Agenda

Introduction
Stormwater Control Measures – at the end of the pipe
Site Level Case Studies
Watershed Level Case Studies
Not-so-emergent Issues
Discussion
What’s the big deal?
Where are we today?

- Point-source technology based standards have largely been successful.
- Water quality-based standards (nonpoint source) have been difficult to achieve and enforce.
Land Conversion in the Great Bay

Percent Impervious

UNH earth systems research center (GRANIT)/ PREPP
Impact of Impervious Cover

Adapted from Schueler
Source: Effects of Urbanization on Stream Quality at Selected Sites in the Seacoast Region in New Hampshire, 2001-03, USGS 2005
Rasmussen, T.J., Poulton, B.C., and Graham, J.L., 2009
Bellucci, Becker, and Beauchene, 2011
Stark, Hanson, Goldstein, Fallon, Fong, Lee, Kroening, and Andrews, 2000
Why We’re Here

Something isn’t working
Why the Center Was Created

Three-Year Study of Conventional Systems
Study Found That...

Systems failed 2/3 of the time!

- 34% Of the time systems offered some kind of treatment
- 26% Of the time systems did nothing
- 40% Of the time systems exported more pollutants
BMP Performance Monitoring

Research Field Facility at UNH
Tc ~ 19 minutes
BMP Performance Monitoring

How We Evaluate Systems
BMP Performance Monitoring

What We Look For

WATER
SEDIMENT
PETROLEUM
METALS
NITROGEN AND PHOSPHORUS
What We Do: Outreach

Data Reports

Web Resources

BMP Fact Sheets

Workshops

Design Specs

Journal Articles
Stormwater Outreach Can Be Challenging

Because we don’t always speak the same language
Imagine the Ultimate System...

Sonic Swirl Enforcer

eliminating everything in its path

100% Removal Guaranteed
Now Consider Bioretention
No Need to Reinvent this Wheel

Use Unit Operations & Processes (UOPs)

- Physical Operations
- Biological Processes
- Chemical Processes
- Hydrologic Operations
Physical UOPs

- Sedimentation
- Enhanced Sedimentation
- Filtration
- Screening
Biological UOPs

Vegetative Process

Microbial Process
Chemical UOPs

- Sorption
- Antibacterial
- Flocculation
- Coagulation
Hydrologic UOPs

- Flow Alteration
- Volume Reduction
Using UOPs to Meet Your Challenges

Number of UOPs that can solve ALL of your problems:

0
Combining UOPs within Systems

Pollutant 1
Pretreatment/Primary Treatment

Pollutant 2
Secondary Treatment

Pollutant 3
Tertiary Treatment
Systems We Will Cover

- Bioretention systems/TBF
- Subsurface gravel wetland
- Pervious pavements
Bioretention Systems

tree filters

bioretention
Bioretention System Design

- 12” Pipe
- 6” Perforated standpipe with 1” orifice plate
- Perforated riser (CPV overflow)
- 12” Qv Bypass
- Geotextile on walls of excavation
- 30” Bioretention soil mix
- 4” 3/8” Pea gravel
- 12” 3/4” Crushed Stone
- 6” Perforated subdrain

*Not drawn to scale, vertical exaggeration*
Bioretention System
Hydraulic Performance

HYDRAULIC PERFORMANCE

<table>
<thead>
<tr>
<th>Flow (GPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

Minutes

Influent | Effluent

Average Peak Flow Reduction
NA | NA | 82%

Average Lag Time (minutes)
NA | NA | 92

34
## Water Quantity Control

<table>
<thead>
<tr>
<th>Systems</th>
<th>Winter</th>
<th>Summer</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioretention 1</td>
<td>77%</td>
<td>74%</td>
<td>75%</td>
</tr>
<tr>
<td>Average Peak Flow Reduction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Lag Time (minutes)</td>
<td>408</td>
<td>108</td>
<td>266</td>
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<tr>
<td>Bioretention 2</td>
<td>74%</td>
<td>85%</td>
<td>79%</td>
</tr>
<tr>
<td>Average Peak Flow Reduction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Lag Time (minutes)</td>
<td>346</td>
<td>265</td>
<td>309</td>
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<tr>
<td>Bioretention 3</td>
<td>84%</td>
<td>85%</td>
<td>84%</td>
</tr>
<tr>
<td>Average Peak Flow Reduction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Lag Time (minutes)</td>
<td>215</td>
<td>217</td>
<td>216</td>
</tr>
<tr>
<td>Bioretention 4</td>
<td>94%</td>
<td>95%</td>
<td>95%</td>
</tr>
<tr>
<td>Average Peak Flow Reduction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Lag Time (minutes)</td>
<td>52</td>
<td>67</td>
<td>61</td>
</tr>
</tbody>
</table>
Bioretention System
Water Quality Treatment

% Removal Efficiency

TSS | TPH-D | Zn | DIN | TP
--- | --- | --- | --- | ---
Bio I | 90 | 80 | 70 | 60 | 50
Bio II | 80 | 70 | 60 | 50 | 40
Bio III | 70 | 60 | 50 | 40 | 30
Bio IV | 60 | 50 | 40 | 30 | 20

NA
Tree Filter System
Water Quality Treatment

% Removal Efficiency

UNHSC Tree Filter
MTD Tree Filter

TSS
TPH-D
Zn
DIN
TP
Nitrogen is first flush weighted
Phosphorus Results

Phase 2 - Phosphorus as PO4-P

![Graph showing phosphorus levels across different treatments.](image-url)
Optimization
# Bioretention System Report Card

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>UOP</th>
<th>TARGET</th>
<th>GRADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrologic</td>
<td>Flow alteration</td>
<td>Divert flow</td>
<td>✓</td>
</tr>
<tr>
<td>Volume reduction</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Physical</td>
<td>Sedimentation</td>
<td>Sediment</td>
<td>✓</td>
</tr>
<tr>
<td>Enhanced sedimentation</td>
<td></td>
<td>Sediment</td>
<td>✓</td>
</tr>
<tr>
<td>Filtration</td>
<td></td>
<td>Sediment</td>
<td>✓</td>
</tr>
<tr>
<td>Biological</td>
<td>Microbial</td>
<td>Nitrogen</td>
<td>✓</td>
</tr>
<tr>
<td>Vegetative</td>
<td>Nitrogen/Phosphorus</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Chemical</td>
<td>Sorption</td>
<td>Phosphorus</td>
<td>✓</td>
</tr>
</tbody>
</table>
Subsurface Gravel Wetland
Subsurface Gravel Wetland Components
Dissolved Oxygen in Gravel Wetland Effluent

- Flow
- Dissolved Oxygen

Graph showing dissolved oxygen levels in gravel wetland effluent with time (12:00 PM, 4:00 PM, 8:00 PM, 12:00 AM) and influent flow (gpm) from 0 to 4000.
Subsurface Gravel Wetland Hydraulic Performance

**HYDRAULIC PERFORMANCE**

<table>
<thead>
<tr>
<th>Flow (GPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
</tr>
<tr>
<td>200</td>
</tr>
<tr>
<td>150</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

- **Influent**
- **Effluent**

**Minutes**

| 0 | 100 | 200 | 300 | 400 | 500 | 600 |

**Average Peak Flow Reduction**

- Winter: 85%
- Summer: 77%
- Annual Average: 81%

**Average Lag Time (minutes)**

- 318
- 313
- 315
Subsurface Gravel Wetland Median Removal Efficiencies

6 years of data with Influent EMC medians

- TSS: 98%
- TPH-D: 99%
- Zn: 83%
- DIN: 75%
- TN: 56%
- TP: 56%
- OrP: 75%
Nitrogen Results

![Graph showing DIN (mg/l) results for different percentages and time intervals compared to influent. The graph indicates a decrease in DIN with increasing time and percentage of rainwater harvesting.]
Other Questions

What is the max design ponding depth?

A: It depends on chosen plant communities and the possibility of driving water vertically through the wetland soil. Preferably = 18 in.

Is the WQV storage in the system static or dynamically sized?

A: Static. Volume of storage above-ground is equal to the WQV. Draindown is controlled by the restrictive outlet hydraulics.
**How important is the 2-cell treatment approach?**

**A:** The primary benefit is the built-in redundancy should one of the cells need repair or maintenance.

**Is there a specific reason for the 15’ flow path?**

**A:** Some of our tests with a horizontal flow gravel sluice verified this sizing based on performance.
### Gravel Wetland Report Card

<table>
<thead>
<tr>
<th>category</th>
<th>uop</th>
<th>target</th>
<th>“grade”</th>
</tr>
</thead>
<tbody>
<tr>
<td>hydrologic</td>
<td>flow alteration</td>
<td>divert flow</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>volume reduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>physical</td>
<td>sedimentation</td>
<td>sediment</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>enhanced sedimentation</td>
<td>sediment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>filtration</td>
<td>sediment</td>
<td>✓</td>
</tr>
<tr>
<td>biological</td>
<td>microbial</td>
<td>nitrogen</td>
<td>✓+</td>
</tr>
<tr>
<td></td>
<td>vegetative</td>
<td>nitrogen phosphorus</td>
<td>✓+</td>
</tr>
<tr>
<td>chemical</td>
<td>sorption</td>
<td>phosphorus</td>
<td>✓</td>
</tr>
</tbody>
</table>
Pervious Pavements
Porous Pavements Design

Please note:
This design includes subbase design for cold climates and drainage for low permeability soils.
Hydraulic Performance of Porous Pavements

**Porous Asphalt (HSG-C)**

**Pervious Concrete (HSG-B)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Winter</th>
<th>Summer</th>
<th>Annual Average</th>
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</thead>
<tbody>
<tr>
<td>Average Peak Flow Reduction</td>
<td>76%</td>
<td>86%</td>
<td>82%</td>
</tr>
<tr>
<td>Average Lag Time (minutes)</td>
<td>1,163</td>
<td>1,375</td>
<td>1,275</td>
</tr>
<tr>
<td>Average Peak Flow Reduction</td>
<td>88%</td>
<td>97%</td>
<td>93%</td>
</tr>
<tr>
<td>Average Lag Time (minutes)</td>
<td>848</td>
<td>1,365</td>
<td>1,144</td>
</tr>
<tr>
<td>Average Volume Reduction</td>
<td>91%</td>
<td>98%</td>
<td>95%</td>
</tr>
</tbody>
</table>
Water Quantity

UNH PICP - Total Volume & Rainfall

<table>
<thead>
<tr>
<th>Date</th>
<th>Total Influent Volume (Vi) (gal)</th>
<th>Total Effluent Volume (Vo) (gal)</th>
<th>% Volume Reduction (Vr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>23</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>Average</td>
<td>2950</td>
<td>0.69</td>
<td>99.97%</td>
</tr>
<tr>
<td>Median</td>
<td>2723</td>
<td>0.38</td>
<td>99.99%</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>2311</td>
<td>0.90</td>
<td>0.00</td>
</tr>
<tr>
<td>Coefficient of Variation</td>
<td>0.78</td>
<td>1.30</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Average 2950 0.69 99.97%
Median 2723 0.38 99.99%
Standard Deviation 2311 0.90 0.00
Coefficient of Variation 0.78 1.30 0.00
Porous Pavement System Water Quality Treatment

% Removal Efficiency

- TSS
- TPH-D
- Zn
- DIN
- TP

Porous Asphalt
Pervious Concrete
PICP
Curve Number

Curves on this sheet are for the case \( I_a = 0.2S \), so that

\[
Q = \frac{(P - 0.2S)^2}{P + 0.8S}
\]
Methods of Teasing CN from the Data

1. Method 1-- Depth of Runoff: Measure P and Q, invert basic SCS equation

2. Method 2-- Lag Method: Measure P and outflow hydrograph (q), measure lag, estimate CN from lag equations

3. Method 3– Graphical Peak Discharge: Measure Q and $q_p$, estimate CN from peak discharge equations
## Results

<table>
<thead>
<tr>
<th>CN Method 1</th>
<th>CN Method 2</th>
<th>CN Method 2</th>
<th>CN Method 2</th>
<th>CN Method C</th>
<th>CN Method 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>74</td>
<td>11</td>
<td>6</td>
<td>6</td>
<td>51</td>
</tr>
<tr>
<td>Median</td>
<td>75</td>
<td>8</td>
<td>2</td>
<td>3</td>
<td>13</td>
</tr>
</tbody>
</table>

Natural state for Hinckley-Charlton soil (HSG – B/C) = 60 - 72
Summer Temperatures
How do they compare?
TSS Removal Efficiencies

- TSS % Removal Efficiency

Bar chart showing TSS removal efficiencies for various methods:
- Stone-lined Swale
- Vegetated Swale
- Berm
- Swale
- Retention Pond
- HDS Systems
- ADS detention
- Initiitation
- StormTech detention
- Initiitation
- AquaFilter filtration
- Bioretention (4)
- Tree Filter (2)
- Gravel Wetland
- Porous Asphalt

The chart indicates a high percentage removal efficiency for most methods, with some methods achieving removal efficiencies close to 100%.
DIN Removal Efficiencies

DIN % Removal Efficiency

- Stone-lined Swale
- Vegetated Swale
- Berm
- Swale
- Retention Pond
- HDS Systems
- ADS detention infiltration
- StormTech detention infiltration
- AquaFiler filtration
- Bioretention (4)
- Tree Filter
- Gravel Wetland
- Porous Asphalt
TP Removal Efficiencies

TP % Removal Efficiency

- Stone-lined Swale
- Vegetated Swale
- Berm
- Swale
- Retention Pond
- HDS Systems
- ADS detention
- Infiltration
- StormTech detention
- Infiltration
- AquaFilter filtration
- Bioretention (4)
- Tree Filter (2)
- Gravel Wetland
- Porous Asphalt
Site Level Case Studies
Boulder Hills, Pelham, NH

- 2009 Installation of 900’ of first PA private residential road in Northeast
- LID subdivision 55+ Active Adult Community
- Large sand deposit
- Cost 25% greater per ton installed
Conventional Site Design

LID Design
Boulder Hills

- Built on 9% grade

- Avoided use of 1616’ of curbing, 785’ pipe, 8 catch-basins, 2 detention basins, 2 outlet control structures

- 1.3 acres less of land clearing

- Conventional SWM=$789,500 vs LID SWM=$740,300,

- $49,000 savings (6.2%)
Comparison of Unit Costs

<table>
<thead>
<tr>
<th>Item</th>
<th>Conventional</th>
<th>LID</th>
<th>Difference</th>
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</thead>
<tbody>
<tr>
<td>SITE PREPARATION</td>
<td>$23,200.00</td>
<td>$18,000.00</td>
<td>–$5,200.00</td>
</tr>
<tr>
<td>TEMP. EROSION CONTROL</td>
<td>$5,800.00</td>
<td>$3,800.00</td>
<td>–$2,000.00</td>
</tr>
<tr>
<td>DRAINAGE</td>
<td>$92,400.00</td>
<td>$20,100.00</td>
<td>–$72,300.00</td>
</tr>
<tr>
<td>ROADWAY</td>
<td>$82,000.00</td>
<td>$128,000.00</td>
<td>$46,000.00</td>
</tr>
<tr>
<td>DRIVEWAYS</td>
<td>$19,700.00</td>
<td>$30,100.00</td>
<td>$10,400.00</td>
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<tr>
<td>CURBING</td>
<td>$6,500.00</td>
<td>$0.00</td>
<td>–$6,500.00</td>
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<tr>
<td>PERM. EROSION CONTROL</td>
<td>$70,000.00</td>
<td>$50,600.00</td>
<td>–$19,400.00</td>
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<tr>
<td>ADDITIONAL ITEMS</td>
<td>$489,700.00</td>
<td>$489,700.00</td>
<td>$0.00</td>
</tr>
<tr>
<td>BUILDINGS</td>
<td>$3,600,000.00</td>
<td>$3,600,000.00</td>
<td>$0.00</td>
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<tr>
<td>PROJECT TOTAL</td>
<td>$4,389,300.00</td>
<td>$4,340,300.00</td>
<td>–$49,000.00</td>
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</table>

6% savings on total cost of SW infrastructure for a ~zero discharge site
Greenland Meadows

- “Gold-Star” Commercial Development
- Cost of doing business
- near Impaired Waters/303D
- Saved $900k in SWM on costly piping and advanced SWM proprietary
- Brownfields site, ideal location, 15yrs
- Proposed site >10,000 Average Daily Traffic count on >30 acres
Greenland Meadows
## Comparison of Unit Costs

<table>
<thead>
<tr>
<th>Item</th>
<th>Conventional Option</th>
<th>LID Option</th>
<th>Cost Difference</th>
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</thead>
<tbody>
<tr>
<td>MOBILIZATION / DEMOLITION</td>
<td>$555,500</td>
<td>$555,500</td>
<td>$0</td>
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<tr>
<td>SITE PREPARATION</td>
<td>$167,000</td>
<td>$167,000</td>
<td>$0</td>
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<tr>
<td>SEDIMENT / EROSION CONTROL</td>
<td>$378,000</td>
<td>$378,000</td>
<td>$0</td>
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<tr>
<td>EARTHWORK</td>
<td>$2,174,500</td>
<td>$2,103,500</td>
<td>–$71,000</td>
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<tr>
<td>PAVING</td>
<td>$1,843,500</td>
<td>$2,727,500</td>
<td>$884,000</td>
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<tr>
<td>STORMWATER MANAGEMENT</td>
<td>$2,751,800</td>
<td>$1,008,800</td>
<td>–$1,743,000</td>
</tr>
<tr>
<td>ADDITIONAL WORK-RELATED ACTIVITY</td>
<td>$2,720,000</td>
<td>$2,720,000</td>
<td>$0</td>
</tr>
<tr>
<td>PROJECT TOTAL</td>
<td>$10,590,300</td>
<td>$9,660,300</td>
<td>–$930,000</td>
</tr>
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</table>
Median TSS

- Median TSS EMC (mg/L)

- Effluent
- Pickering Brook

Median TN

- Median TN EMC (mg/L)

- Effluent
- Pickering Brook

Median TP

- Median TP EMC (mg/L)

- Effluent
- Pickering Brook
Watershed Level Case Studies
## Berry Brook Watershed Overview

### Impervious Surfaces

<table>
<thead>
<tr>
<th>Surface</th>
<th>Area (acres)</th>
</tr>
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<tbody>
<tr>
<td>Total Watershed</td>
<td>185</td>
</tr>
<tr>
<td>Pervious</td>
<td>129.4</td>
</tr>
<tr>
<td>Impervious Total</td>
<td>55.3 (30%)</td>
</tr>
</tbody>
</table>

Source: Adapted from Mapping Impervious Surfaces in the Berry Brook Watershed Complex Systems Research Center, August, 2011
Inside Slow Sand Filter
Demolition
Wetland Outlet Structure
Construction of Step-Pools
Walls at Tightest Floodplain
Part of the Solution – Watershed approach all communities can access
EIC Reduction Target Rates for Berry Brook, Dover, NH

- 2011 (16.9 Ac/yr)
- IC Target
Berry Brook

EIC Reduction Target Rates for Berry Brook, Dover, NH

- 2011 (16.9 Ac/yr)
- 2012 (7.1 Ac/yr)
- IC Target

Impervious Cover

2011 2012 2013 2014 2015
Berry Brook

EIC Reduction Target Rates for Berry Brook, Dover, NH

- 2011 (16.9 Ac/yr)
- 2012 (7.1 Ac/yr)
- IC Target
- Future Reductions

Impervious Cover

- 2011
- 2012
- 2013
- 2014
- 2015
EIC Pre vs. Post (Lower Watershed-Station)

Direct Runoff (in) vs. Rainfall Depth (in)

- Red squares: Pre-Measured
- Green diamonds: Post-Measured
- Red line: Linear (Pre-Measured)
- Green line: Linear (Post-Measured)
Flow Duration Curves by Time Period

- PretID-BB_Station
- PostLID-BB_Station

Average Daily Flow per Watershed Area (cfs/ac)
Interim Results

• EIC is approximating predevelopment hydrology – we are moving toward hydrologic transparency!

• Data supports the use of EIC in general as a predictor of watershed health (strong for hydrology, developing for chemistry and aquatic health)

• Need more monitoring

• IC disconnection as a surrogate for water quality seems to be a very effective measure
Maintenance
1,000 Pound Gorilla

Who has primary responsibility for maintenance?

- local governments or public agencies?
- States and the Federal Governments?
- Private property owners and associations?
What is Maintenance

- Often Maintenance only occurs when there is failure
- There is a perception that LID systems require more maintenance
- Conventional practices have a high degree of failure and significant cost impacts—however we are familiar with it
Detention Basin  Retention Pond  Stone Swale  Veg Swale

Porous Asphalt  Gravel Wetland  Sand Filter  Bioretention Unit (3)
## Maintenance Complexity is defined as

<table>
<thead>
<tr>
<th>Minimal</th>
<th>Simple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stormwater Professional or</td>
<td>Stormwater Professional or Consultant is</td>
</tr>
<tr>
<td>Consultant is seldom</td>
<td>occasionally needed</td>
</tr>
<tr>
<td>needed</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Moderate</th>
<th>Complicated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stormwater Professional or</td>
<td>Stormwater Professional or Consultant is</td>
</tr>
<tr>
<td>Consultant is needed half</td>
<td>always needed</td>
</tr>
<tr>
<td>the time</td>
<td></td>
</tr>
</tbody>
</table>
Adapted from Reese, A.J., Presler, H.H., 2005

<table>
<thead>
<tr>
<th>Reactive</th>
<th>Periodic/Predictive</th>
<th>Proactive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Episodic maintenance, cheap in short term, expensive in the long term</td>
<td>Science basis, schedulable activities, more cost effective</td>
<td>Cost effective, preventative operations</td>
</tr>
</tbody>
</table>

Adapted from Reese, A.J., Presler, H.H., 2005
But we design things to be low maintenance!
Tools of the trade...
Tools of the trade...
Tools of the trade...
Components of a best-case scenario:

1. Appropriate Design

2. Installation

.... Then Maintenance
Yearly BMP Maintenance (per acre treated)

- Retention Pond: $3,500
- Detention Pond: $3,000
- Vegetated Swale: $2,500
- Sand Filter: $2,000
- Bioretention Ave: $1,500
- Gravel Wetland: $1,000
- Porous Asphalt: $500

Cost $
### Economics of Installation vs Maintenance Costs, normalized by area

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Vegetated Swale</th>
<th>Wet Pond</th>
<th>Dry Pond</th>
<th>Sand Filter</th>
<th>Gravel Wetland</th>
<th>Bioretention</th>
<th>Porous Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost ($)</td>
<td>12,000</td>
<td>13,500</td>
<td>13,500</td>
<td>12,500</td>
<td>22,500</td>
<td>21,550</td>
<td>21,800</td>
</tr>
<tr>
<td>Inflated 2012 Capital Cost</td>
<td>14,600</td>
<td>16,500</td>
<td>16,500</td>
<td>15,200</td>
<td>27,400</td>
<td>25,600</td>
<td>26,600</td>
</tr>
<tr>
<td>Maintenance and Capital Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personnel (hr/yr)</td>
<td>9.5</td>
<td>28.0</td>
<td>24.0</td>
<td>28.5</td>
<td>21.7</td>
<td>20.7</td>
<td>6.0</td>
</tr>
<tr>
<td>Personnel ($/yr)</td>
<td>823</td>
<td>3,060</td>
<td>2,380</td>
<td>2,808</td>
<td>2,138</td>
<td>1,890</td>
<td>380</td>
</tr>
<tr>
<td>Subcontractor Cost ($/yr)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>700</td>
</tr>
<tr>
<td>Total Operational Cost ($/yr)</td>
<td>823</td>
<td>3,060</td>
<td>2,380</td>
<td>2,808</td>
<td>2,138</td>
<td>1,890</td>
<td>1,080</td>
</tr>
<tr>
<td>Operation/Capital Cost (%)</td>
<td>6%</td>
<td>19%</td>
<td>14%</td>
<td>18%</td>
<td>8%</td>
<td>8%</td>
<td>4%</td>
</tr>
</tbody>
</table>
A tale of two raingardens
Maintenance solved?
QUESTIONS ???