

Determining Site-Specific Mean Annual Mass Removal Efficiencies Using ICPR

- An Alternative to the Harper Methodology –

by

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**ASCE Florida West Coast Branch
Water and Environment Committee
One-Day Seminar
“WE ARE CHANGING THE RULES”**

**September 25, 2008
Tampa, Florida**

Qualifier

The method described in this presentation for determining mean annual mass removal efficiencies using ICPR has not been submitted (yet) to FDEP or any other agency for formal approval. It is presented here, for the first time, to stimulate discussion on some of the shortcomings of the Harper Methodology as identified by the Technical Advisory Committee.

Regardless, the approach presented herein is based on sound engineering principles that have been approved by various Florida regulatory agencies in a different setting.

Statewide Stormwater Treatment Rule

- Projected Adoption Date: May 2009
- Projected Effective Date: July 1, 2009
- Relies Heavily on the “Harper Methodology”

Mean Annual Mass Removal Efficiencies For Dry Retention Systems Based on the Harper Methodology

Tables of "Removal Efficiencies" are available based on %DCIA and Non-DCIA CN

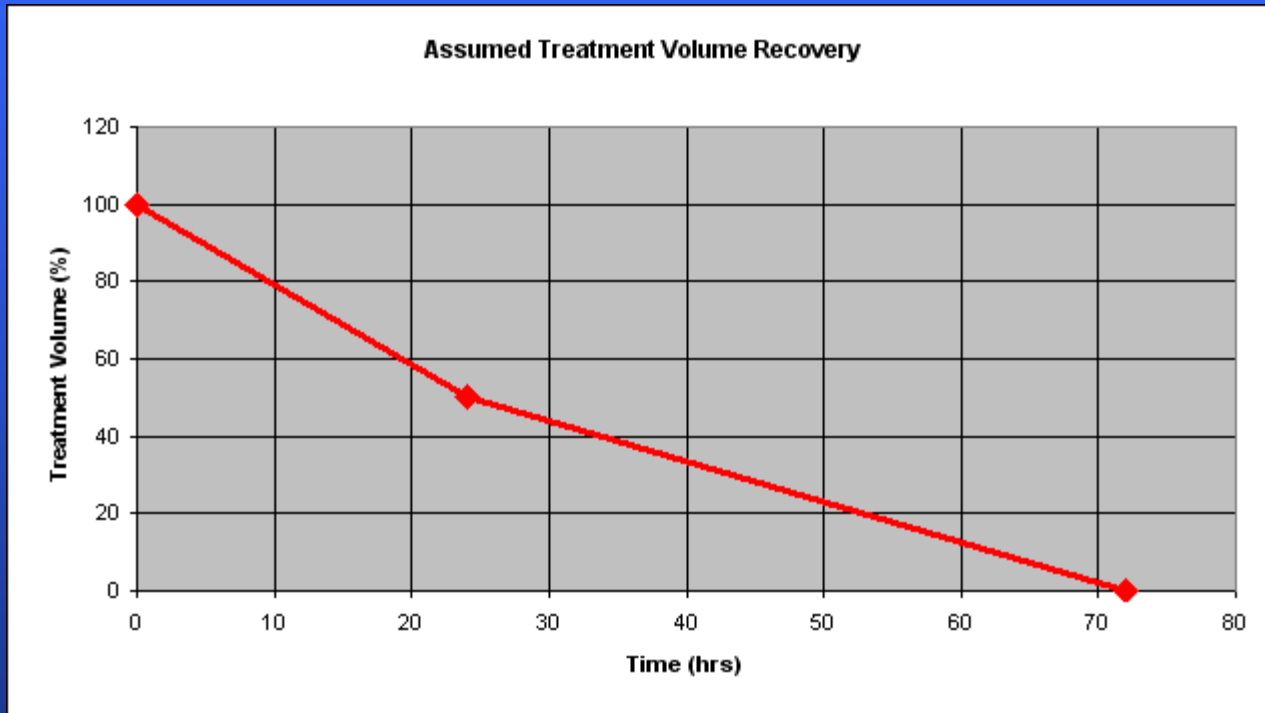
Mean Annual Mass Removal Efficiencies for 1.50-inches of Retention in Zone 2

NDCIA CN	Percent DCIA																			
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
30	99.2	99.4	99.3	99.1	98.7	98.2	97.6	96.8	95.9	94.9	93.7	92.5	91.3	89.9	88.6	87.2	85.7	84.3	82.9	81.5
35	98.6	99.0	99.0	98.8	98.5	98.0	97.4	96.6	95.7	94.7	93.6	92.4	91.2	89.8	88.5	87.1	85.7	84.3	82.9	81.5
40	97.8	98.4	98.5	98.4	98.1	97.6	97.1	96.3	95.5	94.5	93.4	92.2	91.0	89.7	88.4	87.1	85.7	84.3	82.9	81.5
45	96.9	97.8	98.0	97.9	97.6	97.2	96.7	96.0	95.1	94.2	93.1	92.0	90.8	89.6	88.3	87.0	85.6	84.2	82.9	81.5
50	95.9	96.9	97.2	97.2	97.0	96.7	96.2	95.5	94.7	93.8	92.8	91.8	90.6	89.4	88.2	86.9	85.5	84.2	82.8	81.5
55	94.6	95.9	96.3	96.4	96.3	96.0	95.6	95.0	94.2	93.4	92.4	91.4	90.3	89.2	88.0	86.7	85.4	84.1	82.8	81.5
60	93.1	94.7	95.3	95.5	95.4	95.2	94.8	94.3	93.6	92.8	92.0	91.0	90.0	88.9	87.7	86.5	85.3	84.0	82.8	81.5
65	91.7	93.4	94.1	94.4	94.4	94.2	93.9	93.4	92.8	92.1	91.3	90.5	89.5	88.5	87.4	86.3	85.1	83.9	82.7	81.5
70	90.1	91.9	92.7	93.0	93.1	93.0	92.7	92.3	91.9	91.2	90.6	89.8	88.9	88.0	87.0	86.0	84.9	83.8	82.6	81.5
75	88.5	90.2	91.0	91.5	91.6	91.6	91.4	91.1	90.7	90.2	89.6	88.9	88.2	87.4	86.6	85.6	84.6	83.6	82.6	81.5
80	86.9	88.4	89.2	89.6	89.9	89.9	89.8	89.6	89.3	88.9	88.4	87.9	87.3	86.6	85.9	85.1	84.1	83.1	82.1	81.5
85	85.4	86.5	87.2	87.6	87.9	88.0	87.9	87.8	87.6	87.3	87.0	86.6	86.1	85.6	85.0	84.4	83.8	83.2	82.6	81.5
90	84.1	84.7	85.1	85.4	85.6	85.7	85.8	85.7	85.6	85.5	85.3	85.0	84.7	84.4	84.0	83.5	83.0	82.5	82.0	81.5
95	82.7	82.9	83.1	83.2	83.3	83.3	83.4	83.4	83.4	83.3	83.2	83.1	83.0	82.8	82.6	82.4	82.2	82.0	81.8	81.5
98	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.1	82.1	82.1	82.0	82.0	81.9	81.9	81.8	81.7	81.7	81.6	81.5

86.5%

Critical Underlying Assumption:

50% of treatment volume is recovered in 24 hours and 100% in 72 hours



Methodology Issues Cited by the TAC

- “The [Harper] methodology assumes fixed recovery criteria ... Those numbers are not practical and no credit is given for ponds that recover more quickly.”
- “The continuous simulation for developing the curves does not take into account the faster infiltration rate outside the 3 to 4 week wet season ... ”

Other Issues with the Harper Methodology

Type and configuration of dry retention system is not considered.

Swale \neq Pond \neq Exfiltration Trench

 \neq  \neq  \neq 

Other Issues with the Harper Methodology

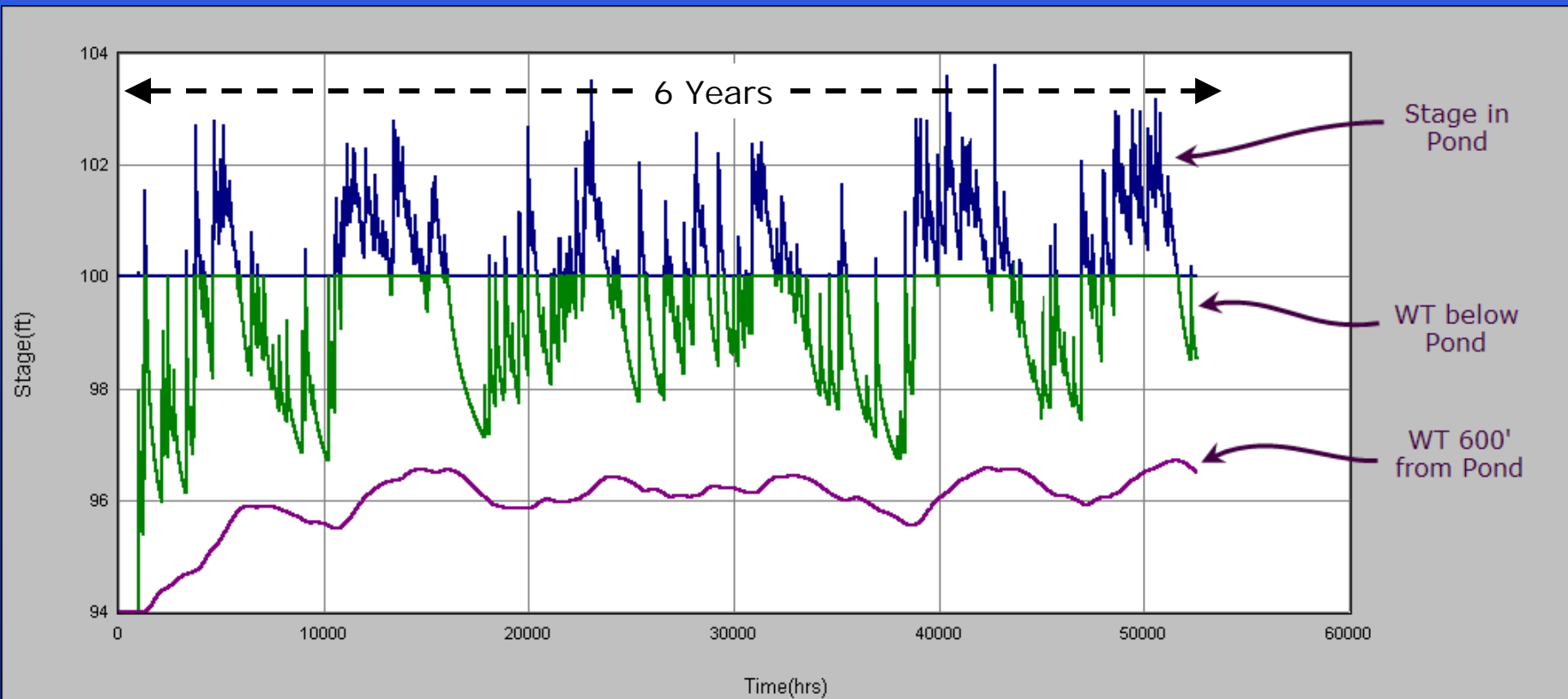
Distributive effects of multiple dry retention systems are not considered.

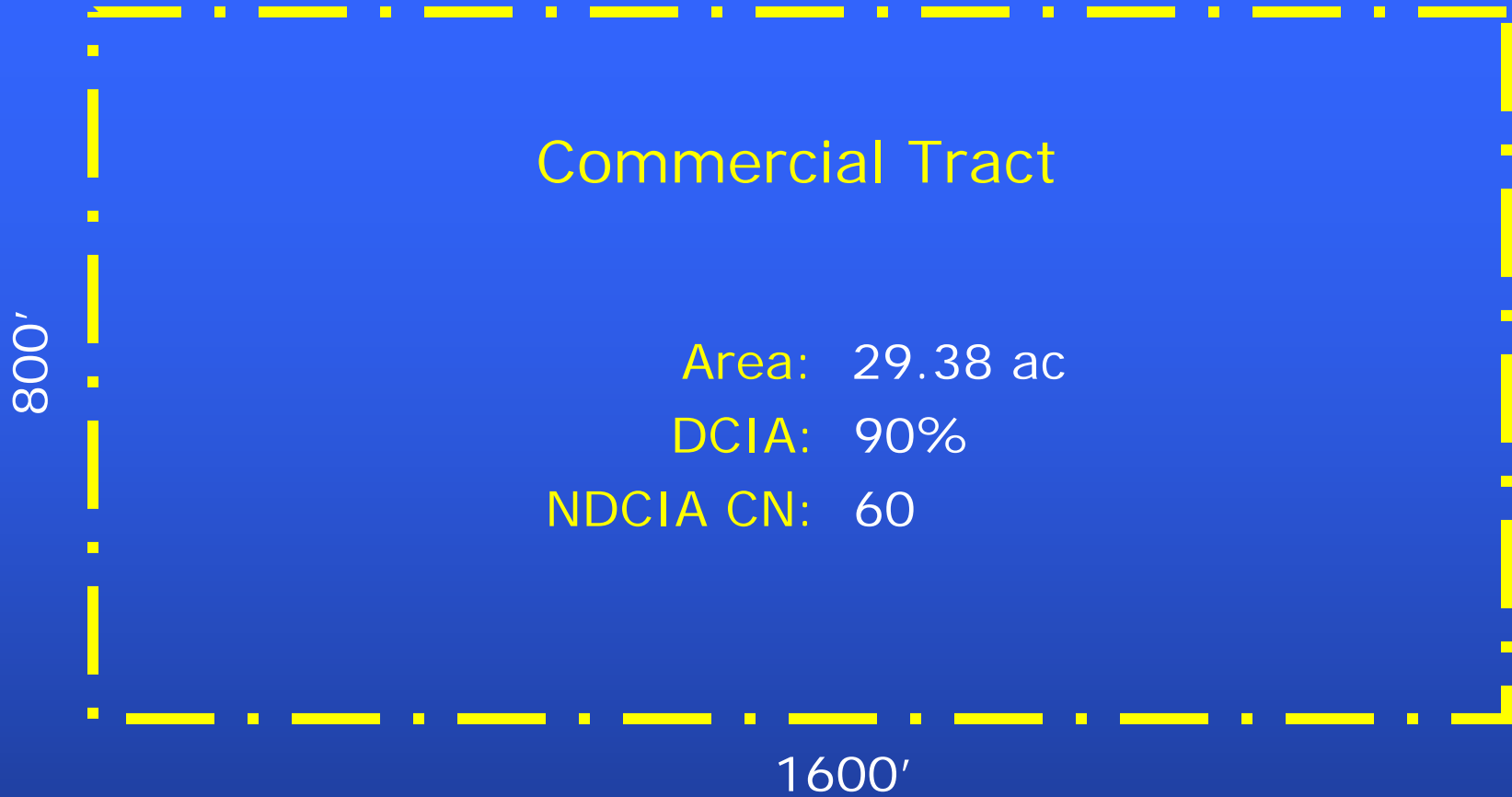


One big pond is not the same as four smaller ponds with the same total treatment volume.

Other Issues with the Harper Methodology

Groundwater mounding impacts and evaporation losses are not considered, especially long term cumulative impacts.





Harper Method Treatment Requirements

80% Removal Efficiency:	1.30"
95% Removal Efficiency:	2.85"

Swale and Pond Configurations



Circular Pond



Square Pond ($L=W$)



Rectangular Pond ($L=2W$)



Rectangular Pond ($L=3W$)



Rectangular Pond ($L=6W$)



Swale ($BW=10'$, $SS=3:1$)

Design Treatment Depth = 2'



Pond Btm (el. 100')

Ambient WT (el. 94')

Vertical Conductivities: 7.5, 11.25 & 15.0 fpd
Horizontal Conductivities: 15.0, 22.5 & 30.0 fpd

Aquifer Base (el. 80')

Treatment Footprint - average surface area -

Area in Acres
1.30"
(80%) 2.85"
(95%)



1.67

3.59

1.66

3.60

1.67

3.61

1.68

3.61

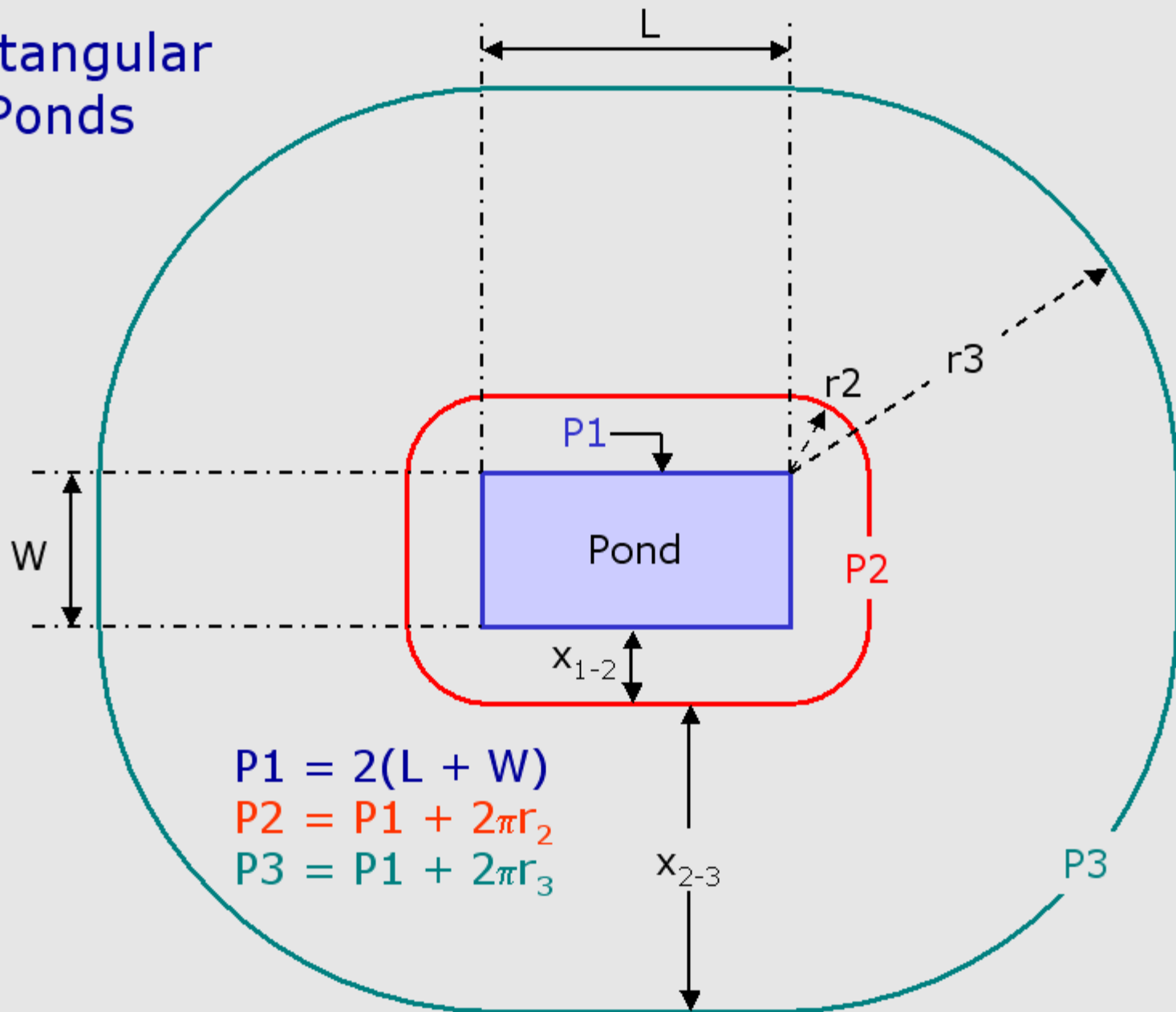
1.70

3.65

2.19

4.80

Rectangular Ponds



Treatment Footprint Perimeters

Perimeter, P1 (ft)
1.30"
(80%) 2.85"
(95%)



936

1,382

1,052

1,560

1,116

1,656

1,216

1,800

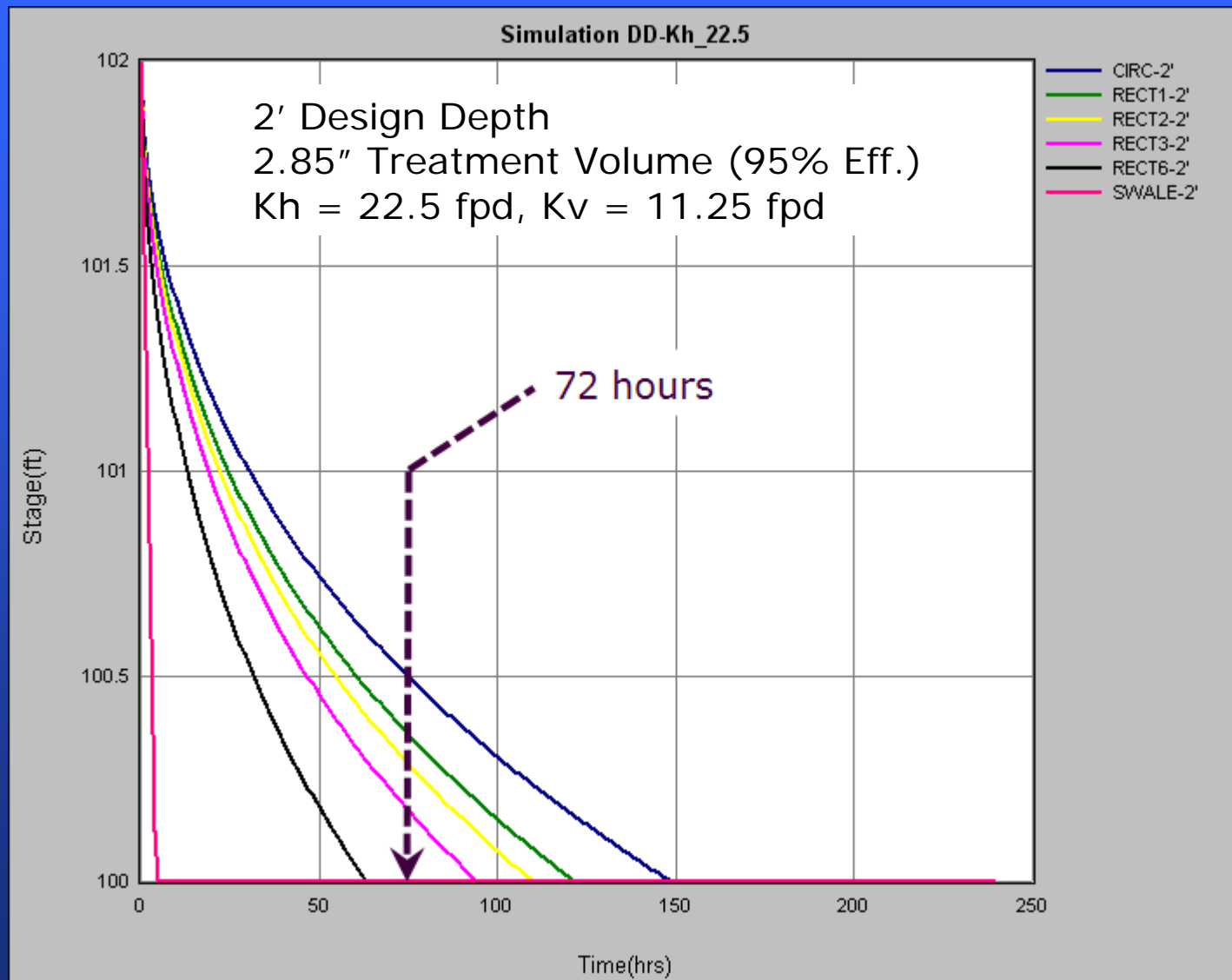
1,505

2,229

8,666

19,000

Typical Drawdown Curves Based on Slug Load



Drawdown Times (hrs) 2' Depth, 1.30" Treatment

Kh (fpd)

15.0

22.5

30.0



1:1

2:1

3:1

6:1



Failed 72-hr
Drawdown Test

95

64

48

77

52

39

70

47

36

61

41

31

42

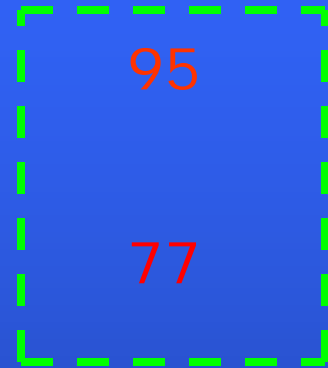
28

21

7

5

4



Drawdown Times (hrs) 2' Depth, 2.85" Treatment

Kh (fpd)

15.0

22.5

30.0



Failed 72-hr Drawdown Test

219

149

113

180

122

92

163

111

84

140

95

72

95

64

48

7

5

4



A 2.85" treatment volume would have to be fully recovered within 72 hours according to the proposed rule even though only 1.6% of all rain events in Orlando are greater than 2.5".

TABLE 3-2

PERCENTAGE OF ANNUAL RAIN EVENTS OCCURRING IN SELECTED EVENT INTERVALS

RAINFALL STATION	AVERAGE NUMBER OF RAIN EVENTS	PERCENTAGE OF THE NUMBER OF RAIN EVENTS FOR VARIOUS RAINFALL EVENT INTERVALS																			
		0.00-0.10	0.11-0.20	0.21-0.30	0.31-0.40	0.41-0.50	0.51-1.00	1.01-1.50	1.51-2.00	2.01-2.50	2.51-3.00	3.01-3.50	3.51-4.00	4.01-4.50	4.51-5.00	5.01-6.00	6.01-7.00	7.01-8.00	8.01-9.00	9.01-15.00	15.01-20.00
Branford	105.85	39.8	13.2	8.2	6.0	4.4	14.6	6.4	3.6	1.7	0.8	0.4	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.1	0.0
Cross City	104.23	36.8	14.0	8.6	6.6	4.8	14.5	6.8	3.3	1.9	1.1	0.6	0.3	0.2	0.1	0.2	0.1	0.0	0.1	0.0	0.0
Ft. Myers	108.96	39.2	14.7	9.0	5.2	4.5	13.8	6.4	3.3	1.7	0.8	0.5	0.2	0.1	0.2	0.2	0.0	0.1	0.1	0.0	0.0
Jacksonville	127.23	43.8	14.5	7.7	6.2	3.8	12.5	5.3	2.7	1.4	0.9	0.3	0.3	0.2	0.2	0.1	0.1	0.0	0.1	0.1	0.0
Key West	127.51	53.7	14.6	6.7	5.5	3.2	9.4	3.2	1.6	0.6	0.4	0.3	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Melbourne	107.38	41.8	15.8	7.8	6.0	4.0	12.9	5.9	2.7	1.2	0.7	0.4	0.2	0.2	0.1	0.1	0.0	0.1	0.0	0.0	0.0
Miami	158.03	50.2	14.6	7.0	5.3	3.5	9.9	4.2	2.2	1.2	0.8	0.3	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Orlando	126.53	43.3	15.6	7.2	5.7	4.2	12.9	5.5	2.6	1.2	0.7	0.3	0.2	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0
Pensacola	126.09	45.6	12.9	5.9	4.9	3.4	12.2	6.4	3.4	1.9	1.1	0.6	0.3	0.4	0.2	0.3	0.1	0.2	0.0	0.1	0.0
Tallahassee	123.78	40.4	12.6	7.0	6.1	4.3	13.8	7.1	3.4	1.9	1.1	0.9	0.4	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.0
Tampa	111.74	43.4	14.0	7.8	6.1	4.4	12.6	5.7	2.7	1.4	0.6	0.5	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.1	0.0
Minimum	104.23	36.8	12.6	5.9	4.9	3.2	9.4	3.2	1.6	0.6	0.4	0.3	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Maximum	158.03	53.7	15.8	9.0	6.6	4.8	14.6	7.1	3.6	1.9	1.1	0.9	0.4	0.4	0.2	0.3	0.2	0.2	0.1	0.1	0.0
Mean	120.67	43.5	14.2	7.5	5.8	4.1	12.7	5.7	2.9	1.5	0.8	0.5	0.3	0.2	0.1	0.2	0.1	0.1	0.0	0.1	0.0

Rainfall Data for Long Term Simulations

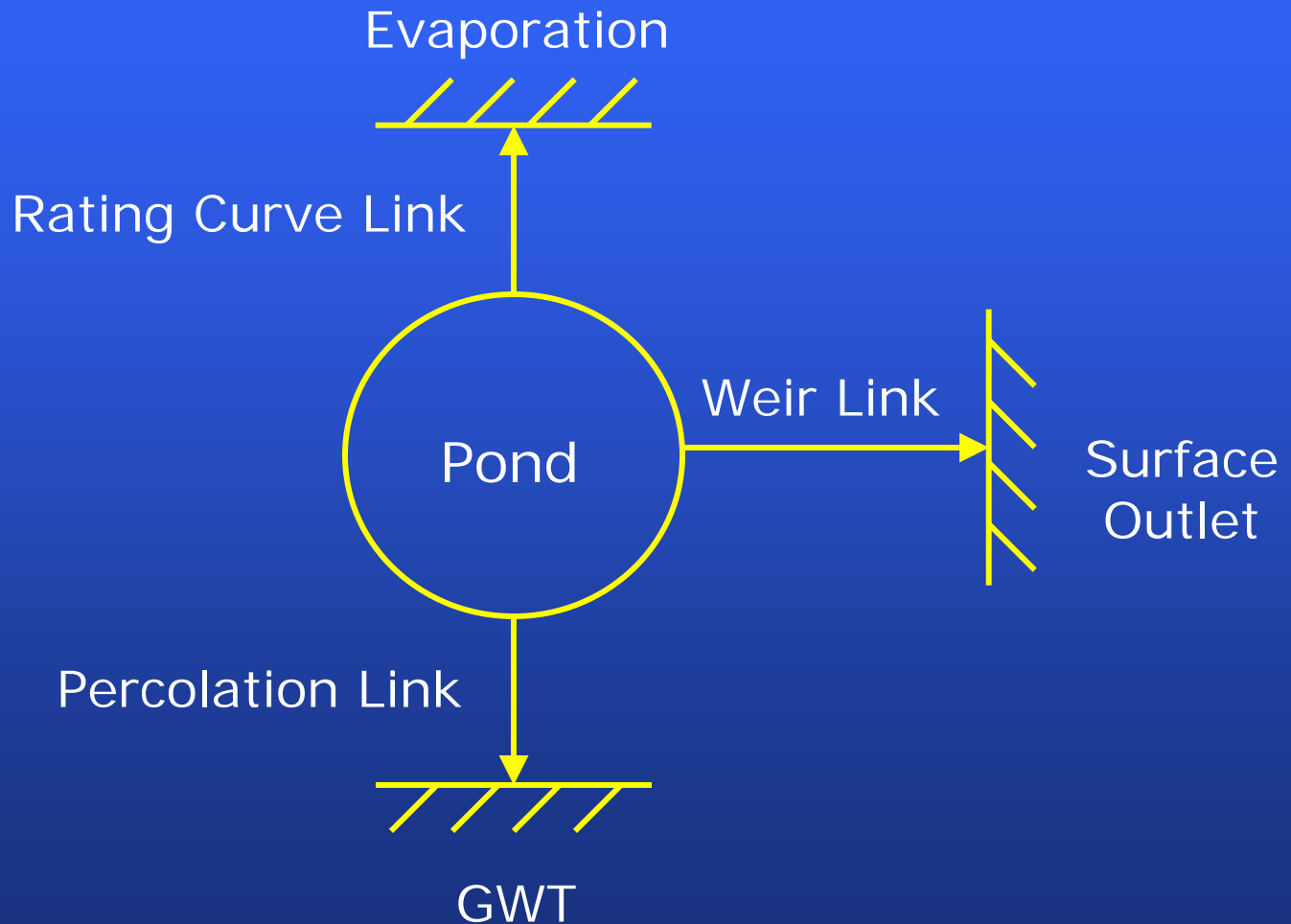
1990	36.9"	dry
1991	50.5"	average
1992	48.7"	average
1993	39.2"	dry
1994	65.1"	wet
1995	58.2"	wet
Total	298.6"	

Note: Mean Annual Rainfall for Orlando International Airport is 50.0"

Evaporation Data

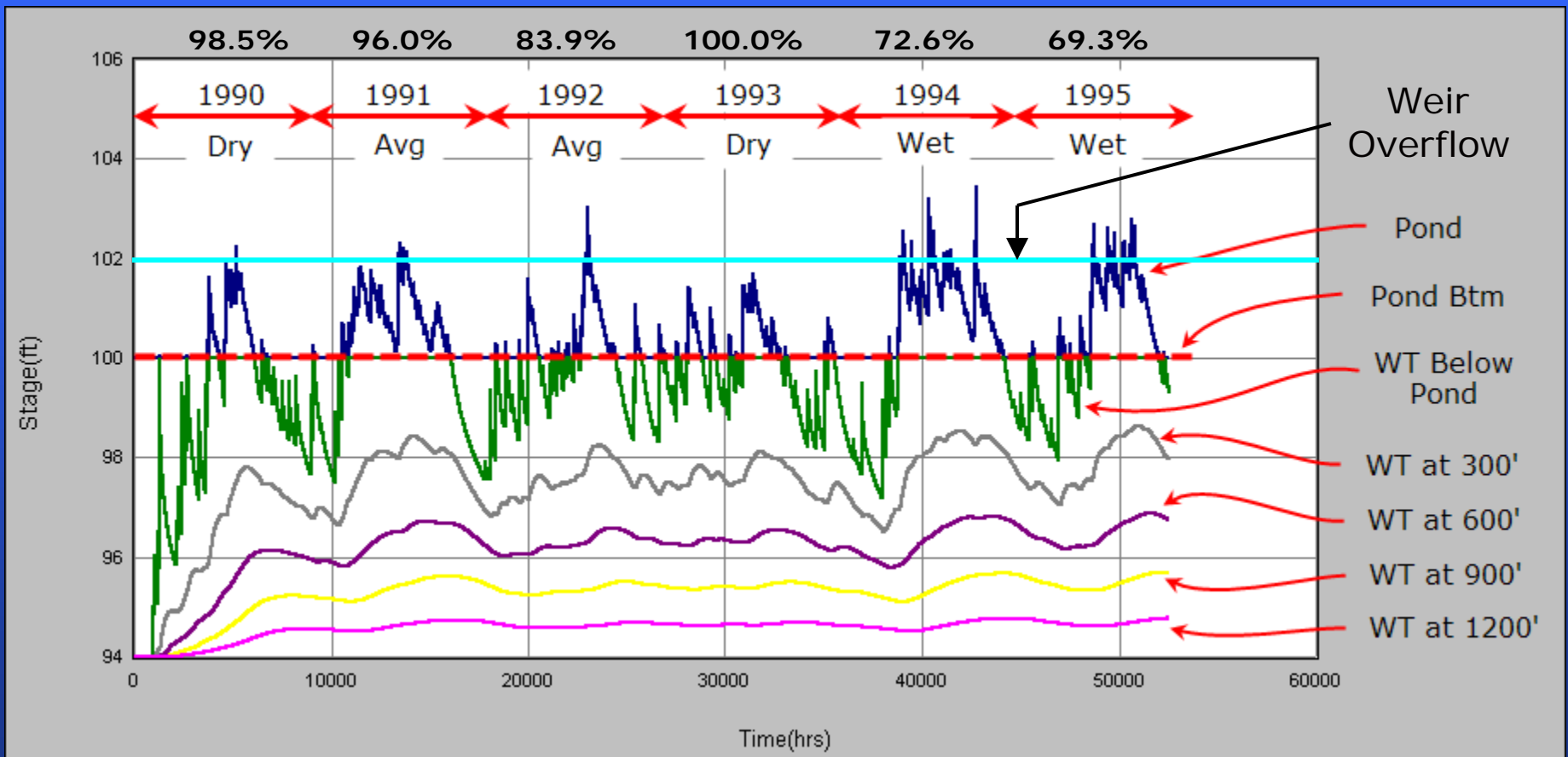
January	2.20"	July	6.20"
February	2.49"	August	5.49"
March	3.91"	September	4.41"
April	5.49"	October	3.60"
May	6.70"	November	2.31"
June	6.00"	December	2.20"
Total Annual Evaporation	51.0"		

Typical ICPR Nodal Schematic

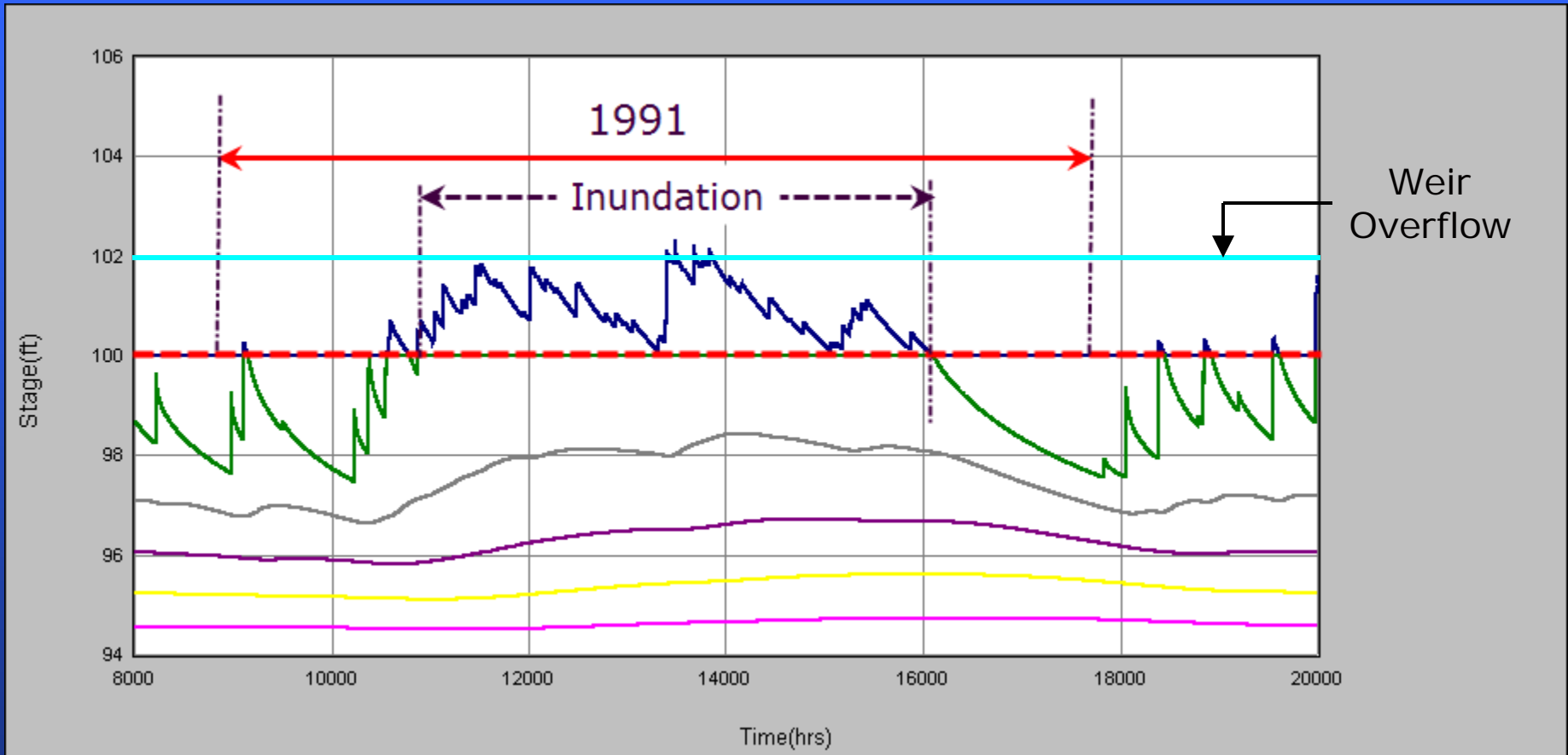


Circular Pond

2' Depth, 95% Target Eff., $K_h=22.5$ fpd

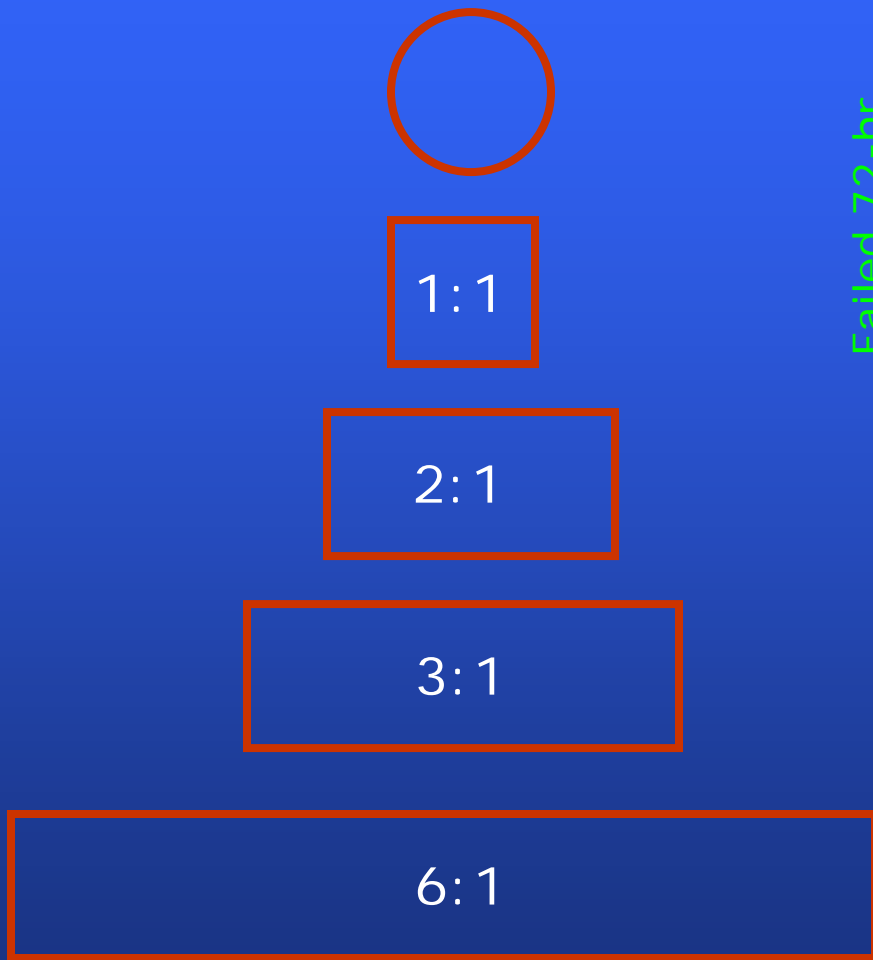


Circular Pond 2' Depth, 95% Target Eff.



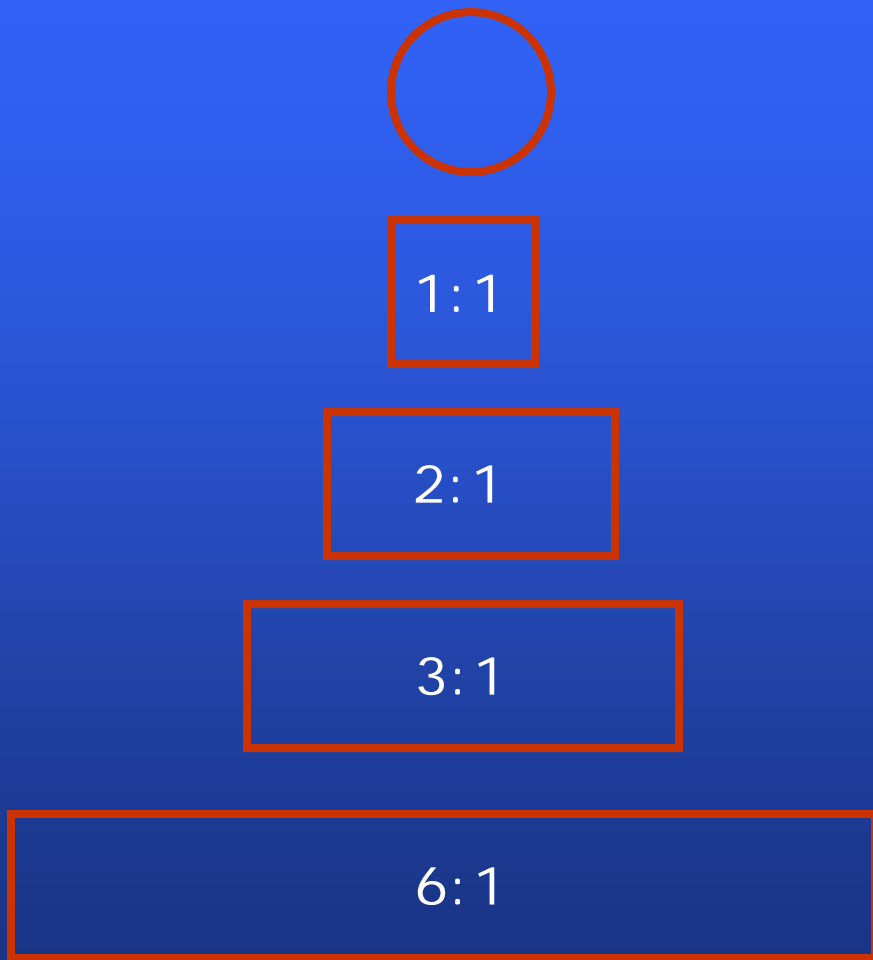
Note: Although the 72-hour drawdown is not met for this pond configuration and the pond is inundated for a long period, the 95% target efficiency is still achieved for 1991, an average year.

Removal Efficiencies for 1991 2' Depth, 80% Target Eff.



	Kh (fpd)		
	15.0	22.5	30.0
	64.0%	78.9%	87.4%
Failed 72-hr Drawdown Test	66.3%	81.0%	89.7%
	67.6%	82.0%	90.7%
	69.7%	83.7%	92.3%
	75.0%	88.2%	94.9%
	100.0%	100.0%	100.0%

Removal Efficiencies for 1991 2' Depth, 95% Target Eff.

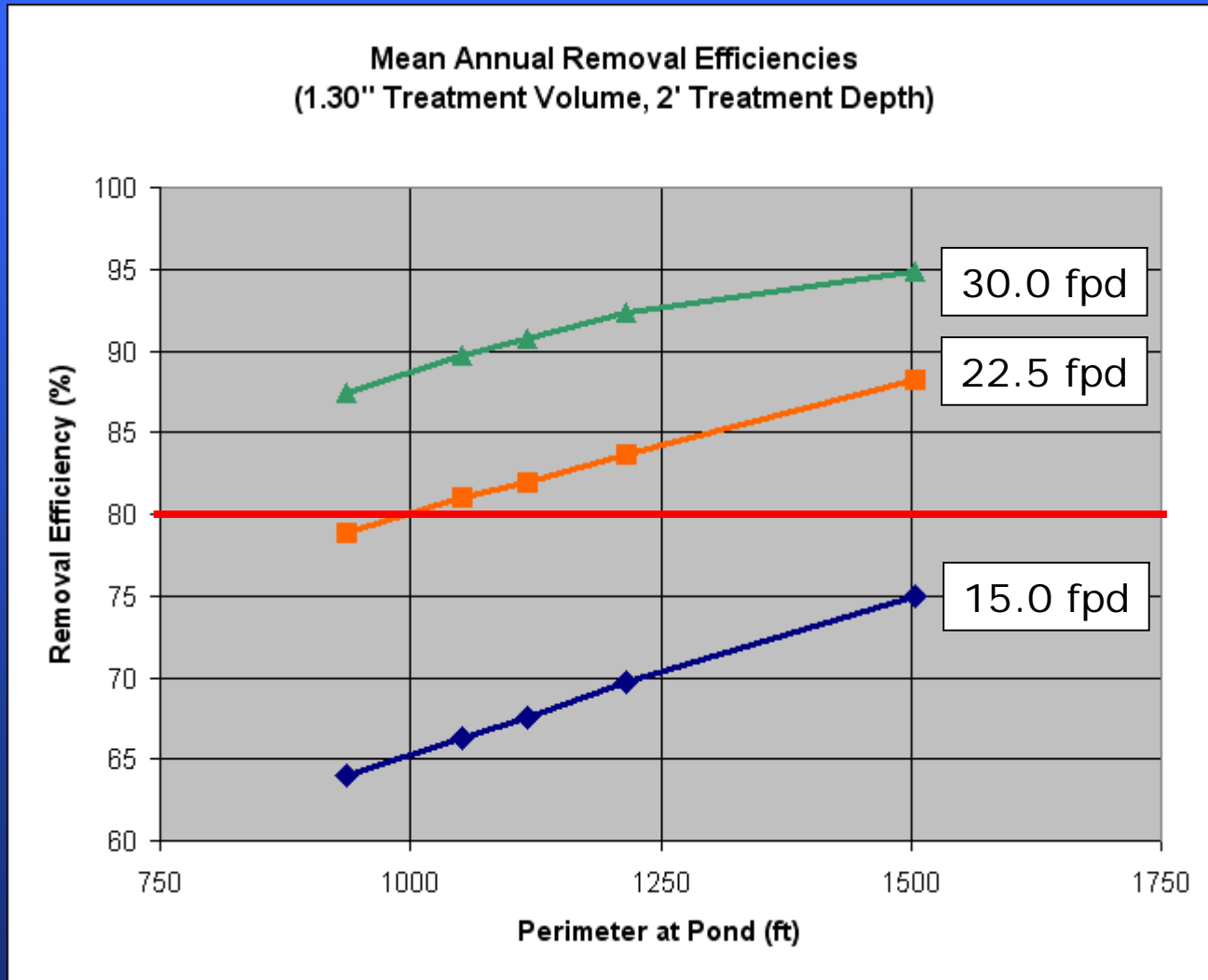


	Kh (fpd)		
	15.0	22.5	30.0
Circle	84.3%	96.0%	100.0%
1:1	87.1%	98.3%	100.0%
2:1	88.1%	98.7%	100.0%
3:1	90.2%	99.7%	100.0%
6:1	94.7%	100.0%	100.0%
Dashed Red Line	100.0%	100.0%	100.0%

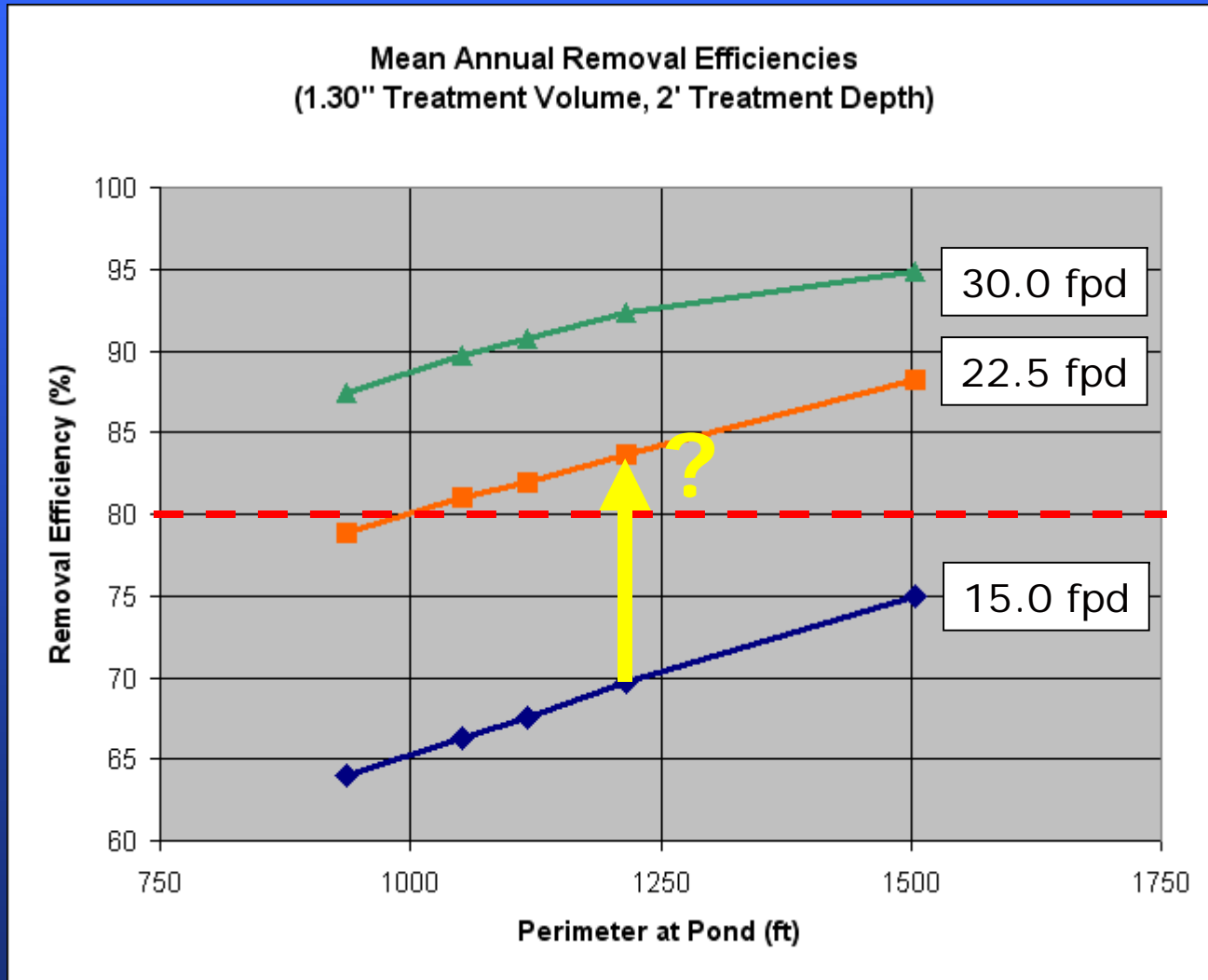
Failed 72-hr Drawdown Test

1991 Removal Efficiencies Versus Pond Perimeter

2' Depth, 80% Target Efficiency

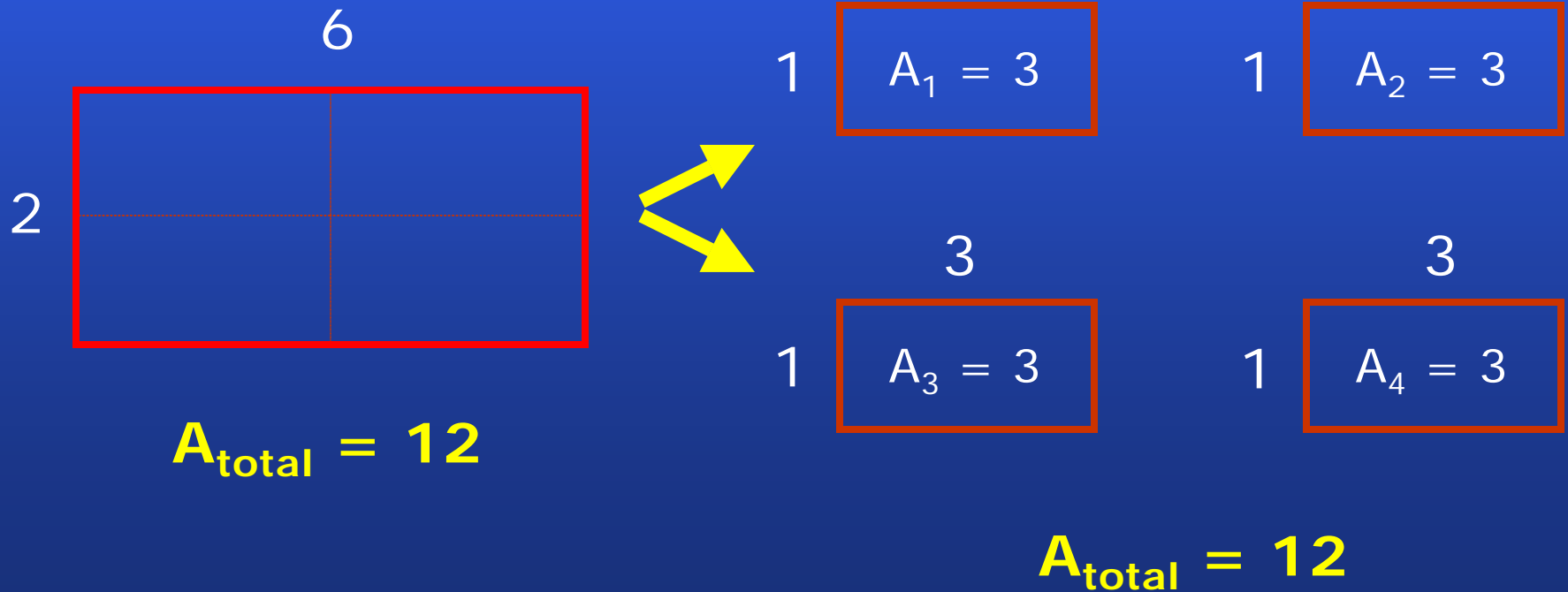


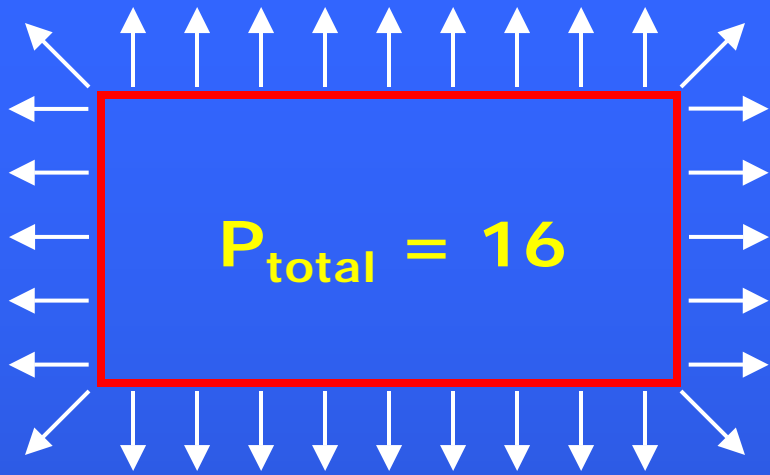
How can treatment efficiency be increased without increasing the treatment footprint?



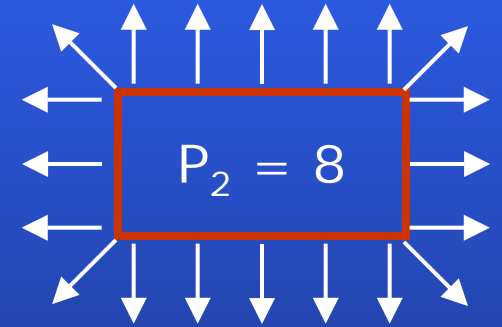
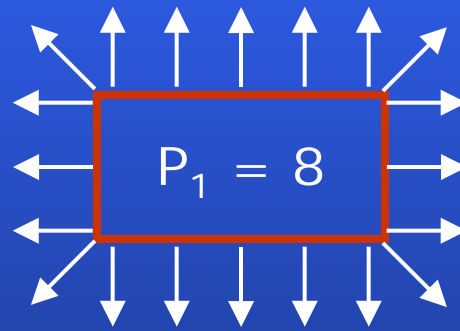
Distribute the Ponds

Instead of using a single large pond, multiple ponds distributed throughout the project site can create major improvements to the overall treatment efficiency without increasing the net "treatment footprint".

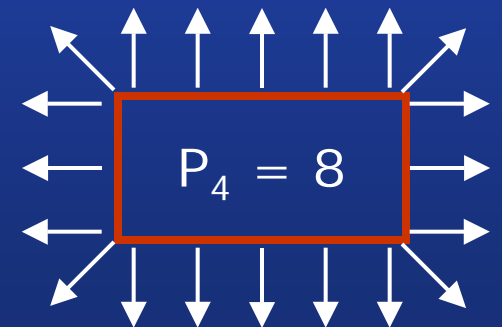
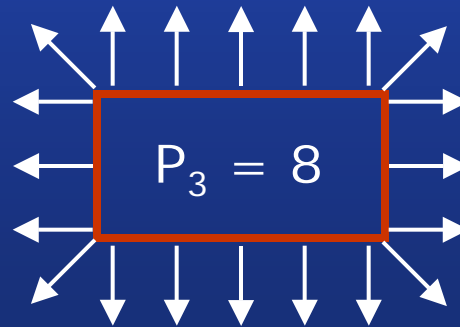




Since groundwater flow is radially outward from a given pond, increasing the overall perimeter increases the percolation.



$P_{\text{total}} = 32$

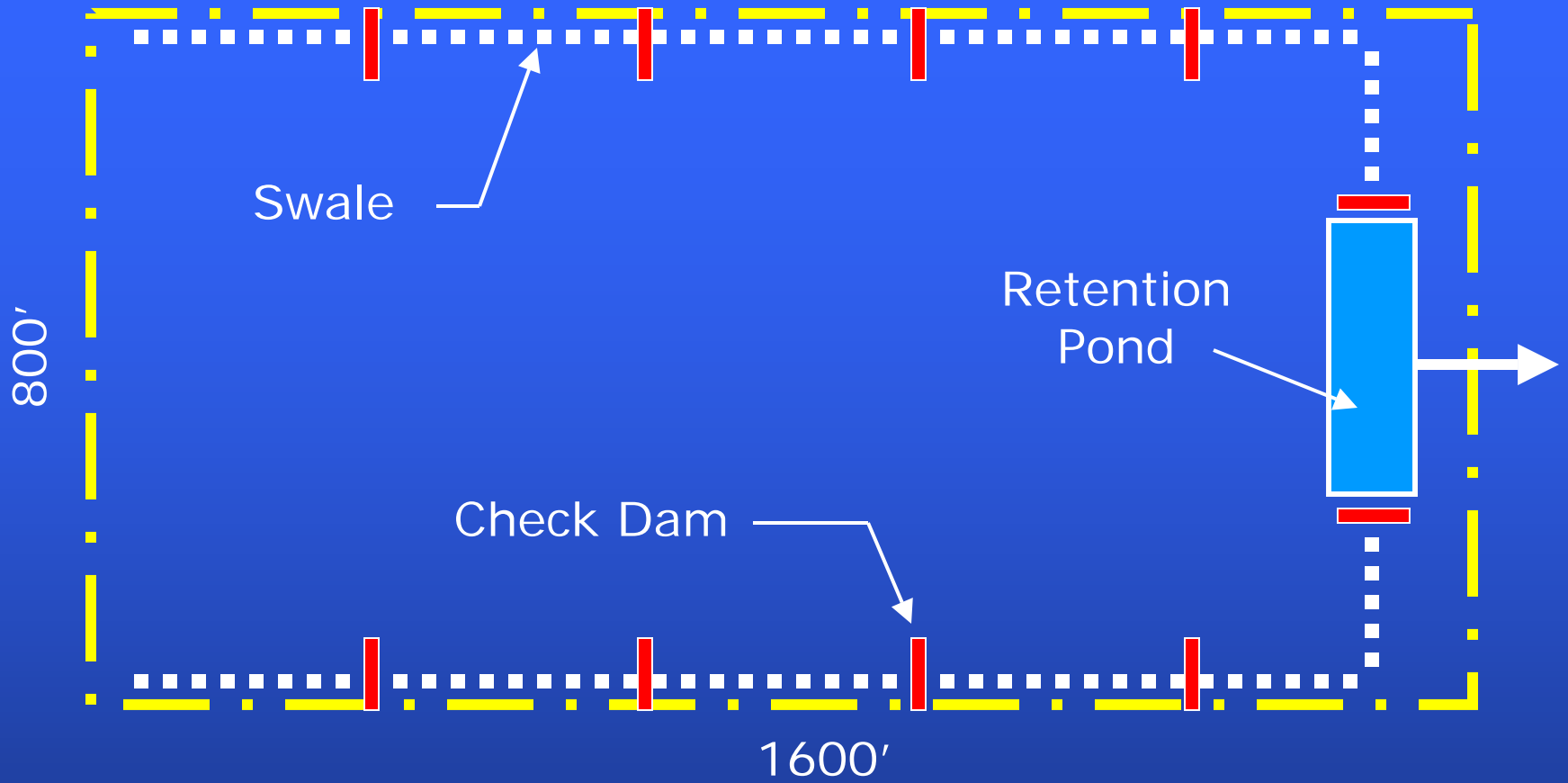


Summary of Removal Efficiencies for Rectangular Pond (3:1 Aspect Ratio, 2' Depth, Kh= 15 fpd)

80% Target

95% Target

Year	Rainfall	1-Pond	4-Pond	1-Pond	4-Pond
1990	36.9"	77.0%	93.8%	96.9%	100.0%
1991	50.5"	69.7%	97.9%	90.2%	100.0%
1992	48.7"	65.7%	88.5%	81.0%	97.2%
1993	39.2"	80.0%	98.3%	99.9%	100.0%
1994	65.1"	48.6%	80.5%	64.5%	91.9%
1995	58.2"	47.9%	82.8%	62.7%	98.4%
6-Yr Avg	49.8"	61.7%	88.7%	78.9%	97.4%



Various Treatment Methods can be Combined and Integrated to Optimize Performance

Conclusions

- 72-hour drawdown requirement is not a good indicator of treatment efficiency
- Shape matters!
- Distribute to increase efficiency
- Integrate systems to optimize
- Evaporation can be a significant factor