Stormwater BMP Specifications

Chapter 3

Center for Watershed Protection

Changes to the Stormwater Guidebook

New BMPs	Existing BMPs
3.2 Green Roof	3.7 Filtering Systems
3.3 Rainwater Harvesting	3.8 Infiltration
3.4 Impervious Surface Disconnection	3.9 Open Channels
3.5 Permeable Pavement	3.10 Ponds
3.6 Bioretention	3.11 Wetlands
3.13 Proprietary Practices	3.12 Storage Practices
3.14 Tree Planting and Preservation	

Specification Format

- Feasibility Criteria
- Conveyance Criteria
- Pretreatment Criteria
- Design Criteria
- Landscaping Criteria
- Construction Sequence
- Maintenance Criteria
- Retention Value Calculations
- References

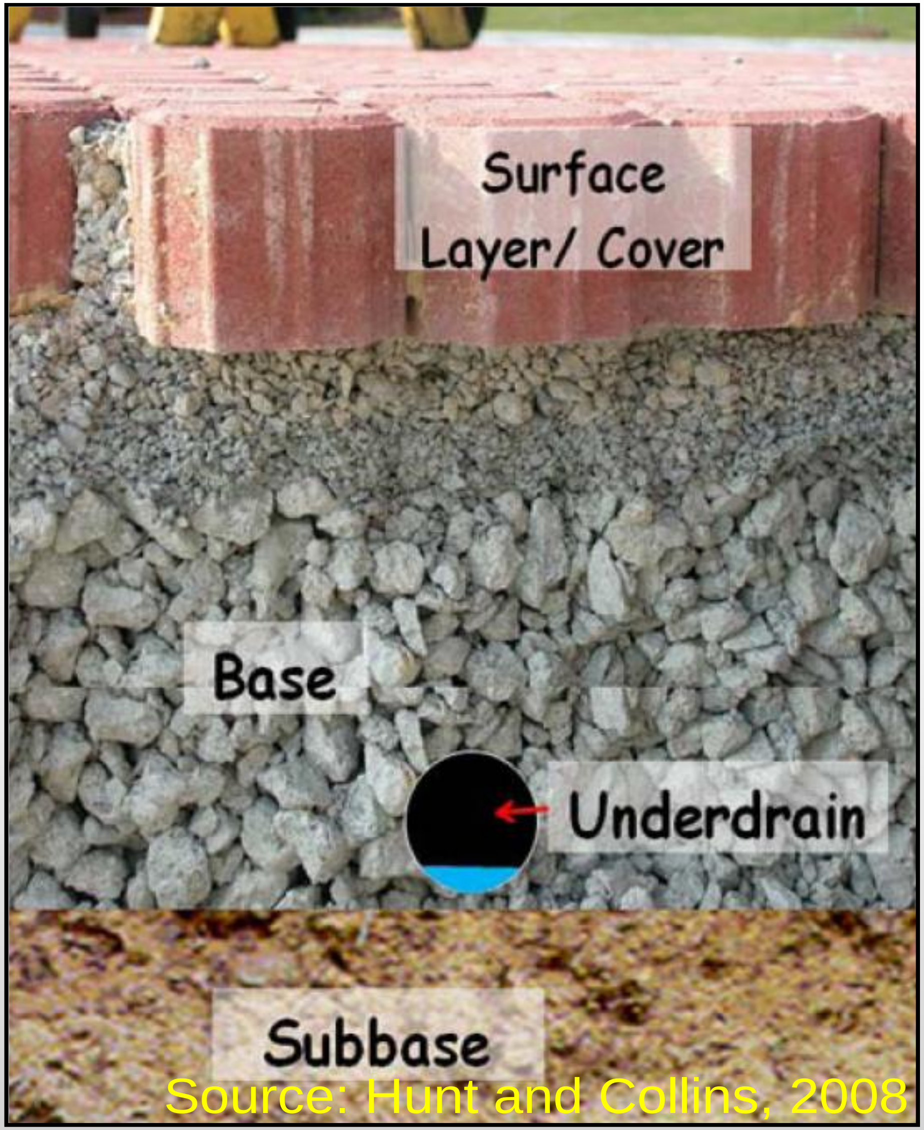
3.5 Permeable Pavement

Permeable Pavers

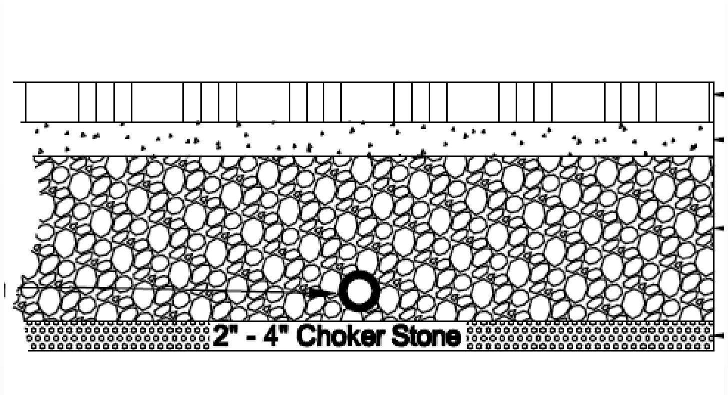
Pervious Concrete

Porous Asphalt

Typical Cross Section

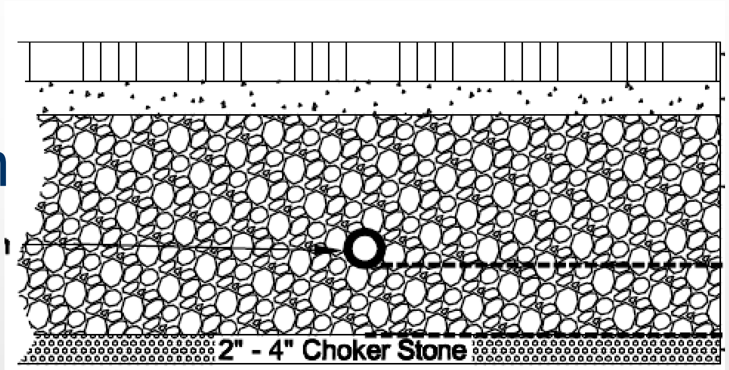


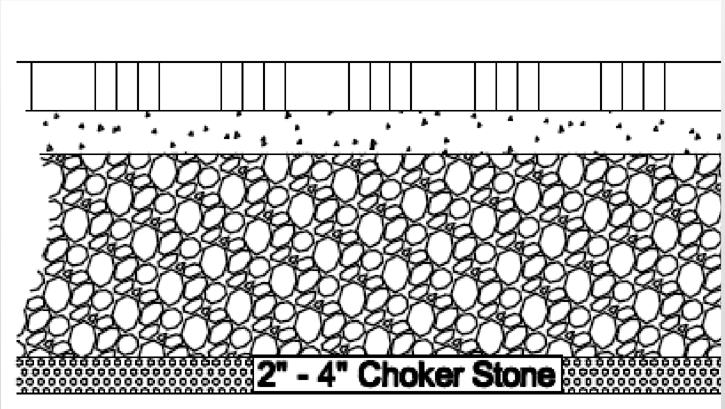
Permeable Pavement Versions



Standard

Enhanced with Underdrain





Enhanced without Underdrain

Permeable Pavement Feasibility Criteria

- Ratio of external contributing impervious surface to permeable pavement is **5:1**
- CDA should be impervious

- Other requirements
  - Water table depth
  - Minimum head
  - Setbacks
  - Slopes
  - Etc.

Conveyance Criteria and Pretreatment

- Large storm events must be managed
  - Overdrains/overflow inlets
  - Extra storage depth
  - Underground detention

- Pretreatment not required if CDA is 100% impervious

Permeable Pavement Design Criteria

- Specifications for each layer/element
  - Reservoir Layer – No. 57 or No. 2 stone; sized for design storm
  - Underdrains – PVC with 3/8 inch perforations; drain practice in 48 hours
  - Infiltration Sump – No. 57 or No. 2 stone; must drain in 48 hours
  - Filter Layer – No. 8 choker stone for optional separation

Permeable Pavement Design Criteria

Equation 3.2:

$$d_p = \frac{\left(\frac{P \times Rv_I \times DA}{A_p}\right) - \left(\frac{i}{2} \times t_f\right)}{\eta_r}$$

- d_p = Depth of the reservoir layer (or the depth of the infiltration sump, for enhanced designs with underdrains) (ft)
- DA = Total contributing drainage area, including the permeable pavement surface (sf.)
- A_p = Permeable pavement surface area (ft^2)
- P = The rainfall depth for the SWRv or other design storm (ft)
- Rv_I = Runoff coefficient for impervious cover (0.95)
- i = The field-verified infiltration rate for the subgrade soils (ft./day). If an impermeable liner is used in the design then i = 0.
- t_f = The time to fill the reservoir layer (day) – assume 2 hours or 0.083 day
- η_r = The effective porosity for the reservoir layer (0.35)

Permeable Pavement Design Criteria

$$t_d = \frac{d_p \times \eta_r}{\left(\frac{i}{2}\right)} = \frac{d_p \times \eta_r \times 2}{i}$$

Equation 3.3:

For enhanced design only

t_d= Time to drain (days) (must be < 2.0)

d_p = Depth of the reservoir layer (ft)

η_r = The effective porosity for the reservoir layer (0.35)

i = The field-verified infiltration rate for the subgrade soils (ft./day). If an impermeable liner is used in the design then i = 0

$$Sv = Ap \times \left[(d_p \times \eta_r) + \left(\frac{i \times t_f}{2} \right) \right]$$

Equation 3.4:

Sv = Storage Volume of Practice (ft^3)

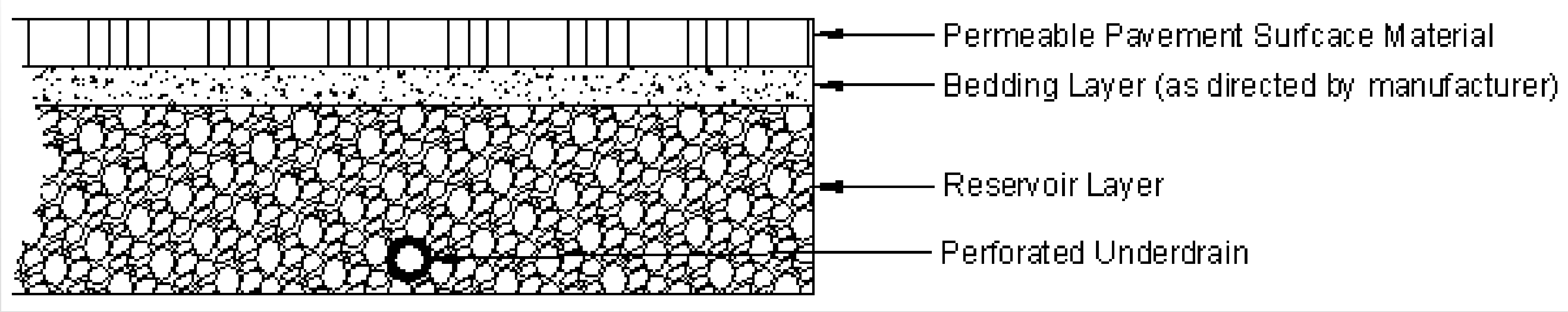
Ap = The permeable pavement surface area (ft^2)

t_f = The time to fill the reservoir layer (day) – assume 2 hours or 0.083 day

Permeable Pavement Retention Value Calculations

Standard Design

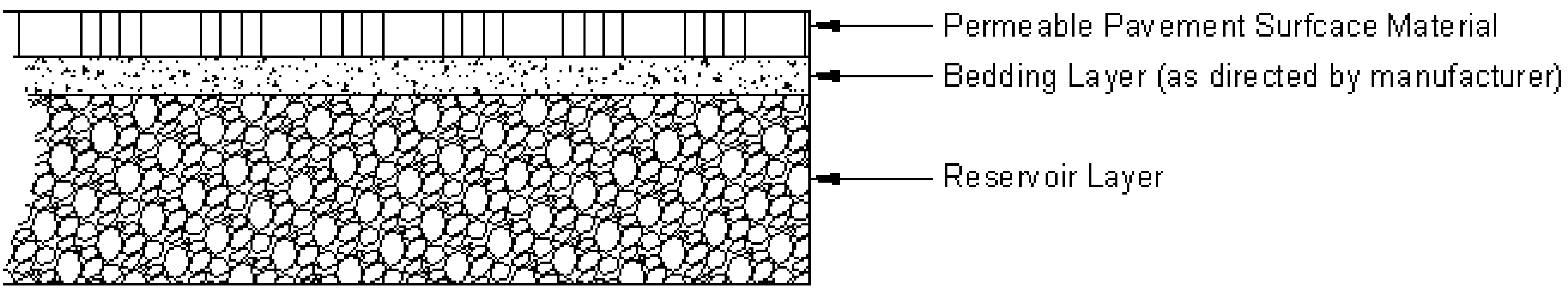
- Retention Value = 4.5 CF per 100 SF of practice area
- Accepted TSS removal practice



Permeable Pavement Retention Value Calculations

Enhanced Design without Underdrain

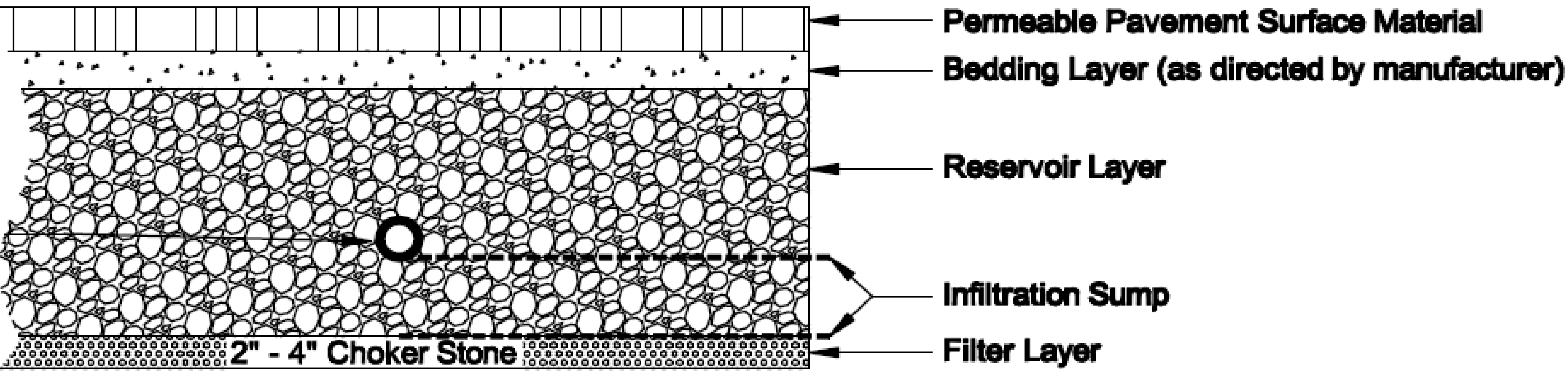
- Retention Value = 100% of Storage Volume in Reservoir Layer



Permeable Pavement Retention Value Calculations

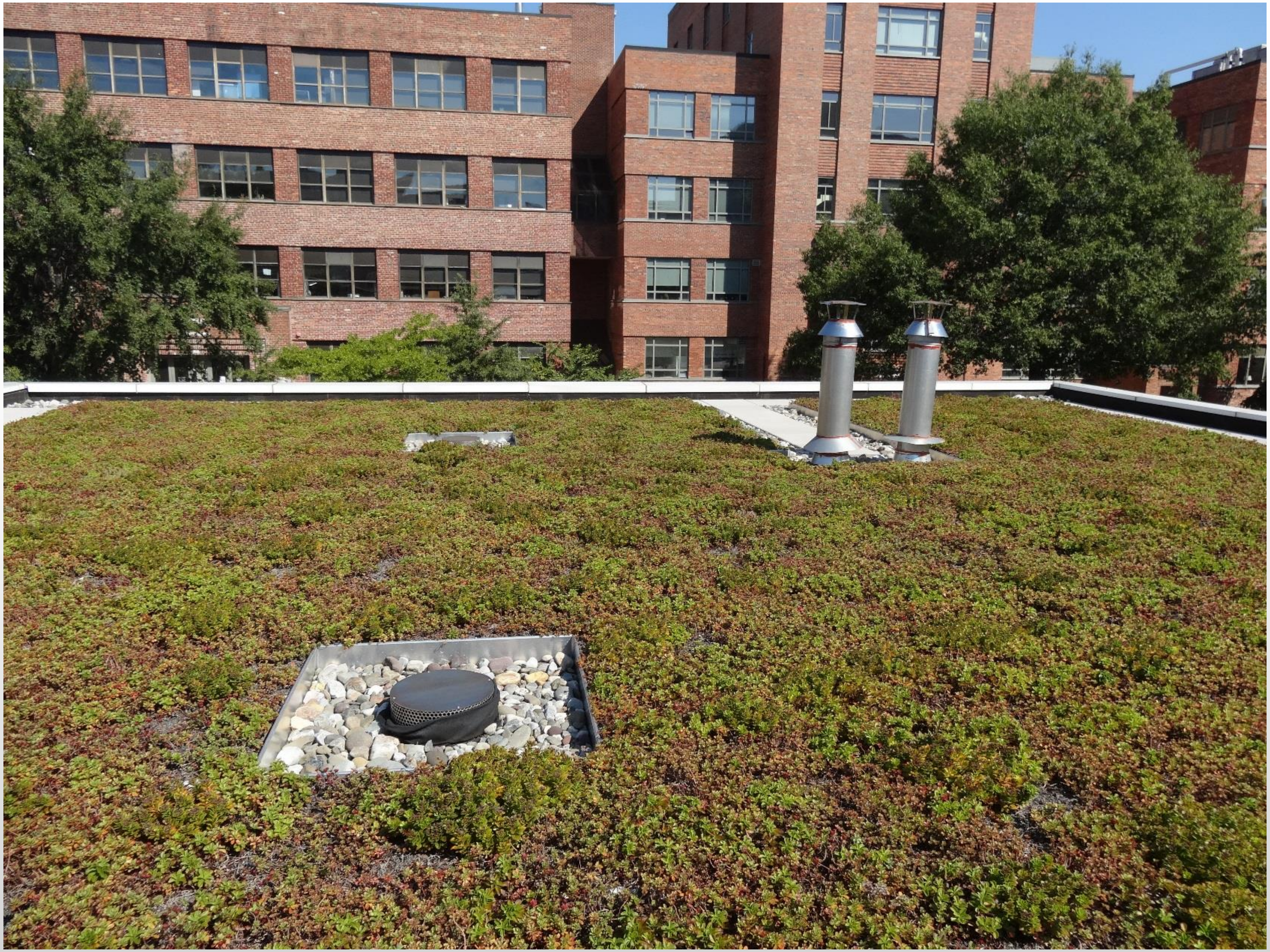
Enhanced Design with Underdrain

- Retention Value = 100% of Storage Volume in Infiltration Sump Layer
- Additional 4.5 CF per 100 SF of practice area



Questions?

3.2 Green Roofs



Green Roof Specification

- Preferred practice in high intensity redevelopment areas
- Allow for many different vendors and systems
- Follow ASTM specifications

Green Roofs

- Extensive or Intensive
- Structural design considerations
- High installation cost
- Increased roof longevity
- Additional urban environmental benefits
- Major element of compliance at urban development sites

Intensive

Extensive

Green Roof Feasibility Criteria

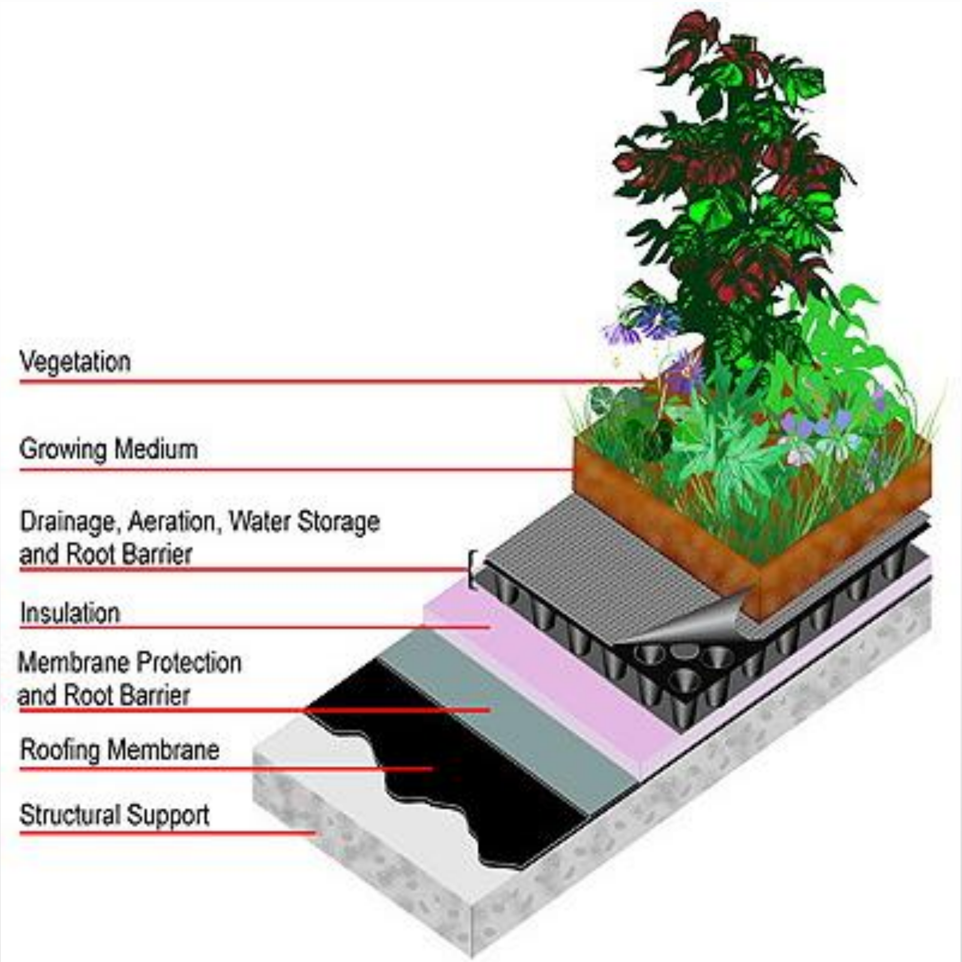
- Structural capacity of roof
- Roof pitch
- Setbacks from HVAC, etc.
- Compliance with building codes, fire code

Conveyance and Pretreatment

- Drainage layer and roof drains must safely convey overflows
- No requirements for pretreatment

Green Roof Design Criteria

- Material specifications for each layer



Green Roof Design Criteria

Sizing Equation

$$Sv = \frac{SA \times \left[\left(d \times \eta_1 \right) + \left(DL \times \eta_2 \right) \right]}{12}$$

Sv = storage volume (ft^3)

SA = green roof area (ft^2)

d = media depth (in) (minimum 3 in.)

η_1 = verified media maximum water retention (use 0.15 as a baseline default in the absence of verification data)

DL = drainage layer depth (in.)

η_2 = verified drainage layer maximum water retention (use 0.15 as a baseline default in the absence of verification data)

Green Roof Landscaping Criteria

Plants need to resist and withstand

- Drought
- Fire
- Wind
- Snow-loading
- Heat-stress
- Etc.

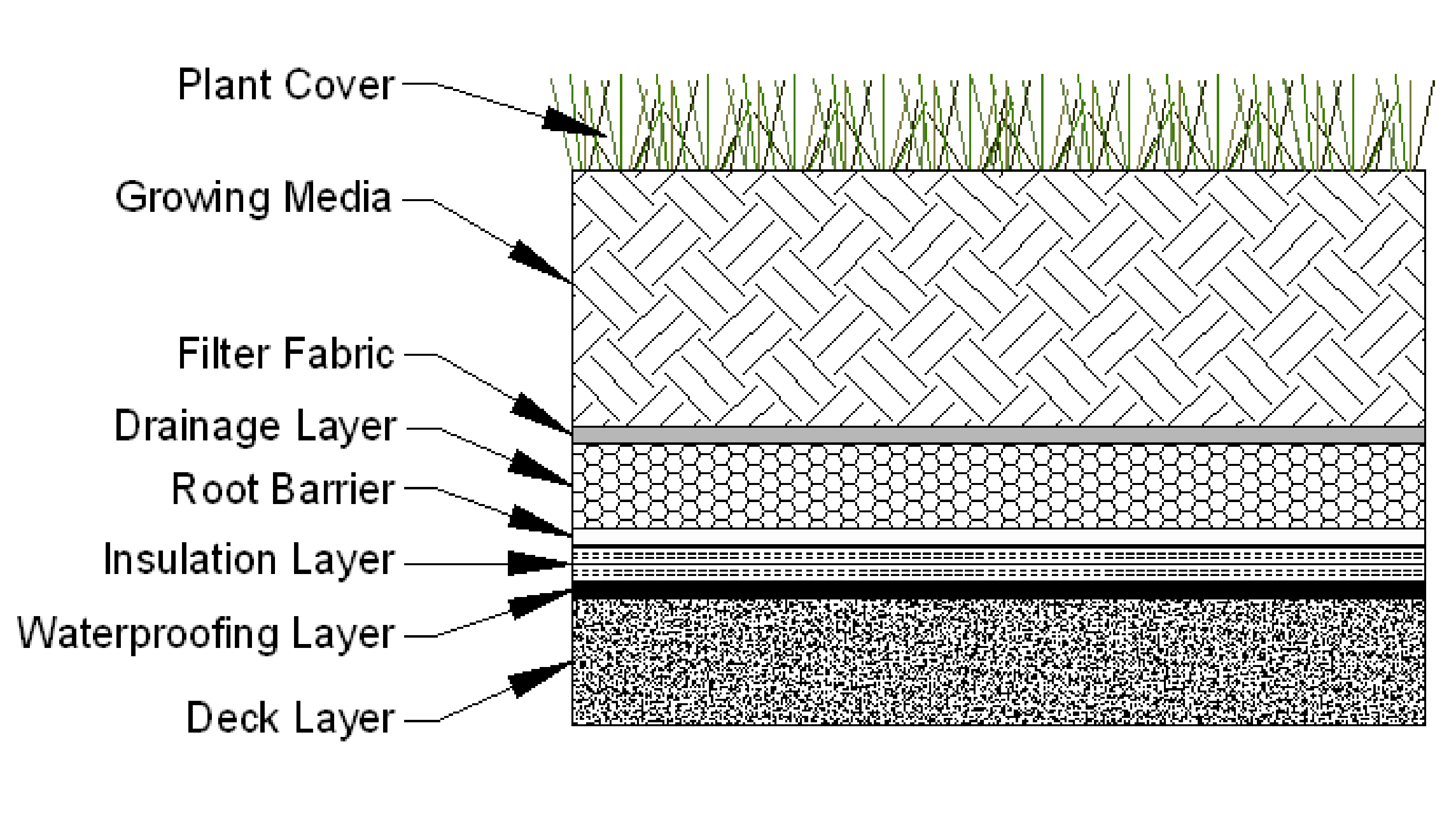
Table 3.1.2. Ground Covers appropriate for Green roofs in the District.

Plant	Light	Moisture Requirement	Notes
Delosperma cooperii	Full Sun	Dry	Pink flowers; grows rapidly
Delosperma 'Kelaidis'	Full Sun	Dry	Salmon flowers; grows rapidly
Delosperma nubigenum 'Basutoland'	Full Sun	Moist-Dry	Yellow flowers; very hardy
Sedum album	Full Sun	Dry	White flowers; hardy
Sedum lanceolatum	Full Sun	Dry	Yellow flowers; native to U.S.
Sedum oreganum	Part Shade	Moist	Yellow flowers; native to U.S.
Sedum stoloniferum	Sun	Moist	Pink flowers; drought tolerant
Sedum telephiodes	Sun	Dry	Blue green foliage; native to region
Sedum ternatum	Part Shade-Shade	Dry-Moist	White flowers; grows in shade
Talinum calycinum	Sun	Dry	Pink flowers; self sows

Note: Designers should choose species based on shade tolerance, ability to sow or not, foliage height, and spreading rate. See Snodgrass and Snodgrass (2006) for definitive list of green roof plants, including accent plants.

Green Roof Retention Value Calculations

Retention Value = Sv = 100% of Storage Volume in Media and Drainage Layer



Questions?

3.6 Bioretention

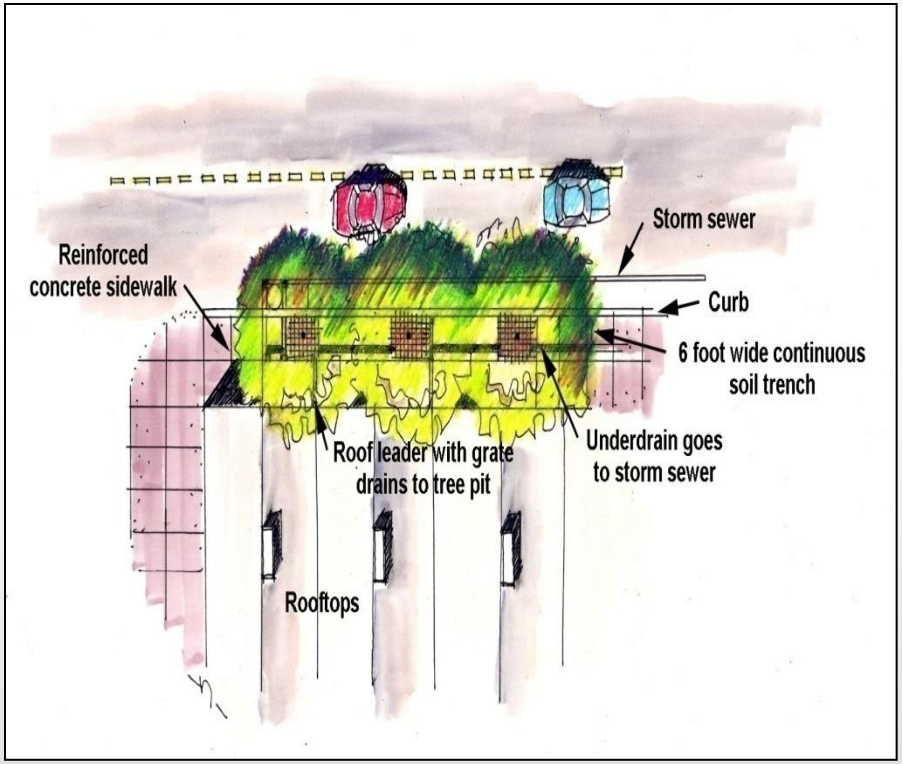
Bioretention Specification

- Little detail on bioretention in previous Guidebook
- Popular practice on sites with some surface land available
- New research and experience
- Multiple design options

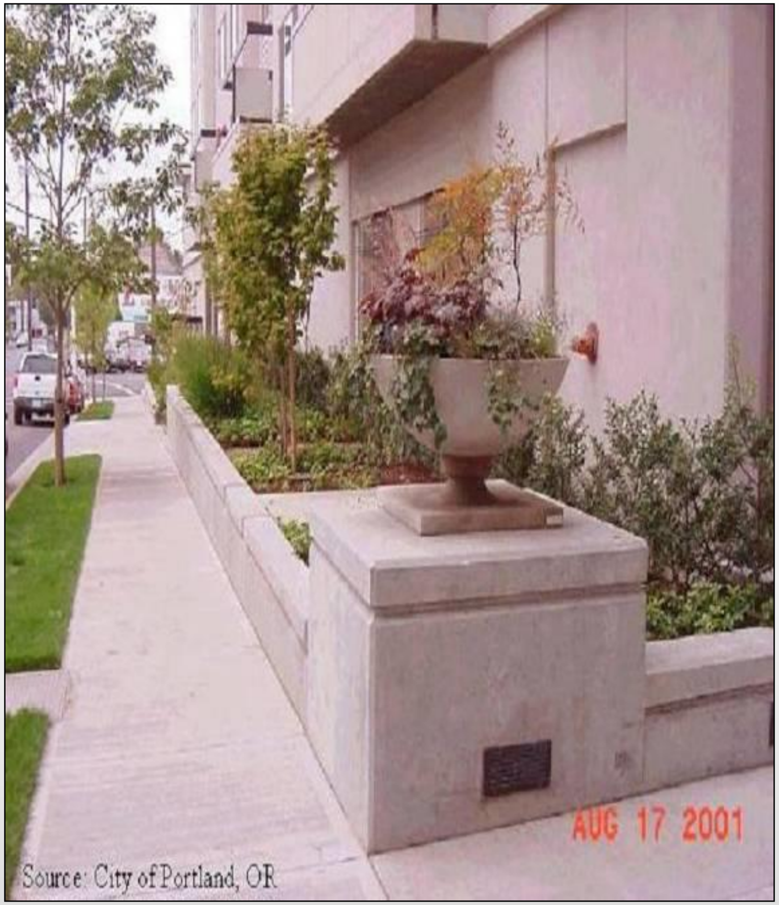
B-1 Traditional Bioretention

B-2 Streetscape Bioretention

B-3 Engineered Tree Pits

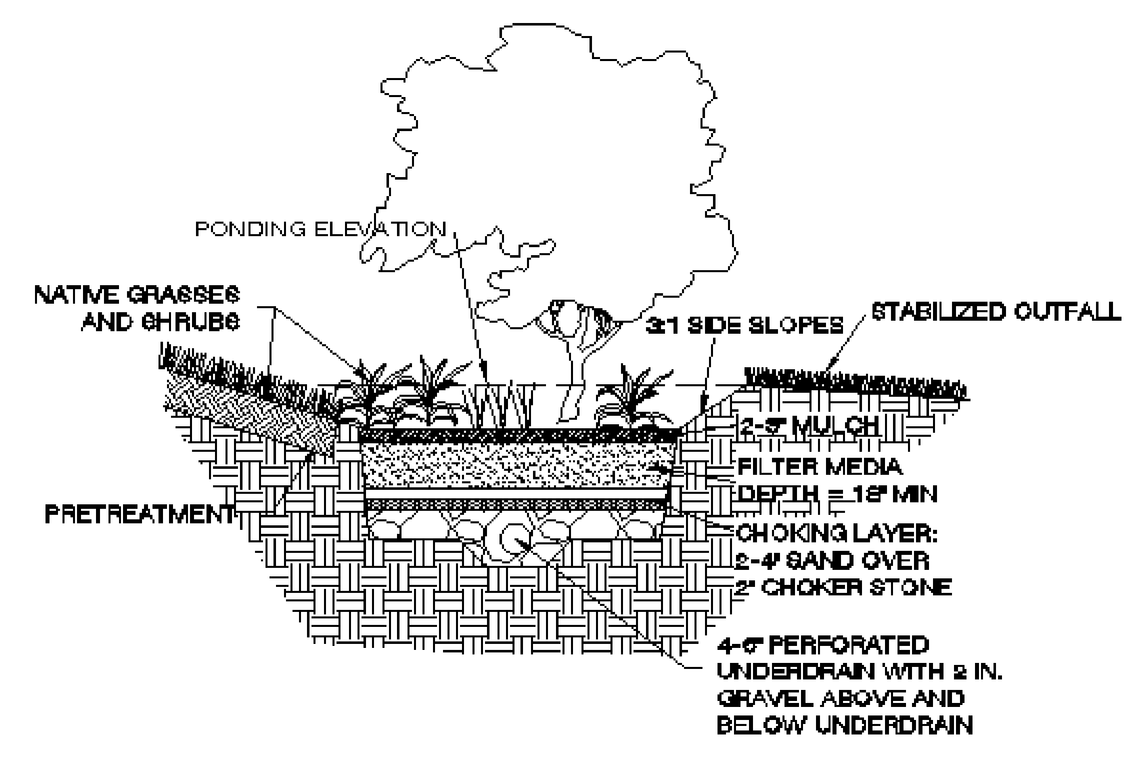


B-4 Foundation Planters



B-5 Residential Rain Gardens

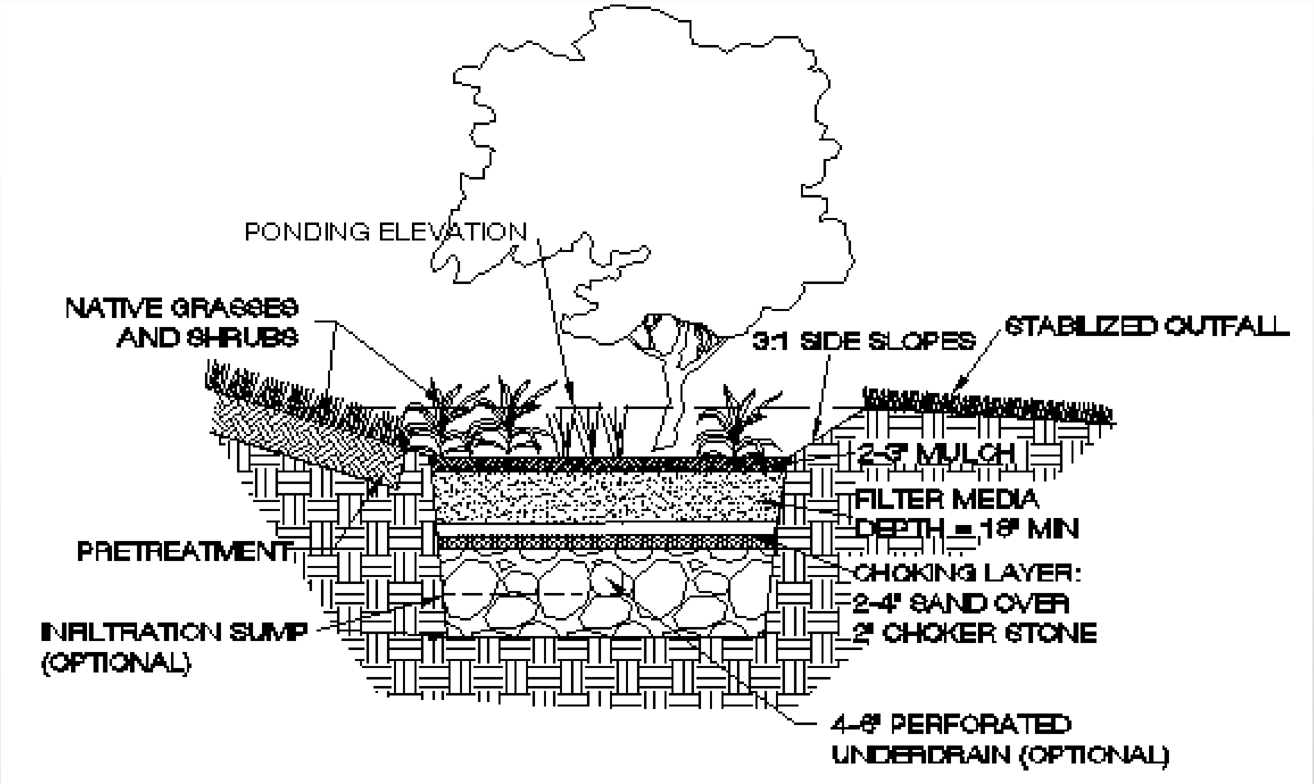
Standard Bioretention Design



- Underdrain designs without enhanced features
- < 24” media
- 60% retention value for the design storm captured
- Additional TSS removal
- Oversizing practice can result in meeting full criteria

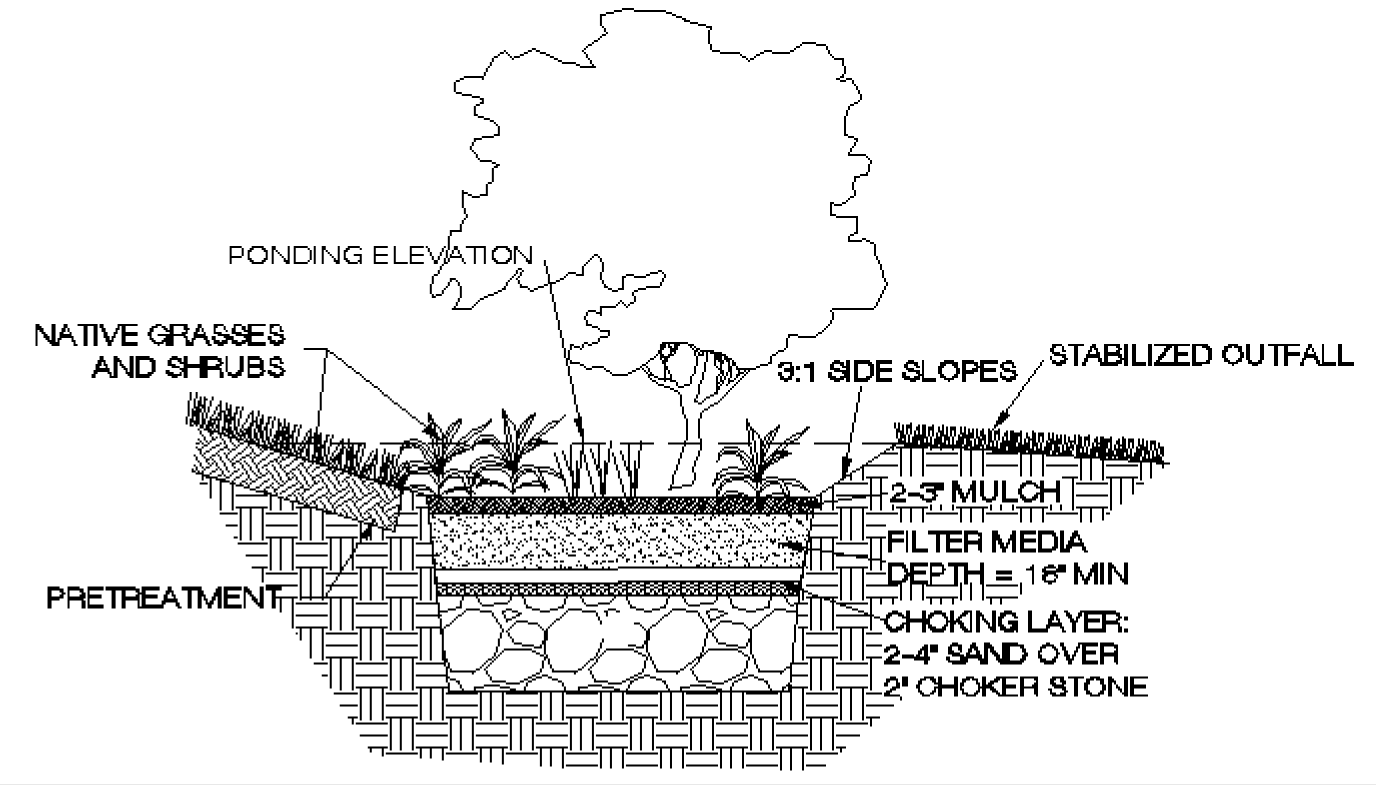
Enhanced Bioretention 1

- Underdrain designs with infiltration sump and 24” media
- 100% retention value for the design storm captured



Enhanced Bioretention 2 (Infiltration)

- For infiltration designs (storage volume must infiltrate within 72 hours)
- Retention value for the design storm captured



Bioretention Feasibility Criteria

- Works for all soil types and most site conditions
- 4 to 5 feet of head
- No irrigation or baseflow
- Liner required for hotspots

Conveyance Criteria and Pretreatment

- Conveyance: Off-line vs. On-line
  - On-line requires overflow device
- Pretreatment Required
  - Pretreatment Cell
  - Grass Filter Strips
  - Stone Diaphragm
  - Etc.

Bioretention Design Criteria

- Maximum ponding depth
  - 18” with 3:1 side slopes
- Minimum filter depth
  - 24” for enhanced designs
  - 18” for small-scale practices
- Infiltration designs
  - Volume must infiltrate within 72 hours

Bioretention Design Criteria

- Maximum filter media depth
  - The runoff coefficient of the CDA to the BMP (RvCDA)
  - The bioretention ratio of BMP surface area to the BMP CDA (SA:CDA) (in percent)
  - See Table 3.21

Table 3.21 Determining Maximum Filter Media Depth (feet)

SA:CDA (%)	RvCDA								
	0.25	0.3	0.40	0.50	0.60	0.70	0.80	0.90	0.95
0.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
1.0	5.0	5.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
1.5	3.5	4.0	5.0	6.0	6.0	6.5	6.5	6.5	6.5
2.0		3.0	4.0	5.0	5.5	6.0	6.0	6.5	6.5
2.5			3.5	4.5	4.5	5.0	5.5	6.0	6.0
3.0				3.5	4.0	4.5	5.0	5.5	5.5
3.5					3.5	4.0	4.5	5.0	5.0
4.0					3.0	3.5	4.0	4.5	4.5
4.5						3.5	3.5	4.0	4.0
5.0							3.5	4.0	4.0
5.5								3.5	3.5
6.0								3.0	3.5
6.5									3.0
7.0									
7.5									
8.0									
8.5									
9.0									
9.5									
10.0									

Bioretention Design Criteria

- Filter Media Specifications
  - 80%-90% sand (at least 75% is classified as coarse or very coarse sand)
  - 10%-20% soil fines (silt and clay; maximum 10% clay)
  - 3%-5% organic matter (leaf compost)
  - P concentrations between 5 and 15 mg/kg (Mehlich I) or 18 and 40 mg/kg (Mehlich III)

Table 3.20 Filter Media Criteria for Bioretention

<table>
<tr><th>Soil Media Criterion</th><th>Description</th><th colspan="3">Standard(s)</th></tr>
<tr><td>General Composition</td><td>Soil media must have the proper proportions of sand, fines, and organic matter to promote plant growth, drain at the proper rate, and filter pollutants</td><td colspan="3">80% to 90% sand (75% of which is coarse or very coarse);
10% to 20% soil fines
Max. 10% clay; and
3% to 5% organic matter</td></tr>
<tr><td rowspan="9">Sand</td><td rowspan="9">Silica based coarse aggregate[1]</td><td>Sieve</td><td>Size</td><td>% Passing</td></tr>
<tr><td>3/8 in</td><td>9.50 mm</td><td>100</td></tr>
<tr><td>No. 4</td><td>4.75 mm</td><td>95 to 100</td></tr>
<tr><td>No. 8</td><td>2.36 mm</td><td>80 to 100</td></tr>
<tr><td>No. 16</td><td>1.18 mm</td><td>45 to 85</td></tr>
<tr><td>No. 30</td><td>0.6 mm</td><td>15 to 60</td></tr>
<tr><td>No. 50</td><td>0.3 mm</td><td>3 to 15</td></tr>
<tr><td>No. 100</td><td>0.15 mm</td><td>0 to 4</td></tr>
<tr><td colspan="3">Effective Particle size (D10) > 0.3mm
Uniformity Coefficient (D60/D10) < 4.0</td></tr>
<tr><td>Top Soil</td><td>Loamy sand or Sandy Loam</td><td colspan="3">USDA Textural Triangle</td></tr>
<tr><td>Organic Matter</td><td>Well aged, clean compost</td><td colspan="3">Appendix J</td></tr>
<tr><td>P-Index or Phosphorus (P) content</td><td>Soil media with high P levels will export P through the media and potentially to downstream conveyances or receiving waters</td><td colspan="3">P content = 5 to 15 mg/kg (Mehlich I) or 18 to 40 mg/kg (Mehlich III)</td></tr>
<tr><td>Cation Exchange Capacity (CEC)</td><td>The CEC is determined by the amount of soil fines and organic matter. Higher CEC will promote pollutant removal</td><td colspan="3">CEC > 5 milliequivalents per 100 grams</td></tr>
</table>

[1]Many specifications for sand refer to ASTM C-33. The ASTM C-33 specification allows a particle size distribution that contains a large fraction of fines (silt and clay sized particles - < 0.05 mm). The smaller fines fill the voids between the larger sand sized particles, resulting in smaller and more convoluted pore spaces. While this condition provides a high degree of treatment, it also encourages clogging of the remaining void spaces with suspended solids and biological growth, resulting in a greater chance of a restrictive biomat forming. By limiting the fine particles allowed in the sand component, the combined media recipe of sand and the fines associated with the soil and organic material will be less prone to clogging, while also providing an

Bioretention Design Criteria

- Surface Cover Options
  - Mulch and perennial vegetation
  - Turf
  - Stone with perennial vegetation

Bioretention Design Criteria

Sizing Equation

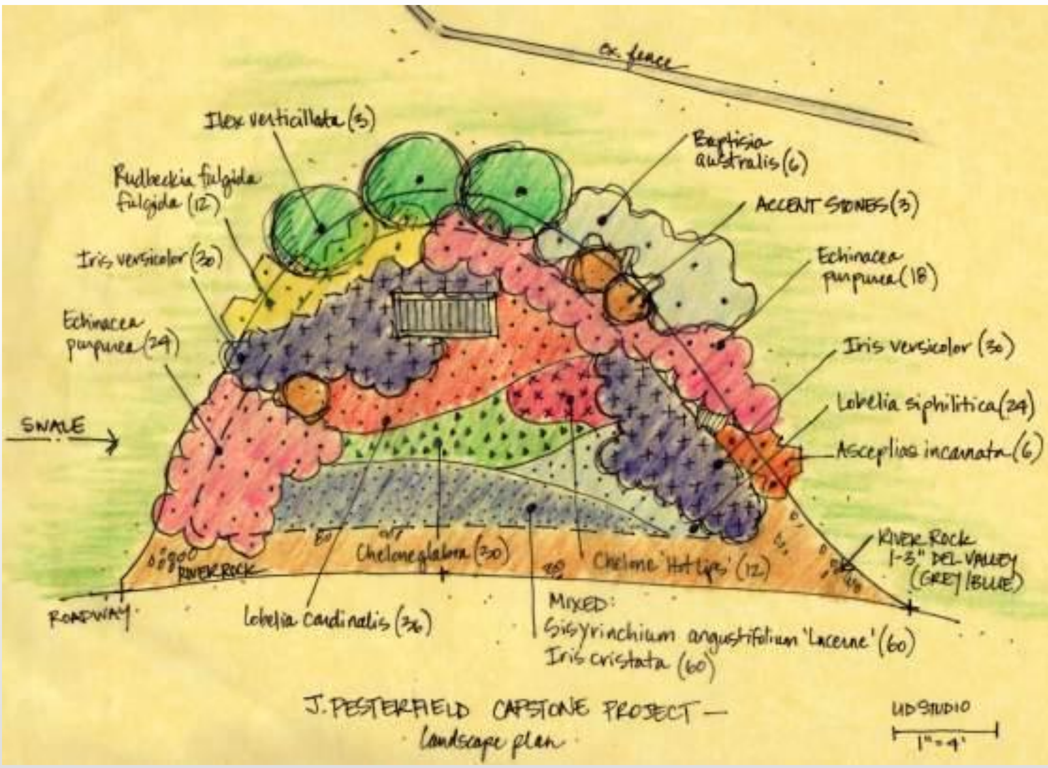
$$Sv = SA_{bottom} \times [(d_{media} \times \eta_{media}) + (d_{gravel} \times \eta_{gravel})] + (SA_{average} \times d_{ponding})$$

- Where:
- Svpractice = total storage volume of practice (ft3)
- SAbottom = bottom surface area of practice (ft2)
- dmedia = depth of the filter media (ft)
- ηmedia = effective porosity of the filter media (typically 0.25)
- dgravel = depth of the underdrain and underground storage gravel layer (ft)
- ηgravel = effective porosity of the gravel layer (typically 0.4)
- SAaverage = the average surface area of the practice (ft2)

$$SA_{average} = \frac{SA_{bottom} + SA_{top}}{2}$$

- dponding = the maximum ponding depth of the practice (ft).

Bioretention Landscaping Criteria



Questions?

3.3 Rainwater Harvesting

Rainwater Harvesting Feasibility Criteria

- Effectiveness for retention requirements
  - Tank size
  - Dedicated demand
- Minimal space or setback requirements
- Filters, pumps, and overflow devices are generally necessary
- **Risk Assessment needed to determine any treatment requirements**
- Appendix M

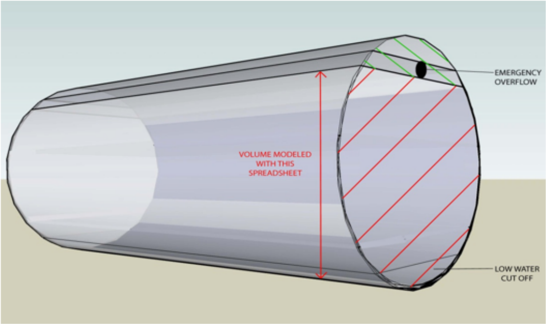
Rainwater Harvesting Retention Calculator

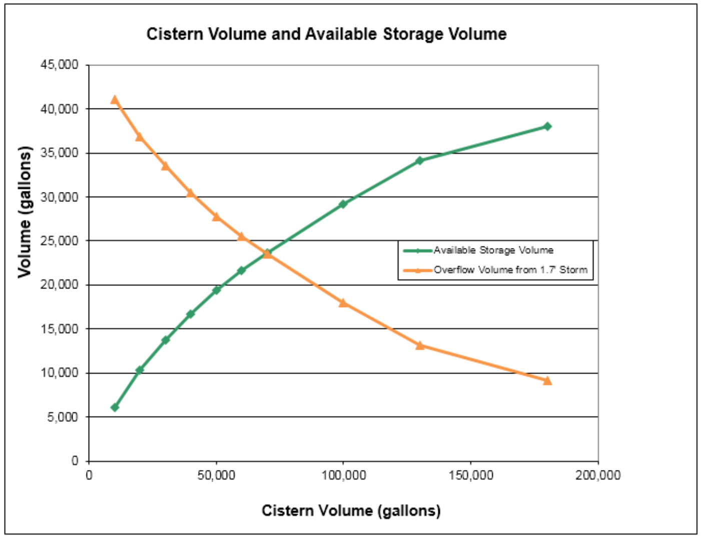
Retention value determined through rainwater harvesting spreadsheet.

DC_RainwaterHarvestingSpreadsheet_apr_2015.xlsx - Excel

Storage Volume Summary: Results for a P" Storm, where P" = 1.7"

Cistern Volume (gallons)	Average Volume in Cistern (1977-2007)	Overflow Volume caused by 1.7" Storm (gallons)	Available Storage Volume (gallons)	Available Storage Volume (Sv) (cubic feet)
10,000	3,889	41,081	6,111	817
20,000	9,687	36,879	10,313	1379
30,000	16,306	33,497	13,694	1831
40,000	23,290	30,482	16,710	2234
50,000	30,615	27,806	19,385	2592
60,000	38,373	25,564	21,627	2891
70,000	46,346	23,538	23,654	3162
100,000	70,824	18,015	29,176	3901
130,000	95,911	13,102	34,089	4557
180,000	141,954	9,145	38,046	5086





Note: Cistern Volume does not include detention for larger storm events.
Detention volume that will be drawn down after each storm event should be modeled separately.

Instructions | Input | Storage Volume Results

Questions?

3.4 Impervious Surface Disconnection

Disconnection Specifications

- Difficult in ultra-urban situations
- Requires careful site planning
- Utilizes green space efficiently
- Turns runoff source into BMP

Three Disconnection Options

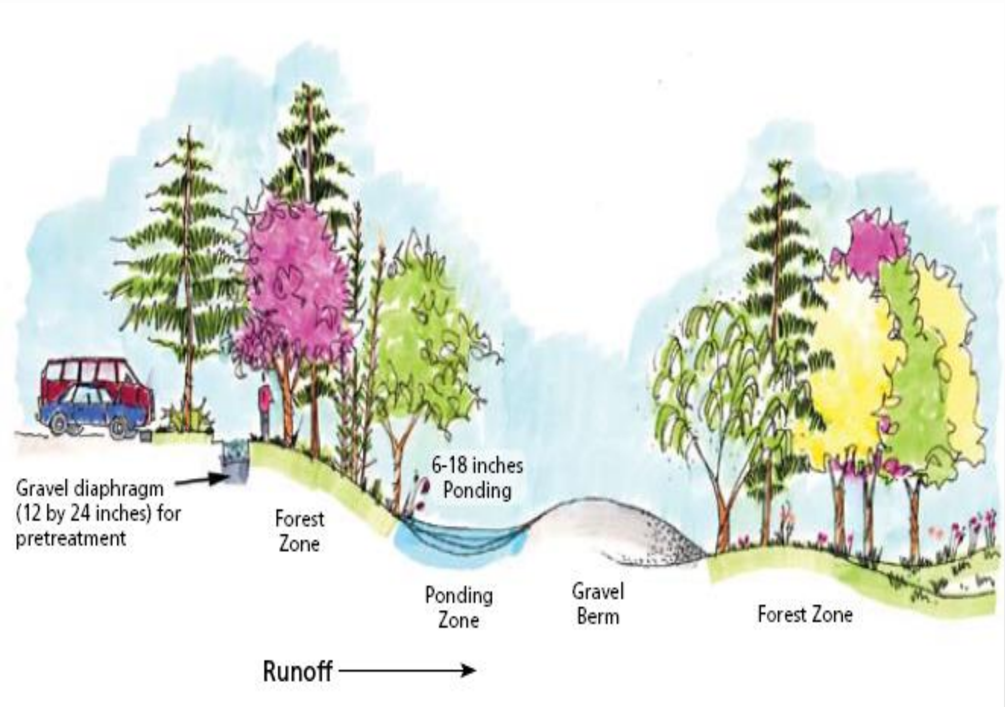
D-1 Simple Disconnection to Pervious Area

D-2 Simple Disconnection to Conservation Area

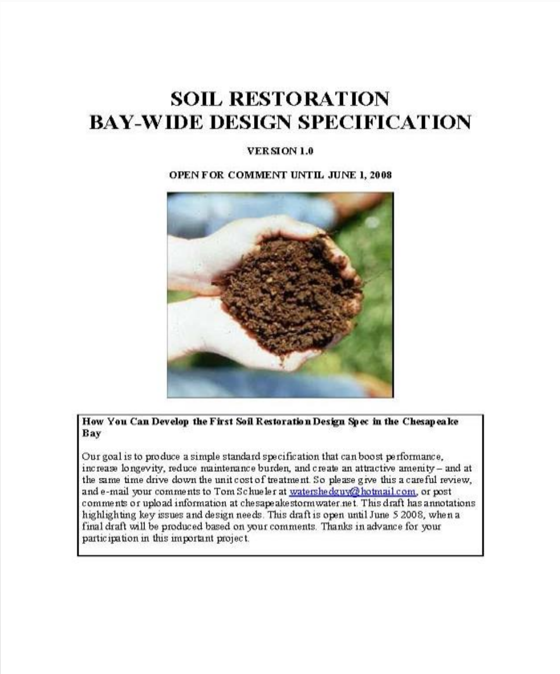
D-3 Simple Disconnection to Compost Amended Filter Path

D-1 Disconnection to Pervious Area

D-2 Disconnection to Conservation Area



D-3 Disconnection to Compost Amended Filter Path



SOIL RESTORATION
BAY-WIDE DESIGN SPECIFICATION

VERSION 1.0

OPEN FOR COMMENT UNTIL JUNE 1, 2008

How You Can Develop the First Soil Restoration Design Spec in the Chesapeake Bay

Our goal is to produce a simple standard specification that can boost performance, increase longevity, reduce maintenance burden, and create an attractive amenity – and at the same time drive down the unit cost of treatment. So please give this a careful review, and e-mail your comments to Tom Schueler at watershedguy@hotmail.com, or post comments or upload information at chesapeakestormwater.net. This draft has annotations highlighting key issues and design needs. This draft is open until June 5 2008, when a final draft will be produced based on your comments. Thanks in advance for your participation in this important project.

Impermeable Surface Disconnection

- For rooftops, CDA ≤ 1,000 ft^2 per disconnection
- For non-rooftop, the longest contributing
- impervious area flow path ≤ 75 ft
- The available receiving area must be at least
- 10 ft – 25 ft wide and 15 ft – 100 ft long
- Width can be greater if runoff is conveyed via sheet flow or a level spreader

Disconnection Retention Values

To a pervious area:

- 2.0 CF per 100 SQ of receiving pervious area
  (21% volume reduction)

To a conservation area:

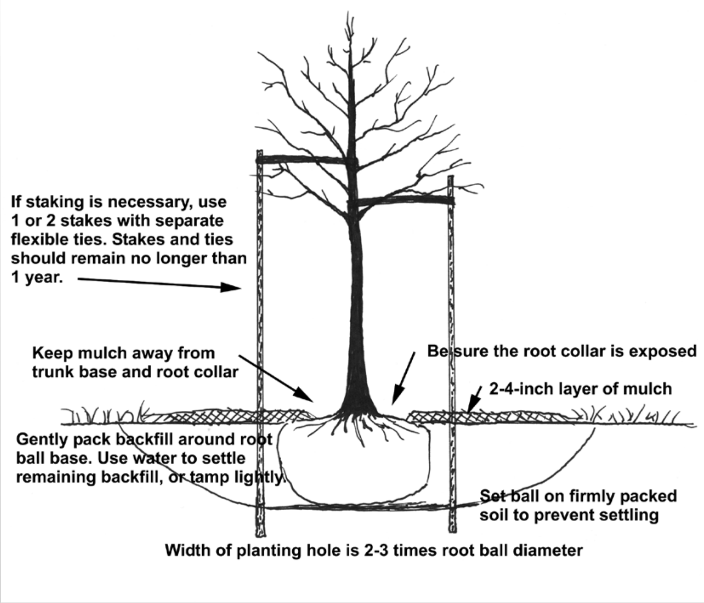
- 6.0 CF per 100 SF of receiving pervious conservation area
  (63% volume reduction)

To a soil compost amended filter path:

- 4.0 CF per 100 SF of receiving pervious area
  (42% volume reduction)

3.14 Tree Planting and Preservation

- Gives Retention Value for individual trees
- Proper planting and maintenance required
- Each preserved tree gets 20 cubic foot retention value
- Each newly planted tree gets 10 cubic foot retention value



3.13 Proprietary Practices

- Approval procedures involve field studies and/or lab tests
- Variable retention and TSS removals
- Generally low retention value and high TSS removal
- Approval follows NJDEP Protocol
- Appendix S

Image: Filterra.com

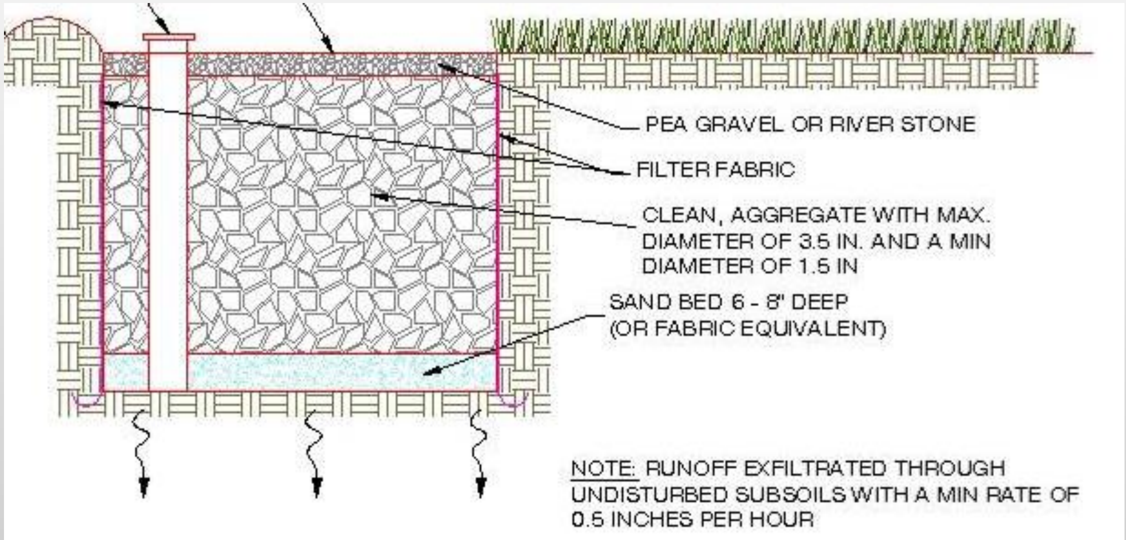
3.7 Filtering Systems

- Updated, but kept largely the same
- 0% Retention Value
- Accepted TSS removal practice
- Likely be less prevalent in the future

Image: Albemarle County

3.8 Infiltration

- Expanded, especially for materials, installation, and maintenance
- 100% Retention Value for water that infiltrates in 72 hours
- ½ measured infiltration rate used as safety factor



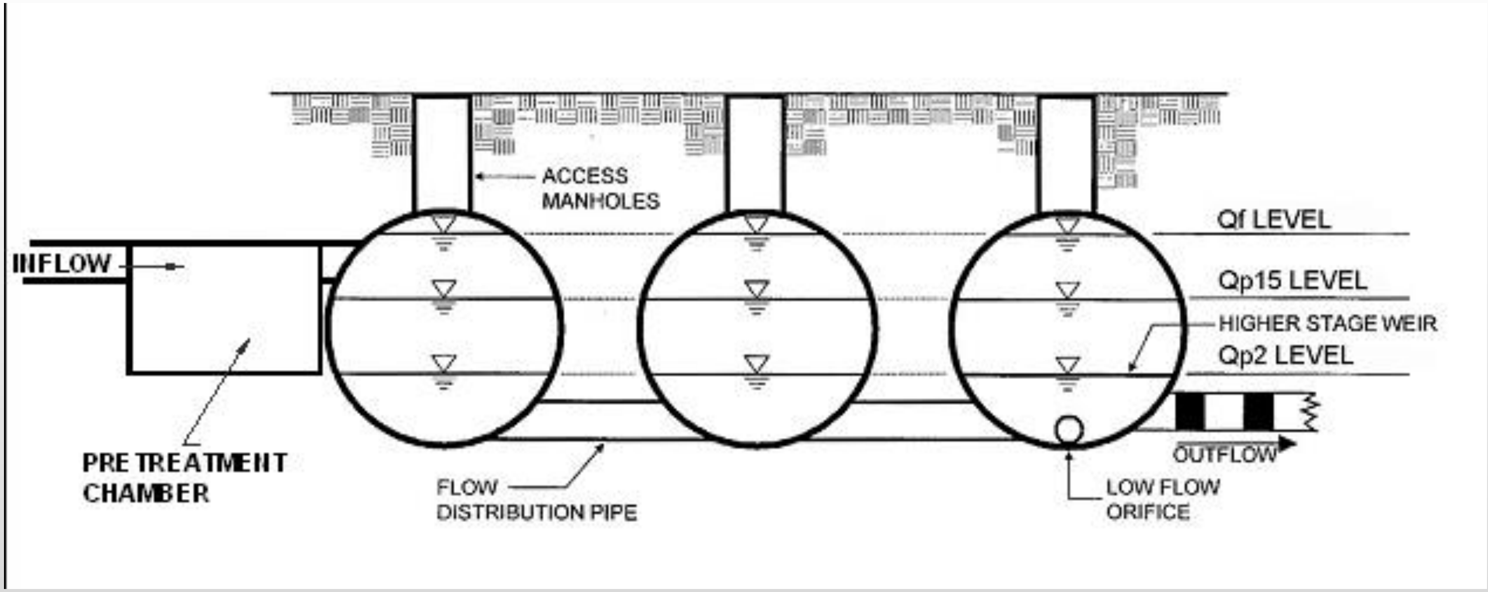
3.9 Open Channels

- Dry swale, wet swale, and grass channel
- Not high priority BMPs

- Dry Swale = 60% Retention + accepted TSS removal practice
- Wet Swale = 10% Retention + accepted TSS removal practice
- Grass Channel = 10% - 30% Retention

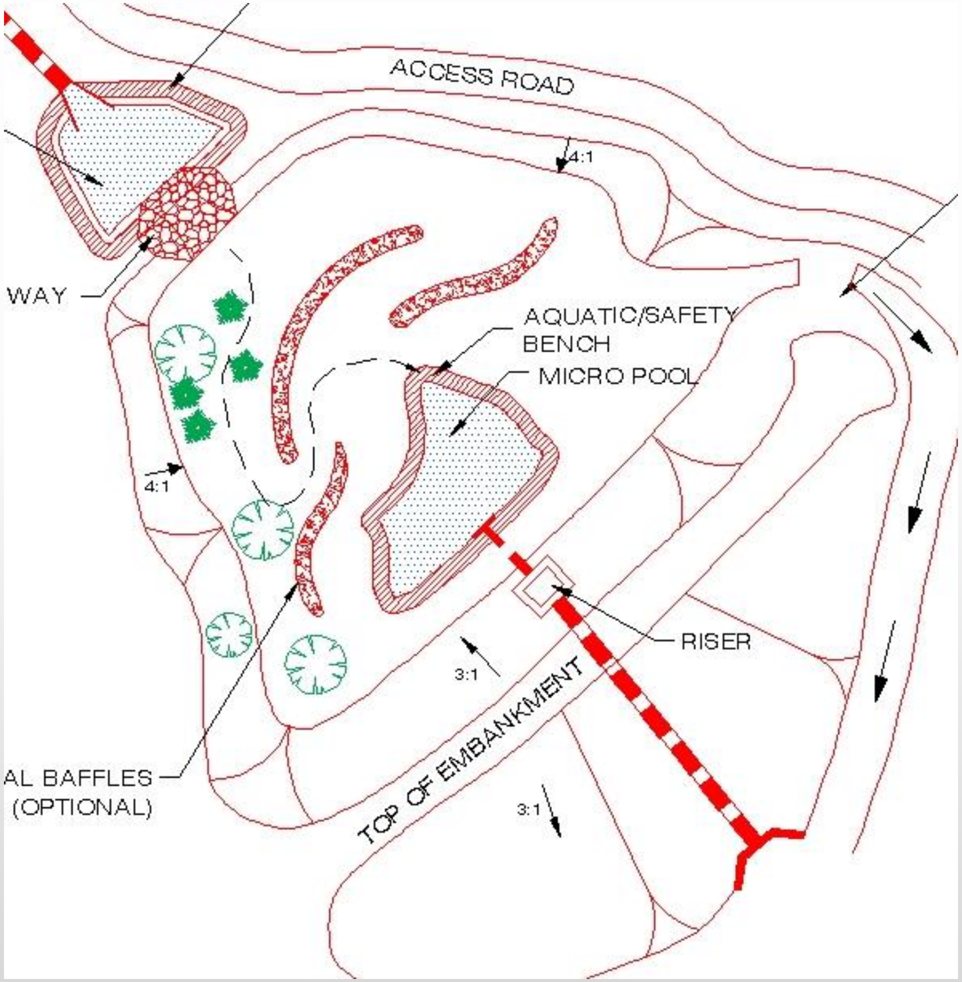
3.12 Storage Practices

- More detailed specification
- No retention or TSS removal value
- Intended only for large storm events



3.10 Stormwater Ponds & 3.11 Stormwater Wetlands

- More detailed specifications
- Few major changes
- 10% retention value
- Accepted TSS removal practice



Questions?