Coordinating ESD's And WIP with Smart Green And Growing

Where We Have Come From and Ideas to Consider from an Engineer's Perspective

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SWM Pre-1980's

- Concerned about major stream flooding resulted in the following.
  - Regional Dams – Flood control, recreation, and water supply
  - Levees
  - Concrete channels or large pipes
  - Move the water past the site as quickly as possible and fill areas in the floodplain.
- Channels and pipes usually designed for less than a 100 year storm and existing conditions.

MDE SWM Issues Early 1980's

- Concerned about water quality degradation, ground water recharge, low flow volume during dry periods, and accelerated stream erosion.
- Laws to preserve wetlands are more rigorously enforced which precludes channelization of streams.
- Stream erosion is a big issue along with flooding of properties from the from smaller storm events.

MDE SWM Regulations Early 1980's

- Two and ten year peak flow control required along with infiltration of 0.5" of runoff from impervious areas.
- Maintenance was hit or miss. The more hidden the pond, the less maintenance that was achieved.
- Most ponds had little or no landscaping and were hidden to be out of sight to as many people as possible.
- The ponds were placed in areas that were harder to develop and not as valuable, i.e. required but not wanted by many people.

Poor Maintenance

Better Maintenance

Dry Pond with No Landscaping

MDE SWM Issues in the Mid-Late 1990's

- Poor results from the 1980's laws.
- Many ponds tended to be poorly maintained unless they were located in a central area visible to many people.
- Low flow devices were easily clogged, which meant that even a two year control was not being achieved.
- Stream erosion still occurring because the two year storm is not the correct storm event to control to prevent channel erosion.
- Needed to revise law to achieve water quality improvements in the Chesapeake Bay as voluntary efforts were not achieving the goals fast enough.

Stream Erosion

SWM – Poor/Nonexistent Maintenance

Beaver lodge in a dry pond.

MDE SWM Law 2000

- Infiltration still required, but raised to the first inch of rainfall for the total area. Approximately 85-90% of the rainfalls events are less than a one inch of rainfall.
- By requiring treatment of the first inch of rainfall, effectively 80-85% of the rainfall volume in a year is treated or peak controlled.
- ESD was encouraged to some extent by the manual, but not required - therefore rarely implemented.
- Implement Channel Protection Volume (CPv) by controlling the 1 year storm with extended detention to provide additional protection to the stream channels.
- SWM ponds and underground facilities are still part of the menu of items to implement CPv control.
- Additional controls for downstream flooding could still be required.

Bioretention – Circa 2003 Construction
(Current Status)

Bioretention - Circa 2008 Construction

MDE SWM Law Revised 2007

- Still concerned about water quality degradation, ground water recharge, low flow volume during dry periods, and accelerated stream erosion.
- Environmental Site Design(ESD) to the Maximum Extent Practicable (MEP) is required.
- Planning of development requires evaluating all of the factors of a site including soils and environmental impacts and their preservation. Therefore planners, landscape architects, stormwater engineers, and soil engineers need to be on the design team.
- Total water volume treated is similar to the 2000 Maryland Design manual.
- Water Quality Volume(WQv) combined where practical with Channel Protection Volume (CPv) i.e. 1 year extended detention, in small, numerous devices with smaller contributing drainage areas.

Prince George's County ESD Matrix: Alternative Surfaces and Disconnections – Circa 2009

Environmental Site Design
Maximum Extent Practicable Determination

		A-1 Green Roof	A-2 Permeable Concrete	A-3 Reinforced Turf (interlocking Sturctural Units)	N-1 Disconnection of Rooftop Runoff	N-2 Disconnection of Non-Rooftop Runoff	N-3 Sheetflow to Conservation Area
Slope Limitations		None	< 5 %	< 5 %	< 5 % unless terraces or berms	< 5 % unless terraces or berms	< 5 % or with level spreaders
Soils	A	Yes	Yes	Yes	Yes	Yes	Yes
	B	Yes	Yes	Yes	Yes	Yes	Yes
	C	Yes	Yes	Yes	Yes	Yes	Yes
	D	Yes	No [6]	No [6]	Yes	Yes	Yes
	Marlboro	Yes	No	No	Yes	Yes	Yes
	Compacted Fill	Yes	No [6]	No [6]	Yes	Yes	Yes
High Groundwater		Yes	Yes [2]	Yes	Yes	Yes	Yes
Maint. Resp.	DPWT	No	No	No	No	No	No
	Private	Yes	Yes	Yes	Yes	Yes	Yes
Road R/W		No	No	No	No	Yes	Yes
Residential	> 1 ac lot	Not desirable	Yes [1]	Yes [1]	Yes	Yes	Yes
	>0.5 ac lot	Not desirable	Yes [1]	Yes [1]	Yes	Yes	Yes
	<0.5 ac lot	Not desirable	Yes [1]	Yes [1]	Yes	Yes	Yes
	Multi	Not desirable	Yes [1]	Yes [1]	Yes	Yes	Yes
Commercial		Yes	Yes	Yes	Yes	Yes	Yes
Stormwater Hotspot		Yes	No	No	No [7]	No [7]	No
Drainage Area	<500 sf	Yes	Yes	Yes	Yes	Yes	Yes
	<1,000 sf	Yes	Yes	Yes	No	Yes	Yes
	<10,000 sf	Yes	Yes	Yes	No	No	Yes
	Other		Yes [3]				
Notes			Permeable asphalt not permitted.				Conservation area min 20,000 sf., min. width 50 ft.

Footnotes:
1 Acceptable for pedestrian walkways, parking lots, driveways, plazas and access roads.
2 Facility subbase must be a minimum 4' above high water table.
3 Facilities shall be designed as infiltration practices, as outlined in Appendix D.13 in the MD Design Manual.
4 Special design required. Standard rain barrel not acceptable.
5 Not acceptable on soils that have low shear strength, or identified as "slough prone" or "landslide prone."
6 If designed per County detail, then Yes.
7 If discharge is beyond hotspot use, the Yes.
8 Pretreatment and soil testing to verify infiltration rates are required for drainage areas larger than 10,000 sf.

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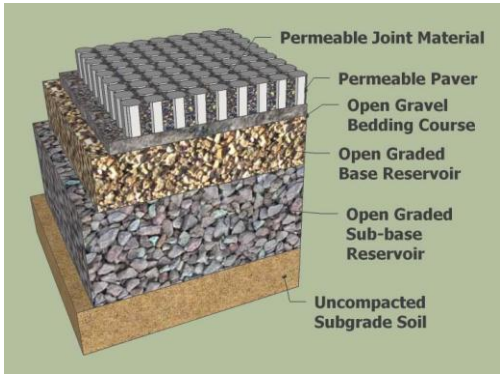
ESD Menu – Alternative Surfaces



Source: Chesapeake Stormwater and American Wick Drain Corp.

Source: Nevue-Ngan Associates

Source: Invisible Structures, Inc. and Terrafirm Enterprises

A-1
Green Roofs

A-2
Permeable Concrete, Permeable Asphalt and Interlocking Pavers

A-3
Reinforced Turf

Prince George's County - ESD Matrix: Micro Practices – Circa 2009

Environmental Site Design
Maximum Extent Practicable Determination

		M-1 Rainwater Harvesting (Rain Barrell)	M-2 Submerged Gravel Wetlands	M-3 Landscape Infiltration	M-4 Infiltration Berms	M-5 Dry Wells
Slope Limitations		None	<2%	sheet flow or level spreader	up to 10 %	up to 20 %
Soils	A	Yes	If lined	Yes	Yes [5]	Yes
	B	Yes	If lined	Yes	Yes [5]	Yes
	C	Yes	Yes	No	Yes [5]	No
	D	Yes	Yes	No	Yes [5]	No
	Marlboro	No	If lined	No	No	No
	Compacted Fill	Yes	No	No	No	No
High Groundwater		Yes	Yes	Yes [2]	Yes	Yes [2]
Maint. Resp.	DPWT	No	No	No	No	No
	Private	Yes	Yes	Yes	Yes	Yes
Road R/W		No	No	No	No	No
Residential	> 1 ac lot	Yes	Common areas only	Common areas only	Common areas only	Yes
	>0.5 ac lot	Yes	Common areas only	Common areas only	Common areas only	Yes
	<0.5 ac lot	Yes	Common areas only	Common areas only	Common areas only	Yes
	Multi	Yes	Common areas only	Common areas only	Common areas only	Yes
Commercial		Yes	Yes	Yes	Yes	Yes
Stormwater Hotspot		Rooftop runoff only	Yes with Liner	No	No	No
Drainage Area	<500 sf	Yes	No	Yes	Yes	Yes
	<1,000 sf	Yes [4]	No	Yes	Must sheet flow into berm	Yes
	<10,000 sf	Yes [4]	No	Yes	Must sheet flow into berm	Yes [3]
	Other		1 Ac Minimum	Yes [8]		
Notes					Used to augment other devices, or for pretreatment	Setback 100' from 15% fill slopes, 200' from 25% fill slopes

Footnotes:
1 Acceptable for pedestrian walkways, parking lots, driveways, plazas and access roads.
2 Facility subbase must be a minimum 4' above high water table.
3 Facilities shall be designed as infiltration practices, as outlined in Appendix D.13 in the MD Design Manual.
4 Special design required. Standard rain barrel not acceptable.
5 Not acceptable on soils that have low shear strength, or identified as "slough prone" or "landslide prone."
6 If designed per County detail, then Yes.
7 If discharge is beyond hotspot use, the Yes.
8 Pretreatment and soil testing to verify infiltration rates are required for drainage areas larger than 10,000 sf.

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Environmental Site Design
Maximum Extent Practicable Determination

		M-6 Micro-Bioretention	M-7 Rain Gardens	M-8 Grass Swales	M-8 Bio Swales	M-8 Wet Swales
Slope Limitations		< 5 % or with level spreaders	< 5 % unless terraces or berms	1 % min, 4 % max	1 % min, 4 % max	1 % min, 4 % max
Soils	A	Yes	Yes	Yes	Yes	No
	B	Yes	Yes	Yes	Yes	No
	C	Yes, with underdrain	Yes	Yes	Yes, with underdrain	Yes
	D	Yes, with underdrain	No	Yes	Yes, with underdrain	Yes
	Marlboro	Yes, with underdrain	No	Yes, if flow is < 3 cfs	Yes, with underdrain	No
	Compacted Fill	Yes, with underdrain	No	Yes	Yes, with underdrain	No
High Groundwater		Yes, above	Yes, 2' above	Yes	Yes, with underdrain	Yes
Maint. Resp.	DPWT	No	No	Yes	Yes	No
	Private	Yes	Yes	Yes	Yes	Yes
Road R/W		No	No	Rural - open section only	No	No
Residential	> 1 ac lot	Common areas only	Common areas only	Yes	Common areas only	Common areas only
	>0.5 ac lot	Common areas only	Common areas only	Yes	Common areas only	Common areas only
	<0.5 ac lot	Common areas only	Common areas only	No	Common areas only	Common areas only
	Multi	Common areas only	Common areas only	No	Common areas only	Common areas only
Commercial		Yes	Yes	Yes	Yes	Yes
Stormwater Hotspot		No	No	No	No	No
Drainage Area	<500 sf	Yes	Yes	Yes	Yes	Yes
	<1,000 sf	Yes	Yes	Yes	Yes	Yes
	<10,000 sf	Yes	Commercial max 10,000 sf	Yes	Yes	Yes
	Other	Max 0.5 ac	Residential max 2,000 sf			
Notes		4' above groundwater if infiltrating.				

Footnotes:
1 Acceptable for pedestrian walkways, parking lots, driveways, plazas and access roads.
2 Facility subbase must be a minimum 4' above high water table.
3 Facilities shall be designed as infiltration practices, as outlined in Appendix D.13 in the MD Design Manual.
4 Special design required. Standard rain barrel not acceptable.
5 Not acceptable on soils that have low shear strength, or identified as "slough prone" or "landslide prone."
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ESD Menu – Micro Practices

Not shown: M-2 Submerged Gravel Wetlands, M-4 Infiltration Berms, M-8 Wet Swales.

Micro Bioretention

ESD Impacts to Sites

- Space required to provide stormwater control - estimated at 15 - 20% of site area for commercial/retail if alternative surfaces, green roofs or cisterns are not used.

- If surface devices such as microbioretention, swales, etc. are the only acceptable control, there will be a reduction in available land for site improvements, building SF, or residential units for less dense developments.

- ESD green space is usually not available for passive/active recreation measures, therefore structural measures would be required.

- Areas previously set aside for SWM may be used to help make up for density loss elsewhere.

ESD Impacts to Sites

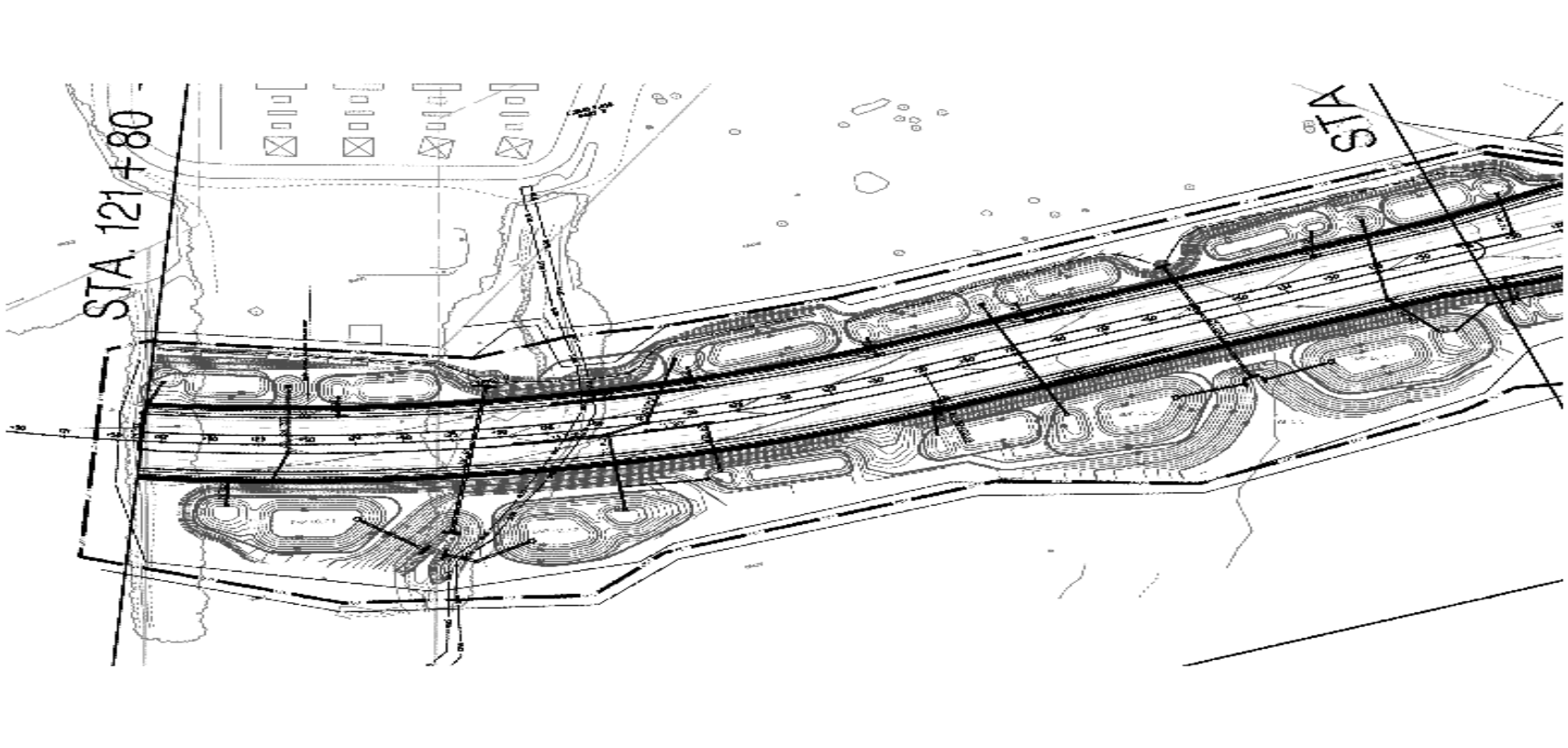
- The denser the development, such as mixed use, the more difficult it is to achieve ESD without structural practices and still maintain density. i.e. Smart Growth.

- Impediments to ESD need to be removed, such as allowing narrower roads or drive aisles, reduce parking space size, allow more storm flow in yards, etc. The basic goal is to reduce impervious area. If the impervious area is smaller, less treatment area is required for the smaller impervious area, therefore more green space is available for the devices.

- Requires buy-in by ultimate user. i.e. Education of benefits to the public for acceptance and maintenance.

- Linear projects approaches 100% increase of right of way to accommodate practices.

Linear Project



Don't let ESD be the next mandated visual clutter in the landscape.

General Design Considerations

- Select devices starting with low hanging fruits, i.e. inexpensive devices such as dry wells. Dry wells are also effective as they don't take up space that can be used for other functions.

- Try to use an area for more than one function. i.e. porous paving or pavers serve two purposes, parking or sidewalks and water quality. This applies also when trying to meet landscape and forest conservation requirements as the two are not mutually exclusive.

- For commercial sites use porous paving and resizing of landscape islands that can be used for micro-bioretention.

- Consider cisterns that can double storage areas for irrigation of landscaping or water reuse in a building.

General Design Considerations – Con'd

- Designs need to be constructible. Too sharp of curves too make a device more natural makes construction far more difficult and expensive.
- How can maintenance be assured so it easy to maintain. What type of equipment will be used, access, maintenance schedule.
- Lack of maintenance means all the money spent to construct ESD is just being washed into the Bay along with pollutants. It also means the Bay will not get cleaner.
- Currently, the made soil for rain gardens, bio retention facilities is costing $100 per cubic yard. Cheaper alternatives need to be found.
- Design manuals need to be updated to incorporate the new ESD strategies and not just pasted into a current manual

Water Quality Features Guidance Menu

TYPE	SIZE OF FEATURE	PAVED AREA TREATED (WQv ONLY)	PAVED AREA TREATED (ESD to the MEP)
Micro-Bioretention (Filter Area Only)	500 SF	14,000 SF	6,000 SF
Dry Well	4′ x 5′ x 5′	500 SF	200 SF
Rain Barrel	55 Gal	90 SF	40 SF
Cisterns	1,000 CF	12,000 SF	4,600 SF
Street Tree System (Planter boxes)	120 SF	2,500 SF	1,000 SF
Green Roof – 8″ Thick	1,000 SF	2,000 SF	650 SF
Porous Paving/Pavers	12″ thick /1,000 SF	2,600 SF	1,000 SF

- Assumes B soil and 6″ dry storage depth and 3 ‘ deep made soil material for Micro Bioretention and Street Tree System.
- Assume 100% impervious contributing drainage area

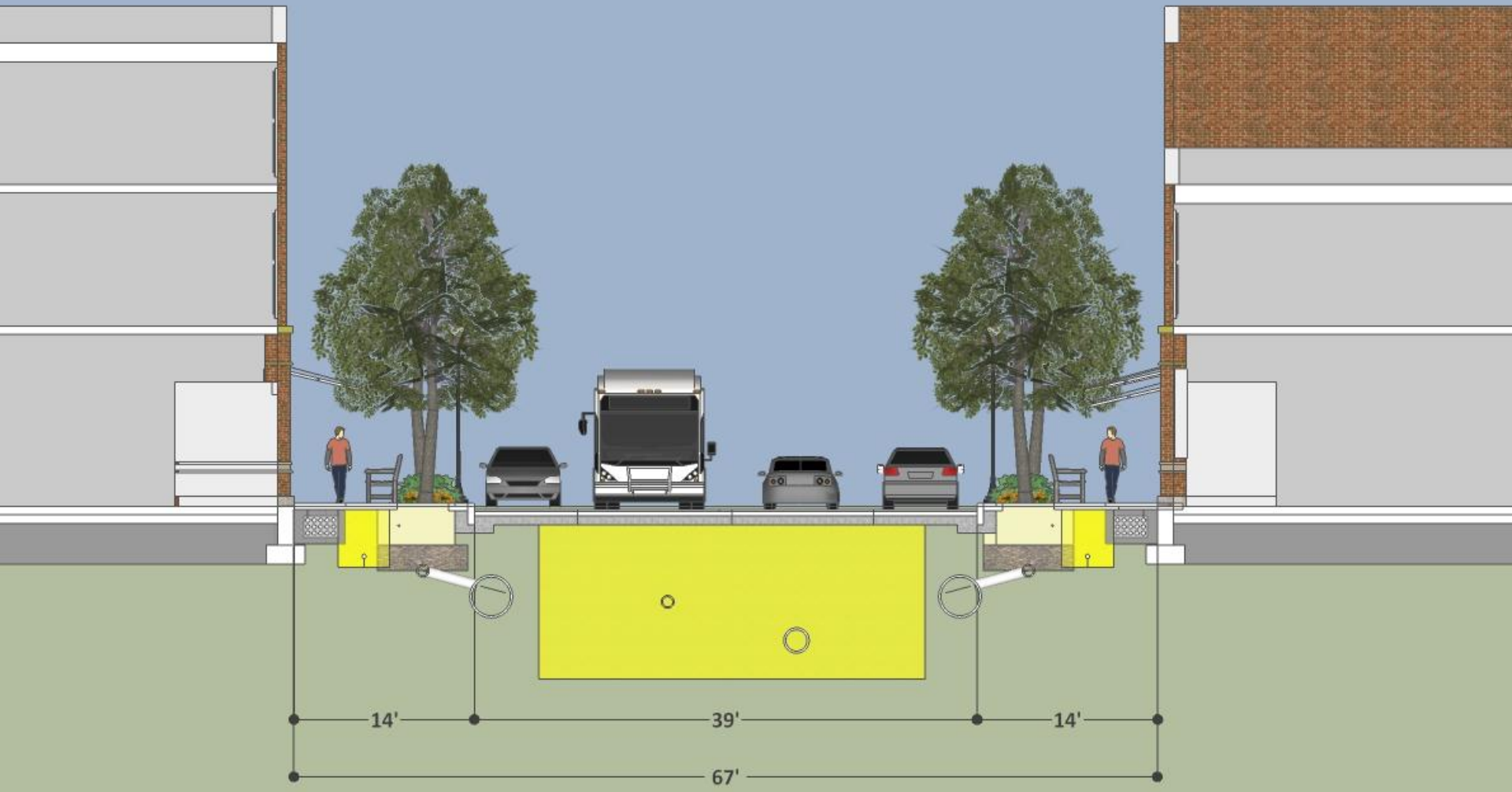
B Soils

Water Quality Features Guidance Menu

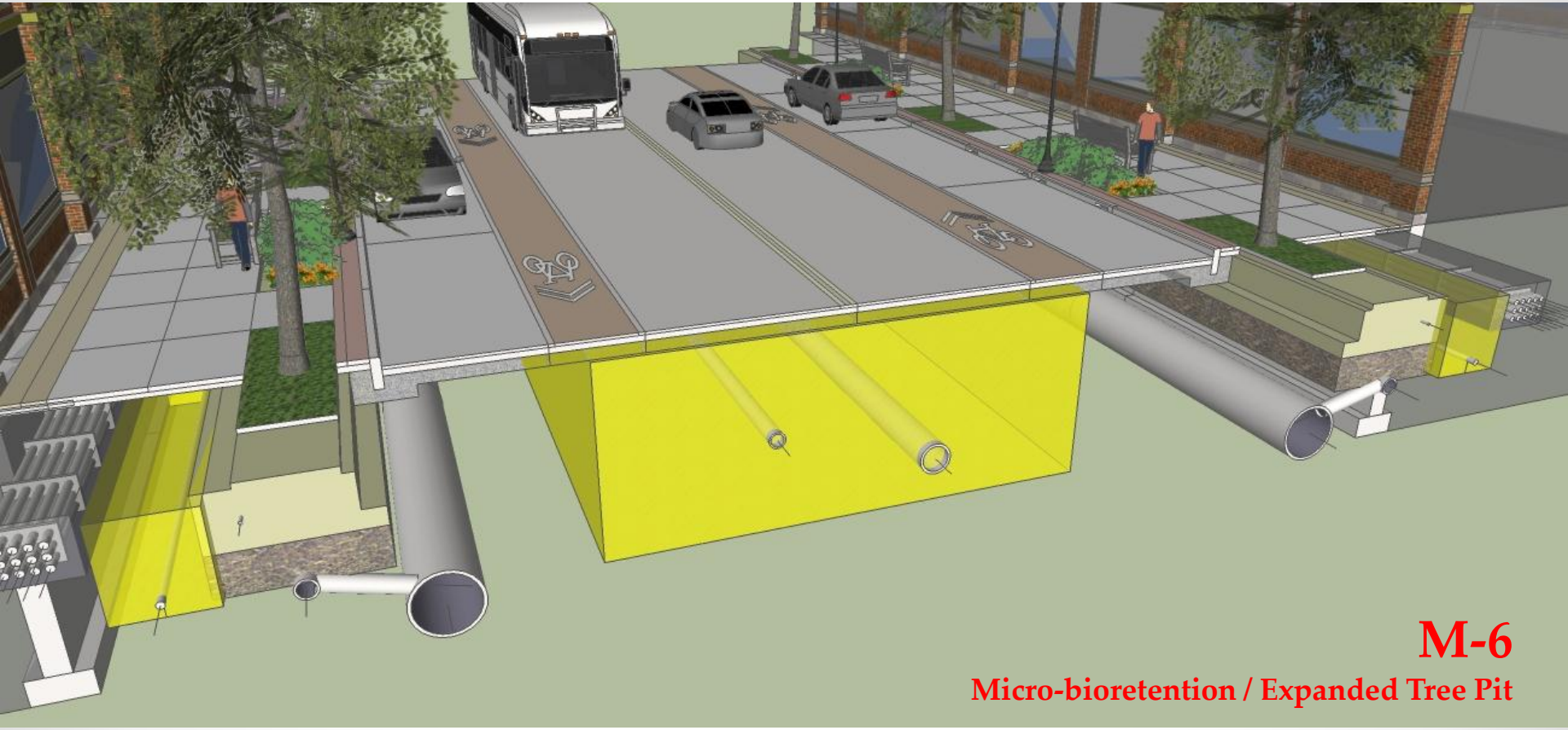
TYPE	SIZE OF FEATURE	PAVED AREA TREATED (WQv ONLY)	PAVED AREA TREATED (ESD to the MEP)
Micro-Bioretention (Filter Area Only)	500 SF	15,000 SF	7,000 SF
Dry Well	4′ x 5′ x 5′	500 SF	230 SF
Rain Barrel	55 Gal	90 SF	45 SF
Cisterns	1,000 CF	12,000 SF	5,400 SF
Street Tree System (Planter boxes)	120 SF	3,300 SF	1,500 SF
Green Roof – 8″ Thick	1,000 SF	2,000 SF	650 SF
Porous Paving/Pavers	12″ thick /1,000 SF	2,100 SF	1,000 SF

- Assumes C soil and 6″ dry storage depth and 3 ‘ deep made soil material for Micro Bioretention and Street Tree System.
- Assumes 100% impervious contributing drainage area

C Soils


14'
39'
14'
67'

ESD Menu – Micro Practices

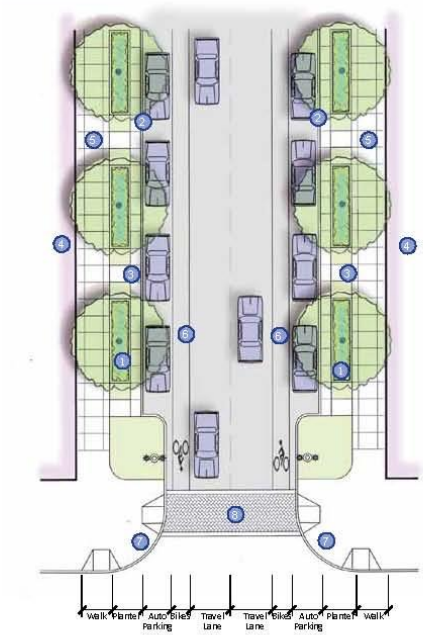


Micro Bioretention – Cul de Sac

Micro Bioretention - Suburban

4.3 Commercial Main Streets

Stormwater Planters with On-Street Parking



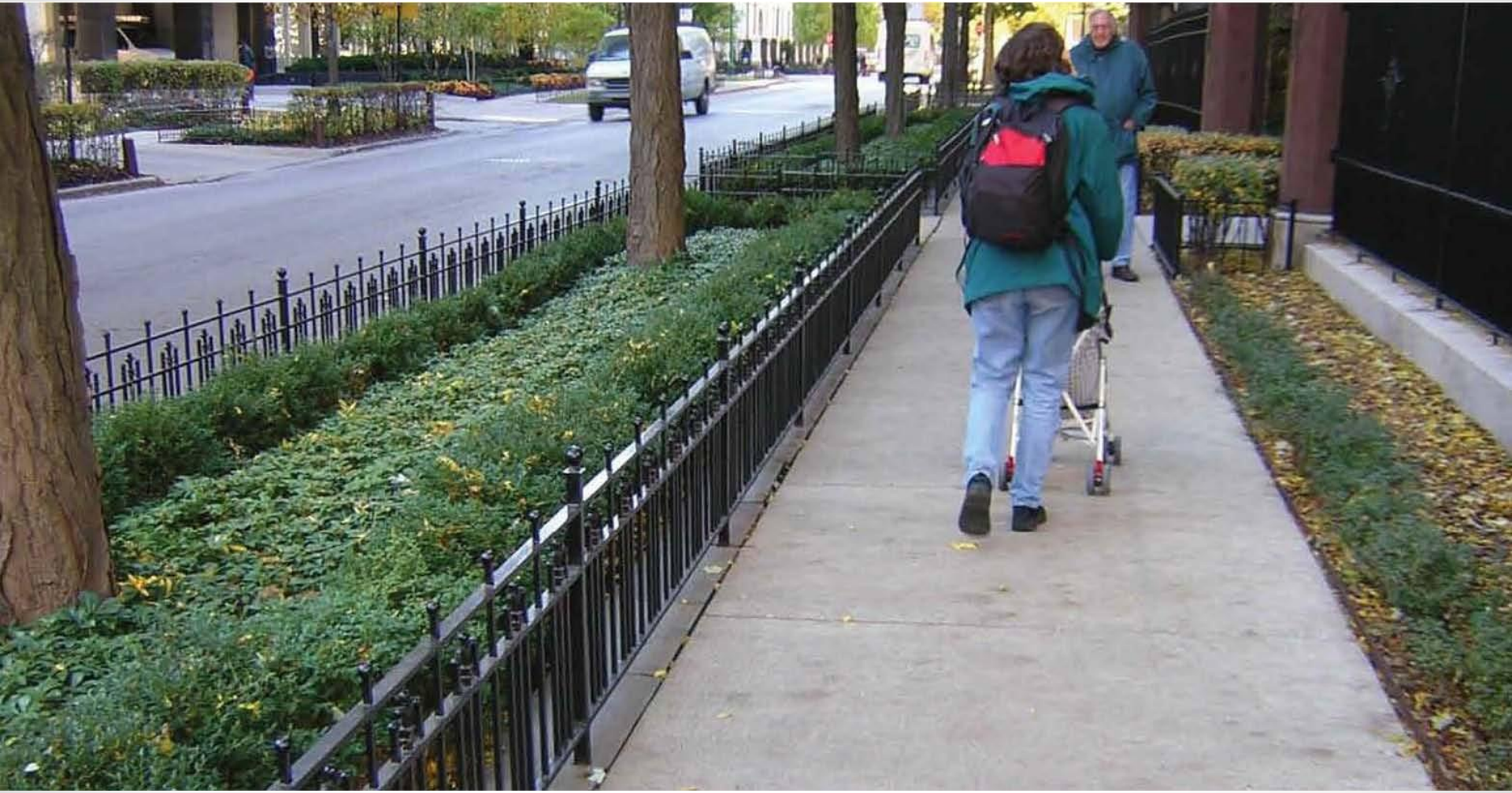
Key Design Elements

1. Stormwater planters allow for on-street parking by providing an egress zone for people to access their vehicles and the sidewalk.
2. Grated curb cuts allow runoff to enter/exit the stormwater facility.
3. On-street parking zone.
4. Building frontage.
5. Sidewalk zone.
6. Bike lanes.
7. Accessible ADA ramps at street intersection.
8. Curb extensions narrow the pedestrian crossing distance, but allow two-way vehicular traffic

▲ *EXAMPLE: A residential "curbless" street example that allows stormwater runoff to sheet flow into a continuous green gutter system. The sidewalk is also constructed with pervious concrete.*

Source: Environmental Services, San Mateo County, CA and Nevue-Ngan Associates

Micro Bioretention - Suburban



Source: Environmental Services, San Mateo County, CA and Nevue-Ngan Associates

Micro Bioretention - Urban

Source: Environmental Services, San Mateo County, CA and Nevue-Ngan Associates

Micro Bioretention - Urban

Source: Environmental Services, San Mateo County, CA and Nevue-Ngan Associates

WIP Cost Information

Table 2. Preliminary scenario for urban impervious retrofits to meet County MS4 permit by 2017

BMP type	Impervious area (acres)	Pervious area (acres)	Estimated cost per impervious acre ($/acre)	Estimated total cost
County				
Bioretention areas	305	1,728[a]	$100,000	$30,500,000
Filtering practices	379	2,148[a]	$100,000	$37,900,000
Infiltration practices	1,124	6,369[a]	$100,000	$112,400,000
Filtration ponds	725	4,108[a]	$35,000	$25,375,000
Wetland restoration	251[b]	199[b]	$82,669[c]	$20,750,000
Stream restoration	645[b]	3,655[a]	$55,764[c]	$35,968,000
Forest buffer	484[d]	939[e]	$11,763[c]	$5,693,273
Dry pond retrofits	1,222[b]	3,477[b]	$15,712[c]	$19,200,000
Urban nutrient management	1,222[d]	11,108[e]	Minimal	$100,000
Impervious area disconnect	975[e]		$30,000	$29,235,000
State phosphorus fertilizer reduction	tbd[f]	tbd	Minimal	Minimal
Sum for County	7,109	33,732	$44,607	$317,121,273
Municipal without Bowie				
Bioretention areas	75	175[a]	$100,000	$7,500,000
Filtering practices	89	208[a]	$100,000	$8,900,000
Infiltration practices	329	768[a]	$100,000	$32,900,000
Filtration ponds	216	504[a]	$35,000	$7,560,000
Urban nutrient management	111[d]	1,232[e]	Minimal	Included in above
Impervious area disconnect	108[e]		$30,000	$3,240,000
State phosphorus fertilizer reduction	tbd	tbd	Minimal	Minimal
Sum for Municipal without Bowie	928	2,886	$64,771	$60,100,000
County and Municipal (without Bowie)				
Total	8,037	36,618	$46,936	$377,221,273

Notes:

a. Pervious area estimated from amount of impervious land treated.

b. Known number of acres.

c. Estimated cost per acre is based on known total projected project cost.

d. Impervious area is calculated from equivalent impervious acres per MDE's June 2011 draft document, Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated.

e. Estimated/assumed amount.

f. These amounts will be determined by the state.

WIP Cost Information

Table 3. Preliminary additional BMP scenario for urban impervious retrofits for 2017–2020				
BMP type	Impervious area (acres)	Pervious area (acres)	Estimated cost per impervious acre ($/acre)	Estimated total cost
County				
Bioretention areas	691	3,916[a]	$85,000	$58,735,000
Filtering practices	275	1,558[a]	$85,000	$23,375,000
Infiltration practices	675	3,825[a]	$85,000	$57,375,000
Filtration ponds	1,265	7,168[a]	$35,000	$44,275,000
Wetland restoration	502	398	$82,669[b]	$41,500,000
Stream restoration	1,290	7,310	$55,764[b]	$71,936,000
Forest buffer	484	2,743	$11,763[b]	$5,693,273
Impervious area disconnect	975[c]		$30,000	$29,235,000
Sum for County	6,157	26,918		$332,124,273
Municipal without Bowie				
Bioretention areas	165	385[a]	$85,000	$14,025,000
Filtering practices	85	198[a]	$85,000	$7,225,000
Infiltration practices	216	504[a]	$85,000	$18,360,000
Filtration ponds	716	1,671[a]	$35,000	$25,060,000
Impervious area disconnect	108[c]		$30,000	$3,240,000
Sum for Municipal without Bowie	1,290	2,758		$67,910,000
County and Municipal (without Bowie)				
Total	7,447	26,918	$53,721	$400,034,273
Notes:				
a Pervious area estimated from amount of impervious land treated.				
b. Estimated cost per acre is based on known total projected project cost from 2017 scenario.				
c. Estimated/assumed amount.				

Urban nutrient management was represented in Table 2. Once installed, structural BMPs and impervious disconnection will begin performing towards required pollutant reduction with appropriate maintenance. Urban nutrient program is an institutional control that should continue to be implemented continuously to meet required pollutant reduction and is only needs to be input into the model/MAST once, as reported in Table 2.

Maintenance of ESD Devices

- **Lack of maintenance means investment by County Agencies (Taxpayers) as part of the WIP requirements or developers for new or redevelopment projects is being wasted.**

- **Lack of maintenance could also include removal of the device by owner, bankruptcy, diversion around device, device failure, and other means that prevent the device from meeting it's design intent.**

- **Lack of maintenance means the Chesapeake Bay cleanup goals will not be met.**

WIP Cost Information

DRAFT FINAL REPORT (October 10, 2011)

Table 2b

County SWBMP Unit Cost Development – Part 2, Annual and Intermittent Costs

Planning Level Unit Cost Development for Stormwater Best Management Practices (BMPs)

PART 2: Annual Maintenance Costs

Stormwater BMP	Routine and Intermittent Maintenance Costs			Average Annual County Implementation Costs[3]	Maintenance, Intermittent Repair, and Implementation Costs[4]	
	Annual Routine Maintenance[1]	Average Annual Intermittent Maintenance[2]	Total Annual Maintenance Costs		Total (Over 20 Years)	Average Annual (Over 20 Years)
Impervious Urban Surface Reduction	$ 875	$ -	$ 875	$ 10.34	$ 17,707	$ 885
Urban Forest Buffers	$ 600	$ 600	$ 1,200	$ 10.34	$ 24,207	$ 1,210
Urban Grass Buffers	$ 430	$ 430	$ 860	$ 10.34	$ 17,407	$ 870
Urban Tree Planting	$ 600	$ 600	$ 1,200	$ 10.34	$ 24,207	$ 1,210
Wet Ponds and Wetlands (New)	$ 371	$ 371	$ 742	$ 20.67	$ 15,253	$ 763
Wet Ponds and Wetlands (Retrofit)	$ 371	$ 371	$ 742	$ 20.67	$ 15,253	$ 763
Dry Detention Ponds (New)	$ 600	$ 600	$ 1,200	$ 31.01	$ 24,620	$ 1,231
Hydrodynamic Structures (New)	$ 1,750	$ 1,750	$ 3,500	$ 31.01	$ 70,620	$ 3,531
Dry Extended Detention Ponds (New)	$ 600	$ 600	$ 1,200	$ 31.01	$ 24,620	$ 1,231
Dry Extended Detention Ponds (Retrofit)	$ 600	$ 600	$ 1,200	$ 31.01	$ 24,620	$ 1,231
Infiltration Practices w/o Sand, Veg. (New)	$ 418	$ 418	$ 835	$ 31.01	$ 17,320	$ 866
Infiltration Practices w/ Sand, Veg. (New)	$ 438	$ 438	$ 875	$ 31.01	$ 18,120	$ 906
Filtering Practices (Sand, above ground)	$ 700	$ 700	$ 1,400	$ 31.01	$ 28,620	$ 1,431
Filtering Practices (Sand, below ground)	$ 800	$ 800	$ 1,600	$ 31.01	$ 32,620	$ 1,631
Erosion and Sediment Control	$ -	$ -	$ -	$ 10.34	$ 207	$ 10
Urban Nutrient Management	$ -	$ -	$ -	$ 31.01	$ 620	$ 31
Street Sweeping	$ 431	$ -	$ 431	$ 20.67	$ 9,030	$ 451
Urban Stream Restoration	$ -	$ 860	$ 860	$ 31.01	$ 17,820	$ 891
Bioretention (New - Suburban)	$ 750	$ 750	$ 1,500	$ 31.01	$ 30,620	$ 1,531
Bioretention (Retrofit - Highly Urban)	$ 750	$ 750	$ 1,500	$ 31.01	$ 30,620	$ 1,531
Vegetated Open Channels	$ 400	$ 200	$ 600	$ 10.34	$ 12,207	$ 610
Bioswale (New)	$ 600	$ 300	$ 900	$ 31.01	$ 18,620	$ 931
Permeable Pavement w/o Sand, Veg. (New)	$ 1,089	$ 1,089	$ 2,178	$ 10.34	$ 43,767	$ 2,188
Permeable Pavement w/ Sand, Veg. (New)	$ 1,525	$ 1,525	$ 3,049	$ 10.34	$ 61,191	$ 3,060

[1] Annual routine maintenance costs over 20 years; assumes a 3% discount rate, but also a 3% annual increase in maintenance cost which washes out the effect of discounting resulting in a constant present value annual cost throughout the 20 year period.

[2] Intermittent/corrective maintenance tasks are those that accrue every 3 to 5 years; these are averaged here over the 20 year period.

[3] Average annual county cost of inspecting and monitoring stormwater BMPs and enforcing construction and maintanance standards.

[4] Combined annual operating, implementation, and maintenance costs.

"Costs of Stormwater Management Practices in Maryland Counties" by Dennis King and Patrick Hagan

Bioretention (Slide 11) – March 2008

Bioretention – September 2009

Bioretention – April 2011

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