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# Maintenance and Costs of Green Infrastructure

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# Rain Garden/Bioretention System Maintenance

- Remove litter, weed, water, mulch, and trim
- Inspect for sediment build up, the health of the vegetation and erosion
- Clean out and inspect outlets, inlets, overflow risers, etc.
- Keep inlets free and clear so water does not bypass the system



# Landscape Features Maintenance

- Trees
  - Watering
  - pruning
- Vegetation
  - Weeding
  - Mulching
  - Watering
  - pruning/cutback
  - landscape replacement



# Landscape Features Maintenance

- General Maintenance
  - Frequency:
    - Annually
  - Tools and supplies:
    - Trash bags, gloves, shovels
  - Soil Amendment with organic matter:
    - Years 2 and 4
    - Apply 2 inches of compost into 2 inches of top soil
    - No contact with exposed roots or the trunk of the tree/ shrub
  - Keep weed whackers and lawn movers more than 2 feet from the trunk





# Landscape Features Maintenance

- Pruning (improve the strength of plants, prevents pest problem, improves safety/ security for residents/visitors, reduces future maintenance)
  - Frequency:
    - Year one remove damaged and dead branches
    - Year three correction of structural issues
  - Tools and supplies:
    - Trash bags, gloves, saw, pruners, loopers



# Landscape Features Maintenance

- Maintenance of Vegetation
  - Frequency:
    - Checking vegetation for damage caused by a lawnmower, string trimmers, edger, or other power equipment
    - Weeding: early and often- 3x spring, 1x fall and summer
      - Pull weeds from there roots use tool if it is difficult
      - Avoid compacting the soil and other plants
      - Remove invasive plants
  - Tools and supplies:
    - Trash bags, gloves, shovels, trowels, weed id guide



# Landscape Features Maintenance

- Mulching
  - Frequency:
    - apply 2-3 inches of mulch in the spring
      - Keep mulch away from the stem of the plants
      - May need to remove or mix up old mulch that is already there
  - Tools and supplies:
    - Trash bags, gloves, shovels, Hardwood mulch





# Landscape Features Maintenance

- Watering:
  - Frequency:
    - 1 inch the first week installed
    - ½ inch the first 4-6 weeks of the growing season for years 2 and 3 and for drought in years 2 and 3
    - Water the roots not the leaves
    - Soil should be moist 2 -3 inches below grade
    - Properly used hoses are more efficient then sprinklers
  - Tools and supplies:
    - Hose and water source
    - Gator bags





# Landscape Features Maintenance

- Removal of dead vegetation:
  - Frequency:
    - 2x a year to prepare the bed for the winter (spring and fall)
  - Tools and supplies:
    - Trash bags, gloves, gardening scissors, clippers
- Landscape Cutback:
  - Fall cleanup up includes cutting perennials back 4 inches above the ground
  - Some plants like iris shouldn't be cut back while they are still green



# Landscape Features Maintenance

- Landscape Plant Replacement (Involves replacing dead, missing, dead or diseased plants)
  - Frequency:
    - Planting should be done in the spring or the fall
  - Tools and supplies:
    - Trash bags, gloves, shovels, replacement plants



## Costs for Rain Gardens / Bioretention Systems

Type	Low Cost	High Cost	Project Range
Small systems (up to 200 sq. ft.)	\$5.00	\$10.00	\$1,000 - \$2,000
Large systems (up to 1,000 sq. ft.)	\$10.00	\$35.00	\$2,000 - \$35,000

### Construction work to include:

- Excavation
- Disposal of excess soil
- Soil amendments
- Mulch
- Plants
- Stone
- Piping





## Costs for Roadway Bioretention Systems

Type	Low Cost	High Cost	Project Range
Roadway bioretention systems (up to 500 sq. ft.)	\$85.00	\$105.00	\$42,500 - \$52,500

Construction work for curb rain gardens, stormwater planters, and bump outs:

- Demolition of existing paving and curbing
- Excavation
- Disposal of excess soil
- Soil amendments
- Mulch
- Plants
- Stone
- Piping
- Curbing
- BEWARE: Costs for Traffic Control!!!



## Costs for Enhanced Tree Pits

Type	Low Cost	High Cost	Project Range
Tree Pit (each pit at 4'x8' or 4'x6' with tree)	\$2,500.00	\$3,000.00	\$2,500 - \$3,000

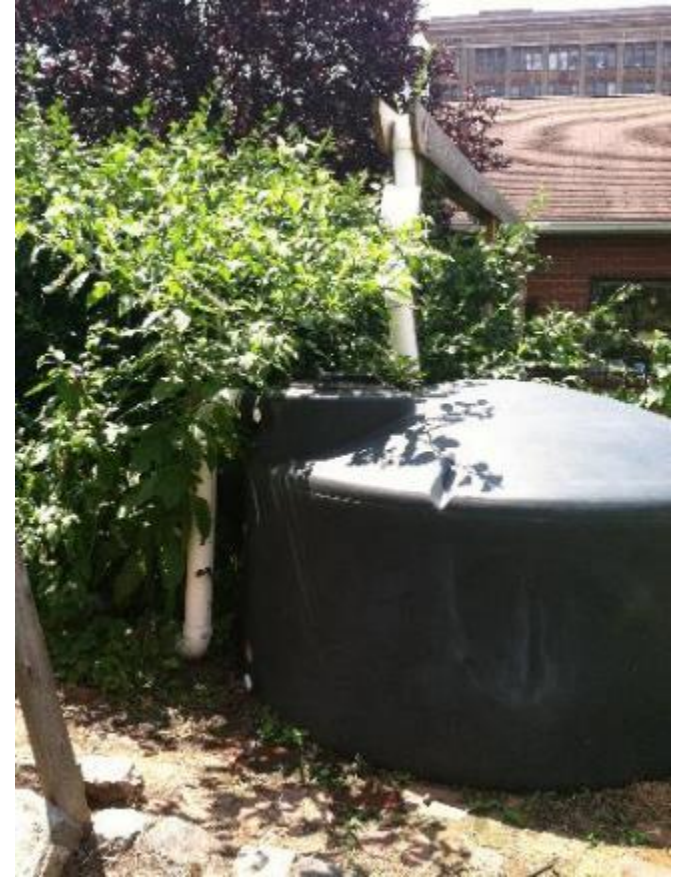
### Construction work for enhanced tree pits:

- Demolition of existing paving and curbing
- Excavation
- Disposal of excess soil
- Soil amendments
- Stone
- Tree
- Tree grate



## Cistern / Rain Barrel Maintenance

- Release the water in there before the next rain event
- Rain barrels, cisterns and downspouts should be inspected and cleaned regularly
- Seals on the infrastructure need to be inspected to prevent mosquito infestation
- Winterize





# Cistern/ Rain Barrel Maintenance

- Cistern/Rain Barrel (provides supplemental water supply for irrigation and other nonpotable water use)
  - Frequency:
    - Annually release all the water before the winter
  - Tools and supplies:
    - Trash bags, gloves, wrench
  - Procedure:
    - Refer to guidance document in handout



## Costs for Rain Barrels & Cisterns

Type	Low Cost	High Cost	Project Range
Residential rain barrel (50-75 gallons)	\$50.00	\$300.00	\$50 - \$300
Small Cistern (up to 100-600 gallons)	\$300.00	\$2,000.00	\$300 - \$2,000
Large Cistern (up to 5,000 gallons)	\$6,500	\$12,000	\$6,500 - \$12,000

### Installation to include:

- Purchase and delivery of tank
- Placement of tank on stable foundation
- Connection of piping to roof drain (external)
- Installation of first-flush diverter
- Installation of overflow
- Providing supplemental electric pump  
(\$1,500 - \$2,000)



## Planter Box Maintenance

- Apply mulch / stone
- Install plantings
- Remove weeds
- Check/maintain inflow
- Keep overflow clear of debris
- Ensure proper drainage
- Winterize





## Costs for Downspout Planter Boxes

Type	Low Cost	High Cost	Project Range
Residential planter box (each box up to 6 sq. ft.)	\$250.00	\$500.00	\$250 - \$500
Institutional planter boxes (larger systems over 6 sq. ft.)	\$500.00	\$8,000.00	\$500 - \$8,000

### Construction work to include:

- Constructing free standing box
- Providing stable foundation
- Installing underdrain pipe
- Placement of stone and soil layers
- Piping connections to roof drains and overflow
- Plantings



# Permeable Pavement Maintenance

- Porous Pavement Vacuuming
- Porous Pavement Power Washing
- Porous Paver Maintenance (Restoring Aggregate)
- Winter Maintenance for Porous Pavement



# Permeable Pavement Maintenance

- Permeable Pavement Vacuuming (process removes sediment which can lead to clogging of the porous surface which prevents infiltration of water)
  - Frequency:
    - Semi Annually for Porous Asphalt, Porous Concrete, Flexible Porous Pavement
    - Annually for Porous Pavers
  - Tools and supplies:
    - Porous pavement vacuum
    - Water source
    - Trash bags, gloves, safety cones, street broom



# Permeable Pavement Maintenance

- Porous Pavement Power Washing (should be done if pavement is clogged; NEVER power wash porous pavers)
  - Frequency:
    - Once every three years
    - Power wash after thorough vacuuming
    - Perform task in the spring
  - Tools and supplies:
    - Power washer
    - Water source
    - Trash bags, gloves, safety cones, street broom





# Permeable Pavement Maintenance

## Porous Pavers Maintenance

### 1) Inspect:

- Look for damage to the surface of the porous pavement (clogs)
- Record observations in maintenance report log

### 2) Prepare Site:

- Dispose of trash and debris
- Sweep away any loose debris

### 3) Clean out clogged Voids

- Use a manhole pick to clean out the voids till you are able to see clean aggregate



# Permeable Pavement Maintenance

## Porous Pavers Maintenance (restoring aggregate)

- Frequency:
  - When gravel infill is less than  $\frac{1}{2}$  inch of the paver surface
  - Perform after vacuuming
- Tools and supplies:
  - Shovel, manhole pick, wheelbarrow
  - Cleaned washed small aggregate
  - Trash bags, gloves, safety cones, street broom



# Permeable Pavement Maintenance

- Winter Maintenance for Permeable Pavements Procedures
  - Frequency:
    - As necessary following snowfall and/or icy conditions
  - Tools and supplies:
    - Truck with snow plow
    - Salt
    - Hand shovel





# Permeable Pavement Maintenance

## Winter Maintenance for Porous Pavements Procedures

### 1) Inspect:

- If location is no visible look at site plan to identify where its located
- Locate where obstacles are located like speed bumps, bushes, trees so the snowplow can be raised
- Record observations in maintenance report log

### 2) Plow Site:

- Use a rubber plow blade
- Plow 1" above the pavement to prevent hitting the plow on a edge or a paver and ripping it up

### 3) Storage of snow piles:

- Don't store snow piles on top of porous pavement surfaces; move the snow piles on lawn or non porous pavement

### 4) Salting

- Use in moderation

### 5) Record observations in maintenance report log and clean up





## Costs for Permeable Pavements

Type	Low Cost	High Cost	Project Range (1,000 sq. ft.)
Porous asphalt (per sq. ft.)	\$12.00	\$22.00	\$12,000 - \$22,000
Pervious concrete (per sq. ft.)	\$18.00	\$28.00	\$18,000 - \$28,000
Permeable pavers (per sq. ft.)	\$22.00	\$34.00	\$22,000 - \$34,000
Grass pavers (per sq. ft.)	\$16.00	\$18.00	\$16,000 - \$18,000

### Installation to include:

- Demolition of existing pavement
- Excavation and disposal of existing soil
- Placement of stone reservoir layers
- Installation of under drain piping and cleanouts
- Paving materials



# COMMON PROBLEMS



## Issues and Concerns: Pedestrian Safety

- Obstructions to sidewalks
- Line of sight obstruction
- Tripping hazards
- Standing water (over 72 hours)
- Icing



## Issues and Concerns: Vehicle Safety

- Branches/debris in roadway or parking area
- Lines of sight at intersections or parking areas
- Water overflow and icing in the roadway





# Issues and Concerns: Sediment & Debris

- Trash accumulation
- Sediment accumulation
- Erosion
- Dumping
- Road salt and sand
- Bare soils



## Issues and Concerns: Clogging

- Leaves and plant material
- Sediment
- Debris
- Ponding
- Filter screen or fabric
- Stone



## Issues and Concerns: Ponding

- Standing water for more than 72 hours
- Saturated soils
- Plant loss
- Poor soil infiltration
- High groundwater
- Insufficient drain piping
- Too much water



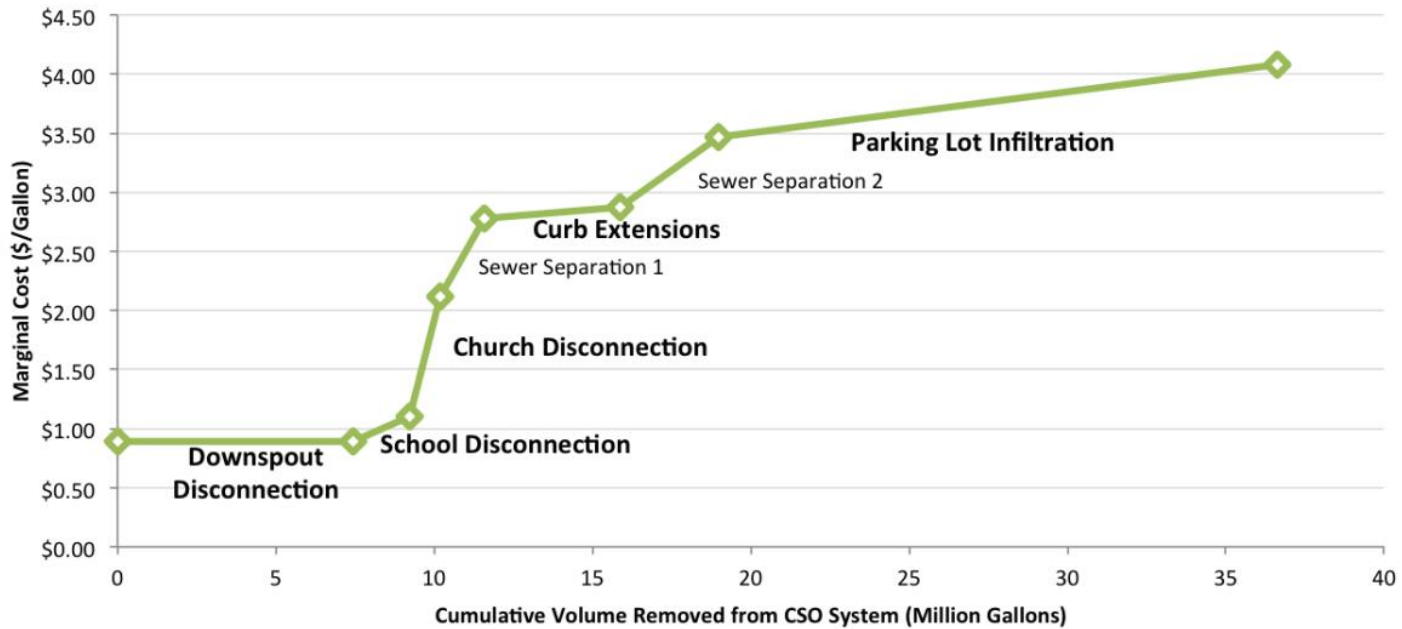
## Issues and Concerns: Winterizing

- Drain all piping, storage drums, and fixtures
- Clean all filters and screens
- Divert flow from storage tanks





# Portland, OR: Costs per gallons managed (\$0.89-\$4.08)



**Figure 2.** Costs and Cumulative Volume of Stormwater Removed from the CSO System through Various Grey and Green Strategies (Green in Bold). Source: ECONorthwest, with data from City of Portland 2005



# Washington D.C.: Typical Construction Estimates

<b>D.C. Water Green Infrastructure Cost Evaluation</b>		
<b>Green Infrastructure Practice</b>	<b>Cost</b>	<b>Unit</b>
Bioretention: Residential	\$5.00 - \$12.00	SF
Bioretention: Commercial	\$15.00 - \$60.00	SF
Pervious Pavement	\$2.00 - \$15.00	SF
Soil System Detention: Suburban/Rural	\$0.10 - \$0.75	SF
Soil System Detention: Urban	\$1.00 - \$5.00	SF
Vegetated Swales	\$20,000 - \$30,000	Drainage Area (ac)
Green Roofs: Extensive	\$8.00 - \$20.00	SF
Green Roofs: Intensive	\$15.00 - \$50.00	SF
Rainwater Harvesting: Rain Barrels	\$2.00 - \$4.00	Gal
Rainwater Harvesting: Cistern	\$0.50 - \$4.00	Gal
Rainwater Harvesting: Gray Water Systems	\$20.00 - \$30.00	Gal
Blue Roof	\$5.00 - \$8.00	SF
Filter Systems: Multichamber	\$70,000.00 - \$136,000.00	Drainage Area (ac)
Filter Systems: Surface	\$25,000.00 - \$35,000.00	Drainage Area (ac)
Filter Systems: Subsurface	\$20,000.00 - \$40,000.00	Drainage Area (ac)
Filter Systems: Proprietary	\$24,000.00	Drainage Area (ac)



# Resources and References: Costs

Source	Title	Link	Notes
NRDC	Rooftops to Rivers II	<a href="http://www.nrdc.org/water/pollution/rooftopsii/files/rooftopstoriversII.pdf">http://www.nrdc.org/water/pollution/rooftopsii/files/rooftopstoriversII.pdf</a>	Onondaga County, NY
NYC EP	NYC Green Infrastructure Plan	<a href="http://www.nyc.gov/html/dep/pdf/green_infrastructure/NYCGreenInfrastructurePlan_ExecutiveSummary.pdf">http://www.nyc.gov/html/dep/pdf/green_infrastructure/NYCGreenInfrastructurePlan_ExecutiveSummary.pdf</a>	Contains NYC GI Costs
American Rivers, ASLA	Banking on Green	<a href="https://www.asla.org/uploadedFiles/CMS/Government_Affairs/Federal_Government_Affairs/Banking%20on%20Green%20HighRes.pdf">https://www.asla.org/uploadedFiles/CMS/Government_Affairs/Federal_Government_Affairs/Banking%20on%20Green%20HighRes.pdf</a>	Contains Portland GI Costs
CNT	The Value of Green Infrastructure	<a href="http://www.cnt.org/sites/default/files/publications/CNT_Value-of-Green-Infrastructure.pdf">http://www.cnt.org/sites/default/files/publications/CNT_Value-of-Green-Infrastructure.pdf</a>	Overview of GI BMP's. Case studies: Aurora Illinois, Chicago, Milwalki NYC, Philadelphia, Portland, Seattle
EPA	Green Infrastructure Implementation Strategy for the Town of Franklin, Massachusetts	<a href="http://www.epa.gov/sites/production/files/2015-10/documents/franklin_report.pdf">http://www.epa.gov/sites/production/files/2015-10/documents/franklin_report.pdf</a>	Franklin, Massachusetts
NOAA	Green Infrastructure Options to Reduce Flooding	<a href="https://coast.noaa.gov/data/docs/digitalcoast/gi-econ.pdf">https://coast.noaa.gov/data/docs/digitalcoast/gi-econ.pdf</a>	Storage Potential and Costs
EPA	The Economic Benefits of Green Infrastructure A Case Study of Lancaster, PA	<a href="http://www.floods.org/ace-files/NAI/July2015_IL/IL_NAI_Workshop_CNT_EPA_LancasterGICaseStudy.pdf">http://www.floods.org/ace-files/NAI/July2015_IL/IL_NAI_Workshop_CNT_EPA_LancasterGICaseStudy.pdf</a>	Lancaster, PA
UMD	The 'Impact' and 'Benefits' of Green Infrastructure in Stormwater Financing Programs	<a href="http://efc.umd.edu/assets/stormwater_financing_manual/10.2efc_stormwater_financing_manual_appendix_a.pdf">http://efc.umd.edu/assets/stormwater_financing_manual/10.2efc_stormwater_financing_manual_appendix_a.pdf</a>	Lancaster, PA
D.C. Water	Long Term Control P January 2014 Modification for Green Infrastructure	<a href="https://www.dwater.com/education/gi_challenge_images/gi_public_comment_draft.pdf">https://www.dwater.com/education/gi_challenge_images/gi_public_comment_draft.pdf</a>	DC
Seattle, WA	Green Stormwater Infrastructure in Seattle	<a href="http://www.seattle.gov/Documents/Departments/OSE/GSI_Spreads_v2_July_2015_WEB.pdf">http://www.seattle.gov/Documents/Departments/OSE/GSI_Spreads_v2_July_2015_WEB.pdf</a>	Seattle, WA
	Economics and LID Practices	<a href="http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/docs/FTL_Chapter3%20LR.pdf">http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/docs/FTL_Chapter3%20LR.pdf</a>	



# Resources and References: Maintenance

## Caitlin Feehan: A Survey of Green Infrastructure Maintenance Programs in the United States

Available at: [http://hixon.yale.edu/sites/default/files/files/fellows/paper/feehan\\_hixonpaper20131.pdf](http://hixon.yale.edu/sites/default/files/files/fellows/paper/feehan_hixonpaper20131.pdf)

## Onondaga County, NY: Save the Rain Program Green Infrastructure Maintenance Training

Available at:

<http://savetherain.us/wp-content/uploads/2012/03/MaintenanceTrainingBinder.pdf>

## Philadelphia, PA: Green City, Clean Waters Green Infrastructure Maintenance Manual

Available at:

<http://phillywatersheds.org/ltcpu/Green%20Infrastructure%20Maintenance%20Manual%20Development%20Process%20Plan.pdf>

## Chesapeake Bay: Strategies to Improve Operations and Maintenance of Green Infrastructure

Available at:

<https://www.americanrivers.org/assets/pdfs/reports-and-publications/staying-green-strategies-improve-operations-and-maintenance.pdf>





# Questions?

