MAINTENANCE

Operation and Maintenance of Green Infrastructure and Other Stormwater BMPs

Long-Term Maintenance

- All stormwater systems require maintenance
- With traditional infrastructure often maintenance only occurs when there is failure because it is 'out of sight and out of mind'
- Most green infrastructure is visible, and considered an aesthetic amenity; it's harder to ignore maintenance needs
- Small problems are less likely to turn into system failures

Key Reasons Why BMP Maintenance Has Historically Been Difficult to Implement

1. Inability to physically locate the management practices
2. Inability to track responsible parties
3. Dedicated staff not assigned to inspection
4. Designs not conducive to easy maintenance
5. Lack of enforcement authority and access
6. Owners are unaware of their responsibilities
7. Proliferation of management practices that require intensive maintenance
8. Insufficient funding sources

WERF 2005, CWP 2004

WERF Finding

*"Probably **80% of the total man hours spent** in the field in many jurisdictions are **associated with grass mowing**, rather than the issues one might expects such as sediment, debris and trash removal, or structural repair. Of this 80%, **most of the effort has little effect on BMP performance**, but results from the level of service **expectations of residents** living near these facilities. The frequency of maintenance has been found to be dependent on the economic status of the neighborhood and the visibility of the system."*

WERF 2005 Performance and Whole Life Costs of Best Management Practices and Sustainable Urban Drainage Systems

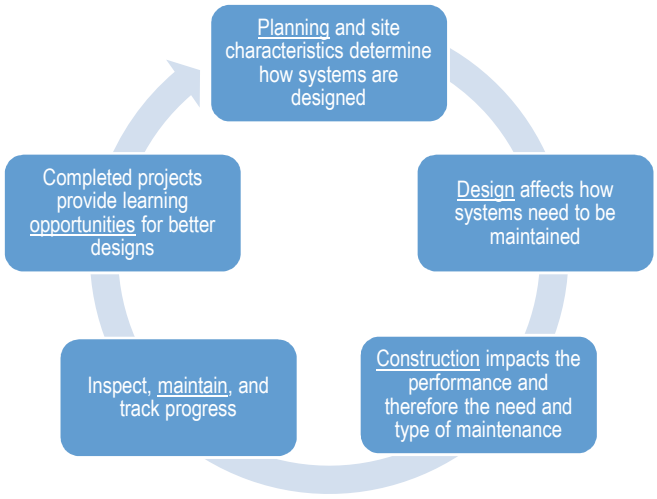
Factors Affecting Performance

	Sediment Buildup	Litter & Debris	Pipe Clogging	Invasive Vegetation
Surface Sand or Soil Filter	50%	30%	10%	0%
Infiltration Basins or Trenches	36%	21%	10%	5%
Wet Ponds	26% *	19%	21%	10%
Underground Sedimentation Devices	58%	21%	11%	0%
Rain Gardens	33%	22%	7%	26%
Filter Strips or Swales	21%	26%	5%	26%

- * PAH's becoming a significant concern for wet pond sediments
- Maintenance Survey of 38 cities and counties in Minnesota and Wisconsin
- Multiple-answers allowed

Erickson, A.J., Gulliver, J.S., Weiss, P.T., and Wilson, C.B. (2009). "Survey of Stormwater BMP Maintenance Practices." Proceedings of the Universities Council on Water Resources/National Institutes for Water Resources Annual Conference. July 7-9, Chicago, IL.

Continuous Improvement



DESIGN WITH MAINTENANCE IN MIND

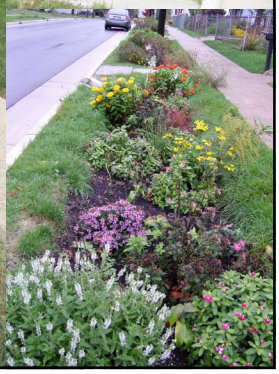
Only build what you're willing to maintain

Design

- Accessibility (ROW, easements, vehicle access, cleanouts)
- Design documentation (remove sediment when?)
- Communicate presence, function, use and specialized maintenance needs (signage, manuals, etc.)
- Help from neighbors
- Involve maintenance staff on selection and design
- Pretreatment (sediment traps, vegetative buffer, etc.)
- Anti-clogging devices (inlet/outlet)
- Infiltration tests
- Vegetation (suitable selection)
- **Maintenance Plan written as part of design**

December 09, 2014

Plant Selection



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If it's vegetated, you may need to irrigate


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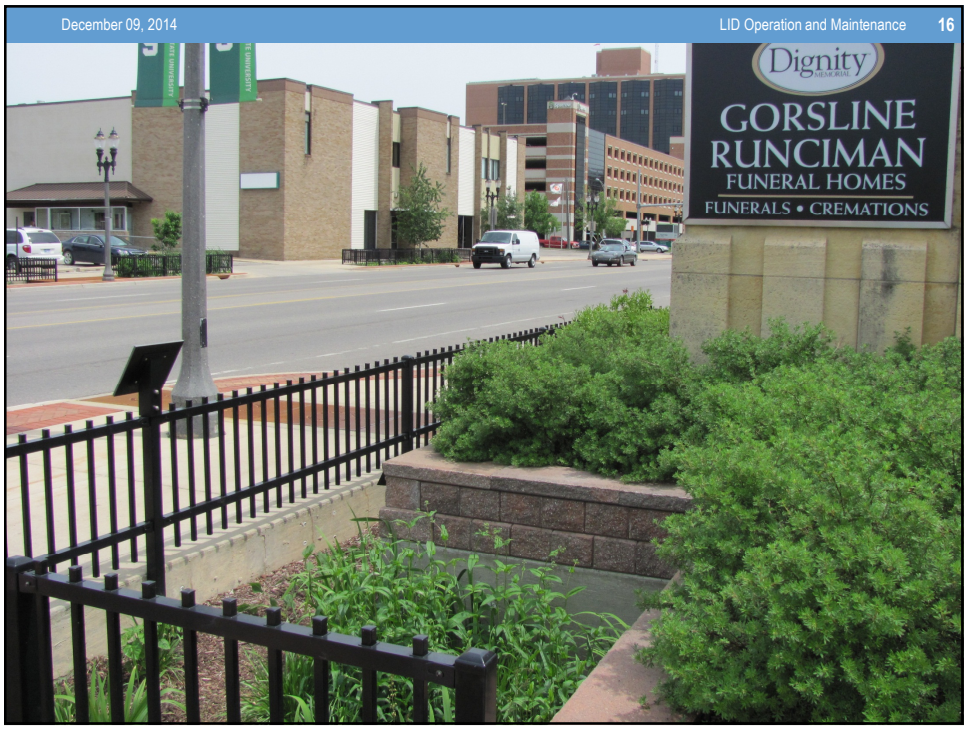
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Dignity
GORSLINE
RUNCIMAN
FUNERAL HOMES
FUNERALS • CREMATIONS

CONSTRUCTION

Construction practices for successful stormwater controls

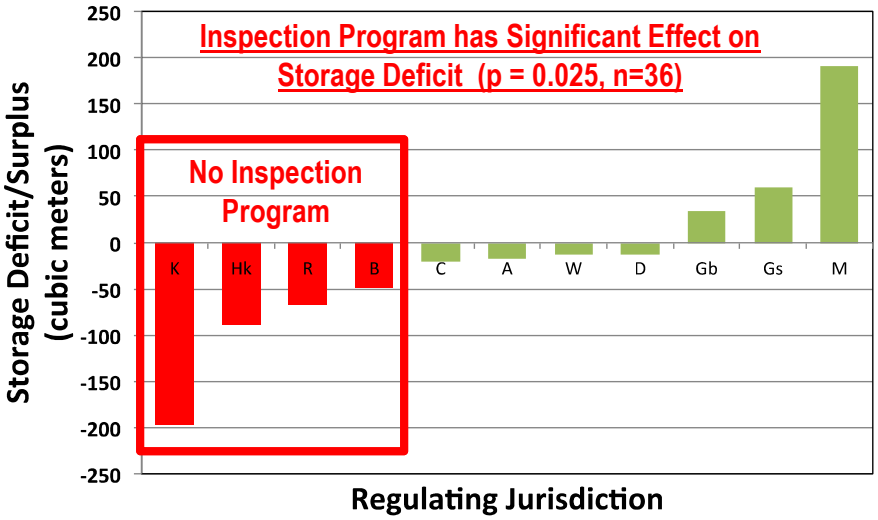
Assessing Bioretention Installations

- Soil Analysis
  - 82% of constructed bioretention cells failed to soil specifications
- Compared design volume with constructed volume

Category	% of Design Volume	% of Practices in Category
Severely Undersized	<-25%	28%
Moderately Undersized	-25% to -10%	22%
Adequate	**-10% to 10%**	**17%**
Moderately Oversized	10% to 25%	17%
Severely Oversized	>25%	17%

Wardynski, B. and Hunt, W. (2011) Assessing the Accuracy of Bioretention Installation in North Carolina. World Environmental and Water Resources Congress 2011: pp. 347-355.

Impacts of Implementing an Inspection Program



Wardynski, B. and Hunt, W. (2011) Assessing the Accuracy of Bioretention Installation in North Carolina. World Environmental and Water Resources Congress 2011: pp. 347-355.

Infiltration Testing

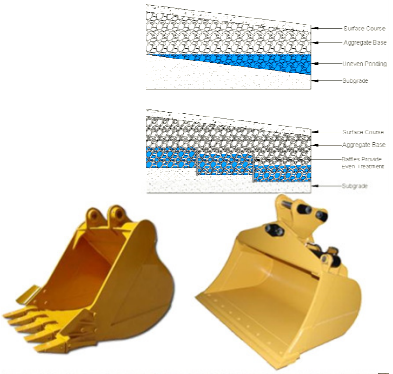
- During Construction
  - Infiltration rate of in situ native soil
  - Bottom of excavation
  - Purpose: if not testing during design phase, provides measured infiltration capacity of soil
- Immediately After Construction
  - Purpose: baseline measurement for future comparisons
  - Vegetated Areas
  - Permeable Pavements

Soil Erosion during Construction

- Keep soil erosion sediment off
  - Aggregate storage reservoirs
  - Planting soil
  - Permeable pavements (all types)
- Bioretention is designed to work AFTER construction is completed and the watershed is STABLE
- Do not install if exposed soil is obvious or surrounding drainage is not stabilized
- Use standard E & S control measures to stabilize disturbed or potentially erosive surfaces for onsite and potential offsite sources

Soil Compaction

- Level bottom preferred
- On slopes terrace the bottom or use heck dams
- Compact
  - Infrastructure subgrades and bases = **Yes**
  - In situ soil below stormwater practices typically do not (should not) be compacted before placing aggregate and/or soil overtop
  - Aggregate reservoirs = **Yes**
  - Planting soil = **No**
- Loosen and scarify soils
  - Before planting
  - Before placing aggregate or soil layer



Substitutions and Certifications

- Check and certify before accepting
- Shop drawing submittals for all critical components
- Watch out for substitutions (e.g. plants)

City of Los Angeles

STORMWATER OBSERVATION REPORT FORM

- STANDARD URBAN STORMWATER MITIGATION PLAN (SUSMP) -
- SITE SPECIFIC MITIGATION PLAN -

STORMWATER OBSERVATION means the visual observation of the stormwater related Best Management Practices (BMPs) for conformance with the approved SUSMP/Site Specific Mitigation Plan at significant construction stages and at completion of the project. Stormwater observation does not include or waive the responsibility for the inspections required by Section 106 or other sections of the City of Los Angeles Building Code.

STORMWATER OBSERVATION must be performed by the engineer or architect responsible for the approved SUSMP/Site Specific Mitigation Plan or designated staff in their employment.

STORMWATER OBSERVATION REPORT must be signed and stamped (wet-below) by the engineer or architect responsible for the approved SUSMP and submitted to the city prior to the issuance to the certificate of occupancy.

Project Address:	Building Permit No.:
Name of Engineer or Architect responsible for the approved SUSMP/Site Specific Mitigation Plan:	Phone Number:
Name of SUSMP/Site Specific Mitigation Plan Observer:	Phone Number:

As-Built Certification

I DECLARE THAT THE FOLLOWING STATEMENTS ARE TRUE TO THE BEST OF MY KNOWLEDGE:

1. I AM THE ENGINEER OR ARCHITECT RESPONSIBLE FOR THE APPROVED SUSMP/SITE SPECIFIC MITIGATION PLAN, AND
2. I, OR DESIGNATED STAFF UNDER MY RESPONSIBLE CHARGE, HAS PERFORMED THE REQUIRED SITE VISITS AT EACH SIGNIFICANT CONSTRUCTION STAGE AND AT COMPLETION TO VERIFY THAT THE BEST MANAGEMENT PRACTICES AS SHOWN ON THE APPROVED PLAN HAVE BEEN CONSTRUCTED AND INSTALLED IN ACCORDANCE WITH THE APPROVED SUSMP/SITE SPECIFIC MITIGATION PLAN.

Stamp of Engineer or Architect responsible for the approved SUSMP

Water Runs Downhill

- Proper elevation grading is paramount
- Practice design, drainage area and runoff volume are intricately linked
- Field changes may require design changes
- Inlets must let water in

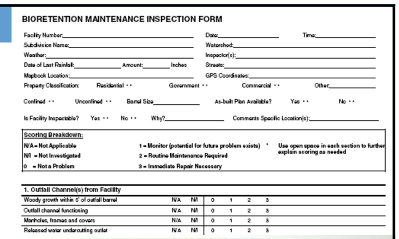
Details are the difference between success and failure

Details are the difference between success and failure

SHORT AND LONG TERM CARE AND MAINTENANCE

Maintenance

- Inspect
  - Regular intervals
  - Use checklist
  - Inlets, outlets, storage, upstream drainage area, downstream impacts etc.
  - Vegetation management
  - Infiltration
  - Sediment accumulation
  - Trash and debris
- Track
  - Inventory of existing practices
  - Maintenance and inspection
  - Documentation for legal action
  - Relate design to performance



BIORETENTION MAINTENANCE INSPECTION FORM

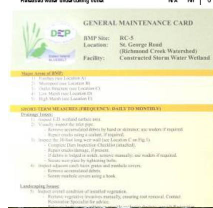
Facility Number:___ Date:___ Time:___
Subdivision Name:___ Watershed:___
Weather:___ Inspector(s):___
Date of Last Rainfall:___ Amount:___ Inches Streets:___
Mapbook Location:___ GPS Coordinates:___
Property Classification: Residential Government Commercial Other:___

Confined Unconfined Barrel Size___ As-built Plan Available? Yes No

Is Facility Inspectable? Yes No Why?___ Comments Specific Location(s):___

Scoring Breakdown:
N/A = Not Applicable; 1 = Monitor (potential for future problem exists); * Use open space in each section to further explain scoring as needed
N/I = Not Investigated; 2 = Routine Maintenance Required
0 = Not a Problem; 3 = Immediate Repair Necessary

1. Outfall Channel(s) from Facility						
Woody growth within 5' of outfall barrel	N/A	N/I	0	1	2	3
Outfall channel functioning	N/A	N/I	0	1	2	3
Manholes, frames and covers	N/A	N/I	0	1	2	3
Released water undercutting outlet	N/A	N/I	0	1	2	3



Typical Activities for Vegetated Systems

Activity	Frequency	Time Period	Description
Irrigation	Weekly (min)	First 3 months	First 3 months during plant establishment
	Biweekly (min)	Year 1 summer months	
Weeding	Regularly	Year 1	Herbicide spot application or hand pulling
	1 to 2 times per year	Long Term	Herbicide spot application or hand pulling
Pruning	1 to 2 times per year	Long Term	Trim back or remove overgrown vegetation
Inspection	After large rainfall	Long Term	Check and clean inlets and outlets. Look for signs of poor drainage. Check and repair erosion problems. Remove trash and debris.
	Annual	Long Term	Check and clean underdrain, exercise the valve
Mulch	Annual	Long Term	Refresh annually and replace every 3 years

Permeable Paver Maintenance

Most common concern is clogging

- Vegetative litter
  - Tree and shrub litter
  - Grass clippings
- Sediment
  - Run-on during construction activities
  - Exposed soil
  - Educate adjacent property owners
  - Winter time abrasive

Street Sweeping

- Mechanical (brush approach)
- Regenerative air (shoot air at angle to pavement)
- Vacuum (demonstrated ability to suction 3 to 4 inches of gravel and dry sand)

Pavement Type	Clogging Depth	Preventive Sweeper	Restorative Sweeper
Concrete Grid Pavers filled with sand (wide gap)	< 0.5 inches	Mechanical	Mechanical
Interlocking Pavers (narrow gap)	< 2 inches	Regenerative Air	Vacuum
Pervious concrete or asphalt	If sand: < 1 inch	Regenerative Air	If Sand: Vacuum?
	If silt/clay: > 3 inches	Regenerative Air	If Silt/Clay: not known

Source: NCSU Urban Waterways 2011

Maintenance

- Inspection
  - Water bottle test
  - Frequency every 2 to 4 months
- Street Sweeping
  - 2 to 4 times per year (preventative)
  - Vacuum most effective when sediment particles are dry
- Replace aggregate in paver applications as needed
- Remove unwanted vegetation
  - Herbicide and then pull
  - Burn
  - Don't let weeds persist

Chicago Green Alley Maintenance: Once or twice per year

Eagle

Tymco

Johnston

Power Washing

Pelican: stiff bristles, vacuum action

Little Wonder

COSTS ASSOCIATED WITH O&M

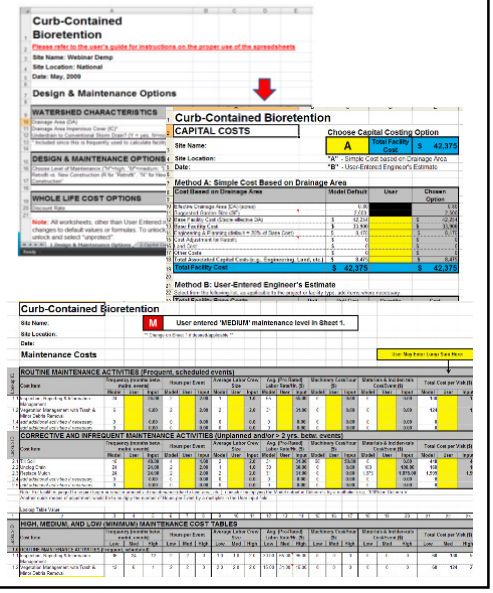
Annual Cost as Percentage of Construction Cost

	USEPA (1999)	Weiss et al. (2005)
Sand Filters	11% -13%	0.9% - 9.5%
Infiltration Trenches	5% - 20%	5.1% – 126%
Infiltration Basins	1% - 3% 5% - 10%	2.8% - 4.9%
Wet Ponds	Not reported	1.9% - 10.2%
Dry Ponds	<1%	1.8% - 2.7%
Rain Gardens	5% - 7%	0.7% - 10.9%
Constructed Wetlands	2%	4% - 14.2%
Swales	5% - 7%	4% - 178%
Filter Strips	$320/Acre (maintained)	-

Weiss, P.T., J. S. Gulliver and A. J. Erickson, (2005). "The Cost and Effectiveness of Stormwater Management Practices," Minnesota Department of Transportation Report 2005-23. http://www.cts.umn.edu/Publications/ResearchReports/reportdetail.html?id=1023

WERF Whole Life Cost Model

- Spreadsheet cost estimation tool designed to estimate whole life costs of several practices
- Capital and maintenance costs
- Peer reviewed
- Customizable



- Download cost tools from: www.werf.org/bmpcost
- EPA webcast archived www.epa.gov/greeninfrastructure

QUESTIONS AND DISCUSSIONS

TETRA TECH

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