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

PONDS Training Workshop
October 9, 2009

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References


- **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

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<th>CLASS 3</th>
<th>OFW</th>
<th>IMPAIRED</th>
<th>TMDL ADOPTED</th>
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The Problem With Achieving High Efficiencies (Dry Pond)

Efficiency vs Retention Depth, CN=75, DCIA=40%

Zone 1 - Pensacola (65" rainfall)
Zone 2 - Orlando (50" rainfall)
Zone 3 - Key Wet (40" rainfall)
Zone 4 - Tampa (51" rainfall)
Zone 5 - Miami (58" rainfall)

85%

Removal Efficiency (%)
Comparison of Efficiency Criteria (example)

Zone 2, Orlando, 50 inches of Rainfall, CN 75, DCIA 40%

- Efficiency = 96.0%
- Efficiency = 97.5%
- Efficiency = 92.7%

Required Retention Depth (inches):
- 100% x (Pre vs Post)
- 85% x Post
- 85% x (Pre vs Post)
- 90% x (Pre vs Post)

Single Family  Multi Family  Low Intensity Commercial

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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

Clusters:

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

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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**

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

Annual Residence Time = \( \frac{50 \text{ ac-ft}}{91.25 \text{ ac-ft/yr}} \) = 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

Percent Removal = \frac{43.75 \cdot t_d}{(4.38 + t_d)}

R^2 = 0.800

Removal Efficiency (%) vs Detention Time, t_d (days)
Phosphorous Removal Efficiency for Wet Pond

\[ \text{Percent Removal} = 44.53 + 6.146 \cdot \ln(t_d) + 0.145 \cdot (\ln(t_d))^2 \]

\[ R^2 = 0.979 \]
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.

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.
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 its 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.

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

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

\[
\text{Total Efficiency} = \text{Eff}_{\text{dry}} + (1 - \text{Eff}_{\text{dry}}) \times \text{Eff}_{\text{wet}}
\]

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

Diagram:
- Basin 1 → Pond 1 → Pond 2 → Basin 3 → Pond 3 → Offsite
- Basin 2 → Pond 2
- Basin 4 → Pond 4 → Pond 3
Efficiency of Chained Wet Ponds

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

\[ T = T_1 + T_2 + T_3 \ldots \rightarrow \text{Efficiency} \]

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

\[ E = E_1 + (1 - E_1) \times E_2 \]  

(Wrong!)
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

ORLANDO RAINFALL STATION

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EIA = Equivalent Impervious Area

\[ EIA = \text{Total Basin Area} \times \text{Weighted Average Runoff Coefficient} \]

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

\[ R_{\text{app}} = R \times \frac{\text{EIA}}{\text{Irrigated Area}} \]

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

\[ V_{\text{storage}} = V \times \text{EIA} \]

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.
Click here to show project data, or right click here to add additional data pages.

Click here to show calculation data.

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
- Mean Annual Rainfall (inches)

[View Map]
**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)

**Treatment Train Summary Results**

<table>
<thead>
<tr>
<th></th>
<th>Required Total</th>
<th>Available Wet Pond</th>
<th>Required Pre-treatment</th>
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<tbody>
<tr>
<td>Nitrogen Removal Efficiency (%)</td>
<td>92.57137</td>
<td>41.91416</td>
<td>87.21095</td>
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<td>Phosphorous Removal Efficiency (%)</td>
<td>97.75096</td>
<td>75.90848</td>
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- **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**: None

### Treatment Train Summary Results

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<tr>
<td><strong>Nitrogen Removal Efficiency (%)</strong></td>
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<td><strong>Phosphorous Removal Efficiency (%)</strong></td>
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### Analysis

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<td>Analyze For</td>
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### Dry Pond Pretreatment

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<td>Required Design Efficiency of Dry Pond (%)</td>
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<td>Required Retention Depth of Dry Pond (inches)</td>
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<td>Required Dry Retention Volume (ac-ft)</td>
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### Wet Pond Properties

<table>
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<tr>
<th>Property</th>
<th>Value</th>
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<td>Annual Runoff Reaching Wet Pond (ac-ft)</td>
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<td>Required Permanent Pool Volume (ac-ft)</td>
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<td>Yearly Phosphorous Load (kg/yr)</td>
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<td>Annual Mass of Unremoved Phosphorous (kg/yr)</td>
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<td>Mean Phosphorous Concentration in Pond (μg/l)</td>
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<td>Estimated Chlorophyll-a Concentration (mg/m²)</td>
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<td>Estimated Secchi Disk Depth (ft)</td>
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<tr>
<td>Estimated Anoxic Depth (ft)</td>
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Stormwater Reuse Pond Option

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

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