Selecting the Most Cost Effective BMPs for the Removal of Specific Nonpoint Source Pollutants

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Jeff Herr, P.E., D.WRE
Hydrology: Most rainfall events are 1-inch or less
Manage common rain events for WQ improvement

<table>
<thead>
<tr>
<th>Rainfall Event Range (inches)</th>
<th>Mean Rainfall Depth (inches)</th>
<th>Mean Rainfall Duration (hours)</th>
<th>Fraction of Annual Rain Events</th>
<th>Number of Annual Events in Range</th>
</tr>
</thead>
</table>
Minimal runoff from pervious areas and N-DCIA
Even in HSG ‘D’ soils – DCIA is the driver

<table>
<thead>
<tr>
<th>Rainfall</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
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<td>1.98</td>
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</table>
Development Impacts Streams and Estuaries

STREAMFLOW

- Large Storm
- Higher and More Rapid Peak Discharge
- Small Storm
- More Runoff Volume
- Lower and Less Rapid Peak
- Gradual Recession

Pre-development
Post-development
Valuable Freshwater Resource Is Lost to Tide
Up to 60% of our water use does not require potable water
Which Pollutants? Which Forms?

- Sediment
- Biochemical oxygen demand
- Pathogens
- Phosphorus: SRP, OP, TP
- Nitrogen: TKN = Org N + NH₃; NOX = NO₂ + NO₃
  \[ TN = TKN + NOX \]
  (Only some forms of nutrients are bioavailable)
- Metals
- Toxic compounds

**Organic or inorganic, dissolved or particulate**
BMP Selection Criteria

- Land area availability/ownership/access
- Site characteristics
- Regulatory requirements and constraints
- Mass pollutant load reduction/environmental benefits
- Construction/Annual O&M/Life cycle cost
- Maintenance staff availability/sophistication
- Decreased maintenance of problem areas
- Public acceptance
- Funding partners/Grant potential
- Piggyback on other planned capital improvements
- Regional vs. many smaller systems
Evaluation and Selection of Projects

- Identify primary and secondary pollutants
- Determine min and max influent pollutant concentrations and stormwater flow rates
- Determine desired removal efficiencies
- Identify available land area
- Identify effective treatment train components
- Evaluate potential treatment trains based on BMP Selection Criteria Factors
- Implement best solution – keep pushing forward, you will have obstacles!
Treatment Train - Implementing Cost Effective BMPs For Non-Point Source Management

**MAXIMIZE**
- Runoff & Load Generation
  - Regulations
  - Public education
  - Erosion control
  - Roof runoff
  - Disconnect IA
  - Landscaping
  - Pervious paving
  - Pavement cleaning

**Conveyance and Pretreatment**
- Swales
- Catch Basins
- Inlets filters
- Oil/water separators
- Trash/sediment traps

**Toolbox**

**MINIMIZE**
- Final Treatment and Attenuation
  - Retention
  - Detention
  - Wetland
  - Chemical
  - Ozone
  - UV
  - Reuse
  - End of pipe

GI
I would remove
LHawks, 3/4/2013
### Relative Comparison of Structural BMP Pollutant Removal Effectiveness

<table>
<thead>
<tr>
<th>POLLUTANT</th>
<th>INFILTRATION/VOLUME REDUCTION</th>
<th>DETENTION</th>
<th>WETLAND</th>
<th>CHEMICAL COAGULATION</th>
<th>FILTRATION/UV</th>
<th>FILTRATION/OZONE</th>
<th>LIQUID/SOLIDS SEPARATION STRUCTURE</th>
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<tbody>
<tr>
<td>Nitrogen</td>
<td>H - VH</td>
<td>L - M</td>
<td>L - H</td>
<td>L - M</td>
<td>L - M</td>
<td>L - M</td>
<td>L</td>
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<tr>
<td>Phosphorus</td>
<td>H - VH</td>
<td>L - M</td>
<td>L - H</td>
<td>H - VH</td>
<td>L - M</td>
<td>L - M</td>
<td>L</td>
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<tr>
<td>TSS</td>
<td>H - VH</td>
<td>H</td>
<td>H</td>
<td>H - VH</td>
<td>H - VH</td>
<td>H - VH</td>
<td>L - M</td>
</tr>
<tr>
<td>BOD</td>
<td>H - VH</td>
<td>L - M</td>
<td>M</td>
<td>M</td>
<td>M - H</td>
<td>M - H</td>
<td>L - M</td>
</tr>
<tr>
<td>Heavy Metals</td>
<td>H - VH</td>
<td>L - M</td>
<td>M - H</td>
<td>M - H</td>
<td>L - M</td>
<td>L - M</td>
<td>L - M</td>
</tr>
<tr>
<td>Pathogens</td>
<td>H - VH</td>
<td>L</td>
<td>L</td>
<td>H - VH</td>
<td>VH</td>
<td>VH</td>
<td>L</td>
</tr>
<tr>
<td>Gross Solids</td>
<td>H - VH</td>
<td>H</td>
<td>H</td>
<td>L - H</td>
<td>VH</td>
<td>VH</td>
<td>H - VH</td>
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</table>

1. Highly dependent on influent pollutant concentration and hydraulic loading rate

VH – Very High   H – High   M – Medium   L – Low
End of Pipe Stormwater Treatment

- Typically for gross solids and sediment removal but new medias effective for removing other pollutants
- Used extensively for removal of primary pollutants
- Minimal land required
- Relatively inexpensive
- Can be implemented relatively quickly

BC Design for CalTrans

Baffle Box
CDS Unit
Vortechnics
Stormceptor
Many others
### Comparison of BMP Treatment Efficiencies for Primary Pollutants

<table>
<thead>
<tr>
<th>Type of BMP</th>
<th>Estimated Removal Efficiencies (% Load Reduction)</th>
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<tr>
<td></td>
<td>TN</td>
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<tr>
<td>INFLTRATION/REUSE</td>
<td></td>
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<tr>
<td>Volume Reduction</td>
<td></td>
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<tr>
<td>1.00” VOLUME</td>
<td>80</td>
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<tr>
<td>1.50” VOLUME</td>
<td>90</td>
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<tr>
<td>WET DET (14-21 day WSRT)</td>
<td>25-35</td>
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<tr>
<td>WET DET/FILTER</td>
<td>0-10</td>
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<tr>
<td>DRY DETENTION</td>
<td>10-20</td>
</tr>
<tr>
<td>DRY DET/FILTER</td>
<td>(-)-20</td>
</tr>
<tr>
<td>CHEMICAL TREATMENT</td>
<td>20-40</td>
</tr>
<tr>
<td>WETLAND TREATMENT</td>
<td>(-)-90</td>
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</table>
Volume Reduction

No volume = no load
Also reduces conveyance requirements and cost.

Disconnect Impervious Areas

Rainwater Harvesting and Reuse

Stormwater Storage and Reuse

Low Impact Development and Infiltration Practices
(permeability of native soils critical)
Permeable Pavers and Porous Pavement

Subgrade and proper material installation critical to success. Maintenance required.
Rainwater Harvesting and Reuse
(relatively clean water)

1-inch of runoff over 3,000 sf = 1,870 gallons.
55 gallon rain barrels provide minimal storage for a typical single family home.
HDPE Tanks ~ $1/gallon storage
Stormwater Reuse

Reduces runoff volume and pollutant load and reduces potable water demand.

Higher concentrations of pollutants than rainwater but can be used for irrigation and gray water.

Must have sediment removal element prior to any underground storage with ability to remove sediment.
Bioretention Area (different than biofiltration)

Research to improve TP and TN removal. Aluminum precipitates for TP (4-5x). Anaerobic zone for denitrification.
Biofiltration/ Biodetention

Lower volume reduction than bioretention but can achieve substantial pollutant concentration reduction. Dense vegetation/engineered soil key.
Bioswales
Blue/ Green Roof
Curb Extension
Sidewalk Planter
Wet Detention and Wetland Treatment

PPV and residence time key factor for wet detention effectiveness (21+ days)

Significant land area required for wetlands, efficiencies highly dependent on influent concentrations and hydraulic loading rate, plan for future maintenance.
- emergent marsh w/ open water pools
- submerged aquatic vegetation (SAV)
- hardwood elements
- design to minimize short circuiting
Lake Claiborne Restoration

- Removed 442,043 lbs/yr TSS/restored PPV
- Completed in 6 months
- $1.2M Construction Cost
- $3.68/lb TSS
- County average cost per pound is $10/lb TSS
- Homeowners happy
- Monitor for WQ and habitat improvements
15 Acre SAV/Wet Detention System treats 600 acres
Construction cost $1M
Annual O&M cost $20,000
Property owned by FDOT
Enhanced Treatment Using Coagulants

- Achieves significantly higher removal efficiencies than traditional treatment methods for many pollutants; **80-90% TP, 99.9% pathogen removal**
- Requires significantly less land than traditional methods
- Typically has the lowest life cycle cost per mass TP and pathogen removed
- Improves receiving surface water quality for aesthetics, recreational use or public health
- Provides source water protection and controls growth of algae and bacteria (including blue-green algae)
How Does the Process Work?

Removal of particulate pollutants

$$\text{Al}_2(\text{SO}_4)_3 + 6\text{HCO}_3^- \rightarrow 2\text{Al(OH)}_3 \text{ (ppt)} + 3\text{SO}_4^{2-} + 6\text{CO}_2$$

Removal of dissolved phosphorus

$$\text{Al}_2(\text{SO}_4)_3 + 2\text{PO}_4^{3-} \rightarrow 2\text{AlPO}_4 \text{ (ppt)} + 3\text{SO}_4^{2-}$$

The addition of acid salts consumes alkalinity and reduces water pH, however, a pH buffer is rarely required.
Before Stormwater Chemical Treatment
No land available in watershed for traditional treatment.
Stormwater Flow Metering and Chemical Feed Equipment
After Stormwater Chemical Treatment
Largo Central Park

1200 acre watershed treated using 3 acre pond, floc pumped to SS
Construction cost = $1,000,000
Annual O&M cost = $50,000
LCWA Nutrient Reduction Facility

Treats flows up to 300 cfs and 50,000 ac-ft of water per year from a 60,000 ac watershed. Meets P TMDL requirements for entire watershed.
Construction Cost $7.5M
Annual O&M Cost $1M
Floc Removal and Dewatering
Capital Trail Cascade Park
Enhanced Wetland Treatment System to Meet TMDL

- 6500 acre watershed treated
- Flows up to 100 cfs diverted

**Construction cost = $2,000,000**
**Annual O&M cost = $75,000**

Reduces chemical requirements; wetland alone achieves desired TP reduction during lower flows.

Dewatered floc used to amend constructed wetland treatment soils to bind P

**Annual load reductions =**
- 2,000 kg TP
- 1,300 kg TN
- 18,000 kg TSS
Influent and Treated Water Monitoring Results

<table>
<thead>
<tr>
<th>Location</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
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<tbody>
<tr>
<td><strong>Influent</strong></td>
<td></td>
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<tr>
<td>Total Coliform (MPN/100mL)</td>
<td>1,400</td>
<td>160,000</td>
<td>33,539</td>
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<tr>
<td>Fecal (E. Coli) (MPN/100mL)</td>
<td>170</td>
<td>30,000</td>
<td>4,266</td>
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<tr>
<td>Enterococcus (MPN/100mL)</td>
<td>15</td>
<td>37,000</td>
<td>5,859</td>
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<tr>
<td><strong>Treated Water</strong></td>
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<td></td>
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<tr>
<td>Total Coliform</td>
<td>2</td>
<td>30</td>
<td>6</td>
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<tr>
<td>Fecal (E. Coli)</td>
<td>2</td>
<td>30</td>
<td>2</td>
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<tr>
<td>Enterococcus</td>
<td>1</td>
<td>140</td>
<td>13</td>
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</table>

Treats 1 cfs Baseflow; Construction Cost $3M, Annual O&M Cost $40,000
UV Disinfection

- Intake line from creek inside of existing box culvert
- Wet well with alternating pumps
- Basket filters
- Multimedia filters
- UV light bulbs
- Discharge from facility reintroduced to creek inside existing box culvert
3 Year Monitoring Results

- >99% Bacteria Kill in Treated Water from the Plant

Treats 0.33 cfs Baseflow, Construction Cost $400,000; Annual O&M Cost $20,000
City of Boise, Idaho
Dixie Drain Enhanced Water Quality Treatment Phosphorus Offset Project

- Nutrient removal
- Integrated watershed approach

- Will be first nonpoint source project used to offset total phosphorus requirements in a wastewater NPDES permit
- Includes coagulant addition facility to precipitate TP from the diverted agricultural flows
Recreational and Educational Elements

Include recreational elements to allow a stormwater treatment system to be useful to the public and a benefit to community.
BMP Life Cycle Cost Comparisons are highly variable

<table>
<thead>
<tr>
<th>Retrofit BMP</th>
<th>Life Cycle Cost per kg TP removed ($)</th>
<th>Life Cycle Cost per kg TN removed ($)</th>
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<tbody>
<tr>
<td>Pet Waste Education</td>
<td>150 - 300</td>
<td>20 - 40</td>
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<tr>
<td>Second Generation Baffle Box</td>
<td>400 - 1,600</td>
<td>250 - 500</td>
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<tr>
<td>Wet Detention Pond</td>
<td>200 - 2,400</td>
<td>100 - 1,000</td>
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<tr>
<td>Dry Detention Basin</td>
<td>1,500 - 7,000</td>
<td>1,250 - 2,500</td>
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<tr>
<td>LID - Bioretention</td>
<td>1,000 - 40,000</td>
<td>500 - 5,000</td>
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<tr>
<td>Stream Restoration</td>
<td>1,000 - 4,000</td>
<td>300 - 600</td>
</tr>
<tr>
<td>Chemical Treatment</td>
<td>90 - 180</td>
<td>50 - 100</td>
</tr>
<tr>
<td>Enhanced Wetland Treatment</td>
<td>100 - 200</td>
<td>100 - 200</td>
</tr>
</tbody>
</table>

Larger - regional systems tend to have significantly lower life cycle costs per mass of TP and TN removed than many smaller systems. LID for new construction is more cost effective.
Questions

Jeff Herr, P.E., D.WRE
jherr@brwncald.com
## Stormwater Pollutant Sources

<table>
<thead>
<tr>
<th>POLLUTANT</th>
<th>PRIMARY SOURCES</th>
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<tbody>
<tr>
<td>Particulates</td>
<td>Erosion, sedimentation, pavement wear, atmosphere-fossil fuels, maintenance</td>
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<tr>
<td>Nutrients – N and P</td>
<td>Fossil fuels, fertilizer application, pets, septic tanks, sewer spills, wastewater reuse</td>
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<tr>
<td>Zinc</td>
<td>Tire wear, motor oil, grease</td>
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<tr>
<td>Copper</td>
<td>Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Tire wear, insecticides</td>
</tr>
<tr>
<td>Chromium</td>
<td>Metal plating, moving engine parts, brake linings</td>
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<tr>
<td>Nickel</td>
<td>Diesel fuel and gasoline, lubricating oils, metal plating, bushing wear, brake linings, asphalt</td>
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<tr>
<td>Petroleum</td>
<td>Spills, leaks or blow-by of motor lubricants, antifreeze and hydraulic fluids, asphalt</td>
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<tr>
<td>Pathogens</td>
<td>Birds, animal waste, septic tanks, sewer spills</td>
</tr>
<tr>
<td>Synthetic organics</td>
<td>Industrial processes, pesticides, insecticides, spills, asphalt</td>
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Maximize Implementation of Non-Structural BMPs

Nutrient Management
Street Sweeping
Catch Basin Cleanout
Material Storage

Typically cost effective pollutant load reduction