BMP Strategies and Design

Stormwater BMP Selection, Design, and Monitoring

Florida Stormwater Association
September 9, 2016

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BMP Selection Must Consider the Type, Form, and Concentration of the Target Pollutant

- Untreated stormwater runoff contains a variety of pollutants
  - Particulates
    - Suspended solids
    - Nutrients
    - Heavy metals
  - Dissolved species
    - Nutrients
    - Heavy metals

- Particulate and dissolved pollutants are removed by different types of mechanisms
  - Type and form of pollutant must be considered in selecting BMPs

- Most BMP system designs and stated removal efficiencies are based on characteristics of untreated raw runoff

- If the characteristics of the runoff change prior to reaching the BMP, then these changes must be considered in the selection process
Impacts of Pre-Treatment Processes

- Runoff characterization data used in models reflect “end-of-pipe” characteristics prior to treatment in stormwater management systems or attenuation in conveyance systems such as swales and canals.

- If the runoff experiences significant pretreatment processes prior to reaching the point of treatment, then the runoff characteristics may change considerably and impact BMP selection.
  - May result in selection of a different BMP
  - May affect the effectiveness of the selected BMP
Impacts of Pre-Treatment Processes – cont’d.

- Ex. - Runoff discharging over grassed or vegetated swales, ditches, or canals may have much of the particulate matter removed
  - Amount of removal depends on particle size and velocity of flow
  - Since much of the particulate matter has been removed, a primarily biological process would be required to remove the remaining dissolved nutrients

- Ex. - Runoff which passes through water bodies prior to reaching the point of treatment may have much of the particulate and dissolved matter already removed
  - This substantially changes the ability to achieve additional reductions and will impact BMP selection
Example:

1. **Retrofit of a lake discharge canal to reduce downstream nutrient loadings**
   a. Consultant designed and submitted a 319 Grant application for a small wet detention pond for the lake outflow
   b. Pond was designed for a 14 day residence time and claimed a 60% load reduction for TP based on Harper (2007)
   c. Relationship between TP removal and detention time is based on untreated stormwater runoff
   d. It is inappropriate to use this relationship for anything other than untreated stormwater runoff
   e. How can you expect to achieve an additional 60% removal in a period of 14 days for water which has already been in a lake for several years?
BMP Treatment Train

- One or more components that work together to remove pollutants utilizing combinations of hydraulic, physical, biological, and chemical methods
  - Concept has been around for several decades

- Processes combined in a manner that ensures management of all target pollutants

- Generally, the highest level of pollutant reduction is achieved in the first BMP, with each successive BMP becoming less effective

- Subsequent BMPs in the treatment train receive runoff that has lower concentrations of pollutants
  - Downstream BMPs must be capable of operating effectively at the lower concentration levels
Example Stormwater Treatment Train Concept

Source: Minnesota Stormwater Manual
**Efficiency Calculation for Treatment Trains in Series**

*Overall Treatment Train Efficiency*

\[ \text{Efficiency} = \text{Eff}_1 + (1 - \text{Eff}_1) \times \text{Eff}_2 + (1 - (\text{Eff}_1 + \text{Eff}_2)) \times \text{Eff}_3 + \ldots \]

where:

- \( \text{Eff}_1 \) = efficiency of initial treatment system
- \( \text{Eff}_2 \) = efficiency of second treatment system
- \( \text{Eff}_3 \) = efficiency of third treatment system

**Assumptions:**

- Each BMP acts independently of upstream BMPs
- Upstream BMPs do not impact performance of downstream BMPs
Stormwater Load Reduction Techniques

**Volume reduction**
- Infiltration techniques
  - Retention ponds
  - Underground exfiltration
  - Stormwater harvesting (reuse)
Stormwater Load Reduction Techniques

- **Concentration reduction**
  - Techniques which involve biological or chemical processes
    - Wet detention
    - Media filtration
    - Floating wetlands
    - Alum treatment
Stormwater Load Reduction Techniques (Continued)

- Both volume and concentration
  - Techniques which include parts of each
    - Dry detention
    - Rain gardens
Stormwater Load Reduction Techniques (Continued)

- **Solids removal**
  - Techniques that capture solids, leaves, and debris
    - Gross pollutant separators
    - Inlet baskets/filters
    - Street sweeping

![Diagram of stormwater load reduction](image)

Bottom of concrete structure is only 4' below the pipe.
Distribution of Particle Sizes in Residential Roadway Solids

Palm Bay, FL
Total Phosphorus Concentrations by Particle Size in Residential Roadway Solids

Palm Bay, FL
Typical Wet Detention Pond

Removes both solids and dissolved nutrients

Most pollutant removal processes occur in the permanent pool volume

The “water quality volume” has little impact on system removal

Overflow Weir
Water Quantity (Peak Attenuation Volume)
Design High Water Elevation
Overflow / Discharge Elevation
Top of Bank
Permanent Pool
Control Water Elevation
Water Quality Volume
Water Quantity Volume
Outfall Pipe
Bleed-Down Device
Outfall Structure
Nutrient Removal Relationships for Wet Ponds

Nutrient Removal is Primarily a Function of Detention Time

These relationships were developed for untreated runoff only.

- The relationships do not apply when the runoff gets pre-treatment.
- Removal of dissolved pollutants is a function of concentration:
  - Removal rates decrease as the water column concentration decreases.
  - Removal stops when irreducible concentration is reached.
Complimentary BMPs

For a treatment train to have maximum effectiveness, the individual BMPs need to be complimentary

- No significant overlap in types of pollutants removed
- Upstream BMPs should not reduce the efficiency of the downstream BMPs
Vacuum Street Sweeping

Removes solids, leaves, and debris

Wet Detention

Removes solids and dissolved nutrients

- Sweeping will remove particulate pollutants
- Particulate pollutants would also be removed in wet detention
Impacts of Vacuum Sweeping on Runoff Characteristics

- Each of the study sites conducted vacuum sweeping 2-3 times per week on parking areas
  - Conducted primarily for removal of trash
  - Not part of any water quality related permit

- Runoff emc values at the commercial sites were ~50% of emc database value
Treatment Train Example No. 1
(Continued)

Nutrient Removal Relationships for Wet Ponds

Total Nitrogen

\[ \text{Efficiency} = \frac{(44.72 \cdot t_d)}{(5.46 + t_d)} \]

\[ R^2 = 0.808 \]

Total Phosphorus

\[ \text{Removal of dissolved species} \]

\[ \text{Removal of particulates} \]

No enhancement in efficiency

Est. TT Eff.: 35% for TN; 65% for TP
Removes solids, leaves, and debris

- Baffle box will remove particulate pollutants
- Particulate pollutants would also be removed in wet detention
- Baffle box may reduce pond maintenance interval

No enhancement in efficiency

Est. TT Eff.: 35% for TN; 65% for TP
Treatment Train Example No. 3

Off-Line Exfiltration System

- Reduces runoff volume
- Exfiltration will reduce runoff volume
- Runoff bypass will discharge to wet detention for treatment
- Wet detention size may be reduced because of runoff volume reduction

Wet Detention

- Removes solids and dissolved nutrients

Efficiency enhancement from loss of runoff volume

\[
\text{TN Eff.} = 60\% \text{ (exfilt.)} + 40\% \cdot 0.35 \text{ (wet det.)} = 74\%
\]

\[
\text{TP Eff.} = 60\% \text{ (exfilt.)} + 40\% \cdot 0.65 \text{ (wet det.)} = 88\%
\]
Treatment Train Example No. 4

Dry Detention

- Reduces runoff volume and removes solids

Wet Detention

- Removes solids and dissolved nutrients

- Dry detention will remove particulates and runoff volume, minimal change in concentration
- Lack of particulates will reduce the efficiency of the wet pond

Efficiency enhancement from loss of runoff volume
Treatment Train Example No. 5

Roadside Swale

- Runoff volume loss, solids removal, small concentration reduction

Wet Detention

- Removes solids and dissolved nutrients

- Roadside swale will remove particulates and runoff volume, reduce runoff concentrations
- Solids would be removed in the wet detention
- Concentration reduction in swale will reduce efficiency of wet detention

Efficiency enhancement equal to runoff volume lost in swale
Treatment Train Example No. 6

Wet Detention

Removes solids and dissolved nutrients

Reuse Irrigation

Runoff volume loss

- Wet detention will provide pre-treatment for the irrigation
- Reuse irrigation will provide loss of runoff volume

Wet detention efficiency will be enhanced by the mass of pollutants removed by irrigation
Treatment Train Example No. 7

Wet Detention ($t_d = 40$ days)

Removes solids and dissolved nutrients

- Efficiency of initial pond is calculated using the removal curves
- Overall efficiency is calculated based on the sum of the two detention times

Wet detention efficiency will be enhanced by small amount

\[ \text{TN Eff.} = 39.3\% + (42.4 - 39.3\%) = 42.4\% \]
\[ (t_d = 40) \quad (t_d = 100) \quad (t_d = 40) \]

\[ \text{TP Eff.} = 66.5\% + (74.0\% - 66.5\%) = 74.0\% \]
\[ (t_d = 40) \quad (t_d = 100) \quad (t_d = 40) \]
Treatment Train Example No. 8

Wet Detention

Removes solids and dissolved nutrients

Efficiency of initial pond is calculated using the removal curves
Wetland will likely add nutrients to treated pond effluent

Wet detention efficiency will be reduced by substantial amount

Hardwood Wetland

Little uptake by vegetation; water reaches equilibrium with soils
Treatment Train Example No. 9

Wet Detention

Removes solids and dissolved nutrients

Vegetated Wetland

Significant uptake by vegetation and biology attached to plant stalks

- Efficiency of initial pond is calculated using the removal curves
- Wetland will remove additional nutrients from treated pond effluent

Wet detention efficiency will be increased
## Summary of Recommended BMPs for Target Pollutants

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Recommended BMP</th>
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<tbody>
<tr>
<td><strong>1. Nutrients</strong></td>
<td>a. Infiltration</td>
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<td></td>
<td>b. Wet detention</td>
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<td></td>
<td>c. Alum treatment</td>
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<td></td>
<td>d. Street Sweeping</td>
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<td><strong>2. Suspended solids, leaves, litter</strong></td>
<td>a. Gross pollutant separators</td>
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<tr>
<td></td>
<td>b. Street sweeping</td>
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<tr>
<td></td>
<td>c. Wet or dry detention</td>
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<td>d. Inlet devices</td>
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<td><strong>3. Heavy metals</strong></td>
<td>a. Infiltration</td>
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<td>b. Wet detention</td>
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<td>c. Alum treatment</td>
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<td>d. Street sweeping</td>
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<td><strong>4. Bacteria</strong></td>
<td>a. Source reduction</td>
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<td></td>
<td>b. Infiltration</td>
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Questions?