

Modeling Percolation from Multiple Ponds in Close Proximity Using ICPR

Peter J. Singhofen, P.E.
Streamline Technologies, Inc.

presented at

The ASCE Suncoast Branch
Water Resources Luncheon
Sarasota, Florida

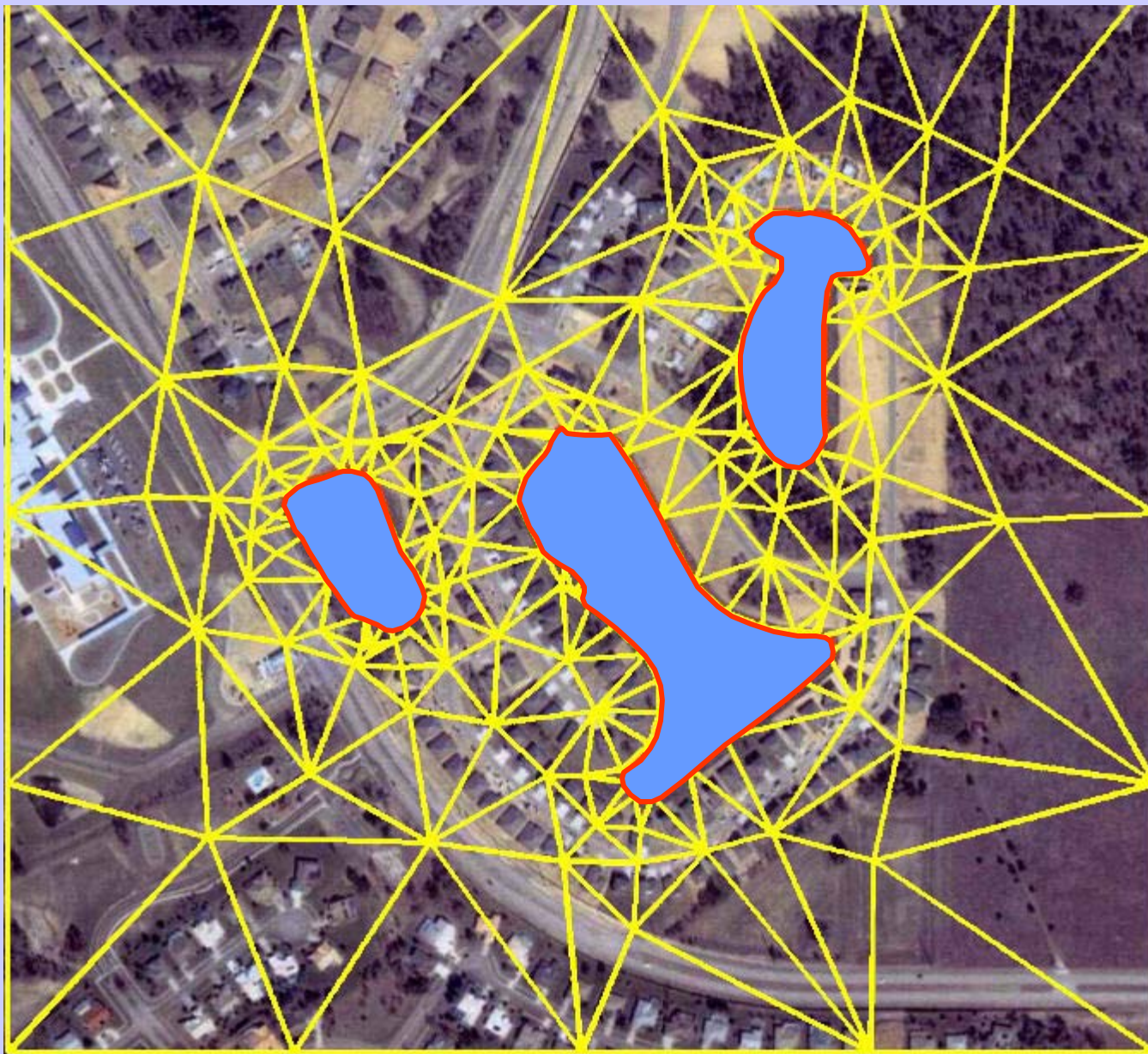
April 23, 2009



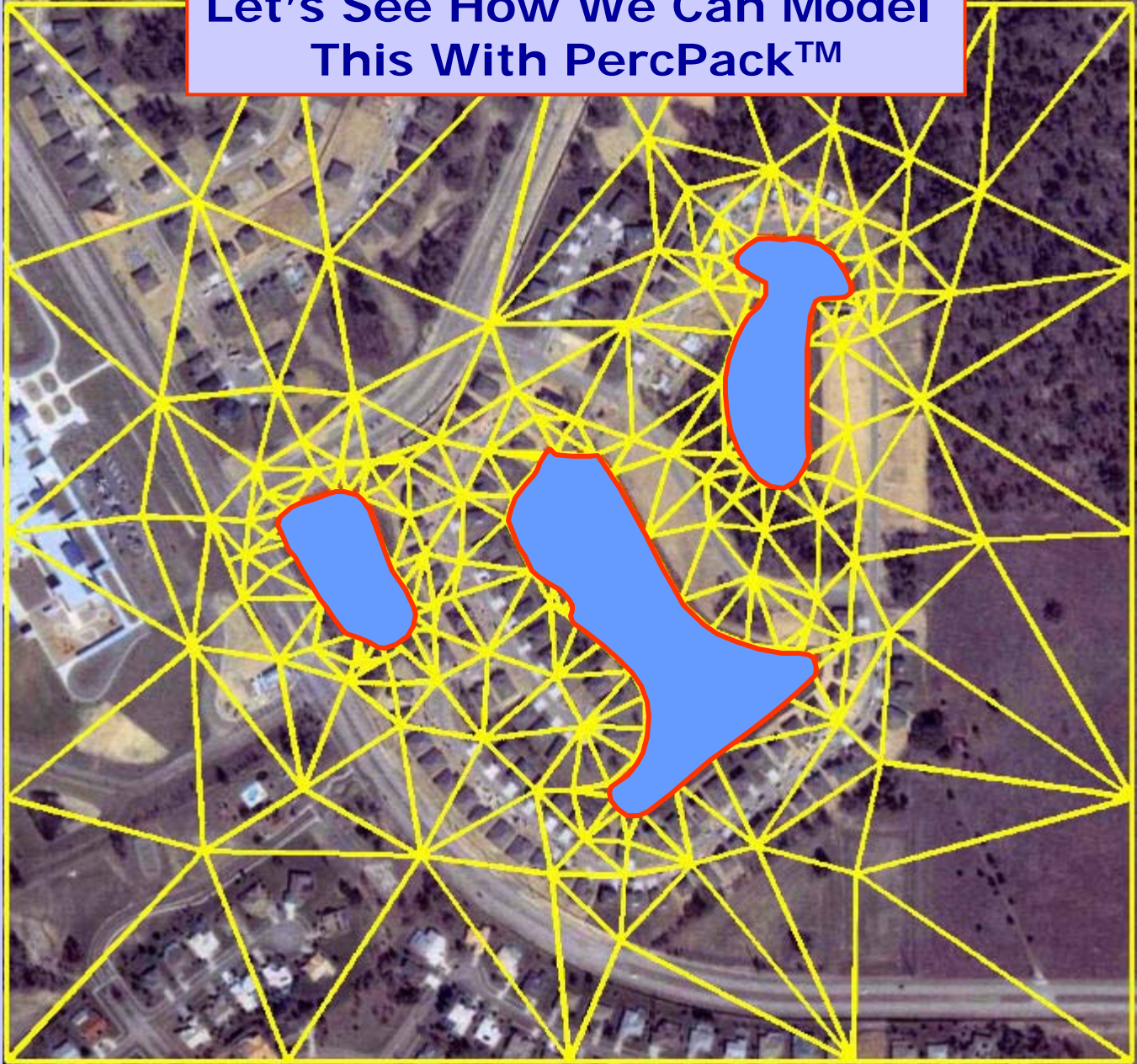
Three Ponds in Close Proximity



Ideally, A 2D Model Would Be Appropriate

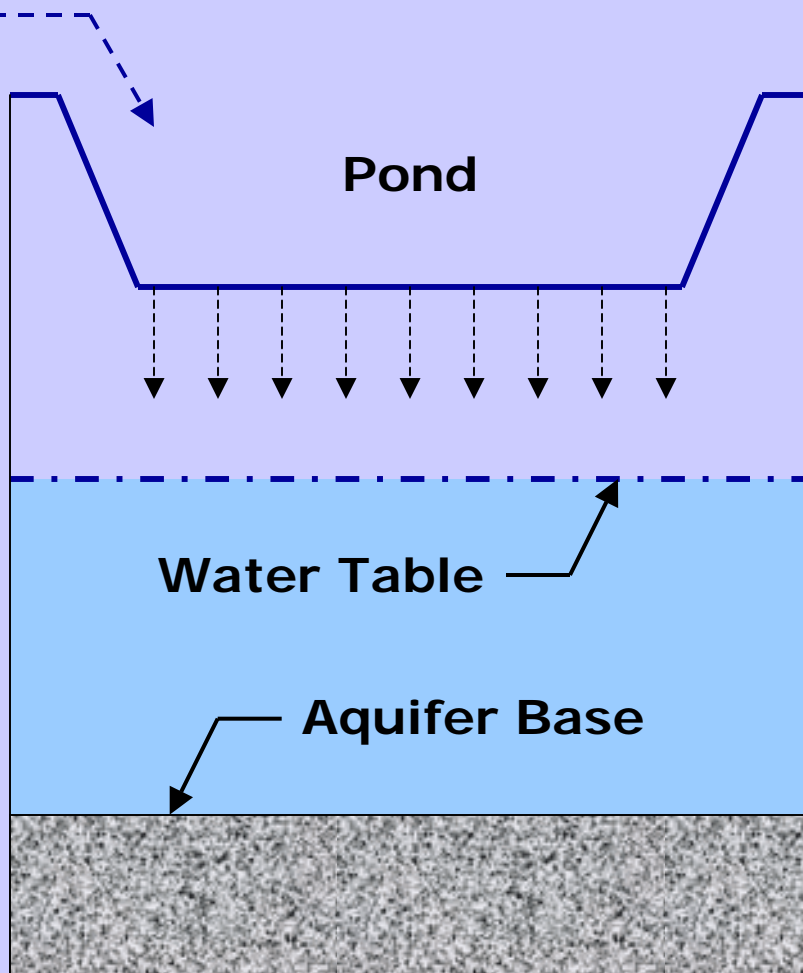


**Let's See How We Can Model
This With PercPack™**

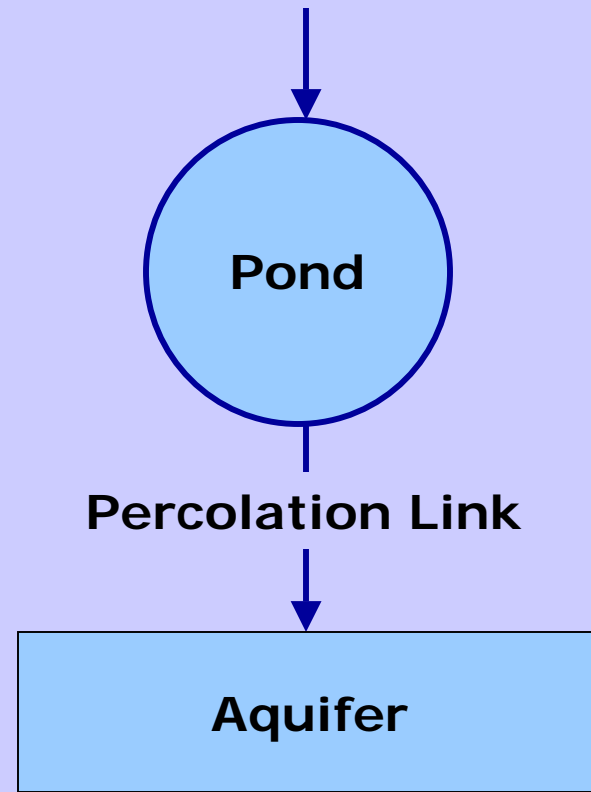


**Before Examining Multiple Ponds,
Let's Take a Look at How
Percolation from a Single Isolated
Pond is Modeled Using PercPack™.**

Surface Runoff

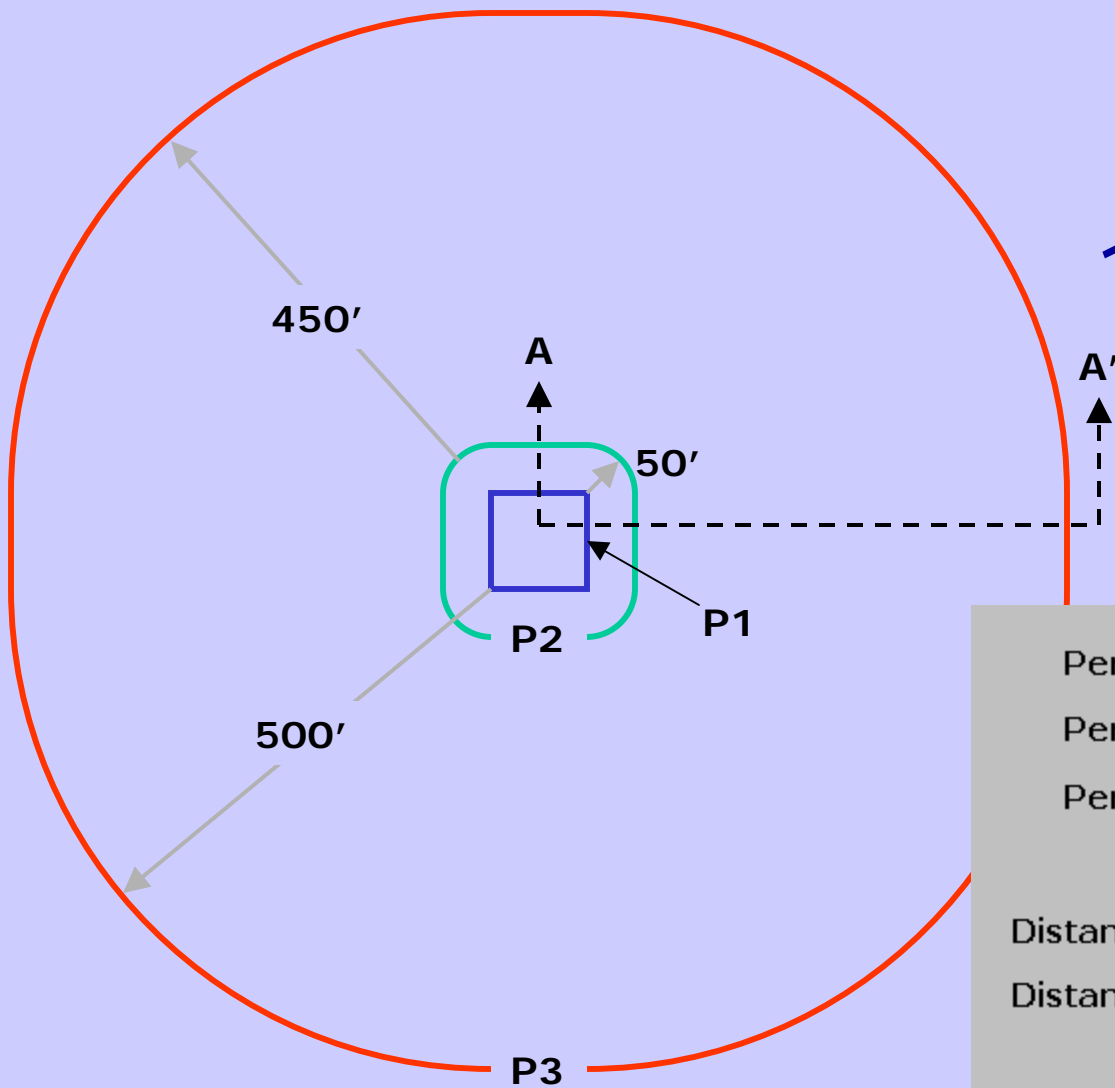


Drainage Basin



ICPR Schematic

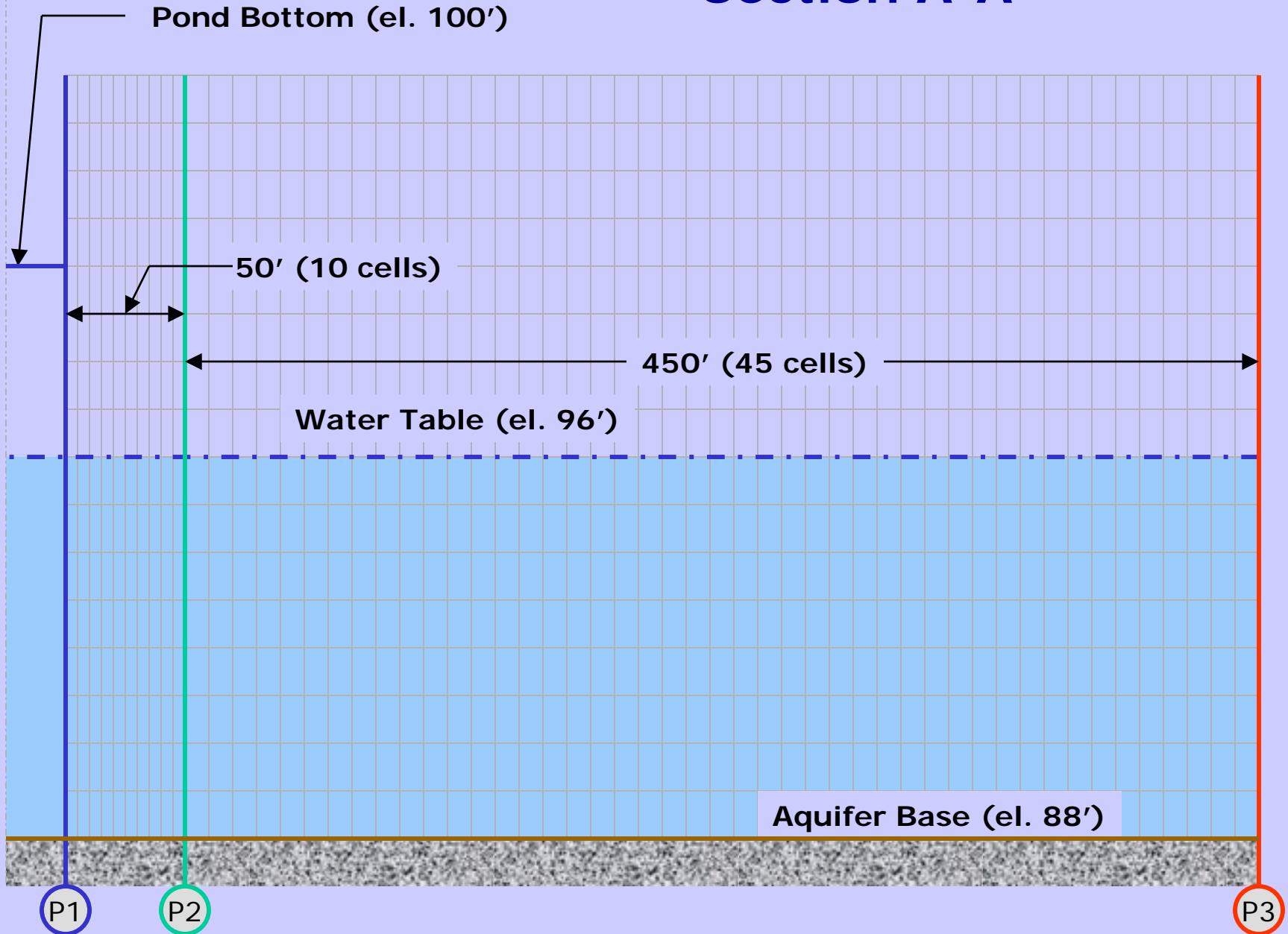
Computational Framework for a 100' Square Pond



Perimeter 1	400
Perimeter 2	714
Perimeter 3	3542
Distance 1 to 2	50
Distance 2 to 3	450
Num Cells 1 to 2	10
Num Cells 2 to 3	45

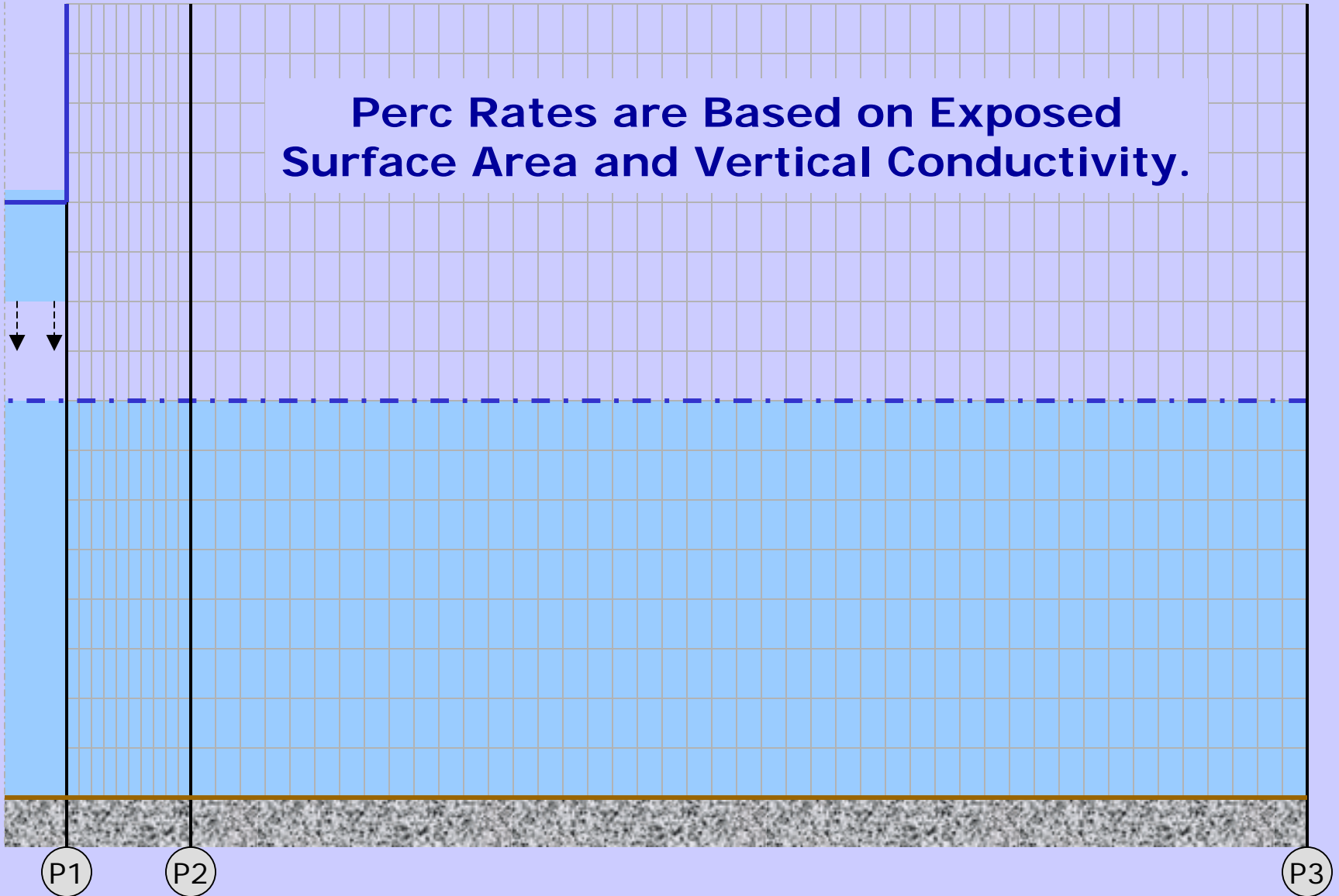
Percolation Link Parameters

Section A-A'



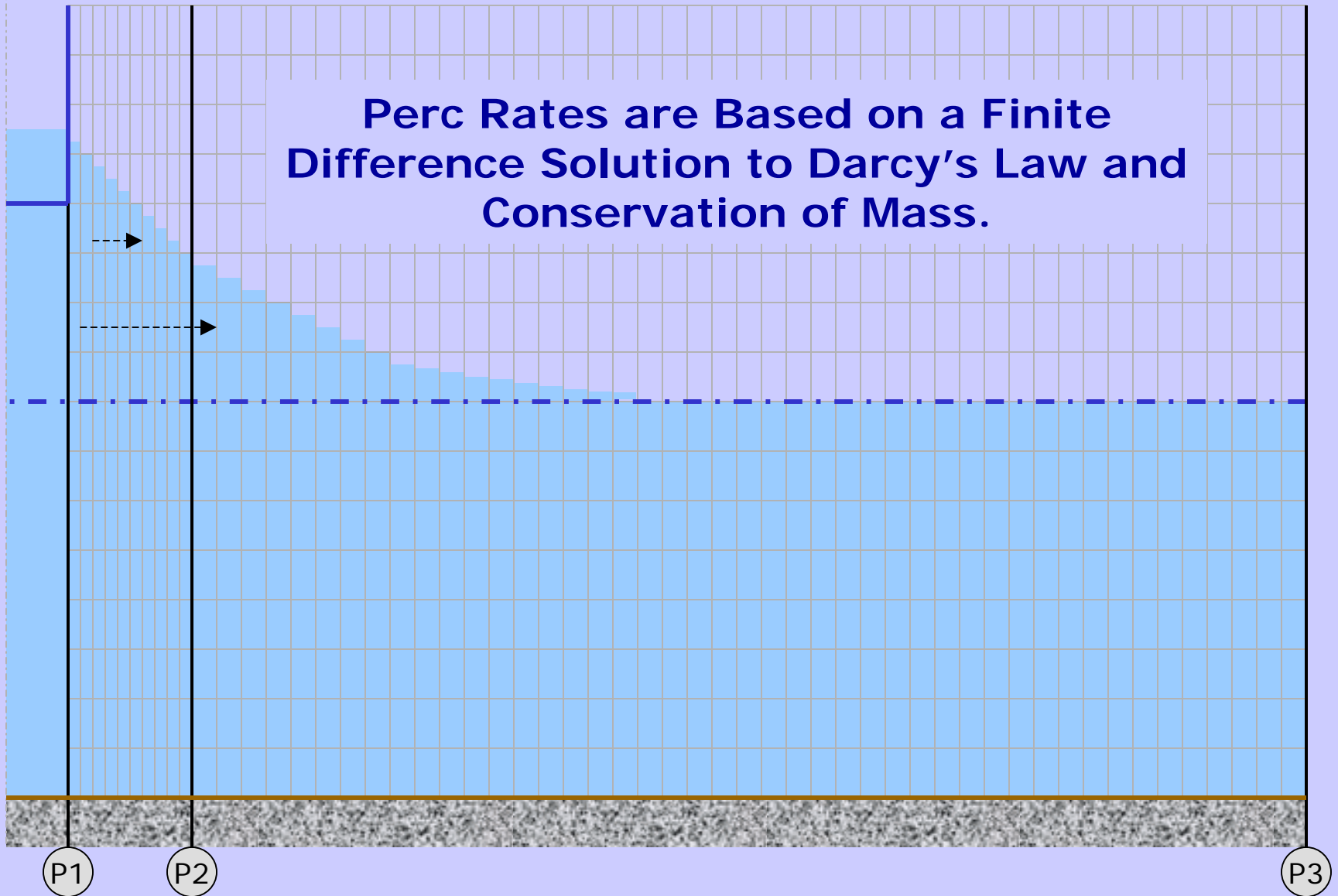
Vertical Unsaturated Flow

Perc Rates are Based on Exposed Surface Area and Vertical Conductivity.



Horizontal Saturated Flow

Perc Rates are Based on a Finite Difference Solution to Darcy's Law and Conservation of Mass.



Aquifer Base Elevation	88
Water Table Elevation	96
Annual Recharge Rate	0
Horizontal Conductivity	15
Vertical Conductivity	7.5
Effective Porosity	0.3
Suction Head	4.17
Layer Thickness	4

Parameters Related to the Surficial Aquifer

Aquifer Base Elevation	88
Water Table Elevation	96
Annual Recharge Rate	0
Horizontal Conductivity	15
Vertical Conductivity	7.5
Effective Porosity	0.3
Suction Head	4.17
Layer Thickness	4

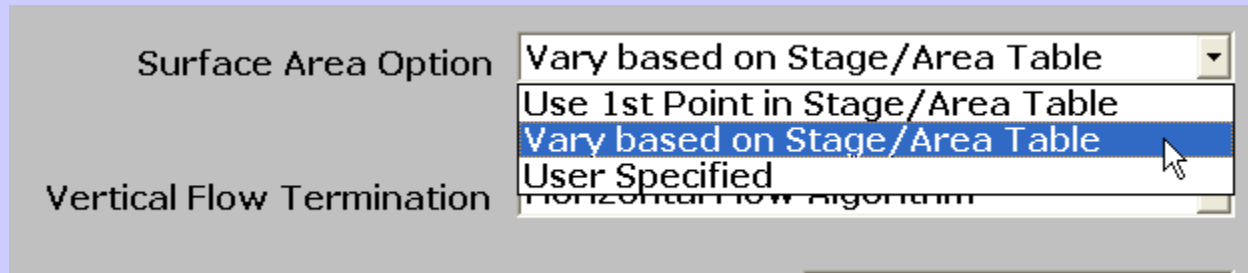
The “Water Table Elevation” is used to initialize each finite difference cell.

Aquifer Base Elevation	88
Water Table Elevation	96
Annual Recharge Rate	0
Horizontal Conductivity	15
Vertical Conductivity	7.5
Effective Porosity	0.3
Suction Head	4.17
Layer Thickness	4

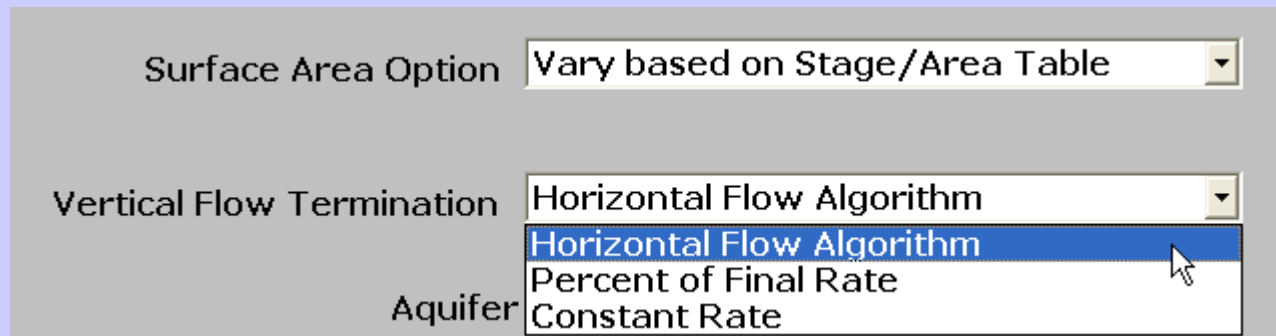
If the “Annual Recharge Rate” is zero, a “**fixed head boundary condition**” is used at the P3 ring. Otherwise, a “**zero flow boundary condition**” is used.

Aquifer Base Elevation	88
Water Table Elevation	96
Annual Recharge Rate	0
Horizontal Conductivity	15
Vertical Conductivity	7.5
Effective Porosity	0.3
Suction Head	4.17
Layer Thickness	4

The “Layer Thickness” is the length of the unsaturated zone directly below the bottom of the pond. If it is set to a very small value or zero, no vertical unsaturated flow will occur.



“Surface Area Option” used for Vertical Unsaturated Flow.



“Vertical Flow Termination” used for Transition to Horizontal Saturated Flow.

Example Hydrologic Data Set

Drainage Basin Data

Area: 5 acres

N-DCIA Curve Number: 65

DCIA: 23%

TC: 20 minutes

Peak Factor: 323

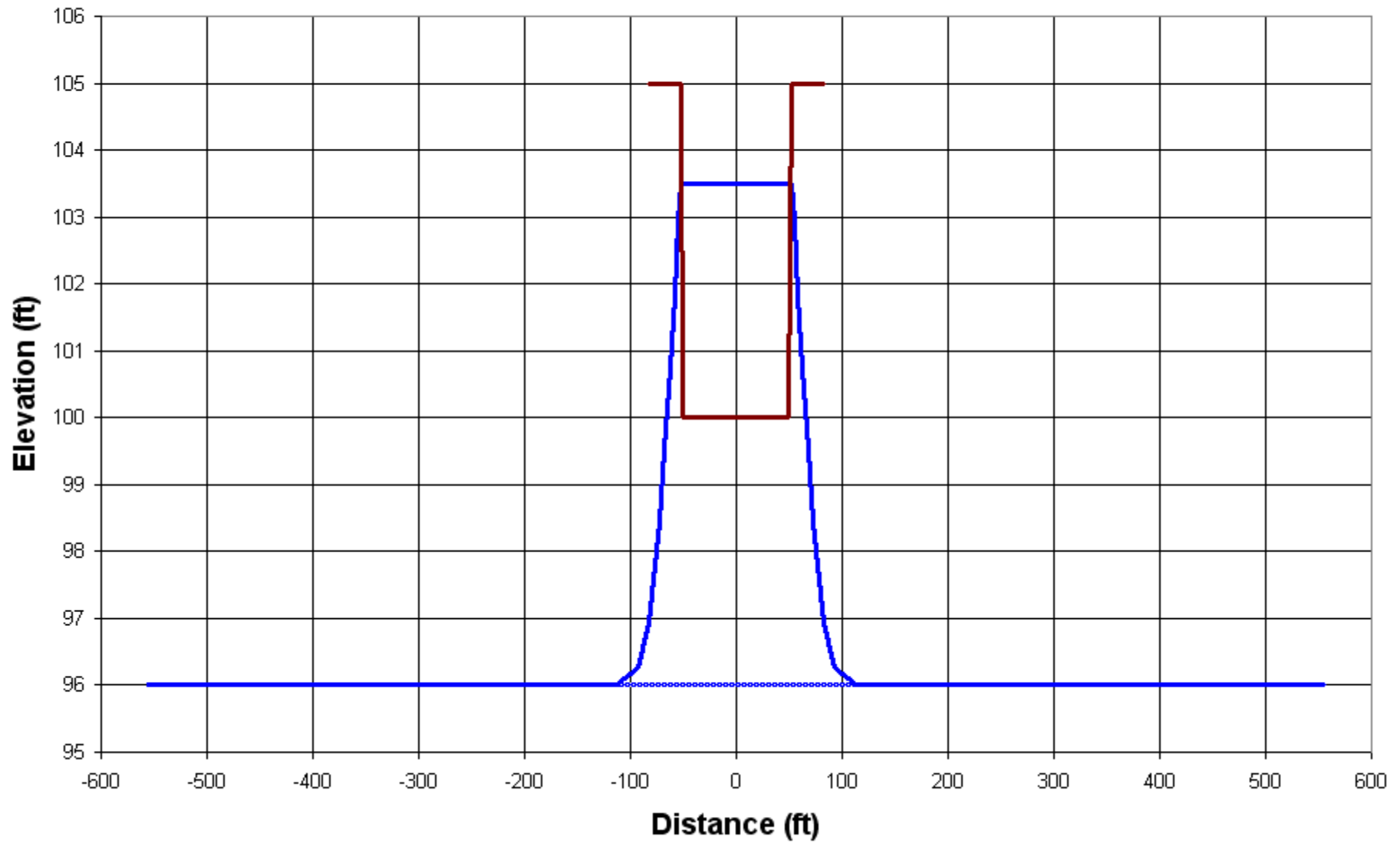
Storm Data

Distribution: Florida Modified

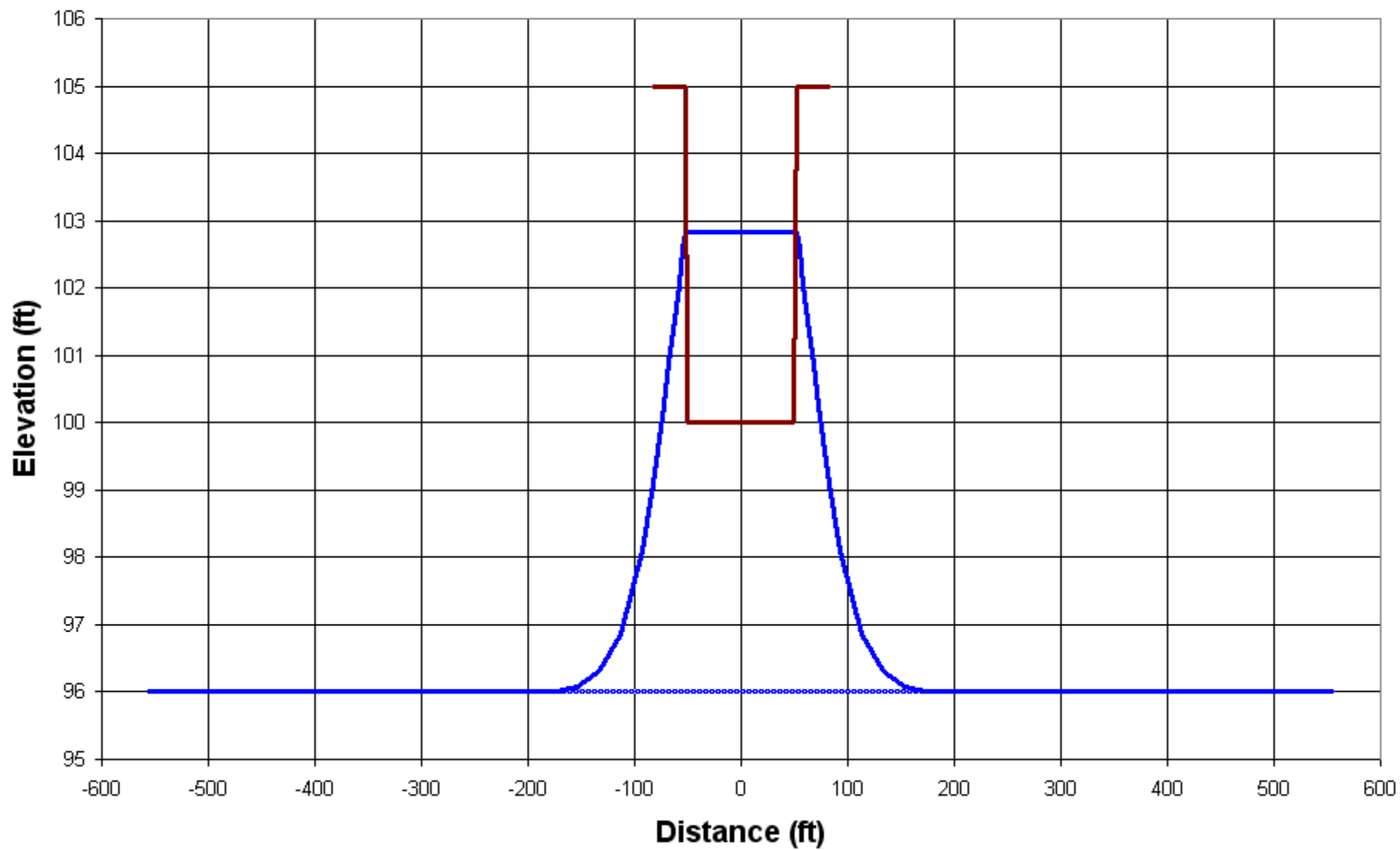
Total Rainfall: 8.6"

Duration: 24 hours

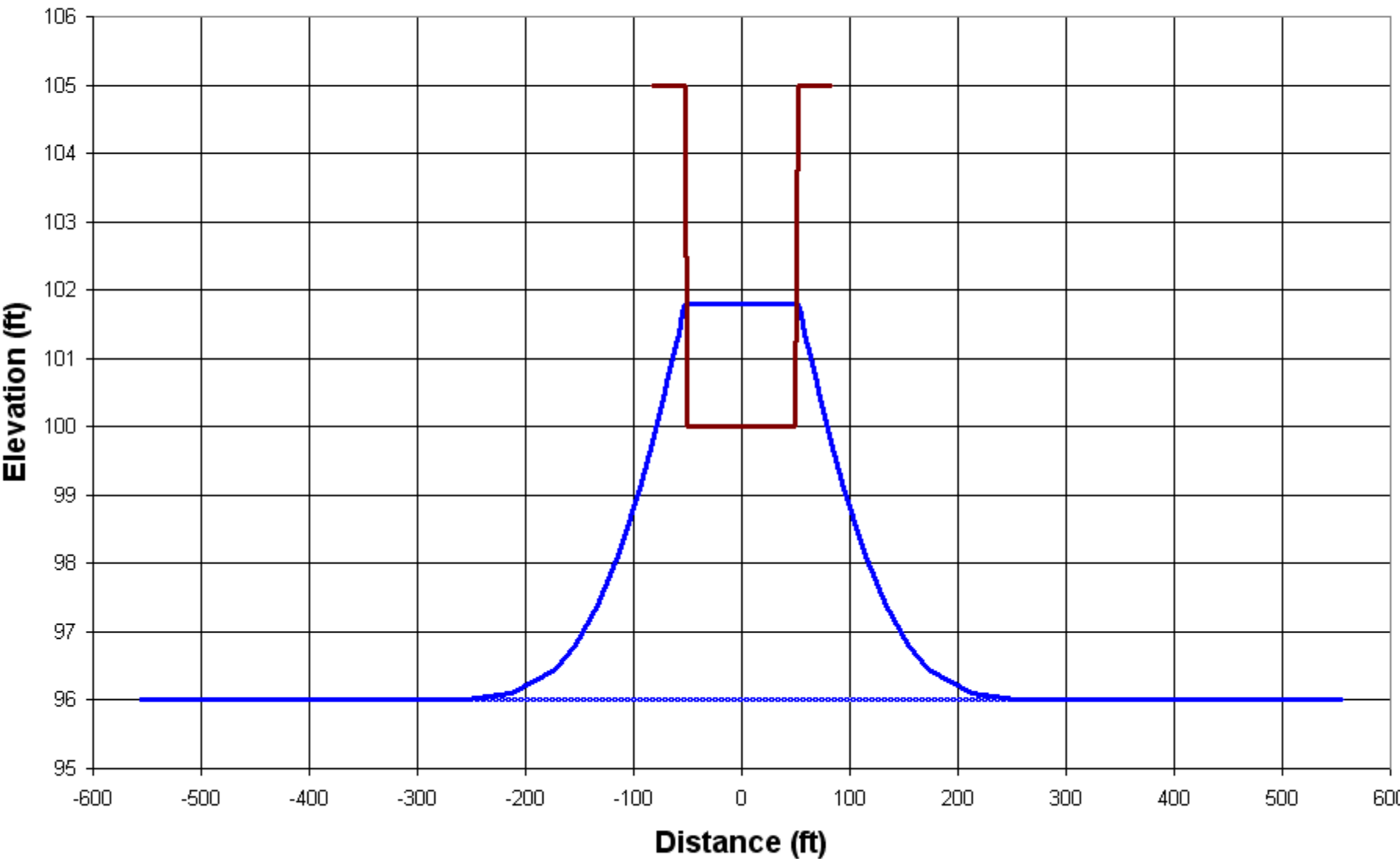
Groundwater Mound - 1 Day



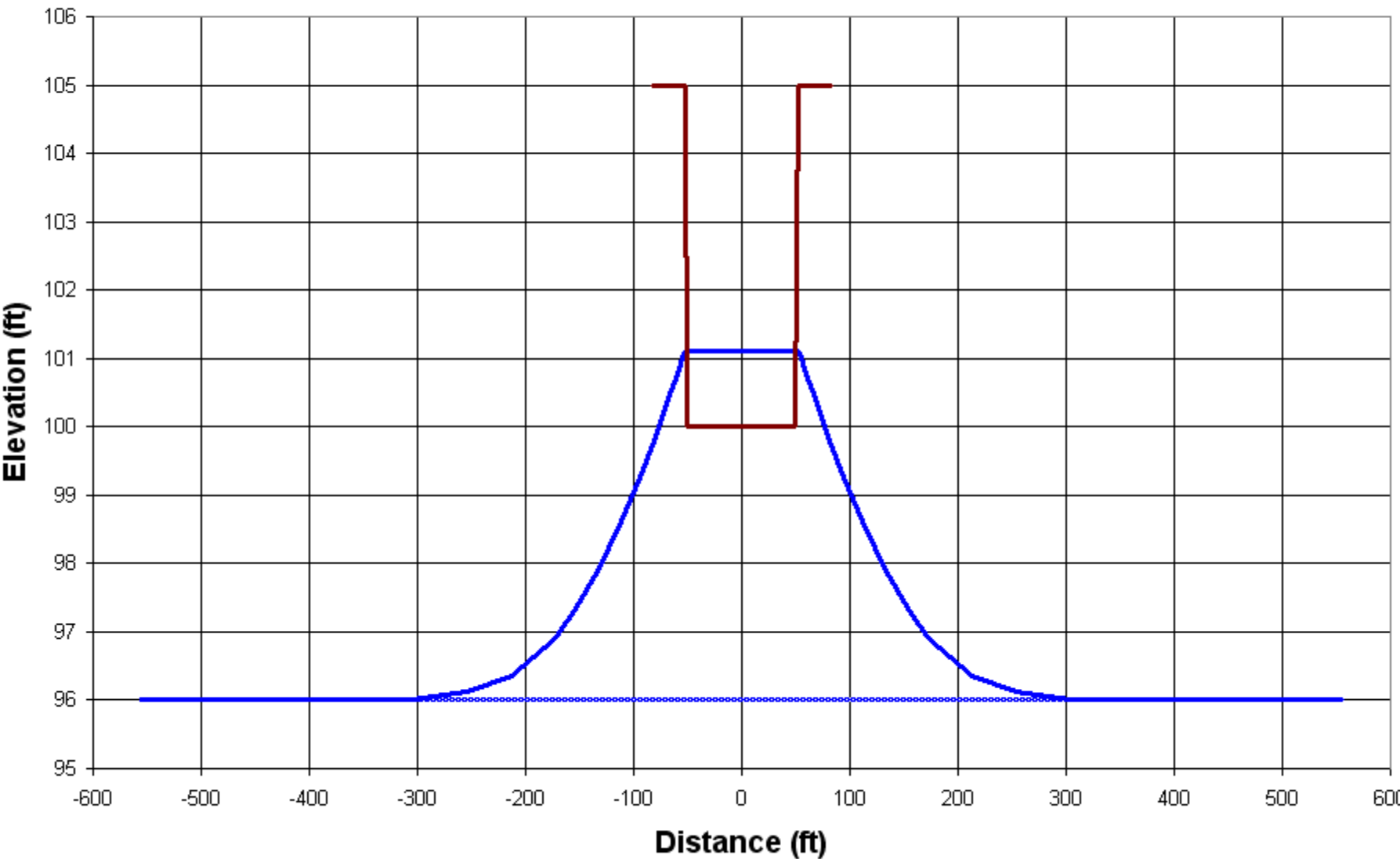
Groundwater Mound - 2 Days



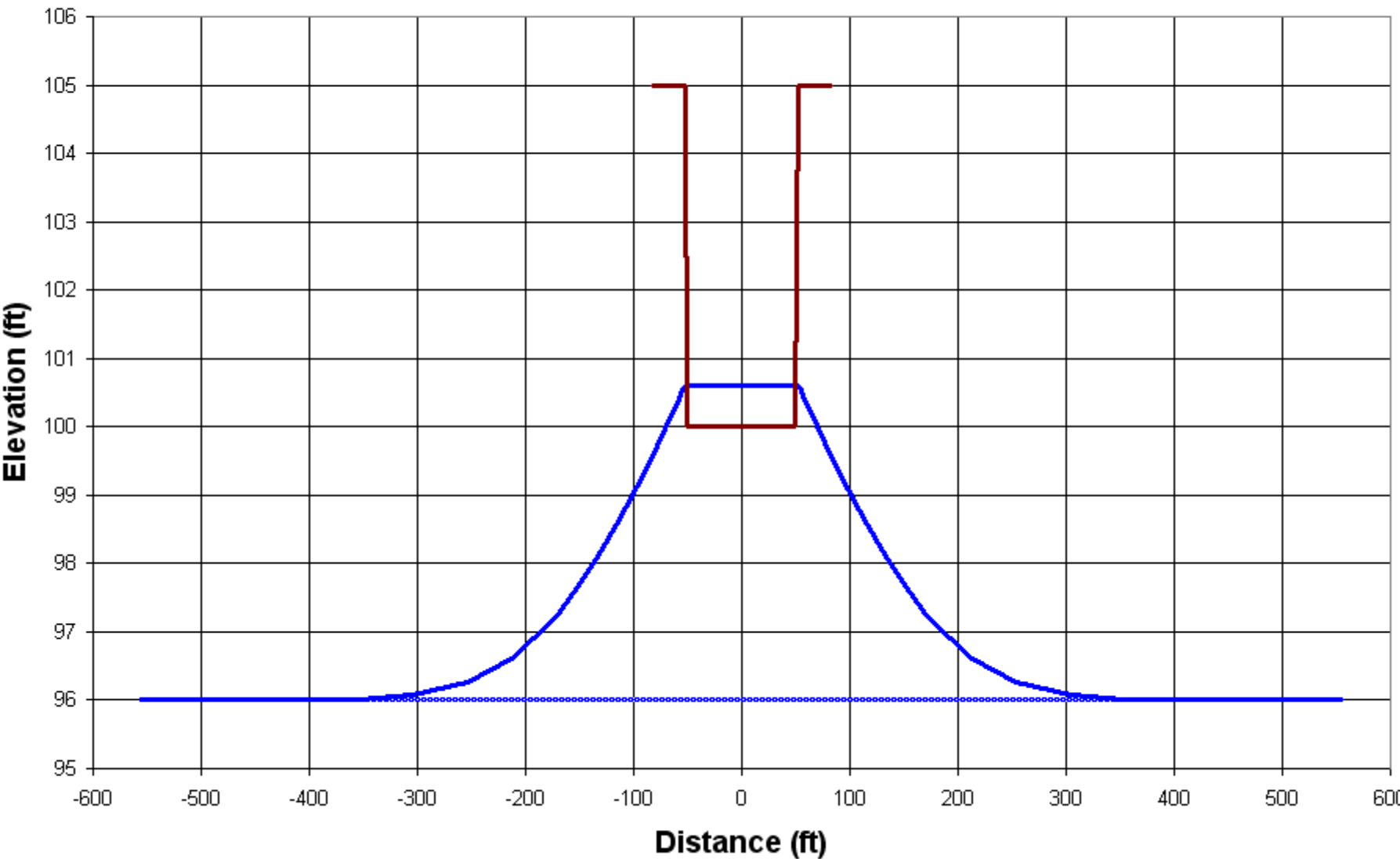
Groundwater Mound - 4 Days



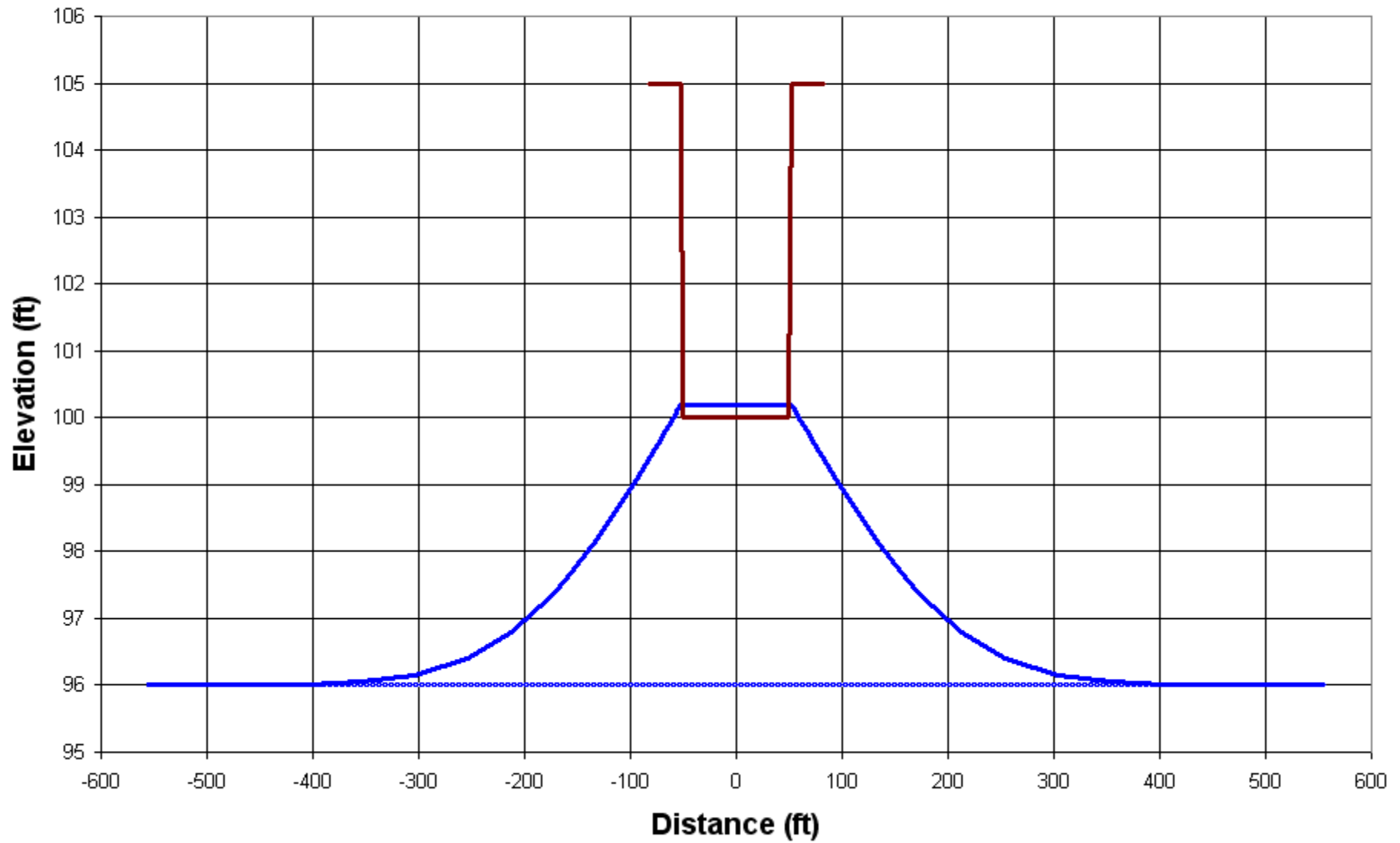
Groundwater Mound - 6 Days



Groundwater Mound - 8 Days



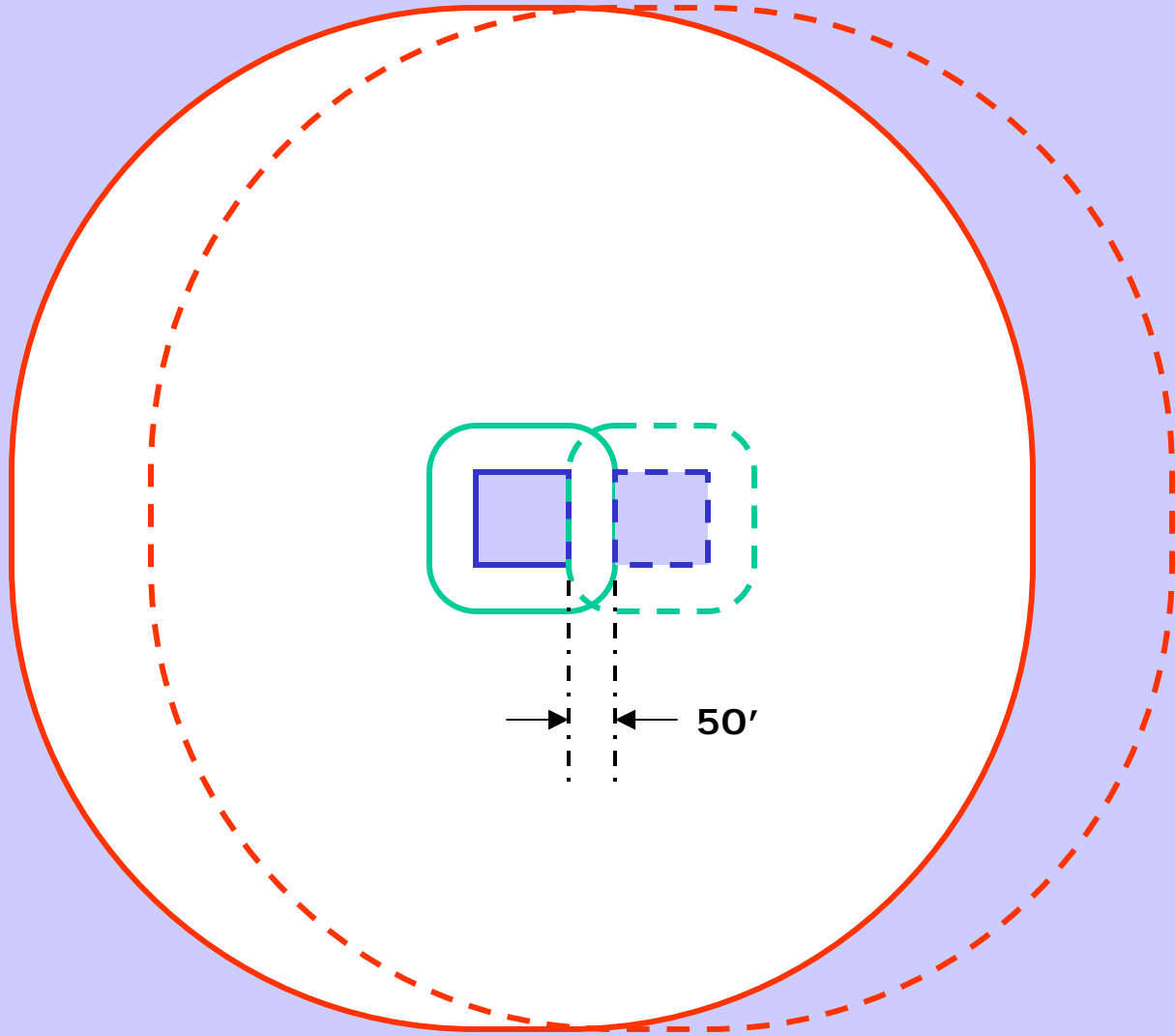
Groundwater Mound - 10 Days

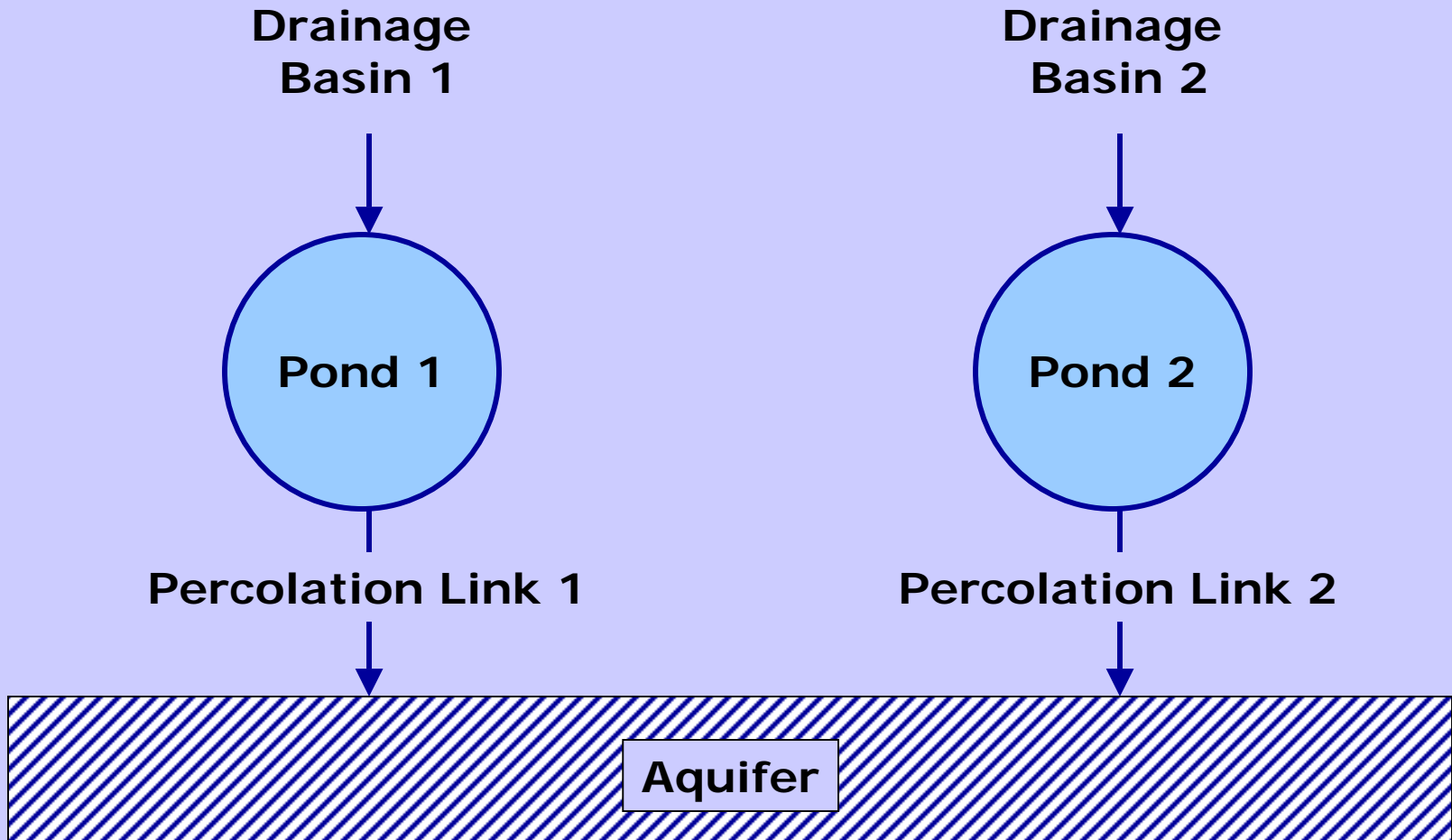


**Now, Let's Examine 2 Identical Ponds
In "Very" Close Proximity.**

Two Identical Ponds 50' Apart

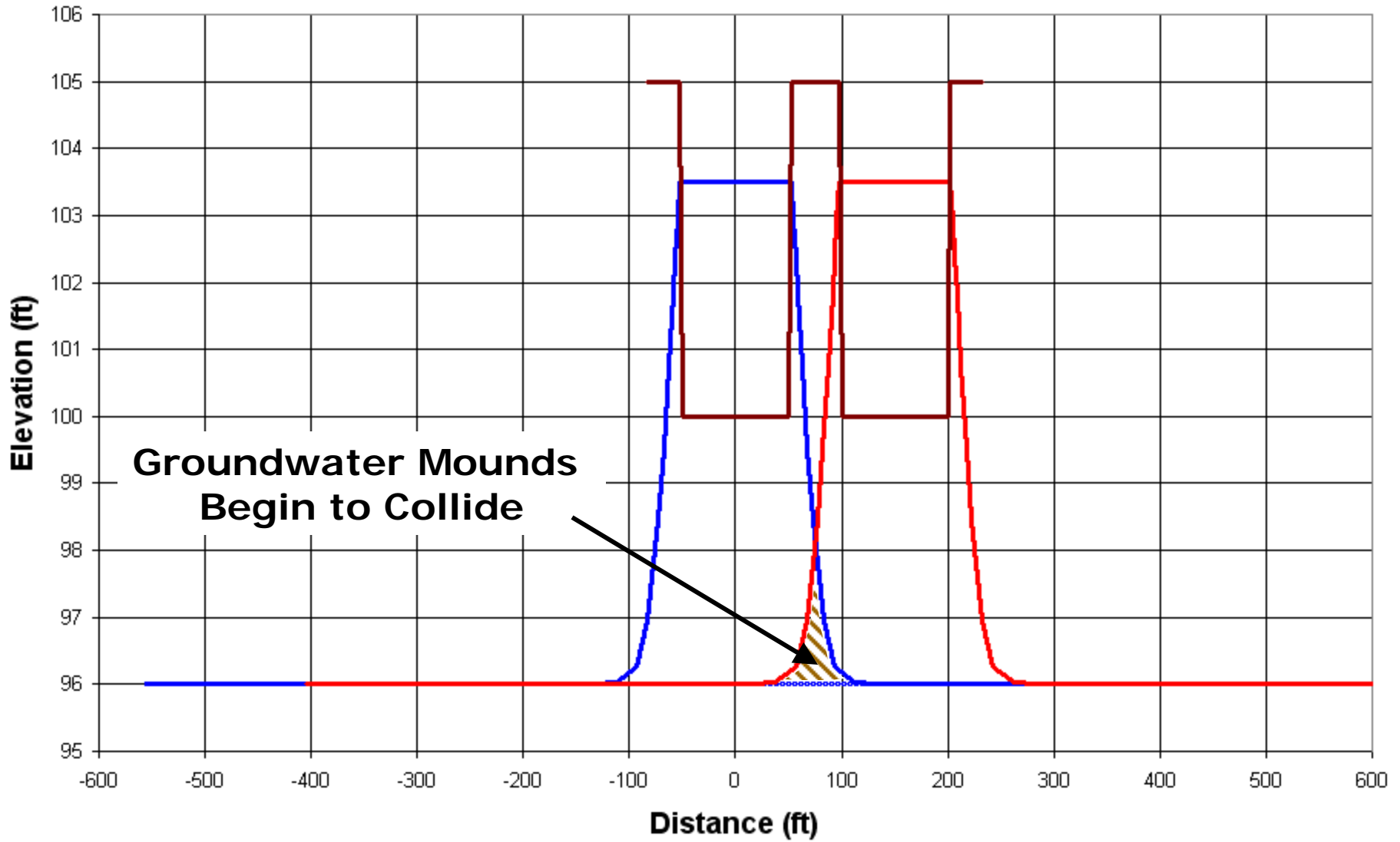
(Computational Rings Overlap)



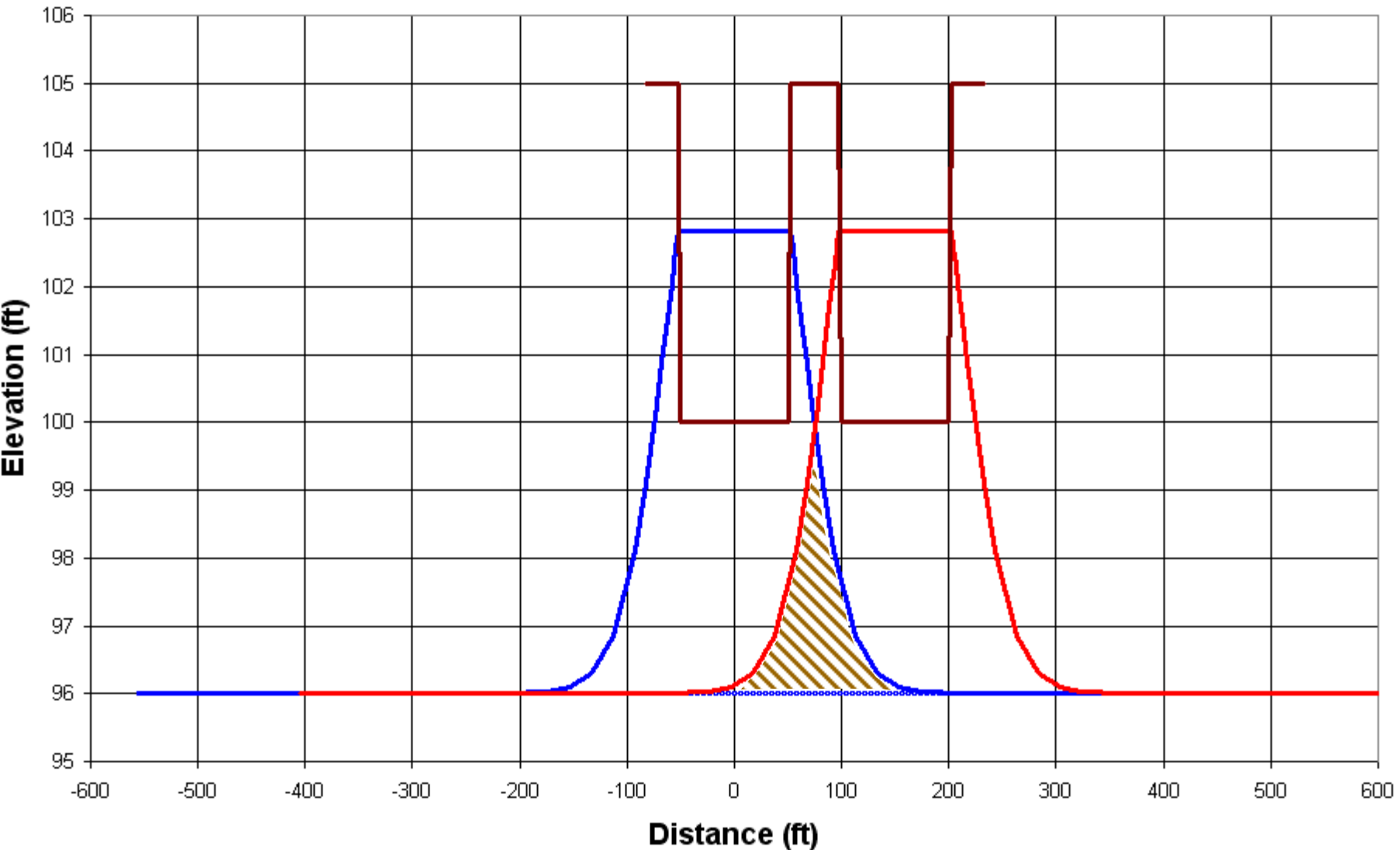


ICPR Schematic
(Perc Links are Independent)

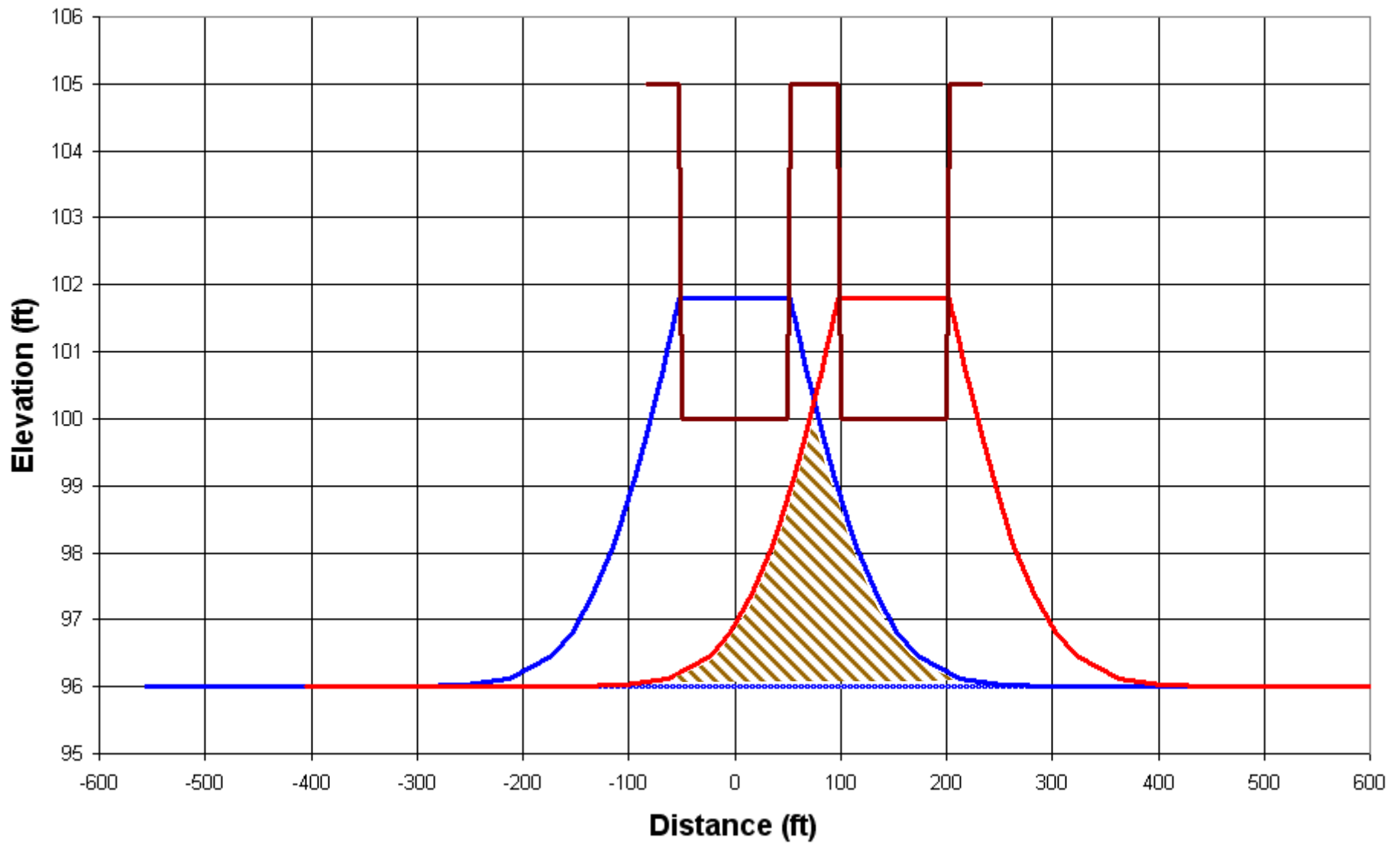
Groundwater Mound - 1 Day



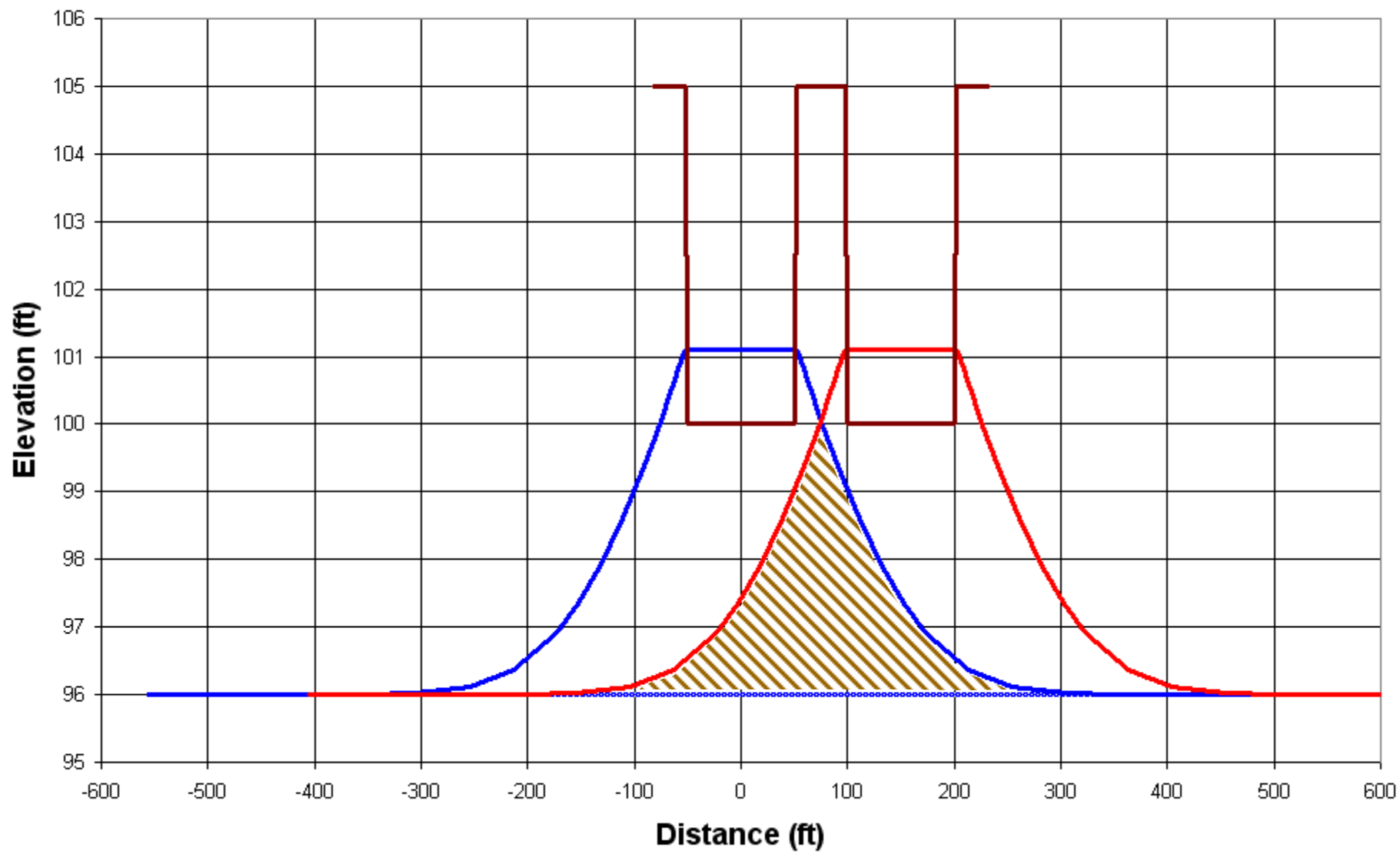
Groundwater Mound - 2 Days



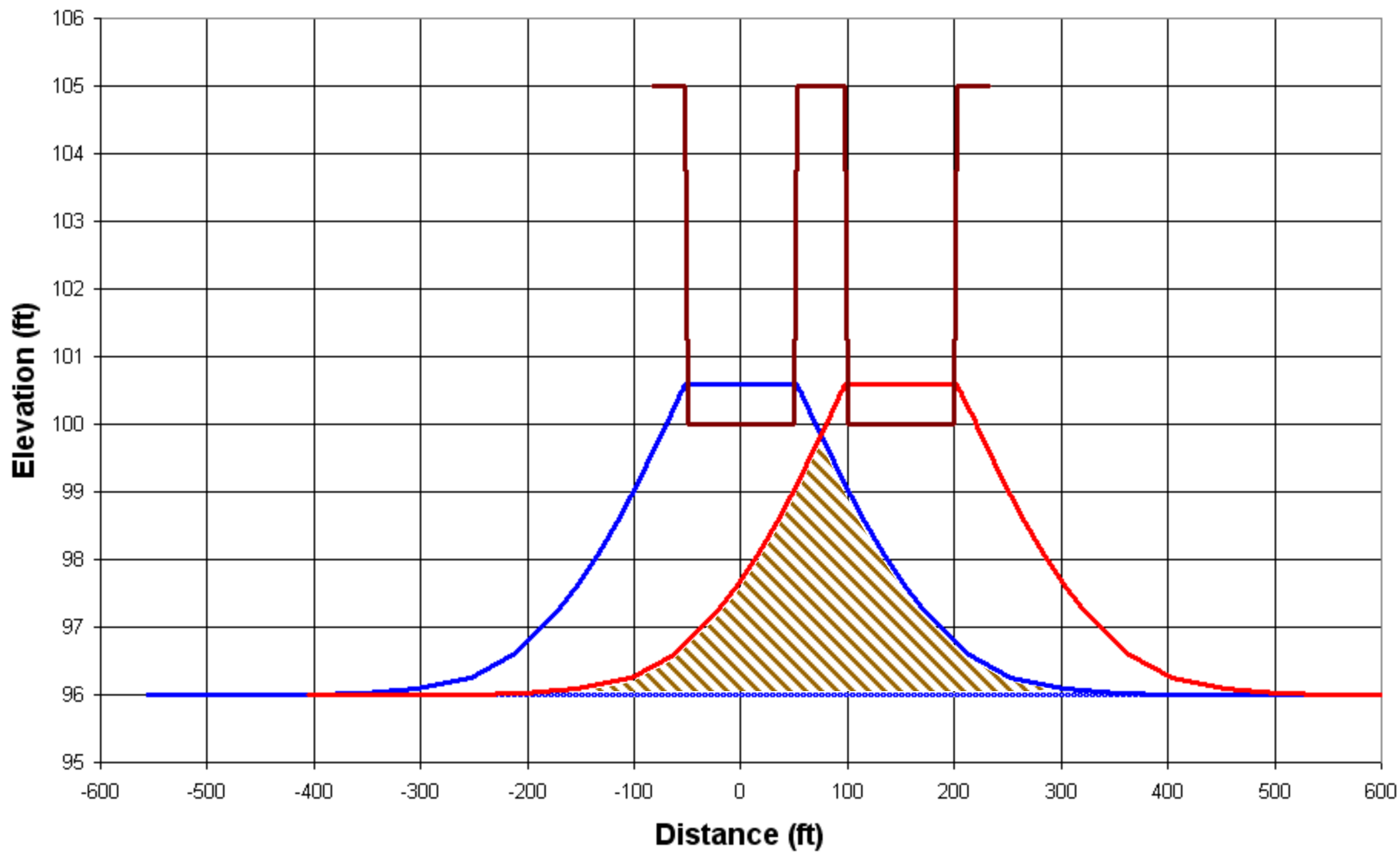
Groundwater Mound - 4 Days



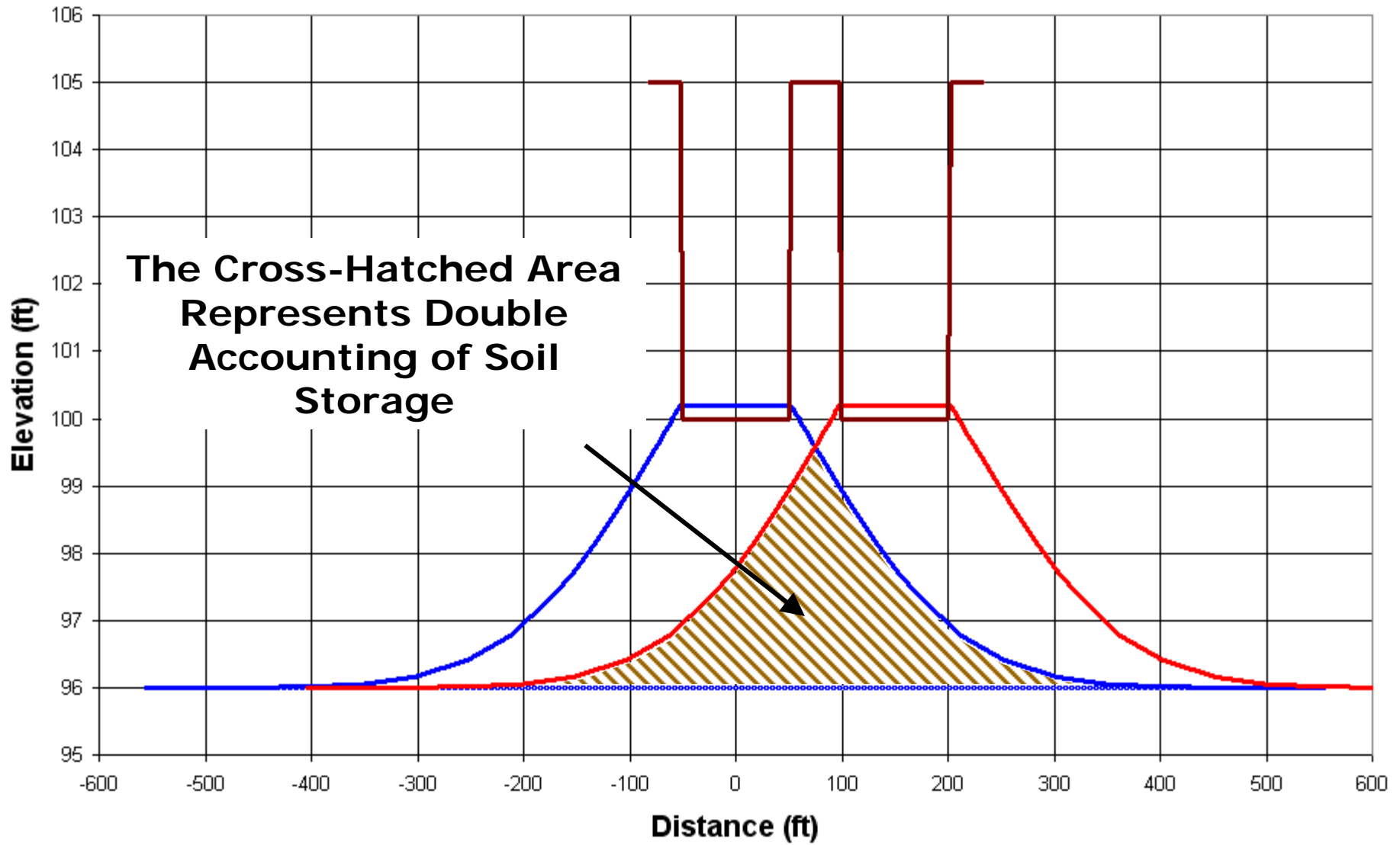
Groundwater Mound - 6 Days



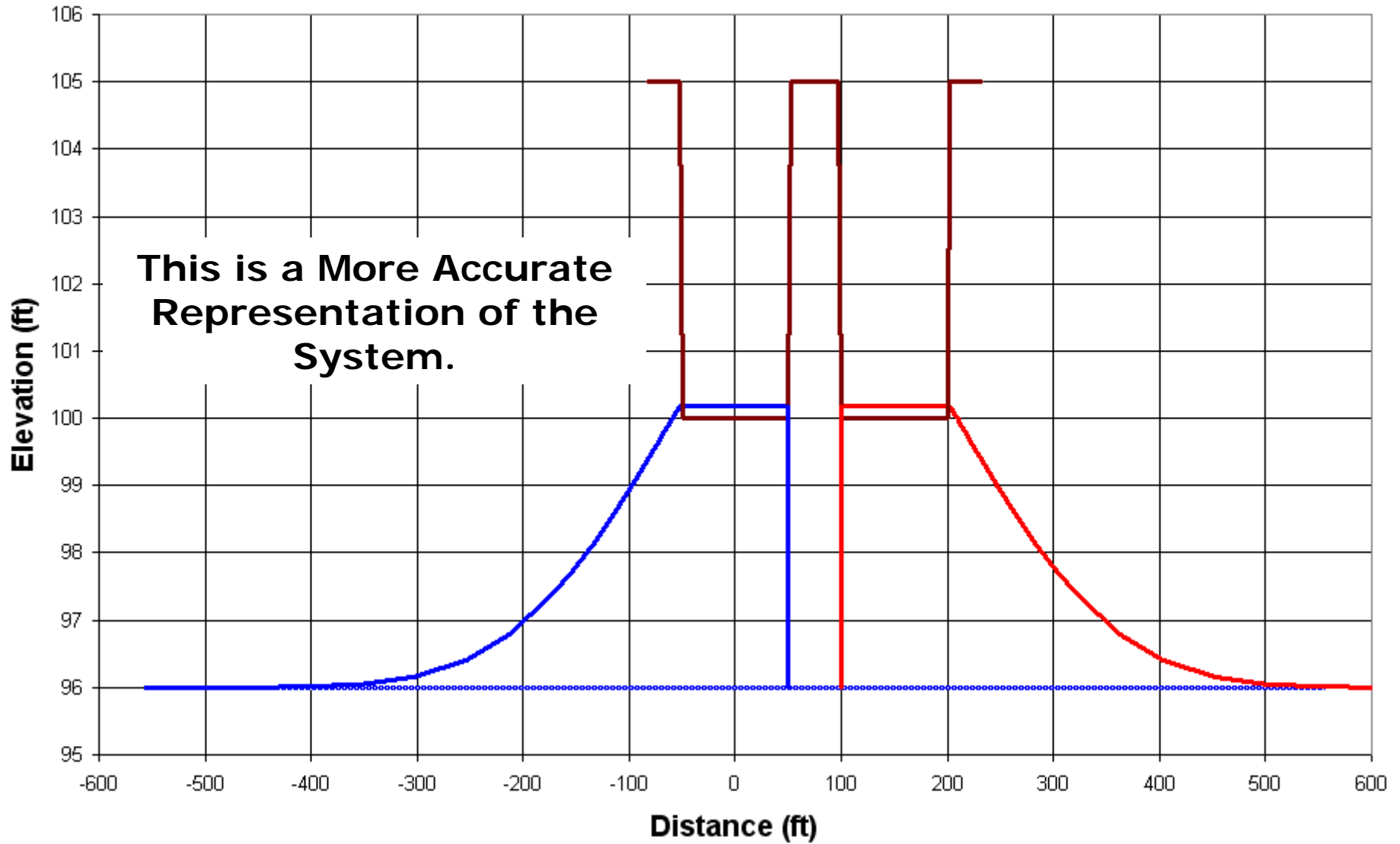
Groundwater Mound - 8 Days



Groundwater Mound - 10 Days



Groundwater Mound - 10 Days



The Approach Presented on the Following Slides Works Well When:

1. There are mild gradients between ponds
2. The horizontal conductivity is not exceptionally high

Steep gradients and/or super high conductivities require additional considerations that are beyond the scope of this presentation.

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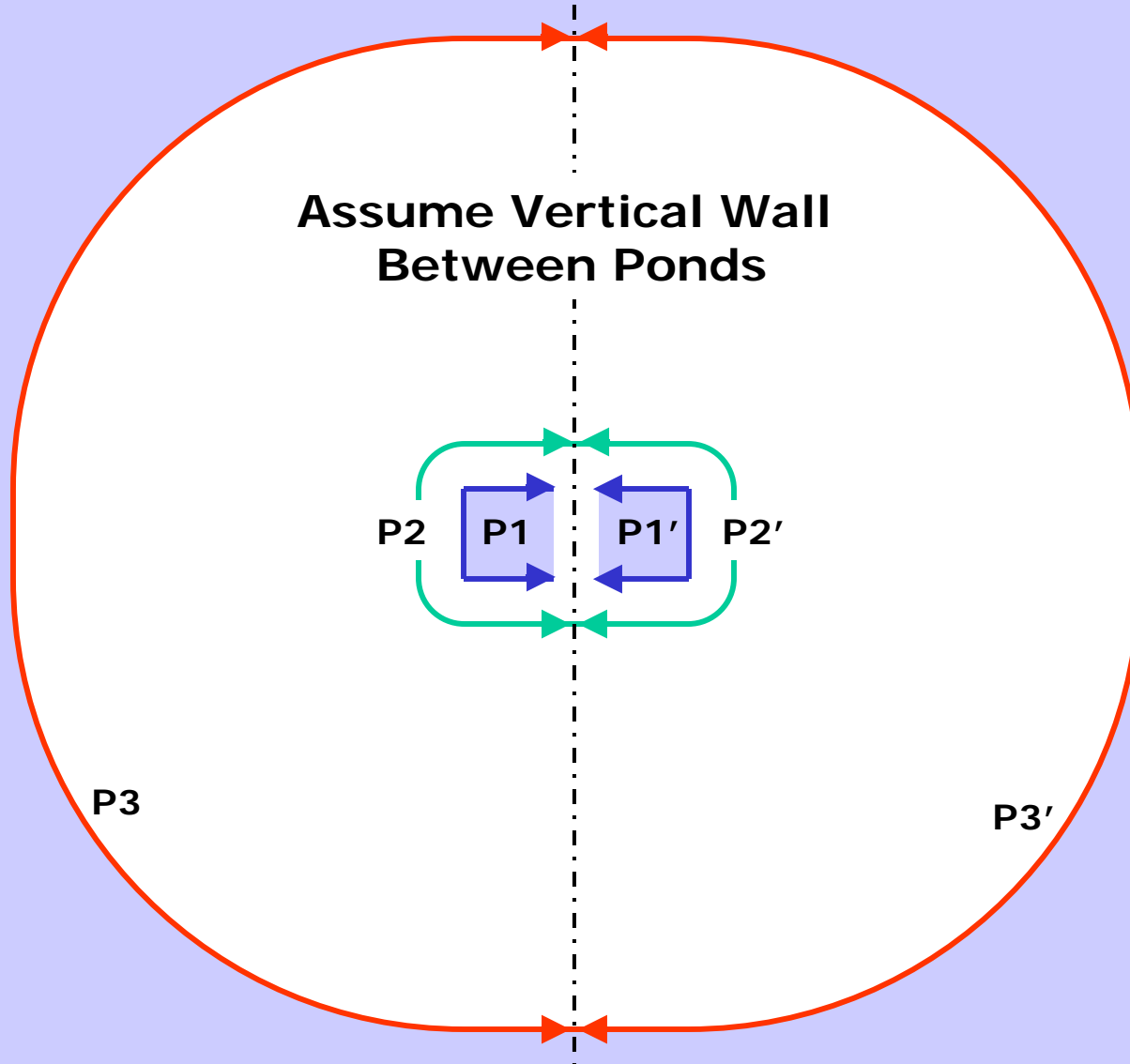
Steep gradients and/or super high conductivities require additional considerations that are beyond the scope of this presentation.

The Approach Presented on the Following Slides Works Well When:

1. There are mild gradients between ponds
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Steep gradients and/or super high conductivities require additional considerations that are beyond the scope of this presentation.

Treat Ponds as a Single System, Then Proportion the Perimeters



Adjusting the Computational Framework (Perc Link Data Forms)

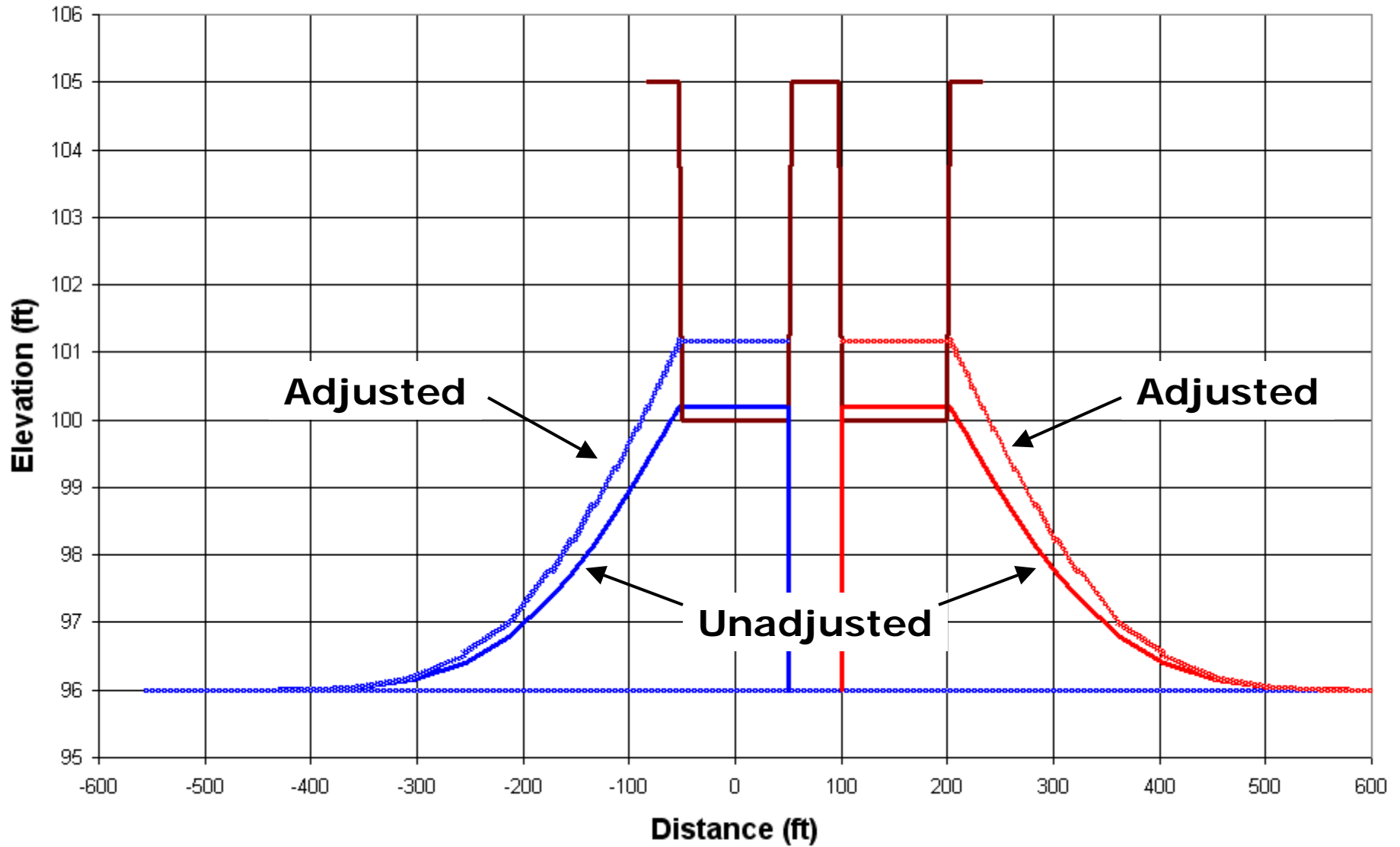
Perimeter 1	<input type="text" value="400"/>
Perimeter 2	<input type="text" value="714"/>
Perimeter 3	<input type="text" value="3542"/>
Distance 1 to 2	<input type="text" value="50"/>
Distance 2 to 3	<input type="text" value="450"/>
Num Cells 1 to 2	<input type="text" value="10"/>
Num Cells 2 to 3	<input type="text" value="45"/>

Single Pond

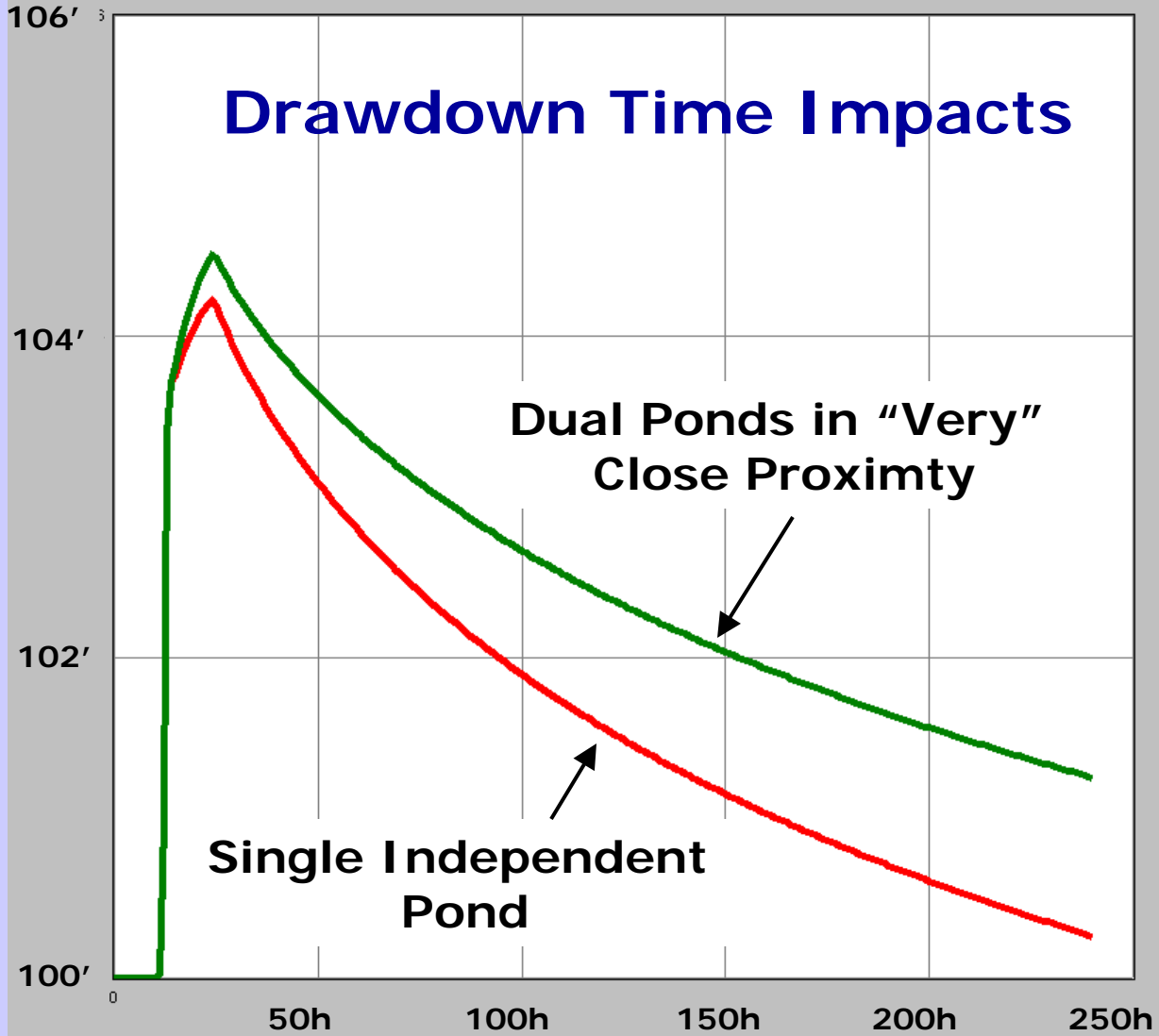
Perimeter 1	<input type="text" value="300"/>
Perimeter 2	<input type="text" value="507"/>
Perimeter 3	<input type="text" value="1921"/>
Distance 1 to 2	<input type="text" value="50"/>
Distance 2 to 3	<input type="text" value="450"/>
Num Cells 1 to 2	<input type="text" value="10"/>
Num Cells 2 to 3	<input type="text" value="45"/>

**Dual Ponds in
"Very" Close Proximty**

Groundwater Mound - 10 Days



Drawdown Time Impacts

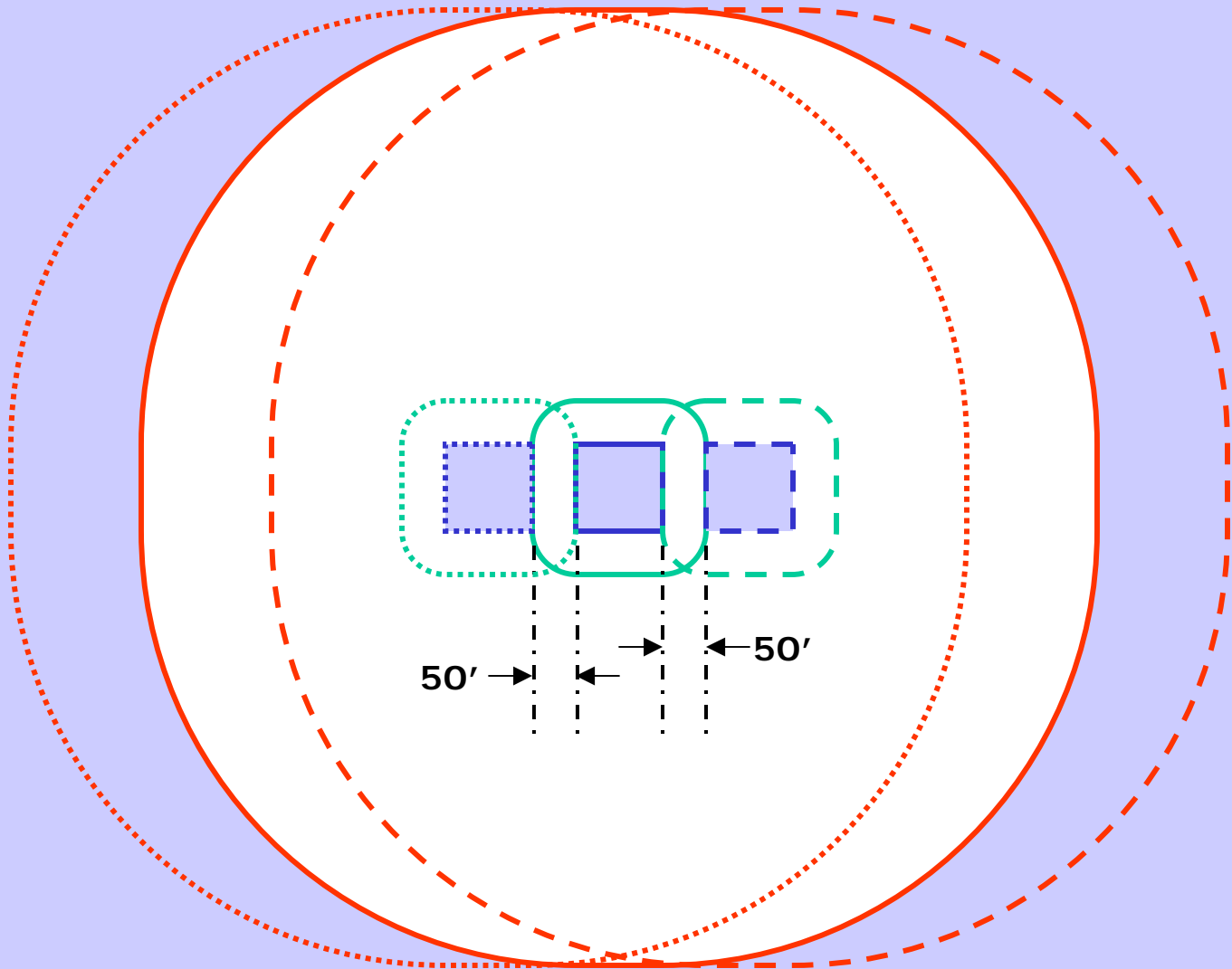


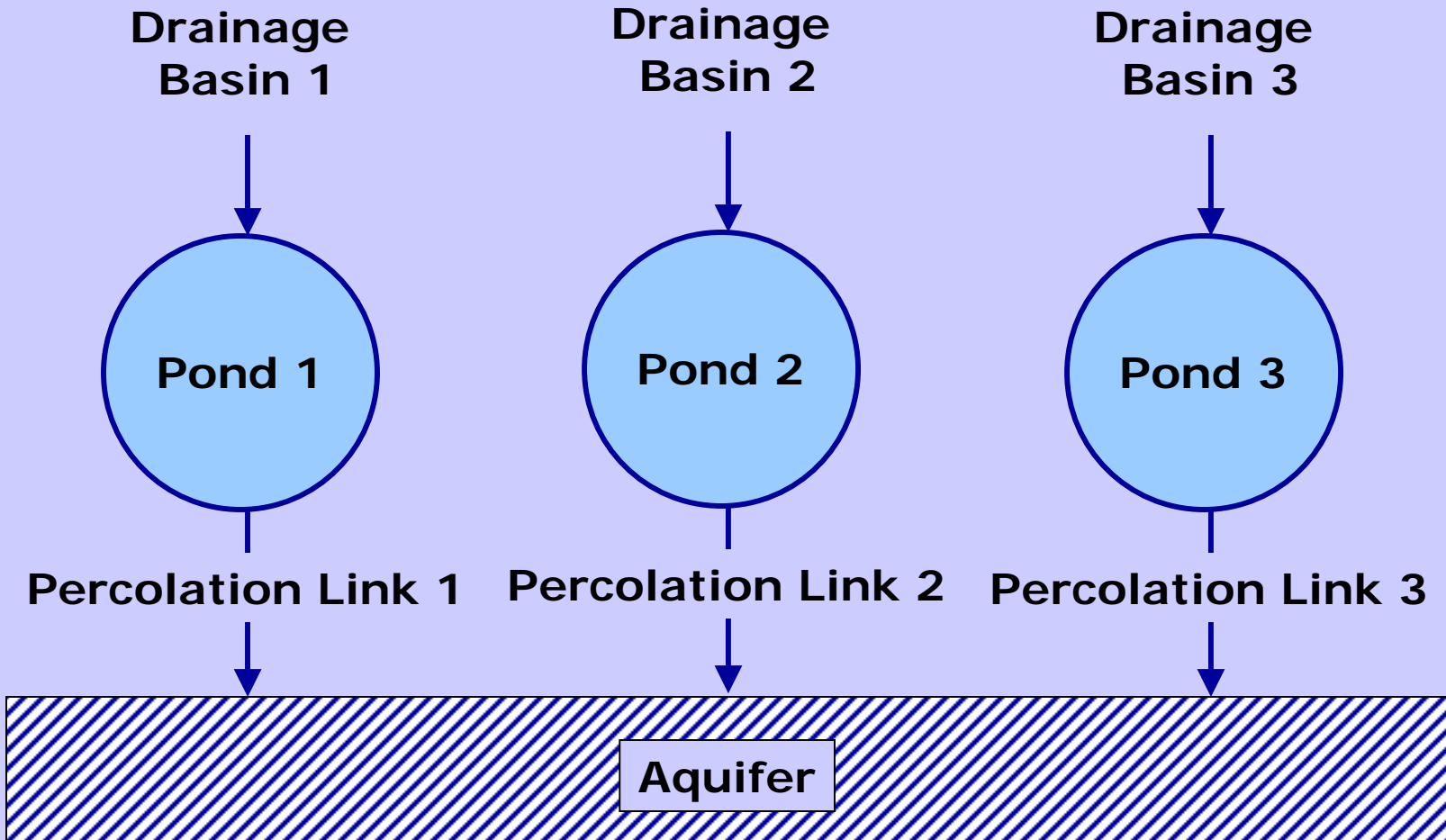
Dual Ponds in "Very"
Close Proximity

Single Independent
Pond

**Next, Let's Examine 3 Identical Ponds
In "Very" Close Proximity.**

Three Ponds 50' Apart

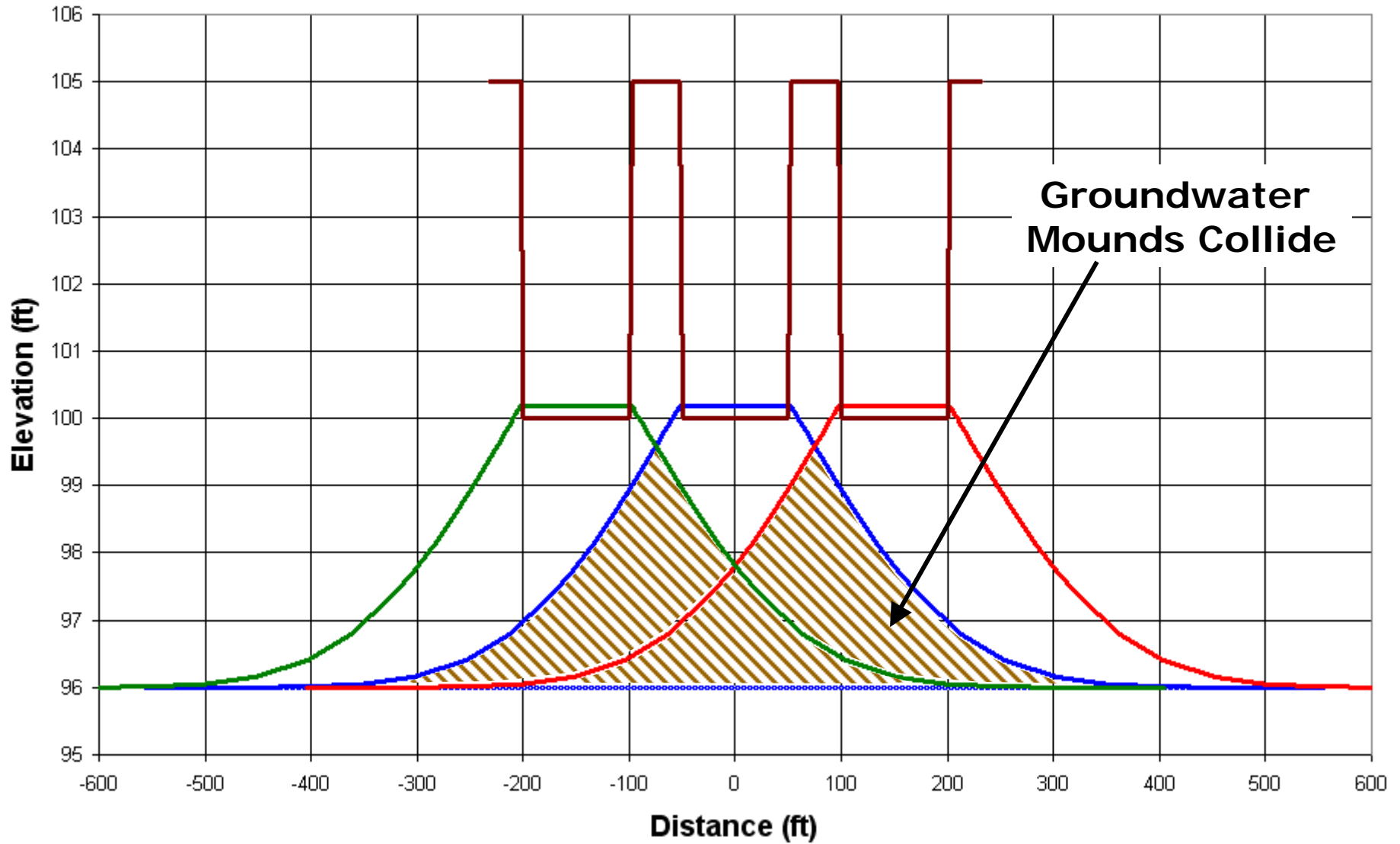




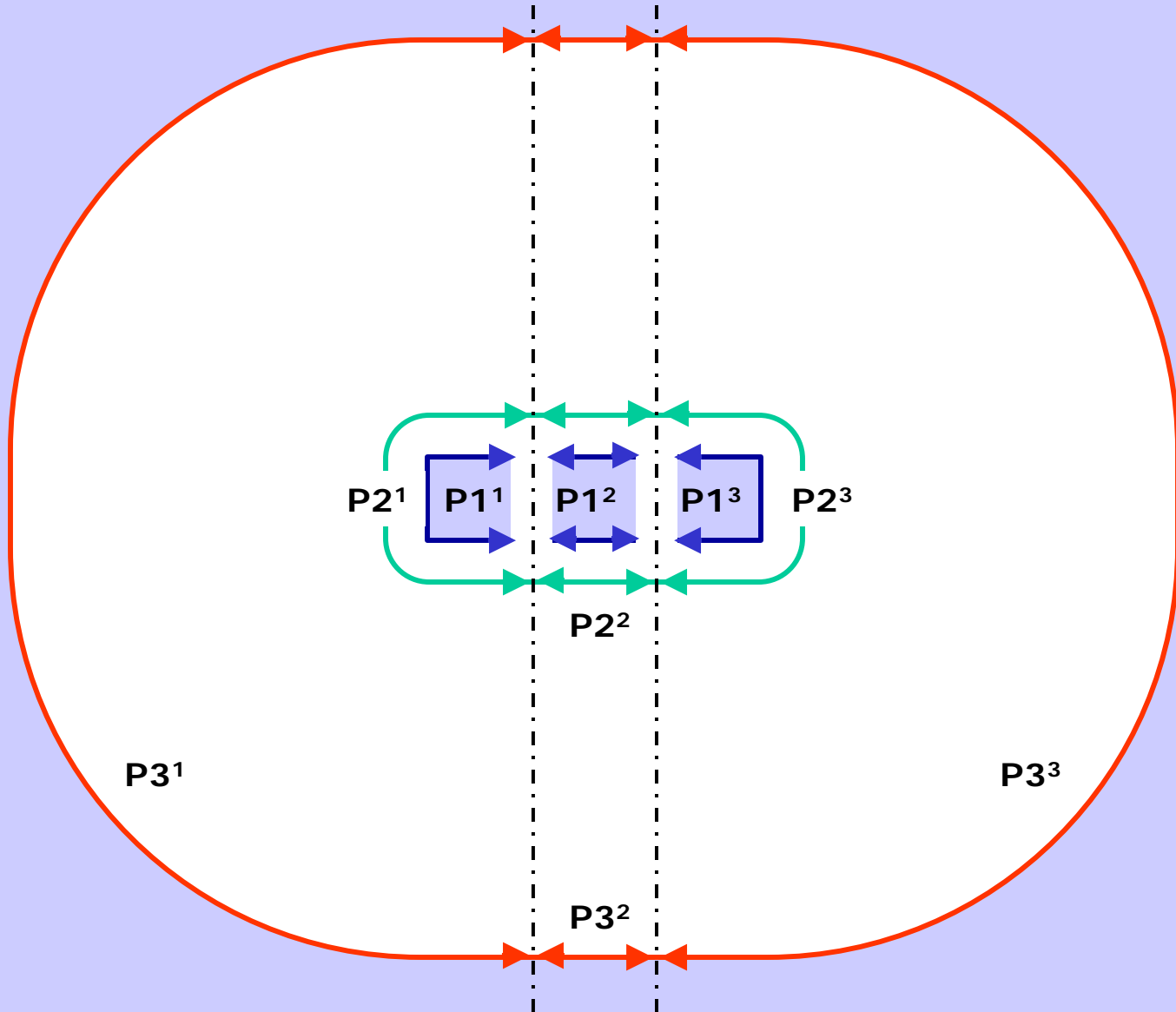
ICPR Schematic

(Perc Links are Independent)

Groundwater Mound - 10 Days



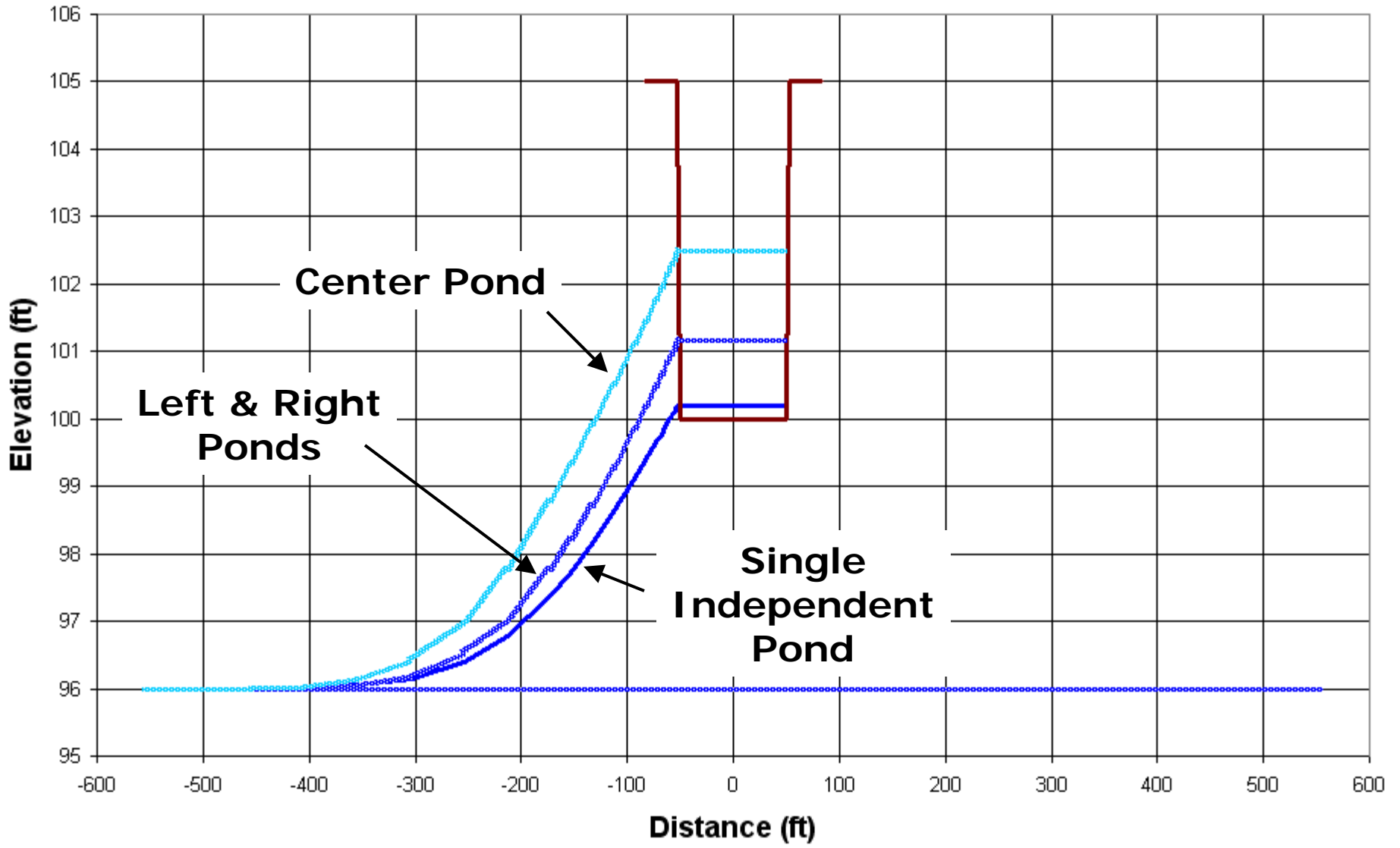
Treat Ponds as a Single System, Then Proportion the Perimeters

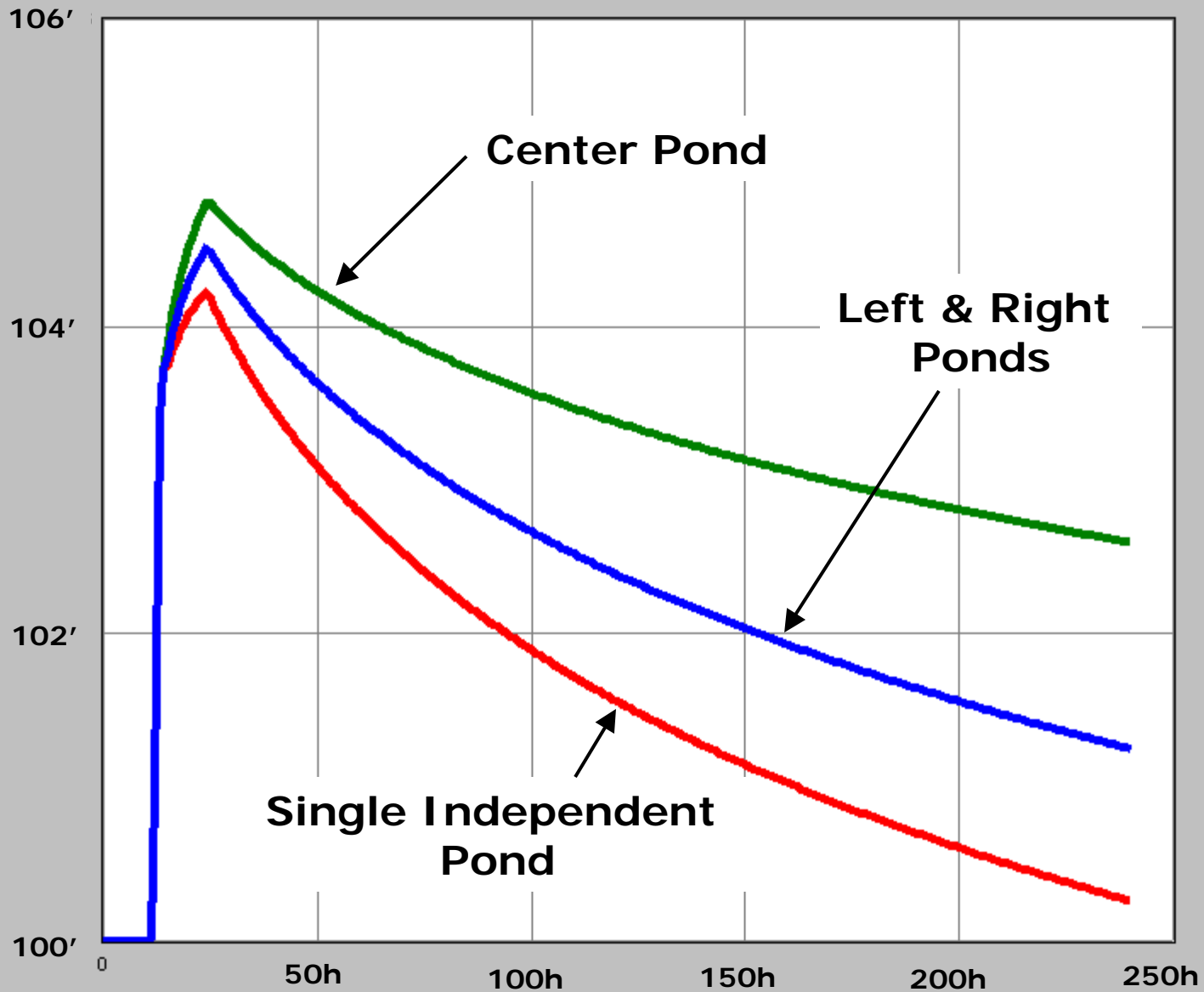


Adjustments to Perimeters for Three-Pond System

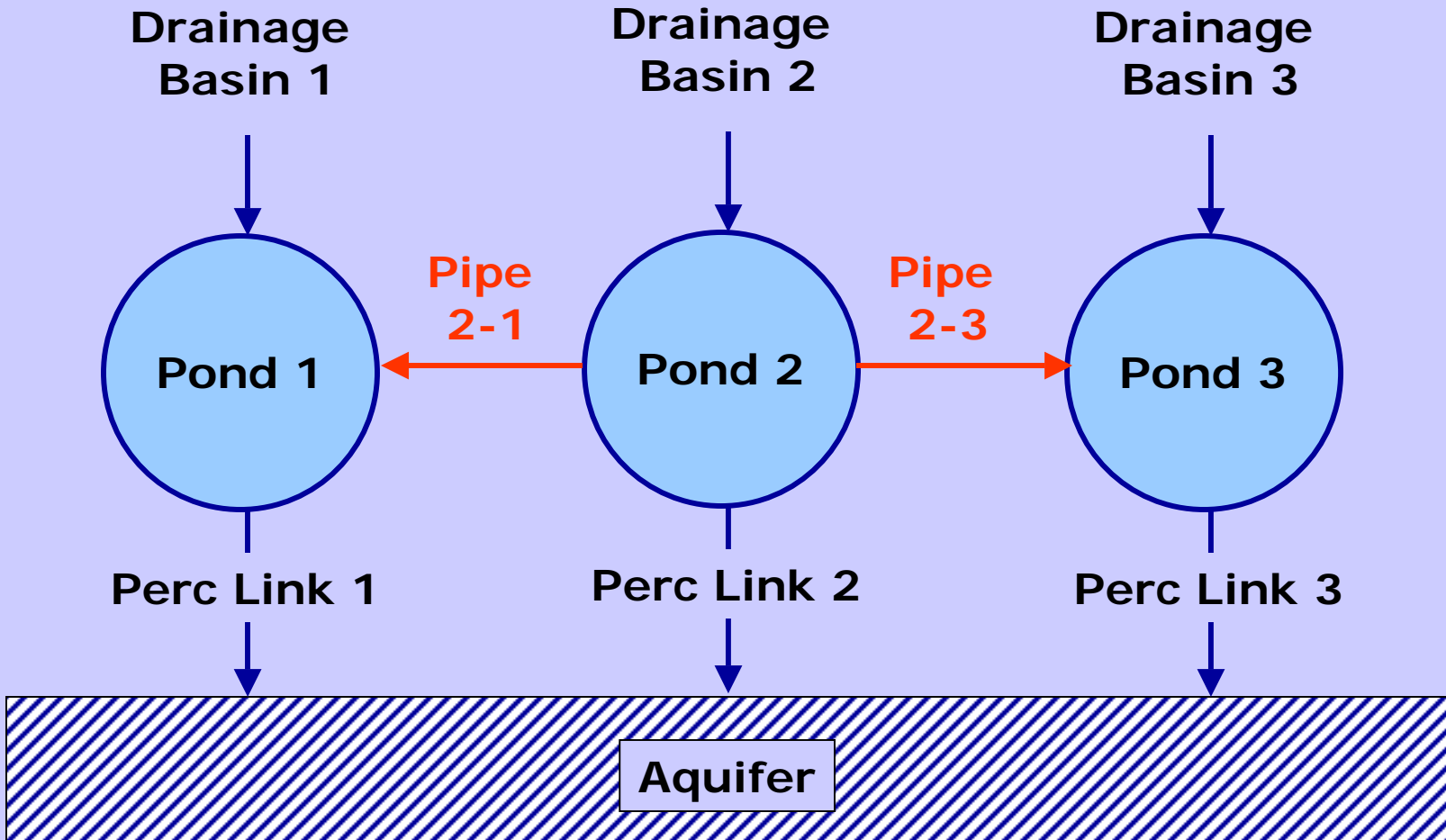
	Single Independent Pond	Left & Right Ponds	Center Pond
Perimeter 1	400'	300'	200'
Perimeter 2	714'	507'	300'
Perimeter 3	3542'	1921'	300'

Groundwater Mound - 10 Days



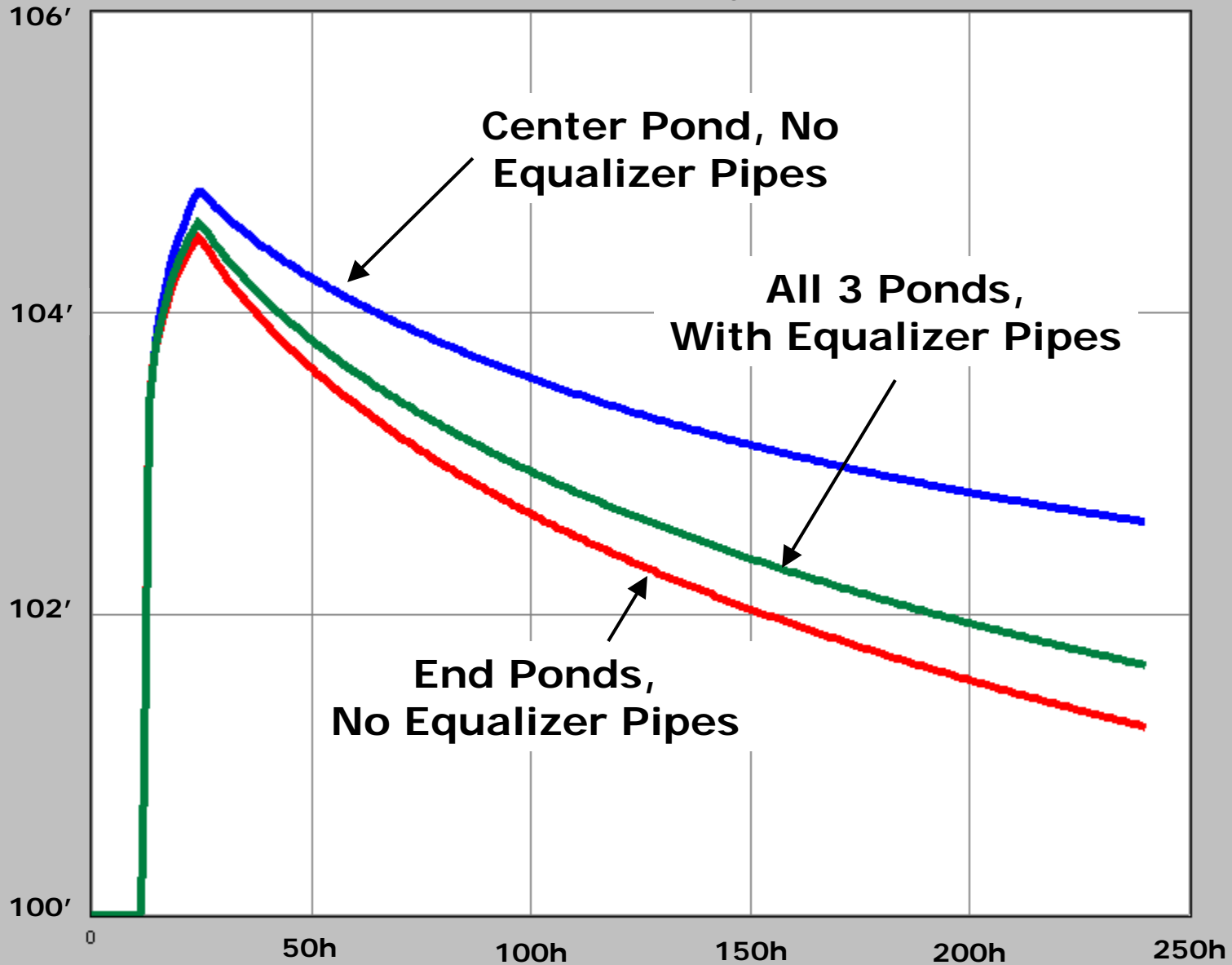


**Same 3-Pond Example Except
Connect the Ponds on the Surface
With Equalizer Pipes.**



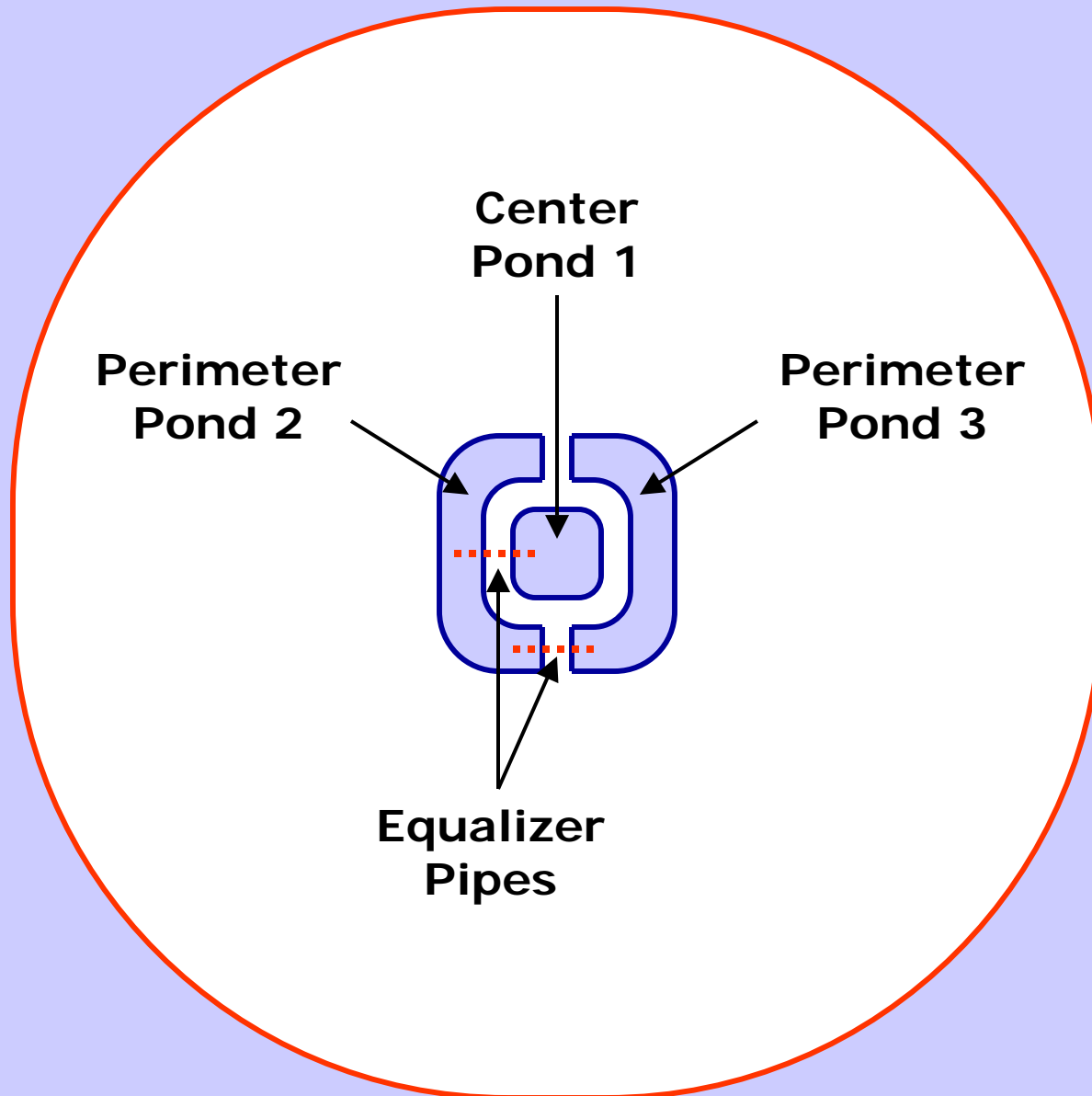
ICPR Schematic
(Add Equalizer Pipes)

Simulation 025-3ponds

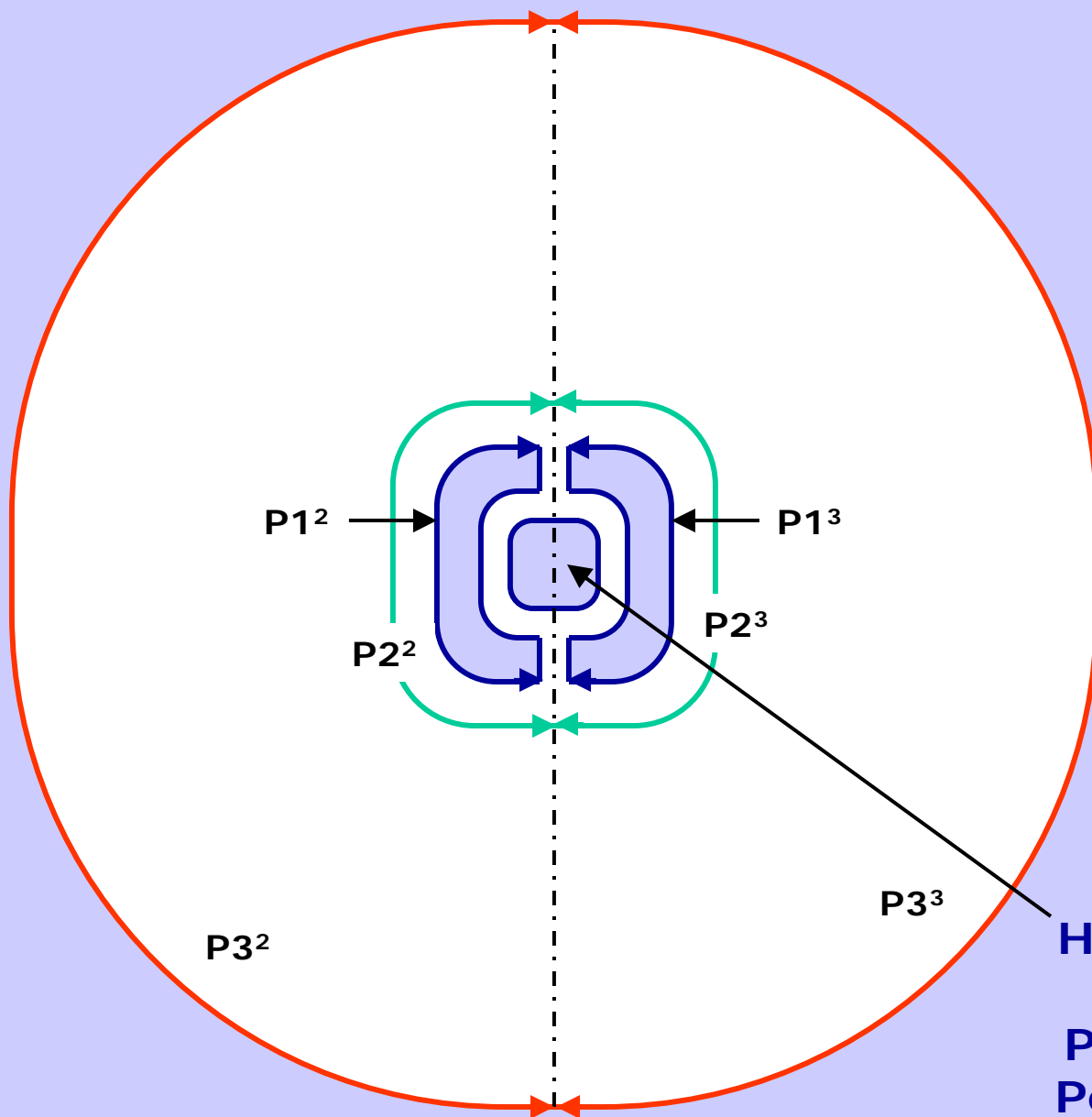


**Another 3-Pond Example
One Center Pond Surrounded by Two
Perimeter Ponds with Equalizer Pipes.**

Center Pond with Two Perimeter Ponds



Treat System as Single Pond, Merge Computational Rings for the Perimeter Ponds and then Proportion



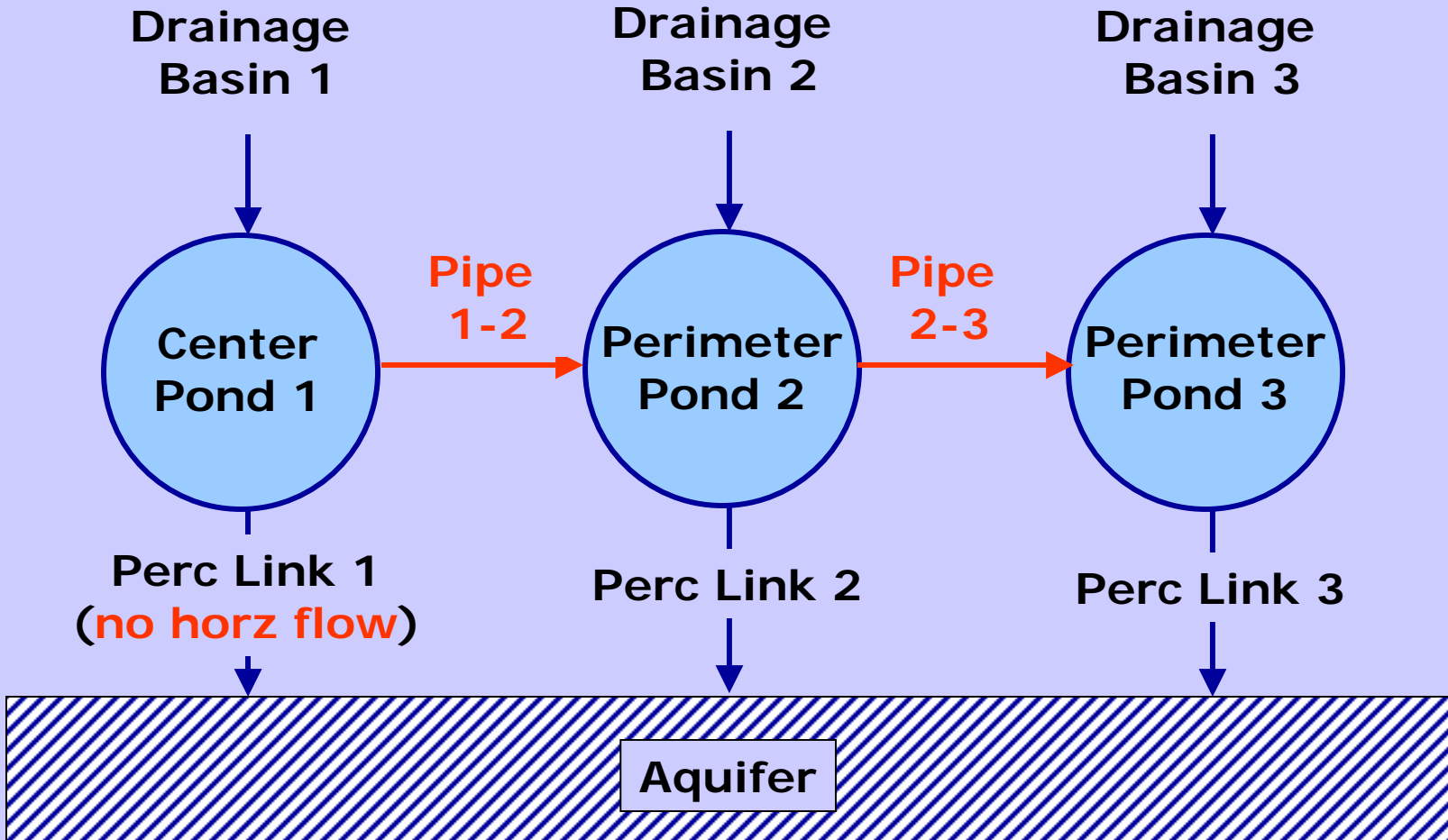
Horizontal Flow from the Center Pond Must be Prevented, Therefore no Perimeters are Required.

Surface Area Option

Vertical Flow Termination

Constant Rate

Prevent Horizontal Flow from Center Pond by Setting the “Vertical Flow Termination” Option to “Constant Rate” with a Rate of Zero.

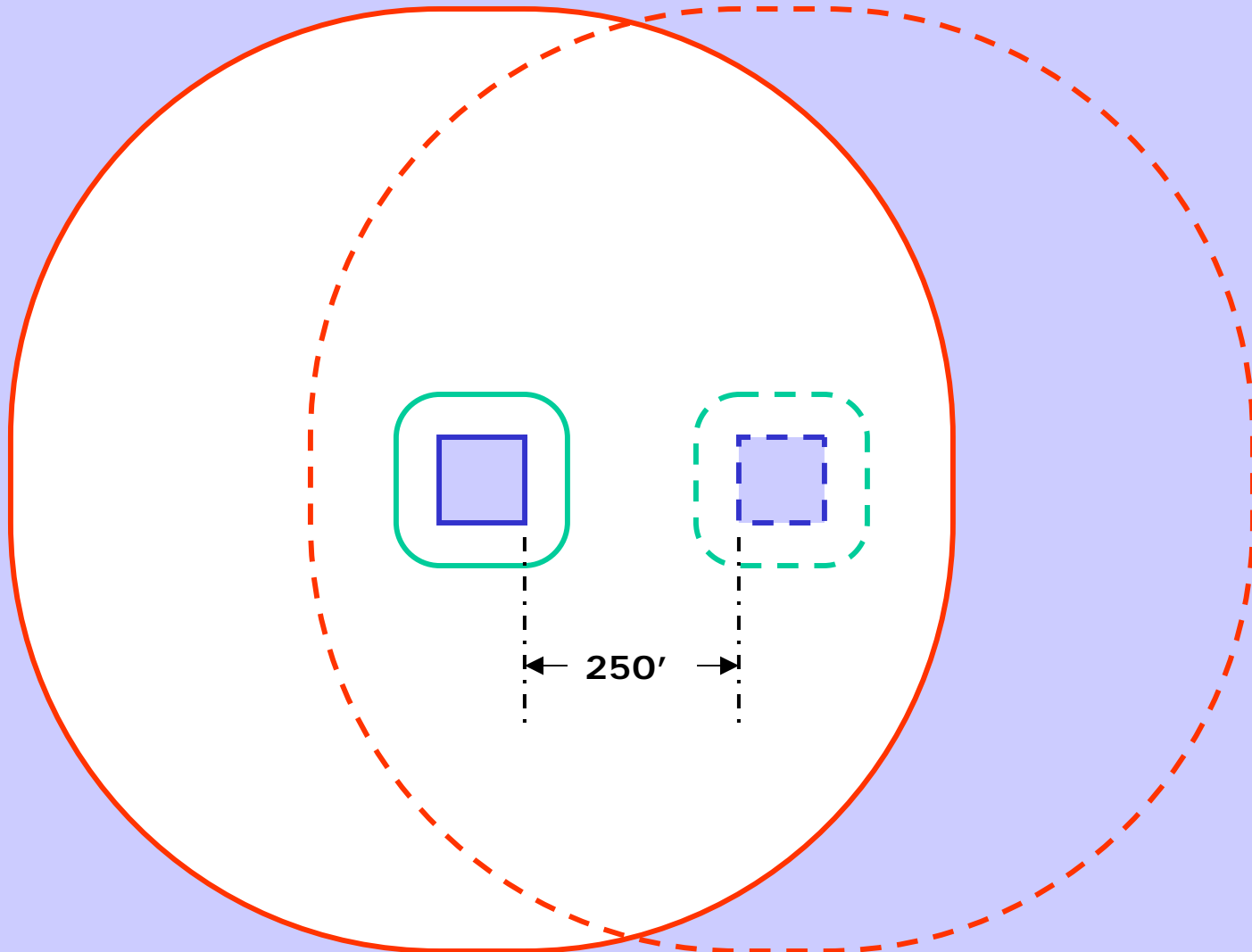


ICPR Schematic

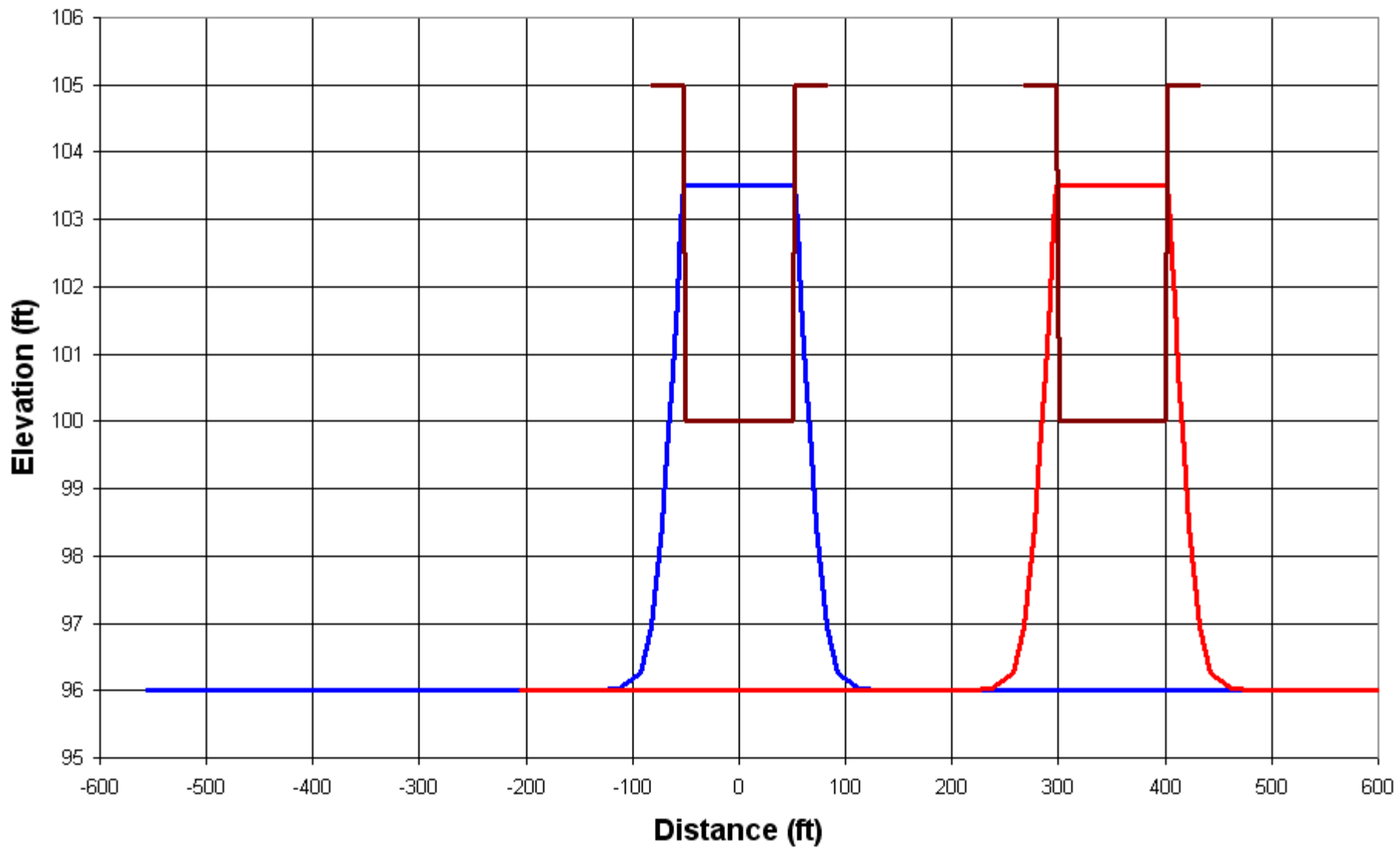
**Two Identical Ponds,
But Not in “Very” Close Proximity**

Two Ponds 250' Apart

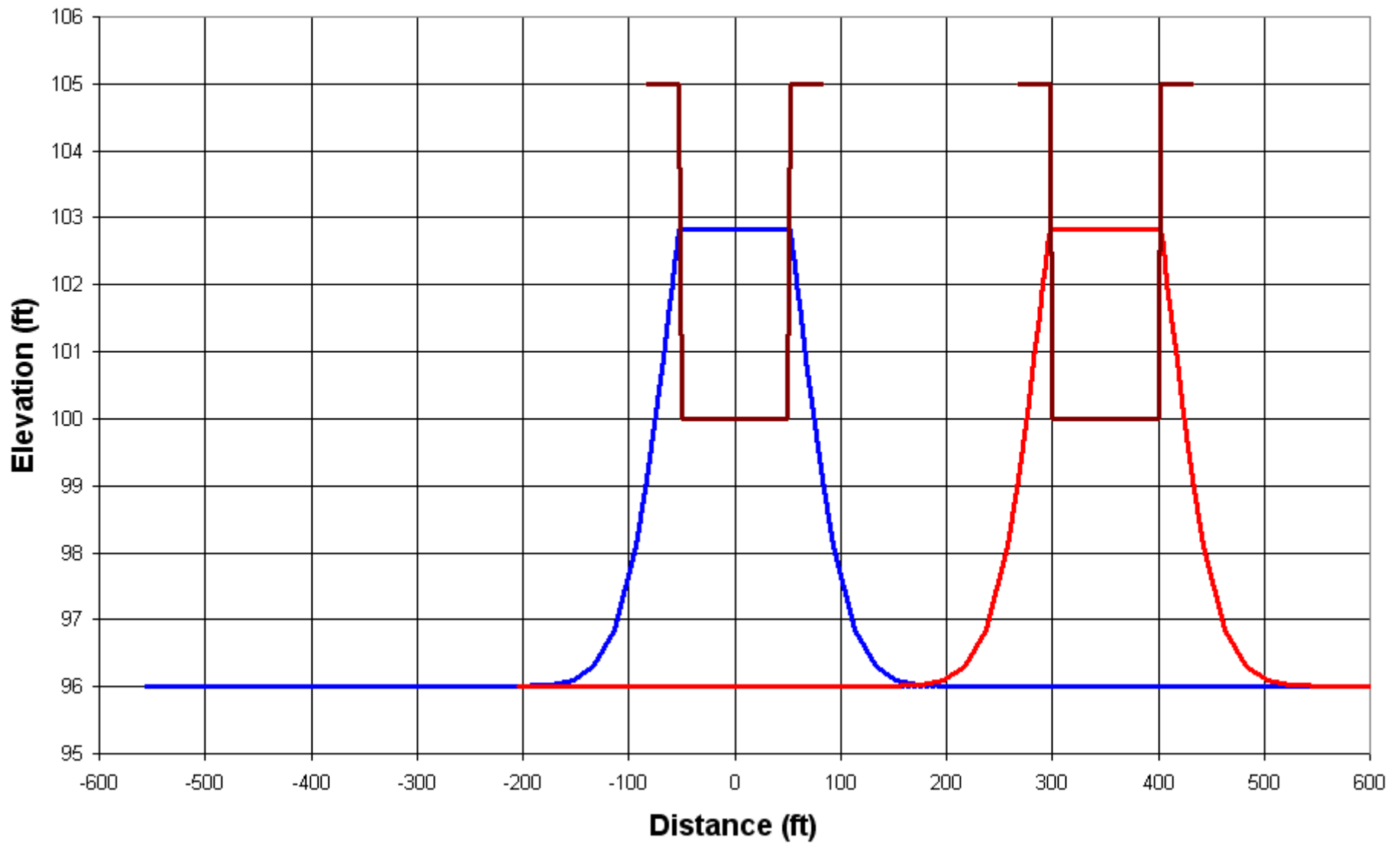
(not in "very" close proximity)



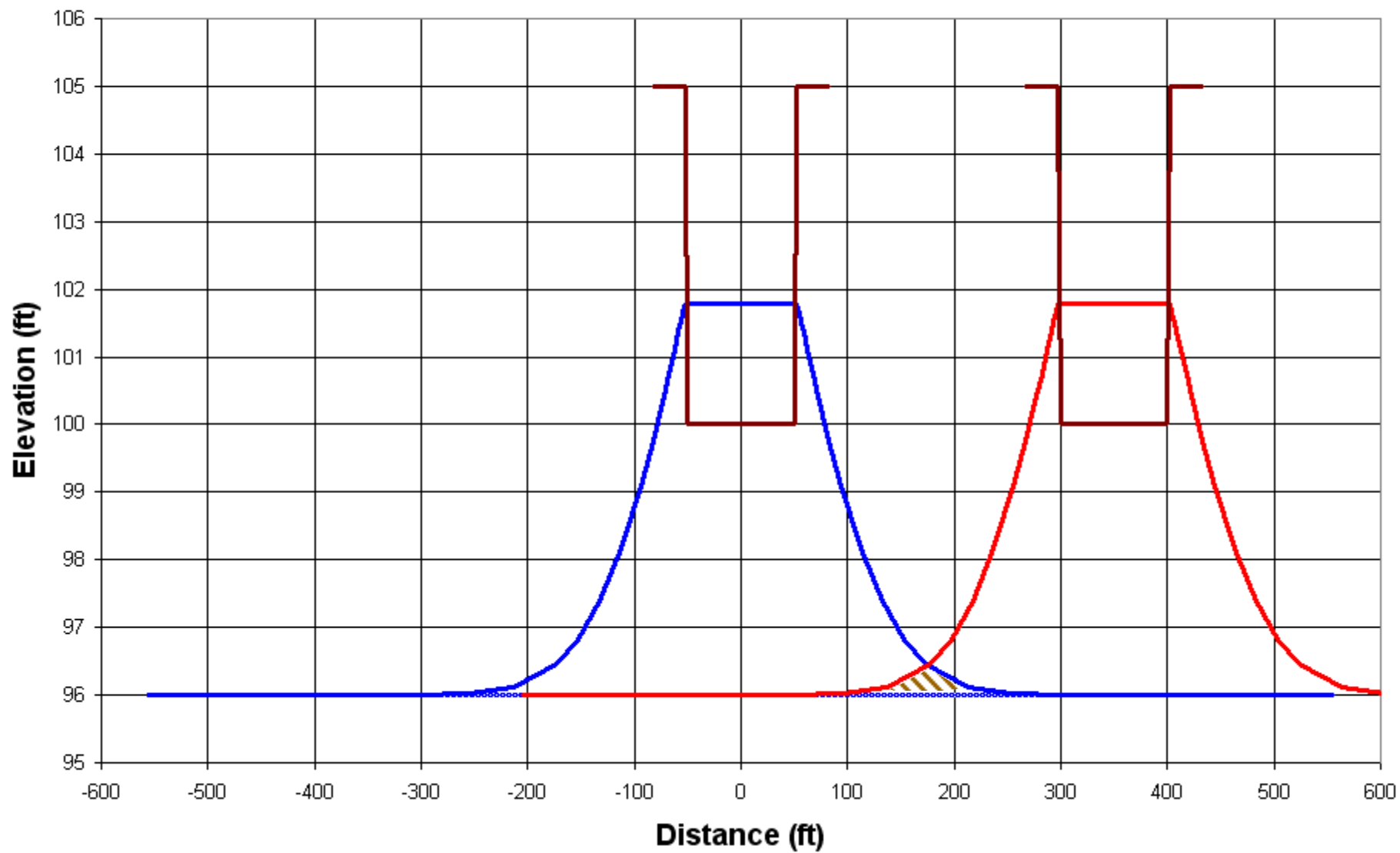
Groundwater Mound - 1 Day



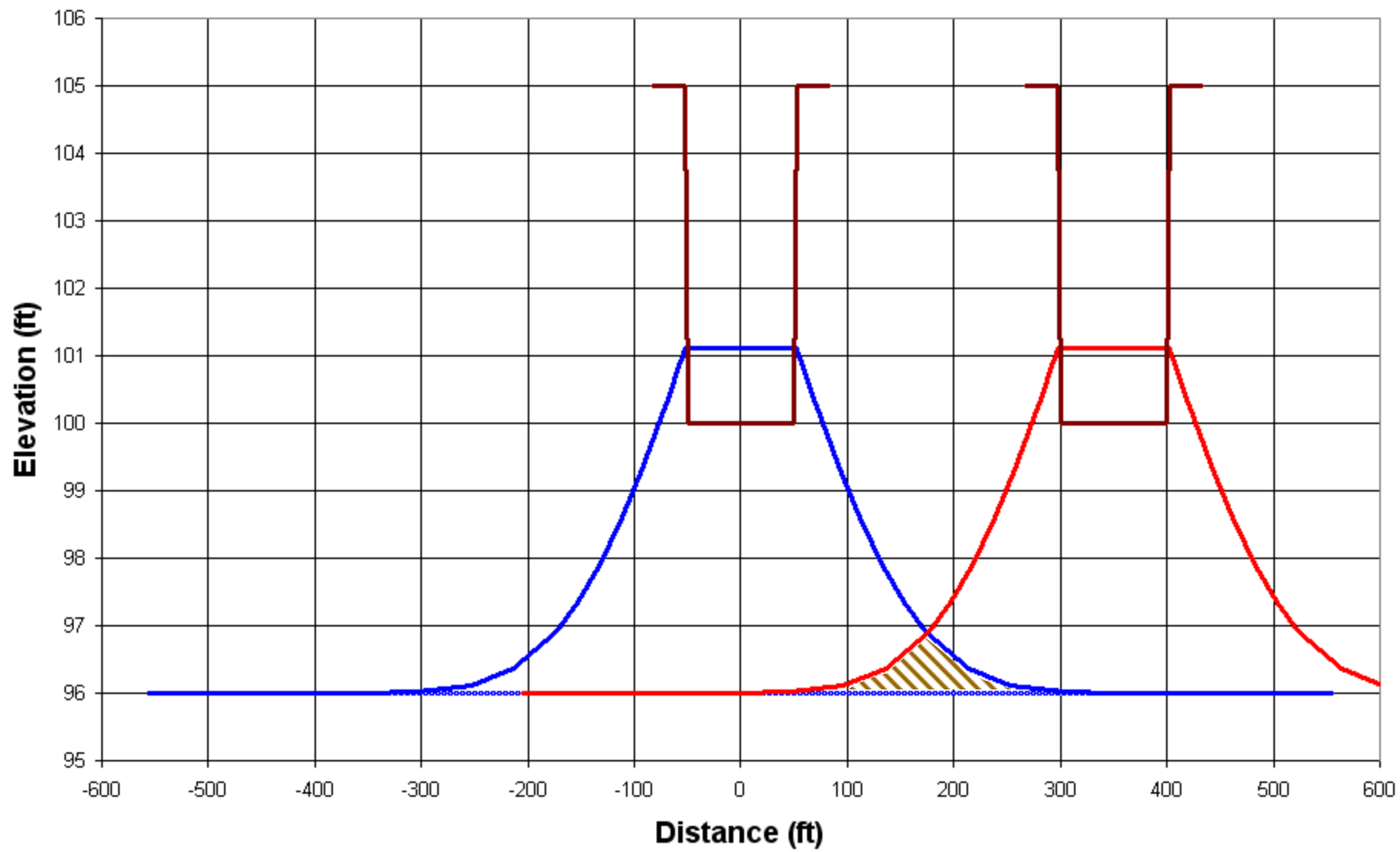
Groundwater Mound - 2 Days



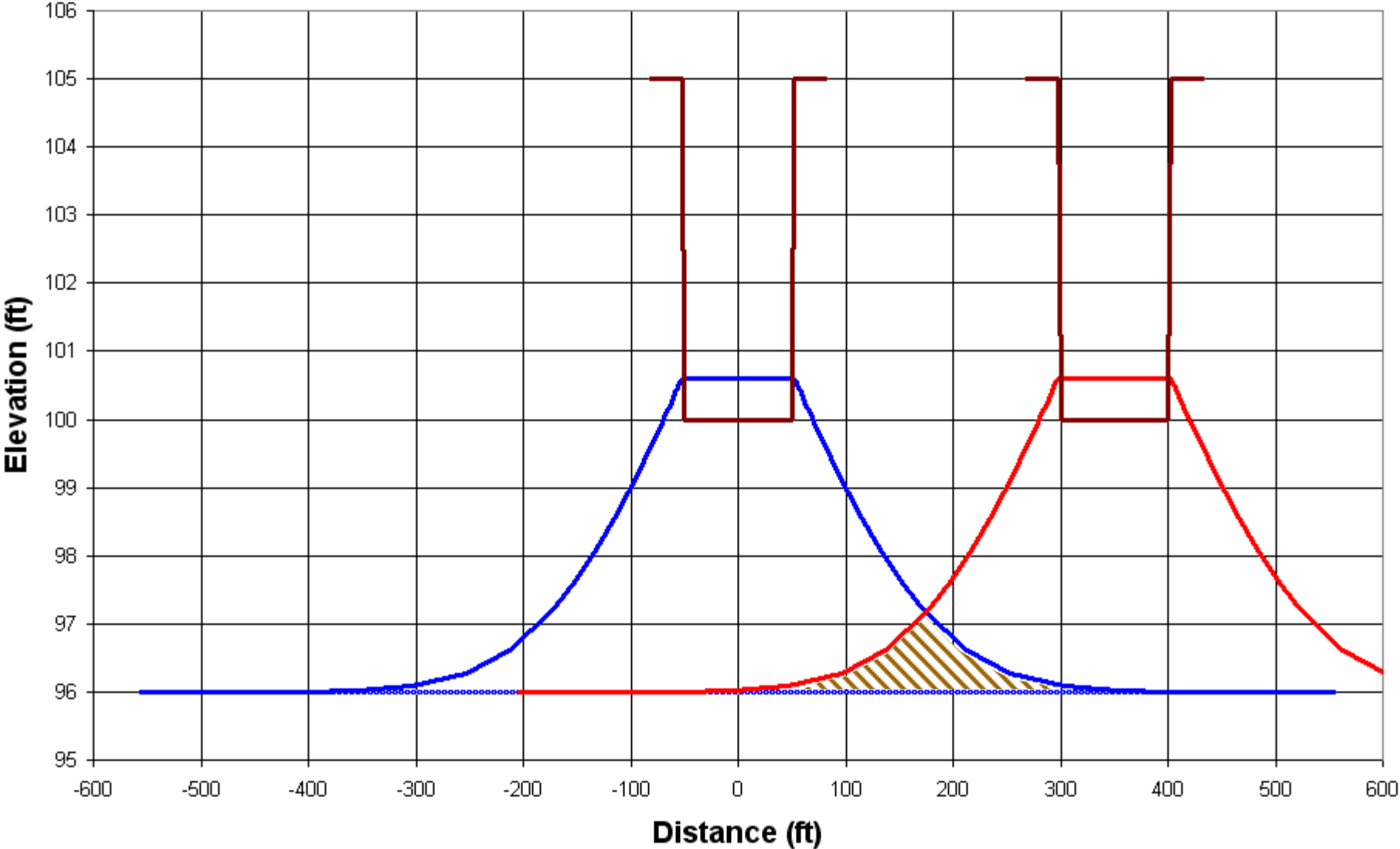
Groundwater Mound - 4 Days



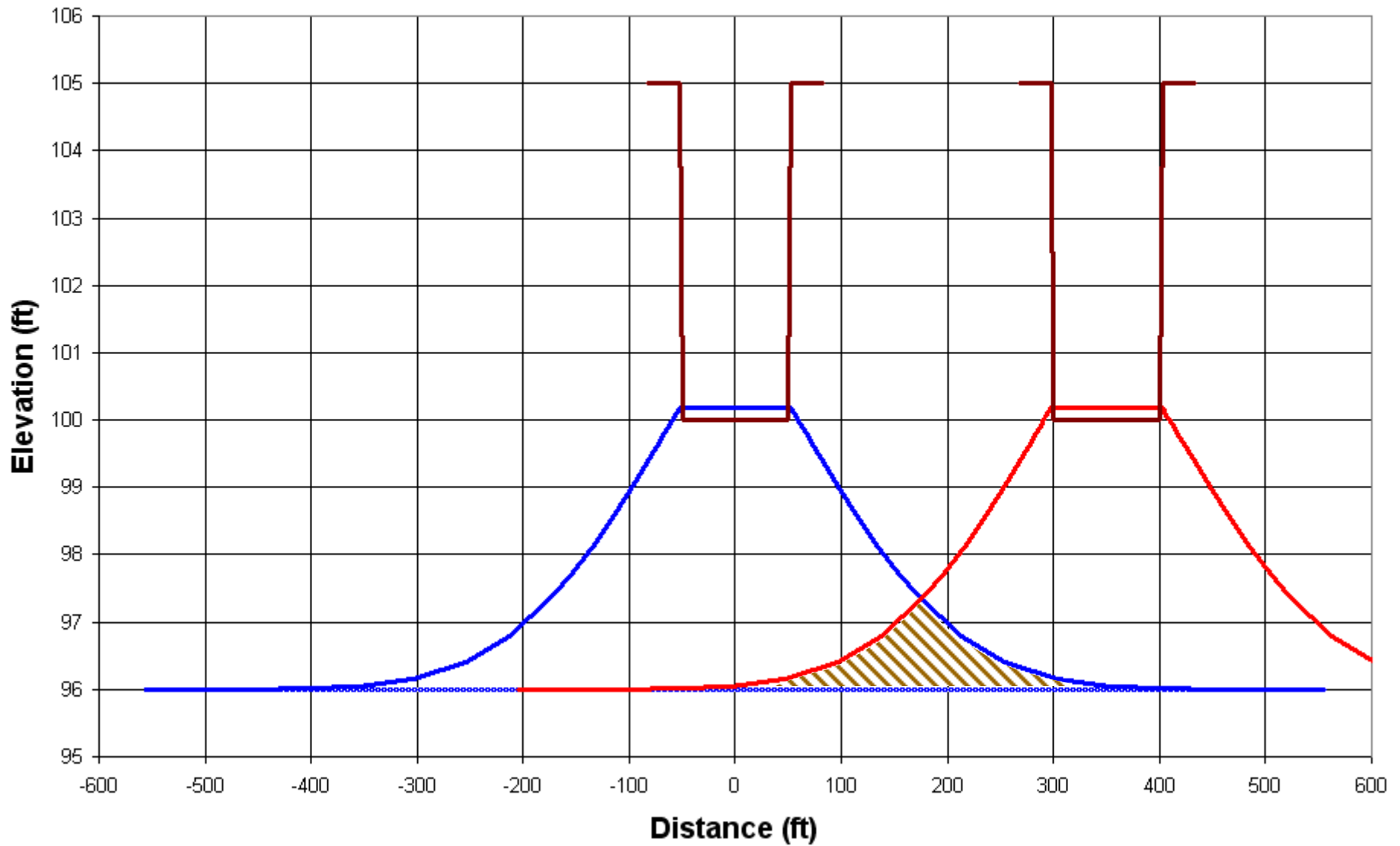
Groundwater Mound - 6 Days

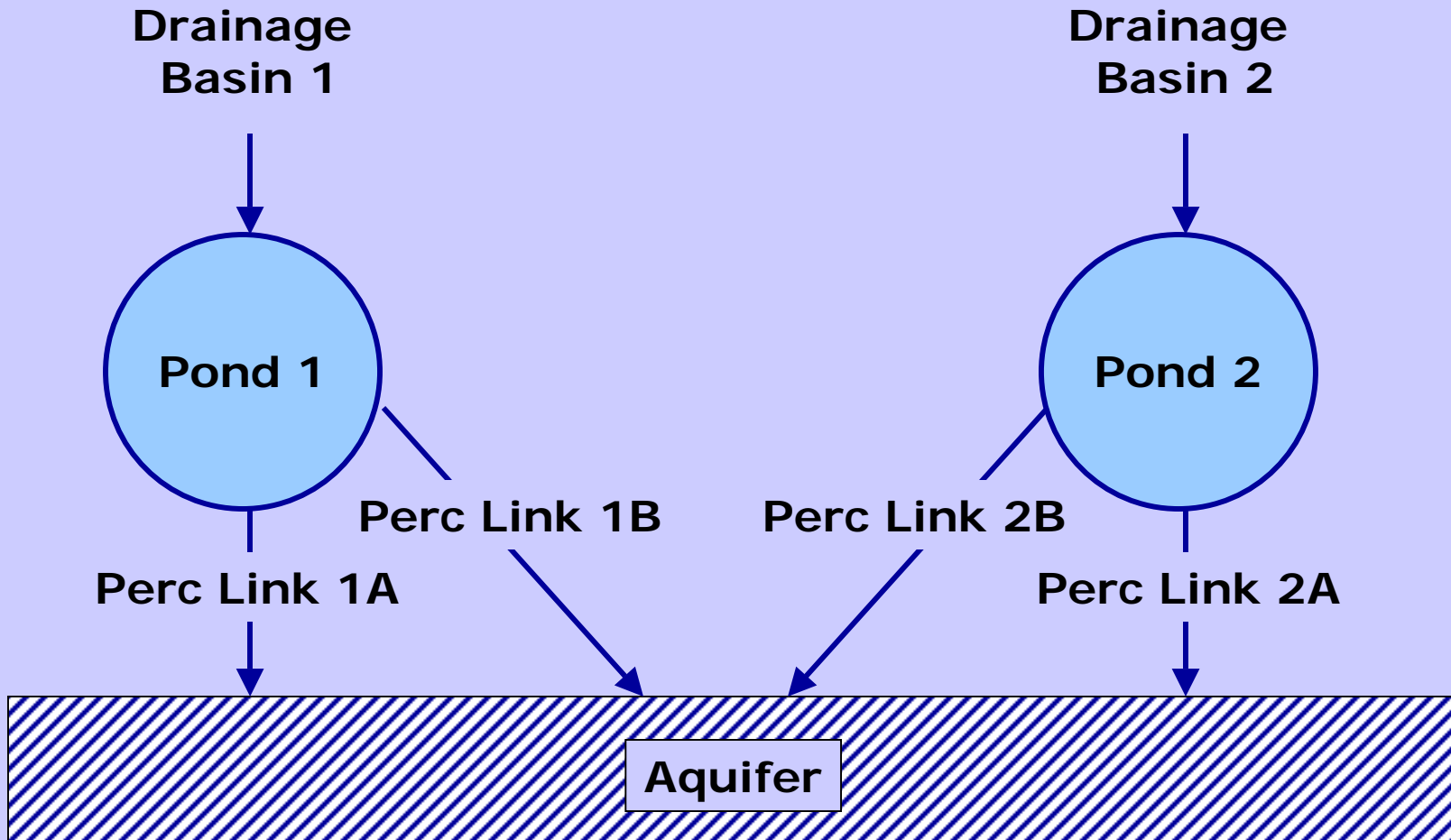


Groundwater Mound - 8 Days



Groundwater Mound - 10 Days

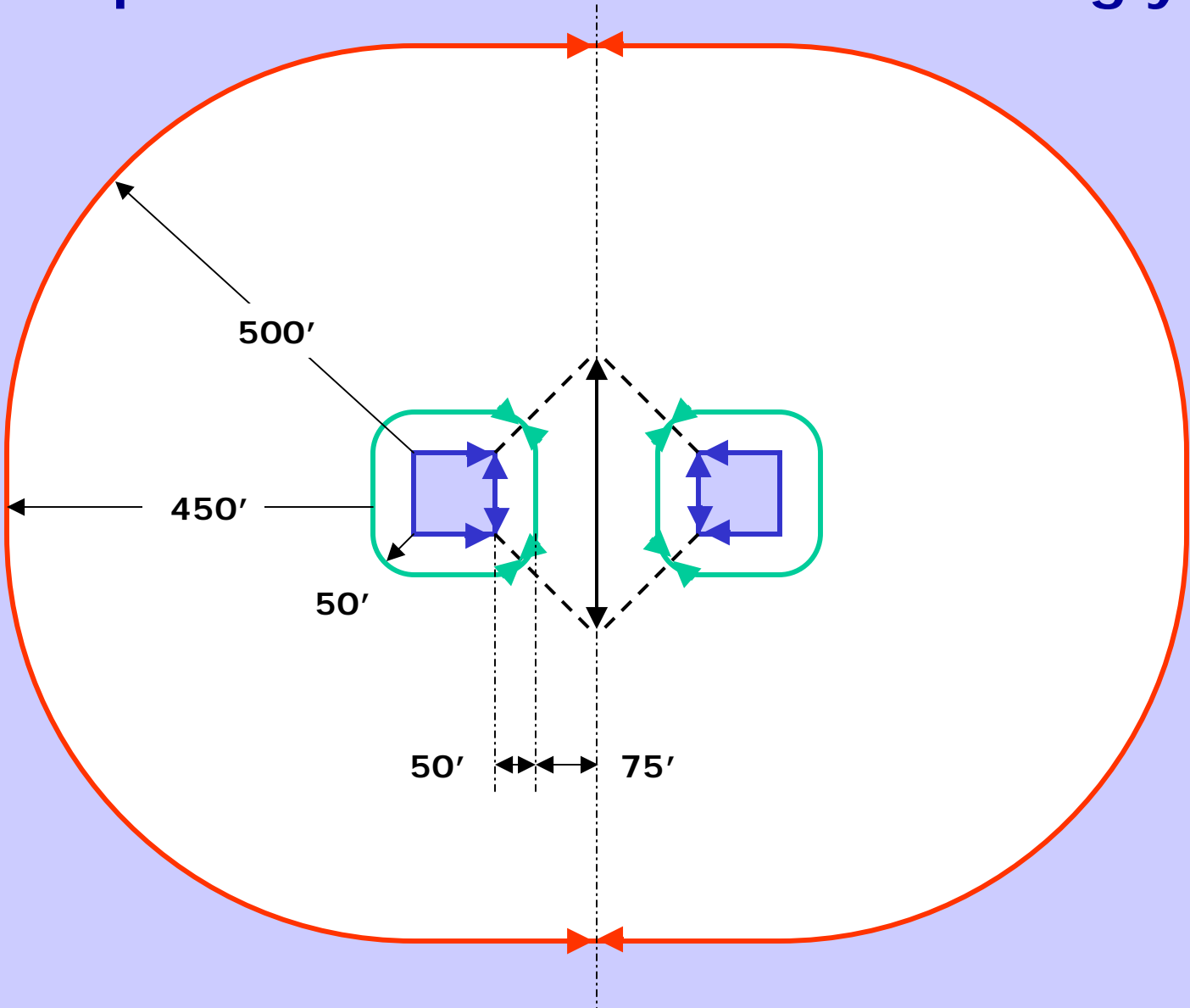




ICPR Schematic

(Perc Links are Independent)

Use Two Perc Links per Pond and Proportion the Perimeters Accordingly



Adjustments to Perimeters for Two-Pond/Four-Perc Link System

	Single Independent Pond	Perc Links 1A & 2A	Perc Links 1B & 2B
Perimeter 1	400'	300'	100'
Perimeter 2	714'	507'	207'
Perimeter 3	3542'	1921'	375'

Perimeter 1

Perimeter 2

Perimeter 3

Distance 1 to 2

Distance 2 to 3

Num Cells 1 to 2

Num Cells 2 to 3

Perc Links 1A & 2A

Perimeter 1

Perimeter 2

Perimeter 3

Distance 1 to 2

Distance 2 to 3

Num Cells 1 to 2

Num Cells 2 to 3

Perc Links 1B & 2B

Perc Links 1A & 2A

Aquifer Base Elevation	88
Water Table Elevation	96
Annual Recharge Rate	0
Horizontal Conductivity	15
Vertical Conductivity	7.5
Effective Porosity	0.3
Suction Head	4.17
Layer Thickness	4

Zero recharge forces a **fixed head boundary condition** at the P3 ring.

This parameter affects soil storage and vertical unsaturated flow.

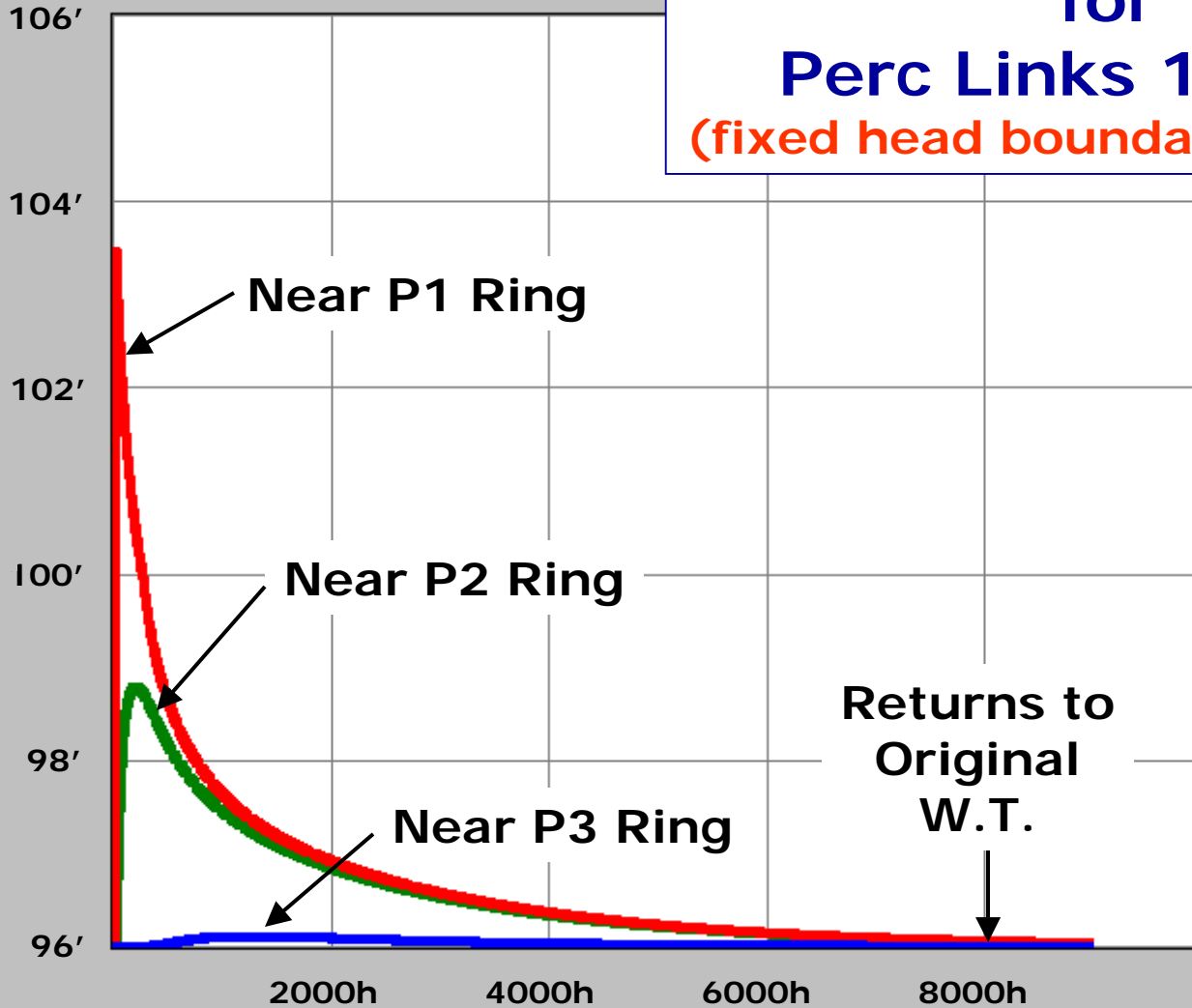
Perc Links 1B & 2B

Aquifer Base Elevation	88
Water Table Elevation	96
Annual Recharge Rate	0.0001
Horizontal Conductivity	15
Vertical Conductivity	7.5
Effective Porosity	0.3
Suction Head	4.17
Layer Thickness	0.001

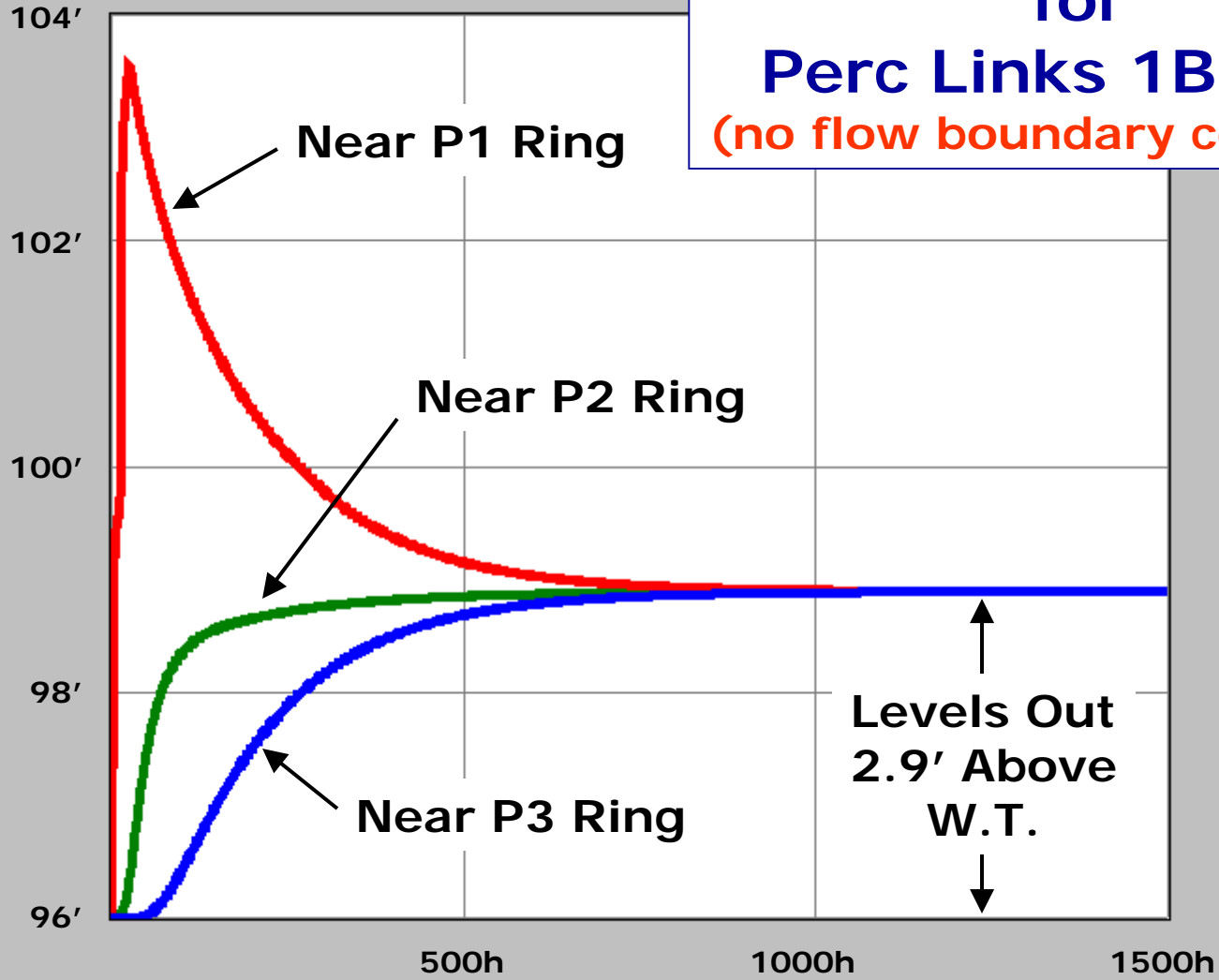
A non-zero recharge rate forces a **zero flow boundary condition** at the P3 ring.

A very small layer thickness prevents vertical unsaturated flow.

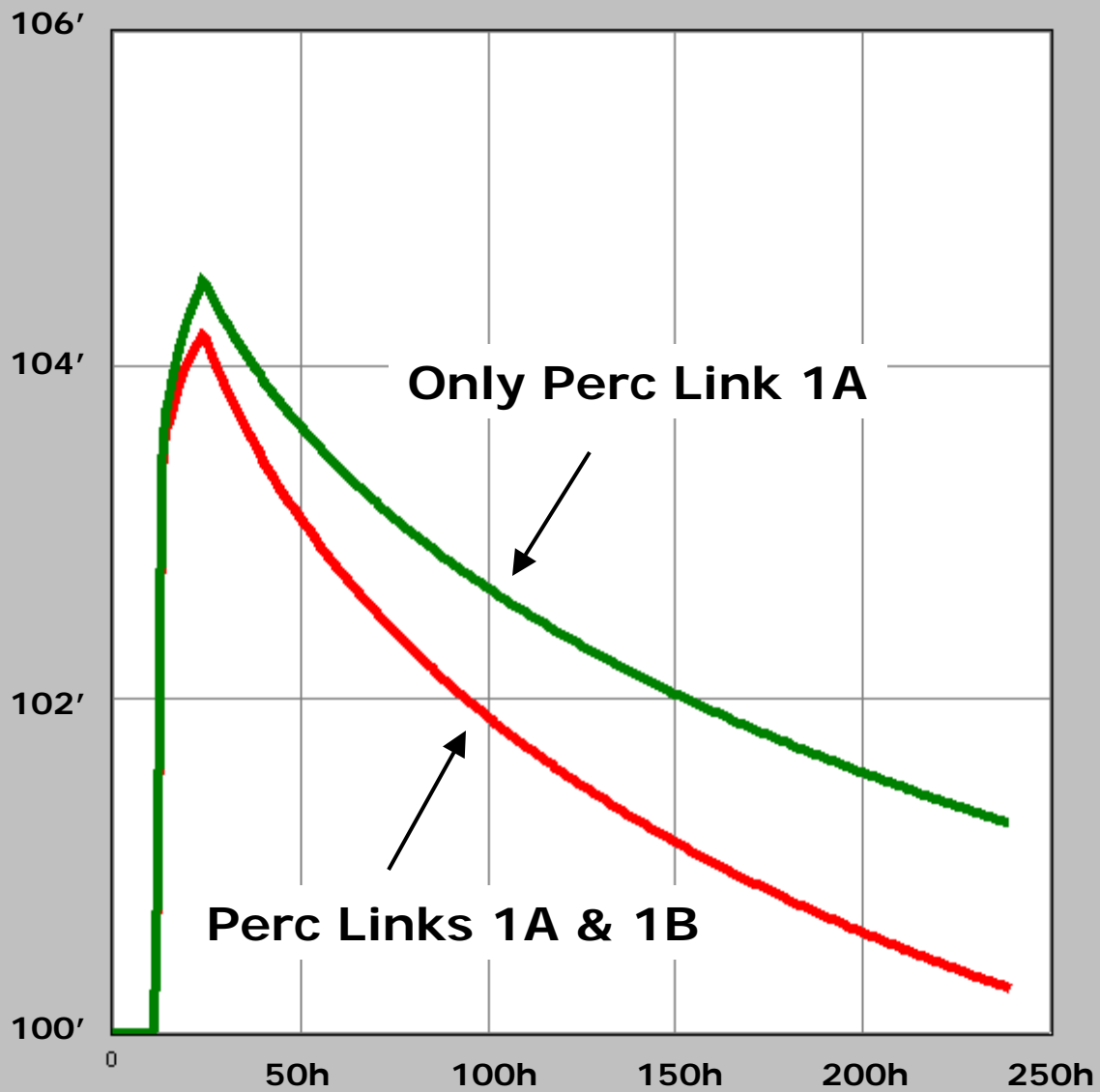
Mounding Impacts for Perc Links 1A & 2A (fixed head boundary condition)



**Mounding Impacts
for
Perc Links 1B & 2B
(no flow boundary condition)**



Levels Out
2.9' Above
W.T.

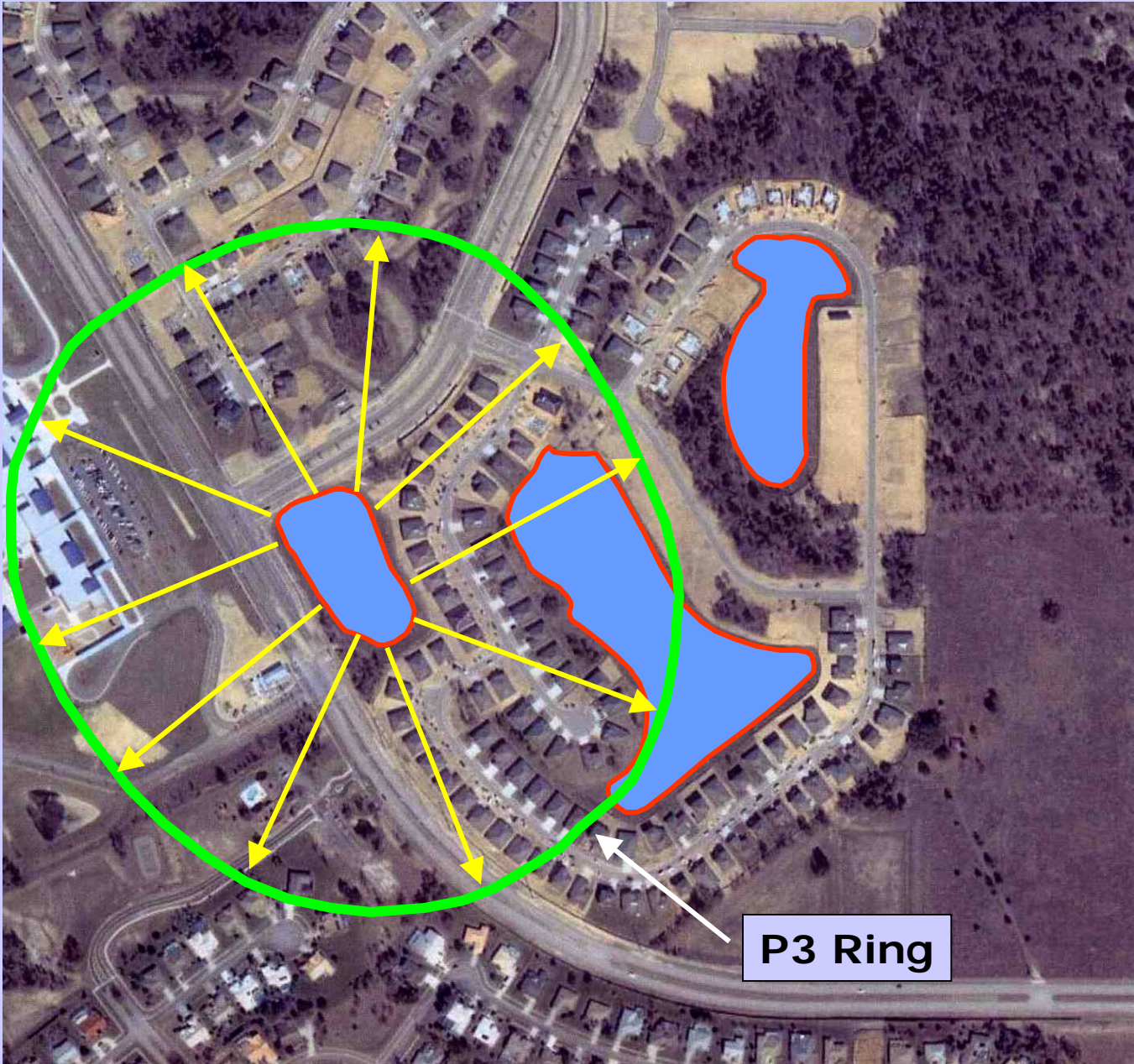


**Now Back to the Original
Three-Pond System.**

Three Ponds in Close Proximity



Groundwater Flow is Radially Outward



P3 Ring

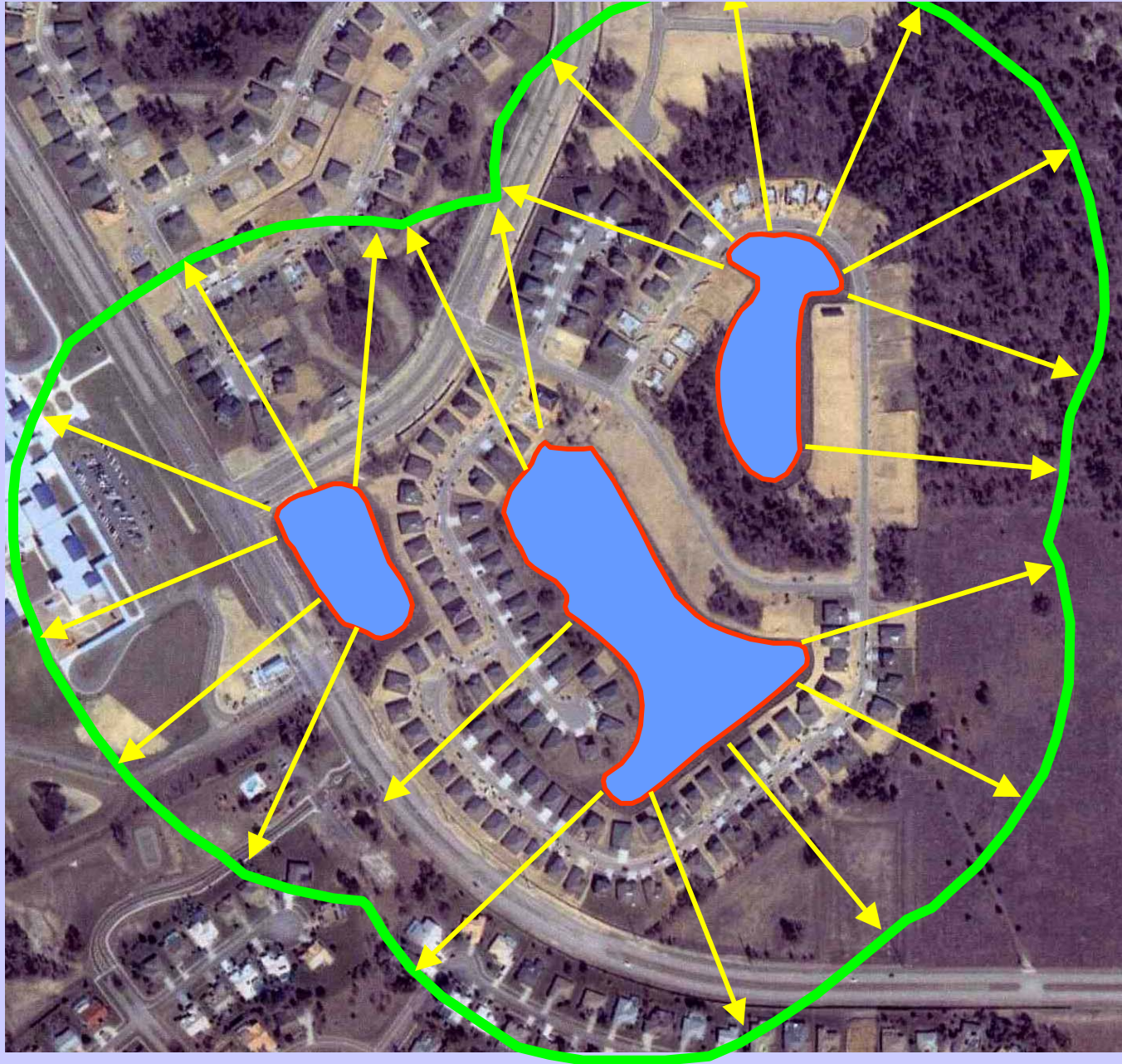
Overlapping Radii of Influence



Shaded Areas Represent Overlap



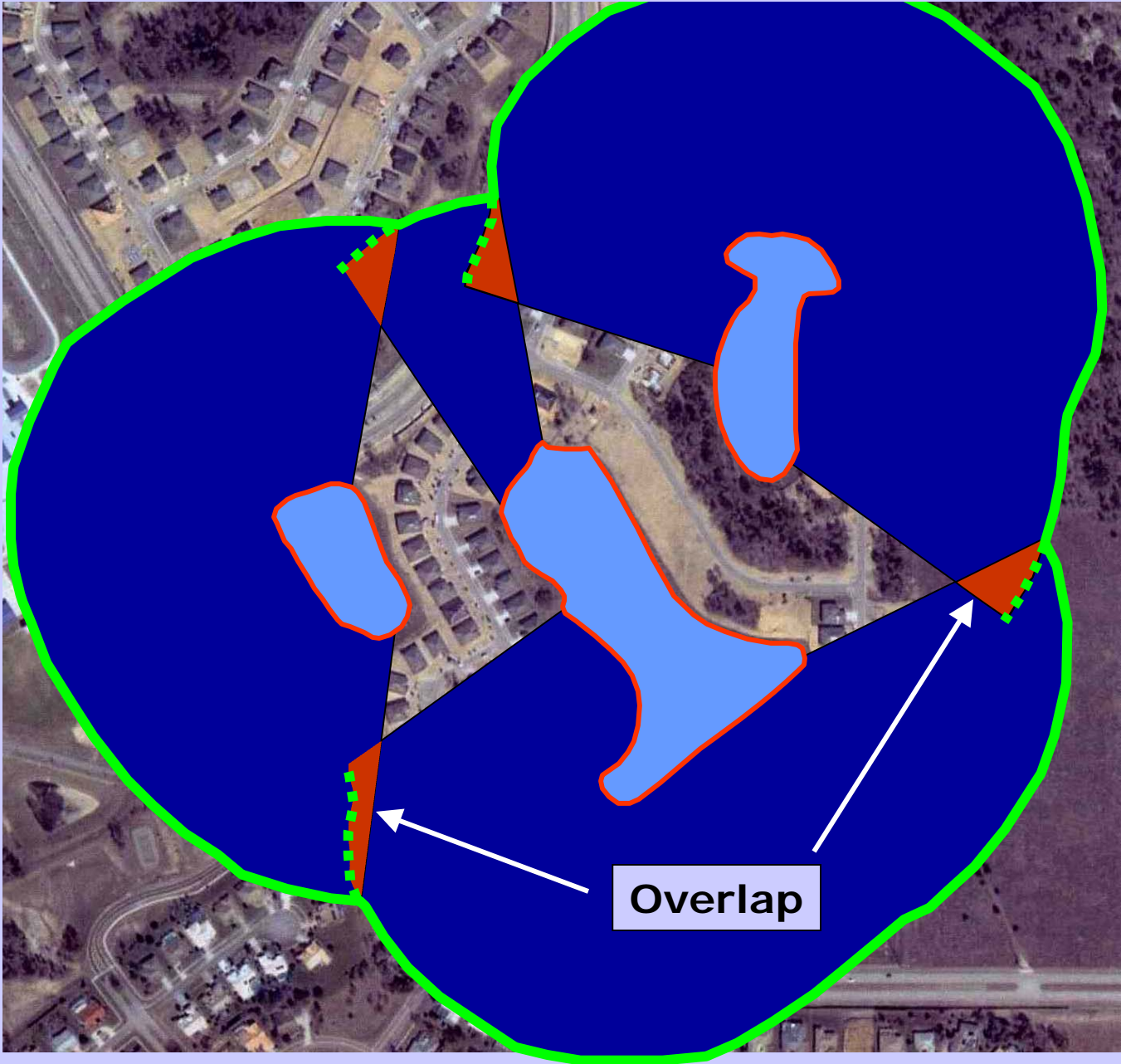
Merge Computational Rings and Proportion



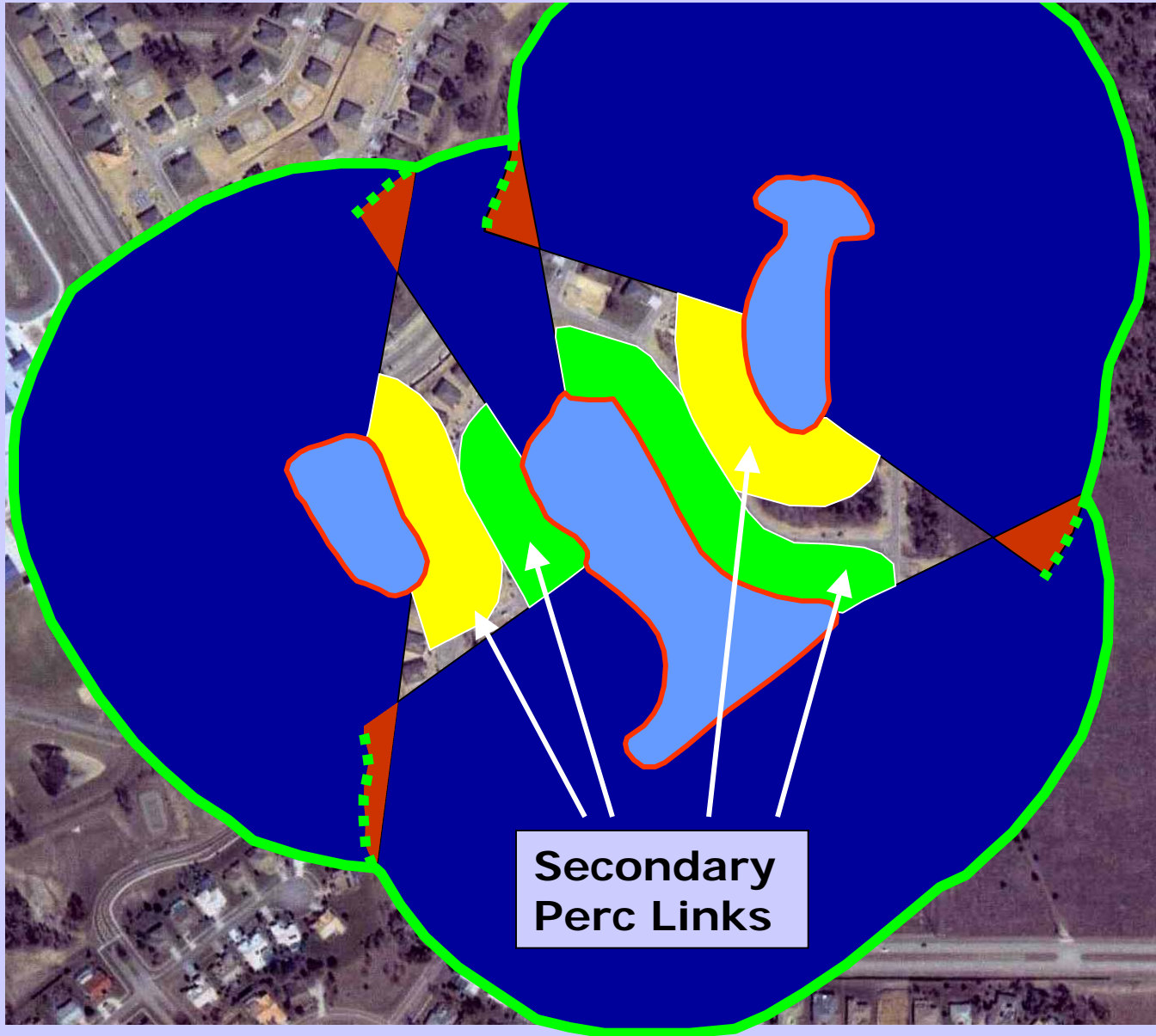
A Single Perc Link Per Pond Can Be Used To Model GW Movement Away From Ponds



Small Overlap Areas



Secondary Perc Links Can Be Used To Model GW Movement Between Ponds



Primary Perc Link
(use fixed head boundary condition)

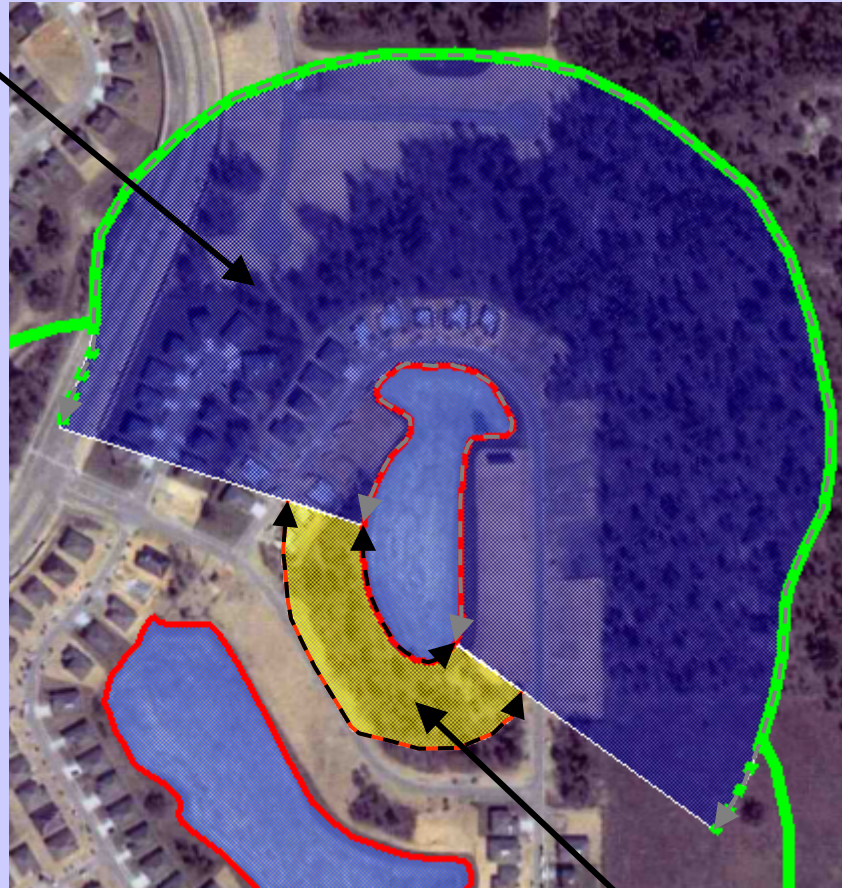
Note: Fixed Head B.C. is established by setting annual recharge to zero.



Secondary Perc Link
(use no flow boundary condition)

Note: No Flow B.C. is established by setting annual recharge to very small non-zero number.

Primary Perc Link
(use fixed head
boundary condition)

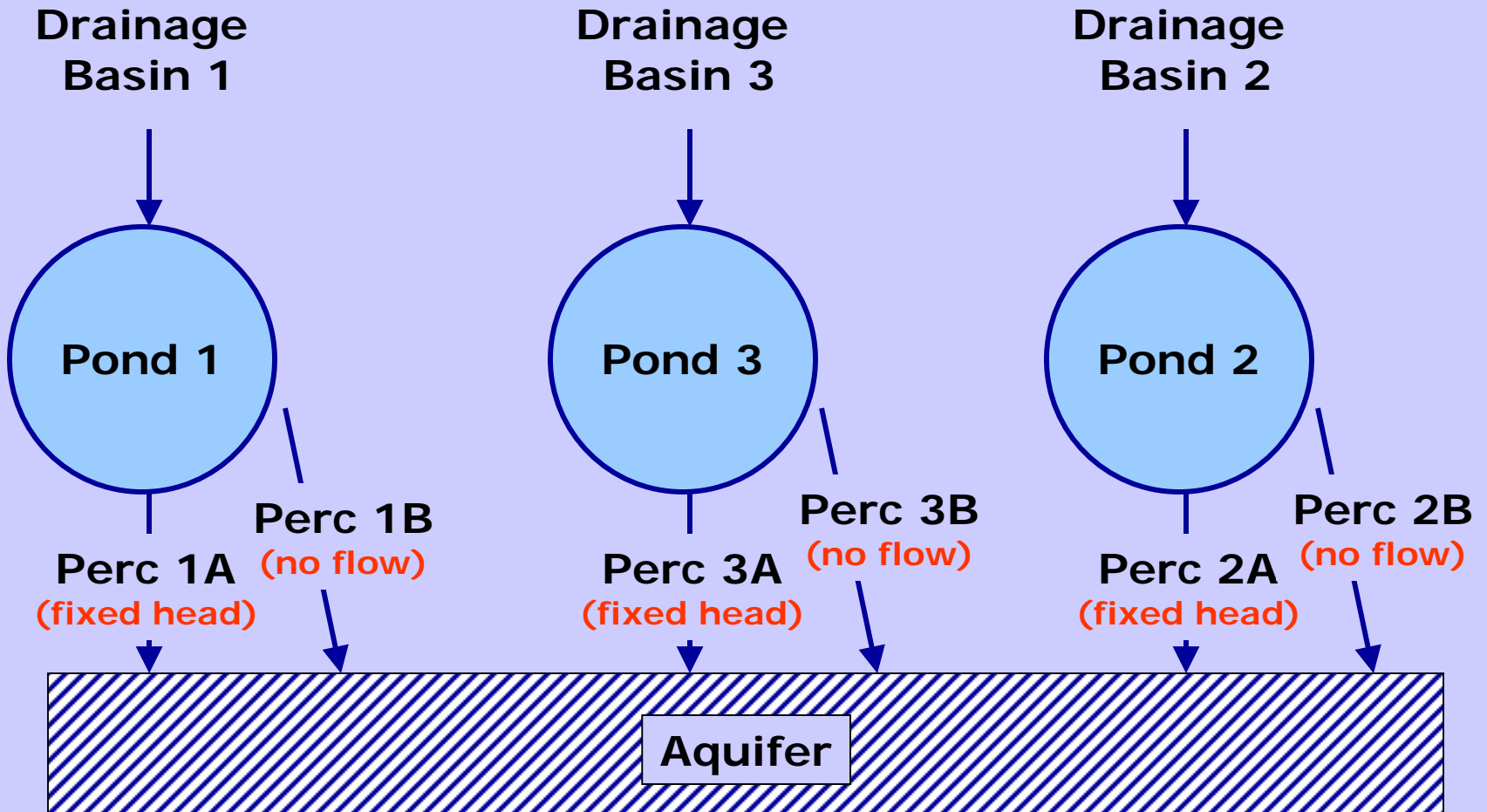


Secondary Perc Link
(use no flow
boundary condition)



Secondary Perc Link
(use no flow
boundary condition)

Primary Perc Link
(use fixed head
boundary condition)



ICPR Schematic
(Perc Links are Independent)

QUESTIONS?