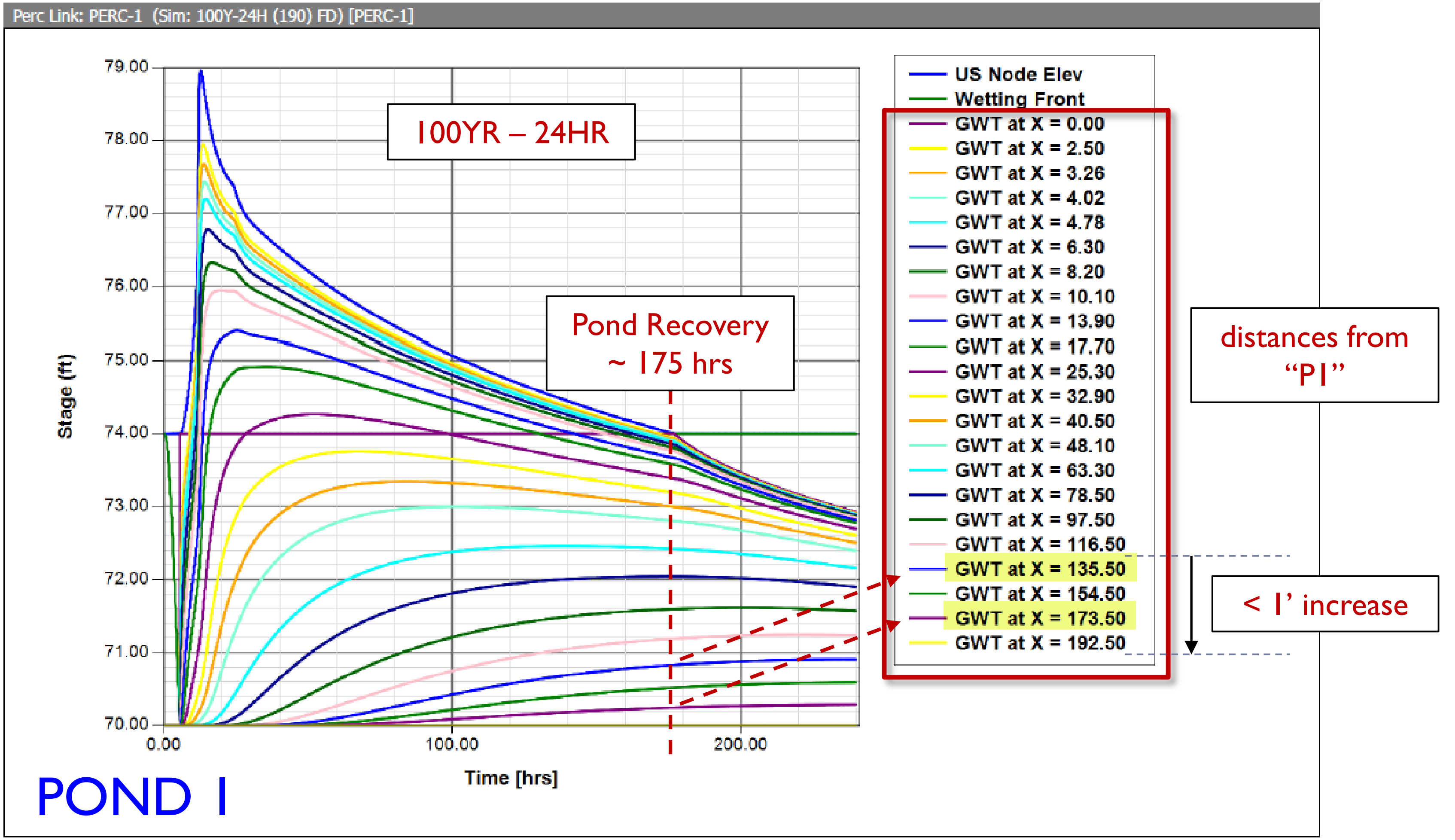
Example #2 – Dual Ponds in Close Proximity

Layout 1 (P3@190’) P3 = WT Elev

Aquifer Base Elevation	62
Water Table Elevation	70
Annual Recharge Rate	0 ← P3= WT Elev
Horizontal Conductivity	20
Vertical Conductivity	10
Fillable Porosity	0.25
Layer Thickness	4

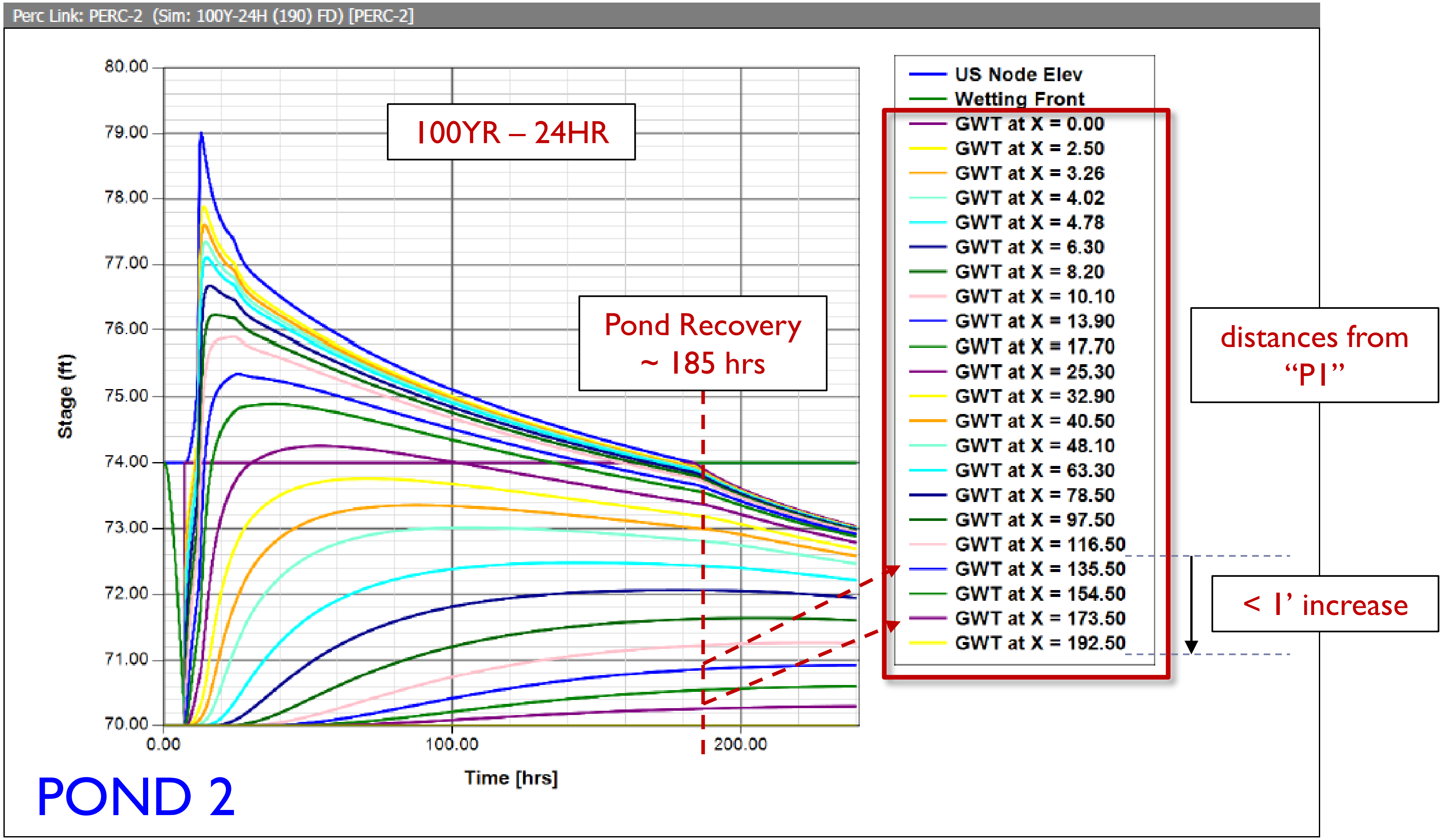
Example #2 – Dual Ponds in Close Proximity

Layout 1 (P3@190') P3 = WT Elev



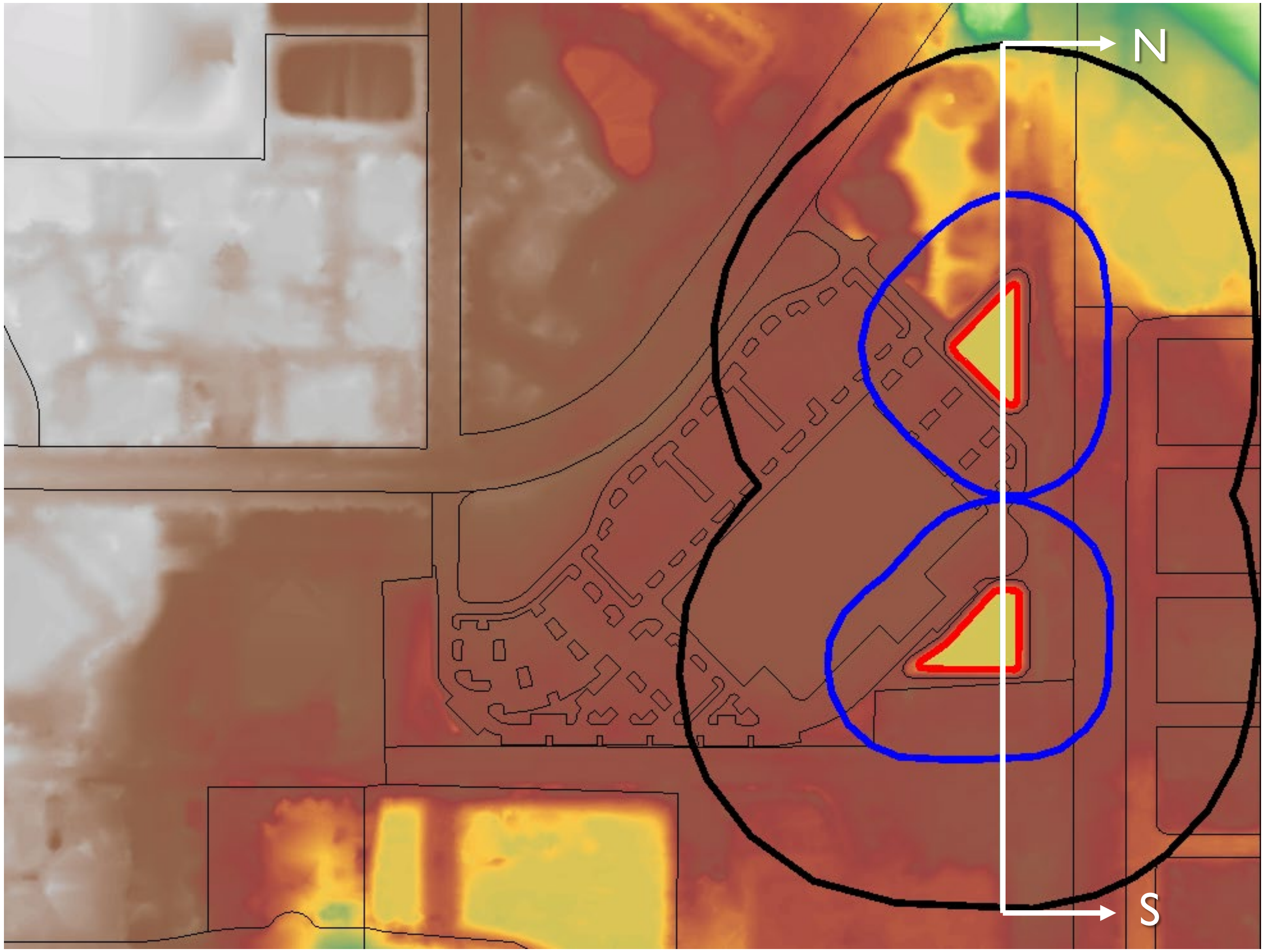
Example #2 – Dual Ponds in Close Proximity

Layout 1 (P3@190') P3 = WT Elev



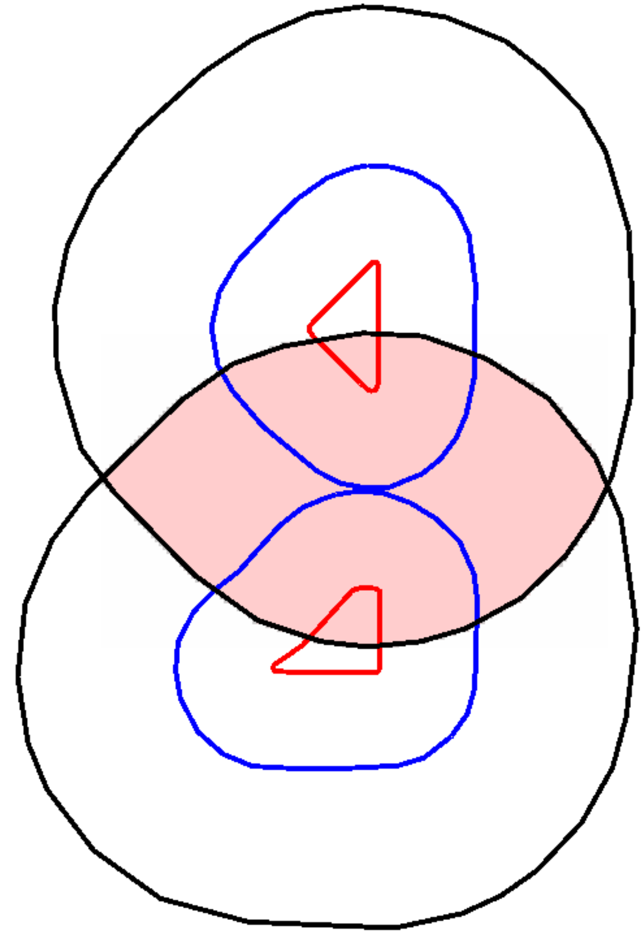
Example #2 – Dual Ponds in Close Proximity

Layout 2 (P3@500')



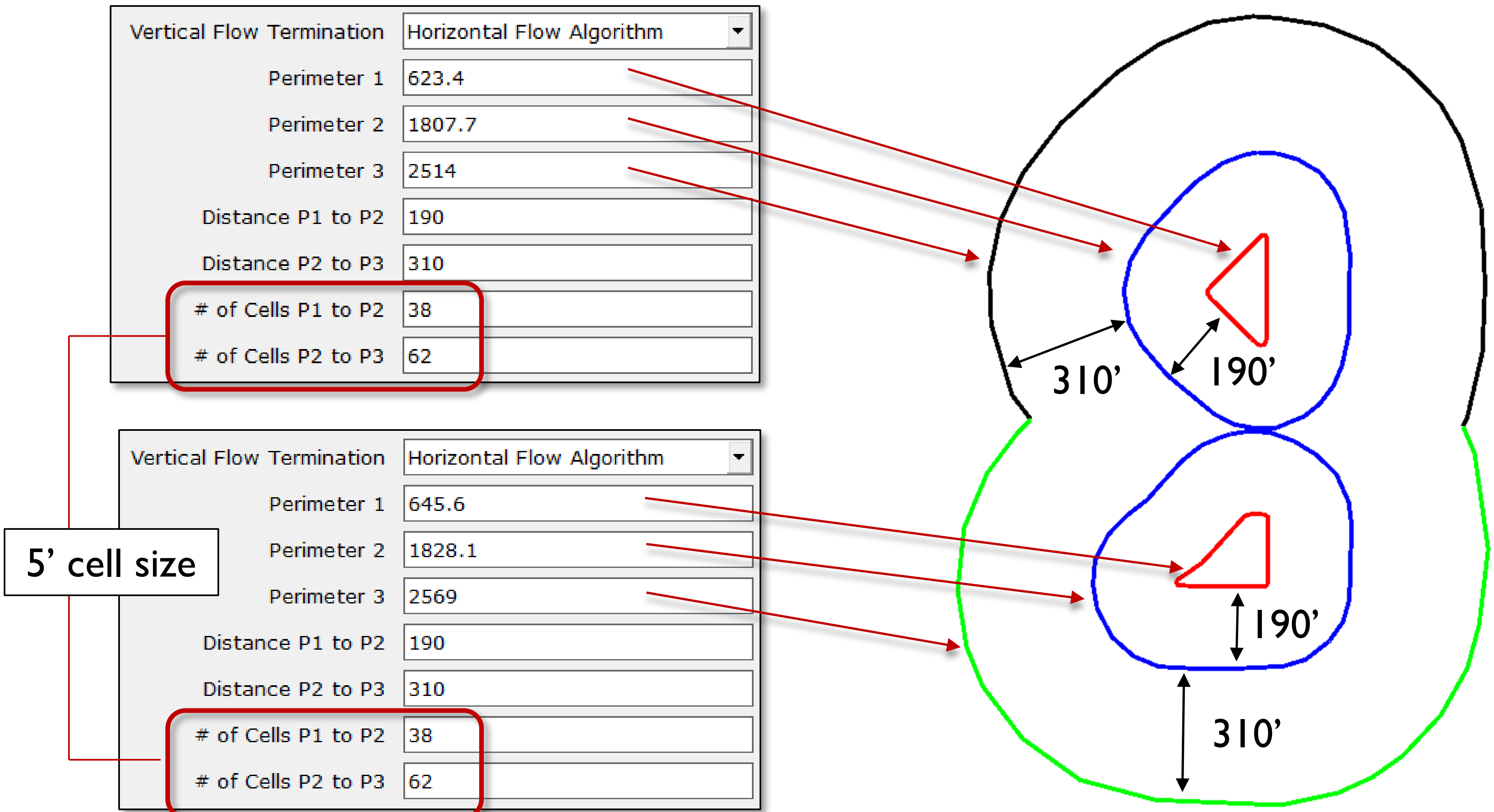
Example #2 – Dual Ponds in Close Proximity

Layout 2 (P3@500’)



Example #2 – Dual Ponds in Close Proximity

Layout 2 (P3@500')



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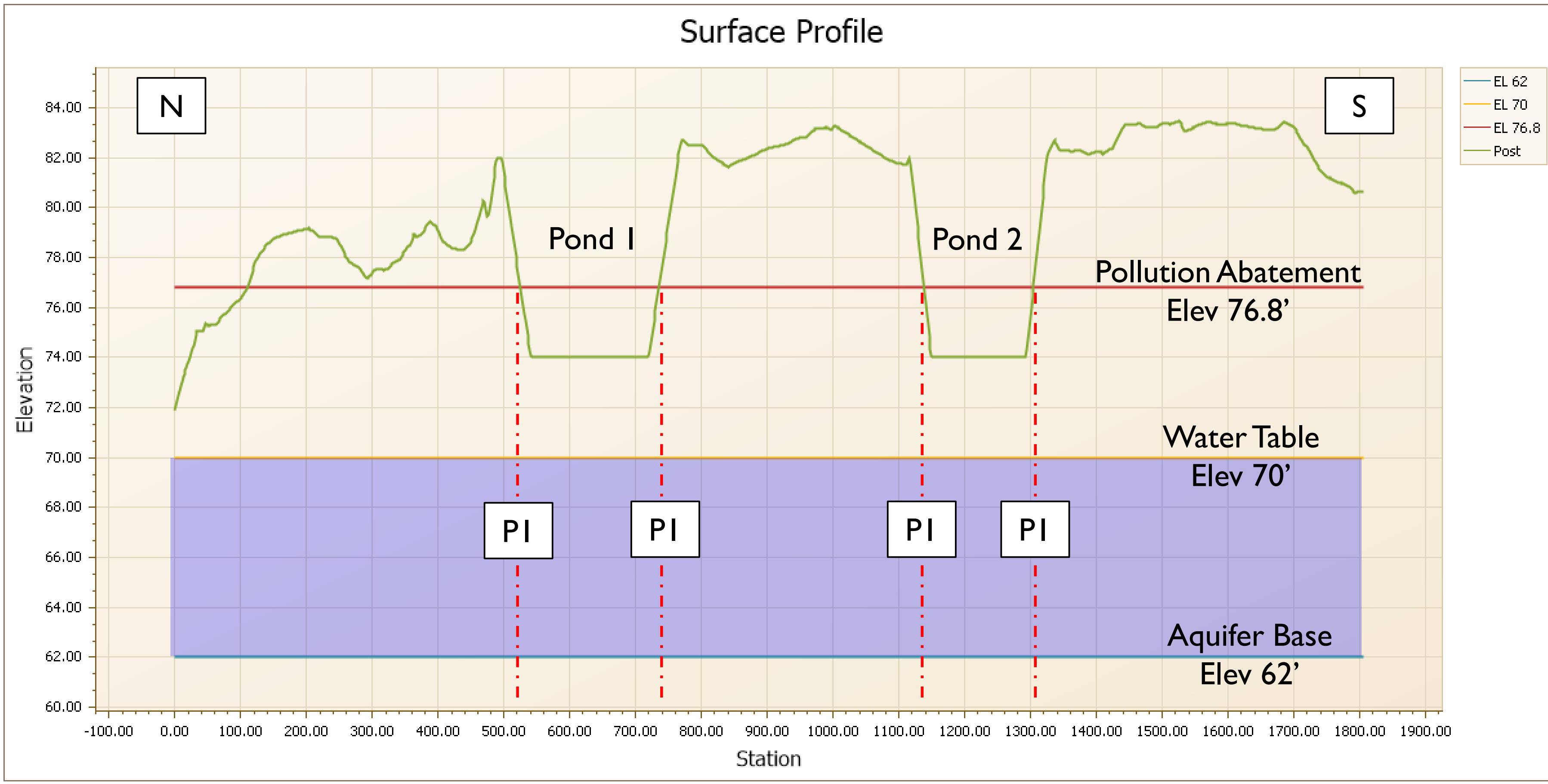
Layout 2 (P3@500')



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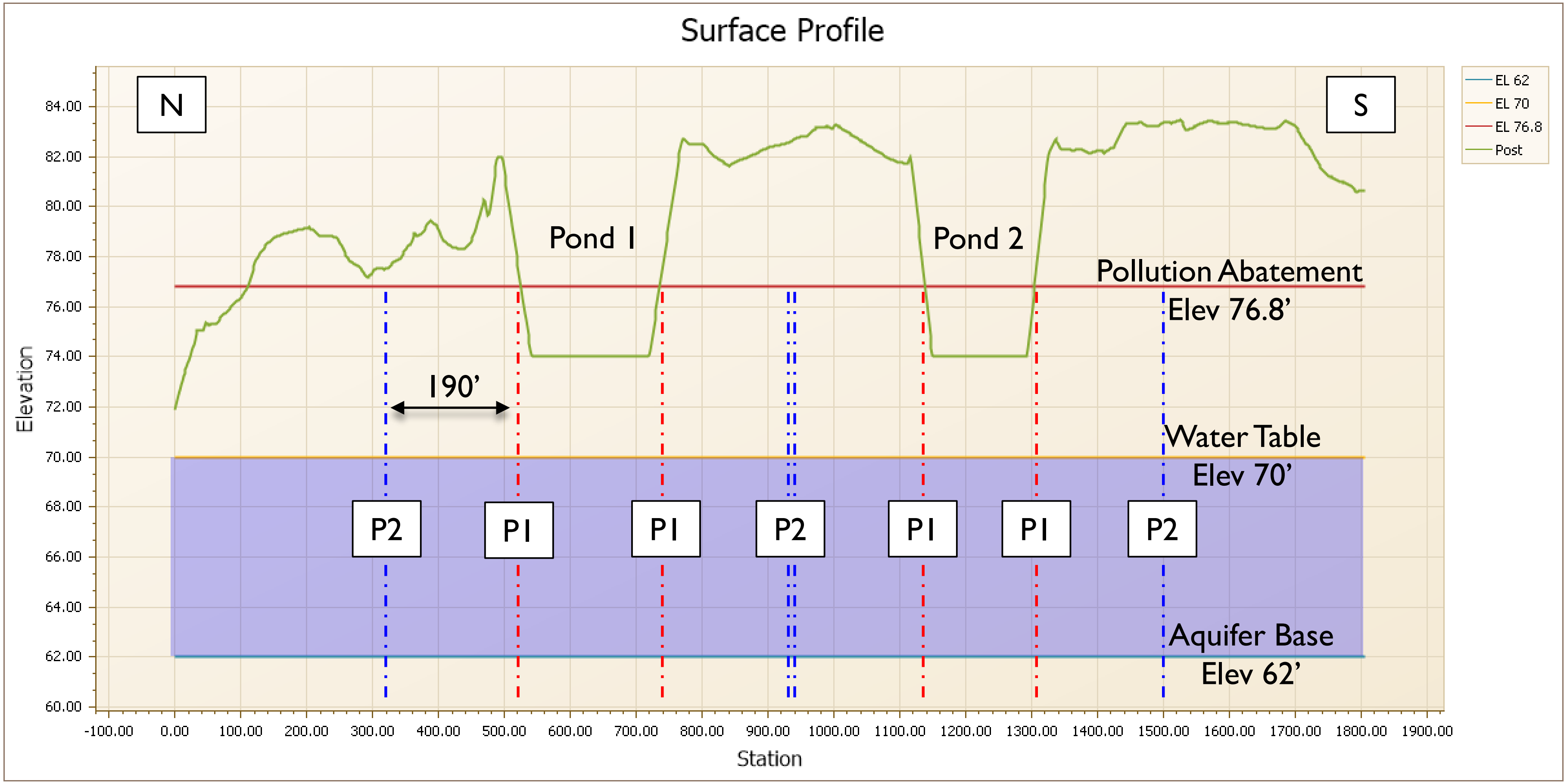
Layout 2 (P3@500')



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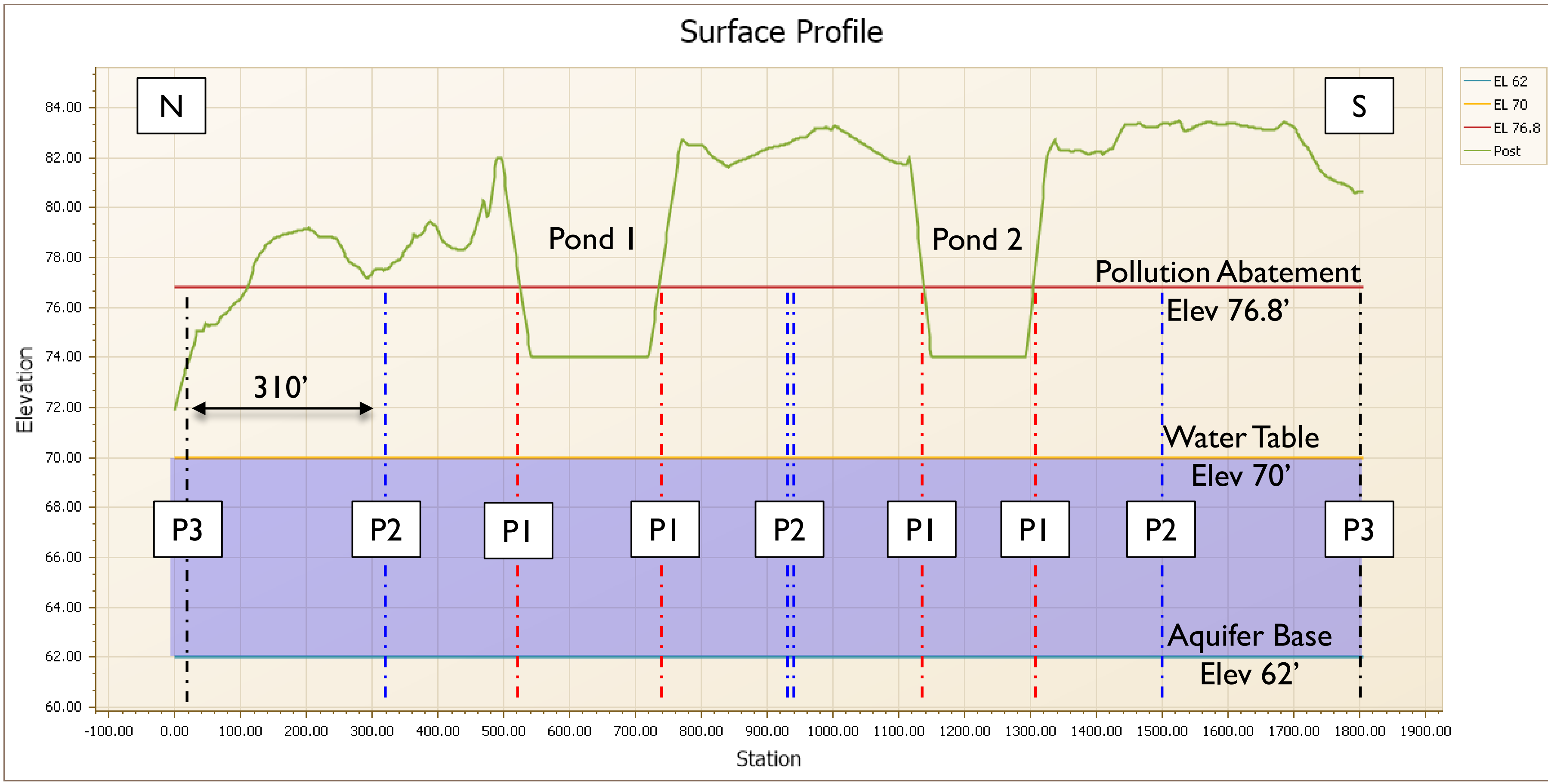
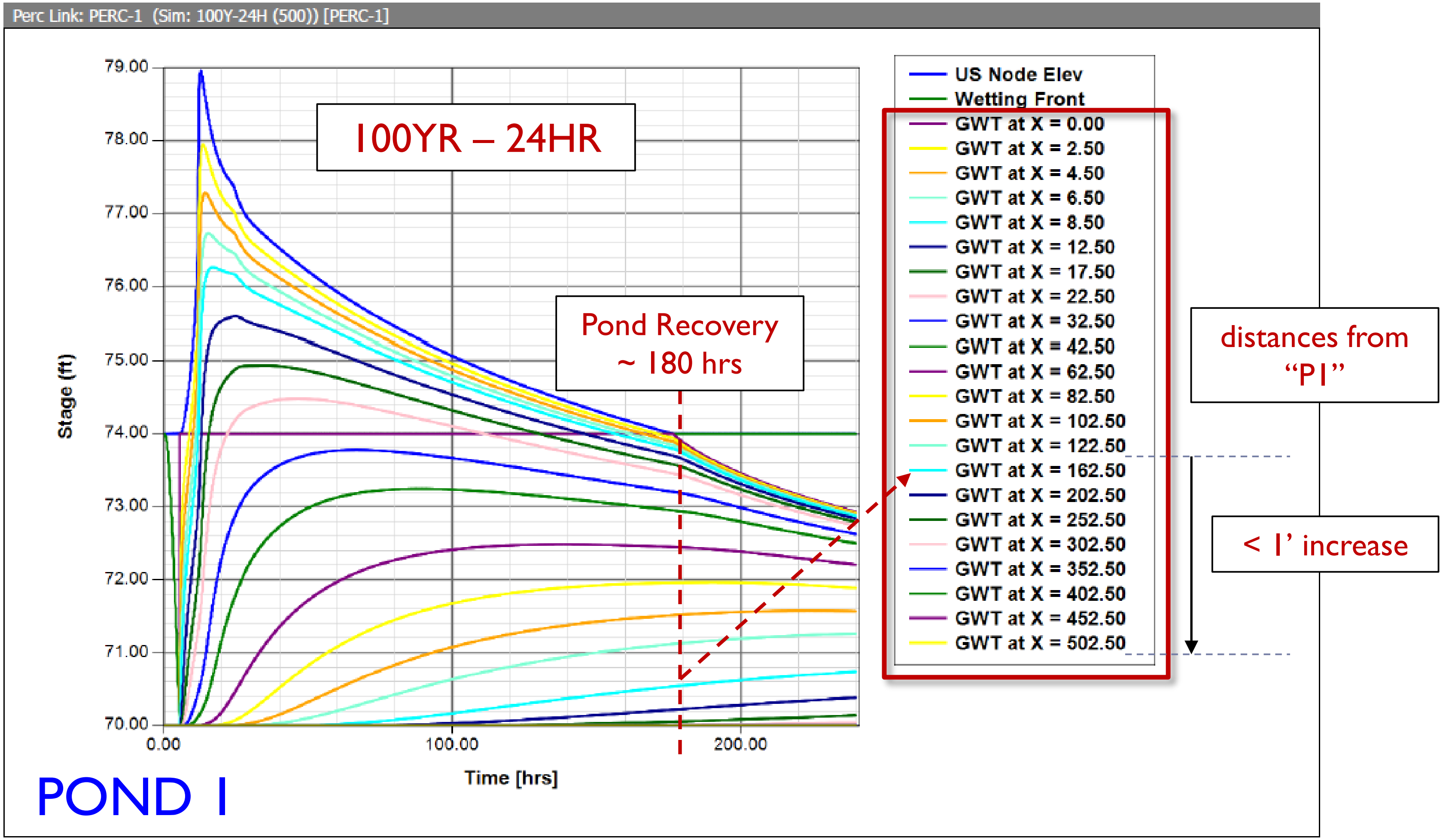
Layout 2 (P3@500')



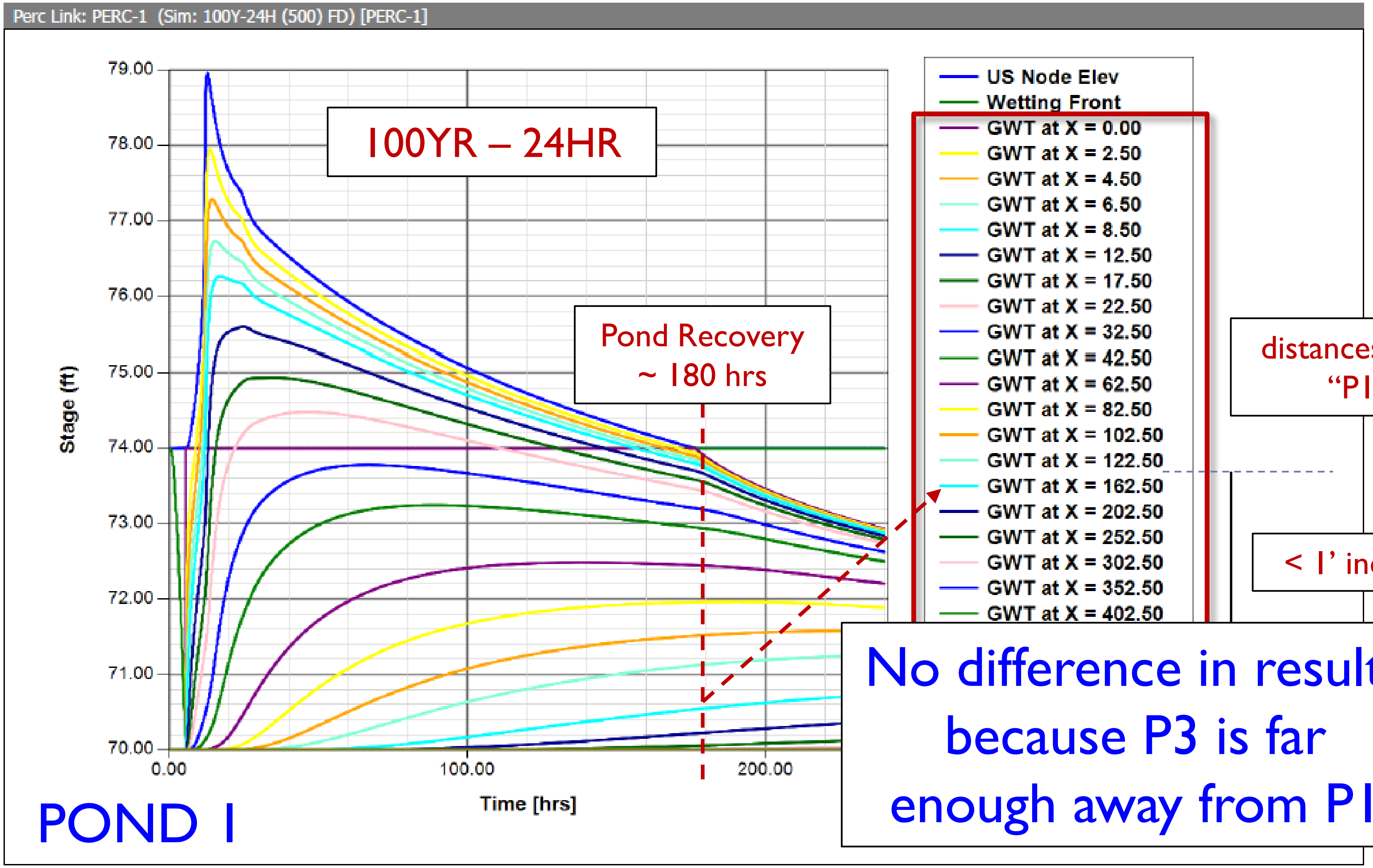
Example #2 – Dual Ponds in Close Proximity

Layout 2 (P3@500') No Flow at P3



Example #2 – Dual Ponds in Close Proximity

Layout 2 (P3@500') P3 = WT Elev



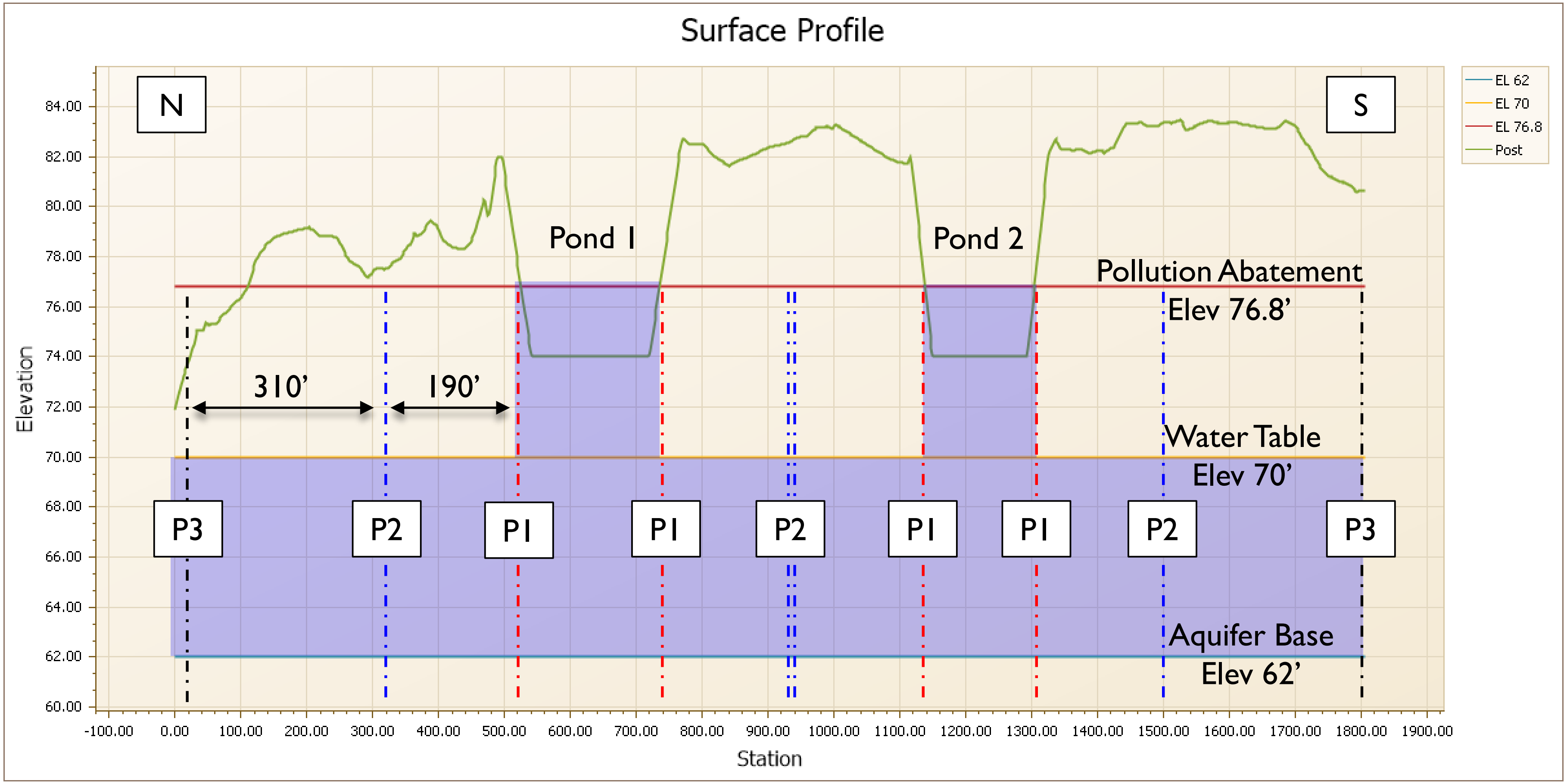
distances from "P1"

< 1' increase

No difference in results because P3 is far enough away from P1

Example #2 – Dual Ponds in Close Proximity

Slug Load Recovery, Layout 2 (P3@500') No Flow at P3



Example #2 – Dual Ponds in Close Proximity

Slug Load Recovery, Layout 2 (P3@500') No Flow at P3

Aquifer Base Elevation	62
Water Table Elevation	70
Annual Recharge Rate	0.0001
Horizontal Conductivity	20
Vertical Conductivity	10
Fillable Porosity	0.25
Layer Thickness	0

Example #2 – Dual Ponds in Close Proximity

Slug Load Recovery, Layout 2 (P3@500') No Flow at P3

Node Data

Name	Scenario	Node Type	Base Flow	Initial Stage	Warning Stage
North_Boundary	Slug Recovery (500)	Time/Stage	0	0	0
Pond 1	Slug Recovery (500)	Stage/Area	0	76.8	80.5
Pond 2	Slug Recovery (500)	Stage/Area	0	76.8	80.5
S-22	Slug Recovery (500)	Stage/Area	0	79	83.5
S-33	Slug Recovery (500)	Stage/Area	0	76.8	81.7
S-35	Slug Recovery (500)	Stage/Area	0	79	83.5
S-37	Slug Recovery (500)	Stage/Area	0	76.8	81.6
S-41	Slug Recovery (500)	Stage/Area	0	78.35	83.5
S-45	Slug Recovery (500)	Stage/Area	0	76.8	82.9
S-48	Slug Recovery (500)	Stage/Area	0	77	82.4
S-50	Slug Recovery (500)	Stage/Area	0	79	83.2
S-52	Slug Recovery (500)	Stage/Area	0	77.5	81.4
S-30	Slug Recovery (500)	Stage/Area	0	78.25	82
S-28	Slug Recovery (500)	Stage/Area	0	77.75	82
S-26	Slug Recovery (500)	Stage/Area	0	77.15	82
S-24	Slug Recovery (500)	Stage/Area	0	76.8	82
S-20	Slug Recovery (500)	Stage/Area	0	76.8	81.7
GWT-1	Slug Recovery (500)	Time/Stage	0	0	0
GWT-2	Slug Recovery (500)	Time/Stage	0	0	0

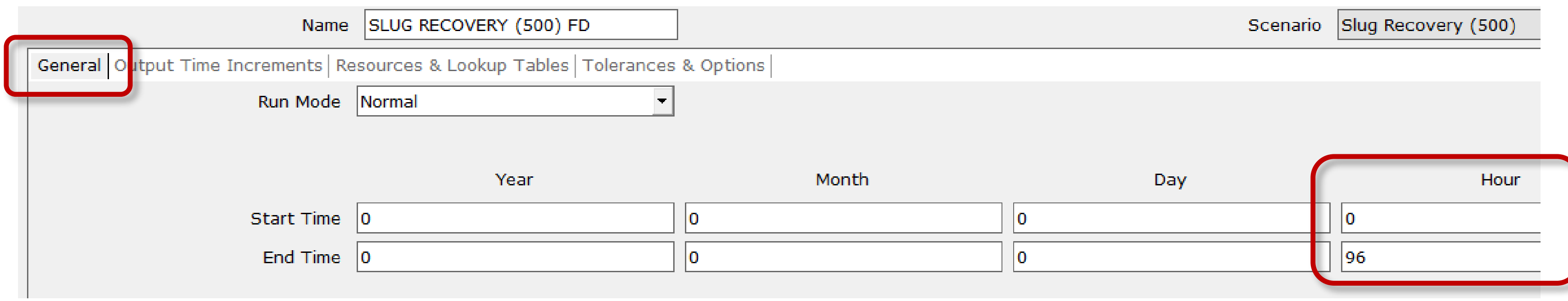
Main | Grid

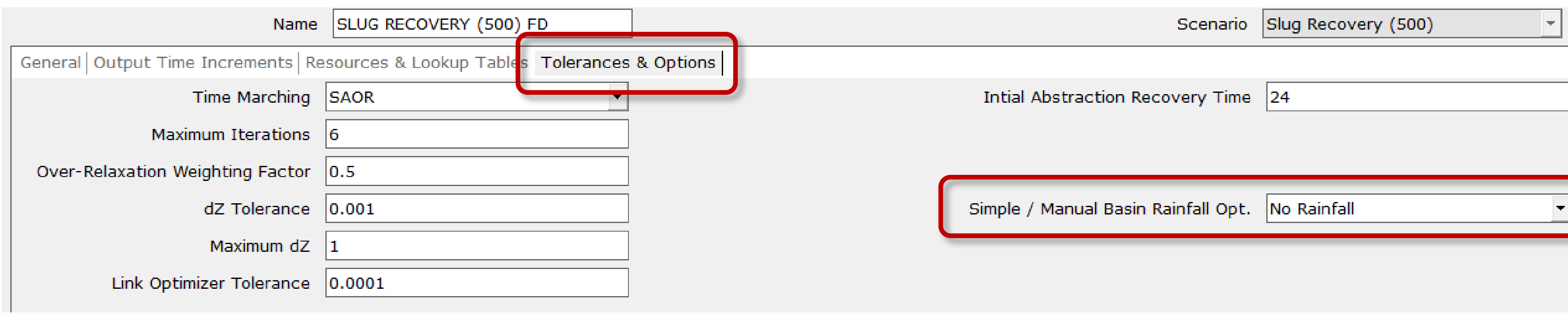
Enter 'Name' | 57 Node(s)

Set initial stages to elevation 76.8' (pollution abatement) or higher, including the storm sewer system

Example #2 – Dual Ponds in Close Proximity

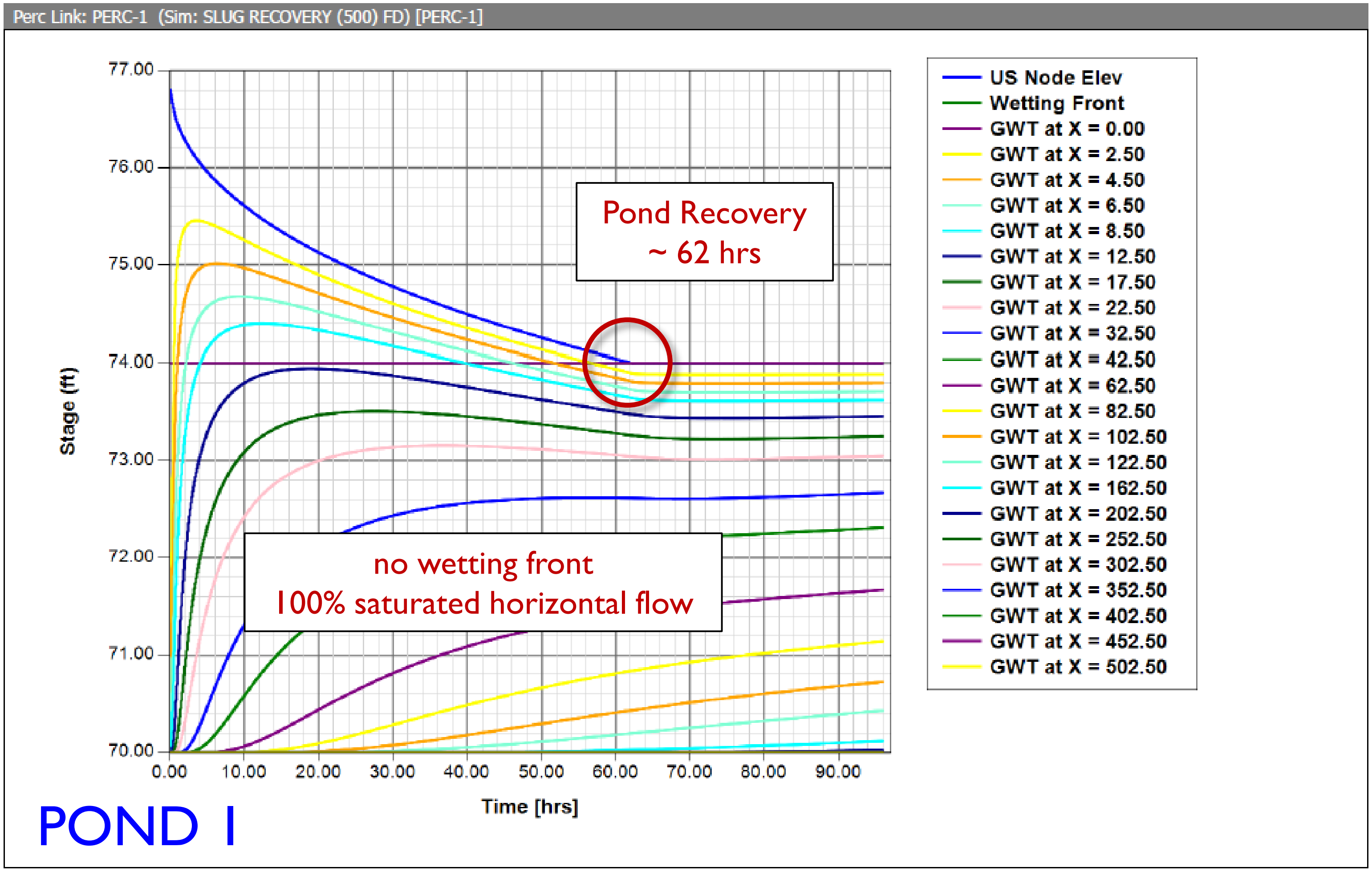
Slug Load Recovery, Layout 2 (P3@500') No Flow at P3





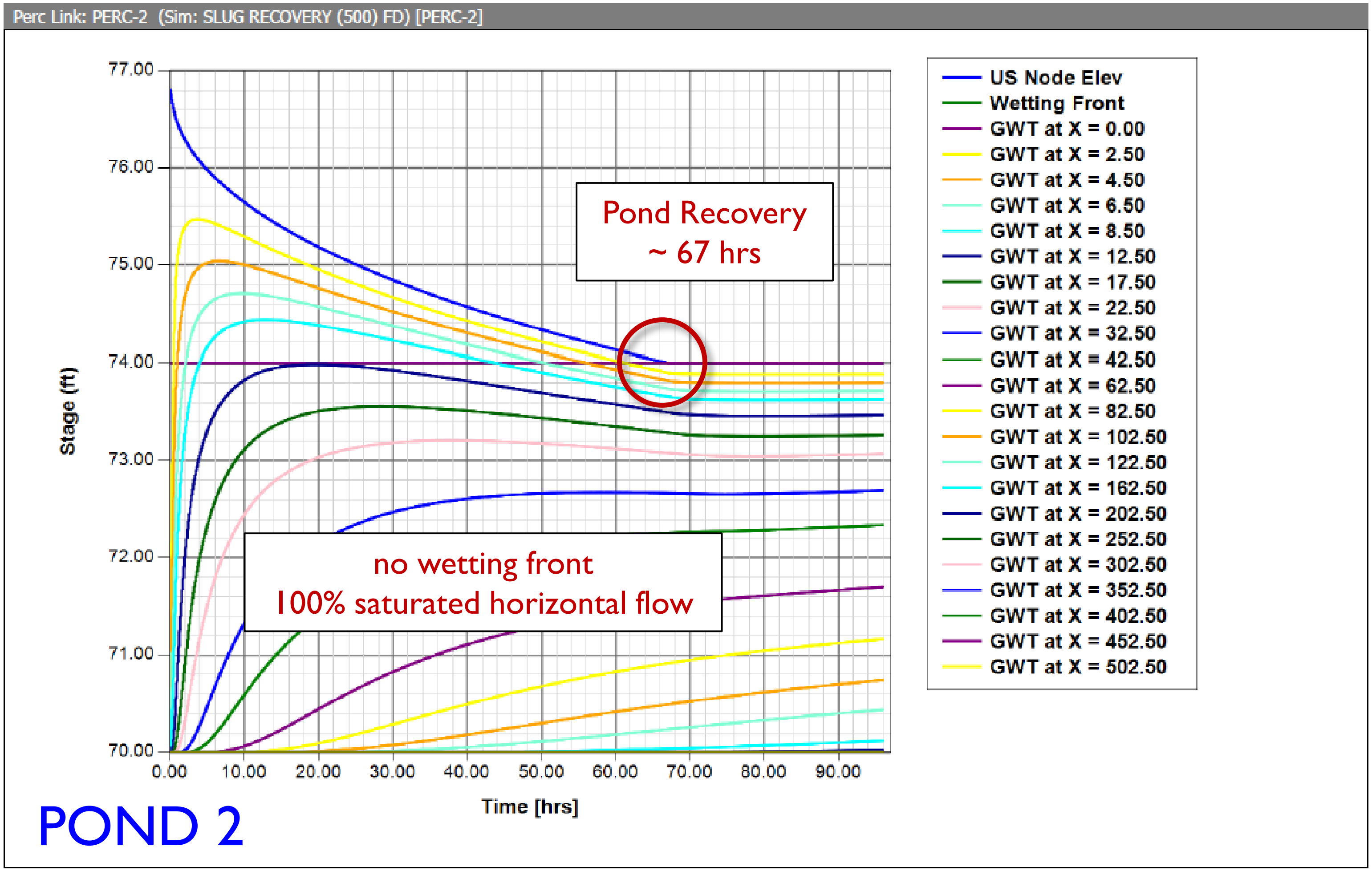
Example #2 – Dual Ponds in Close Proximity

Slug Load Recovery, Layout 2 (P3@500') No Flow at P3



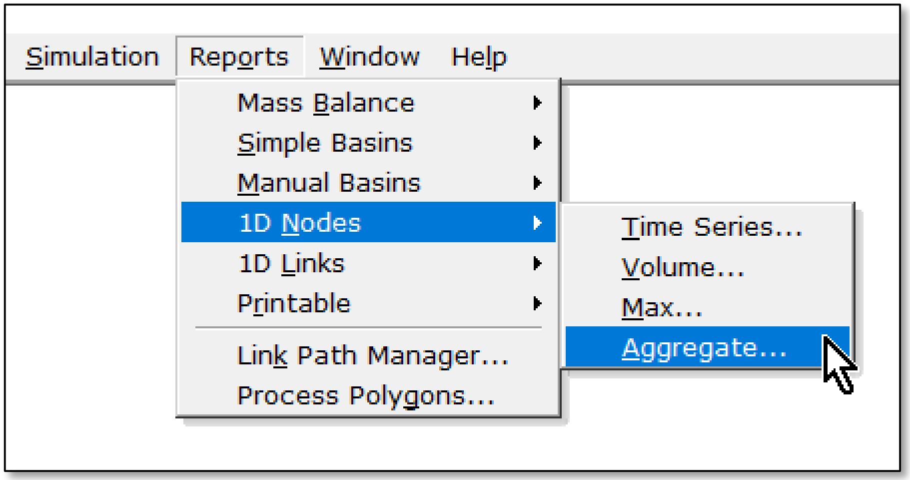
Example #2 – Dual Ponds in Close Proximity

Slug Load Recovery, Layout 2 (P3@500') No Flow at P3

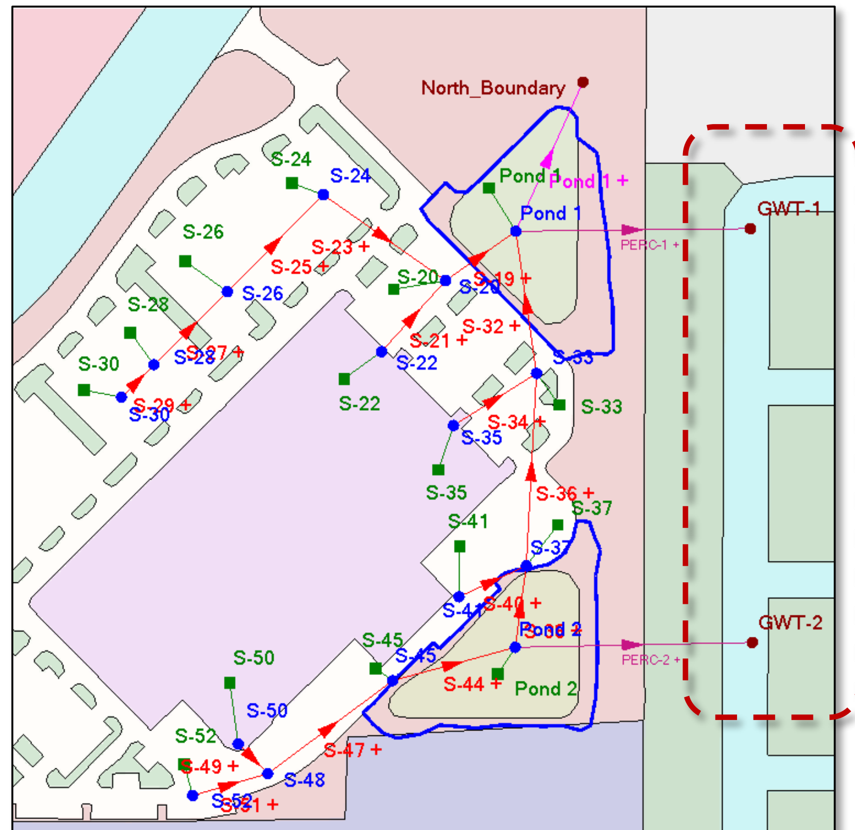


Example #2 – Dual Ponds in Close Proximity

Slug Load Recovery, Layout 2 (P3@500') No Flow at P3

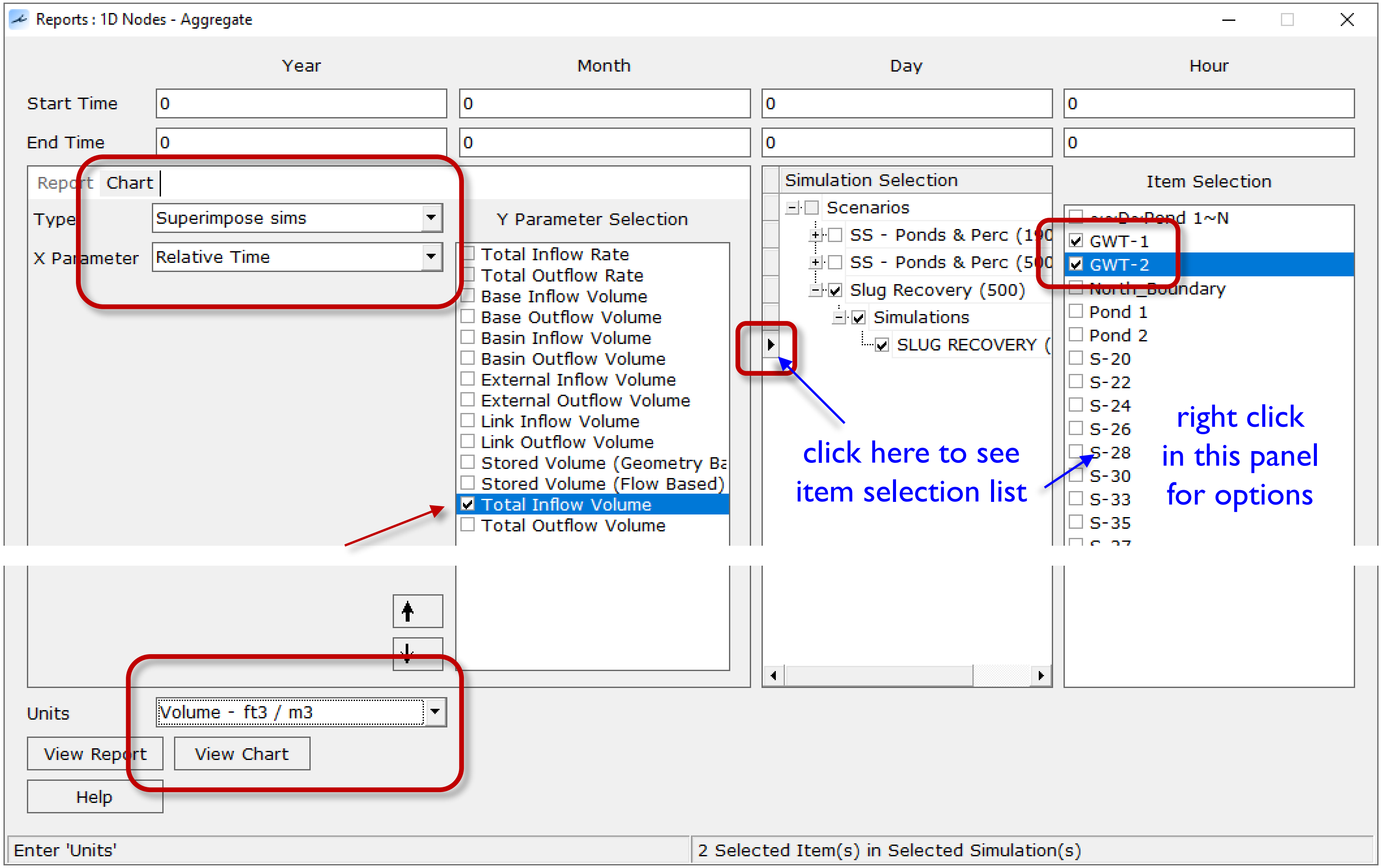


"Aggregate" to add node volumes



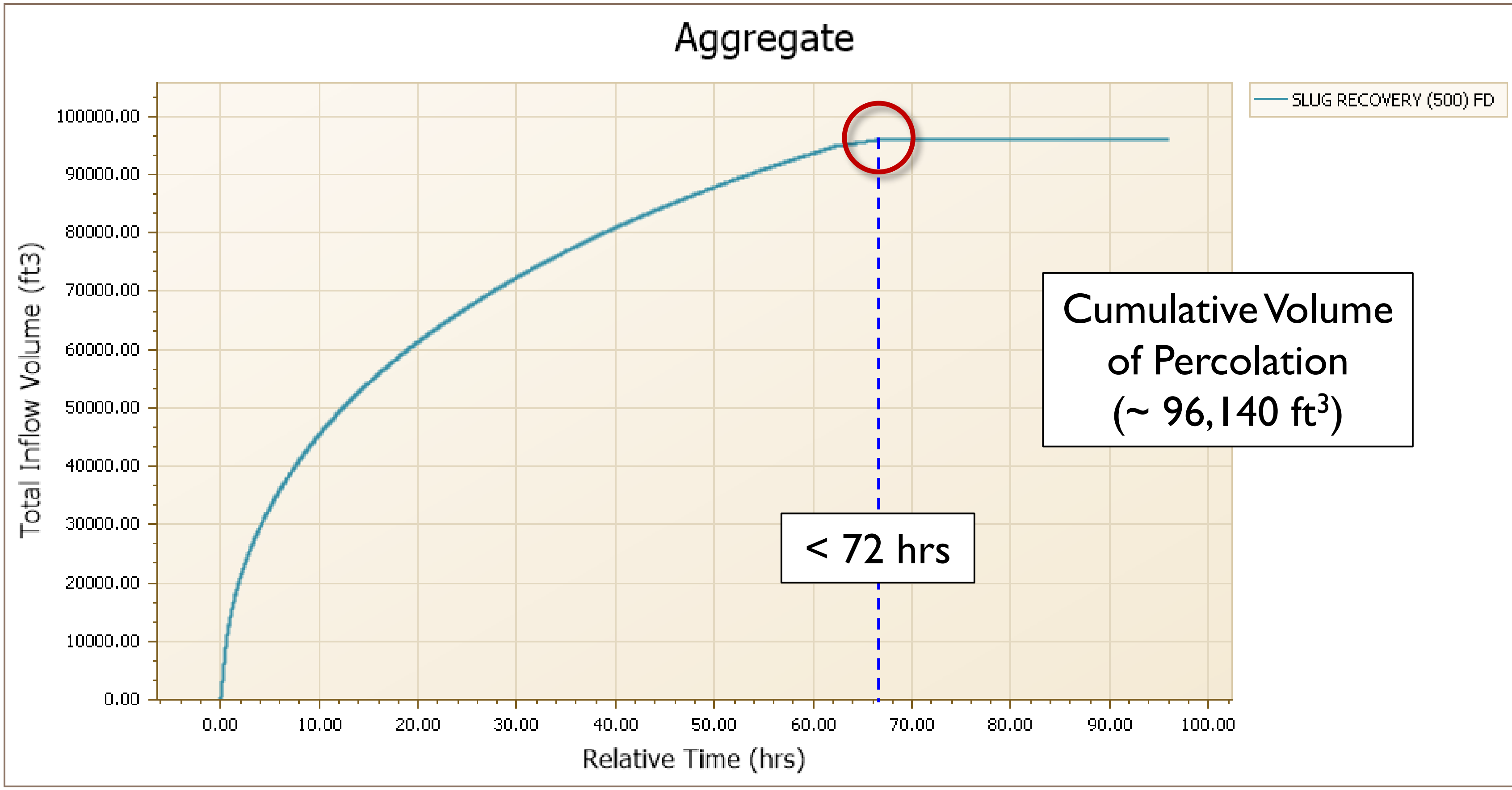
Example #2 – Dual Ponds in Close Proximity

Slug Load Recovery, Layout 2 (P3@500') No Flow at P3



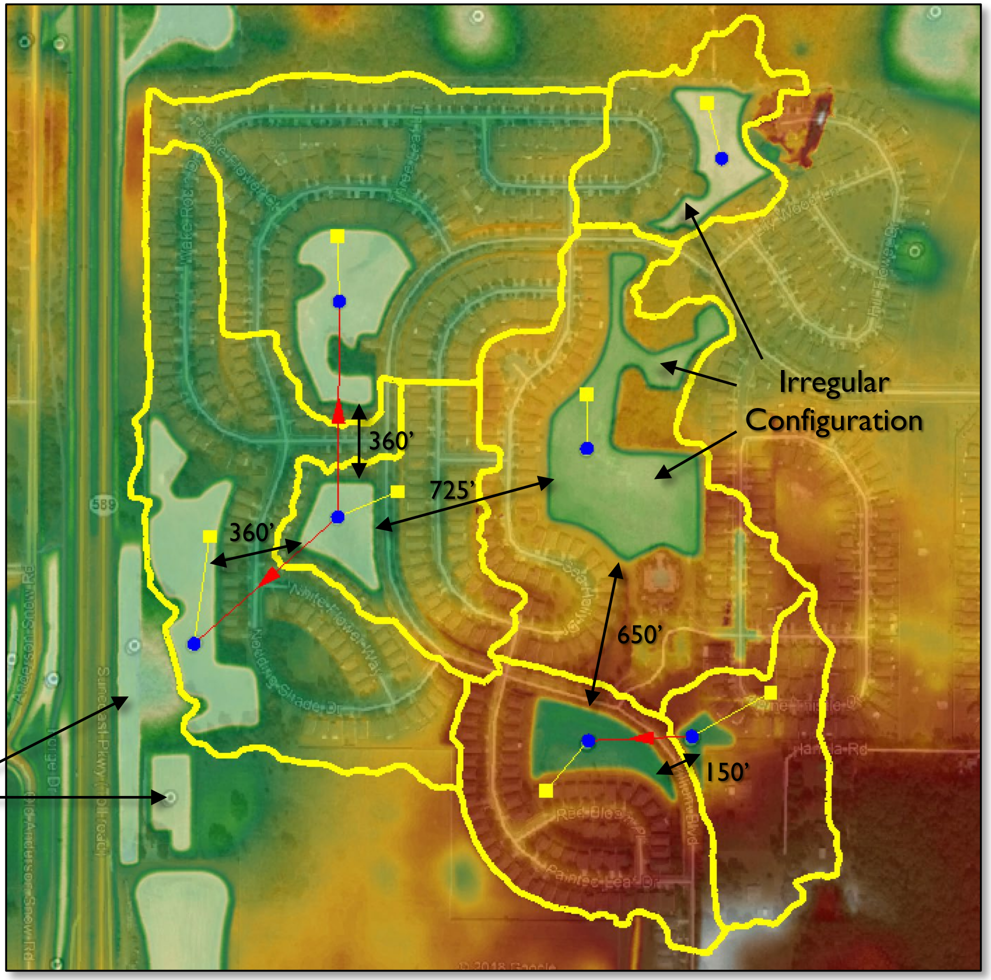
Example #2 – Dual Ponds in Close Proximity

Slug Load Recovery, Layout 2 (P3@500') No Flow at P3



Example #3 – Multiple Land-Locked Ponds

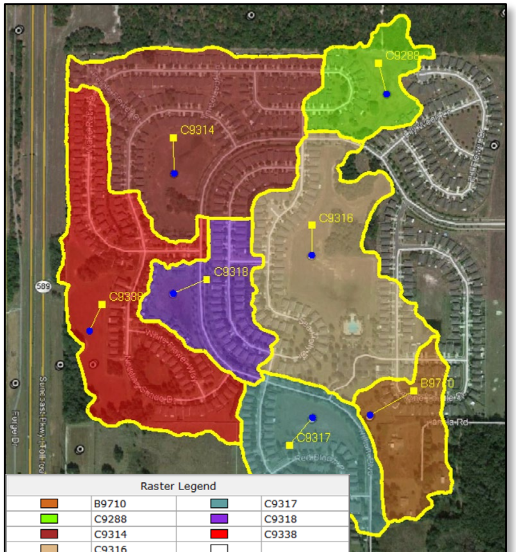
Dry Ponds in Close Proximity



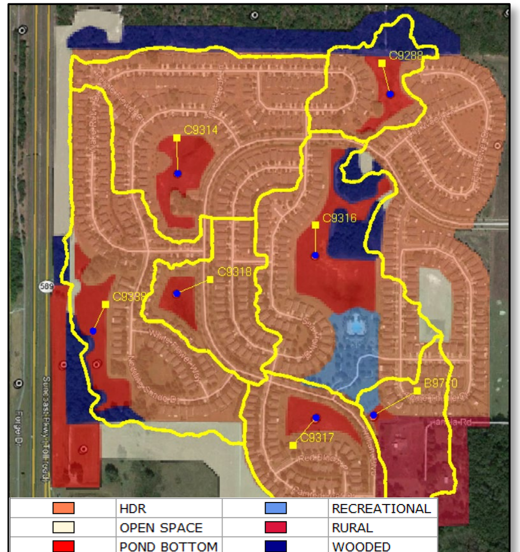
other ponds in close proximity

Example #3 – Multiple Land-Locked Ponds

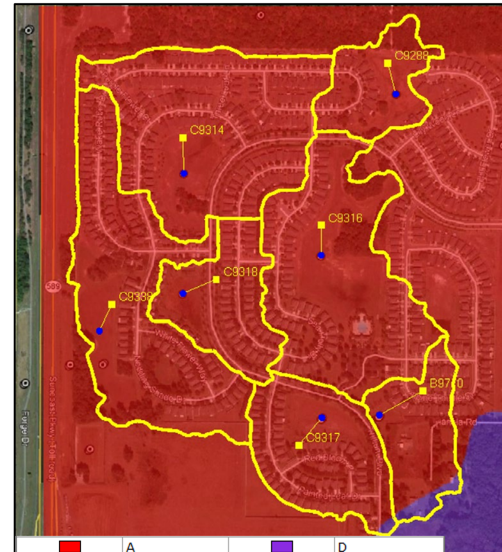
Dry Ponds in Close Proximity



Basins



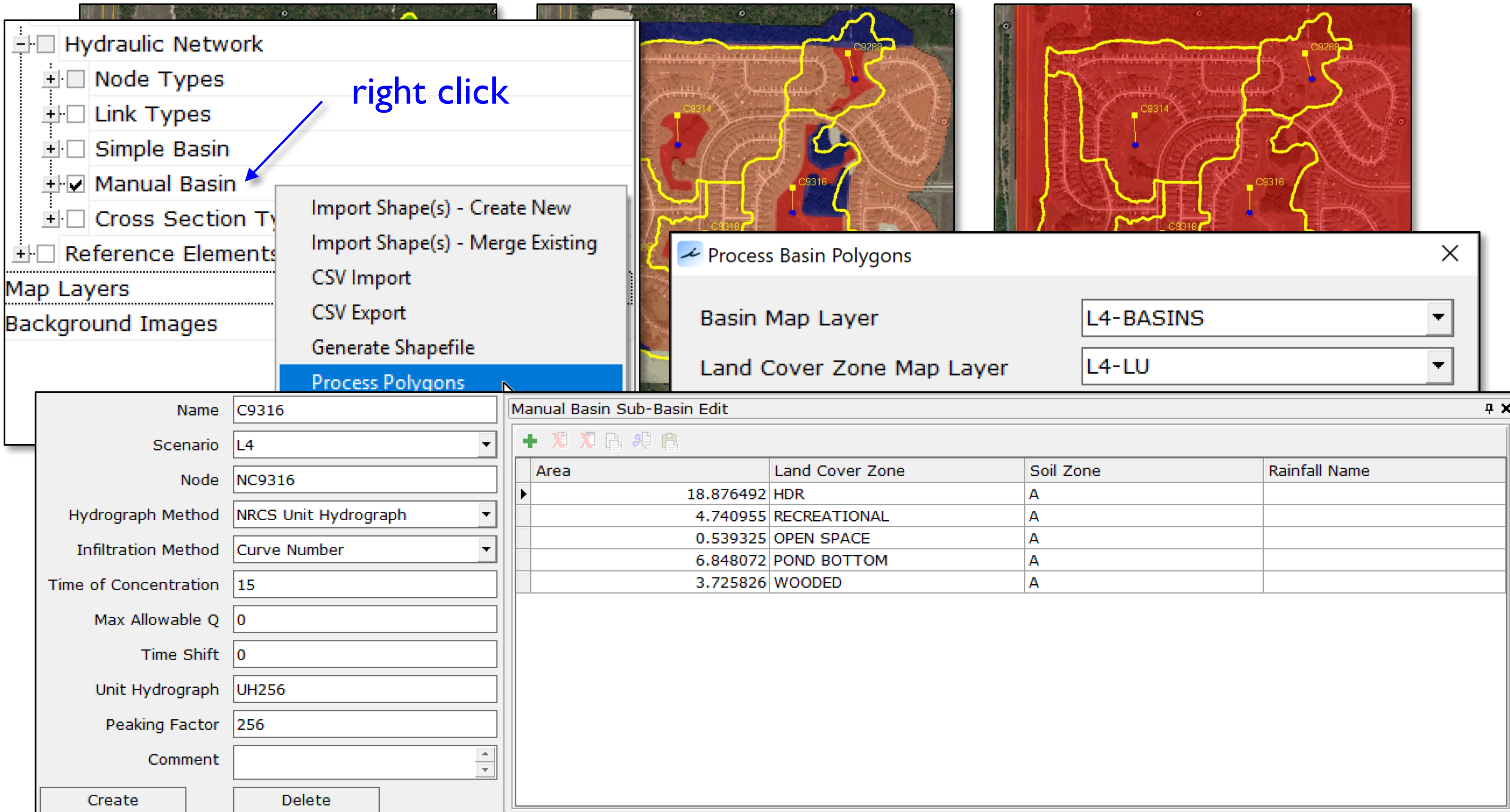
Land Use



Soil Hydrologic Group

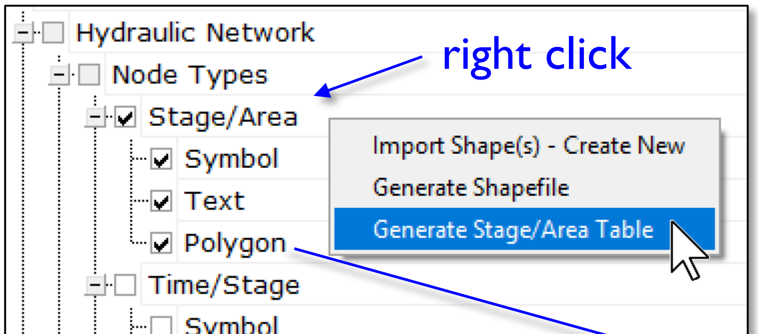
Example #3 – Multiple Land-Locked Ponds

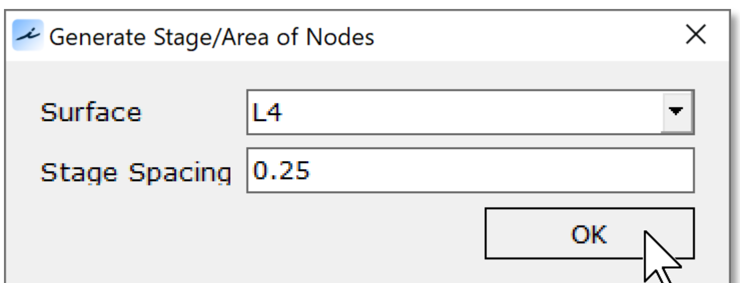
Dry Ponds in Close Proximity

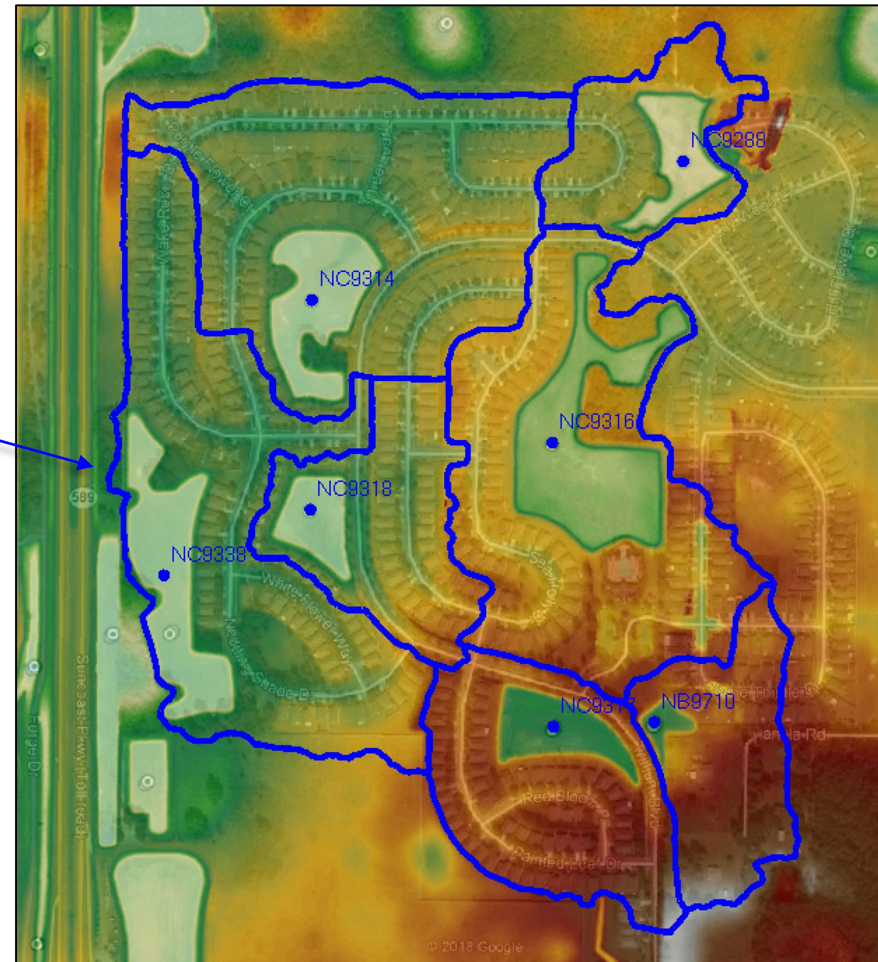


Example #3 – Multiple Land-Locked Ponds

Dry Ponds in Close Proximity

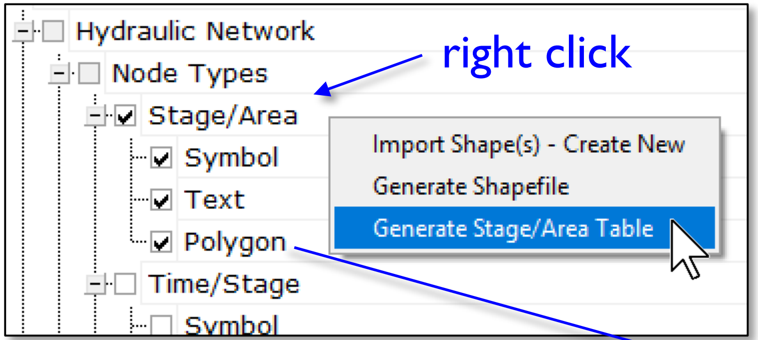


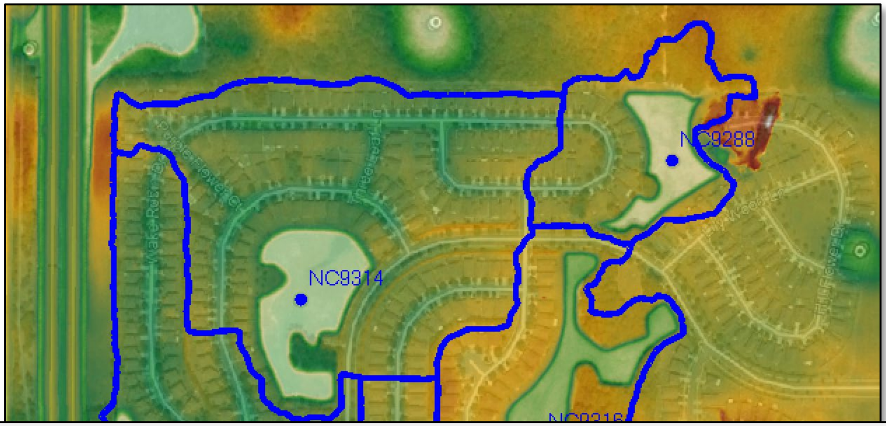


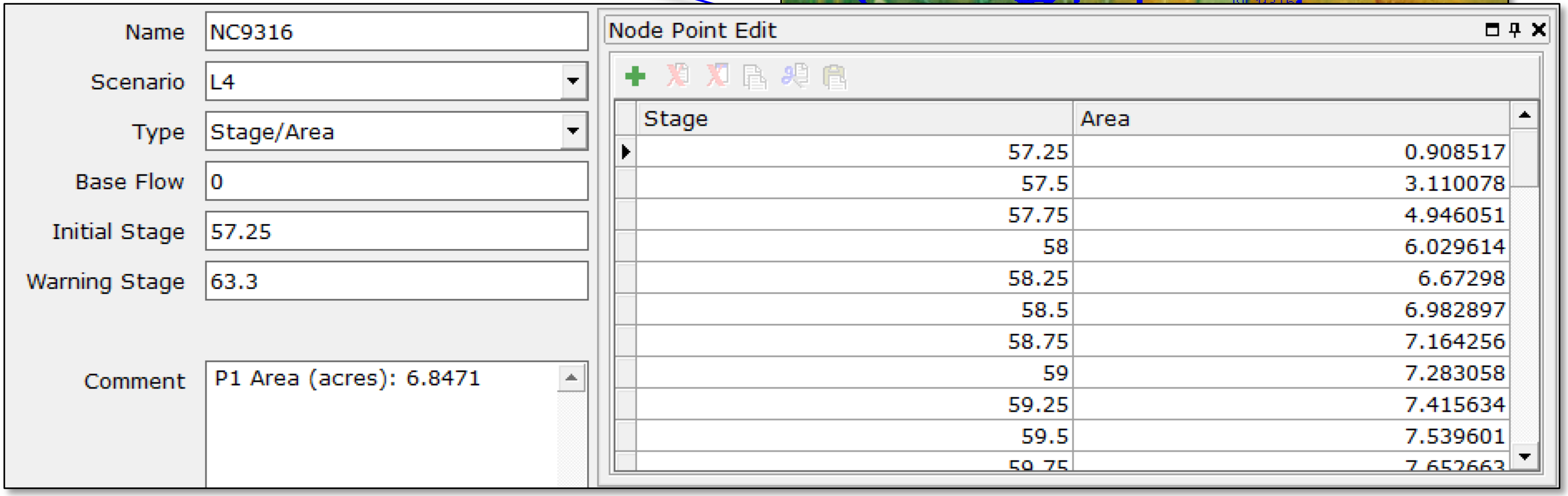


Example #3 – Multiple Land-Locked Ponds

Dry Ponds in Close Proximity



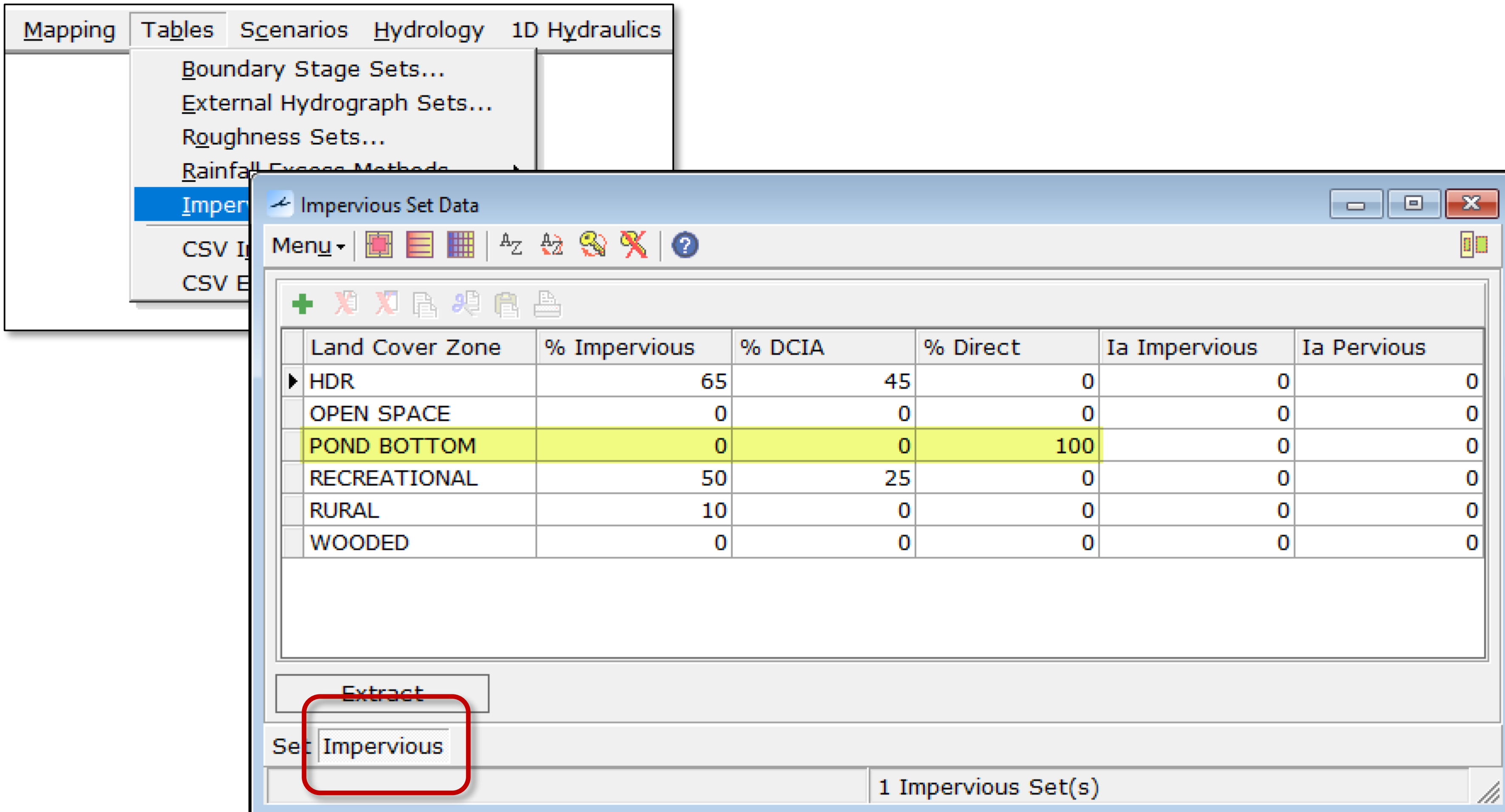




Stage	Area
57.25	0.908517
57.5	3.110078
57.75	4.946051
58	6.029614
58.25	6.67298
58.5	6.982897
58.75	7.164256
59	7.283058
59.25	7.415634
59.5	7.539601

Example #3 – Multiple Land-Locked Ponds

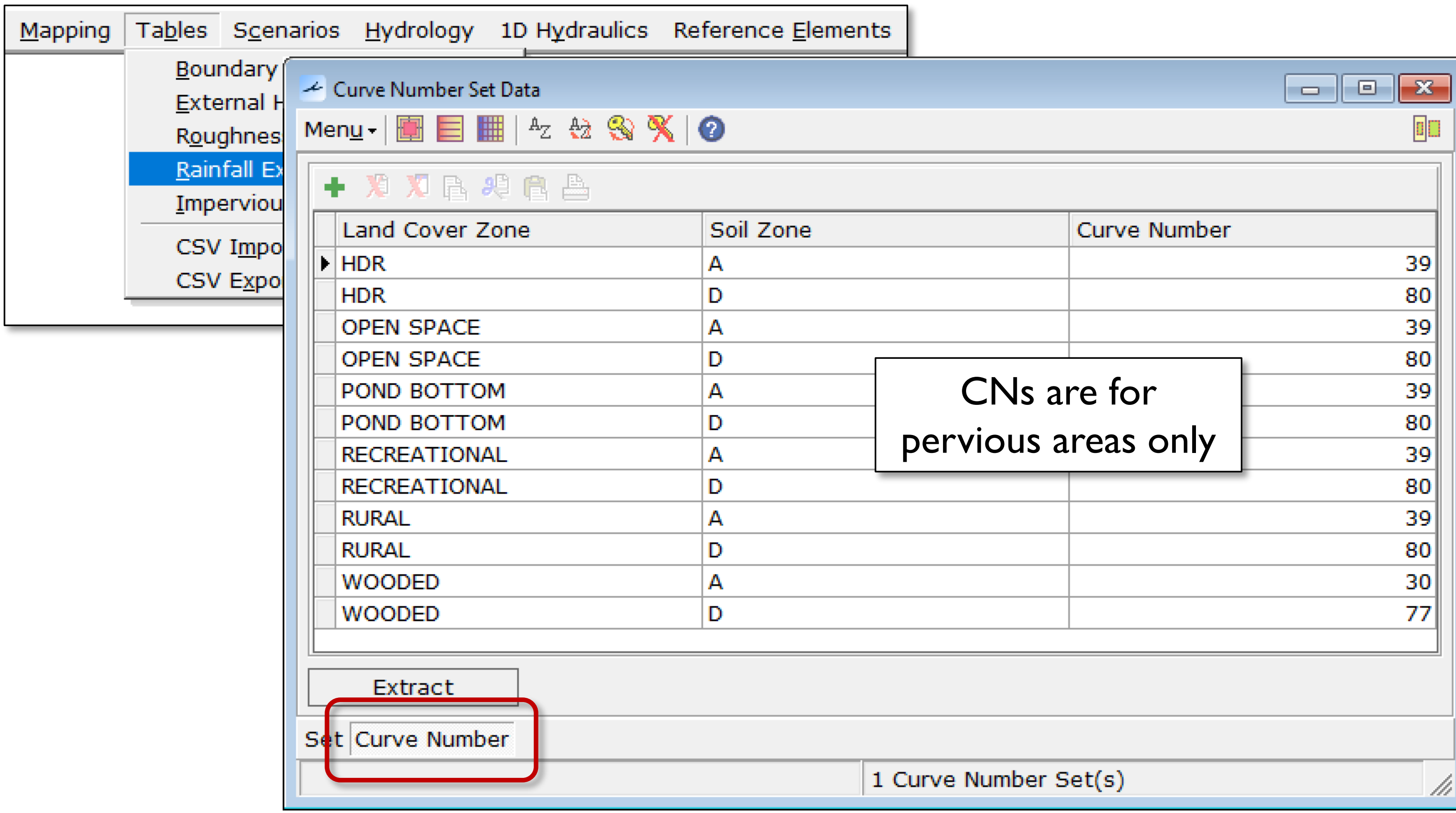
Dry Ponds in Close Proximity



Land Cover Zone	% Impervious	% DCIA	% Direct	Ia Impervious	Ia Pervious
HDR	65	45	0	0	0
OPEN SPACE	0	0	0	0	0
POND BOTTOM	0	0	100	0	0
RECREATIONAL	50	25	0	0	0
RURAL	10	0	0	0	0
WOODED	0	0	0	0	0

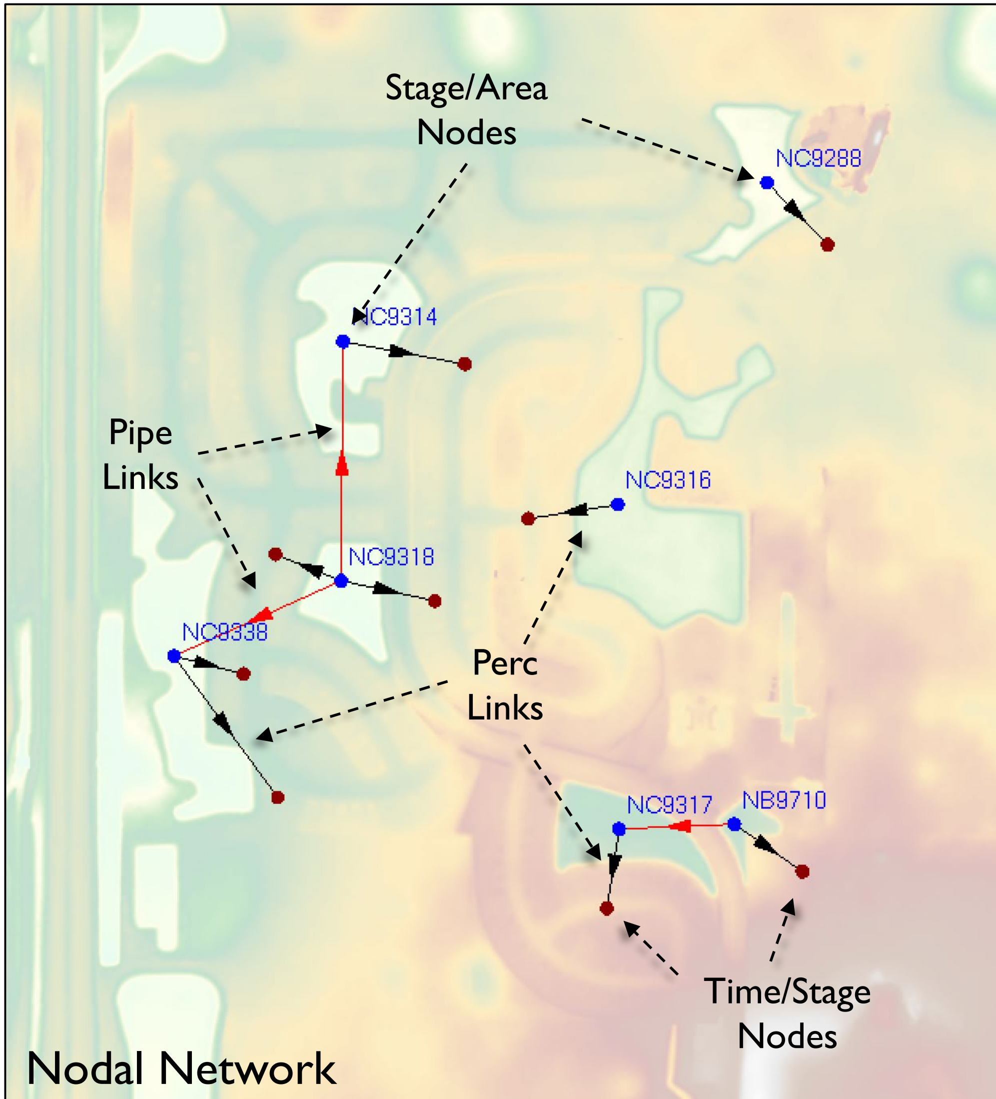
Example #3 – Multiple Land-Locked Ponds

Dry Ponds in Close Proximity



Land Cover Zone	Soil Zone	Curve Number
HDR	A	39
HDR	D	80
OPEN SPACE	A	39
OPEN SPACE	D	80
POND BOTTOM	A	39
POND BOTTOM	D	80
RECREATIONAL	A	39
RECREATIONAL	D	80
RURAL	A	39
RURAL	D	80
WOODED	A	30
WOODED	D	77

Example #3 – Multiple Land-Locked Ponds



Example #3 – Multiple Land-Locked Ponds

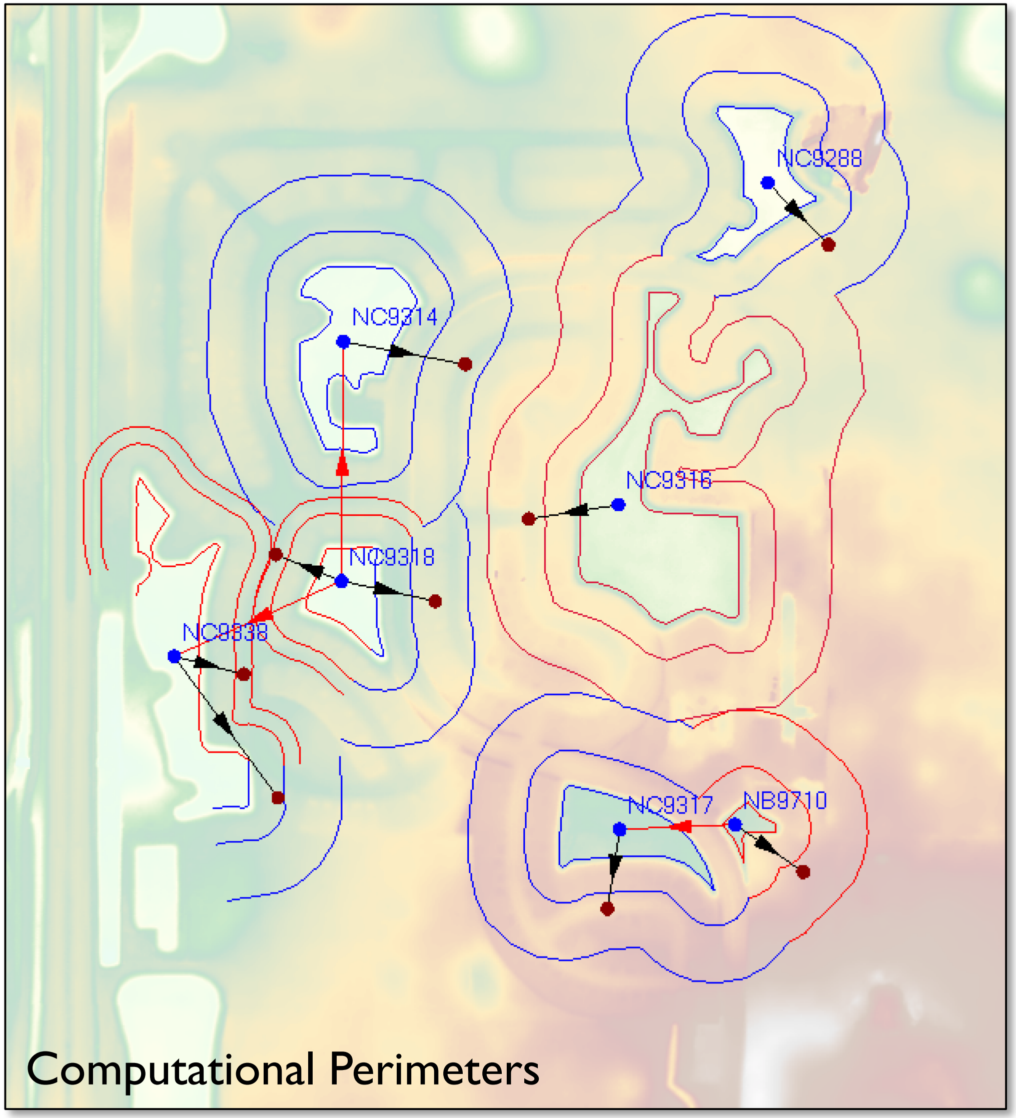
Typical Aquifer Parameters

Aquifer Base Elevation	24.5
Water Table Elevation	48.3
Annual Recharge Rate	0.0001
Horizontal Conductivity	18.7
Vertical Conductivity	12.5
Fillable Porosity	0.2
Layer Thickness	5.2

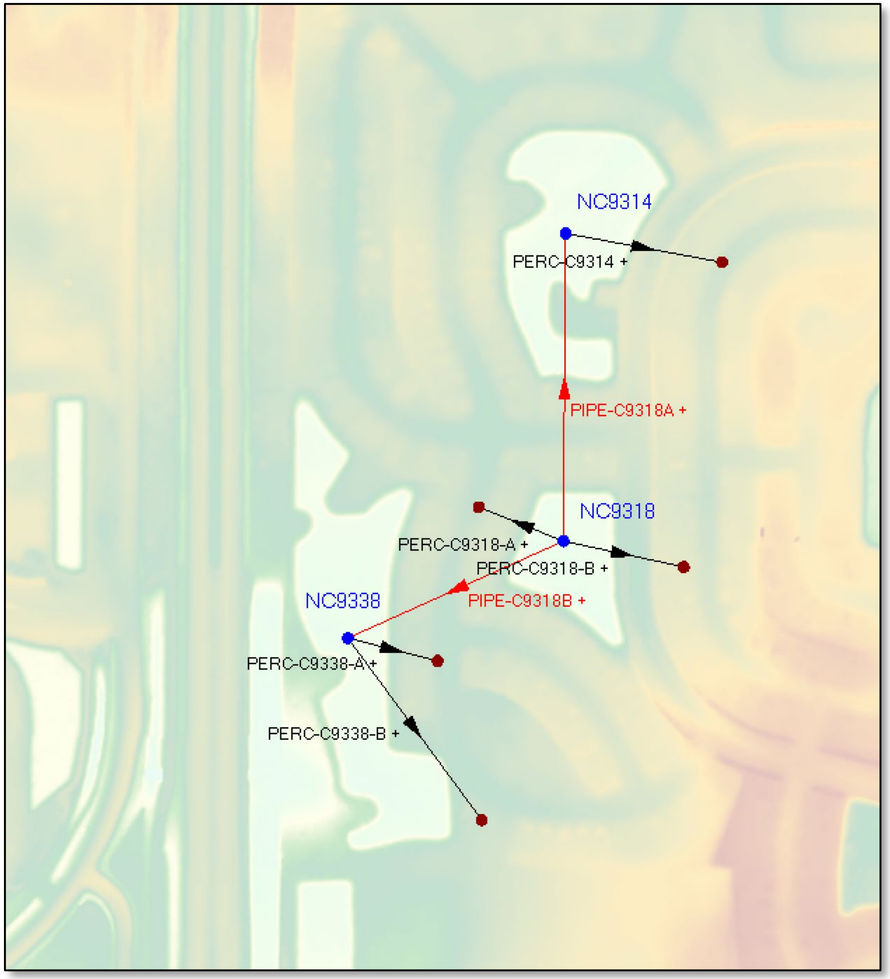
This setting creates a "no flow" boundary condition at perimeter P3, a typical setting for ponds in close proximity to other ponds.

all parameters except "Annual Recharge Rate" vary for each perc link

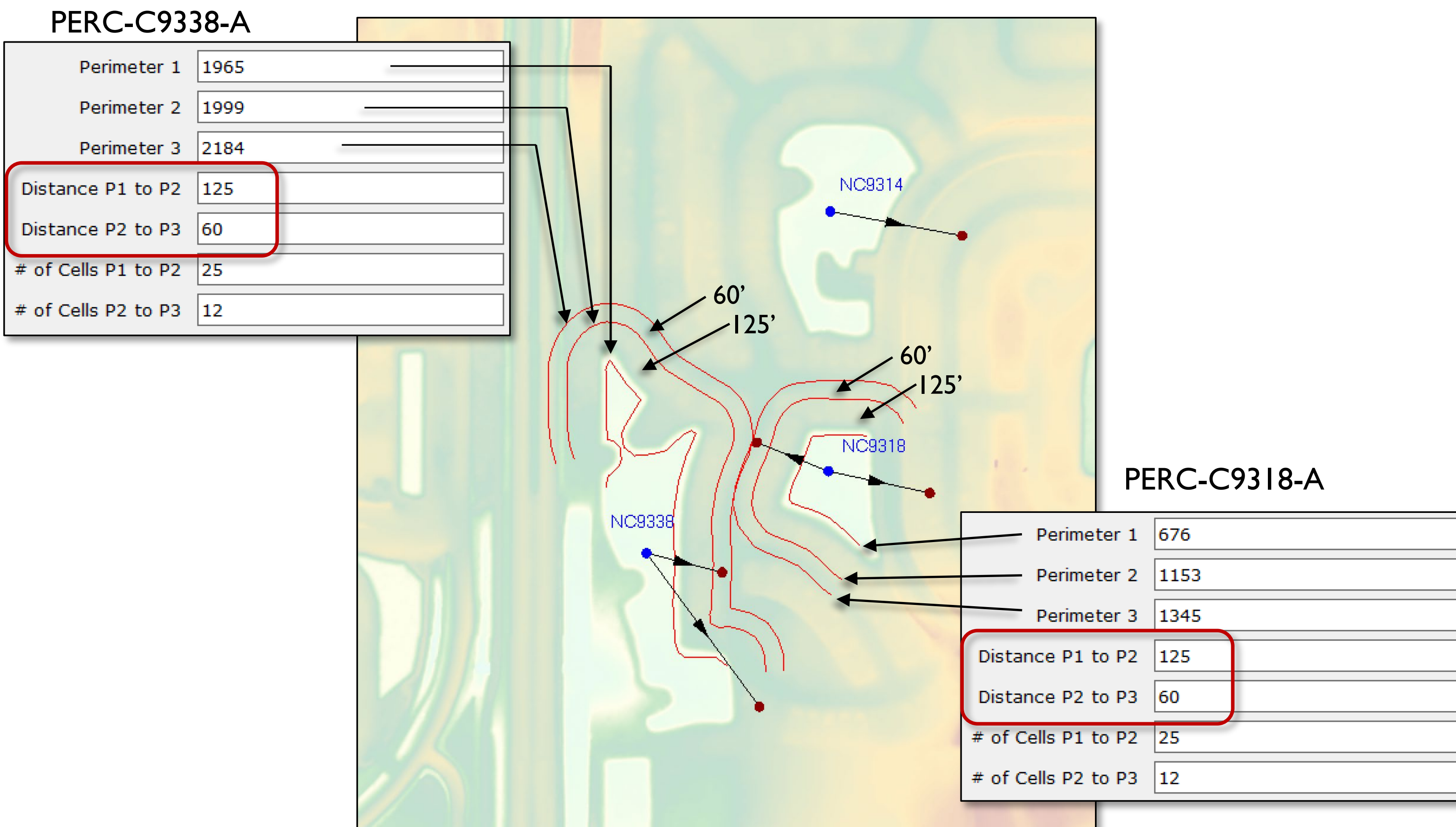
Example #3 – Multiple Land-Locked Ponds



Example #3 – Multiple Land-Locked Ponds



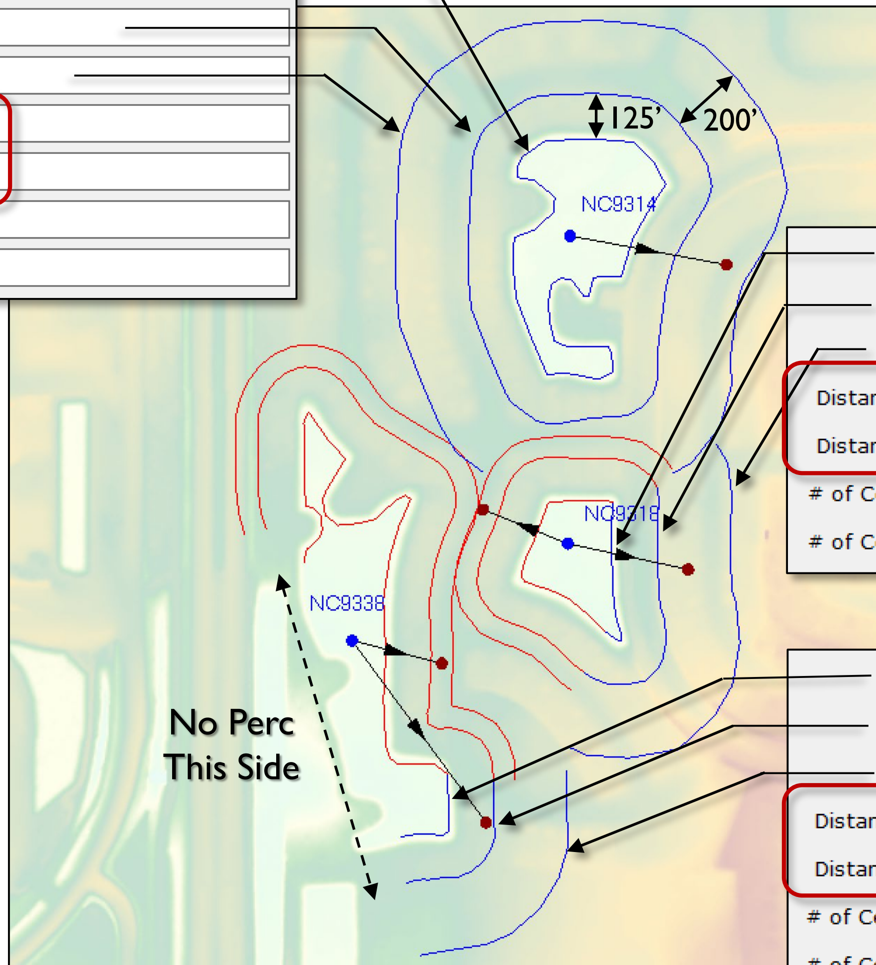
Example #3 – Multiple Land-Locked Ponds



Example #3 – Multiple Land-Locked Ponds

PERC-C9314

Perimeter 1	2321
Perimeter 2	2601
Perimeter 3	3322
Distance P1 to P2	125
Distance P2 to P3	200
# of Cells P1 to P2	25
# of Cells P2 to P3	40



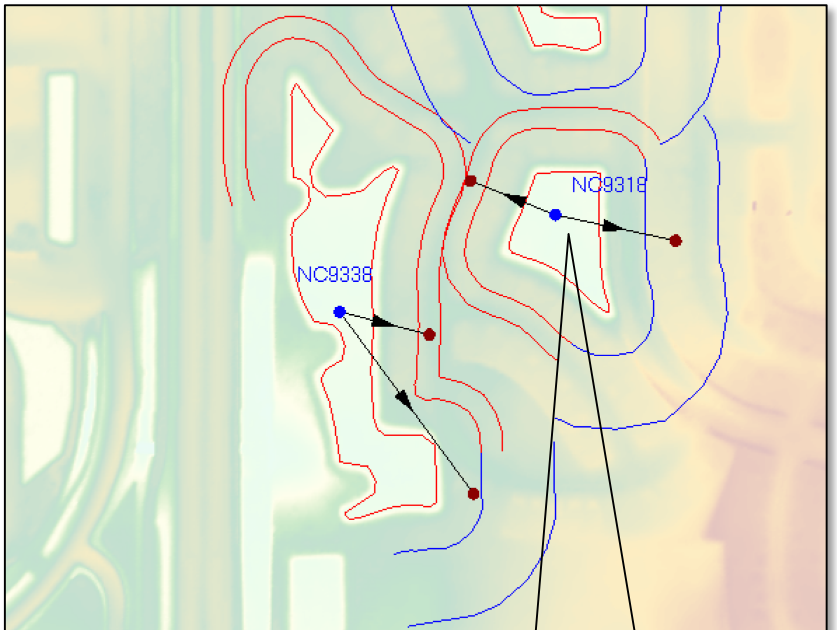
PERC-C9318-B

Perimeter 1	432
Perimeter 2	731
Perimeter 3	1225
Distance P1 to P2	125
Distance P2 to P3	200
# of Cells P1 to P2	25
# of Cells P2 to P3	40

PERC-C9338-B

Perimeter 1	291
Perimeter 2	457
Perimeter 3	763
Distance P1 to P2	125
Distance P2 to P3	200
# of Cells P1 to P2	25
# of Cells P2 to P3	40

Example #3 – Multiple Land-Locked Ponds



PI = 1,108 ft

PI_{area} = 1.45ac

PERC-C9318-A

Surface Area Option	User Specified
Bottom Elevation	53.75
Surface Area	0.88
Vertical Flow Termination	Horizontal Flow Algorithm
Perimeter 1	676

$PI\text{-}A_{area} = PI_{area} \times (PI\text{-}A / PI)$

$= 1.45 \times (676 / 1,108) \quad = 0.88 \text{ ac}$

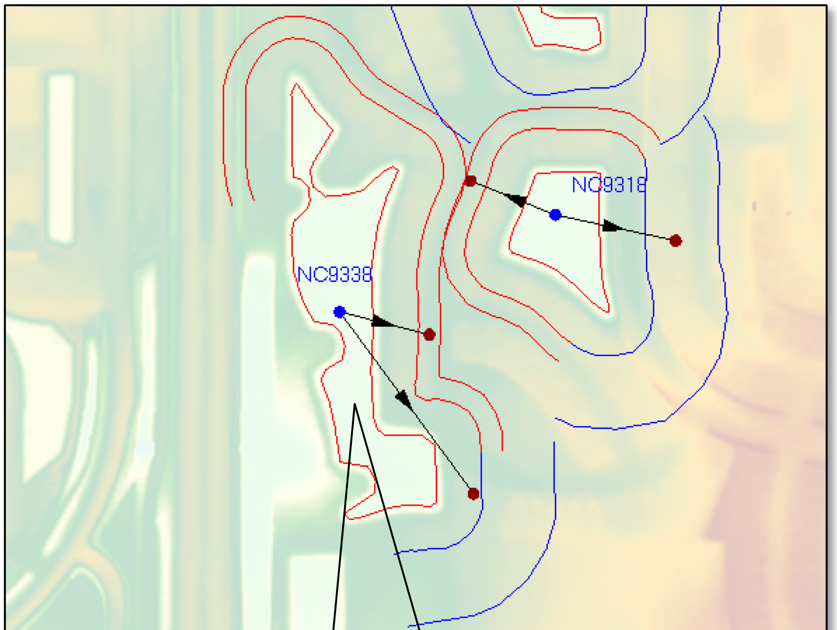
$PI\text{-}B_{area} = PI_{area} \times (PI\text{-}B / PI)$

$= 1.45 \times (432 / 1,108) \quad = 0.57 \text{ ac}$

Surface Area Option	User Specified
Bottom Elevation	53.75
Surface Area	0.57
Vertical Flow Termination	Horizontal Flow Algorithm
Perimeter 1	432

PERC-C9318-B

Example #3 – Multiple Land-Locked Ponds



PI = 2,256 ft
PI_{area} = 3.98 ac

PERC-C9338-A

Surface Area Option	User Specified
Bottom Elevation	53.5
Surface Area	3.47
Vertical Flow Termination	Horizontal Flow Algorithm
Perimeter 1	1965

$PI\text{-}A_{area} = PI_{area} \times (PI\text{-}A / PI)$
$= 3.98 \times (1{,}965 / 2{,}256) = 3.47$ ac

$PI\text{-}B_{area} = PI_{area} \times (PI\text{-}B / PI)$
$= 3.98 \times (291 / 2{,}256) = 0.51$ ac

Surface Area Option	User Specified
Bottom Elevation	53.5
Surface Area	0.51
Vertical Flow Termination	Horizontal Flow Algorithm
Perimeter 1	291

PERC-C9338-B

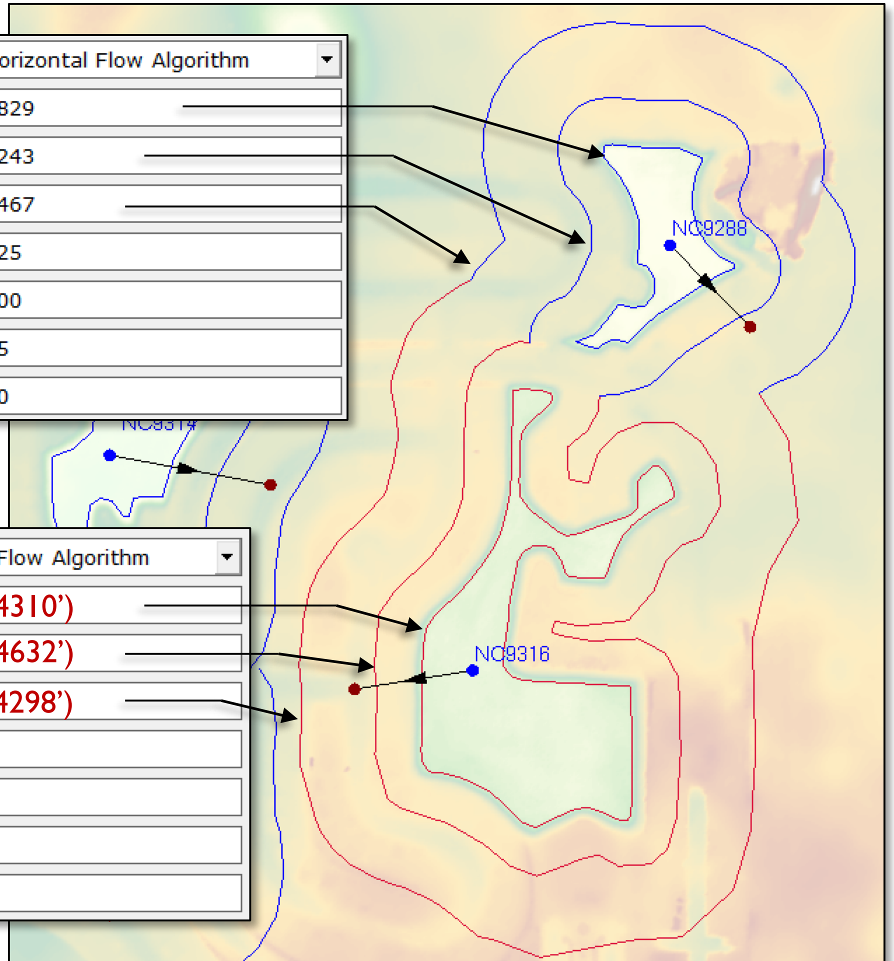
Example #3 – Multiple Land-Locked Ponds

PERC-C9288

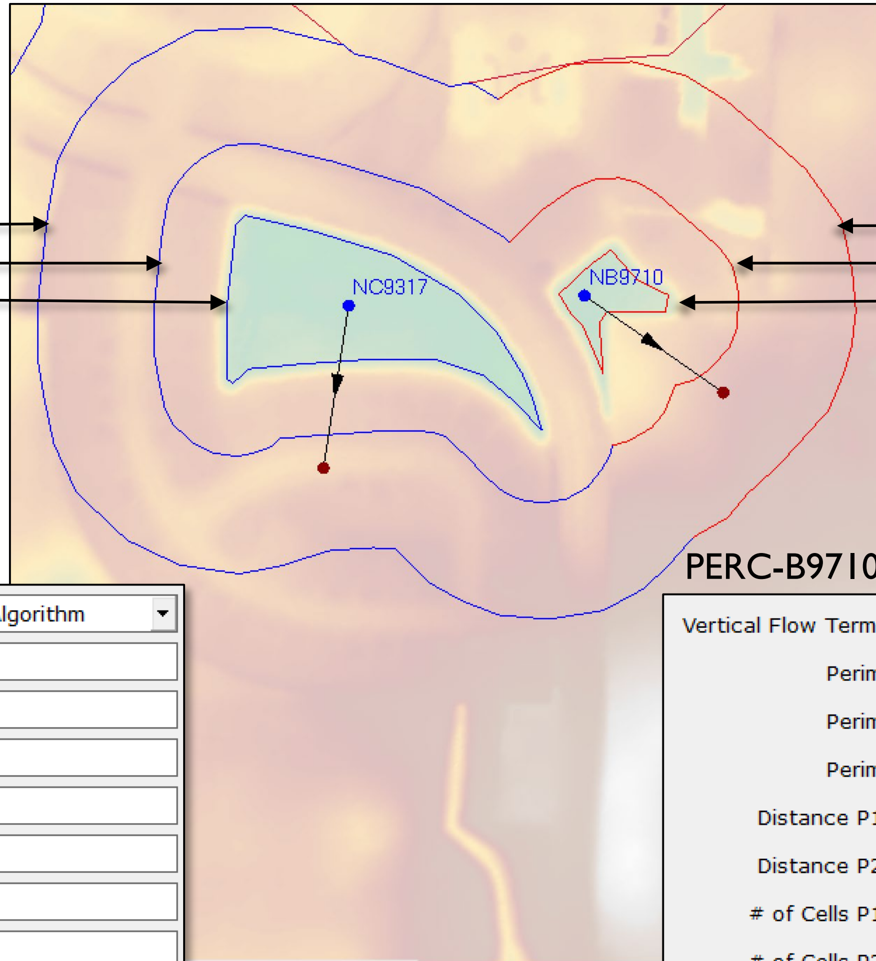
Vertical Flow Termination	Horizontal Flow Algorithm
Perimeter 1	1829
Perimeter 2	2243
Perimeter 3	2467
Distance P1 to P2	125
Distance P2 to P3	200
# of Cells P1 to P2	25
# of Cells P2 to P3	40

PERC-C9316

Vertical Flow Termination	Horizontal Flow Algorithm	
Perimeter 1	4298	(4310')
Perimeter 2	4298	(4632')
Perimeter 3	4298	(4298')
Distance P1 to P2	125	
Distance P2 to P3	200	
# of Cells P1 to P2	25	
# of Cells P2 to P3	40	



Example #3 – Multiple Land-Locked Ponds



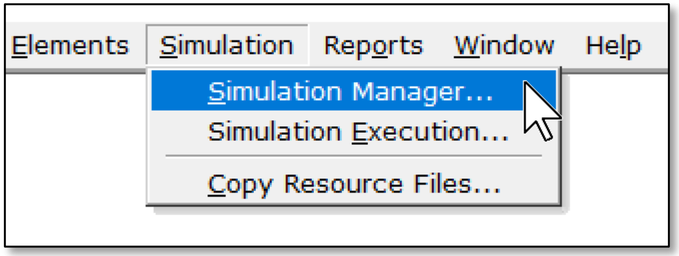
PERC-C9317

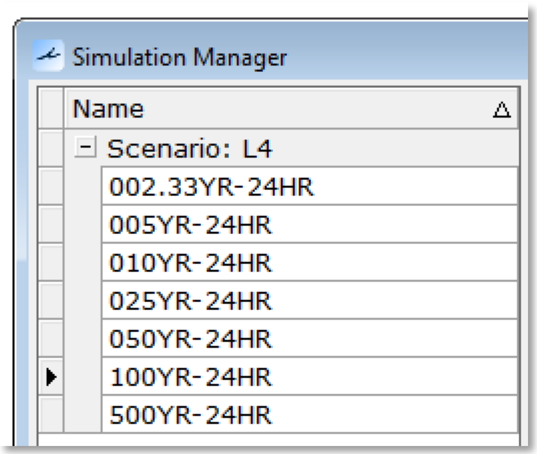
Vertical Flow Termination	Horizontal Flow Algorithm
Perimeter 1	1565
Perimeter 2	1937
Perimeter 3	2672
Distance P1 to P2	125
Distance P2 to P3	200
# of Cells P1 to P2	25
# of Cells P2 to P3	40

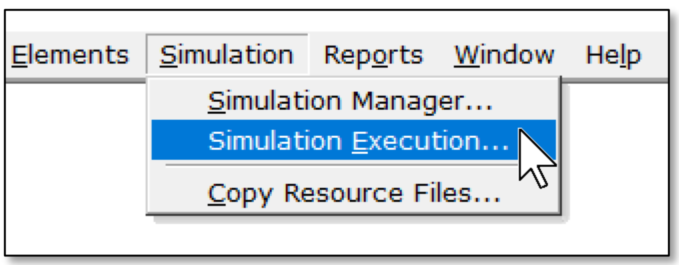
PERC-B9710

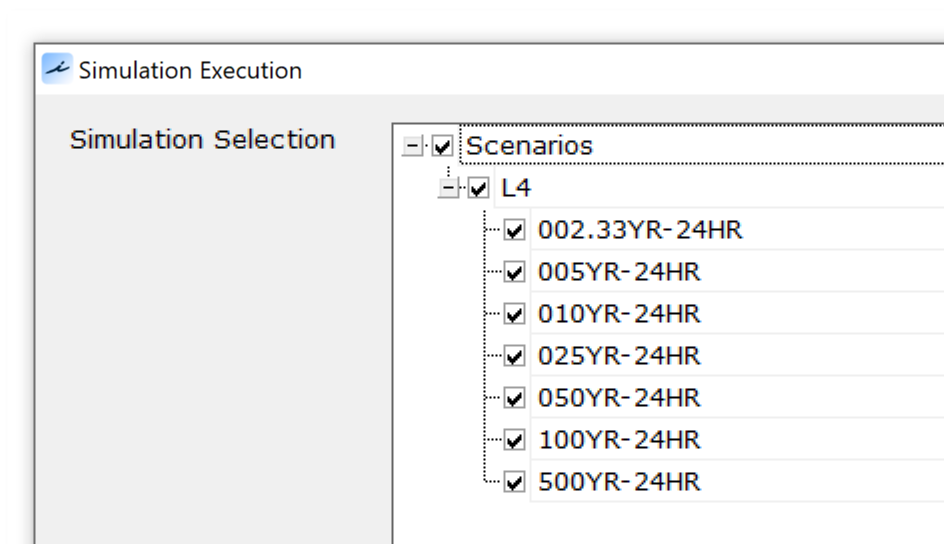
Vertical Flow Termination	Horizontal Flow Algorithm
Perimeter 1	648
Perimeter 2	903
Perimeter 3	1375
Distance P1 to P2	125
Distance P2 to P3	200
# of Cells P1 to P2	25
# of Cells P2 to P3	40

Example #3 – Multiple Land-Locked Ponds

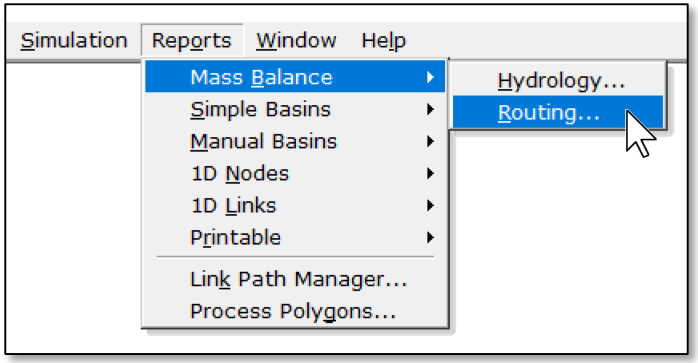


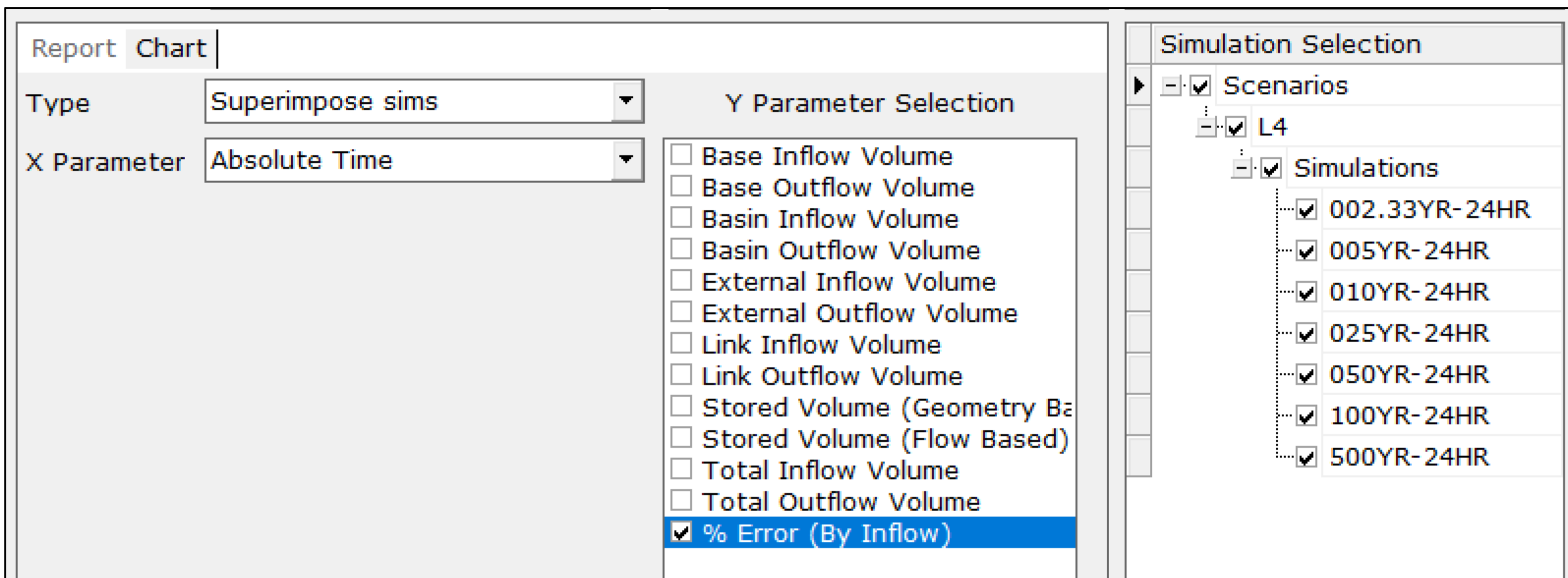




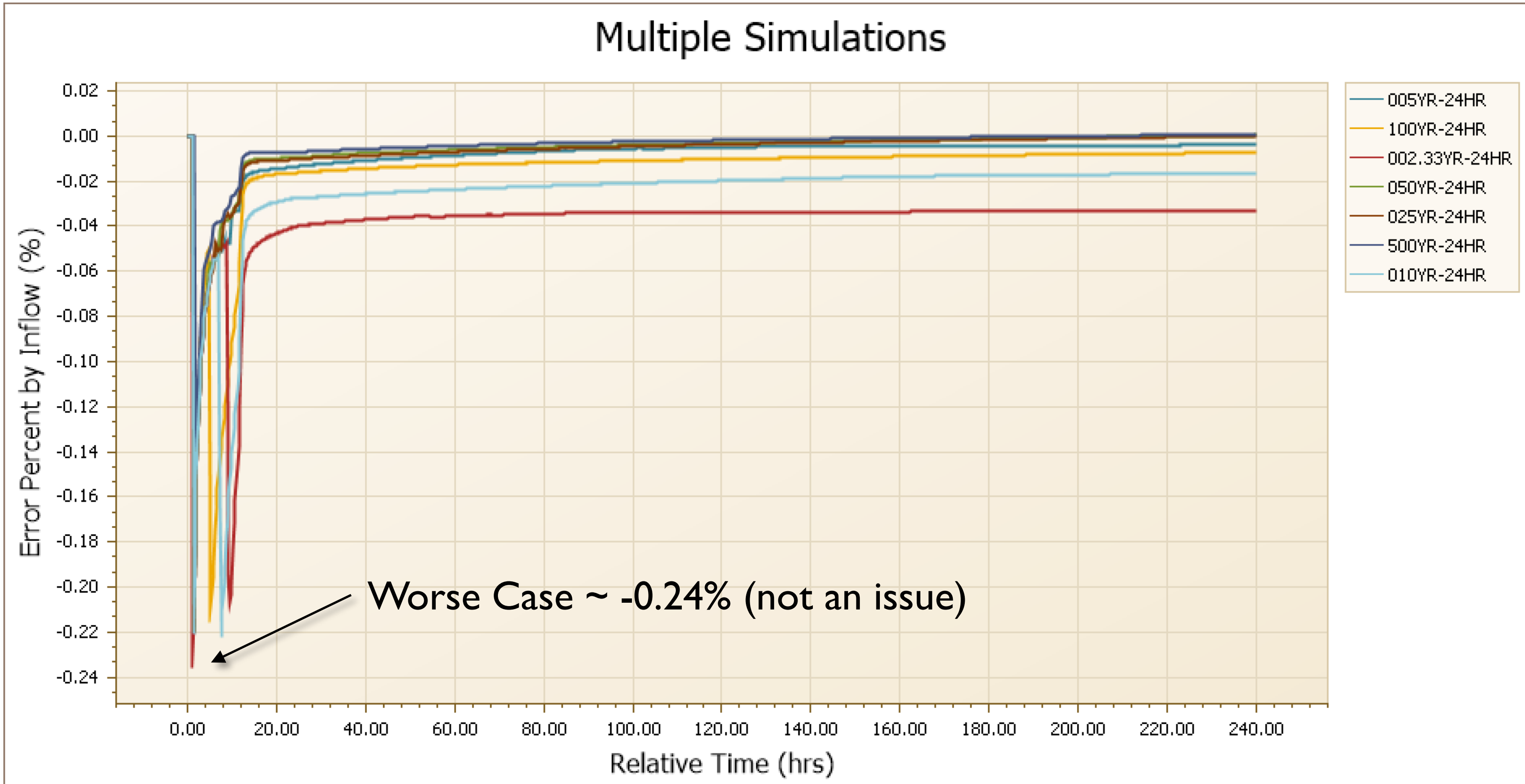


Example #3 – Multiple Land-Locked Ponds

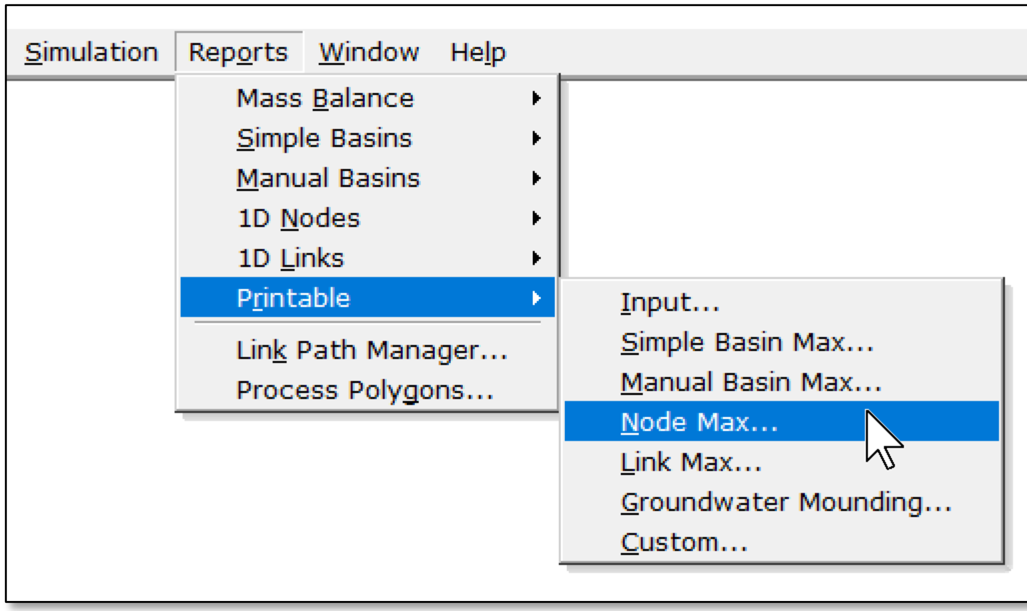




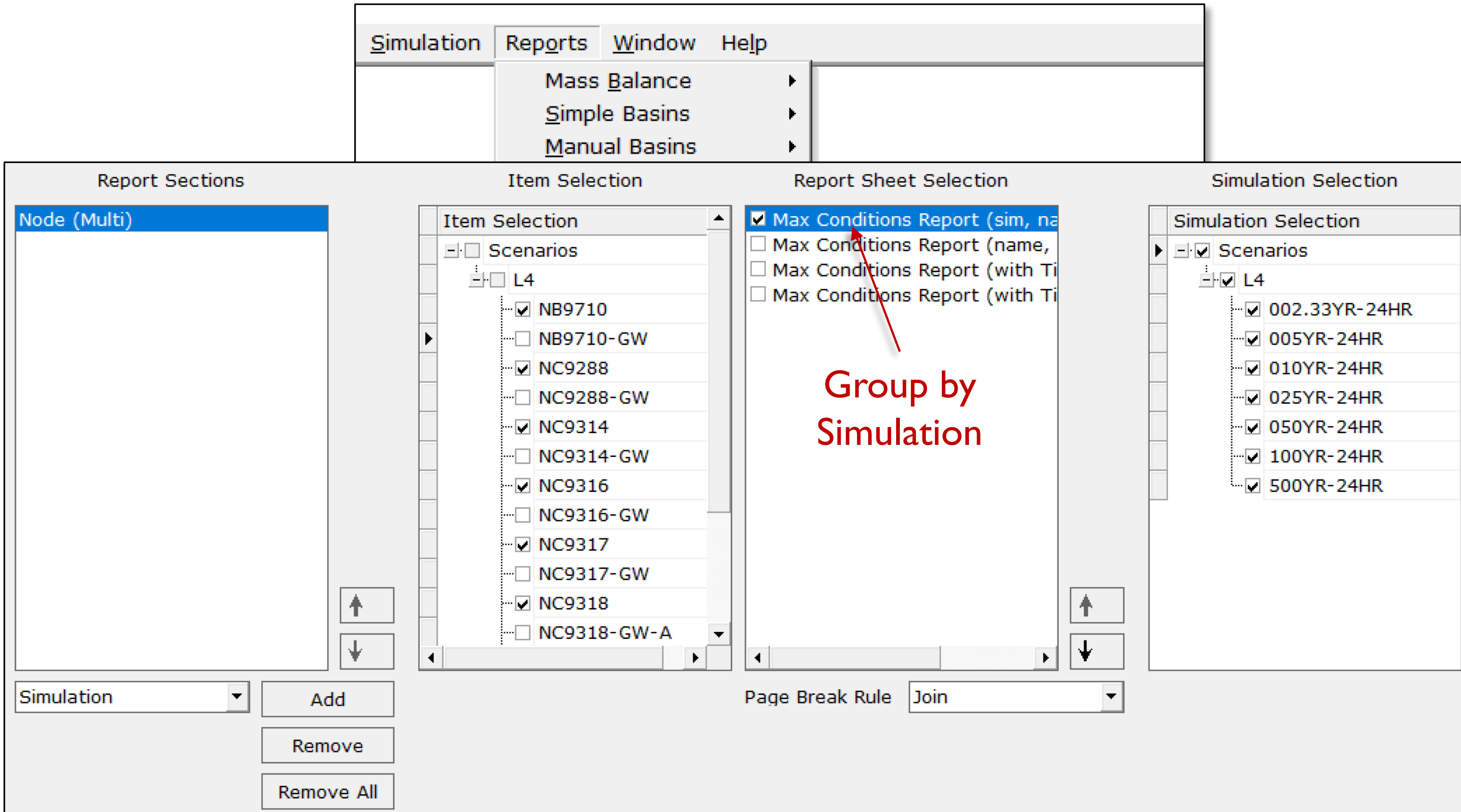
Example #3 – Multiple Land-Locked Ponds



Example #3 – Multiple Land-Locked Ponds



Example #3 – Multiple Land-Locked Ponds

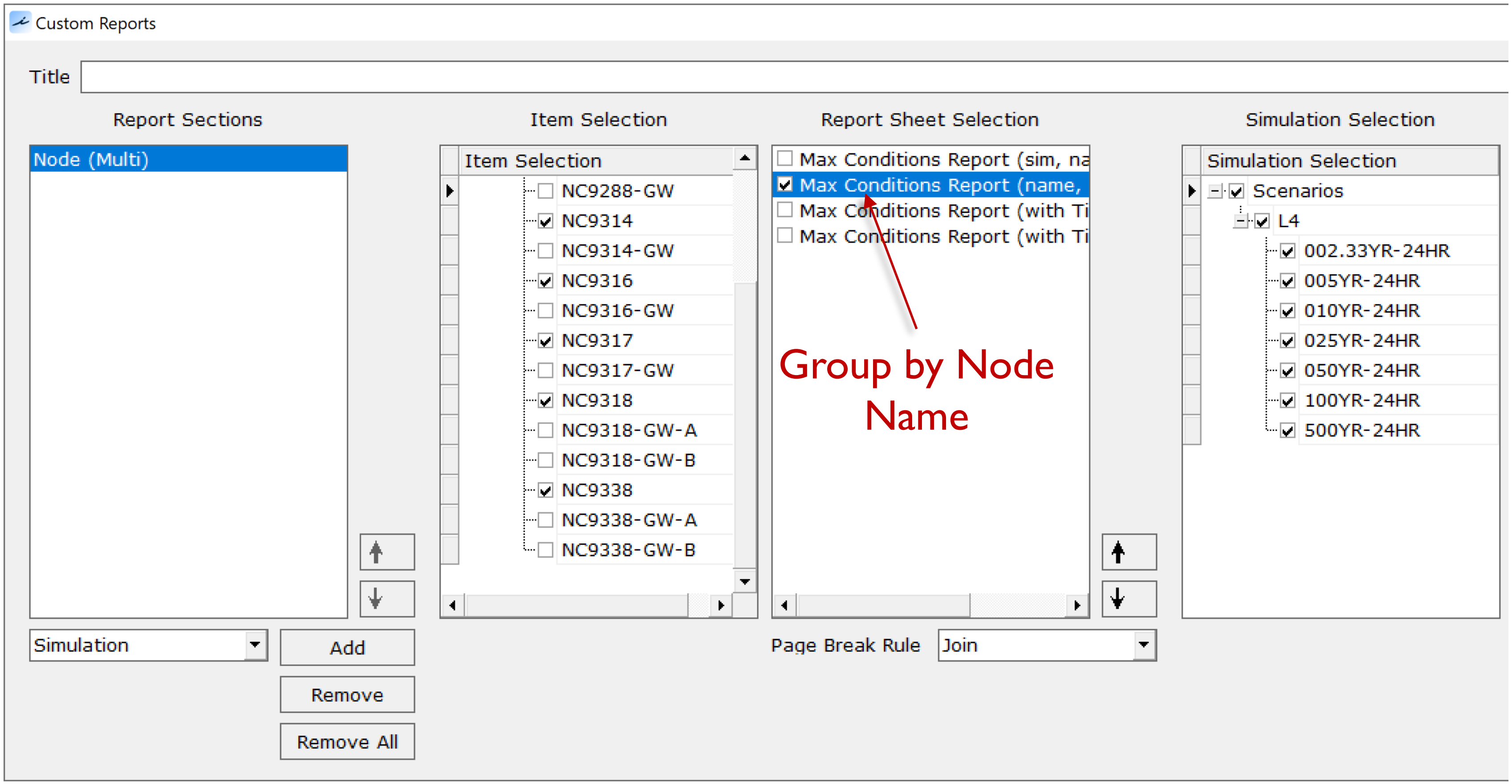


Node Max Conditions [L4]

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]
NB9710	002.33YR-24HR	66.20	62.11	0.0010	8.75	4.61	17792
NC9288	002.33YR-24HR	61.90	56.39	0.0010	15.82	7.96	55054
NC9314	002.33YR-24HR	60.10	55.50	0.0010	53.68	7.78	155673
NC9316	002.33YR-24HR	63.30	58.39	0.0010	52.79	2.17	298407
NC9317	002.33YR-24HR	66.20	62.02	0.0010	28.08	2.84	98775
NC9318	002.33YR-24HR	60.30	55.09	0.0010	22.35	9.96	68821
NC9338	002.33YR-24HR	60.30	54.90	0.0010	48.83	25.17	188017
NB9710	005YR-24HR	66.20	62.49	0.0010	11.62	6.70	19141
NC9288	005YR-24HR	61.90	56.51	0.0010	19.18	8.96	63754
NC9314	005YR-24HR	60.10	55.78	0.0010	66.09	9.94	158902
NC9316	005YR-24HR	63.30	58.62	0.0010	64.28	2.32	307848
NC9317	005YR-24HR	66.20	62.48	0.0010	34.92	2.61	102577
NC9318	005YR-24HR	60.30	55.36	0.0010	27.73	9.75	70462
NC9338	005YR-24HR	60.30	55.36	0.0010	59.90	25.59	199453
NB9710	010YR-24HR	66.20	63.24	0.0010	17.07	10.46	21807
NC9288	010YR-24HR	61.90	56.77	0.0010	24.72	9.44	76169
NC9314	010YR-24HR	60.10	56.22	0.0010	87.05	14.10	163751
NC9316	010YR-24HR	63.30	58.98	0.0010	83.43	2.60	316776
NC9317	010YR-24HR	66.20	63.24	0.0010	46.85	2.44	107304
NC9318	010YR-24HR	60.30	56.03	0.0010	36.99	11.30	73693
NC9338	010YR-24HR	60.30	56.03	0.0010	78.97	26.13	210416
NB9710	025YR-24HR	66.20	64.05	0.0010	23.80	14.72	24381
NC9288	025YR-24HR	61.90	57.08	0.0010	30.97	9.24	82114
NC9314	025YR-24HR	60.10	56.76	0.0010	110.99	17.87	168949
NC9316	025YR-24HR	63.30	59.38	0.0010	105.21	2.94	325821
NC9317	025YR-24HR	66.20	64.05	0.0010	60.95	2.65	112397
NC9318	025YR-24HR	60.30	56.76	0.0010	47.89	15.07	77269
NC9338	025YR-24HR	60.30	56.76	0.0010	101.45	25.31	220696
NB9710	050YR-24HR	66.20	64.65	0.0010	29.16	17.64	27984
NC9288	050YR-24HR	61.90	57.32	0.0010	35.83	8.62	84734
NC9314	050YR-24HR	60.10	57.30	0.0010	129.22	20.35	174318
NC9316	050YR-24HR	63.30	59.68	0.0010	121.95	3.21	331983

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]
NC9317	050YR-24HR	66.20	64.65	0.0010	72.34	2.87	116588
NC9318	050YR-24HR	60.30	57.29	0.0010	56.66	17.32	79052
NC9338	050YR-24HR	60.30	57.29	0.0010	119.29	23.71	228635
NB9710	100YR-24HR	66.20	65.89	0.0010	41.75	22.33	43715
NC9288	100YR-24HR	61.90	57.89	0.0010	47.16	6.85	90165
NC9314	100YR-24HR	60.10	58.45	0.0010	170.46	23.14	185742
NC9316	100YR-24HR	63.30	60.35	0.0010	160.37	3.88	344091
NC9317	100YR-24HR	66.20	65.89	0.0010	98.88	3.36	125336
NC9318	100YR-24HR	60.30	58.45	0.0010	76.93	19.44	84969
NC9338	100YR-24HR	60.30	58.45	0.0010	161.43	25.18	245172
NB9710	500YR-24HR	66.20	66.91	0.0010	56.37	23.86	91619
NC9288	500YR-24HR	61.90	58.57	0.0010	60.25	5.14	95956
NC9314	500YR-24HR	60.10	59.66	0.0010	216.81	23.90	198872
NC9316	500YR-24HR	63.30	61.08	0.0010	204.15	4.64	357156
NC9317	500YR-24HR	66.20	66.91	0.0010	125.91	3.89	222995
NC9318	500YR-24HR	60.30	59.65	0.0010	98.04	20.36	91928
NC9338	500YR-24HR	60.30	59.65	0.0010	210.06	22.11	270417

Example #3 – Multiple Land-Locked Ponds

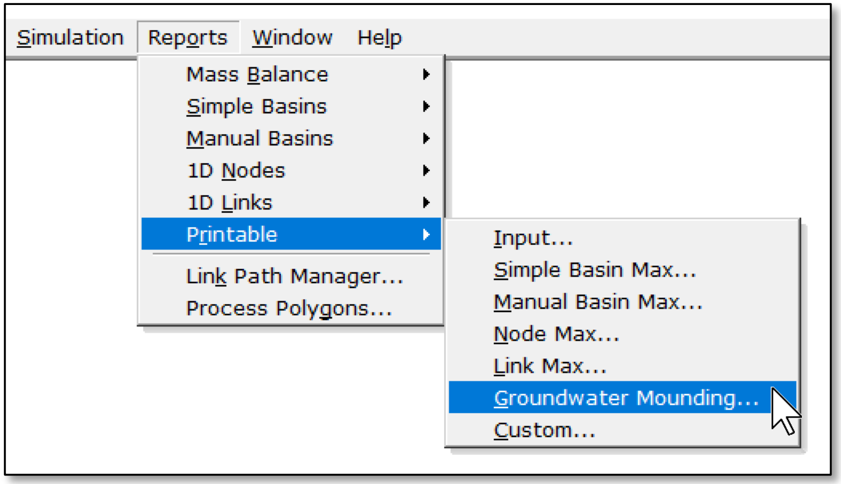


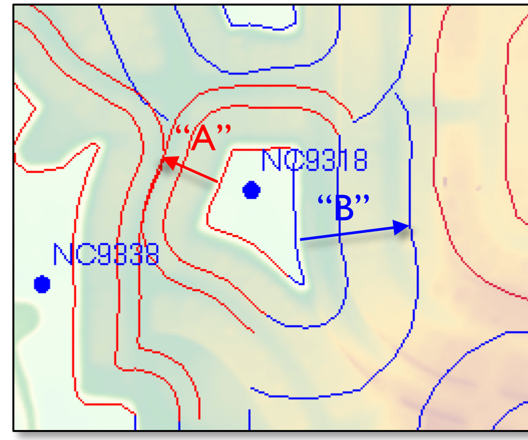
Node Max Conditions [L4]

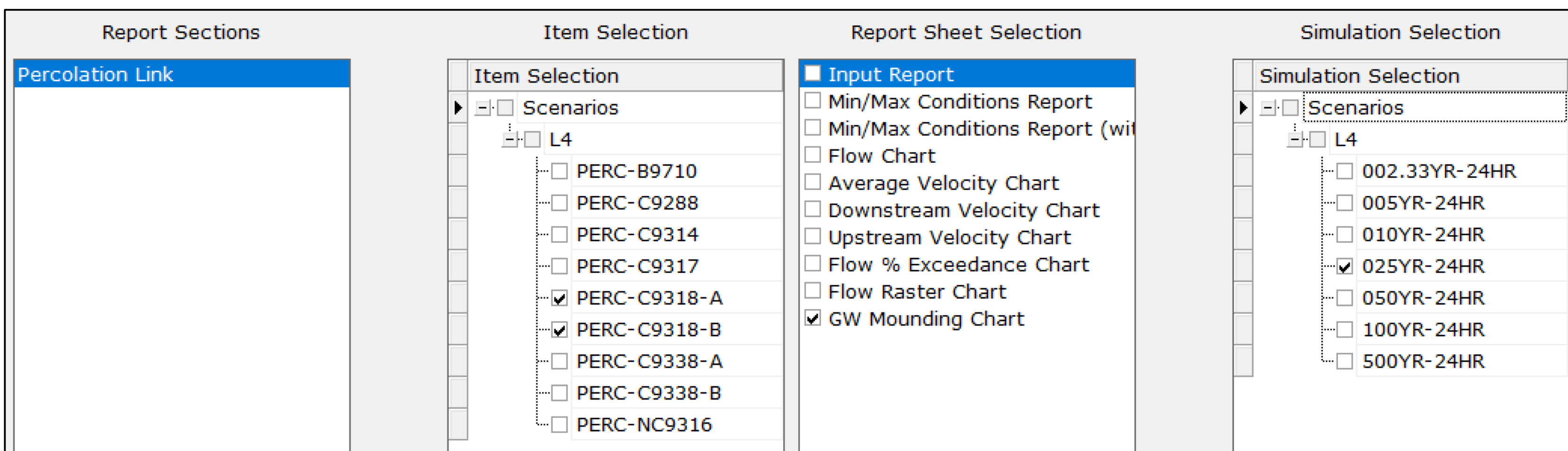
Node Name	Sim Name	Warning Stage [ft]	Max Stage [ft]	Min/Max Delta Stage [ft]	Max Total Inflow [cfs]	Max Total Outflow [cfs]	Max Surface Area [ft2]
NB9710	002.33YR-24HR	66.20	62.11	0.0010	8.75	4.61	17792
NB9710	005YR-24HR	66.20	62.49	0.0010	11.62	6.70	19141
NB9710	010YR-24HR	66.20	63.24	0.0010	17.07	10.46	21807
NB9710	025YR-24HR	66.20	64.05	0.0010	23.80	14.72	24381
NB9710	050YR-24HR	66.20	64.65	0.0010	29.16	17.64	27984
NB9710	100YR-24HR	66.20	65.89	0.0010	41.75	22.33	43715
NB9710	500YR-24HR	66.20	66.91	0.0010	56.37	23.86	91619
NC9288	002.33YR-24HR	61.90	56.39	0.0010	15.82	7.96	55054
NC9288	005YR-24HR	61.90	56.51	0.0010	19.18	8.96	63754
NC9288	010YR-24HR	61.90	56.77	0.0010	24.72	9.44	76169
NC9288	025YR-24HR	61.90	57.08	0.0010	30.97	9.24	82114
NC9288	050YR-24HR	61.90	57.32	0.0010	35.83	8.62	84734
NC9288	100YR-24HR	61.90	57.89	0.0010	47.16	6.85	90165
NC9288	500YR-24HR	61.90	58.57	0.0010	60.25	5.14	95956
NC9314	002.33YR-24HR	60.10	55.50	0.0010	53.68	7.78	155673
NC9314	005YR-24HR	60.10	55.78	0.0010	66.09	9.94	158902
NC9314	010YR-24HR	60.10	56.22	0.0010	87.05	14.10	163751
NC9314	025YR-24HR	60.10	56.76	0.0010	110.99	17.87	168949
NC9314	050YR-24HR	60.10	57.30	0.0010	129.22	20.35	174318
NC9314	100YR-24HR	60.10	58.45	0.0010	170.46	23.14	185742
NC9314	500YR-24HR	60.10	59.66	0.0010	216.81	23.90	198872
NC9316	002.33YR-24HR	63.30	58.39	0.0010	52.79	2.17	298407
NC9316	005YR-24HR	63.30	58.62	0.0010	64.28	2.32	307848
NC9316	010YR-24HR	63.30	58.98	0.0010	83.43	2.60	316776
NC9316	025YR-24HR	63.30	59.38	0.0010	105.21	2.94	325821
NC9316	050YR-24HR	63.30	59.68	0.0010	121.95	3.21	331983
NC9316	100YR-24HR	63.30	60.35	0.0010	160.37	3.88	344091
NC9316	500YR-24HR	63.30	61.08	0.0010	204.15	4.64	357156
NC9317	002.33YR-24HR	66.20	62.02	0.0010	28.08	2.84	98775
NC9317	005YR-24HR	66.20	62.48	0.0010	34.92	2.61	102577
NC9317	010YR-24HR	66.20	63.24	0.0010	46.85	2.44	107304
NC9317	025YR-24HR	66.20	64.05	0.0010	60.95	2.65	112397

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]
NC9317	050YR-24HR	66.20	64.65	0.0010	72.34	2.87	116588
NC9317	100YR-24HR	66.20	65.89	0.0010	98.88	3.36	125336
NC9317	500YR-24HR	66.20	66.91	0.0010	125.91	3.89	222995
NC9318	002.33YR-24HR	60.30	55.09	0.0010	22.35	9.96	68821
NC9318	005YR-24HR	60.30	55.36	0.0010	27.73	9.75	70462
NC9318	010YR-24HR	60.30	56.03	0.0010	36.99	11.30	73693
NC9318	025YR-24HR	60.30	56.76	0.0010	47.89	15.07	77269
NC9318	050YR-24HR	60.30	57.29	0.0010	56.66	17.32	79052
NC9318	100YR-24HR	60.30	58.45	0.0010	76.93	19.44	84969
NC9318	500YR-24HR	60.30	59.65	0.0010	98.04	20.36	91928
NC9338	002.33YR-24HR	60.30	54.90	0.0010	48.83	25.17	188017
NC9338	005YR-24HR	60.30	55.36	0.0010	59.90	25.59	199453
NC9338	010YR-24HR	60.30	56.03	0.0010	78.97	26.13	210416
NC9338	025YR-24HR	60.30	56.76	0.0010	101.45	25.31	220696
NC9338	050YR-24HR	60.30	57.29	0.0010	119.29	23.71	228635
NC9338	100YR-24HR	60.30	58.45	0.0010	161.43	25.18	245172
NC9338	500YR-24HR	60.30	59.65	0.0010	210.06	22.11	270417

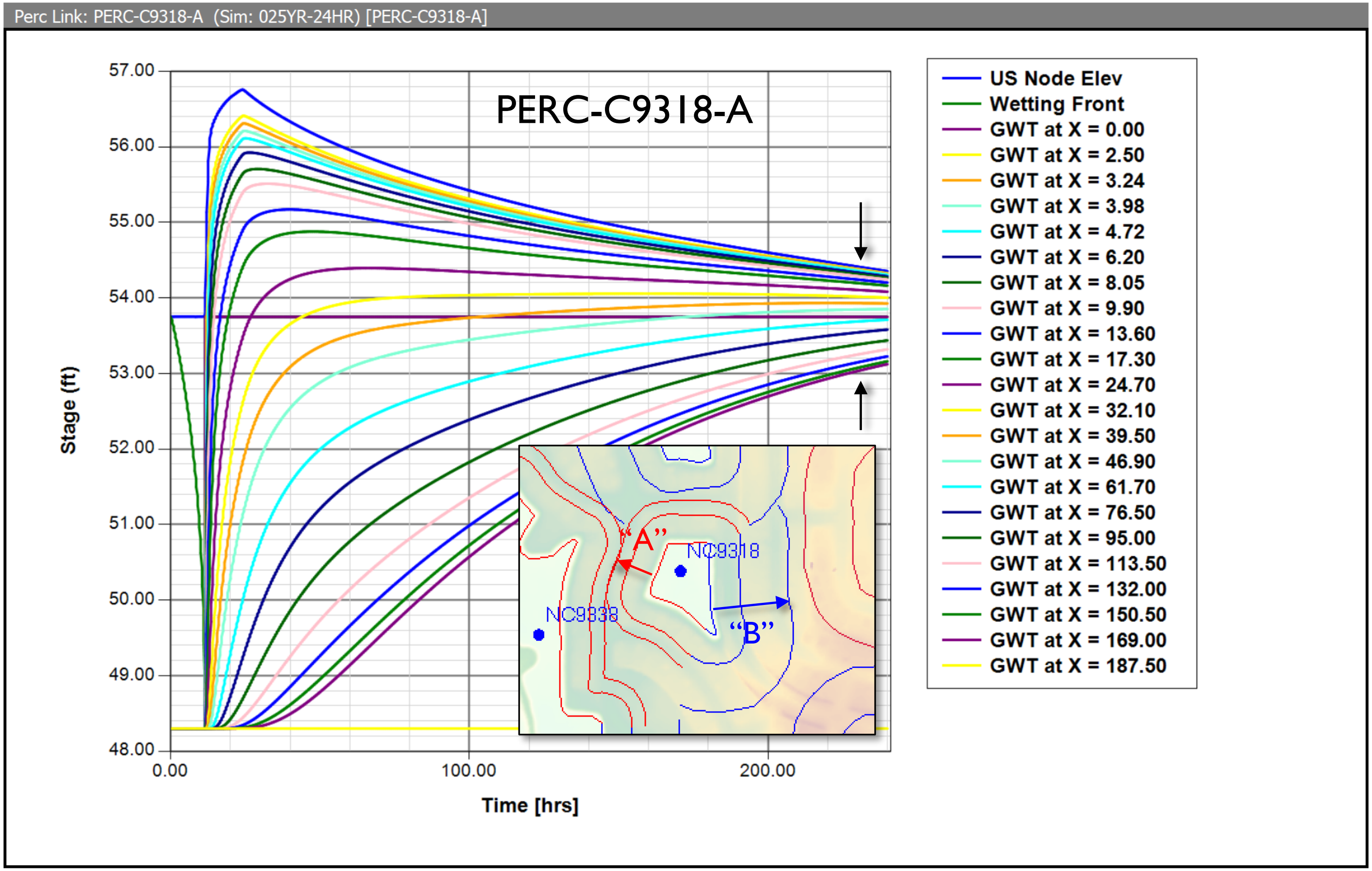
Example #3 – Multiple Land-Locked Ponds



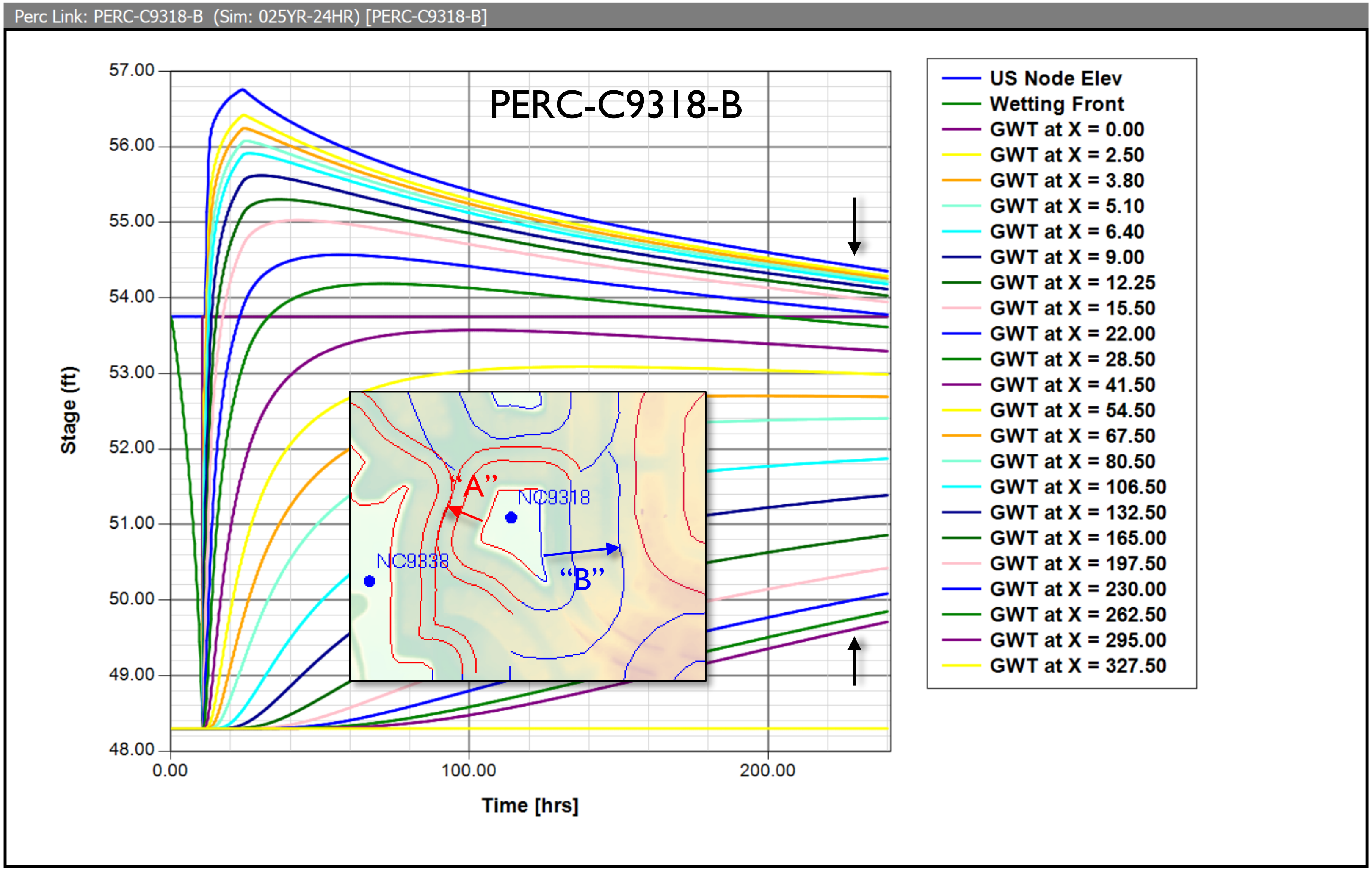




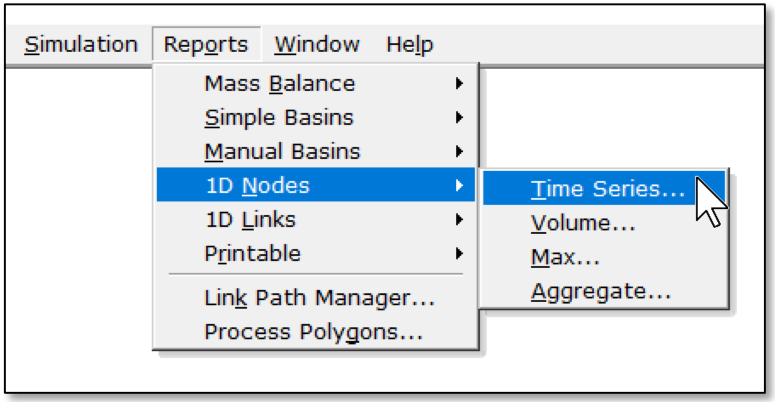
Example #3 – Multiple Land-Locked Ponds

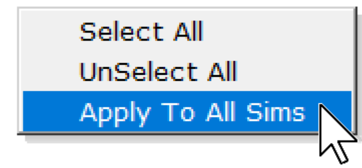


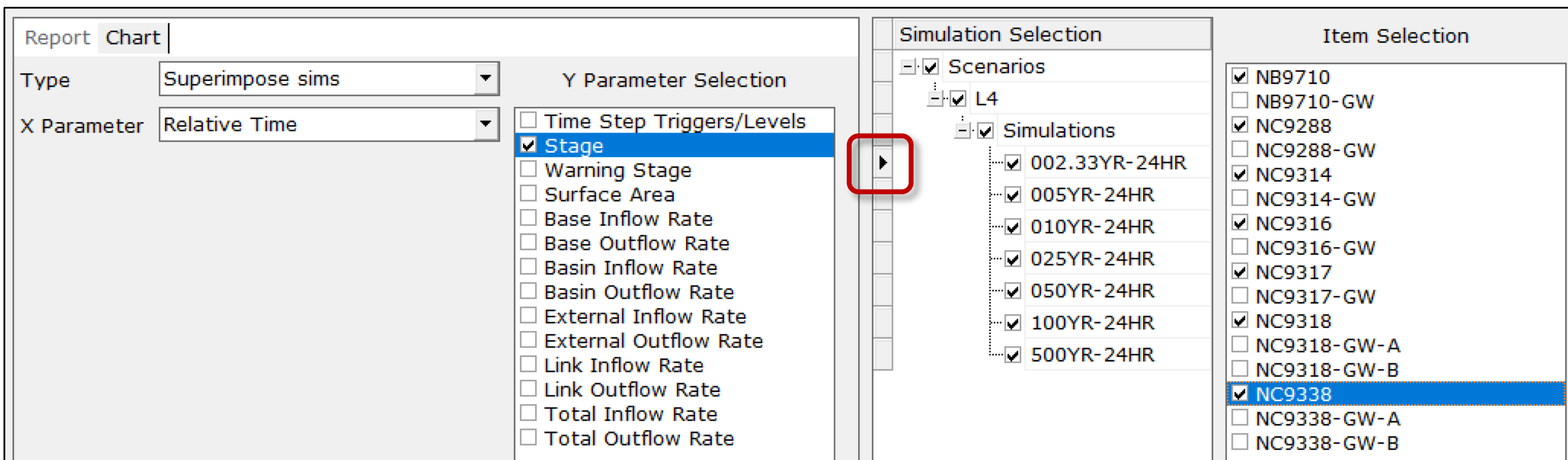
Example #3 – Multiple Land-Locked Ponds



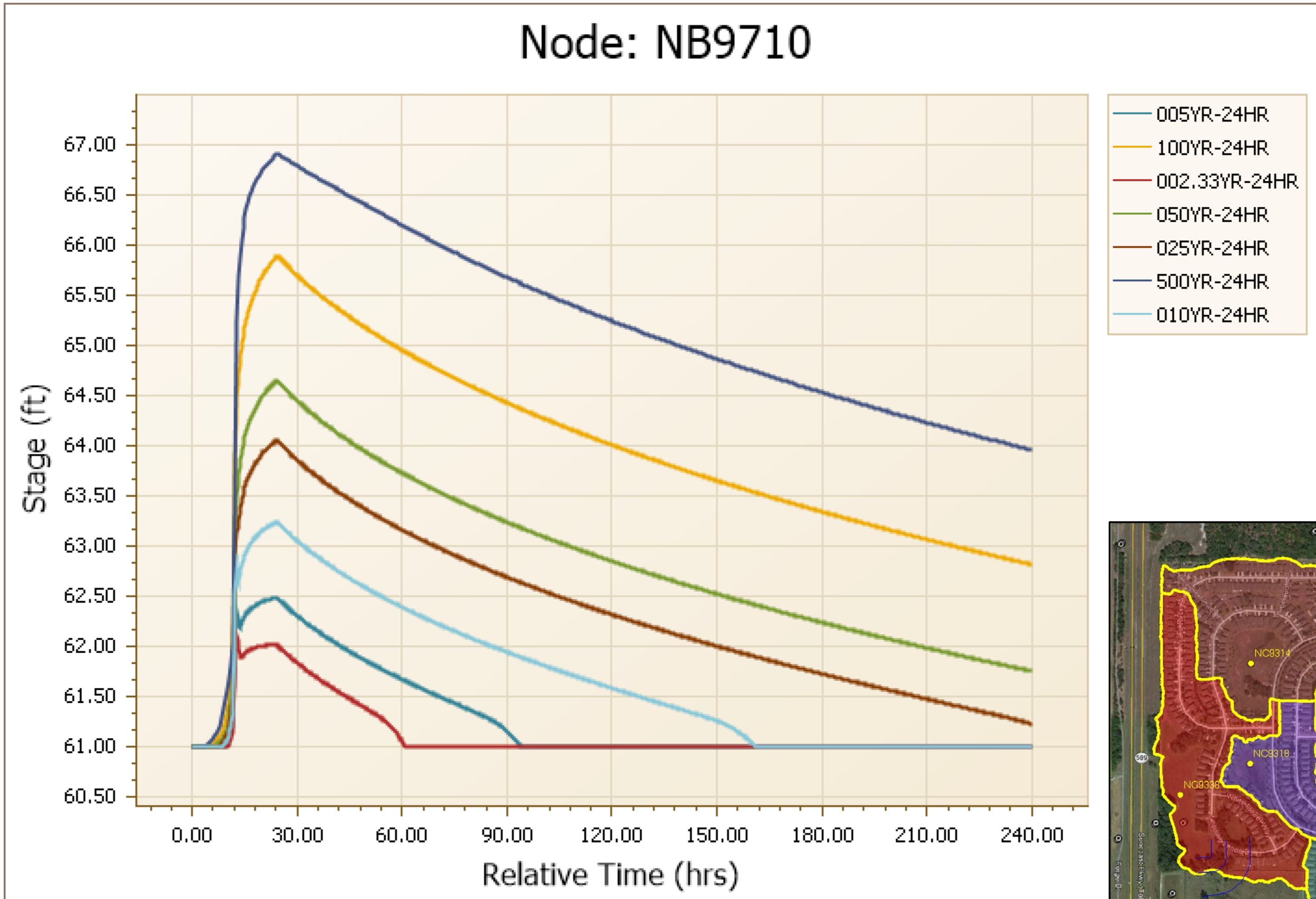
Example #3 – Multiple Land-Locked Ponds

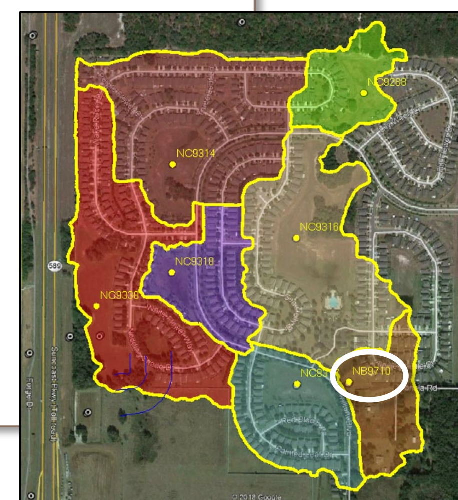




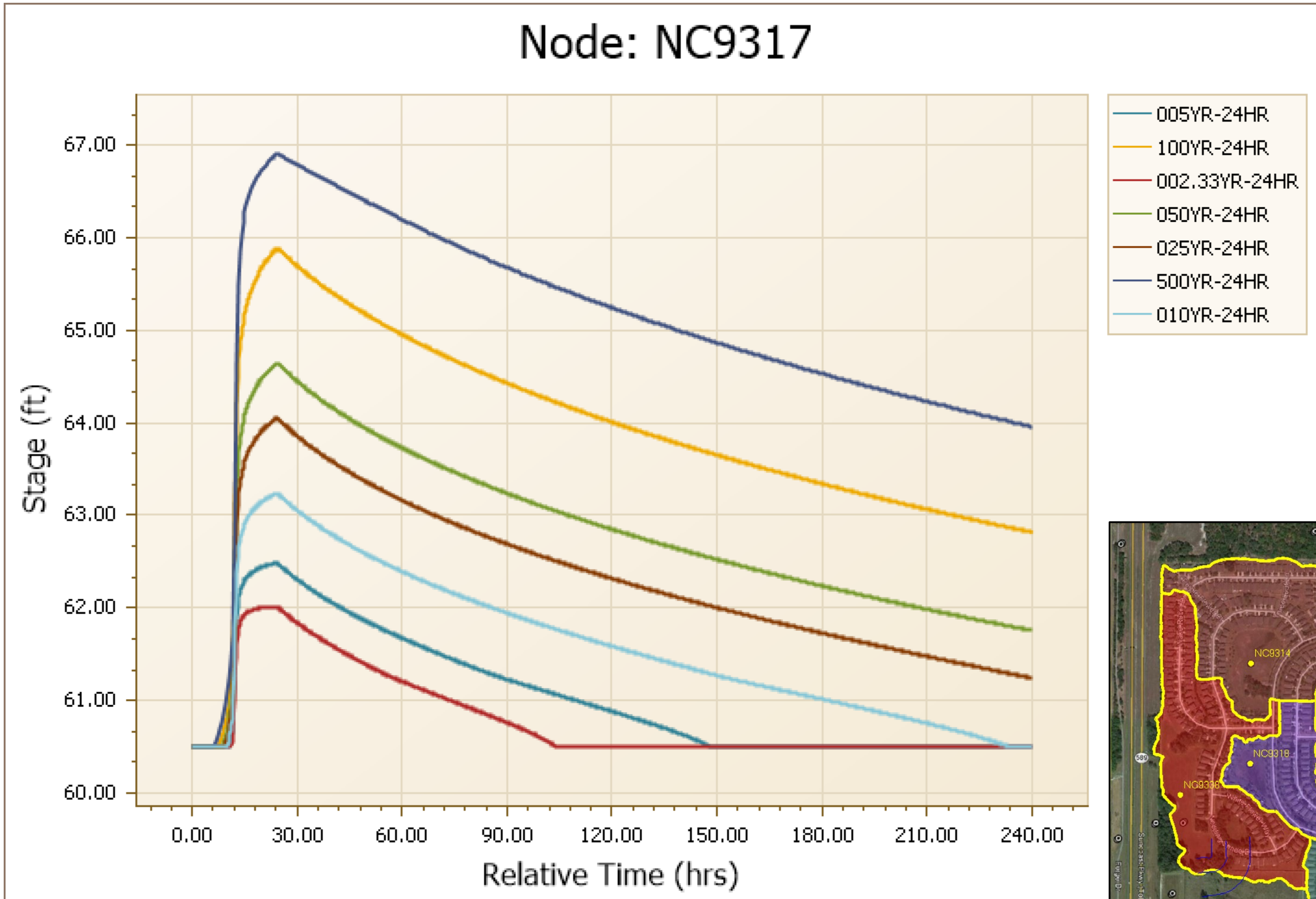


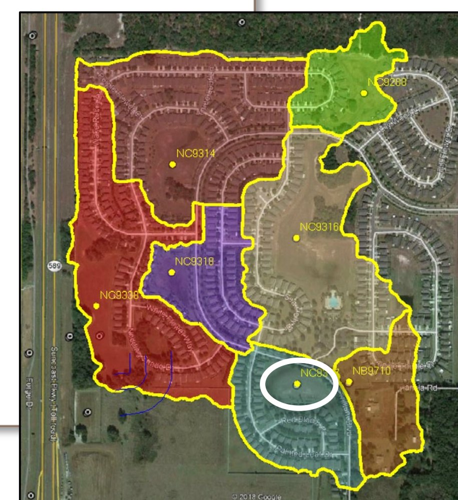
Example #3 – Multiple Land-Locked Ponds



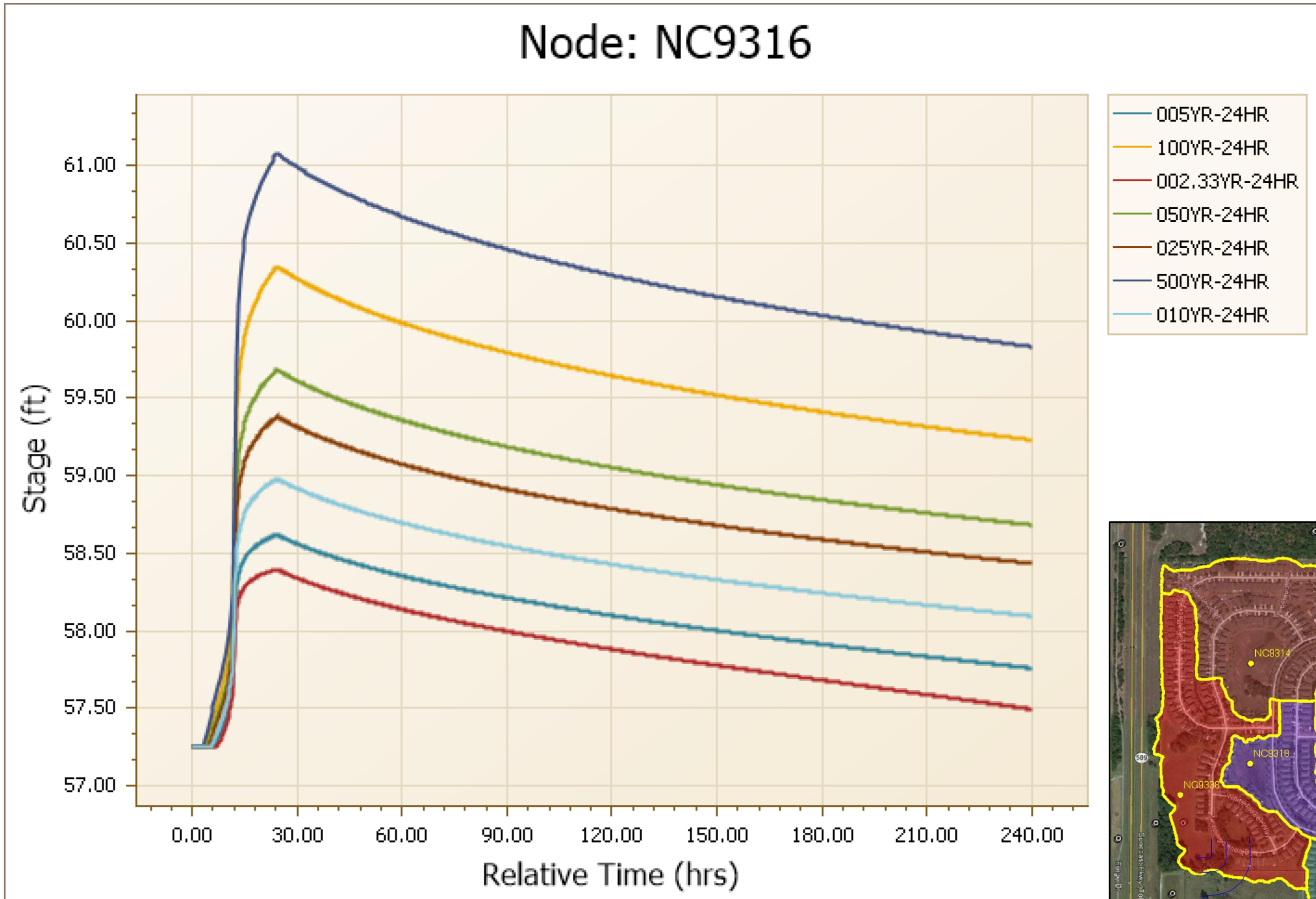


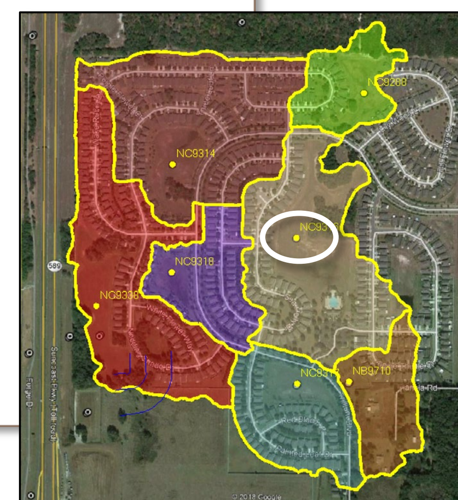
Example #3 – Multiple Land-Locked Ponds



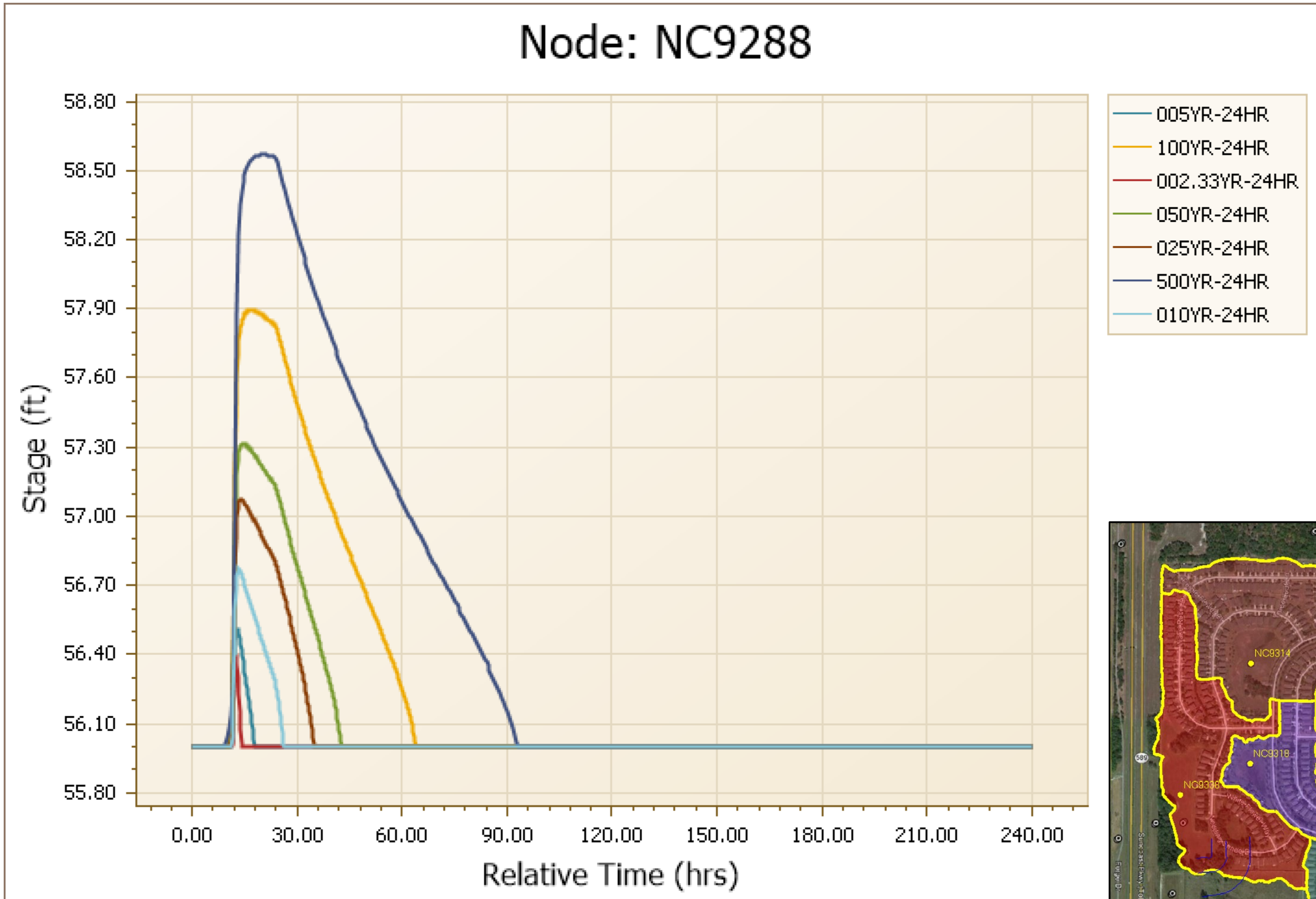


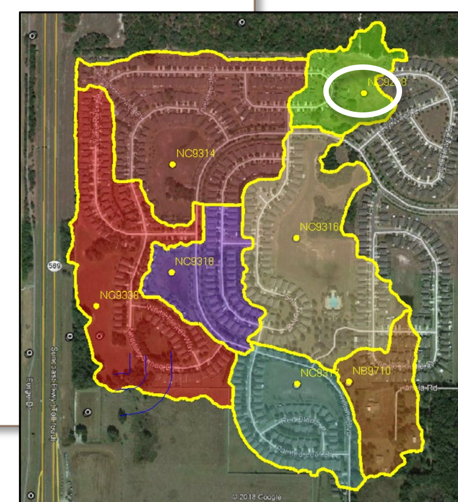
Example #3 – Multiple Land-Locked Ponds



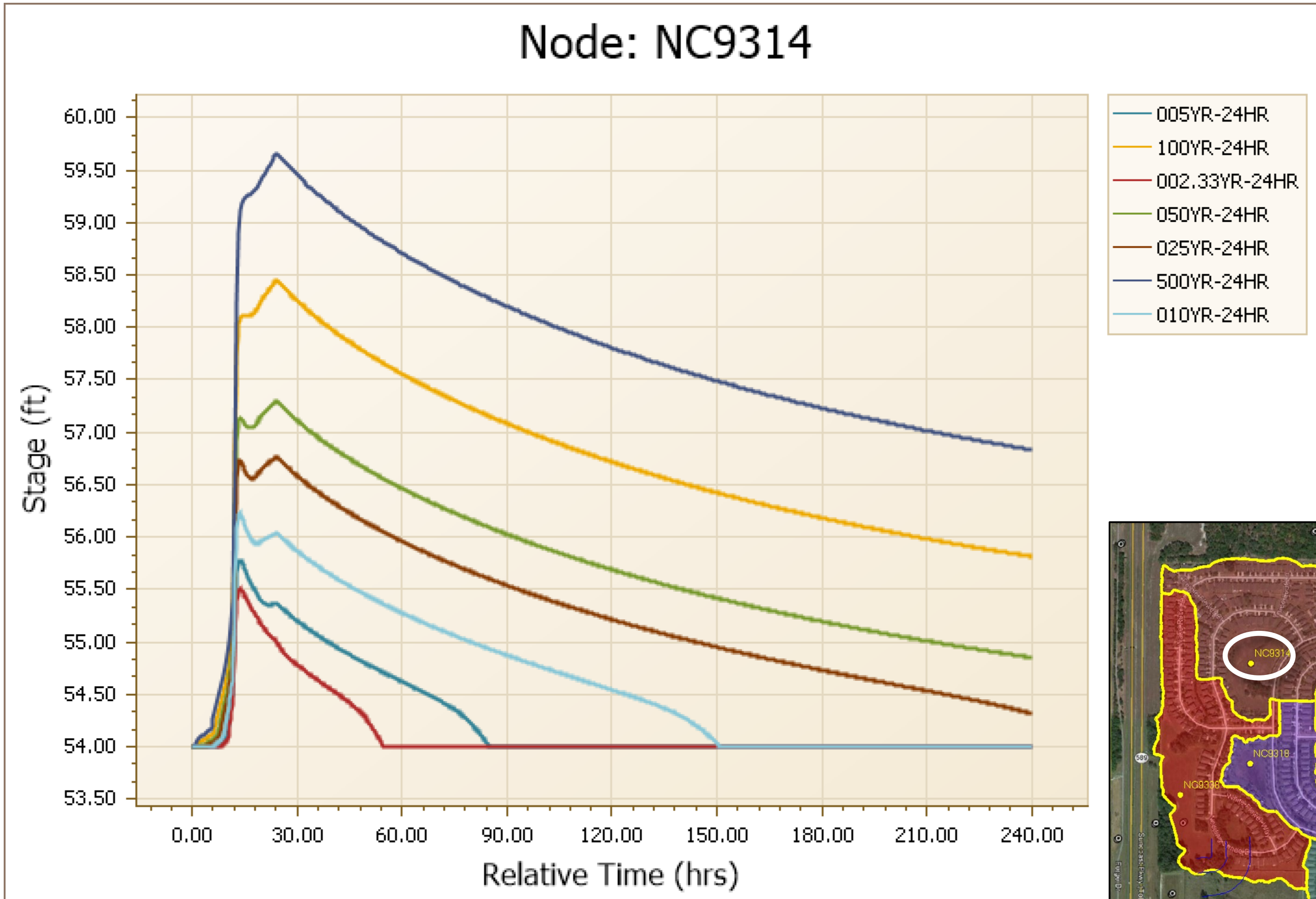


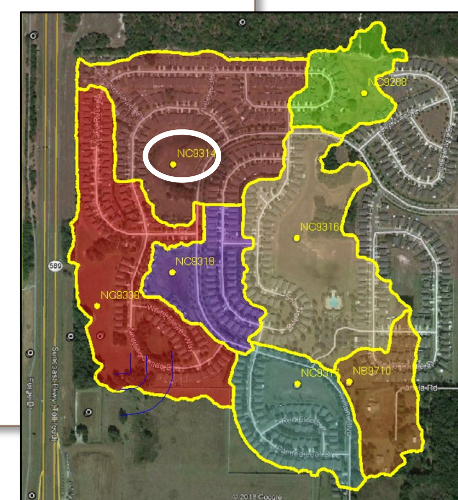
Example #3 – Multiple Land-Locked Ponds



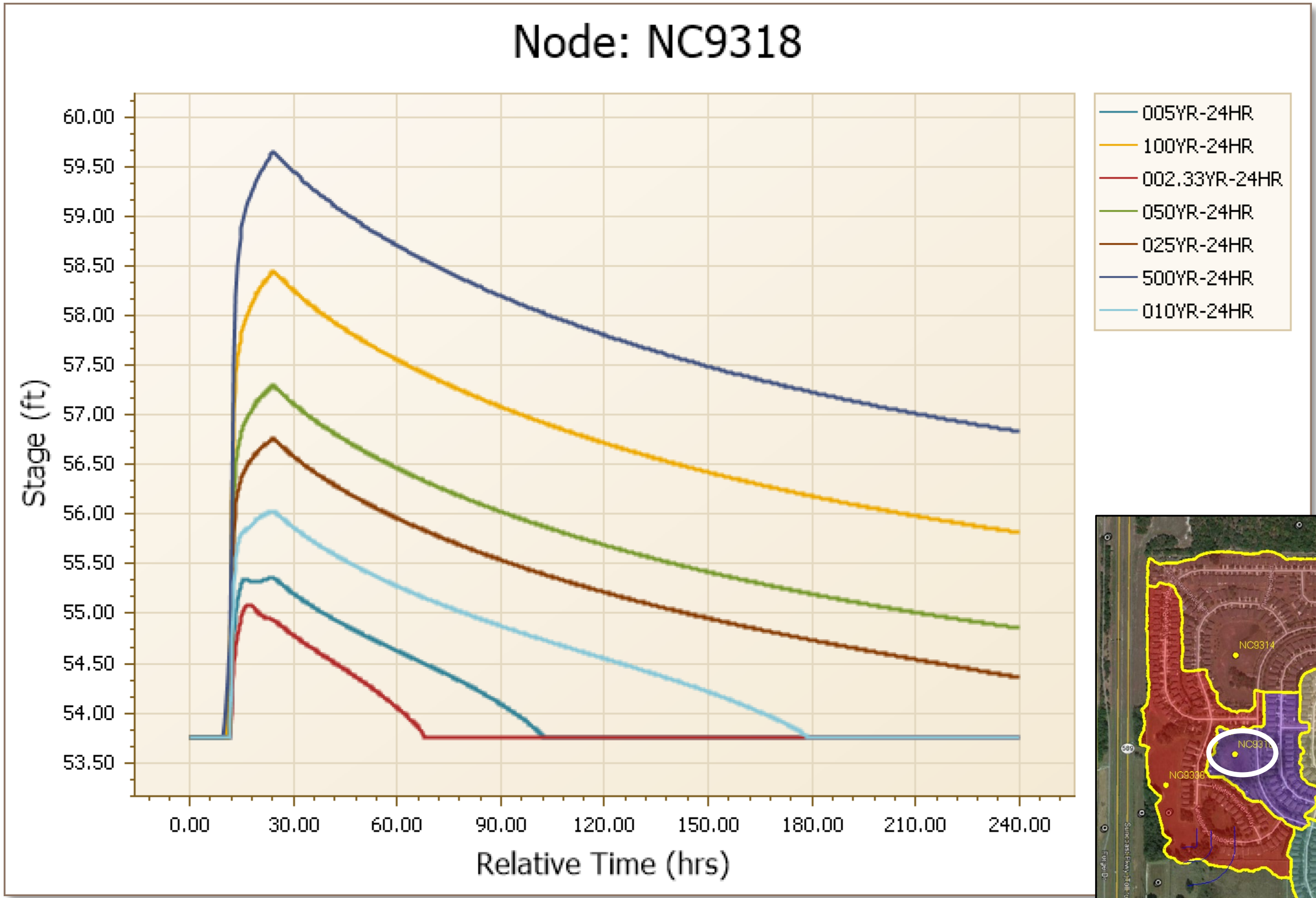


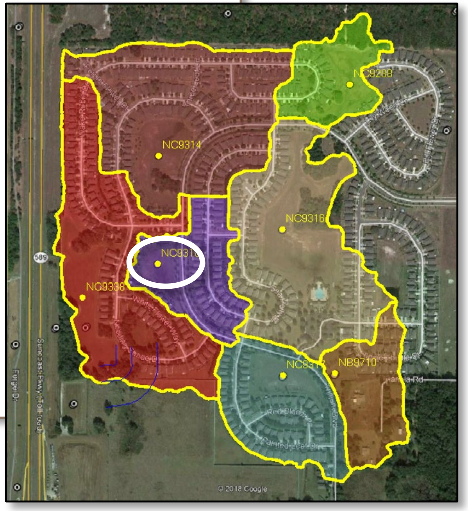
Example #3 – Multiple Land-Locked Ponds



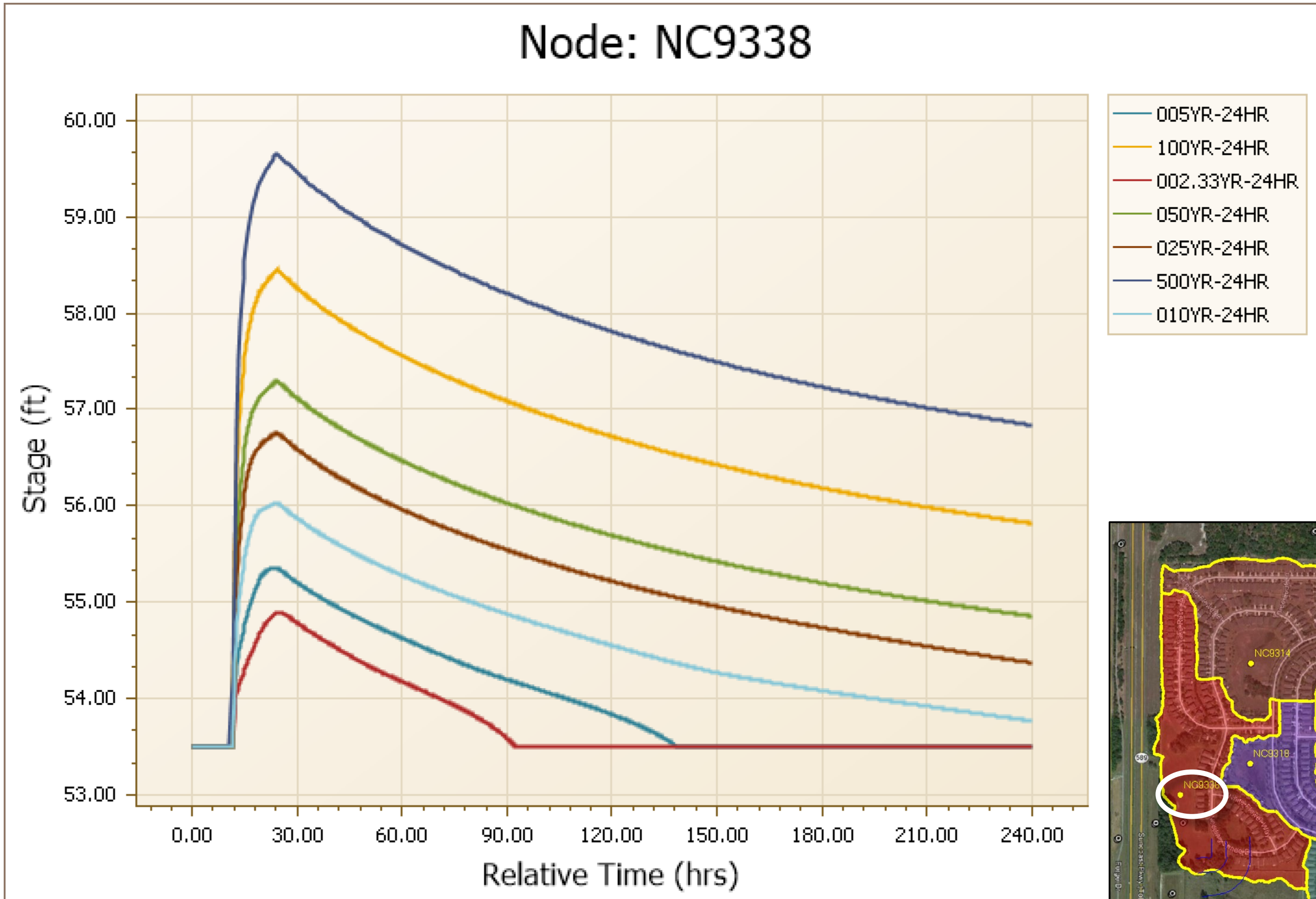


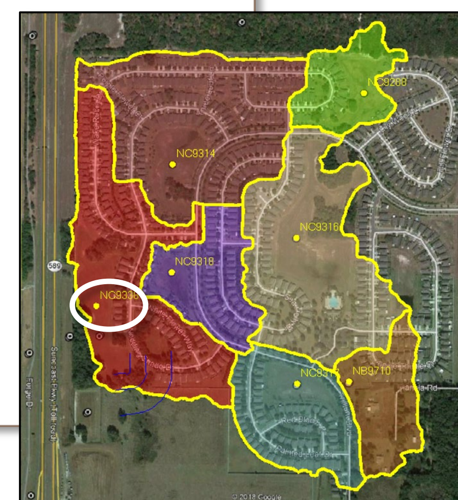
Example #3 – Multiple Land-Locked Ponds





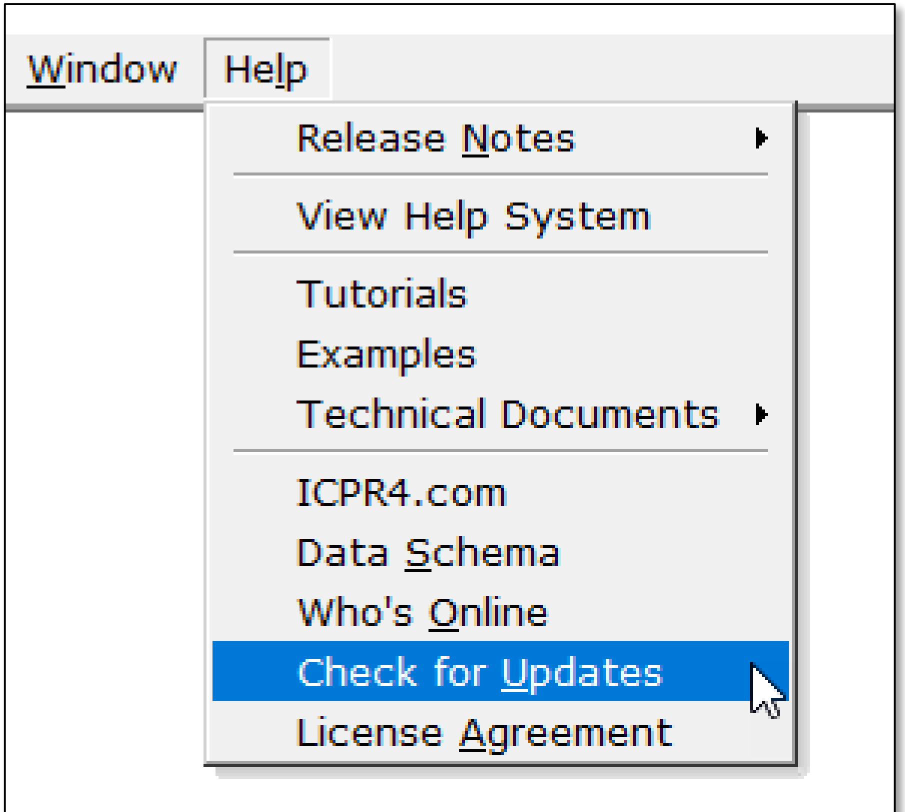
Example #3 – Multiple Land-Locked Ponds





Next Webinar – Lesson 5: Typical Pre/Post Examples

Tuesday November 5, 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