



Green Infrastructure Webcast Series

Retrofits: Green Streets
Operation and Maintenance

Guide to Our Webcasts

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Green Infrastructure Website
www.epa.gov/greeninfrastructure

- General Information
- Key Resources
- Case Studies
- Performance Data
- Partnership Contacts
- Statement of Support





Green Infrastructure Webcast Series

Archived webcasts on the following topics:

- Benefits of Green Infrastructure
- Municipal Case Study: Philadelphia
- Revising Local Plans, Codes and Ordinances
- Water Harvesting
- Models & Calculators
- Municipal Case Study: Louisville
- Site Planning & Design Considerations
- Costs and WERF Cost Tool
- Funding and Incentives
- Brownfield Redevelopment

Additional webcasts coming late Fall – Stay tuned!

Green Highways and Green Streets: Green Infrastructure

Presented by:

The Low Impact Development Center, Inc.

A non-profit water resources and sustainable design organization

www.lowimpactdevelopment.org

Presentation

- Background on Green Highways and Green Streets
- Research
- Implementation
- Case Studies

Green Infrastructure

"Green infrastructure is an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations. As a stormwater treatment approach, Green infrastructure uses natural and engineered systems to cleanse water and reduce excess volumes by filtering and treating it using plants, soils, and microbes. "

What makes a highway or a street green?

Courtesy of Anne English

Navy, Army, and DOD have numerous LID and Green Infrastructure projects in the Chesapeake Bay Region

Pilots!

Naval District Washington LID Demonstration Projects

Building 166 Permeable Pavement

Pervious Concrete

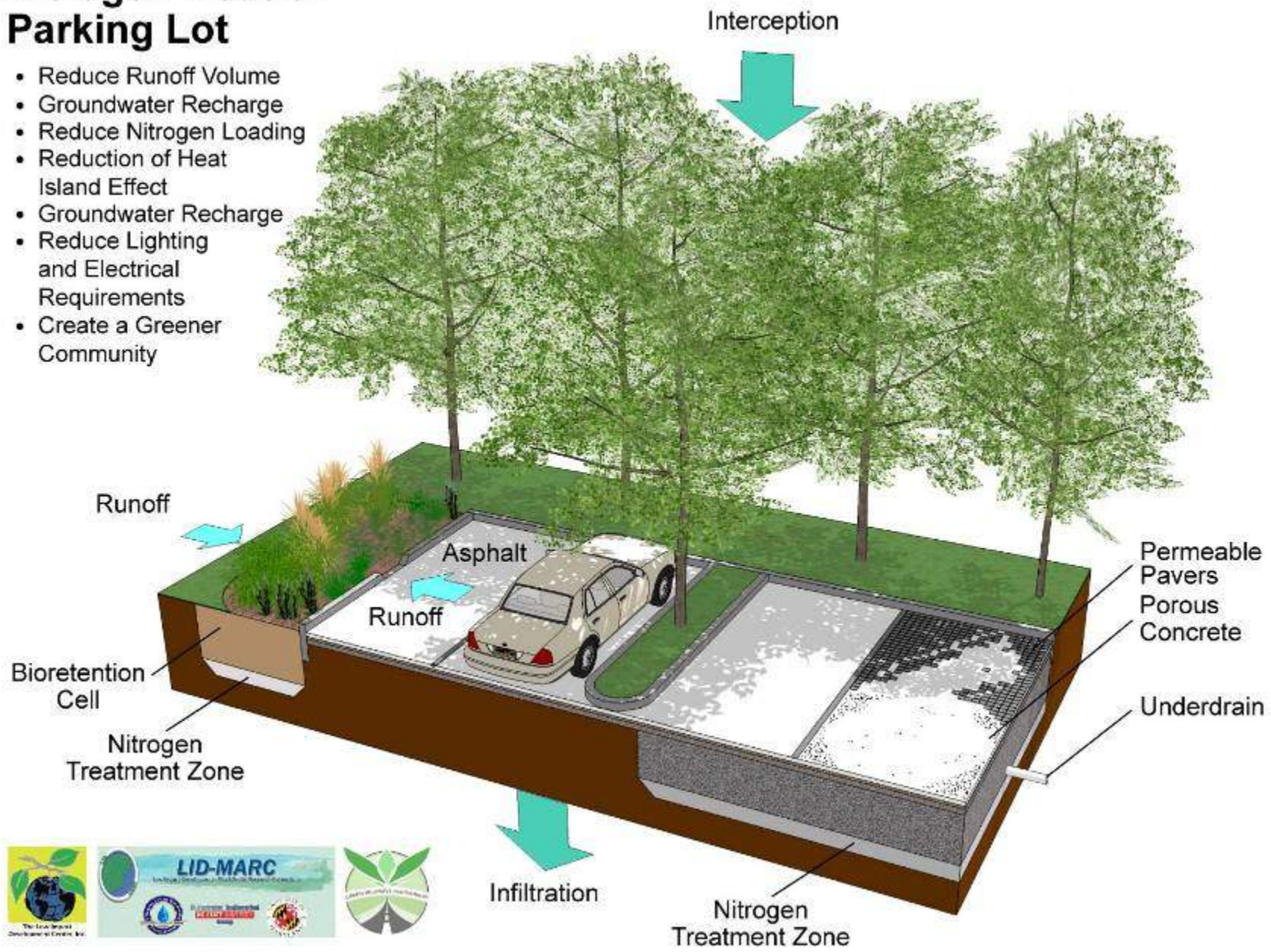
Park & Ride Parking Lot (4 acres)

Serving Site of 2008 Super Bowl – Glendale, Ariz.

Courtesy NRMCA Foundation

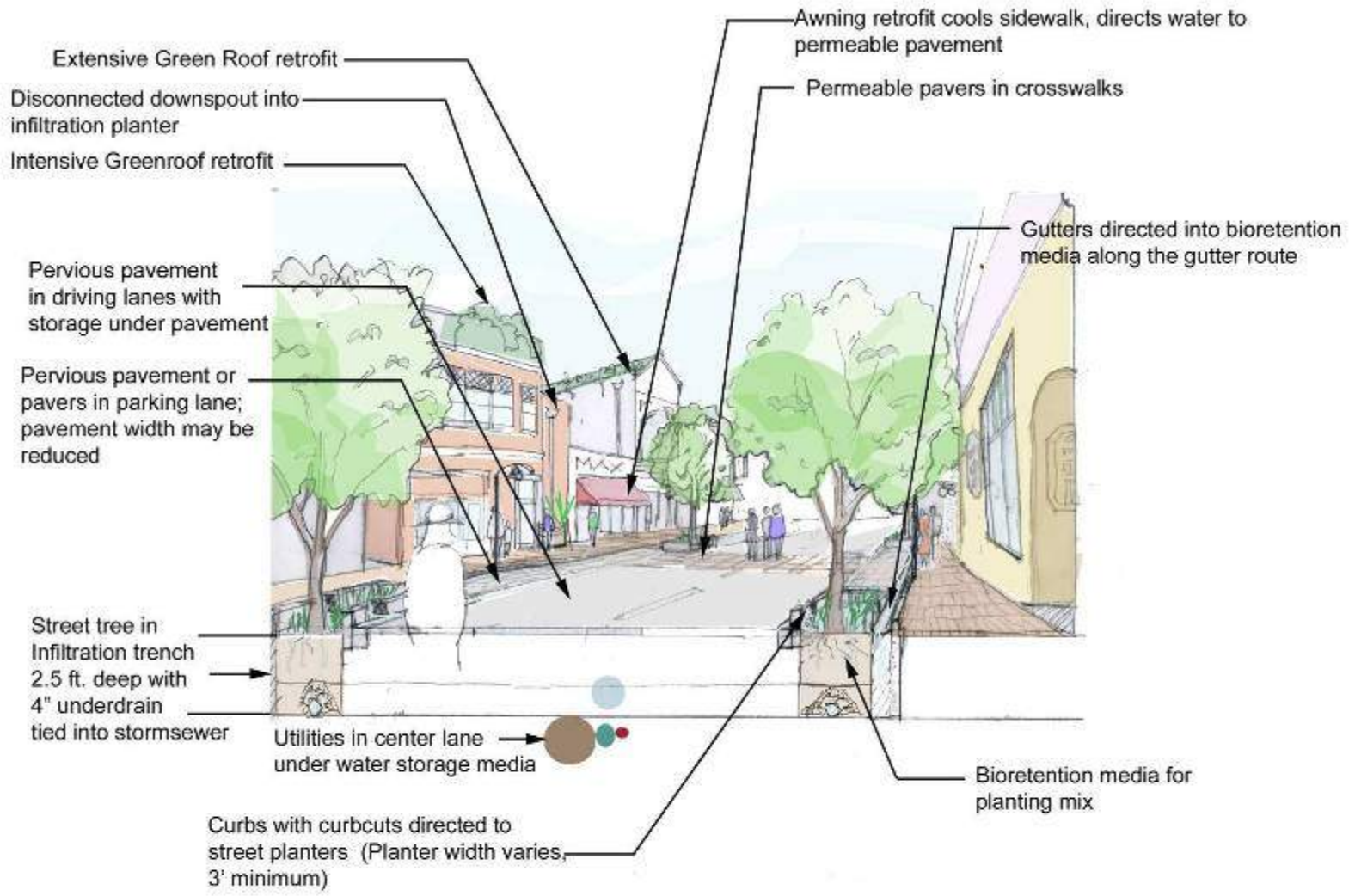
Nitrogen Neutral Parking Lot

- Reduce Runoff Volume
- Groundwater Recharge
- Reduce Nitrogen Loading
- Reduction of Heat Island Effect
- Groundwater Recharge
- Reduce Lighting and Electrical Requirements
- Create a Greener Community



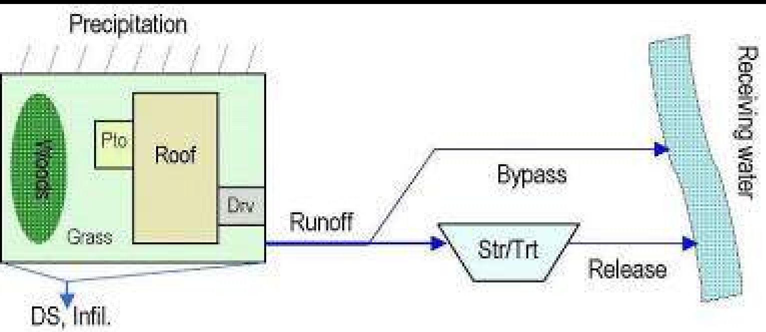
Ready Mix Concrete Research & Education Foundation

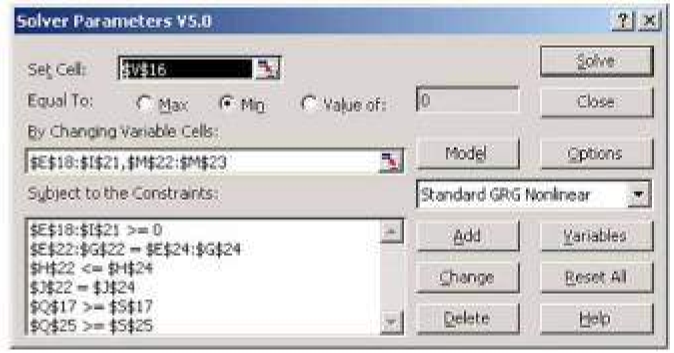
EPA Headquarters



Decentralized Stormwater Controls in Urban Retrofit Streetscape

WERF Decentralized Controls for Urban Retrofit Phases I, II and III





	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1				Spatial	Roof	Patio	Drvwy	Yard	TA			Evapo. rate			Infiltration rate							
2				info	230.51	35.56	45.19	773.467	1084.73			Month	(mm/d)		Infiltr	1.27	(mm/hr)					
3							Max Grs	60%				1	0.381		Del-T	1	(hr)					
4												2	0.457									
5			Land use opt.		Roof	Patio	Drvwy	Grass	Wood			3	0.635		Pollutant Removal (1st order PF)					Cost fnc = a (Str)^c		
6			DS	Opt1	2.7	2.7	1.037	13.5	33.9			4	0.991		Cout = Cin * exp(-k * td)					Storage	a	b
7			(mm)	Opt2	9	7	12.7	22.8	41.6			5	1.651		Cin	10	(mg/L)			On-site	1000	0.6
8				Opt3				32.5	55			6	2.515		k	0.04	(/hr)			Off-site	10000	0.7
9				Opt4					118.5			7	3.226									
10			Unit	Opt1	$0.00	$0.22	$0.65	$1.51	$8.61			8	3.150									
11			Cost	Opt2	$16.15	$0.31	$0.86	$2.69	$15.07			9	1.600			Volume-based					Total cost	
12			($/m2)	Opt3				$3.66	$21.53			10	1.092			Prcp	317.5					Cost
13				Opt4					$32.29			11	0.686			DS	216.45				Land	$3,414
14			Land	Opt1	1	1	1	1	1			12	0.381			Rff	101.05				On-Str	
15			use	Opt2	1	1	1	1	1							Str/Trt	40.42				Off-Str	$24,646
16			Opt	Opt3				1	1			On-site str				BP	60.63		Target		Total	$28,061
17				Opt4					1			Max A	2%	of TA		Capt	40.0%	>=	40.0%			
18			Land	Opt1	230.51	0	0	464.08	309.387			Max A	21.69	(m2)								
19			use	Opt2	0	35.56	45.19	0	0			Max D	0.1	(m)		Pollutant mass						
20			Opt	Opt3	0	0	0	0	0							Mrff	1010.45					
21				Opt4	0	0	0	0	0	Yard		Off-site str/rls				Min	404.181					
22					230.51	35.56	45.19	464.08	309.387	773.467		Storage	3.62783	(mm)		Mbp	606.271					
23					=	=	=	=<		=		Release	0.0221	(mm/h)		Mout	50.52					
24				Area	230.51	35.56	45.19	464.08		773.467		Empty	6.84002	(d)		Mrv	353.658		Target			
25				DS	2.7	7	12.7	13.5	33.9							Rm	35.0%	>=	35.0%			
26	Continuous Simulation																					
27	Total =	317.5													101.045				40.4181	60.6271		50.5232
28	Prcp time series		Dry	ET	DS for each area					Runoff from each area					Overall	Storage-Release-Bypass					Pollutant removal	
29	Time	Prcp	Dry	ET	DSr	DSp	DSd	DSg	DSw	Rff-r	Rff-p	Rff-d	Rff-g	Rff-w	Rff	Str1	Rls	Str2	Trt	BP	td	Mout
30		(mm)	day	(mm/d)	avail	avail	avail	avail	avail									0			(hr)	
31	2000/01/04 12:00	2.54	0	0.381	2.7	7	12.7	13.5	33.9	0	0	0	0	0	0	0	0	0	0	0	0	0
32	2000/01/18 11:00	2.54	13.917	0.381	2.7	7	12.7	13.5	33.9	0	0	0	0	0	0	0	0	0	0	0	0	0
33	2000/01/26 19:00	2.54	8.2917	0.381	2.7	7	12.7	13.5	33.9	0	0	0	0	0	0	0	0	0	0	0	0	0
34	2000/01/26 22:00	2.54	0.0833	0.381	0.19175	4.49175	10.1917	10.9917	31.3917	2.34825	0	0	0	0	0.49902	0.49902	0.0221	0.47692	0.49902	0	11.2903	3.17674
35	2000/01/27 02:00	2.54	0.125	0.381	0.04763	1.99937	7.69937	8.49937	28.8994	2.49238	0.54063	0	0	0	0.54737	0.95798	0.0221	0.93588	0.54737	0	33.9648	1.40685
36	2000/02/15 05:00	2.54	19.083	0.4572	2.7	7	12.7	13.5	33.9	0	0	0	0	0	0	0	0	0	0	0	42.349	0
131	2000/09/24 14:00	2.54	0	1.6002	0	0	0	0	0	2.54	2.54	2.54	1.27	1.27	[illegible]	[illegible]	0.0221	[illegible]	0.0221	[illegible]	[illegible]	[illegible]
132	2000/09/24 15:00	5.08	0	1.6002	0	0	0	0	0	5.08	5.08	5.08	3.81	3.81	3.08773	3.62783	0.0221	3.60574	0.0221	3.06563	163.66	0.00032
133	2000/12/05 19:00	2.54	72.125	0.381	2.7	7	12.7	13.5	27.4796	0	0	0	0	0	0	0	0	0	0	0	163.16	0
134	2000/12/10 21:00	2.54	5.0417	0.381	2.08088	6.38088	12.0809	12.8809	26.8605	0.45912	0	0	0	0	0.09757	0.09757	0.0221	0.07547	0.09757	0	2.20745	0.89321
135	2000/12/22 13:00	2.54	11.625	0.381	2.7	7	12.7	13.5	26.7496	0	0	0	0	0	0	0	0	0	0	0	3.41489	0

WERF Decentralized Controls for Urban Retrofit Phases I, II and III

Decentralized controls integrated into urban infrastructure

BMP	Infiltration	ET*	Interception	Conveyance	Detention	Retention	Reuse**
Downspout Disconnection	◉	○			○	◉	
Filter Strips	○	○	○	○		○	
Infiltration Practices	◉			○		◉	
Pocket Wetlands	◉	◉	○		●	◉	
Porous Pavement	●				●	◉	
Rain Barrels/Cisterns						◉	●
Rain Gardens	●	◉	○		●	◉	
Soil Amendments	◉				○	◉	
Tree Box Filters	◉	◉	○		◉	◉	
Vegetated Roofs	◉	◉	○		●	◉	
Vegetated Swales	◉	○	○	◉	●	○	

* Evapotranspiration

** Collected water can be used for landscaping, non-potable building uses (e.g., toilets), or as raw water to be treated for drinking.

Key: ● High reliance ◉ Medium reliance ○ Low reliance Blank: N/A

Rankings are qualitative. "High reliance" means that the process is integral to the BMP's ability to meet stormwater management objectives, and that the BMP uses the process to its full potential in the urban environment. "Medium reliance" was assigned when a process is a secondary component of the BMP's operation, or when the BMP does not use the process to its full potential. "Low reliance" means that the process only marginally contributes to the BMP's ability to meet stormwater management objectives. The rationale for ranking hydrologic cycle elements is given in Section 2.3.2.

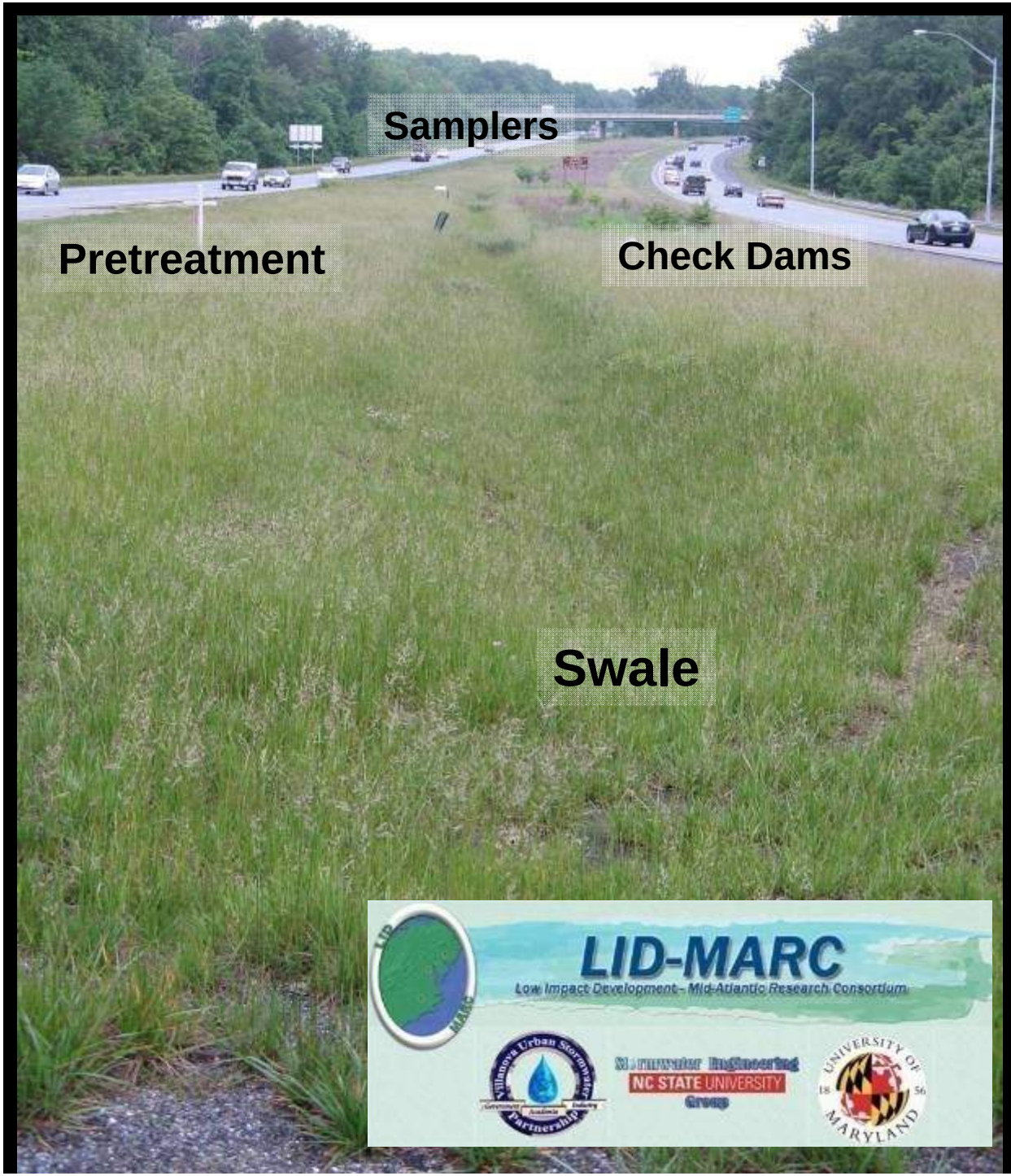
WERF Decentralized Controls for Urban Retrofit Phases I, II and III

Integration into the linear environment

- Pilots and research
- Road codes, standards, details
- Environmental Management Systems

Large R-O-W's for suburban/rural arterials

Compost amendments and filter soxx

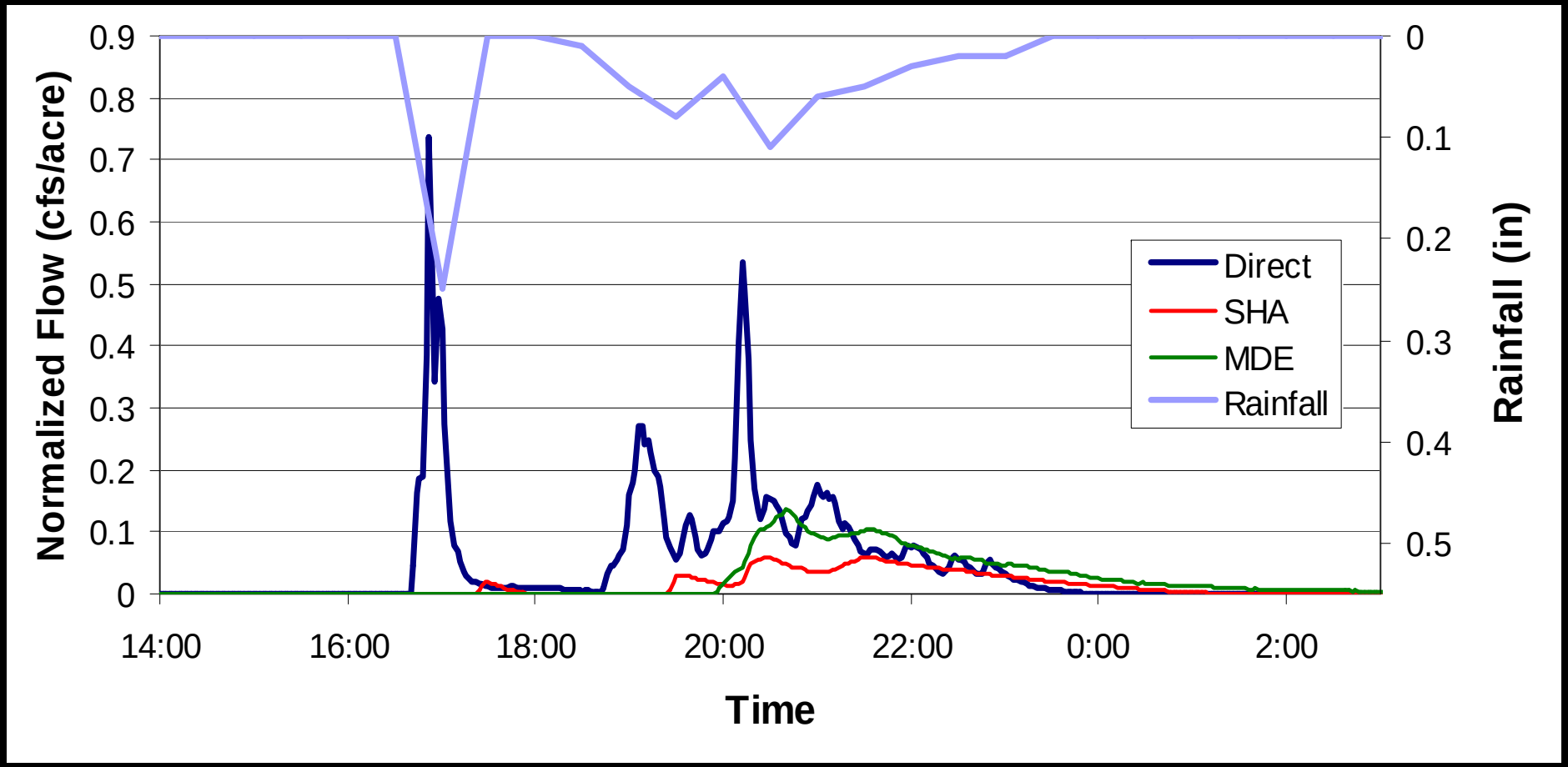


Pretreatment Grass Swale

Courtesy AP Davis

UMCP and MDSHA

Flows 11/16/05 Storm Event



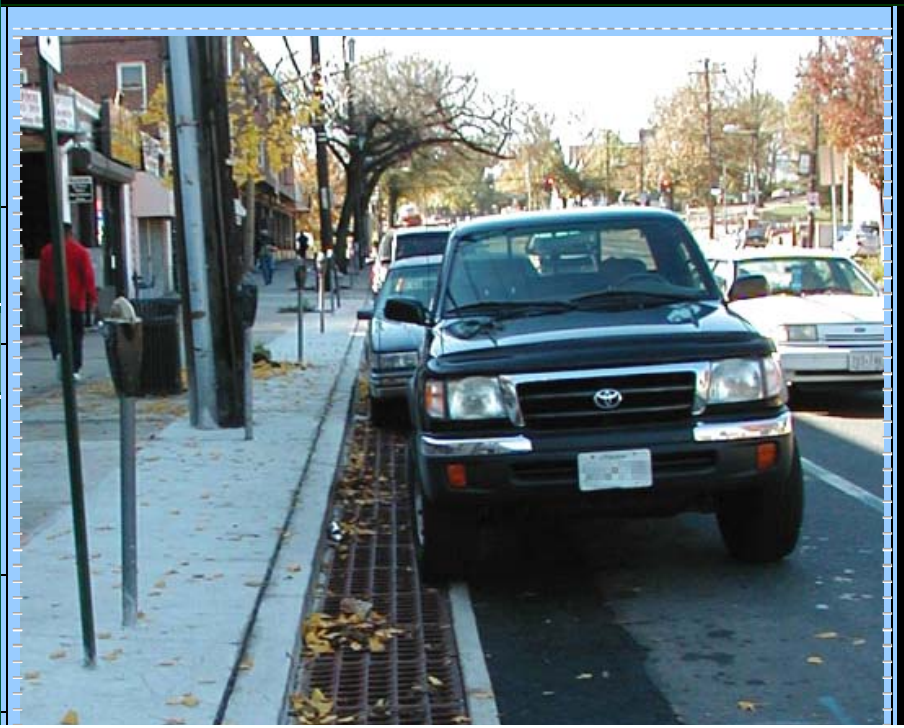
Urban retrofit and reconstruction

NCHRP
REPORT 565

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Evaluation of Best Management Practices for Highway Runoff Control

TRANSPORTATION RESEARCH BOARD



NCHRP 25-31

Guidelines for Evaluating and Selecting Modifications to Existing Roadway Drainage Infrastructure to Improve Water Quality in Ultra-Urban Areas

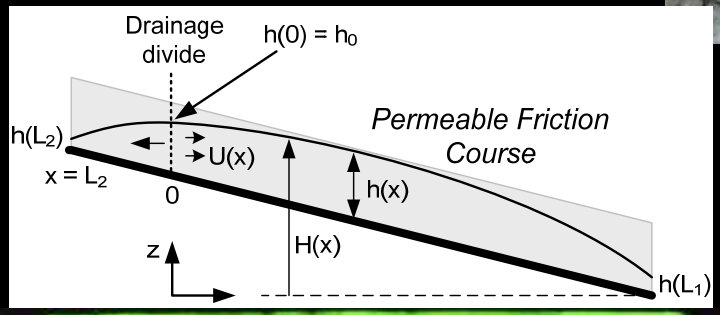
Geosyntec, Oregon State University, Venner Consulting, Wright Water Engineers

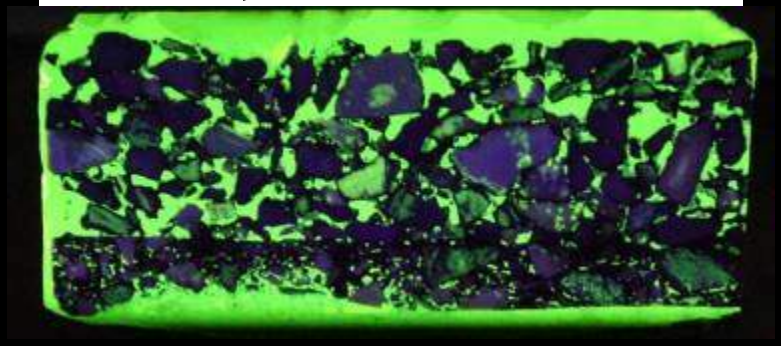
Constructability

"Mt. Ranier Project by MDOT, UMCP, and LIDC selected as one of years 10 best water quality projects by the Sierra Club"

MOT

- Permeable Block Pavers
- Permeable Concrete
- Asphalt Overlays





Alternative Materials

ICPI
INTERLOCKING CONCRETE PAVEMENT INSTITUTE ®

RMC RESEARCH & EDUCATION FOUNDATION

8th Street – Barracks Row

PROJECT PHOTOGRAPH

DESIGN PERSPECTIVE

The streetscape design features environmental innovations including a continuous five-foot-wide strip along the curb to collect most of the surface runoff from the wide sidewalks and a continuous root zone to help promote the growth of new street trees.

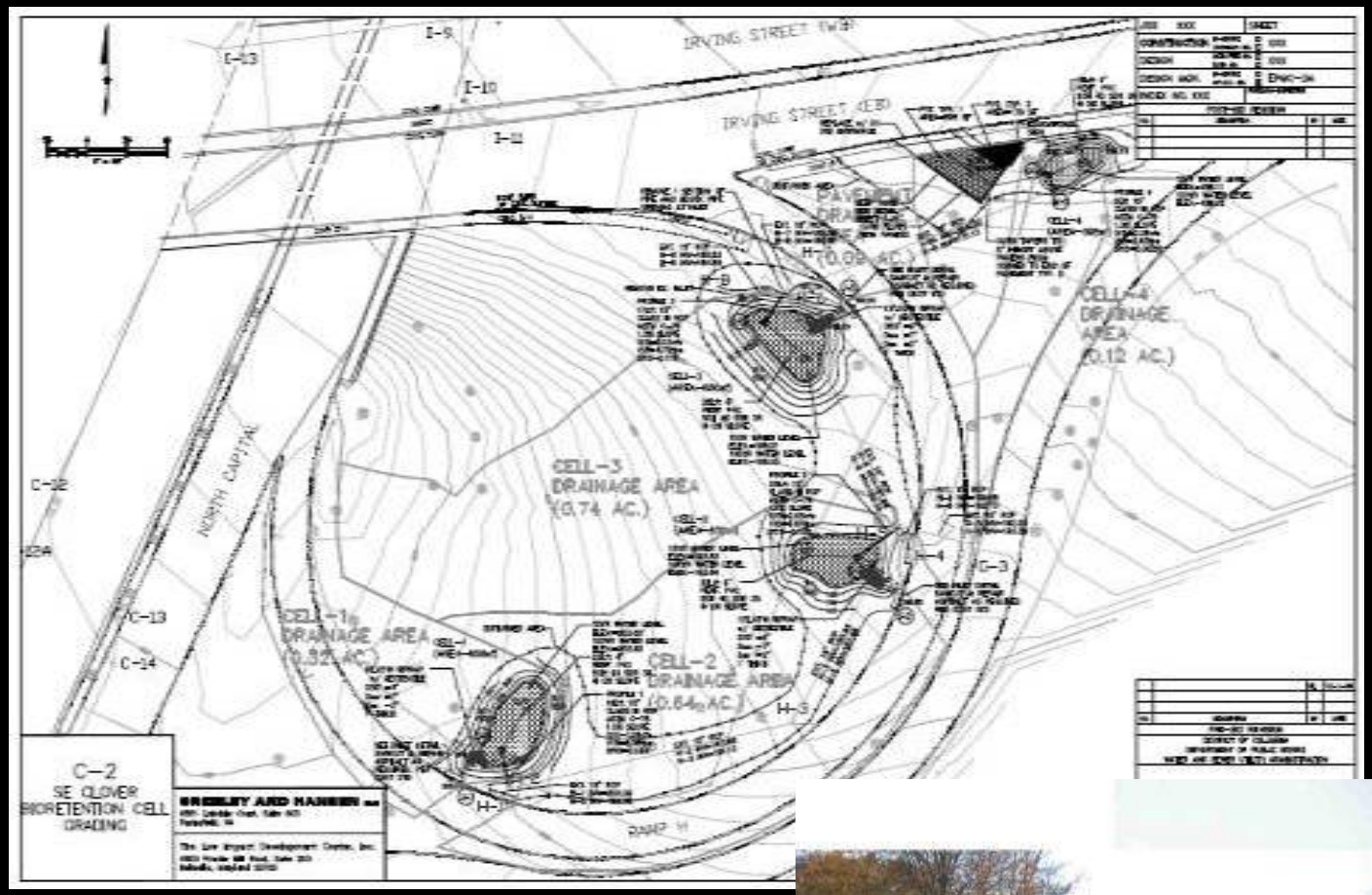
Lily Turf planting beds visually break up wide sidewalks, with bluestone paved areas allowing pedestrian crossing onto new brick sidewalks.

Additional street trees and pedestrian scale Washington globe lights, new bicycle racks, trash receptacles, and cobblestone alleys enhance the historic commercial environment.

Courtesy of Lee + Papa and Associates

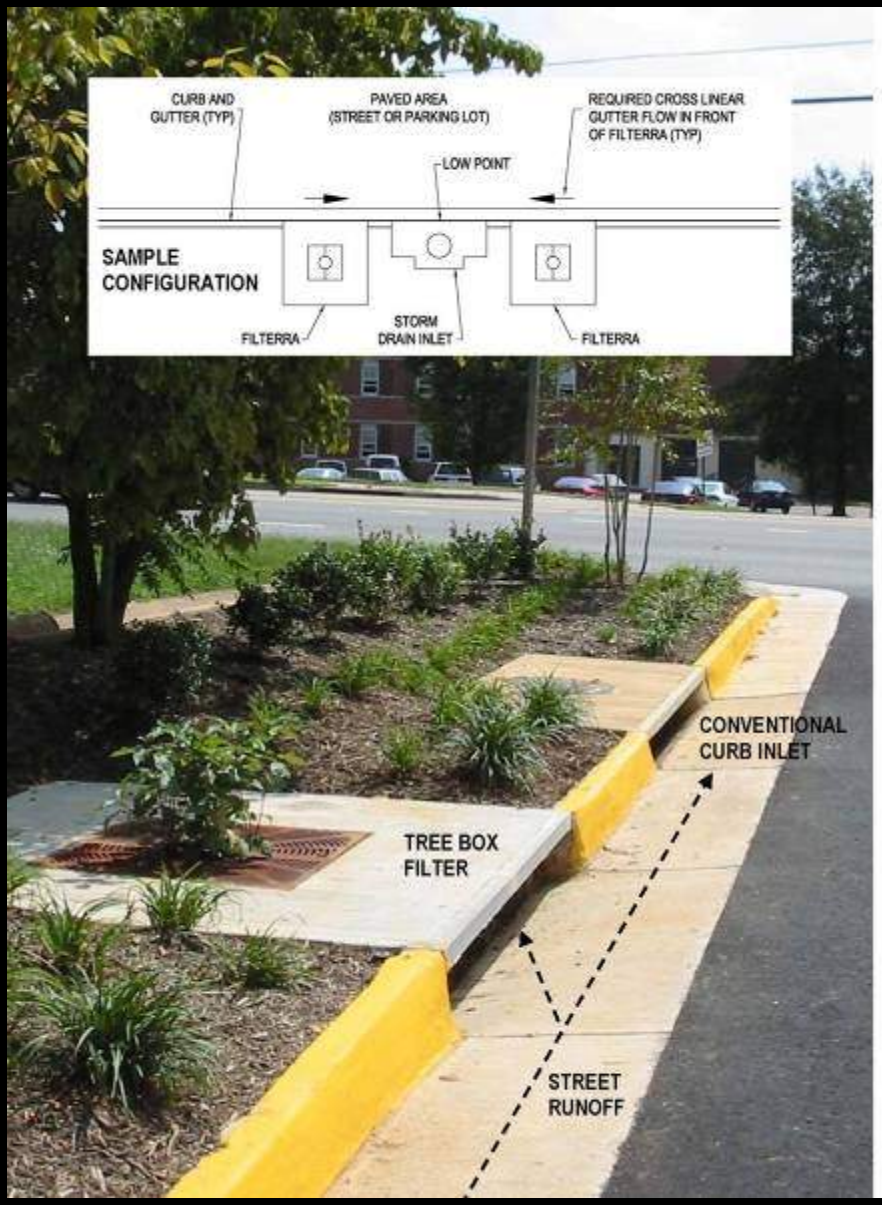
Green Strategies

Reforestation



Erosion and Sediment Control and Site Restoration

Procurement and Inspection



Anacostia Waterfront Transportation Architecture Design Standards

Element: Low Impact Development (LID)
Item: Tree Box Filter – Sidewalk-Furnishing Zone
Classification: Principal Arterials, Minor Arterials, and Collectors; Local
Location: Sidewalk, adjacent to curb

Reference: x.y.z
AWI Guideline
Area Type: Mixed-Use & Residential

Type: Concrete-enclosed infiltration device

Purpose
Tree box filters are concrete boxes filled with bioretention soil and installed below grade at the curb line. A standard street tree is planted in the box, which resembles a curbside planter. Tree box filters are located upstream of a standard curb inlet. For low to moderate flows, stormwater enters through the tree box's inlet, filters through the soil, and exits through an underdrain into the storm drain. For high flows, stormwater will bypass the tree box filter if it is full and flow directly to the downstream curb inlet.

Benefits
- Reduce runoff volume, reduce peak discharge rate, and improve water quality for small, frequently-occurring storms
- Potentially reduce maintenance costs for existing stormwater infrastructure

Effectiveness
Because they are a related technology, tree box filters provide many of the same water quality and quantity benefits as bioretention cells, and effectively treat the "first flush" of stormwater. They can treat over 90% of the annual runoff volume. Removals of several common urban pollutants range from 75 to 95%. The street tree provides aesthetic and habitat benefits.

Objective	Volume	Frequency	Duration	Peak Discharge	Water Quality
Effectiveness	Medium	Medium	Medium	Medium	High

Design Standards
- **Dimensions:**
  - Standard tree box area is 6' x 6' (treats 0.25 acres). Other sizes are available. Max. drainage area for one box is 0.5 ac.
  - To treat 90% of the annual runoff volume, the tree box filter surface area should be at least 0.33% of the drainage area.
- **Placement:**
  - Tree boxes must be regularly spaced along the length of a corridor as appropriate to meet the annual treatment target.
  - The site grading must allow runoff to flow across the tree box inlet (e.g. left-to-right), rather than directly into it as in a sump. Do not place the tree box at the low point. A standard inlet must be present downstream to accept bypass flow.
- **Material:**
  - Pre-cast concrete container (standard sizes)
  - Mulch layer (typically 3")
  - Up to 3.5' of filter media (bioretention soil mix)
  - Observation/cleanout pipe and underdrain pipes
  - One street tree or other suitable plant(s)
  - Grate landscape cover
  - Downstream curb inlet *must* be present

Manufacturer
- Americast (Product: Filterra®)
- Approved Equal

Transportation Elements

DISTRICT DEPARTMENT OF TRANSPORTATION

ENVIRONMENTAL MANAGEMENT SYSTEM

Environmental Management System

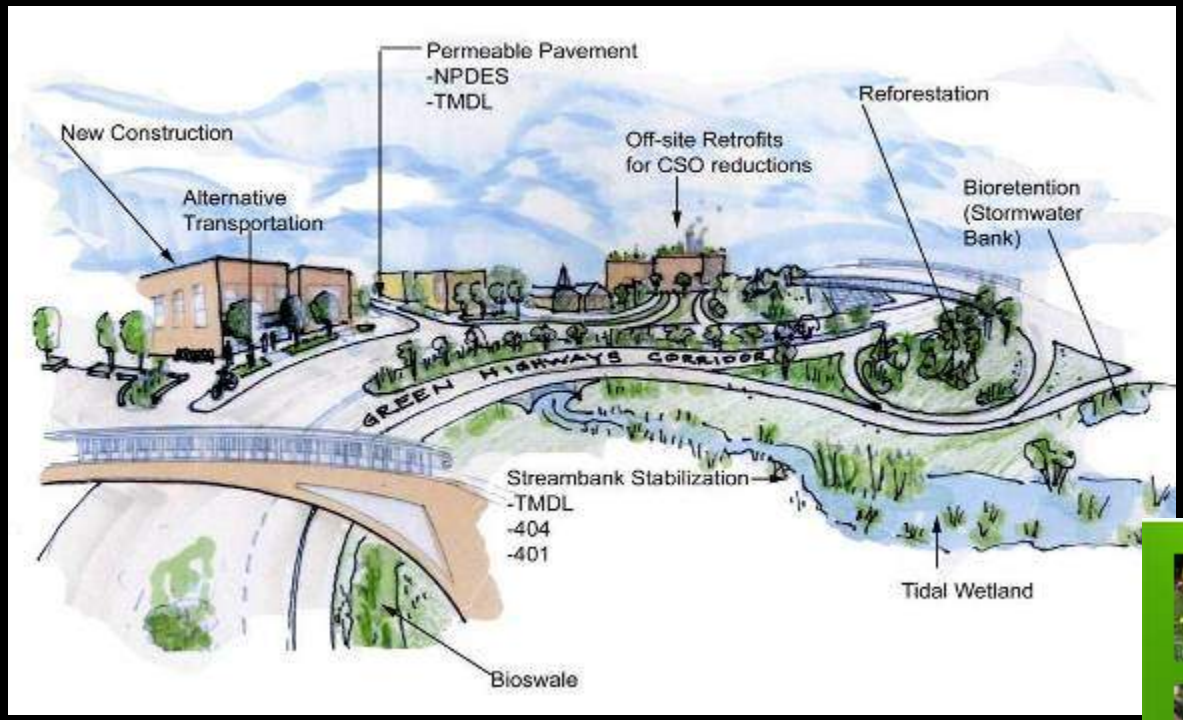
ENVIRONMENTAL MANAGEMENT SYSTEM

d.

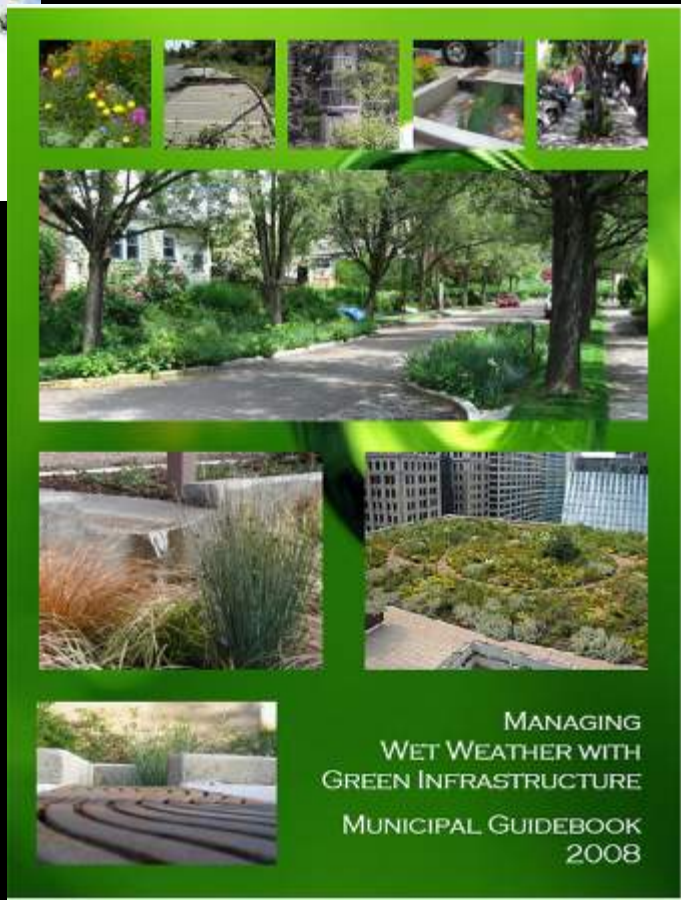
DISTRICT DEPARTMENT OF TRANSPORTATION

ENVIRONMENTAL MANAGEMENT SYSTEM

System integration, consistency and sustainability



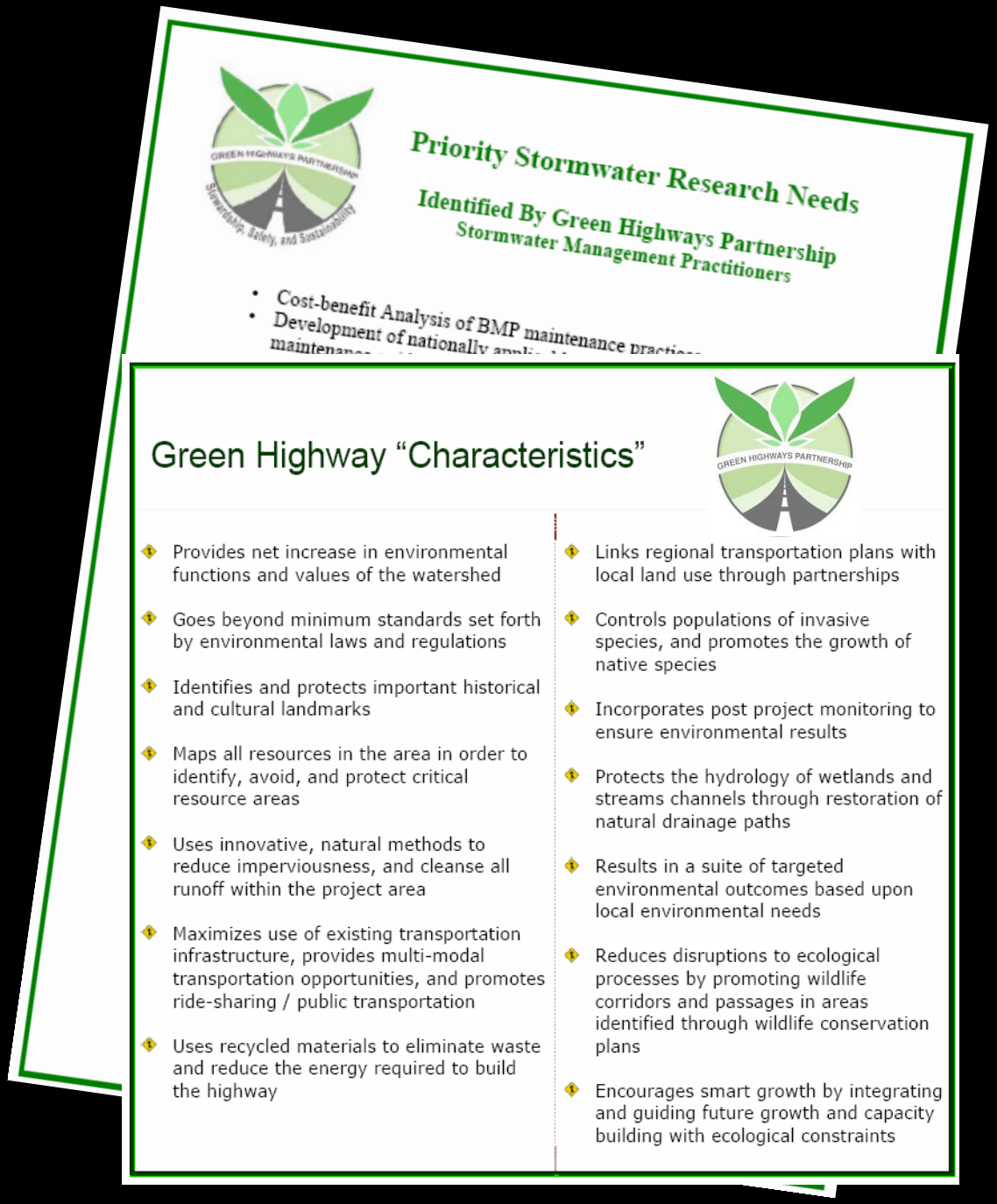
GREEN HIGHWAYS PARTNERSHIP



The Green Highways Partnership (GHP) is a voluntary, public/private initiative that is revolutionizing transportation infrastructure. Through integrated planning, regulatory flexibility, and market-based rewards, GHP seeks to incorporate environmental streamlining and stewardship into all aspects of the highway lifecycle.

Green Highways Partnership Theme Teams

- Watershed driven stormwater management
- Recyclables and reuse
- Conservation



Nannie Helen Burroughs Avenue Great Street LID Toolbox

Stormwater solutions which support sustainable urban design

Bioslope

- *Add green infrastructure*
- *Links to other BMPs*
- *Improve water quality*
- *Reduce runoff volume*
- *Reduce erosion tendency*
- *Requires periodic aeration & compost amendment*
- ***Possible locations:***

40th Street access corridor

Bioswale

- *Linear bioretention feature, may mimic natural stream channel form*
- *Reduces runoff volume as water is conveyed*
- *Removes stormwater pollutants*
- *Links with other BMPs*
- *Provides green infrastructure link and habitat*
- *Planting design conforms to aesthetic design goals for urban design*
- ***Possible locations:***

Minnesota and NHB Intersection, SE Corner
46th Street, Gault to NHB
46th Street, South of Gault

Bioretention Cell

- *Green infrastructure link*
- *Reduces runoff volume*
- *Removes pollutants*
- *Links to other BMPs*
- *Provides habitat*
- *Provides aesthetic character definition*
- ***Possible locations:***

Minnesota and NHB Intersection, SE Corner
46th Street, Slope N side of NHB
46th Street, W Side of 46th, Alley to Gault Pl
46th Street, W Side of 46th, Gault Pl to end of 46th
48th Street, N Bus Stop Bump Out
48th Street, S Bus Stop Bump Out
49th Street, N Bus Stop Bump Out
49th Street, S Bus Stop Bump Out
50th to 51st Street, N Sidewalk Bulge Area
50th to 51st Street, S Sidewalk Bulge Area
51st to Division, N Sidewalk
51st to Division, S Sidewalk
Near Eastern Ave, DC Welcome Sign

Permeable Pavers

- *Community development tool*
- *Reduces runoff volume*
- *Removes pollutants*
- *Reduces urban heat island*
- *Aesthetic enhancement of area; many color options*
- *ADA compliant pavement*
- ***Possible locations:***

46th Street, Sidewalk bottom of N slope
45th Street, End
Gault Pl to 48th, N Designated Parking Lane
Gault Pl to 48th, S Designated Parking Lane
48th to 49th Street, N Designated Parking Lane
48th to 49th Street, S Designated Parking Lane
49th to 50th, N Designated Parking Lane
49th to 50th, S Designated Parking Lane
49th Street, Triangle

Vegetated Filter Strip

- *Filters pollutants from stormwater*
- *Provides stream and waterway buffering*
- *Links with other BMPs*
- *Includes Soil amendments*
- ***Possible locations:***

Gault to 49th, Median
49th to 49th Street, Median
49th Street, Traffic Circle
50th to 51st Street, Median
51st Street to Division N Sidewalk
Division to 55th Street Median

Street Trees

- *Reduces runoff volume*
- *Removes stormwater pollutants*
- *Reduces urban heat island*
- *Promotes pedestrian use of streets*
- *Links community via canopy*
- ***Possible locations:***

All along the NHB Corridor

Nannie Helen Burroughs Ave. is a neighborhood street with "green" practices that builds on its history and park-like context with great access to Watts Branch trail and the Kenilworth Aquatic gardens.

For additional information, please contact:

District Department of Transportation (DDOT) 64 New York Avenue,
Ali Shaken, PE Ward 7 & 8 Program Manager (202) 671-6712 or ali.shaken@

The Low Impact Development Center
www.lowimpactdevelopment.org

EPA/FHWA Grant

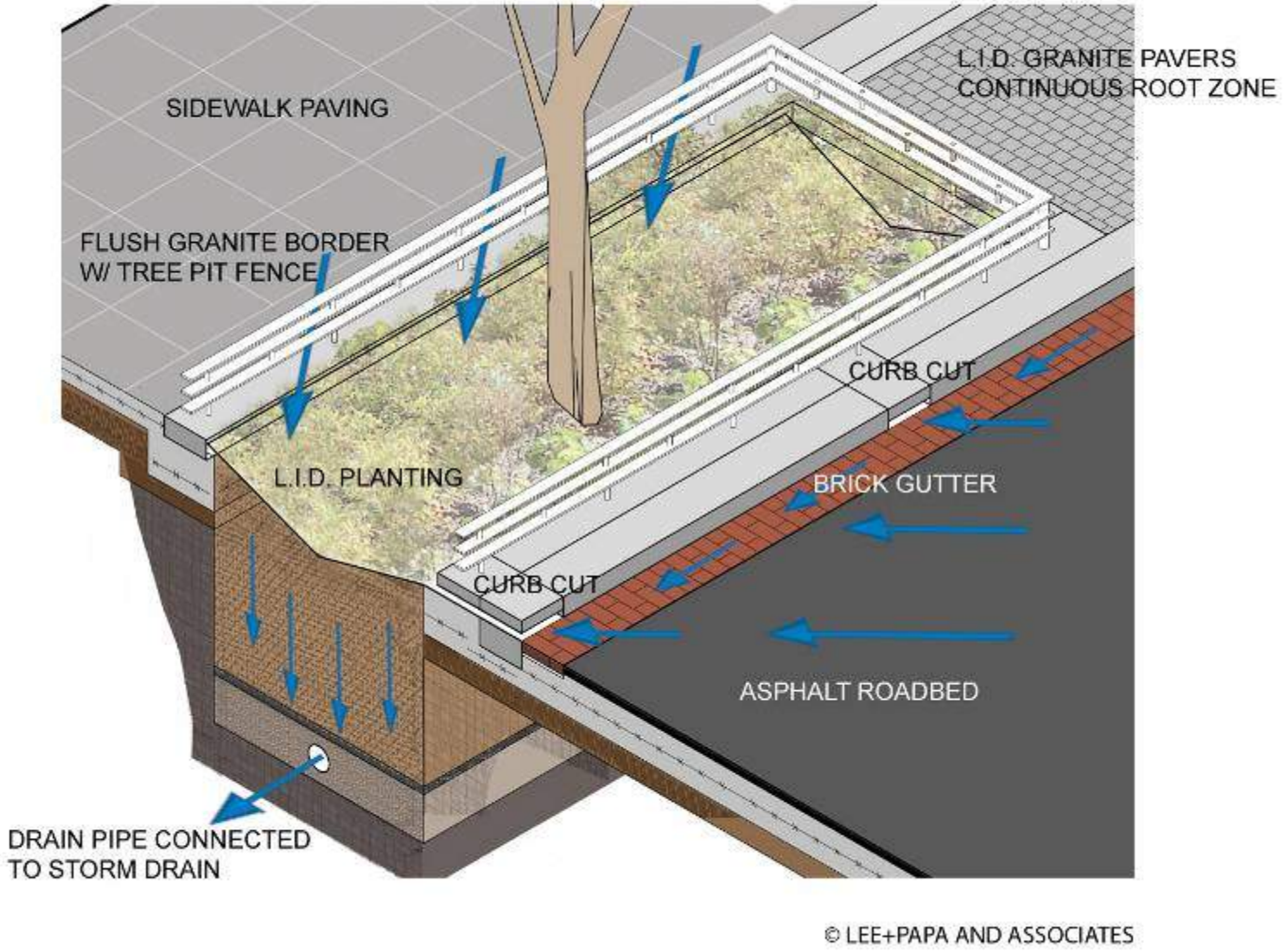
Newsflash!!!

- LIDC and EPA Region 3 establish Green Highways Partnership Training and Development Center (GHPTADC). First ASCE Webinar Fall 2009. Training and Certificate program begins 2010.
- ASCE ***First*** National Conference on Green Highways and Green Streets Denver 2010
- Special Sessions at the Low Impact Development Conference Spring 2010
- GHP Digest

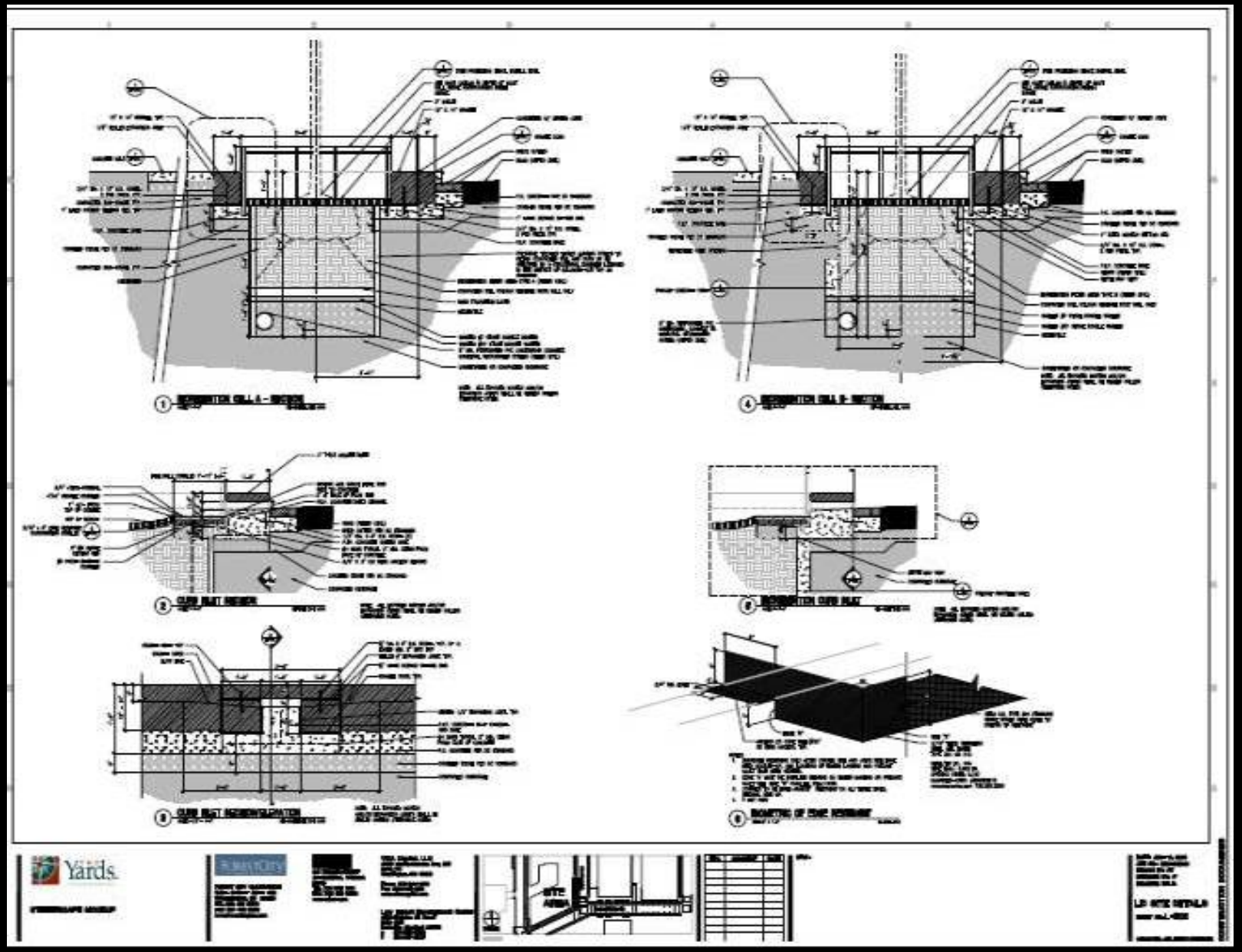
T&DI
TRANSPORTATION AND DEVELOPMENT INSTITUTE
A S C E

Planning and Site Design

Courtesy of Hines Development



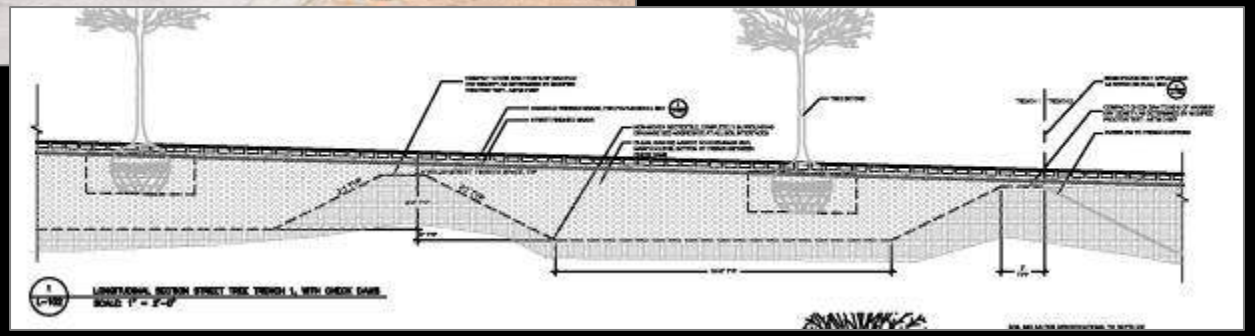
Courtesy of Lee + Papa and Associates



Courtesy of Forest City Development and VIKA

Courtesy of Philadelphia Water

Philadelphia Demonstration Projects



BMPs:
Disconnected Inlets, Pervious Pavers, Subsurface Infiltration

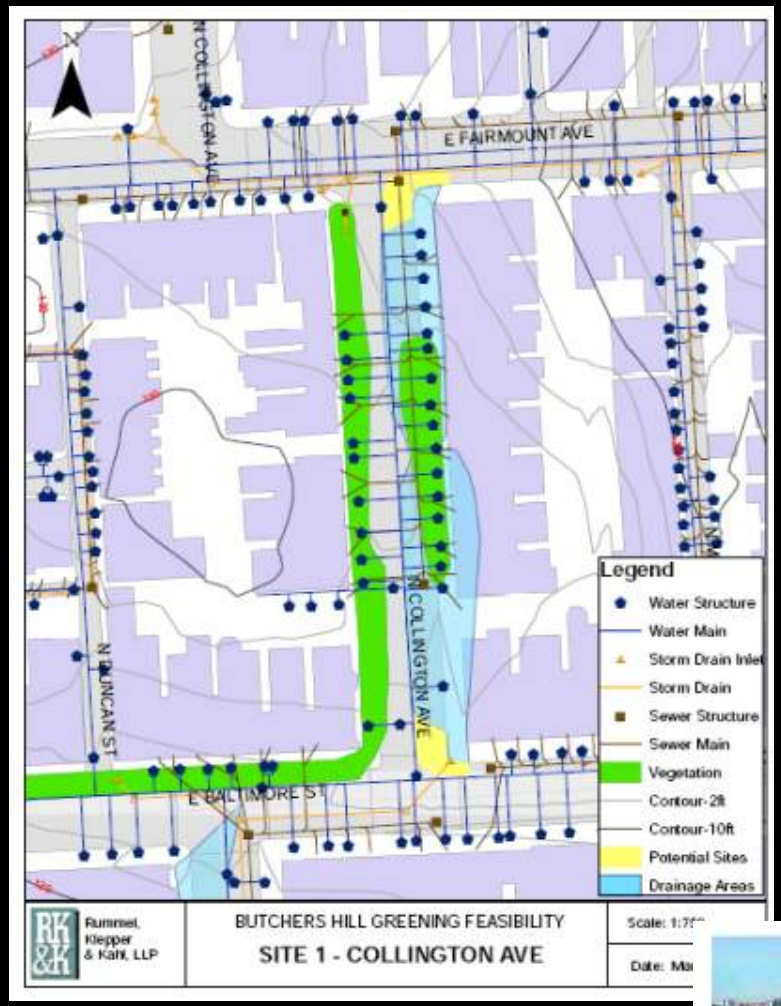


Figure 2: A) Bioretention on one street. B) Bioretention on both streets

City of Baltimore

Green Streets Master Plans

PlaNYC

- Targeted
- Incremental
- Predictable
- Comprehensive
- Cross-cutting

Additional retrofit programs may be required to lower the overall impermeability of the right of way. The Greenstreets program of small plantings in the right of way is one of our most successful retrofit programs. PlaNYC has already committed the funding and planning for 80 new Greenstreets every year for the next decade, with the goal of bringing the total number to 3,000 by 2017. The Parks Department is experimenting with new design standards that would allow for more storage of street runoff. We have evaluated the impacts of a strategy of expanding the Greenstreet program, either by doubling the number built every year, or extending the commitment from 2018 to 2030, an additional 12 years.

…..the City could use this strategy to target intersections prone to nuisance flooding or sub-watersheds with specific CSO problems. Greenstreets are also desirable for other, non-stormwater reasons. They provide community amenities and a positive impact on real estate values, quality of life, and cooling. And their highly-visible presence in the right of way, adjacent in many cases to pedestrian areas, means that Greenstreets installations could provide a unique opportunity for public outreach and education about stormwater impacts and controls.

Chesapeake Bay Trust Urban Greening Grant

Edmonston, MD

A Great Green Town

Community revitalization through the use of low impact development, attraction of green businesses, and attention to health by encouraging biking and walking.

American Recovery and Reinvestment Act

From Main Streets to Green $treets!: Collaboration for Prosperity and Sustainability

A Model for Sustainable, Green Land Use Planning for Low Income Communities located in the Anacostia River Watershed of the Chesapeake Bay

Green Streets
by the Green Highways Partnership

Low Impact Development Center, Inc

Green Highways Partnership

www.cbtrust.org

Greening Tools…

Solar trash compactor; Program information on trash can
Source: LID

Energy-efficient light fixtures; Banner standards on light poles
Source: Cannell Graphics

Source: LID Center

Source: LID Center

Planning for environmentally sustainable growth in the Anacostia Watershed

"From Main Streets to Green $treets!"

Using Green Highways and Green Infrastructure to revitalize our communities: Green Stimulus Plan for the Town of Edmonston, Maryland

What makes this a "Green Street"?

- **A Top (tree canopy) to bottom (water quality) plan**
- **Native tree canopy**
- **Street lighting with clean energy**
- **Walking, running, and biking**
- **Recycled materials**
- **Stormwater bioretention and filtration**
- **Open process and public engagement**
- **Education and replication**

Anticipated Project Benefits:

Social Benefits:
- Reduction in urban heat island effect
- Provides "Green Job" opportunities
- Educational through street kiosks
- Crime reduction benefit
- Health benefit

Economic Benefits:
- Energy cost reduction and water conservation
- "Green Enterprise" business opportunities

Environmental Benefits:
- Carbon sequestration
- Improved water quality through 90% capture of stormwater
- Carbon footprint reduction
- Recycling and beneficial reuse

EPA Region 3 and Headquarters creates partnerships with federal, state, local, and local governments that leverage resources for economic revitalization and environmental restoration.

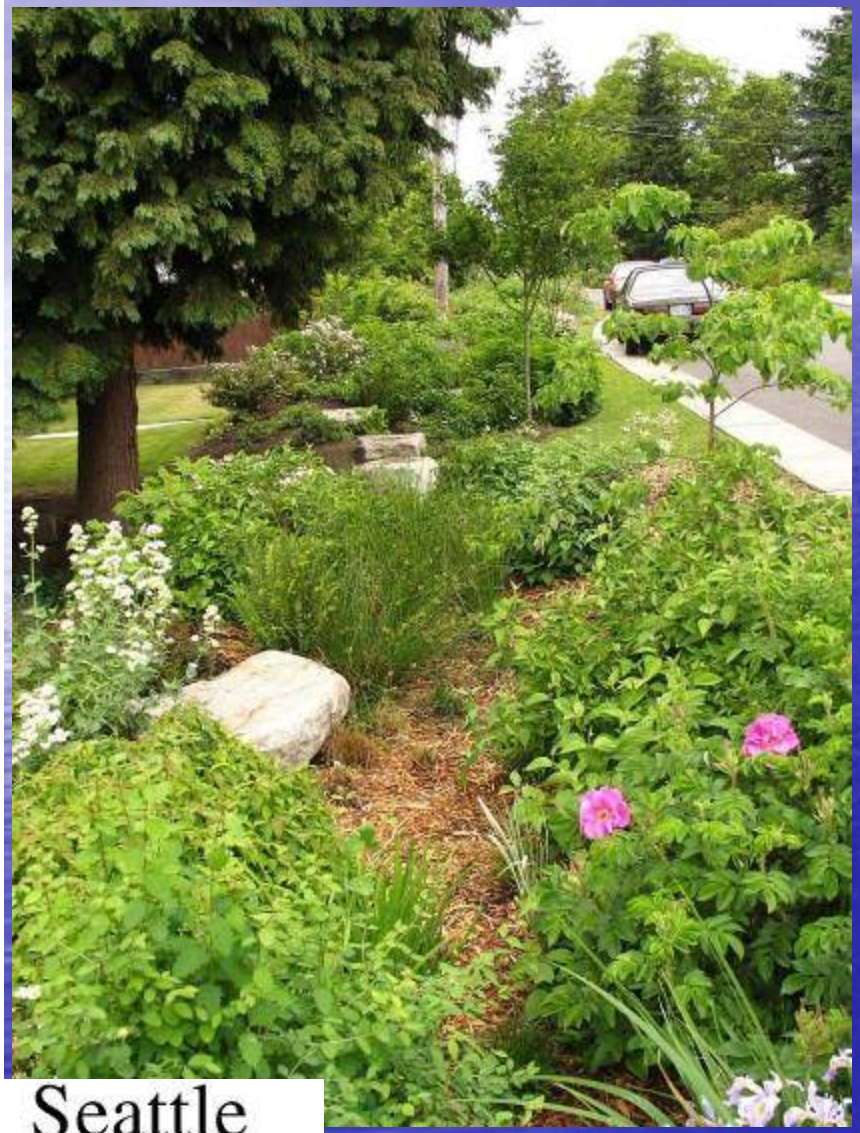
Just a few resources...

http://lowimpactdevelopment.org/green_highways.htm
http://greenhighways.org
http://trb.org/CRP/About/Div.asp
http://asce.org
http://cfpub.epa.gov/npdes/home.cfm?program_id=298
http://www.icip.org
http://www.rmc-foundation.org/
http://www.fhwa.dot.gov/
http://www.washingtonpost.com/wp-dyn/content/article/2009/07/22/AR2009072203470.html

Green Highways and Green Streets let you...

- Develop integrated watershed planning approaches
- Leverage resources
- Integration green elements into infrastructure
- Create partnerships and cross-cutting programs
- Create Context Sensitive Solutions

Seattle Public Utilities Green Stormwater Infrastructure: **Operations and Maintenance**



Seattle Public Utilities

Presentation Outline

- Green Stormwater Infrastructure (GSI) Program Overview
- Natural Drainage Systems partnering with Residents
- Natural Drainage Systems O&M package
- O&M requirements for Code compliance
- O&M requirements for residents receiving incentives

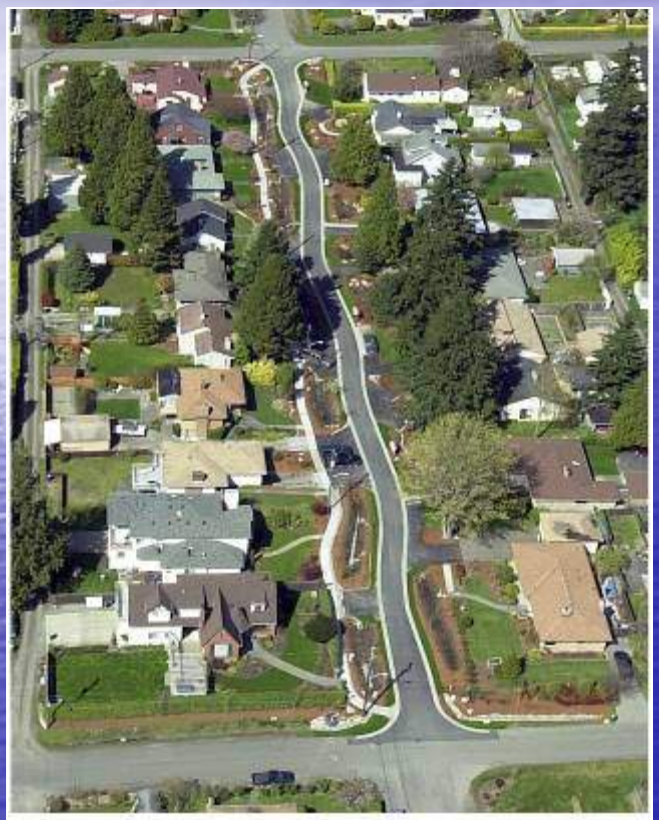
Goals of GSI Use in Seattle

- Separated Basins
  - Creeks: water quality and flow
  - Puget Sound: water quality
- Partially Separated and Combined Basins
  - CSO compliance
  - Sanitary Sewer backup reduction

Locations of GSI

- Right-of-Way
  - Retrofits by Seattle Public Utilities (aka **Natural Drainage Systems**)
  - Stormwater Code Compliance
- Private Parcels
  - Stormwater Code Compliance
  - Seattle funded Incentives (Residential Rainwise)

Natural Drainage Systems



SEA Streets - After Construction
2nd Ave NW - NW 117th St to NW 120th St

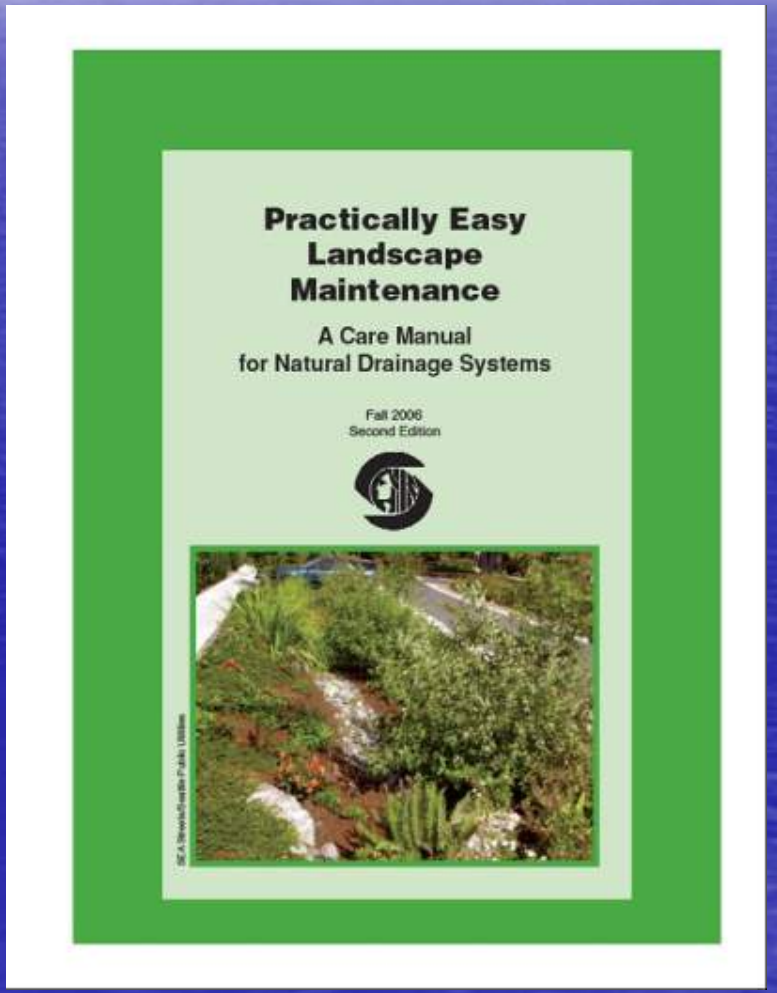
NDS Maintenance By Residents

- Initial Concept
- Watering and weeding
- Grand Visions

Best Case Scenario

Homeowners Landscape Maintenance Manual

- Distributed to homeowners living adjacent to systems
- Identifies responsibilities of the City and the homeowner



Work Parties and Tours

Reality

NDS Maintenance: Lessons Learned

Homeowners front yard is good indicator of gardening level of interest.

(Plant palette should be adjusted accordingly!)

NDS Maintenance: Lessons Learned

- Plant Palette choices

NDS Maintenance: Lessons Learned

Be clear with your messaging from the start.

- What are the city's responsibilities?
- What is the homeowner expected to do?

“The city will maintain the functional elements of the natural drainage system, whether the swale is an eyesore or an amenity is up to you”

Natural Drainage Systems (NDS) Operations and Maintenance

- NDS O&M Maintenance Package
  I. NDS Maintenance Manual for ROW
  II. O&M Facility Checklists
  III. Key Performance Indicators
  IV. O&M Estimating Database Tool
- Lessons Learned

I. NDS Maintenance Manual

- For facilities in the Right-of-Way
  - Bioretention
  - Biofiltration
  - Permeable Pavements
- Defines Routine and Non-routine maintenance activities based on Level-of-Service set for the given system
- Used in combination with Inspection/checklist
- Used to guide scheduling of maintenance activities

NDS Maintenance Manual: Sections

1. Vegetation and Landscaping
2. System Functionality
3. Hardscape and Infra-Structure
4. Infiltration Failure – Swale Ponding
5. Recommended Maintenance for Other Elements
6. Safety, Mobility, and Accessibility

Levels of Service (LOS)

- LOS A
  - Excellent effort
- LOS B
  - Good effort
- LOS C
  - Moderate effort
- LOS D
  - Poor effort

Layout and How To

- Select the desired Service Level for maintenance

Table III. Hardscape Manual

Service Category	Service Level B (Good Effort)	Service Level C (Moderate Effort)	Service Level D (Low Effort)	Recommended Maintenance Activities
HARDSCAPE & INFRA-STRUCTURE	**Summary** • sediment is minimal • infrastructure is always accessible • no competition between roots and pipes • no trash is present • small accumulation of organic debris on grates or screens • limited buildup of sediment behind check dams or log weirs • no erosion or undercutting surrounding weir walls • rockery and walls are stable and secure • stormwater sedimentation structures less than ½ full (NPDES)	**Summary** • some sediment is present • infrastructure is usually accessible • some competition between roots and pipes • small amounts of trash are present • moderate accumulation of organic debris on grates or screens • occasional large sediment deposits behind check dams or log weirs • minimal erosion and/or undercutting surrounding weir walls • occasional loose rocks; walls are secure • stormwater sedimentation structures less than ½ full (NPDES)	**Summary** • Lots of sediment buildup is observed • infrastructure is mostly inaccessible • significant competition between roots and pipes • Trash is present • Heavy accumulations of organic debris on grates or screens • frequent large sediment deposits behind check dams or log weirs • Erosion and/or undercutting surrounding weir walls • Loose rocks; walls are not secure • stormwater sedimentation structures less than ½ full (NPDES)	
□ Sedimentation structures— TYPE 2	Sediment is blocking 10% of structure 	Sediment is blocking 30% of structure 	Sediment is blocking 50% of structure 	□ if sediment present, remove trash and unwanted organic debris □ muck out / vactor structure and dispose of waste properly

Ease of Use

Service Category	Service Level A (Excellent Effort)	Service Level B (Good Effort)	Service Level C (Moderate Effort)	Service Level D (Poor Effort)
	• No erosion, channelization or scouring • Water drains within 24 hours • Minimal bare spots • Acceptable level of sediment or debris accumulation	• Some erosion, channelization or scouring • Most water drains within 24 hours, minimal long-term ponding • A few bare spots • Acceptable level of sediment or debris accumulation	• The presence of long-term ponding (> 72 hours) • Many bare spots • Significant build up of sediment or debris	scouring • The presence of long-term ponding (> 72 hours) • Many bare spots or noxious weeds/grass • Significant build up of sediment or debris
Swale bottom vegetation				
Sediment or debris accumulation				
Conveyance	• Healthy vegetation	• Mostly healthy vegetation	• Some vegetation	• Poor or no vegetation

1-Vegetation and Landscape Maintenance

Example -

Level of Service B:

- Bio-retention swales are ***mostly*** self sustaining
- Maintenance for functionality after establishment period

Level of Service B – Good Effort

1-Vegetation and Landscape Maintenance

Example: Level of Service B checklist includes:

- Vegetation is mostly healthy
- Good appearance
- Small quantities of weeds
- Edges are loosely defined
- Grass encroaching on the swale (or vice versa)

Levels of Service B - Good

1-Vegetation and Landscape Maintenance: Noxious and Nuisance Weeds

- Special considerations need to be identified
- Provide link to jurisdiction's web site
- Photos
- Identification key
- Reporting requirements – *if applicable*

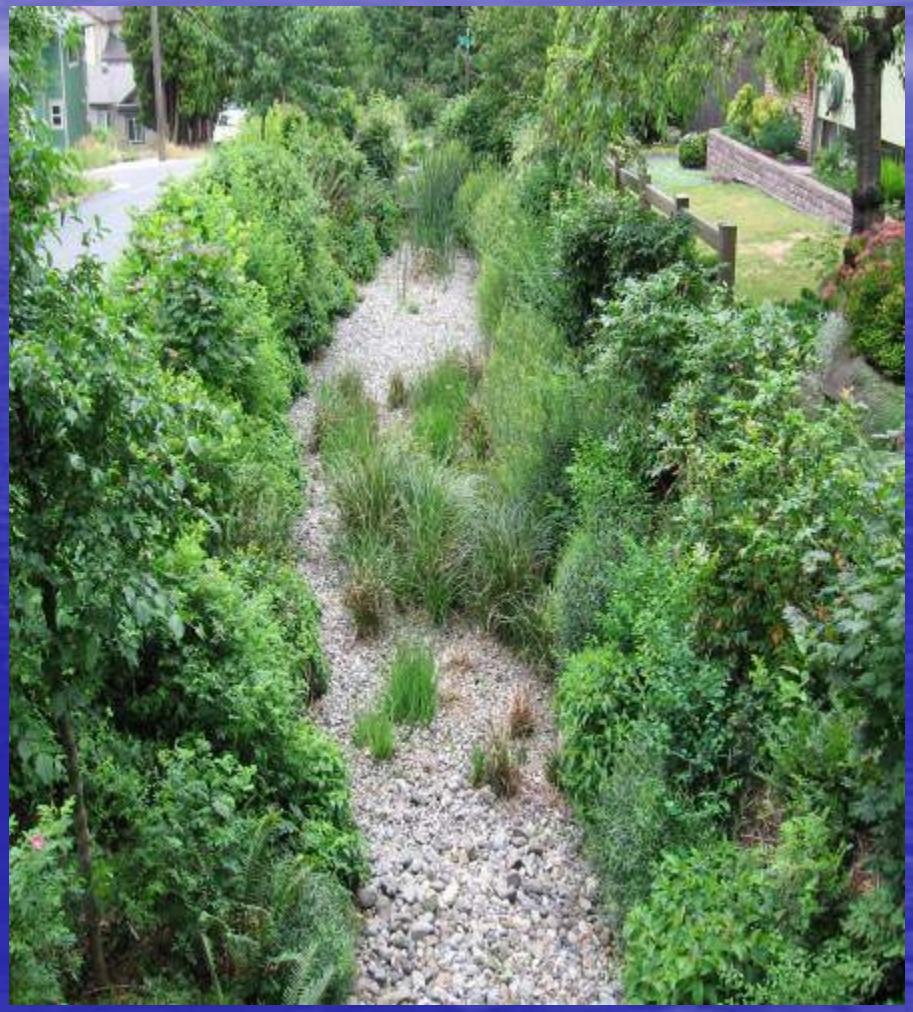
Spotted Knapweed

2-System Functionality

Critical criteria for achieving design function.

For example LOS C for biofiltration

- 40% to 60% bottom covered with healthy vegetation
- Uniformed fine-stemmed at least 18 to 24 inches high



2-System Functionality

For example LOS C for bioretention

- Evidence of vehicle compaction
- Many bare spots
- Significant level of sediment and debris accumulation

3-Hardscape and Infra-Structure

- Debris and sediment removal
- Clearing and cleaning

3-Hardscape and Infra-Structure : Long Term Maintenance

- For lifecycle costing with bioretention, we assume every fifteen years, remove and replace top two inches of soil and replant to restore infiltration function

4-Infiltration Failure

- Evidence of a cell holding water for more than 24 hours needs to be reported to Operations and Maintenance Asset Manager
- Monitor swale for ponding water
- Retrofit swale if standing water greater than 72-hours

5-Recommended Maintenance for Other Elements

- Pest control
- Spill prevention and response
- Safety
- Mobility
- Accessibility
- Permeable pavements
- Irrigation systems

6-Safety, mobility, accessibility

Manual is a Working Document

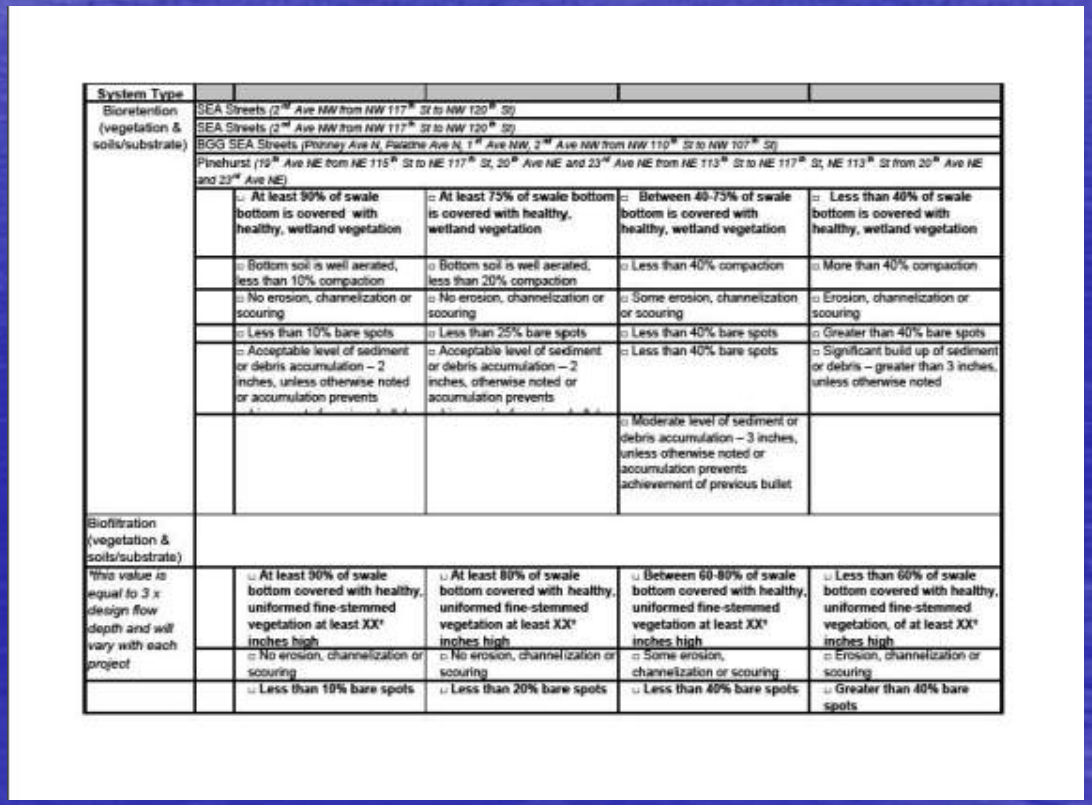
- Work, work, work with field crews
- Update photos to continue refining document
- Document lessons learned

Natural Drainage Systems (NDS) Operations and Maintenance

- NDS O&M Maintenance Package
  I. NDS Maintenance Manual for ROW
  II. O&M Facility Checklists
  III.Key Performance Indicators
  IV.O&M Estimating Database Tool
- Lessons Learned

II. O&M Facility Checklists

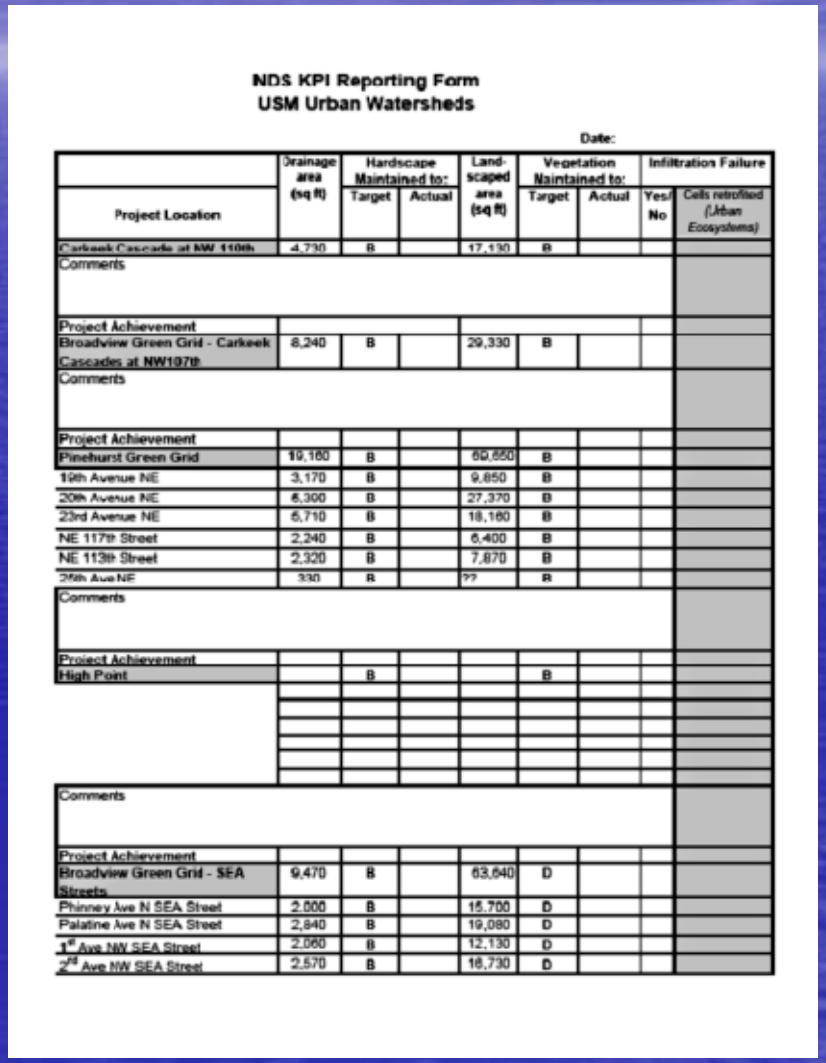
- Condensed version of manual
- Identify key performance indicators



System Type					
Bioretention (vegetation & soils/substrate)	SEA Streets (2nd Ave NW from NW 117th St to NW 120th St)				
	SEA Streets (2nd Ave NW from NW 117th St to NW 120th St)				
	BGG SEA Streets (Pinehurst Ave N, Palatine Ave N, 1st Ave NW, 2nd Ave NW from NW 110th St to NW 107th St)				
	Pinehurst (19th Ave NE from NE 115th St to NE 117th St, 20th Ave NE and 23rd Ave NE from NE 113th St to NE 117th St, NE 113th St from 20th Ave NE and 23rd Ave NE)				
		☐ At least 90% of swale bottom is covered with healthy, wetland vegetation	☐ At least 75% of swale bottom is covered with healthy, wetland vegetation	☐ Between 40-75% of swale bottom is covered with healthy, wetland vegetation	☐ Less than 40% of swale bottom is covered with healthy, wetland vegetation
		☐ Bottom soil is well aerated, less than 10% compaction	☐ Bottom soil is well aerated, less than 20% compaction	☐ Less than 40% compaction	☐ More than 40% compaction
		☐ No erosion, channelization or scouring	☐ No erosion, channelization or scouring	☐ Some erosion, channelization or scouring	☐ Erosion, channelization or scouring
		☐ Less than 10% bare spots	☐ Less than 25% bare spots	☐ Less than 40% bare spots	☐ Greater than 40% bare spots
		☐ Acceptable level of sediment or debris accumulation – 2 inches, unless otherwise noted or accumulation prevents	☐ Acceptable level of sediment or debris accumulation – 2 inches, otherwise noted or accumulation prevents	☐ Less than 40% bare spots	☐ Significant build up of sediment or debris – greater than 3 inches, unless otherwise noted
				☐ Moderate level of sediment or debris accumulation – 3 inches, unless otherwise noted or accumulation prevents achievement of previous bullet	
Biofiltration (vegetation & soils/substrate)					
*this value is equal to 3 x design flow depth and will vary with each project		☐ At least 90% of swale bottom covered with healthy, uniformed fine-stemmed vegetation at least XX* inches high	☐ At least 80% of swale bottom covered with healthy, uniformed fine-stemmed vegetation at least XX* inches high	☐ Between 60-80% of swale bottom covered with healthy, uniformed fine-stemmed vegetation at least XX* inches high	☐ Less than 60% of swale bottom covered with healthy, uniformed fine-stemmed vegetation, of at least XX* inches high
		☐ No erosion, channelization or scouring	☐ No erosion, channelization or scouring	☐ Some erosion, channelization or scouring	☐ Erosion, channelization or scouring
		☐ Less than 10% bare spots	☐ Less than 20% bare spots	☐ Less than 40% bare spots	☐ Greater than 40% bare spots

III. Key Performance Indicators (KPI's)

- Determine LOS achieved for swales
- Provides an overall reporting score for high level management
- Indicators help identify
  - successes
  - areas of improvement
  - failures for each system



NDS KPI Reporting Form
USM Urban Watersheds

Date:

Project Location	Drainage area (sq ft)	Hardscape Maintained to: Target	Hardscape Maintained to: Actual	Landscaped area (sq ft)	Vegetation Maintained to: Target	Vegetation Maintained to: Actual	Infiltration Failure: Yes/No	Infiltration Failure: Cells retrofitted (Urban Ecosystems)
Carkeek Cascade at NW 110th	4,730	B		17,130	B			
Comments								
Project Achievement								
Broadview Green Grid - Carkeek Cascades at NW107th	8,240	B		29,330	B			
Comments								
Project Achievement								
Pinehurst Green Grid	19,160	B		60,650	B			
19th Avenue NE	3,170	B		9,850	B			
20th Avenue NE	6,300	B		27,370	B			
23rd Avenue NE	6,710	B		18,160	B			
NE 117th Street	2,240	B		6,400	B			
NE 113th Street	2,320	B		7,870	B			
25th Ave NE	330	B		??	B			
Comments								
Project Achievement								
High Point		B			B			
Comments								
Project Achievement								
Broadview Green Grid - SEA Streets	9,470	B		63,640	D			
Phinney Ave N SEA Street	2,000	B		15,700	D			
Palatine Ave N SEA Street	2,840	B		19,080	D			
1st Ave NW SEA Street	2,060	B		12,130	D			
2nd Ave NW SEA Street	2,570	B		16,730	D			

Vegetation Estimated O&M Costs

LOS B – 47,290 SQ FT	Annual Value
Initial 3 year Landscape Establishment	
assuming 0% community participation	$65,221
Established (starting year 4)	
0% community participation	$28,615
25% community participation	$21,461
50% community participation	$14,308
75% community participation	$7,154
90% community participation	$2,862
Soil Replacement (every 15yrs)	$23,527

NDS Maintenance: Lessons Learned

NDS Maintenance: Lessons Learned

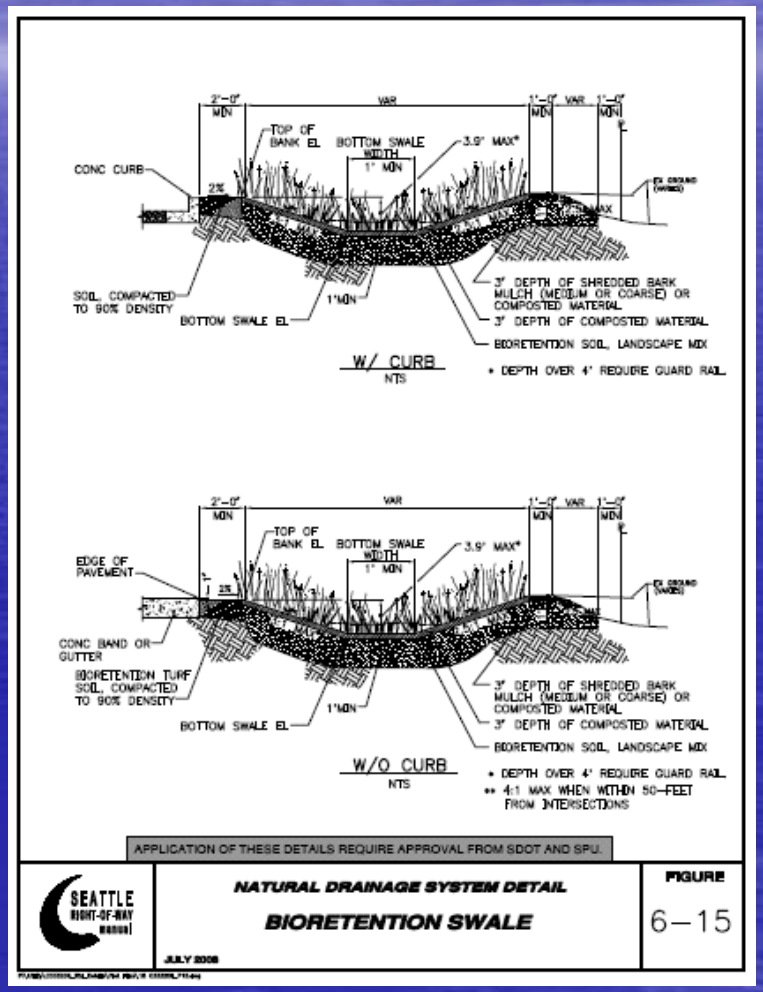
Water costs can increase plant establishment costs by 100-400%

NDS Maintenance: Lessons Learned

Parking will affect edge of vegetation

Stormwater Code Compliance

- Proposed 2009 Stormwater Code requires GSI to MEF
- Code applies to both work in right-of-way and on parcels

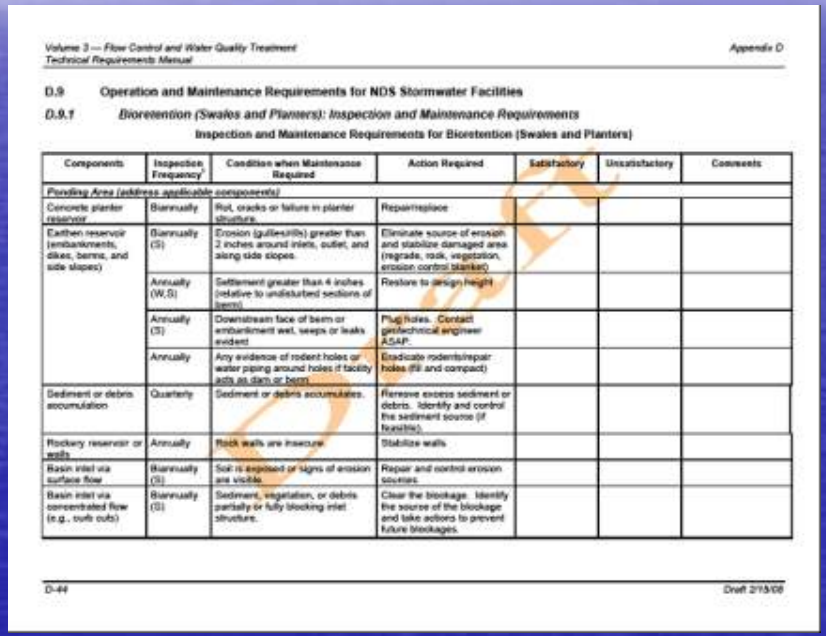


O&M for stormwater Code Compliance

- Define Green Stormwater Infrastructure Minimum O&M requirements

Code Compliance for facilities in Right-of-way

- Require construction installation checklist signed by GSI designer
- Require applicants to provide a 2-year warranty period. (same as Portland)



Volume 3 — Flow Control and Water Quality Treatment Technical Requirements Manual — Appendix D

D.9 Operation and Maintenance Requirements for NDS Stormwater Facilities

D.9.1 Bioretention (Swales and Planters): Inspection and Maintenance Requirements

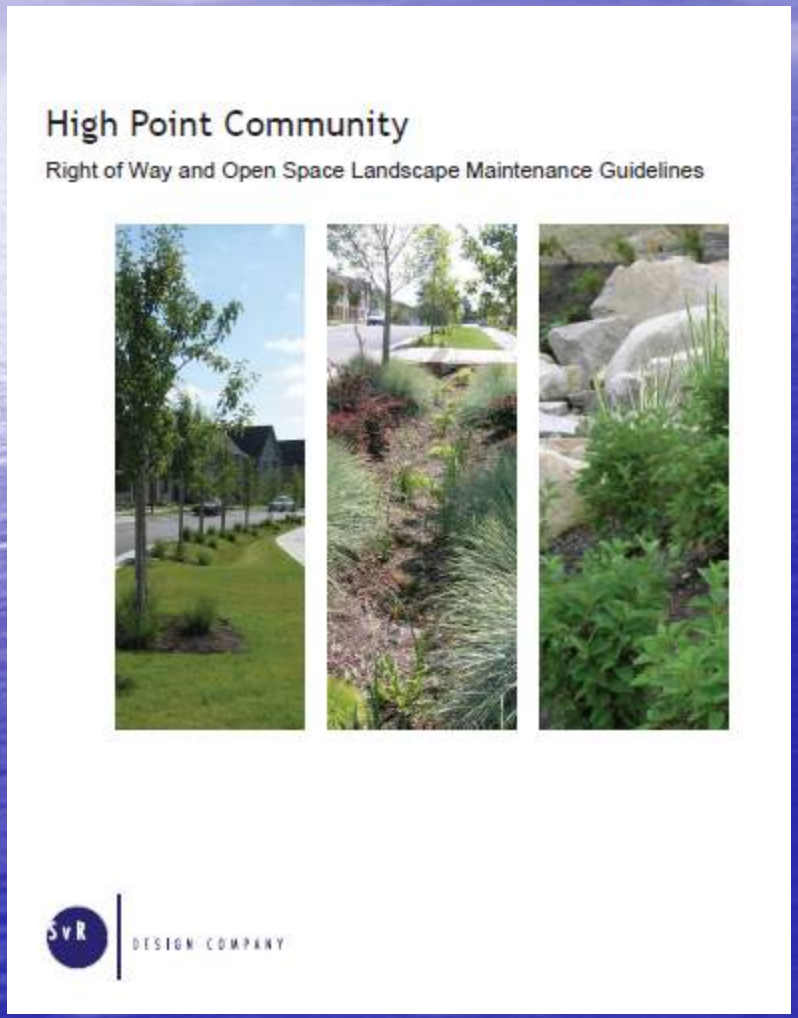
Inspection and Maintenance Requirements for Bioretention (Swales and Planters)

Components	Inspection Frequency[1]	Condition when Maintenance Required	Action Required	Satisfactory	Unsatisfactory	Comments
Ponding Area (address applicable components)						
Concrete planter reservoir	Biannually	Rot, cracks or failure in planter structure.	Repair/replace			
Earthen reservoir (embankments, dikes, berms, and side slopes)	Biannually (S)	Erosion (gullies/rills) greater than 2 inches around inlets, outlet, and along side slopes.	Eliminate source of erosion and stabilize damaged area (regrade, rock, vegetation, erosion control blanket)			
	Annually (W,S)	Settlement greater than 4 inches (relative to undisturbed sections of berm)	Restore to design height			
	Annually (S)	Downstream face of berm or embankment wet, seeps or leaks evident	Plug holes. Contact geotechnical engineer ASAP.			
	Annually	Any evidence of rodent holes or water piping around holes if facility acts as dam or berm	Eradicate rodents/repair holes (fill and compact)			
Sediment or debris accumulation	Quarterly	Sediment or debris accumulates.	Remove excess sediment or debris. Identify and control the sediment source (if feasible).			
Rockery reservoir or walls	Annually	Rock walls are insecure	Stabilize walls			
Basin inlet via surface flow	Biannually (S)	Soil is exposed or signs of erosion are visible	Repair and control erosion sources			
Basin inlet via concentrated flow (e.g., curb cuts)	Biannually (S)	Sediment, vegetation, or debris partially or fully blocking inlet structure.	Clear the blockage. Identify the source of the blockage and take actions to prevent future blockages.			

D-44 — Draft 2/15/08

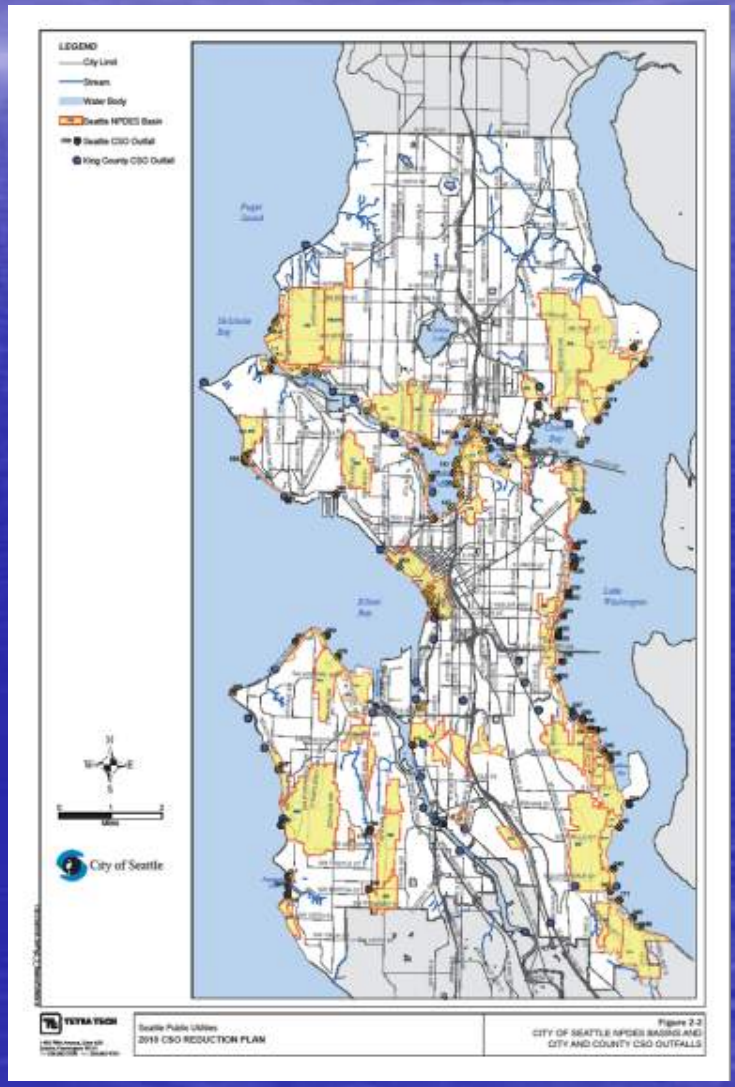
http://www.seattle.gov/dpd/Planning/Stormwater_Grading_and_Drainage_Code_Revisions/Overview/

High Point O&M Manual



O&M requirements for receiving Financial incentives

- Residence in target basin
- Signed Homeowner agreement
- Must agree to care for facility for 5 years



Questions?

www.seattle.gov/util/naturalsystems

Participation Certificate

- If you would like to obtain participation certificates for multiple attendees, click the link below
- You can type each of the attendees names in and print the certificates

http://www.epa.gov/npdes/webcasts/certificate/gi_retrofit_o&m.pdf