Modeling Techniques for Stormwater Pond Sizing to Meet New Criteria in FDEP's State-wide Stormwater Rule

PONDS Training Workshop

October 9, 2009

DEVO Engineering

CONSULTING GEOTECHNICAL ENGINEERS

References

- **Evaluation of Current Stormwater Design Criteria Within the State of Florida, Final Report**. By Harvey H. Harper, Ph.D., P.E. & David M. Baker, P.E., Environmental Research & Design, Inc.
- **Stormwater Quality Applicant's Handbook, Draft (July 2009)**. Department Of Environmental Protection And Water Management Districts

New FDEP Stormwater Rule for Calculating Pollution Treatment Volumes

New stormwater regulations are set to take effect which will :

- Limit the postdevelopment discharge of nutrients in stormwater to less than or equal to predevelopment, i.e., Post = Pre, or
- Require a specified reduction in postdevelopment nutrient discharge
  - 85% reduction in postdevelopment phosphorous discharge
  - 60 to 65% reduction in postdevelopment nitrogen discharge

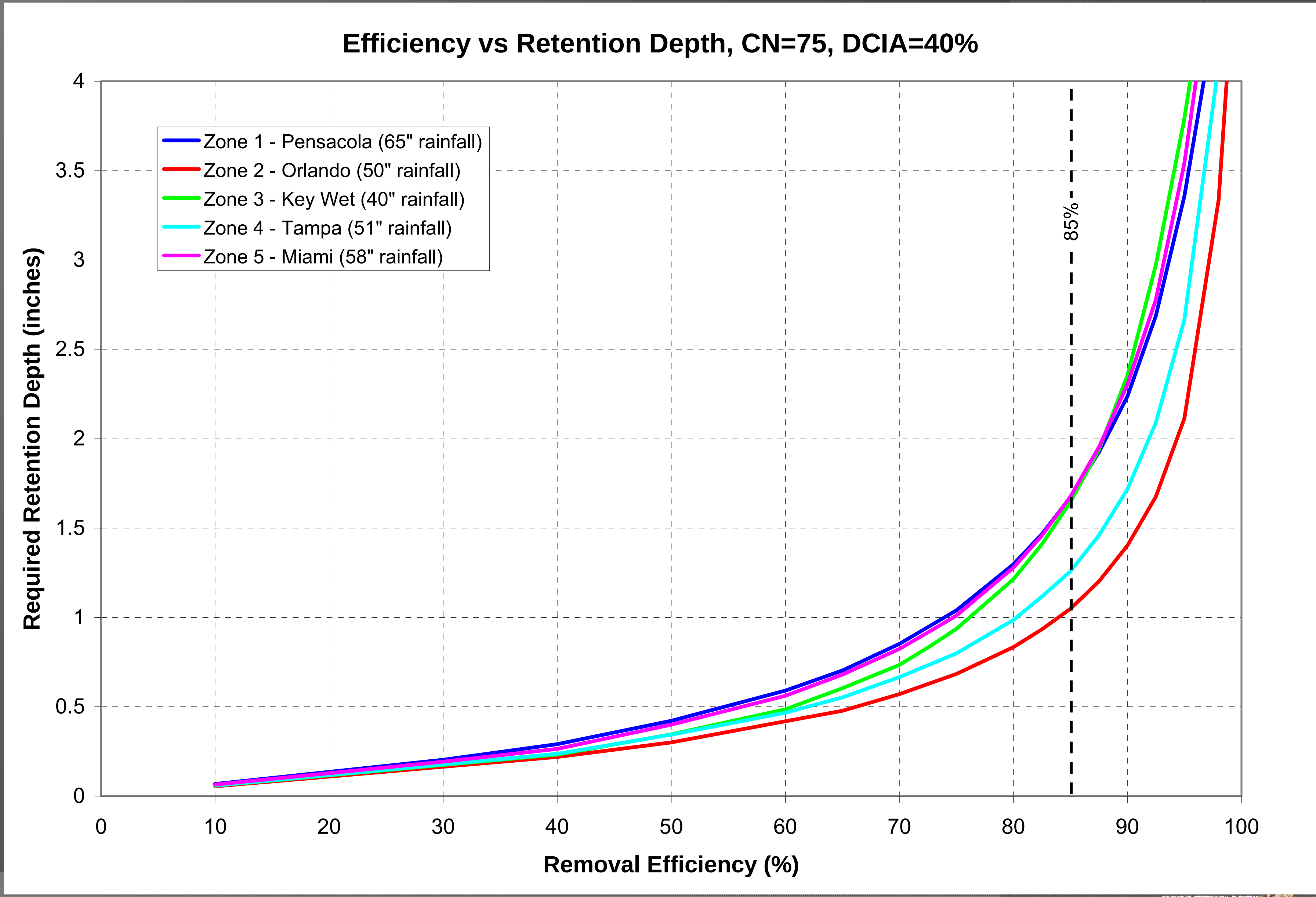
New FDEP Stormwater Rule for Calculating Pollution Treatment Volumes

Direct discharges to Outstanding Florida Waters shall provide a minimum level of treatment that results in the post-development average annual loading of total phosphorus not exceeding the loading from representative native landscapes (e.g., post=pre).

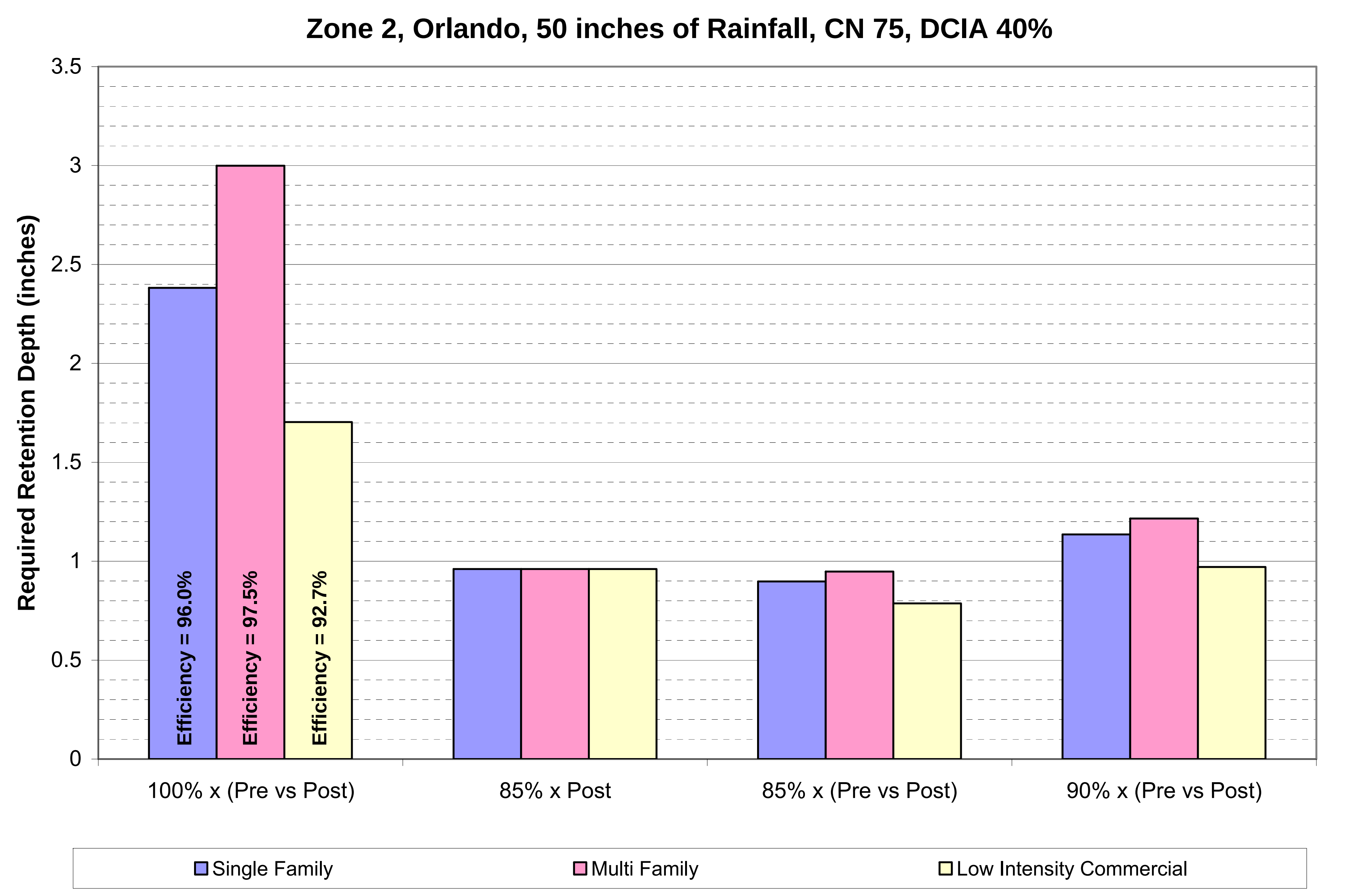
Stormwater Performance Standards

CLASS 3	OFW	IMPAIRED	TMDL ADOPTED	BMAP ADOPTED
New development Infill development 85% or Post=Pre, Whichever is less	New development Infill development Post = Pre	New development Infill development Post = Pre	New development Infill development Post = Pre	New development Infill development Post= Pre unless BMAP specifies otherwise
CLASS 3	**OFW**	**IMPAIRED**	**TMDL ADOPTED**	**BMAP ADOPTED**
Redevelopment Net Improvement	Redevelopment Net improvement	Redevelopment Net improvement	Redevelopment Net improvement or TMDL % reduction, Whichever is greater	Redevelopment Net improvement or TMDL % reduction, Whichever is greater, unless BMAP specifies otherwise

The Problem With Achieving High Efficiencies (Dry Pond)



Comparison of Efficiency Criteria (example)



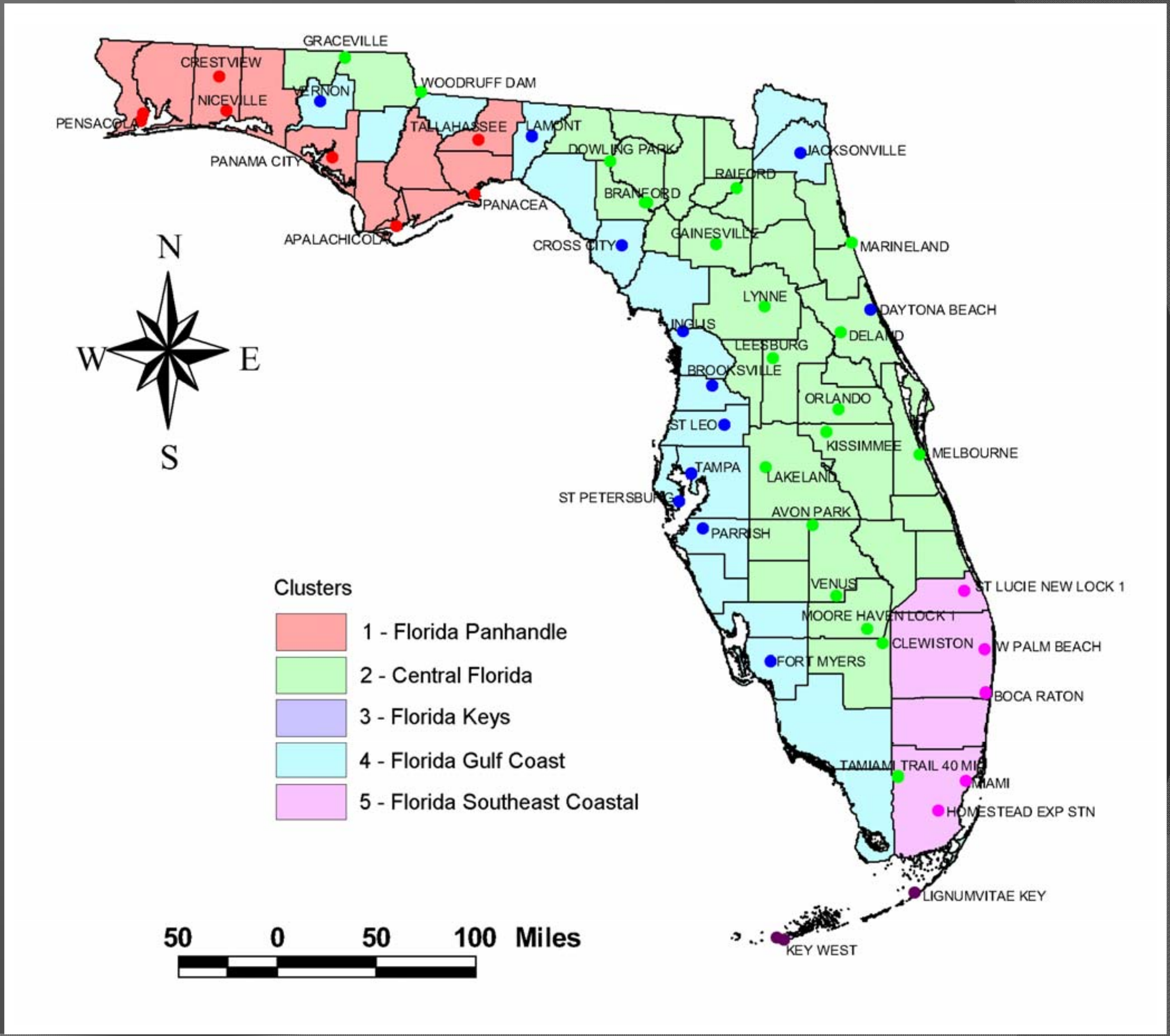
Proposed Methodology

The new rules provide a procedure for calculating the treatment volume requirements for stormwater ponds within the State of Florida.

The methodology divides the State of Florida into five distinct climate zones based on similarities in the average yearly rainfall distribution, etc.

1. Florida Panhandle
2. Central Florida
3. Florida Keys
4. Florida Gulf Coast
5. Florida Southeast Coastal

Climate Zones



Types of Pond Configurations

- Dry Pond
- Wet Pond
- Treatment Train
- Stormwater Reuse Pond
- Chained Wet Ponds

Dry Ponds - Efficiency

Dry pond removal efficiency is simply the percentage of the annual runoff volume which is retained and infiltrated for an average rainfall year.

Wet Ponds

Wet pond removal efficiency of nitrogen and phosphorous is a function of annual residence time.

Uptake of nitrogen and phosphorous in a wet pond is initially fairly rapid but tapers off with time (primarily a function of sedimentation).

Definition of Annual Residence Time

$$\text{Annual Residence Time} = \frac{\text{Wet Pond Volume}}{\text{Yearly Runoff Volume}}$$

Example:

Pond Volume = 50 ac-ft

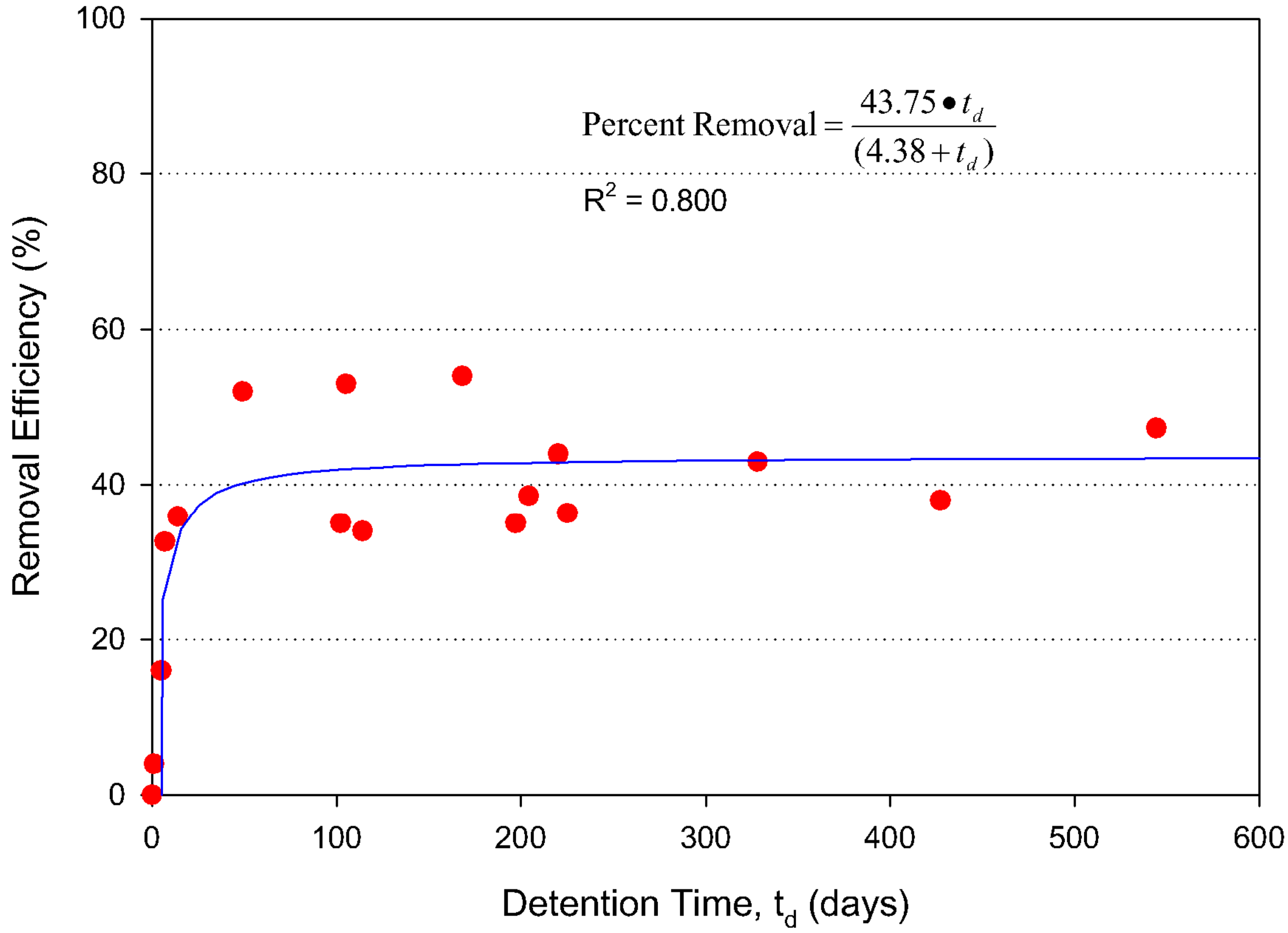
Yearly Runoff = 91.25 ac-ft/yr

$$\text{Annual Residence Time} = \frac{\text{50 ac-ft}}{\text{91.25 ac-ft/yr}} = \text{200 days}$$

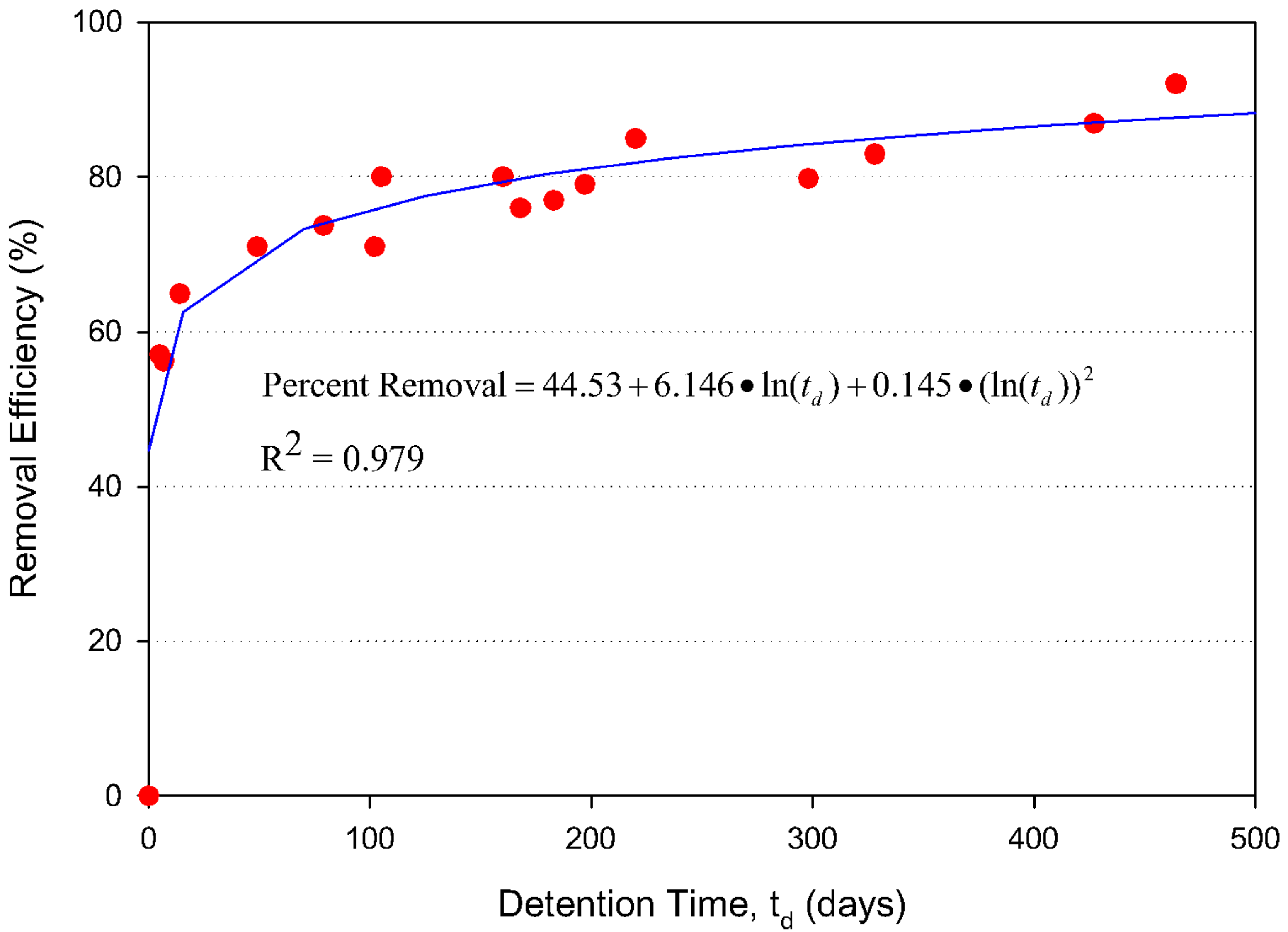
Annual Residence Time (continued)

Note that the residence time used in the calculations is the **annual** residence time as defined in the previous slide. This should not be confused with wet season residence time, or any other definition of residence time.

Nitrogen Removal Efficiency for Wet Pond



Phosphorous Removal Efficiency for Wet Pond



Note to Practitioners in SJRWMD

In SJRWMD, the current removal efficiency limit is 64.5% for a permanent pool volume that provides for a WET SEASON residence time of 21 days.

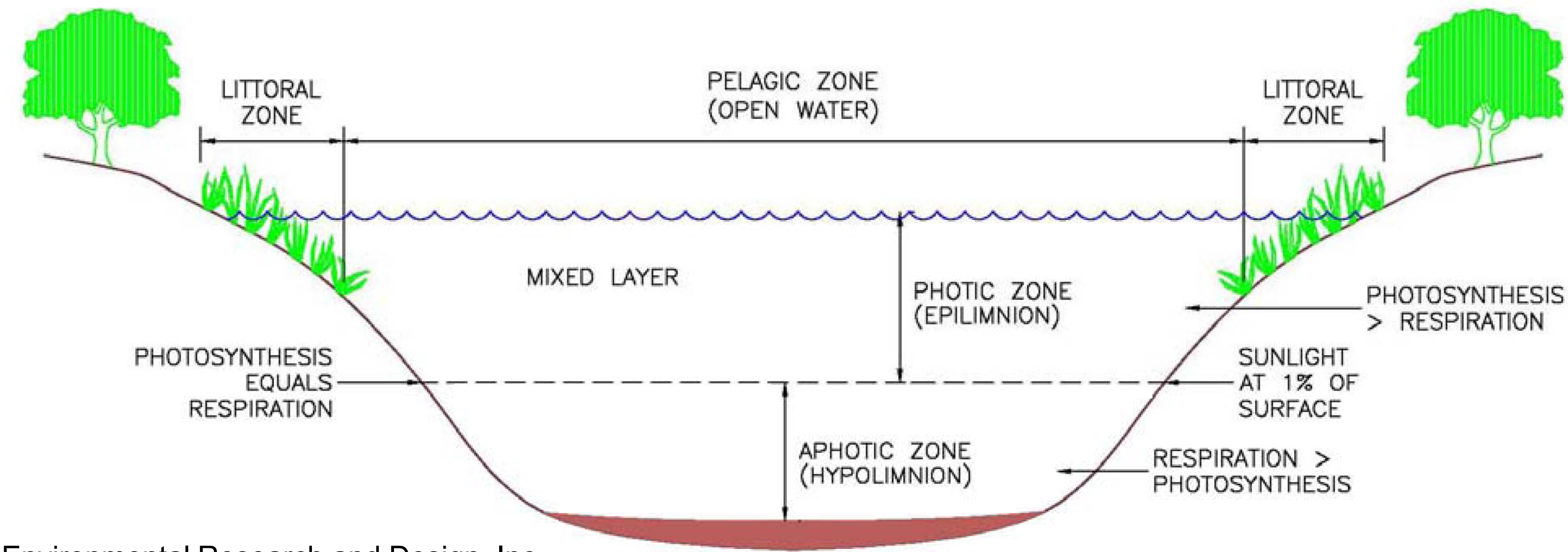
If the WET SEASON residence time is 14 days, then the removal efficiency would be 61.5%.

Also note that the Residence Time entered in the Wet Pond input data in this module is the ANNUAL residence time, not the WET SEASON residence time.

Note that this limitation imposed by SJRWMD may or may not become part of the final rule in SJRWMD.

Anoxic Depth of Pond or Lake

Anoxia is defined as dissolved oxygen concentrations less than 1 mg/l, for waterbodies in Central and South Florida.



Environmental Research and Design, Inc.

The volume of water below the anoxic depth does not provide treatment. Only the volume of water above the anoxic depth is used when calculating the permanent pool volume.

Wet Pond Limitations

Nitrogen removal efficiency for a wet pond quickly reaches a point of diminishing returns. Nitrogen removal efficiency is limited to about 43%.

Therefore, a wet pond alone will probably not work for most sites if nitrogen removal is considered in the analysis.

Treatment Trains

When a wet pond will not remove a sufficient percentage of nutrients on it's own, then pre-treatment of the stormwater runoff can be used. The most efficient way to achieve pre-treatment is by placing a dry pond in series with a wet pond.

→ Dry Pond → Wet Pond →

The dry pond must be sized to remove whatever mass of nutrient can not be removed by the wet pond.

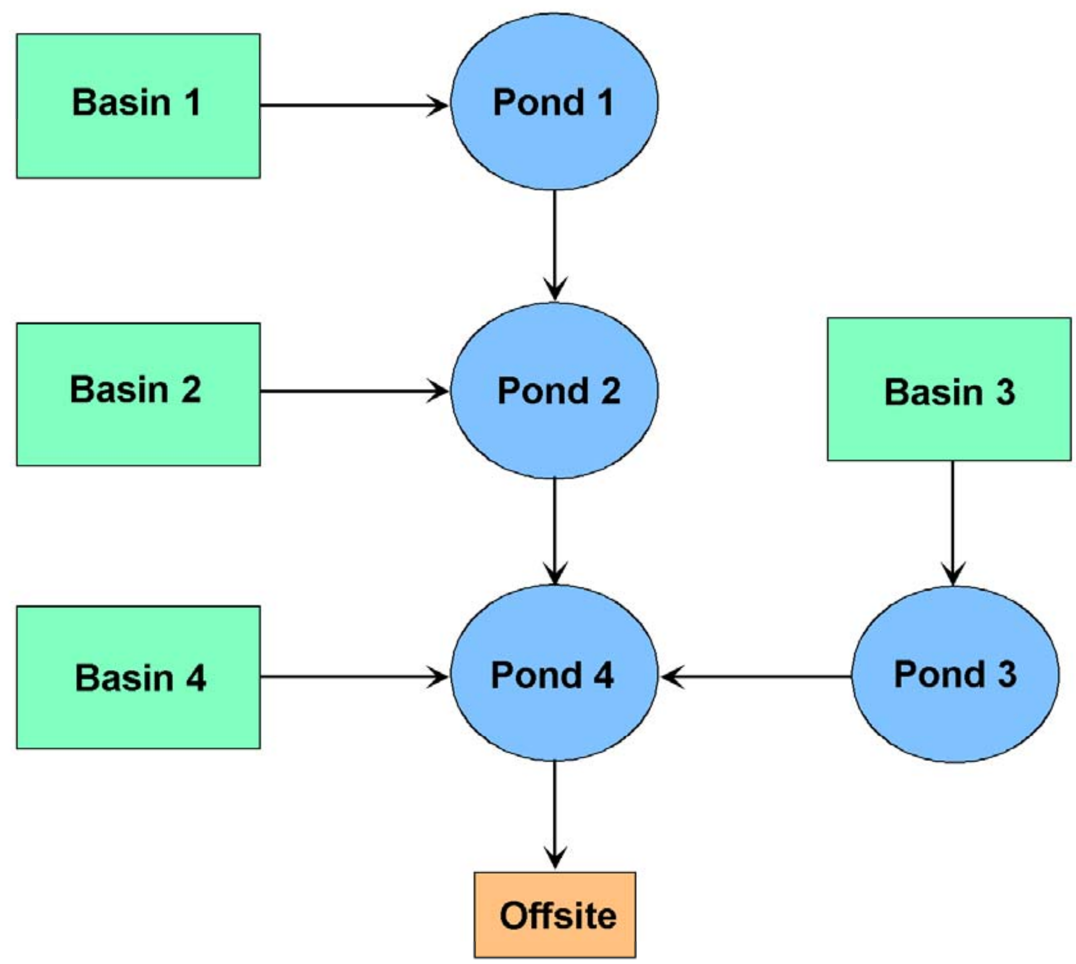
Treatment Train Efficiencies

The total efficiency in a wet/dry treatment train is calculated as follows:

$$\text{Total Efficiency} = Eff_{dry} + (1 - Eff_{dry}) \times Eff_{wet}$$

Note that the wet and dry efficiencies are not simply added. The wet pond removes a percentage of whatever nutrient remains after pretreatment.

Chained Wet Ponds



Efficiency of Chained Wet Ponds

The removal efficiency for a series of chained wet ponds is based on total residence time

$$T = T1 + T2 + T3... \rightarrow \text{Efficiency}$$

Nutrient removal in a wet pond is primarily a function of sedimentation, which depends on the total amount of time that runoff (from a particular basin) is resident within the pond system. Each runoff basin will therefore have a different total residence time.

Efficiency of Chained Wet Ponds (cont'd)

The efficiency of wet ponds in series is NOT calculated by compounding the efficiencies of individual ponds in series, for example

$$E = E1 + (1 - E1) \times E2 \quad \text{(Wrong!)}$$

Stormwater Harvesting Pond

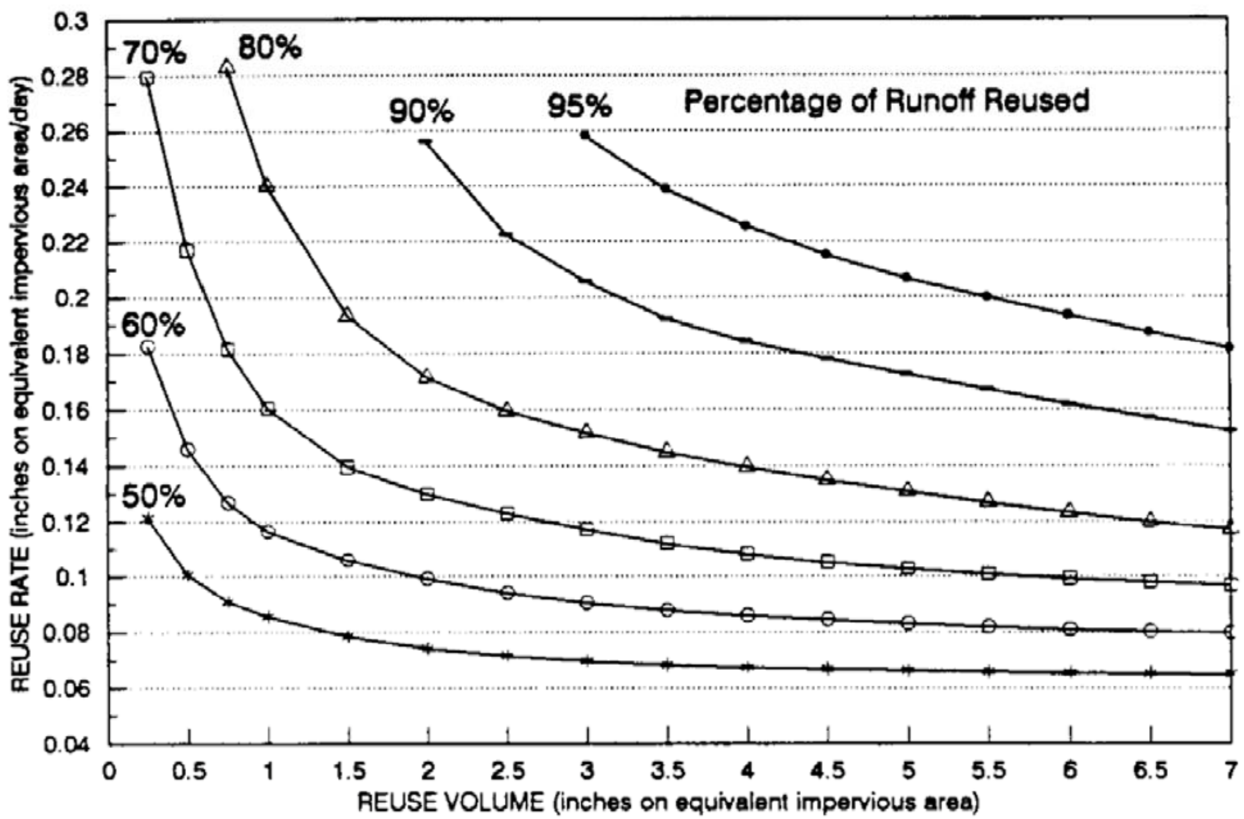
A stormwater harvesting pond (a.k.a. stormwater reuse pond) is a retention pond which is also used as a source for irrigation water (or other non-potable use).

The efficiency of a stormwater harvesting pond is a function of the volume of water which is consumed for irrigation which would otherwise have been discharged offsite.

Design curves for estimating the efficiency of a stormwater harvesting pond are available based on the work of Dr. Marty Wanielista.

Application rates from stormwater harvesting ponds will probably be limited to between 0.7 and 1.0 inches.

R-E-V Design Curves for Stormwater Harvesting Pond



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R-E-V Design Curves for Stormwater Harvesting Pond

EIA = Equivalent Impervious Area

EIA = Total Basin Area * Weighted Average Runoff Coefficient

Reuse Rate (R) is calculated as inches over the equivalent impervious area (EIA). Convert to actual application rate as follows:

$$R_{app} = R \times EIA / \text{Irrigated Area}$$

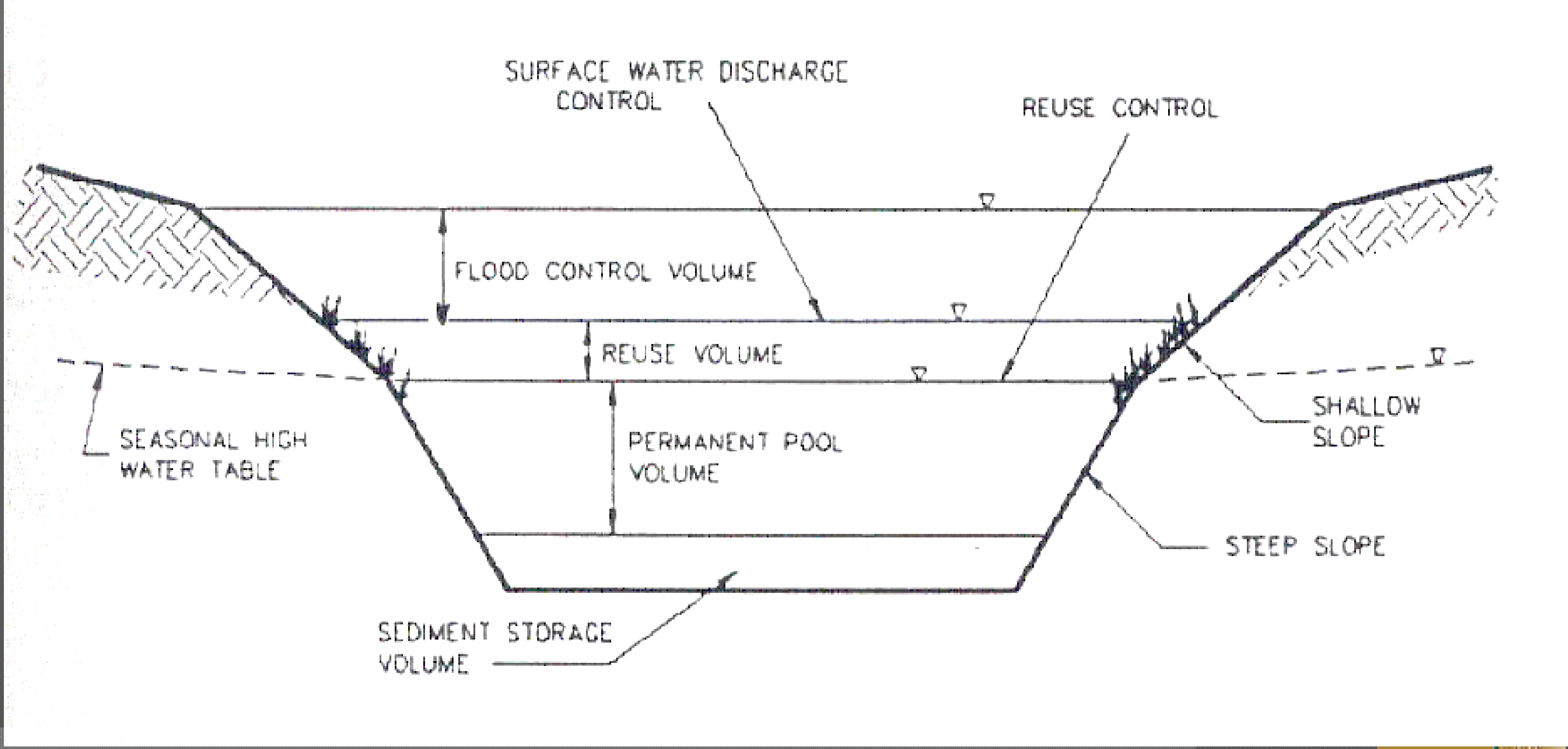
Reuse Volume (V) is calculated as inches over the equivalent impervious area (EIA). Convert to storage volume as follows:

$$V_{storage} = V \times EIA$$

Note: The design curves for stormwater reuse assume that the pond area is included in the calculation of the weighted average runoff coefficient.

Stormwater Harvesting Pond

The stormwater reuse volume is provided between the normal water level and the control elevation of the pond.



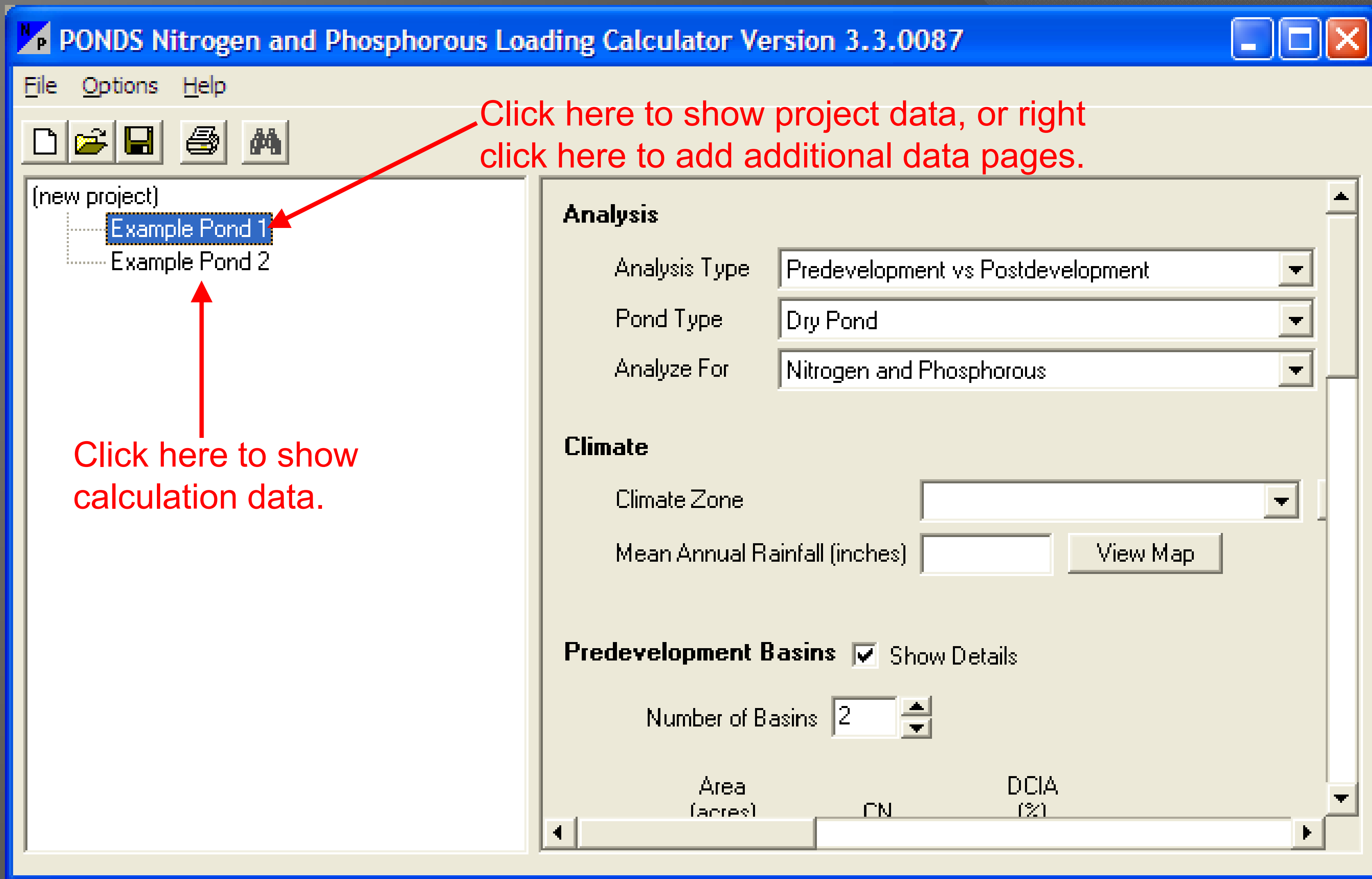
Using the PONDS 3.3

Nitrogen and Phosphorous

Loading Module

First Look

Early adopters of the PONDS N-P module will notice a big change in the data layout of the current program version. The data input has been simplified and made more intuitive.



Left pane shows list of current data pages, for example project data or calculation data pages.

Right pane shows data entry page, for project data or calculations.

A Quick Look at the Calculations Data

Analysis

Analysis Type: Predevelopment vs Postdevelopment

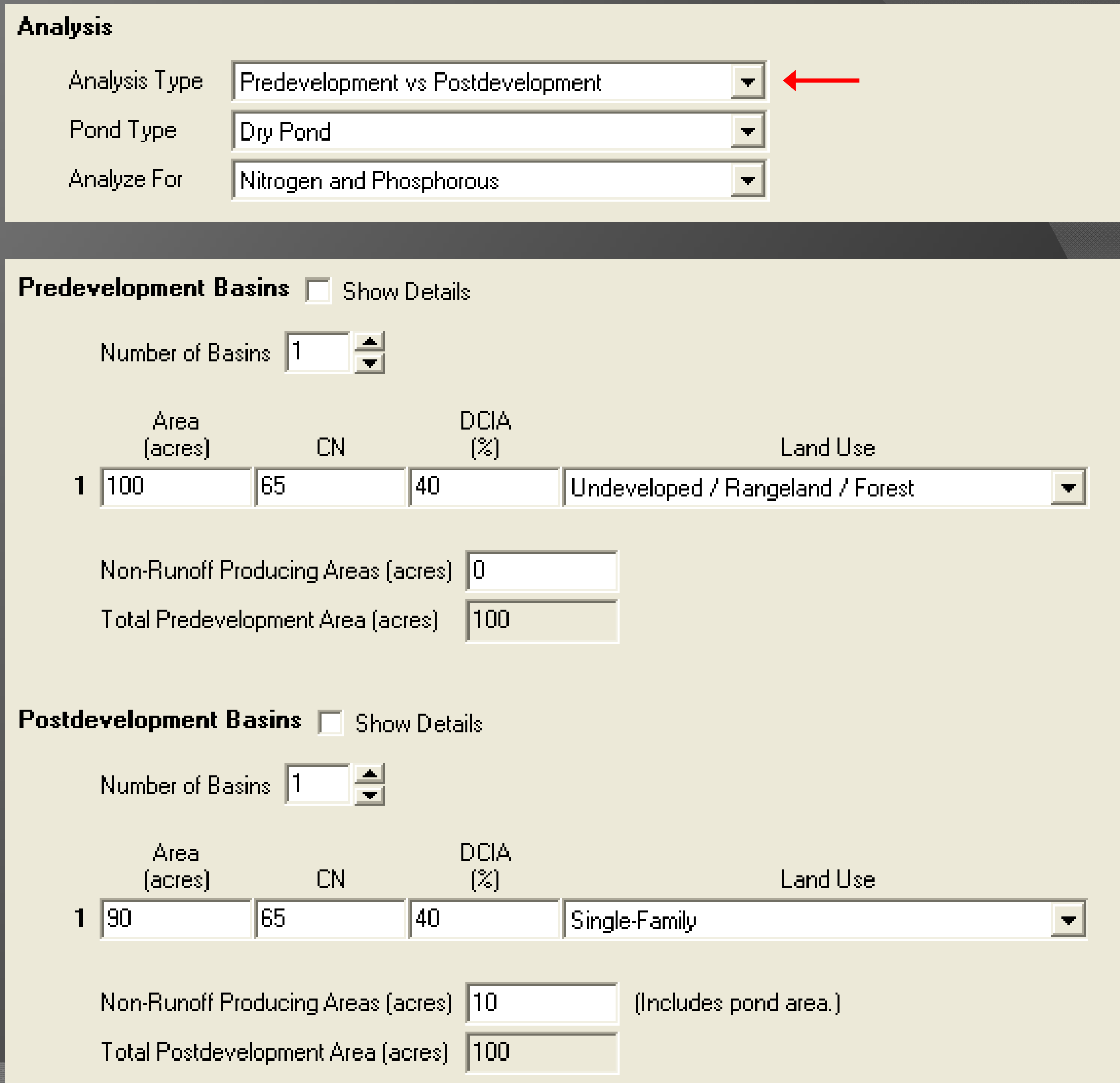
Pond Type: Dry Pond

Analyze For: Nitrogen and Phosphorous

Climate

Climate Zone: [ ] View Map

Mean Annual Rainfall (inches): [ ] View Map


Analysis
Analysis Type
Predevelopment vs Postdevelopment
Pond Type
Dry Pond
Analyze For
Nitrogen and Phosphorous
Predevelopment Basins
Show Details
Number of Basins
1
Area (acres)
CN
DCIA (%)
Land Use
1
100
65
40
Undeveloped / Rangeland / Forest
Non-Runoff Producing Areas (acres)
0
Total Predevelopment Area (acres)
100
Postdevelopment Basins
Show Details
Number of Basins
1
Area (acres)
CN
DCIA (%)
Land Use
1
90
65
40
Single-Family
Non-Runoff Producing Areas (acres)
10
(Includes pond area.)
Total Postdevelopment Area (acres)
100

Analysis

Analysis Type	Predevelopment vs Postdevelopment
Pond Type	Wet Pond With Pretreatment
Analyze For	Nitrogen and Phosphorous

Wet Pond Input

Residence Time (days)	100	
Anoxic Depth Reduction Factor	1.0	(0.75 is current recommendation from FDEP)

☐ Limit Maximum Phosphorous Removal Efficiency to Agency Specified Maximum: ____ %

Treatment Train Summary Results

	Required Total	Available Wet Pond	Required Pre-treatment
Nitrogen Removal Efficiency (%)	92.57137	41.91416	87.21095
Phosphorous Removal Efficiency (%)	97.75096	75.90848	90.6646

Required Permanent Pool Volume of Wet Pond (ac-ft)	3.347318
Estimated Anoxic Depth of Wet Pond (ft)	10.24747

Analysis

Analysis Type: Specified Reduction in Postdevelopment Loading

Pond Type: Wet Pond With Pretreatment

Analyze For: Nitrogen and Phosphorous

Efficiency

Required Nitrogen Removal Efficiency (%): 65

Required Phosphorous Removal Efficiency (%): 85

Wet Pond Input

Residence Time (days): 100

Anoxic Depth Reduction Factor: 1.0 (0.75 is current recommendation from FDEP)

☐ Limit Maximum Phosphorous Removal Efficiency to Agency Specified Maximum: %

Treatment Train Summary Results

	Required Total	Available Wet Pond	Required Pre-treatment
Nitrogen Removal Efficiency (%)	65	41.91416	39.74435
Phosphorous Removal Efficiency (%)	85	75.90848	37.73743

Required Permanent Pool Volume of Wet Pond (ac-ft): 24.00597

Estimated Anoxic Depth of Wet Pond (ft): 10.24747

Analysis

Analysis Type	Specified Reduction in Postdevelopment Loading
Pond Type	Wet Pond With Pretreatment
Analyze For	Nitrogen and Phosphorous

Dry Pond Pretreatment

Required Design Efficiency of Dry Pond (%)	39.74435
Required Retention Depth of Dry Pond (inches)	0.2044463
Required Dry Retention Volume (ac-ft)	1.533347

Wet Pond Properties

Annual Runoff Reaching Wet Pond (ac-ft)	78.85958
Required Permanent Pool Volume (ac-ft)	21.60536
Yearly Phosphorous Load (kg/yr)	31.8079
Wet Pond Phorphorous Removal Efficiency (%)	75.90848
Annual Mass of Unremoved Phosphorous (kg/yr)	7.663007
Mean Phosphorous Concentration in Pond (µg/l)	61.8375
Estimated Chlorophyll-a Concentration (mg/m³)	30.86836
Estimated Sechi Disk Depth (ft)	2.987159
Estimated Anoxic Depth (ft)	10.24747

Stormwater Reuse Pond Option

Analysis

Analysis Type: Predevelopment vs Postdevelopment

Pond Type: Stormwater Reuse Pond

Analyze For: Nitrogen and Phosphorous

Stormwater Reuse

Click here to launch PONDS R-E-V module.

Solve Using REV

Reuse Rate (gpd): 163612.8

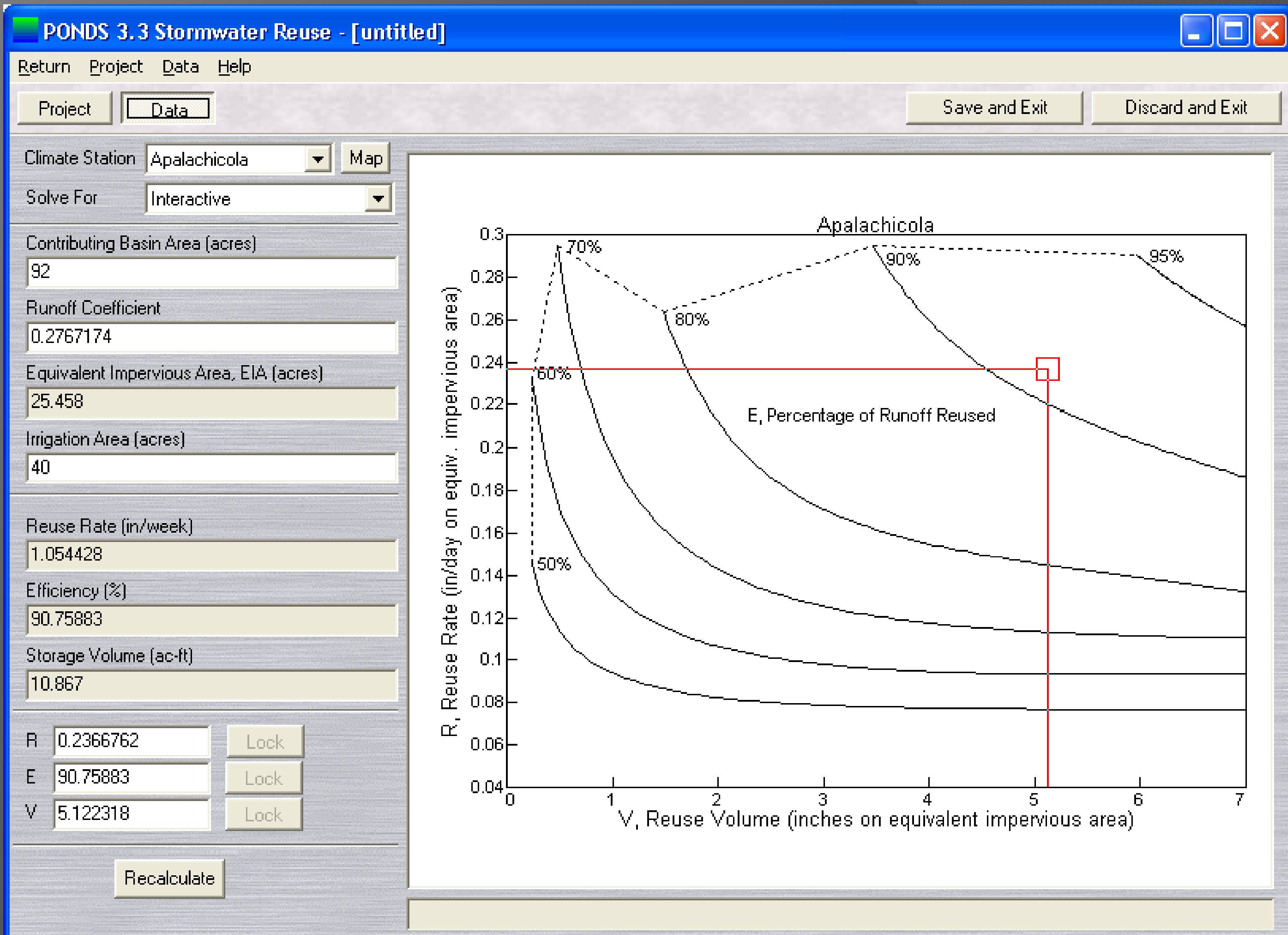
Efficiency (%): 90.75883

Stormwater Reuse Volume (ac-ft): 10.867

Note: If pretreatment requirement is zero, then no pretreatment (dry pond, etc.) is required.

Treatment Train Summary Results

	Req. Total	Avail. Wet	Pre-treatment
Nitrogen Removal Efficiency (%)	79.37243	90.75883	0
Phosphorous Removal Efficiency (%)	90.75214	90.75883	0


PONDS 3.3 Stormwater Reuse - [untitled]
Return Project Data Help
Project
Data
Save and Exit
Discard and Exit
Climate Station
Apalachicola
Map
Solve For
Interactive
Contributing Basin Area (acres)
92
Runoff Coefficient
0.2767174
Equivalent Impervious Area, EIA (acres)
25.458
Irrigation Area (acres)
40
Reuse Rate (in/week)
1.054428
Efficiency (%)
90.75883
Storage Volume (ac-ft)
10.867
R 0.2366762 Lock
E 90.75883 Lock
V 5.122318 Lock
Recalculate
Apalachicola
70%
80%
90%
95%
60%
50%
E, Percentage of Runoff Reused
R, Reuse Rate (in/day on equiv. impervious area)
V, Reuse Volume (inches on equivalent impervious area)
0.3
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0
1
2
3
4
5
6
7