Bioretention "Rain Garden" Technical Seminar

San Francisco Regional Water Quality Control Board
Santa Clara Valley Urban Runoff Pollution Prevention Program

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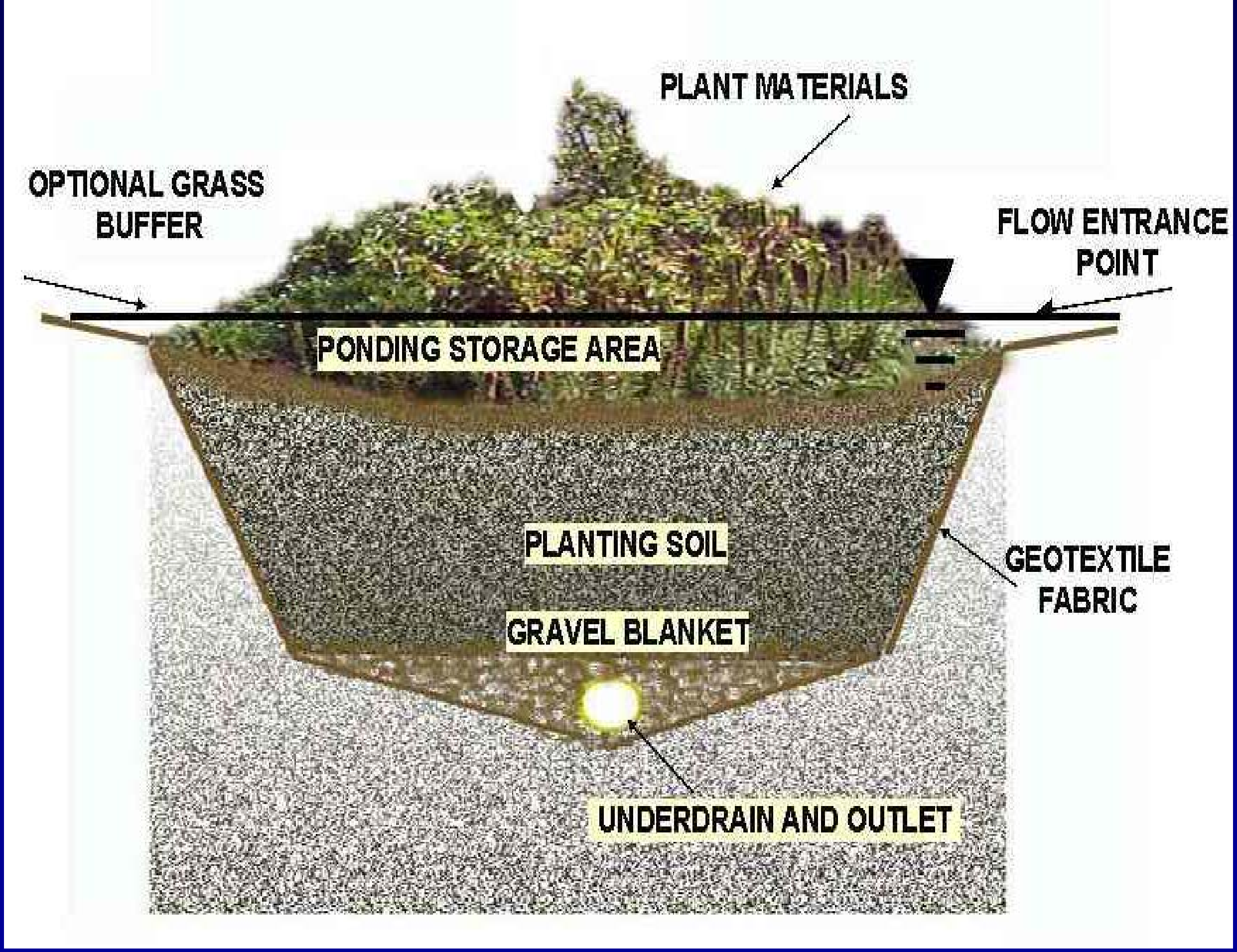
*** Low Impact Development Center**

A Growing Idea in Stormwater Treatment

Manufactured by:
AMERICAST
Filterra Division

Overview

- Functions
- Design Criteria
- Construction
- Maintenance
- Inspection
- Enforcement
- Lessons
- Applications



What is Bioretention?

Filtering stormwater runoff through a terrestrial aerobic (upland) plant / soil / microbe complex to remove pollutants through a variety of physical, chemical and biological processes.

The word “bioretention” was derived from the fact that the biomass of the plant / microbe (flora and fauna) complex retains or uptakes many of the pollutants of concern such as N, P and heavy metals.

It is the optimization and combination of bioretention, biodegradation, physical and chemical that makes this system the most efficient of all BMP’s

Pollutant Removal Mechanisms

"Physical / Chemical / Biological"

Processes

Sedimentation
Filtration
Adsorption
Absorption
Cation Exchange Capacity
Polar / Non-polar Sorption
Microbial Action (aerobic / anaerobic)
    decomposition / nitrification / denitrification
Plant Uptake
Cycling Nutrients / Carbon / Metals
Biomass Retention (Microbes / Plant)
Evaporation / Volatilization

System Components

Mulch
Course Sand
Pore Space
Surface Area
Complex Organics
Microbes
Biofilm
Plants
"Ecological Structure"

Bioretention Pollutant Removal

University of Maryland

Box Experiments

Cumulative Depth (ft)	Copper	Lead	Zinc	Phos-phorus	TKN	Ammonia	Nitrate
			Removal Efficiency (%)				
1	90	93	87	0	37	54	-97
2	93	99	98	73	60	86	-194
3	93	99	99	81	68	79	23
Field	97	96	95	65	52	92	16

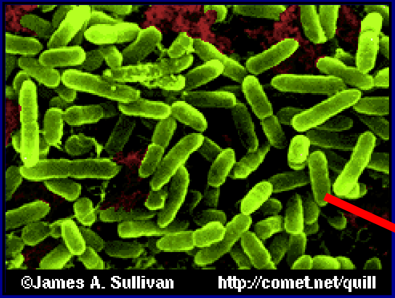
Dr. Allen Davis, University of Maryland

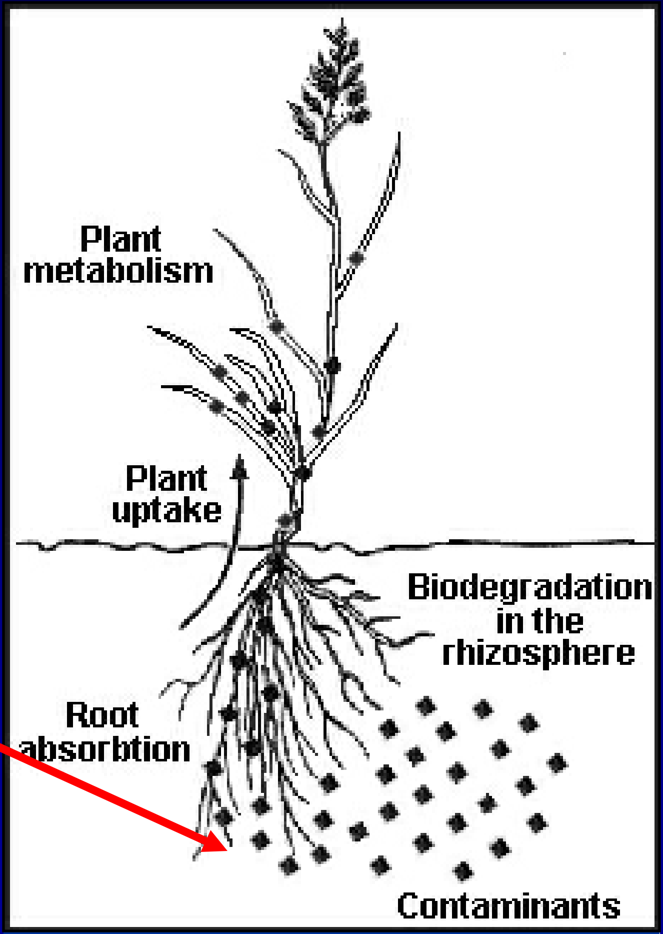
Interesting Study Findings

- Mulch and Metals
- Plants and Metals
- P Uptake
- Capacity / Longevity
- Residence Time
- Oil and Grease 95% Removal
- 90% Bacteria Removal
- Flow rate varies with moisture content

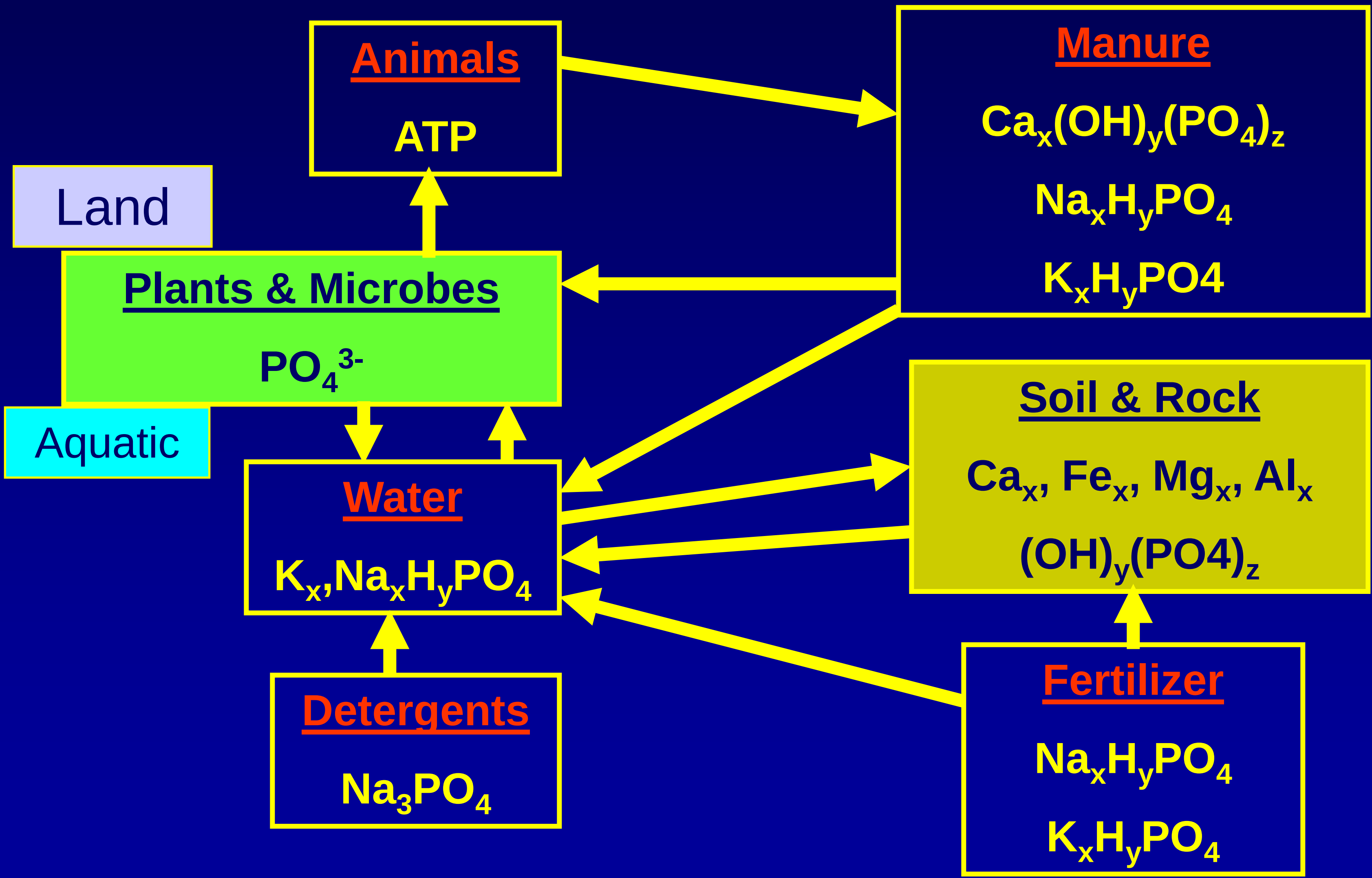
Pollutant Removal - Plant Microbe

- Phytoremediation
  - Translocate
  - Accumulate
  - Metabolize
  - Volatilize
  - Detoxify
  - Degrade
    - Exudates
- Bioremediation
- **Soils**
  - **Capture / Immobilize Pollutants**





Phosphorus Cycle



Louisburg Bioretention
Dr. Bill Hunt
North Carolina State
Research

Load Reductions: Louisburg Removal vs. PI

Cell	TN	TP
L-1 (unlined)	64%	66%
L-2 (lined)	68%	22%

PI
1 to 2
85 to 100

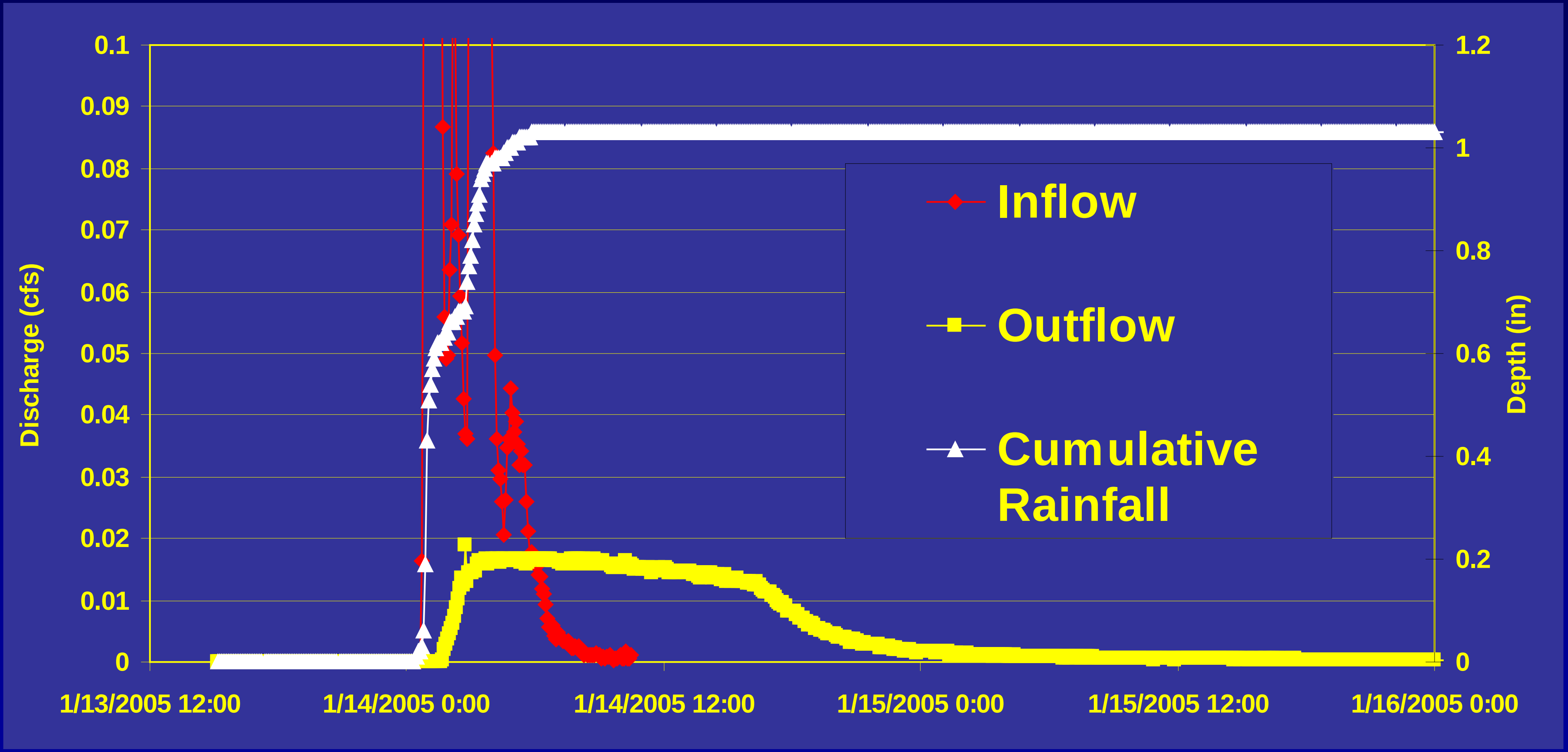
June 2004- February 2005

GSO: Load Reduction

(July 03- Dec 04)

G-1	Inflow Load	Outflow Load	% reduction
H_2O (1000 L)	2670	1170	$\boxed{56}$
TN (kg)	4.69	3.13	33
TP (kg)	0.53	0.48	9
G-2			
H_2O (1000 L)	2670	1010	$\boxed{62}$
TN (kg)	4.36	2.5	43
TP (kg)	.41	.57	-39

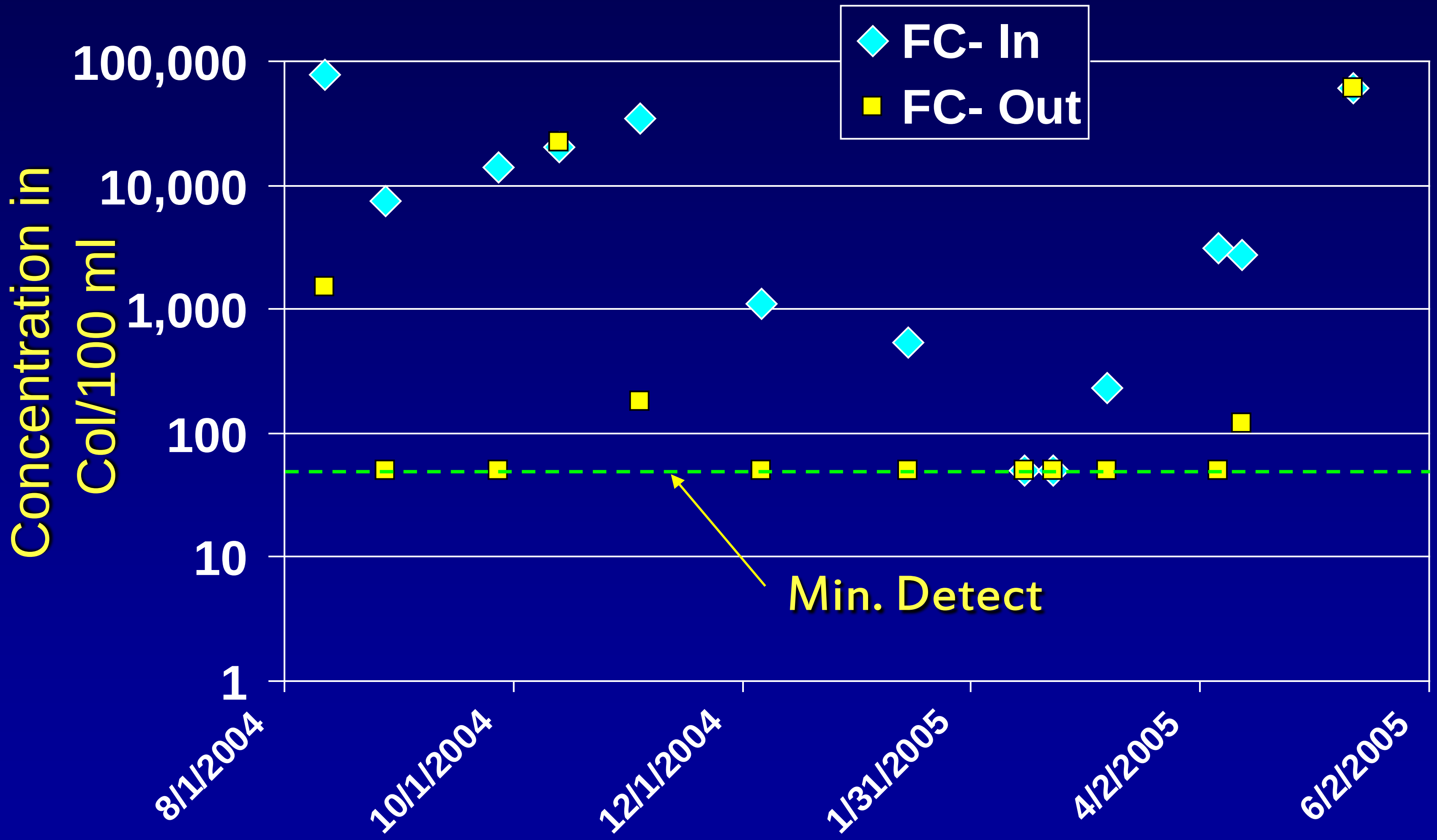
Inflow V. Outflow Rates



NC Shellfish Closures

- 100,000 acres of shellfish waters are permanently or temporarily closed to harvesting.

Hal Marshall Bioretention: Fecal Coliform Concentrations



Bioretention Construction Costs

Excavation (assume no hauling)	\$3 - \$5 / cy
Fill Media	\$15 - \$20 / cy
Vegetation/ Mulch	\$1.00 - \$1.50 / sf
Underdrains /Gravel & Outlet	\$0.50 - \$1.50 / sf
Total	**\$10 - \$14 / sf**

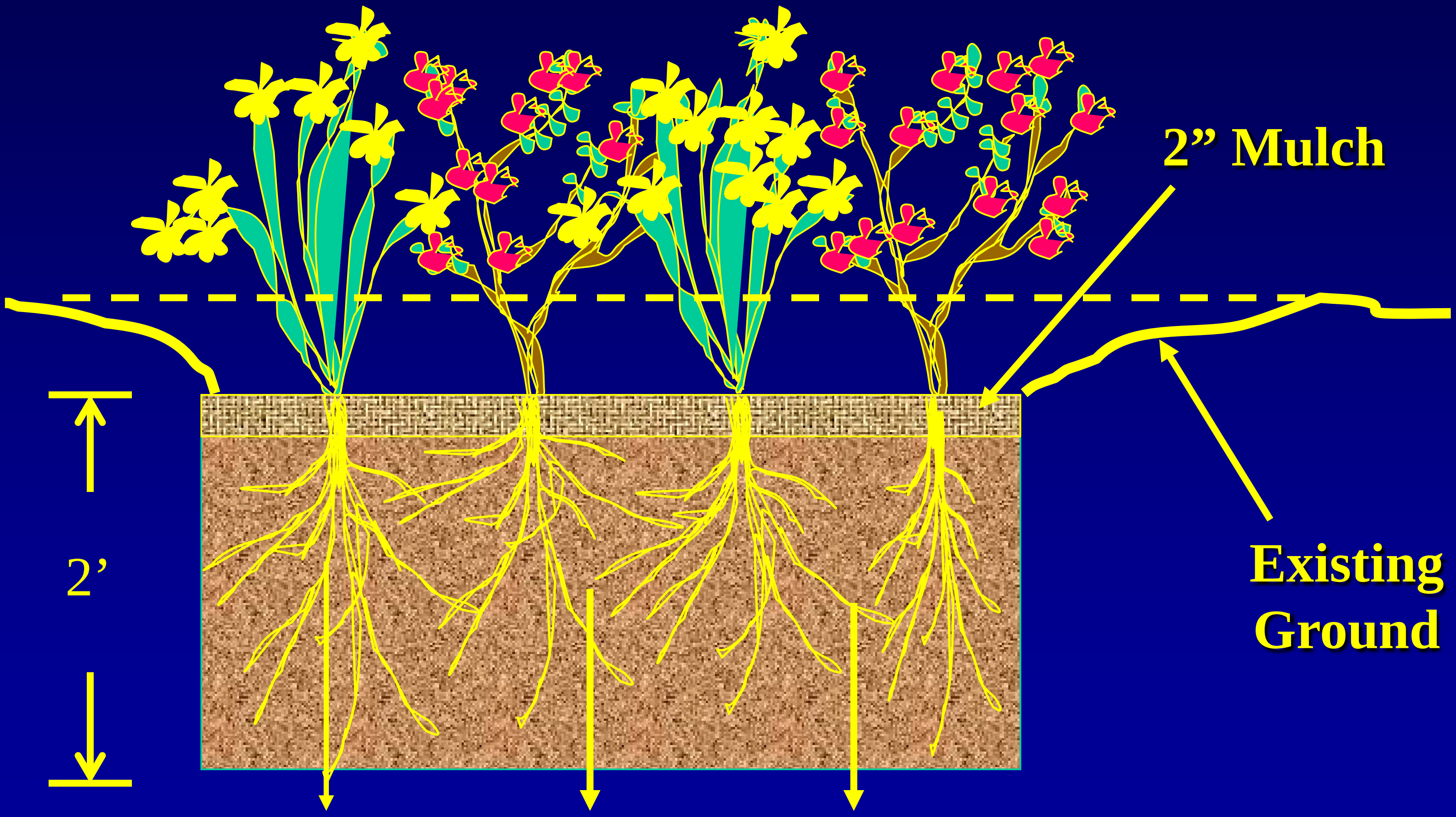
Design Considerations

- Design Objectives (Quality / Volume / Flow / Recharge)
- Media Specifications / Consistency
- Sizing
- Offline / Flow–Through Systems
- Pretreatment
- Unique configurations / designs (costs)
- Custom Application (Bacteria / Metals / Oil and Grease)

Bioretention Design Objectives

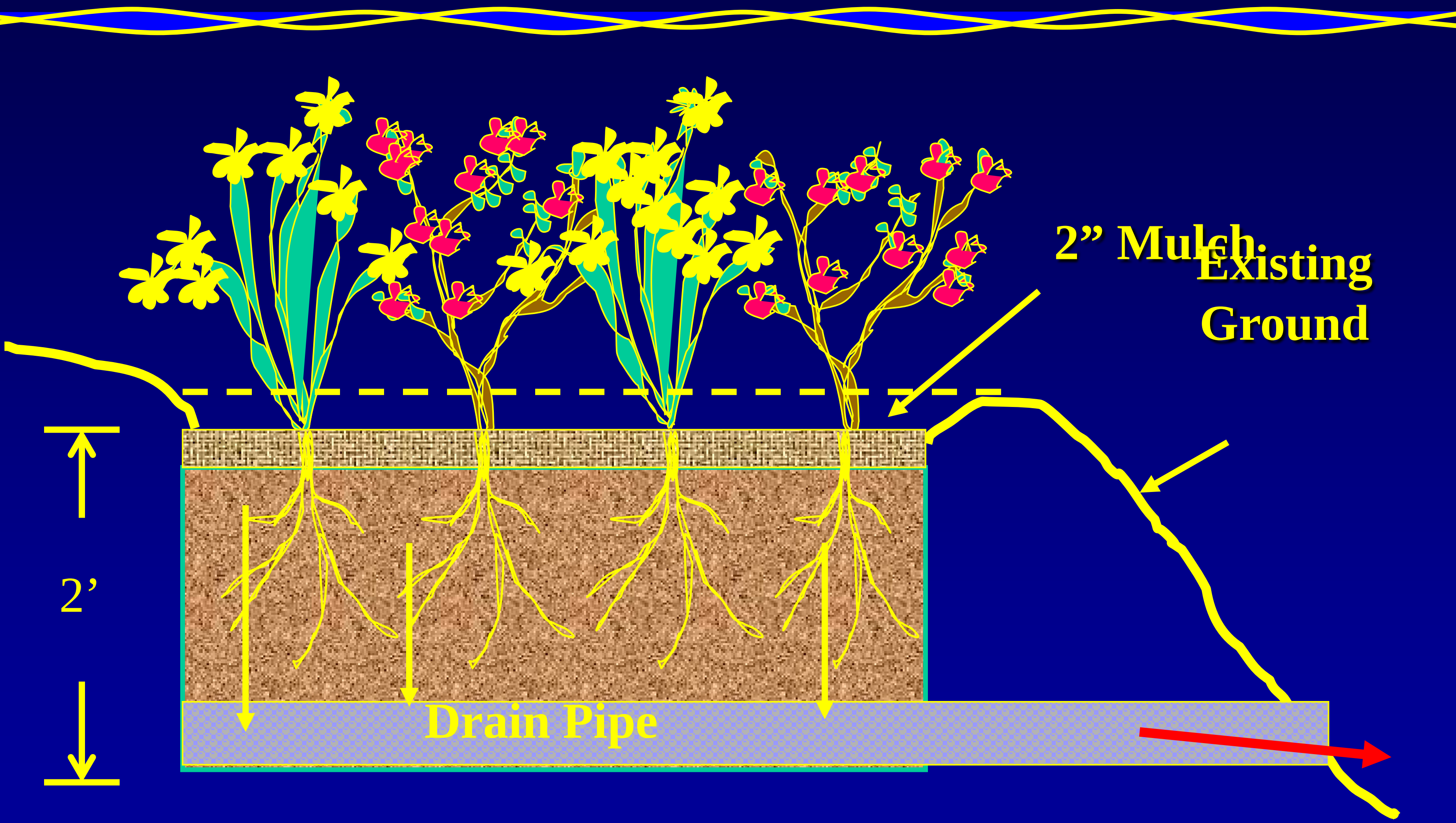
- Peak Discharge Control
  - 1-, 2-, 10-, 15-, 100-year storms
  - Bioretention may provide part or all of this control
- Water Quality Control
  - ½", 1" or 2" rainfall most frequently used
  - Bioretention can provide 100% control
- Ground water recharge
  - Many jurisdictions now require recharge (e.g., MD, PA, NJ, VA)

Infiltration System



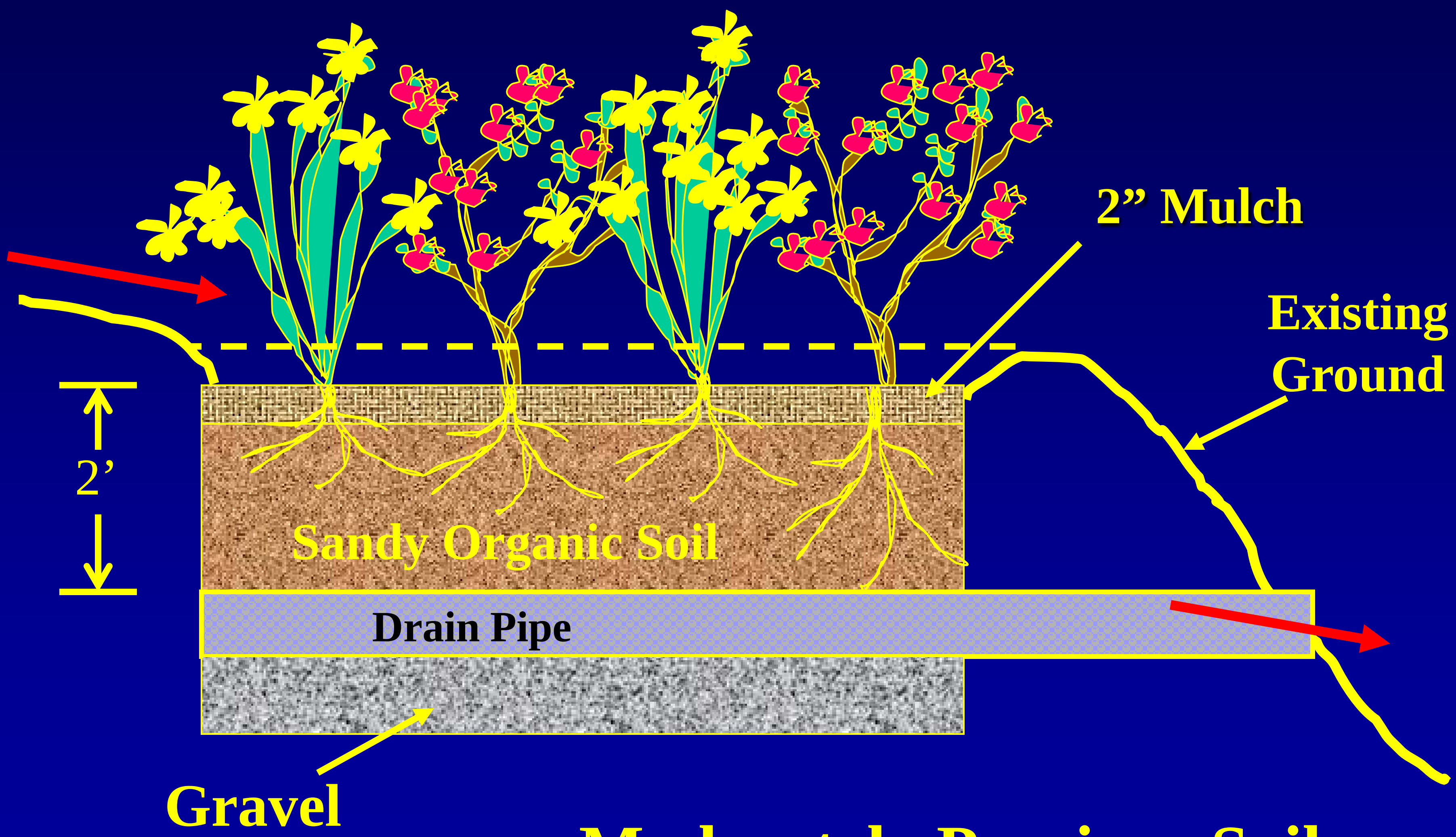
Highly Pervious Soils

Filtration System



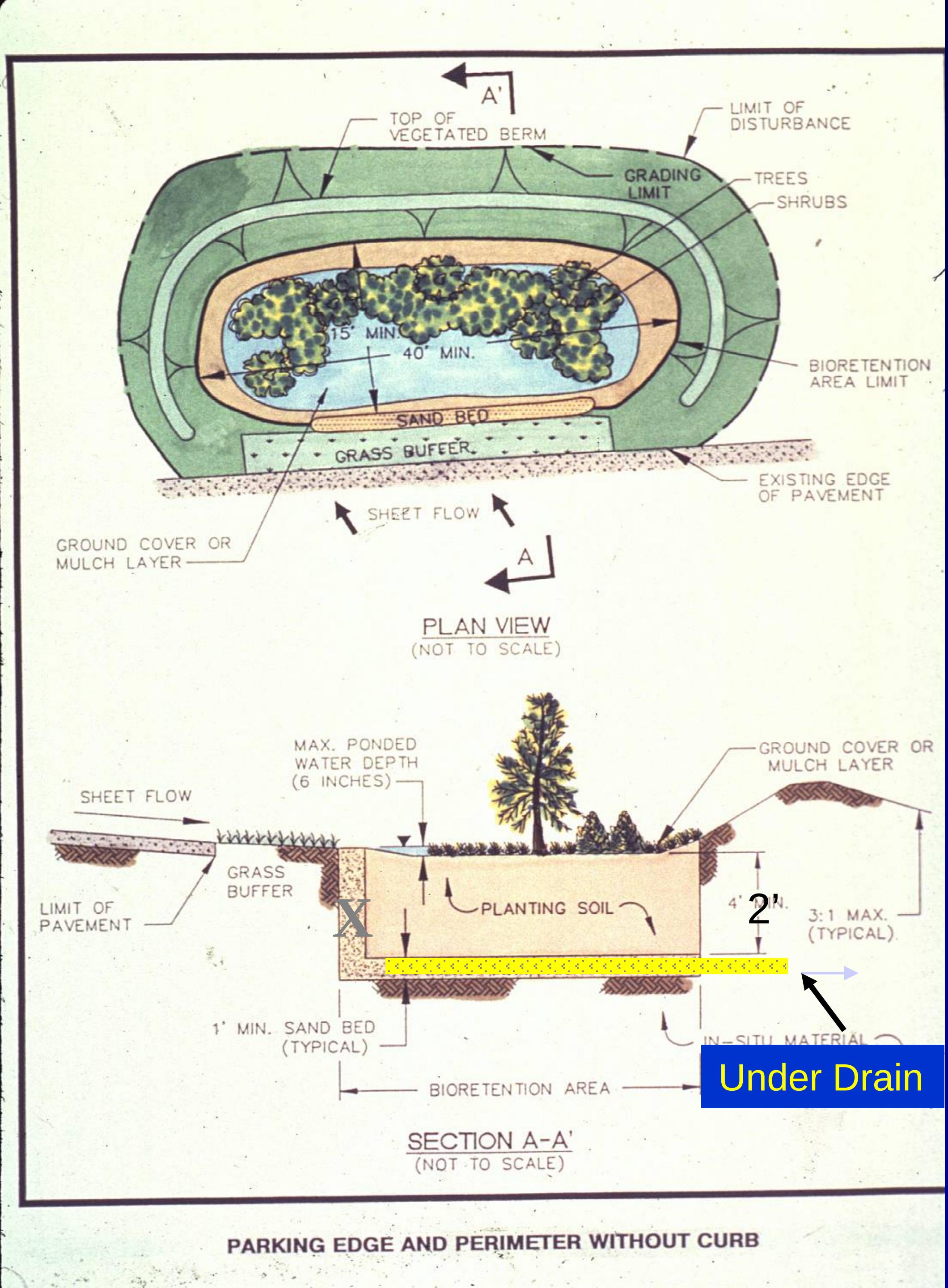
Highly Pervious Soils

Combination Filtration / Infiltration



Moderately Pervious Soils

Bioretention



Shallow Ponding - 4” to 6”

- Mulch 3”
- Soil Depth 2’ - 2.5’
- Sandy Top Soil
  - 65% Sand
  - 20% Sandy Loam
  - 15% Compost
- Under Drain System
- Plants

Low Flow Media
2 to 10 inches / hour
Peat / Sand / Aggregate Matrix - PSD

Peat 15 to 20% by volume

Clay <5% (<0.002 mm)

Silt <5% (0.002-0.05 mm)

Very Fine Sand 5-10% (0.05-0.15 mm)

Fine Sand 15-20% (0.15-0.25 mm)

Medium to Coarse Sand 60-70% (0.25-1.0 mm)

Coarse Sand 5-10% (1.0-2.0 mm)

Fine Gravel <5% (2.0-3.4 mm)

High Flow Media
10 to 50 inches / hour
Peat Sand / Aggregate Matrix - PSD

Peat 5 to 10% by volume

Clay <2% (<0.002 mm)

Silt <2% (0.002-0.05 mm)

Very Fine Sand 5% (0.05-0.15 mm)

Fine Sand 10% (0.15-0.25 mm)

Medium to Coarse Sand 70% (0.25-1.0 mm)

Coarse Sand 10-15% (1.0-2.0 mm)

Fine Gravel 5-10% (2.0-3.4 mm)

City of Portland , OR

Low Flow - 1” to 3” / Hour
“Soaker”

Sand / Municipal Compost

Ocean City, MD

High Flow - + 100” / Hour
Filterra

Corse Sand / Peat

Other Media Considerations

- Homogenous Mixture
- Peat / Clays / Silts slow flows
- Test and standardize the media!
- But performance varies with source!
- Min 1.0’ depth of media
- Max depth varies with vegetation.
- Organic Component (Peat vs. Compost)

Media Components Properties

	Sand	Silt Loam	Compost	Peat
Permeability (cm/hr)	3.3	0.1-0.4	-	0.25-140
Water holding capacity (cm/cm)	0.14	.07-0.1	-	.01-0.2
Bulk density (g/cm)	2.65	1.25	1-2	<0.1-0.3
pH	-	5.7	7.8	3.6-6.0
Organic matter (%)	<1	<20	30-70	80-98
Cation exchange capacity	1-3	12-18	66	183-265
Total phosphorus (%)	0	0.09	<0.1	<0.1
Total nitrogen (%)	0	0.15	<1.0	<2.5
Filtration efficiency after 18 in. (%)	93	94	16	47

Louisburg Bioretention Cells

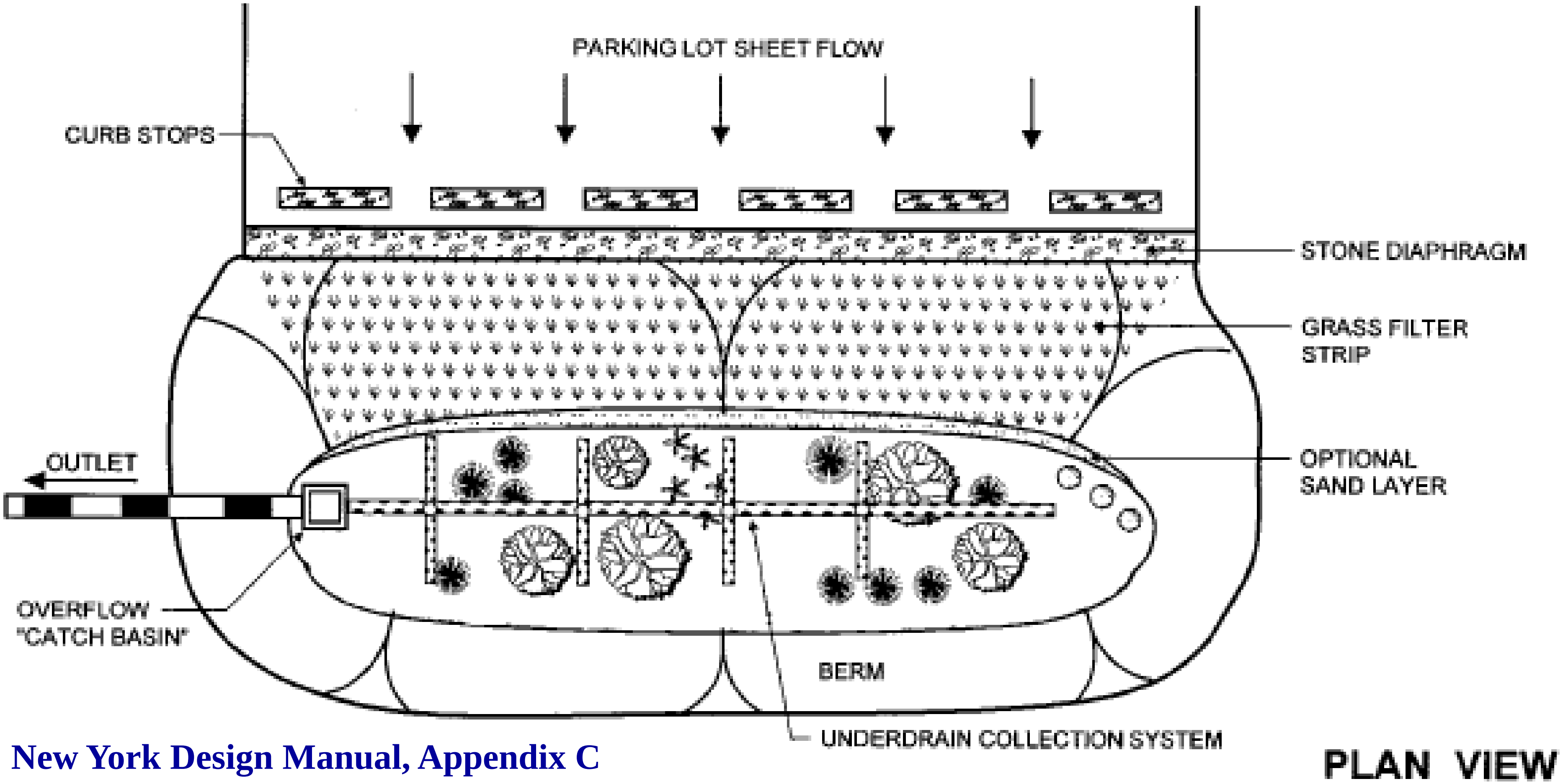
- **Soil Media:**
  - **Nominally 0.75 m Deep**
  - **60% Sand**
  - **40% "Ballfield Mix"**
- **Low PI (1-2) fill**
  - **85% Sand**
  - **10% Fines**
  - **5% Organics**
- **Constructed Spring 2004**

Other Media Considerations

- Mulch
  - Hardwood / Pine bark
  - Use as pretreatment
  - Water retention
  - Pollutant removal
  - Maintenance

Underdrain System

- Avoid Filter Fabric use bridging stone (pea gravel around pipe)
- Minimum of 3" of gravel over pipes; not necessary underneath pipes
- Underdrain Piping ASTM D-1785 or AASHTO M-2786" rigid schedule 40 PVC 3/8" perf. @ 6" on center, 4 holes per row;
- Observation wells



New York Design Manual, Appendix C

Pretreatment – NOT NECESSARY! Little additional benefit

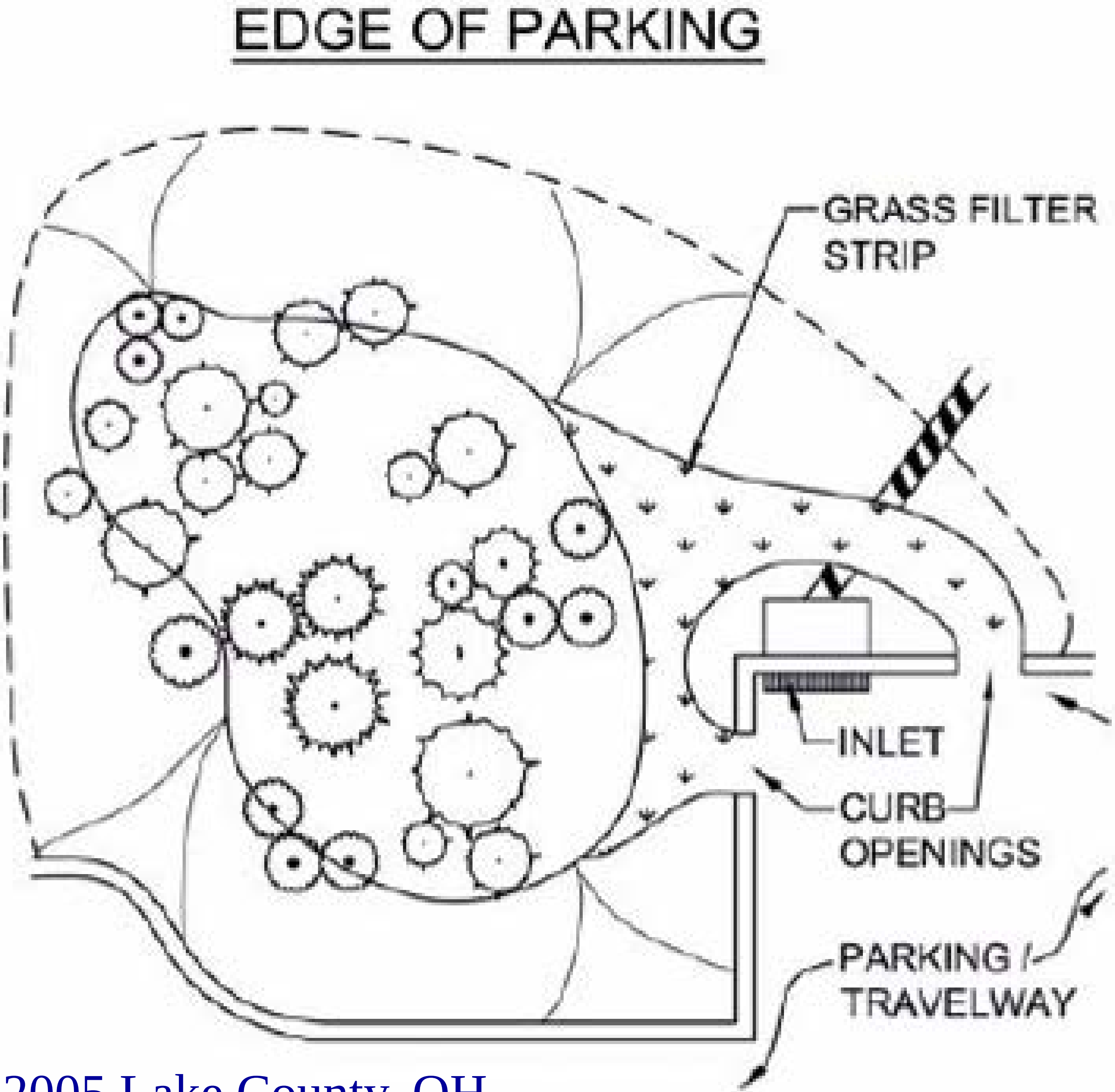
Additional Maintenance issues

Requires additional space

Restricts use

Design Configuration Considerations

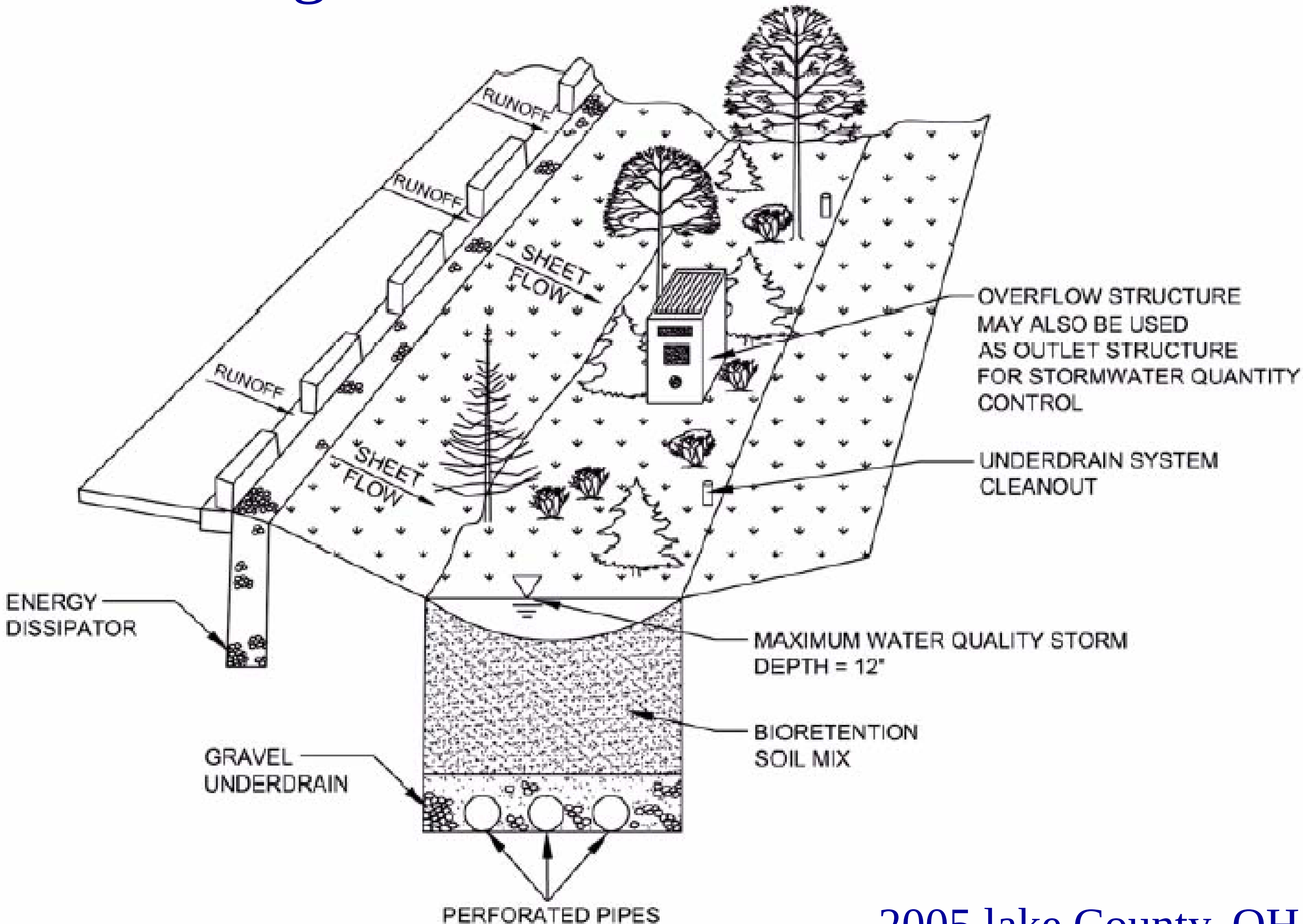
- Off line vs. Flow-through
- Inlet
- Surface Storage
- Underdrain – Dewater media



2005 Lake County, OH

Off-line

Flow-through



2005 lake County, OH

Plants Considerations

- **Pollutant uptake**
- **Evapotranspiration**
- **Soil ecology / structure / function**
- **Number & type of plantings may vary,**
  - **Aesthetics**
  - **Morphology (root structure trees, shrubs and herbaceous)**
  - **Native plants materials**
  - **Trees 2 in. caliper / shrubs 2 gal. size / herbaceous 1 gal size.**
  - **landscape plan will be required as part of the plan.**
  - **Sealed by a registered landscape architect.**
  - **Plants are an integral part no changes unless approved**
  - **Plant survival**
- Irrigation – Typical / customary

Bioretention: Site Analysis

- Map site soils by soil series, hydrologic soil type (A, B,C, D), textural classification and engineering properties
- If possible, avoid laying impervious surfaces (roads, parking lots, driveways) over HSG A and B soils
- Minimize cut and fill in A & B soils (site fingerprinting)
- Infiltration facilities in C & D soils require underdrains.

Sizing

- Flow rate
- Infiltration rate
- Volume
- Intensity
- Void space
- Drainage area (Smaller the Better)

Construction / Inspection

- Preconstruction meeting” with the contractor / owner / architect / engineer
- Geotechnical Report
- Ensure sediment control measures in place
- Sub grade soils and preparation.
- Presence of Ground water
- Under drain and filter media installation.
- Soil certifications for back fill.
- Topsoil layers should be thoroughly wetted achieve settlement.
- Plant placement / warrantee / type
- Proper site grading
- Site stabilization before planting.
- U&O

Inspection / Maintenance

- Require a long term maintenance plan
- Non Erosive Designs Inlet / Outlet / Flow-through
- Sediment build-up
- Annual inspection / plant care
- Excessive ponding (Longer than 8 hours)
- Use underdrains
- Right Vegetation
- Spills

Maintenance Funding

- Poorly addressed and biggest failure!
- Private systems
- Private systems built to public standards
  - Capitalize maintenance costs
  - Maintenance fee
  - General or dedicated funds
- Manufacturer's provide “long term” maintenance
  - Up front options to renew
  - Encourage competition

Enforcement

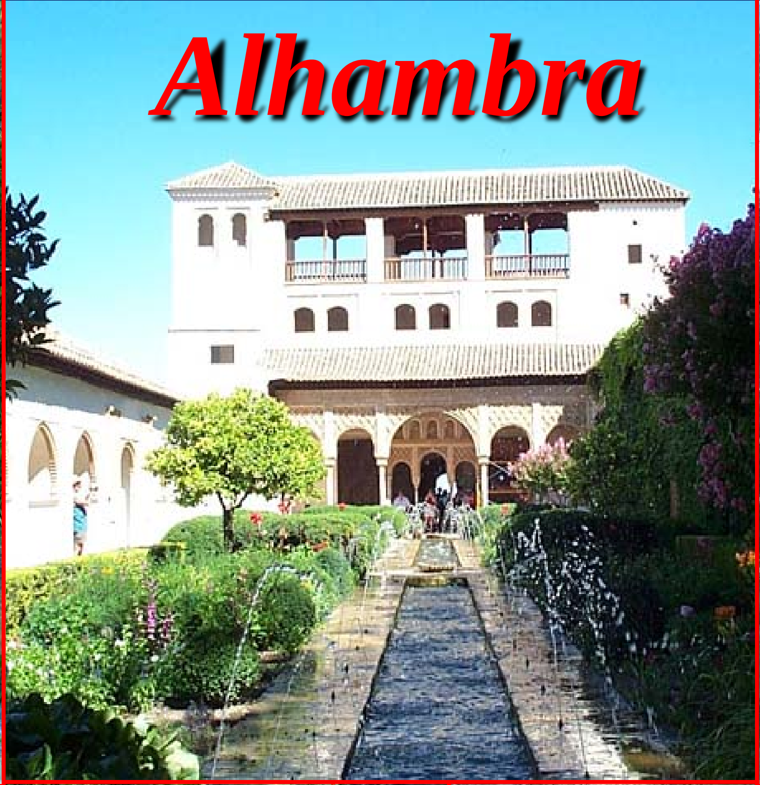
- Site Inspectors – field adjustments
- Site restoration or construction bonds
- Site Inspection fees
- Individual property owner agreement
- Home Owner Association
- Easements / Rights-of-way
  - Enable local government actions
  - Fees / Fines / Penalties
    - Administrative and Court actions
- Community standards
- U&O

Lessons Learned

High Failure Rates Due to:

- Use of Old Design Standards
  - clay / organic / K factor
- Poor Drainage
  - Under drain design / Geo-fabrics / Saturated soils
- Media Variability
  - Reliable Sources
- Contractor Substitutes
- Contamination
  - P, N and Heavy Metals
- Sizing / Space
- Maintenance
  - Can be high as system become larger

Alhambra



Bioretention Applications

Rain Gardens


JEONG H KIM


BUILDING

Rain Garden in an office building project along the G.W. Parkway. (Looking East)

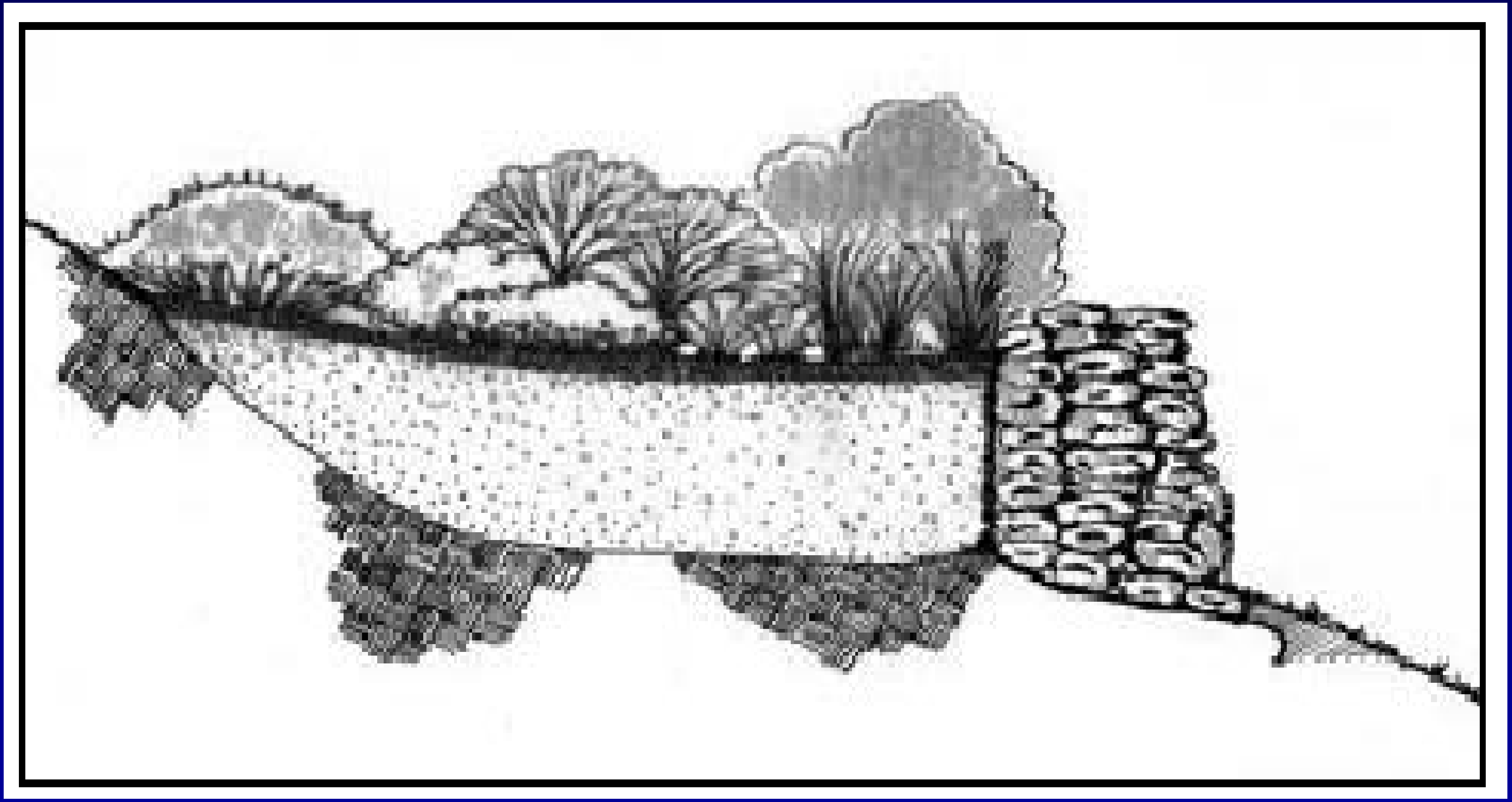
Residential Rain Gardens

Example Bioretention Areas


'98 3 24


'98 3 25

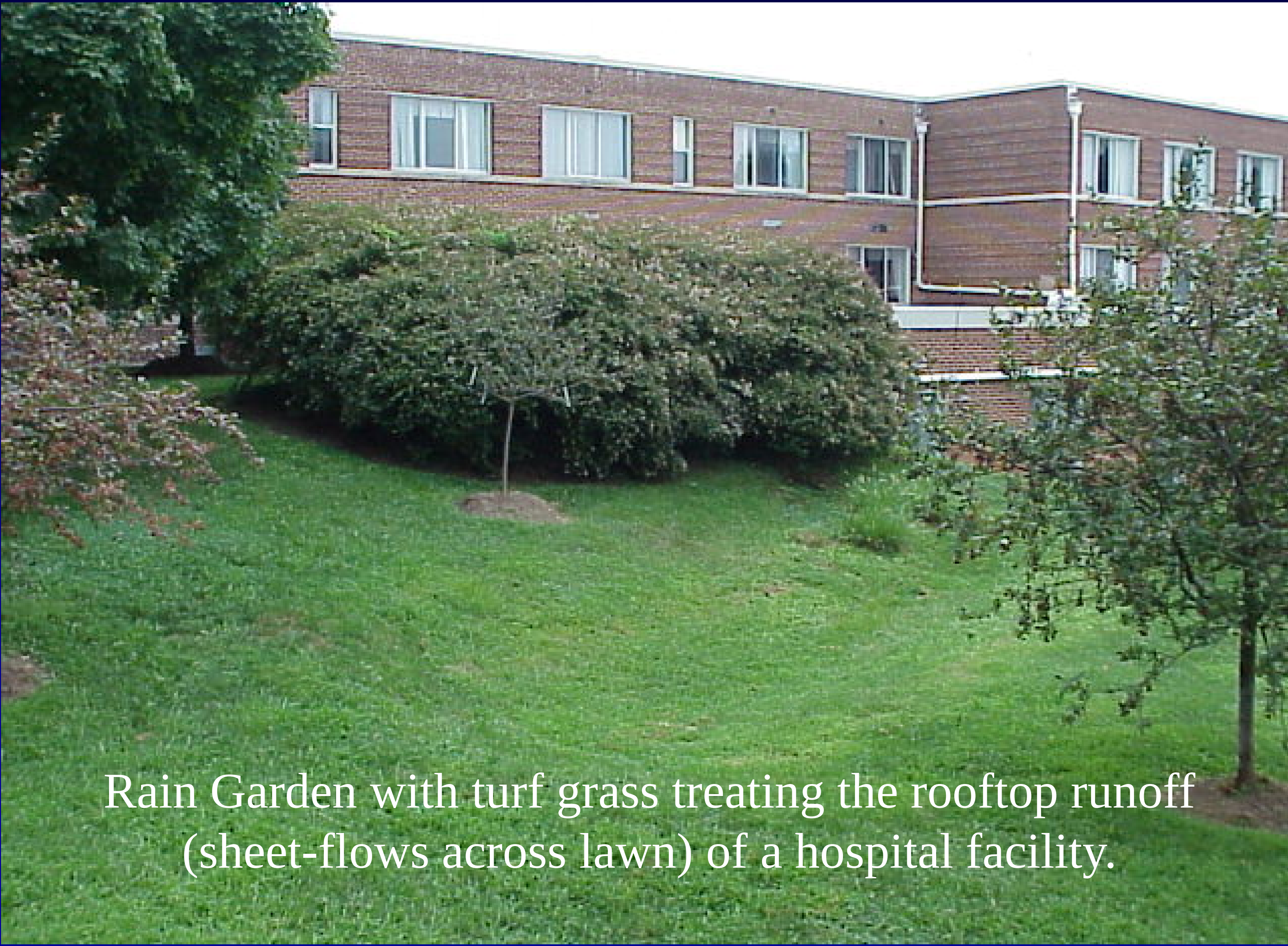
Bioretention Types



Fieldstone weep garden design

Weep Wall Filter

Rain Garden on a commercial project with turf grass near I-395 and Edsall Road.



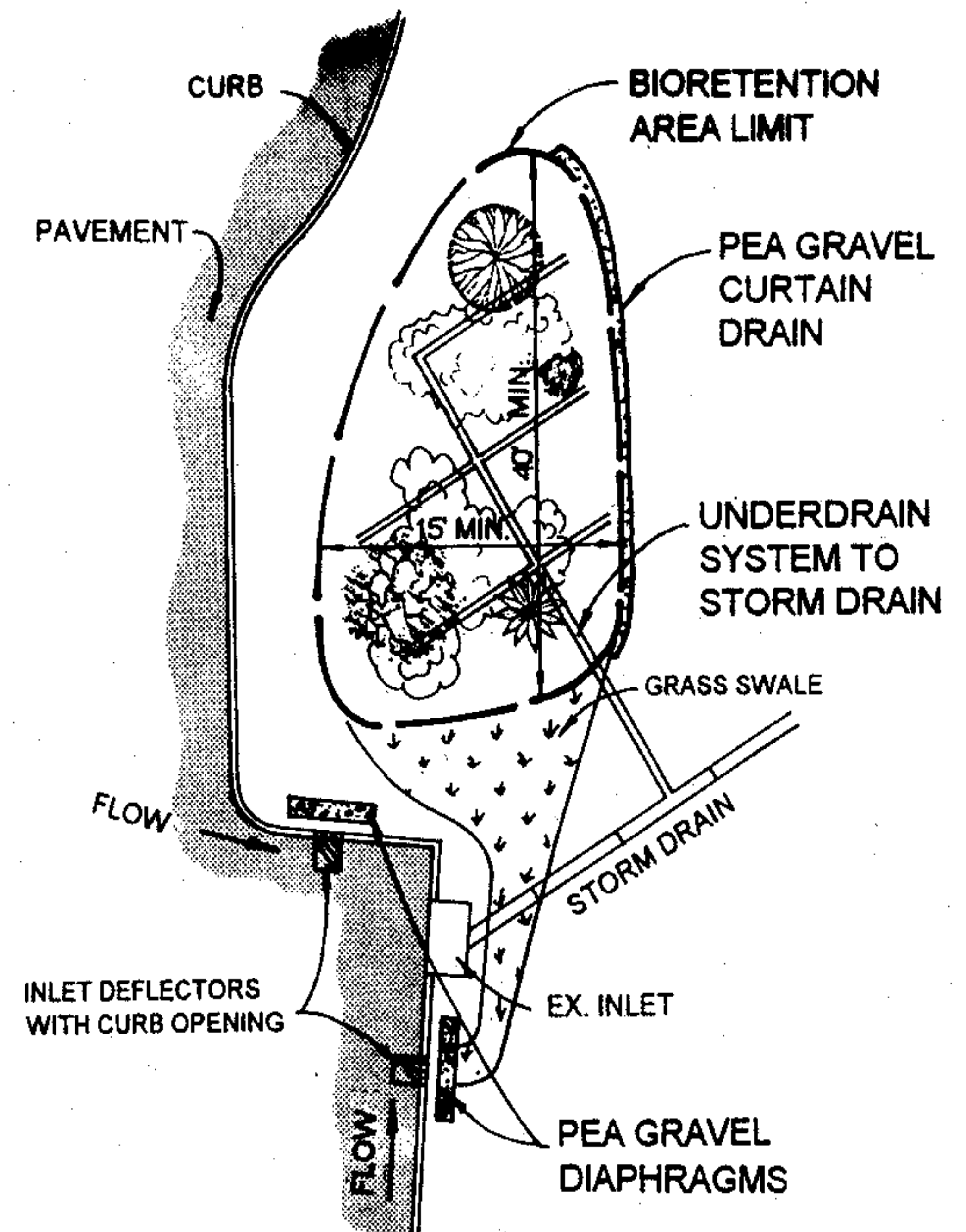
Rain Garden with turf grass treating the rooftop runoff (sheet-flows across lawn) of a hospital facility.

The first Rain Garden in Virginia, located in a turning circle in front of St. Stephens School, Alexandria.

St. Stephens Rain Garden- 5 years later.

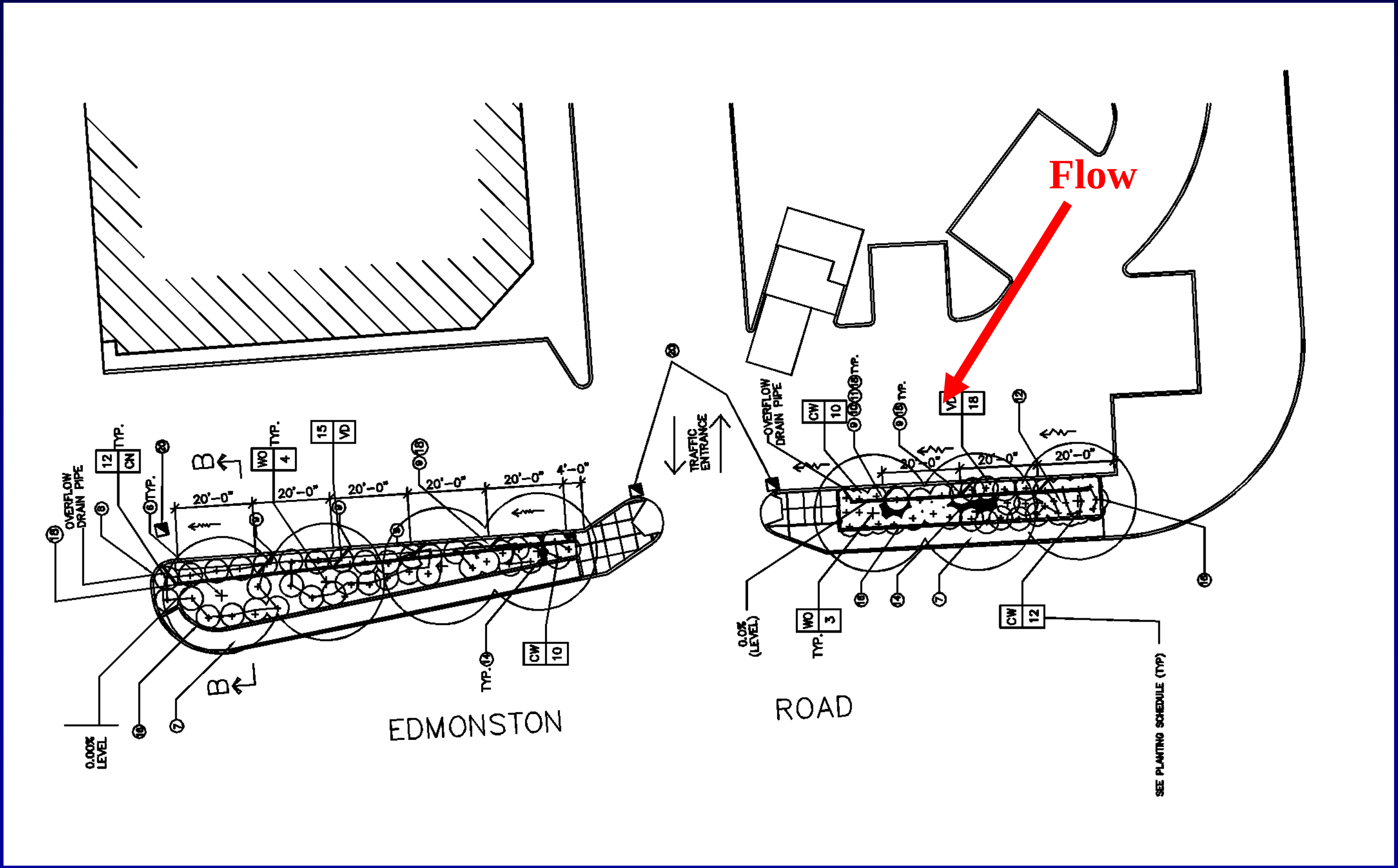
Rain Gardens used through-out the Alexandria Central Library to treat all impervious runoff

New River MCAS



All green space can be designed to be hydrologically functional and treat runoff.

Port Towns Shopping Center



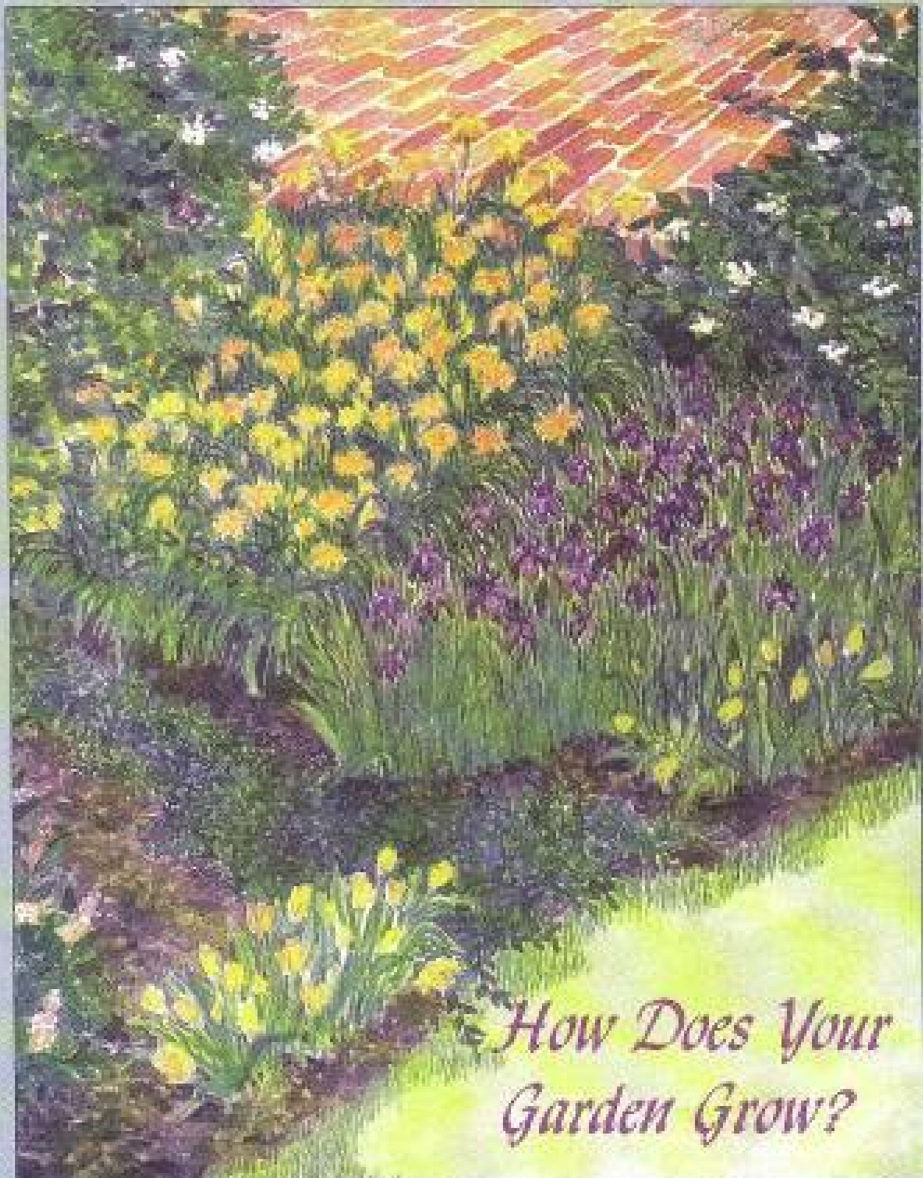

LEASE
0.94 Acres @ $29,000
$30,000 / Ac.
'98 5 14

Buckman Heights courtyard with infiltration garden

Buckman Heights Apartments – Infiltration garden

Division Street Planters


Bassett
FURNITURE DIRECT
Your One Stop Furniture Design Store
1721
Bassett
FURNITURE DIRECT
Your One Stop Furniture Design
Sale
12



A Reference Guide to Enhancing your Rain Garden

Contents

Environmental Education and Outreach

Maintenance

Maintenance Troubleshooting Chart for Bioretention

Problem	Indication/Sign(s)	Probable Cause(s)	Recommended Solution(s)
Pooling Water on Surface			
Soon after installation	Recent sediment/mud in mulch layer	Construction Sediment Contamination; Improper Soil Mixture	Remove contaminated soils/silt; Evaluate soil tickets; eliminate source of sedimentation
Over period of time	Underdrain dry	Clogged soil or filter media	Rake soil surface; puncture soil with reinforcing bar to increase flow avenues; remove and replace soils and filter media as needed
Plant Die-off			
Soon after installation	Wilting, brittle, dry roots	Poor installation, storage, and/or plant quality; saturated or dry soils	Check tags and enforce warrantee period. Check soil conditions
Over period of time	Lack of new growth spurts, brown leaves, brittle, lack of green growth	Insufficient nutrient levels, poor pest control, drowned roots	If beyond warrantee period, replace with more suitable plantings
Suddenly	Yellowing of leaves	Too much water	Reduce water intake/inflow
	Wilting/shriveling	Lack of Water/Wicking	Water as necessary
	Smell/residue	Toxification by salts, petroleum products or chemical spills	For salt; flush with water hose, remove contaminated soils; For petroleum products or spills, contact hazmat and contain
Plant Proliferation			
Weeds	Messy appearance and volunteer plants present	Preferred vegetative cover insufficient to block weeds	Weed as necessary

Invasives	Overgrowth smothering preferred plantings	Windblown or accidental planting	Weed as necessary, replant preferred species more densely
Over-Abundance	Messy appearance and spreading	Great soil structure, possible over fertilization	Divide and distribute; Trim and harvest growth to control
Trash and Debris Accumulation			
Debris Accumulation	Repeated occurrence of trash and debris	Windblown or carried, dettling in depressions	Remove and install catchment device or wind deflecting landscape
Erosion			
Wash-outs	Exposed raw earth; displaced mulch; mulch dams; mulch float		Reduce amount of flow; Replace organic mulch with inorganic mulch materials
Rilling	Ruts in mulch, soil or grass	Concentrated flow over one point	Reseed or provide resistant vegetation; reestablish sheet-flow conditions
Undermining and Sloughing-off	Collapsing border, pavement	Steep slopes; flow-through facility;	Reduce entrance slopes; install energy dissipaters; bring system offline
Settlement and cavitations	Sink holes and depressions	Not enough natural compaction time allowed; Soils washing through system; poor pipe/structure joints	Field investigate; Look for sediment deposits at outfall point; remove questionable soils; seal joints at structure/underdrain interface; refill/overfill soil


TYMCO
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MAINTENANCE SCHEDULE FOR BIORETENTION AREAS

1.0 Plant Care		Spring			Summer			Fall			Winter		
1.1	Trimming, Pruning, & Thinning												
1.2	Mowing												
1.3	Weeding												
1.4	Watering (estab. & drought)												
1.5	Fertilizing												
1.6	Pest Management												
1.7	Plant Replacement												
2.0 Infiltration Maintenance		Spring			Summer			Fall			Winter		
2.1	Ponding and Drainage												
2.2	Trash and Debris Removal												
2.3	Composting												
2.4	Mulching												
2.5	Pet Waste Removal												
2.6	Snow Removal												
2.7	De-Icing												

	Required
	Required at low frequency
	Required as necessary

Any questions?