Module 4 – LID BMP Toolbox

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Learning Objective 4.1

- **Review Nonstructural Low Impact Development (LID) Best Management Practices (BMPs).**

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Nonstructural

What does nonstructural mean?

The primary LID characteristic of nonstructural BMPs is preventing stormwater runoff from the site. This differs from the goal of structural BMPs which is to help mitigate stormwater-related impacts after they have occurred.

More specifically, nonstructural BMPs take broader planning and design approaches, which are less "structural" in their form. Many nonstructural BMPs apply to an entire site and often to an entire community, such as wetland protection through a community wetland ordinance. They are not fixed or specific to one location..

Conceptual plan using conservation design principles
Source: EPA

Nonstructural LID BMPs

The nonstructural BMPs are:

- Minimize Total Disturbed Area
- Preserve Natural Flow Pathways and Patterns
- Protect Riparian Buffer Area
- Protect Sensitive Areas
- Cluster Development
- Minimize Soil Compaction
- Reduce Impervious Surfaces
- Site Fingerprinting

Section overview:

- Overviews of each BMP,
- The benefits of using nonstructural BMPs,
- Considerations for each BMP

Minimize Total Disturbed Area

Key Design Features

- Identify and avoid special value and environmentally sensitive areas (See Protect Sensitive Areas BMP)
- Maximize undisturbed open space
- Minimize disturbance lot-by-lot
- Maximize soil restoration and restore soil permeability
- Minimize and control construction traffic areas
- Minimize and control construction stockpiling and storage areas

Benefits

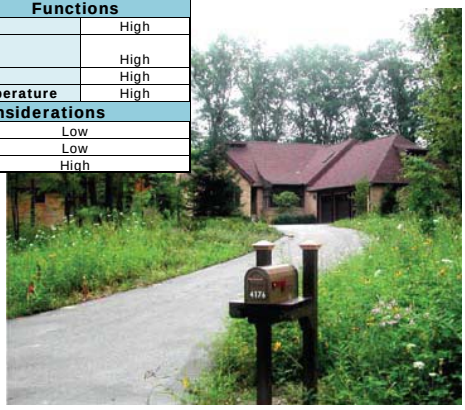
- Reduced runoff volume
- Reduced peak rates
- High water quality benefits
- Increased infiltration capacity
- Provides healthy environment for vegetation

Limitations

- Difficult to achieve on small development sites

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	High
Commercial	Yes	Groundwater Recharge	High
Ultra Urban	Limited	Peak Rate	High
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Limited	TSS	High
Highway / Road	Limited	TP	High
Recreational	Yes	NO3	High
		Temperature	High
Additional Considerations			
Cost		Low	
Maintenance		Low	
Winter Performance		High	

Minimizing disturbance to existing trees during residential construction
Source: Insite Design Studio, Inc.



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Minimize Total Disturbed Area

Best applied in:

Lower density single-family developments

Top right:Woodlands Protected through Minimum Disturbance Practices
Source: SEMCOG
Lower left: Disturbance of native trees minimized during residential construction
Source: SEMCOG
Lower right: Aerial of The Woodlands 2000
Source: DWGPhotos

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Minimize Total Disturbed Area

Maintenance
Avoiding disturbance to natural areas benefits the short term developer and the long-term owner by minimizing time and money needed to maintain artificial surfaces.

Cost
- Reduced costs of minimized grading and earthwork
- Increased costs in site preparation
- Reduced costs in site clearing

View of existing wetland
Source: Longmeadow Development

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Preserve Natural Flow Pathways

Variations
- Check dams to slow velocity
- Earthen berms for additional storage
- Additional native vegetation for increased infiltration

Key Design Features
- Identifies and maps natural drainage features (e.g., swales, channels, ephemeral streams, depressions, etc.)
- Uses natural drainage features to guide site design
- Distributes non-erosive surface flow to natural drainage features
- Keeps non-erosive channel flow within drainage pathways
- Uses native vegetative buffer

Benefits
- Maximizes natural hydrological functions
- Reduces structural management practices
- Reduces management costs

Limitations
- Minimal water quality benefits

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low/Med
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	No	Peak Rate	Med/High
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	Low/Med
Highway/Road	Yes	TP	Low/Med
		NO3	Low
Recreational	Yes	Temperature	Low

Additional Considerations	
Cost	Low
Maintenance	Low/Med
Winter Performance	Low/Med

Natural flow pathway in residential development
Source: Brandywine Conservancy, Environmental management Center, 1998

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Preserve Natural Flow Pathways

Description and Function:

Identify, protect, and use natural drainage Features such as:

- Swales
- Depressions
- Watercourses

Protecting naturally vegetated drainage features benefits by:

- Slowing runoff
- Filtration
- Infiltration
- Evapotranspiration
- Providing open space
- Providing wildlife habitat
- Improving site aesthetics
- Improving property values

Source: mitula

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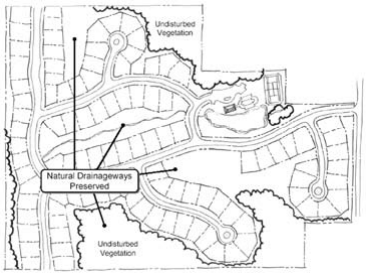
Preserve Natural Flow Pathways

Maintenance

- require very little maintenance
- periodic inspections

Cost

- significant construction cost savings
- results in less disturbance, clearing, and earthwork
- requires less revegetation
- reduces the need and size of costly, engineered stormwater conveyance systems
- reduces and even eliminates the need for stormwater management facilities (structural BMPs), lowering costs even more.



Schematic of a site design protecting natural drainage features

Native prairie vegetation in natural flow pathway

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Protect Riparian Buffer Area

Key Design Features

- Physical protection
- Protection through planning tools

Benefits

- Improves water quality
- Reduces runoff velocities
- Enhances site aesthetics, habitat
- Reduce shoreline and bank erosion
- Improves flood control
- Reduces water temperature

Limitations

- Limited in reducing total runoff volumes
- Size of lot and/or development site may reduce ability to protect riparian buffer

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low/Med
Commercial	Yes	Groundwater Recharge	Low/Med
Ultra Urban	Limited	Peak Rate	Low/Med
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	High
Highway / Road	Limited	TP	High
Recreational	Yes	NO3	Medium
		Temperature	High
Additional Considerations			
Cost		Low/Med	
Maintenance		Low	
Winter Performance		High	

Maintaining a riparian buffer
Source: JFNew

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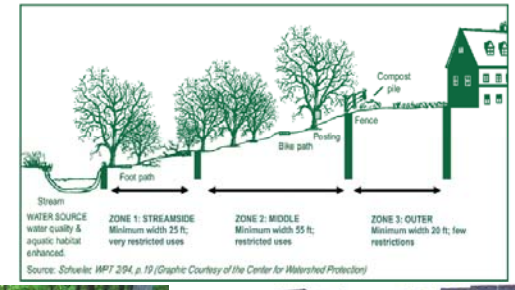
Protect Riparian Buffer Area



Buffer width recommendations
Source: Schueler, Watershed Protection Techniques, 1994 (Graphic courtesy of the Center for Watershed Protection)

Source: Macomb County Public Works Office

Combination of established and new riparian vegetation
Source: Huron River Watershed Council

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Protect Riparian Buffer Area

Cost
Reduce land available for development
HOWEVER
Riparian areas are located in wetlands or floodplains

Source: Iowa State

Source: Iowa Pathways

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Protect Sensitive Areas

Key Design Features

- Identify and map the following: floodplains, riparian areas, wetlands, woodlands, prairies, natural flow pathways, steep slopes, and other sensitive areas.
- Identify and map potential development areas

Benefits

- Improved water quality
- Mitigation of runoff volume and peak rates

Limitations

- Difficult to implement on smaller sites

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low/Med
Commercial	Yes	Groundwater Recharge	Low/Med
Ultra Urban	Limited	Peak Rate	Low/Med
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	High
Highway/Road	Limited	TP	High
		NO3	Medium
Recreational	Yes	Temperature	High
Additional Considerations			
Cost		Low/Med	
Maintenance		Low	
Winter Performance		High	

Protection of existing native woodlands and wetlands, Kalamazoo, MI
Source: Fishbeck, Thompson, Carr & Huber, Inc.

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Protect Sensitive Areas

Resource
Lakes and Streams
Designated Trout Lakes/Streams and Natural Rivers
Wetlands Indicators
Flood Prone Areas
Wellhead Protection Areas
Woodlands
Parks and Recreation Areas
Historic Sites
Heritage Routes and Natural Beauty Roads
Historic Bridges
Nonmotorized Facilities
Sand Dunes

Data Sources for Environmentally Sensitive Areas
Source: SEMCOG

Left: Trail through prairie restoration at the park
Source: Fishbeck, Thompson, Carr & Huber, Inc.
Below: The Woodlands
Source: Lincoln Manufacturing, Inc.

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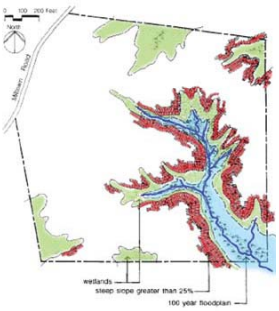
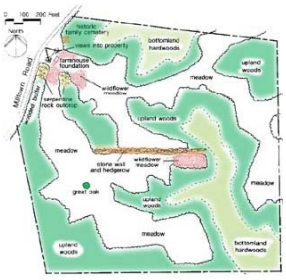
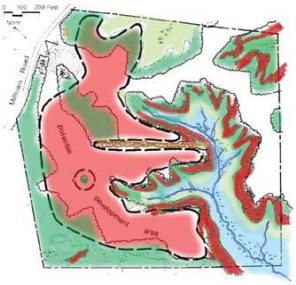
Protect Sensitive Areas



Map of sensitive areas



Map of secondary resources



Potential development area map

Source: Arndt, Randall G. 1997

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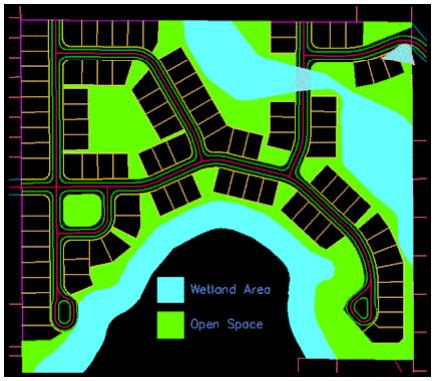
Protect Sensitive Areas

Maintenance
- Varies

Cost
- Protecting sensitive areas results not only in cost savings, but also in water quality benefits.
- Development reduction – train BMPs (apply with cluster development BMP)



Cluster developments

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Cluster Development

Variations
- Clustering as an option
- Clustering mandated by the municipality
- Clustering with incentives such as density bonuses

Key Design Features
- Develop inventory
- Map sensitive areas
- Reduce total site disturbance and develop cluster plan
- Increase undisturbed open space

Benefits
- Reduces required infrastructure
- Increase open space
- Protects environmentally sensitive natural resources

Limitations
- Site specific based on land topography and individual conditions

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	High
Commercial	Yes*	Groundwater Recharge	High
Ultra Urban	Limited	Peak Rate	High
Industrial	Limited	**Stormwater Quality Functions**	
Retrofit	No	TSS	High
Highway/Road	No	TP	High
		NO3	High
Recreational	Limited	Temperature	High
Additional Considerations			
Cost		Low	
Maintenance		Low/Med	
Winter Performance		High	

Aerial view of cluster development in Ann Arbor, MI
Source: Atwell Hicks

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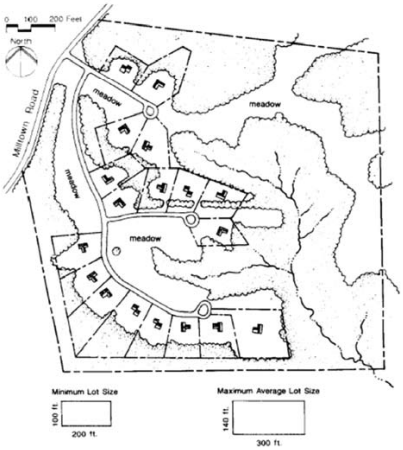
Cluster Development

Conventional development

Clustered development



Left and right source: Growing Greener: Putting Conservation into Local Codes. Natural Lands Trust, Inc. 1997

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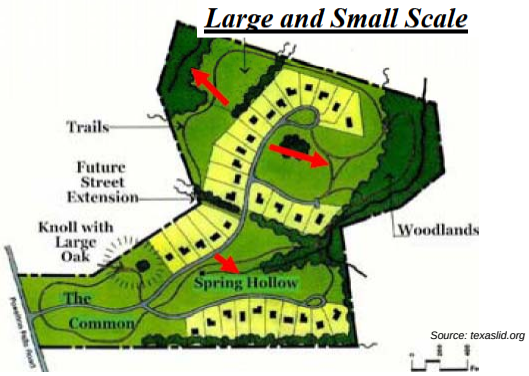
Clustering – Conservation Plans

Local Watershed and Natural Systems

- Forests
- Streams
- Wetlands
- Habitats
- Steep slopes
- Buffers
- Parks
- Scenic areas
- Trails
- Difficult soils
- Quality soils
- Minerals



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Clustering-Maintenance & Cost

Source: SEMCOG

Maintenance actives of open green space is determined by the use of the space.

- Preserved natural areas require little to no maintenance
- Open lawns require higher maintenance

Costs benefits include:

- Less land clearing and grading
- Less road and sidewalk construction (including curbing),
- Less stormwater collection system construction
- Other economies of scale

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Minimize Soil Compaction

Key Design Features

- Reduce disturbance through design and construction practices
- Limit areas of heavy equipment
- Avoid extensive and unnecessary clearing and stockpiling of topsoil
- Use top quality topsoil: maintain topsoil quality during construction

Benefits

- Increases infiltration capacity
- Provides healthy environment for vegetation
- Preserves low areas, which offer added benefit when runoff is directed there from impervious areas

Limitations

- Difficult to implement on small development sites

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Med/High
Commercial	Yes	Groundwater Recharge	Med/High
Ultra Urban	Limited	Peak Rate	Low/Med
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Limited	TSS	Med/High
Highway/ Road	Limited	TP	Med/High
		NO3	Low
Recreational	Yes	Temperature	Med/High
Additional Considerations			
Cost		Low/Med	
Maintenance		Low	
Winter Performance		Low/Med	

Minimizing disturbance of soil to protect wooded area
Source: City of Andover, Minnesota

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Minimize Soil Compaction

Healthy soils perform valuable stormwater functions

- Effectively cycling nutrients,
- Minimizing runoff and erosion,
- Maximizing water-holding capacity,
- Reducing storm runoff surges,
- Absorbing and filtering excess nutrients, sediments,and pollutants to protect surface and groundwater,
- Providing a healthy root environment,
- Creating habitat for microbes, plants, and animals, and reducing the resources needed to care for turf and
- Landscape plantings.

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Minimize Soil Compaction

Applications
Minimizing soil compaction can be performed at any land development site during the design phase. It is especially suited for developments where significant “pervious” areas (i.e., post-development lawns and other maintained landscapes) are being proposed.

Construction site disturbance showing grading and soil compaction
Source: SEMCOG

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Minimize Soil Compaction

Considerations

Early in a project's design phase, the designer should develop a soil management plan. The plan should clearly show the following:

1. **No disturbance areas.**
2. **Minimal disturbance areas.**
3. **Construction traffic areas.**
4. **Topsoil stockpiling and storage areas.**
5. **Topsoil quality and placement.**

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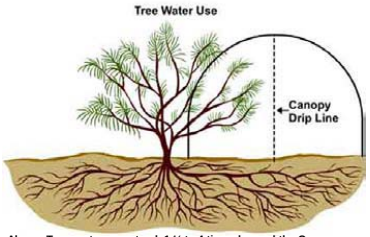
Minimize Soil Compaction

Maintenance

- Landscape vegetation, either retained or re-planted, will likely be healthier, have a higher survival rate, require less irrigation and fertilizer, and have better aesthetics.
- Mowing causes compaction



Above: Tree roots can extend 1 ½ to 4 times beyond the Canopy
(Source: UNCE 2009)

Cost

- Pro – significant construction cost savings
- Con – design costs may increase slightly

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Reduce Impervious Surfaces

Key Design

Features

Streets

- Evaluate traffic volumes and street parking requirements
- Consult with local fire department and road agencies
- If available, consider a private road ordinance as necessary to minimize width
- Minimize pavement widths and lengths by using alternative roadway layout, restricting on-street parking, minimizing cul-de-sac radii, and using permeable pavers

Parking Lots

- Evaluate parking requirements considering average demand as well as peak demand
- Consider smaller parking stalls and/or compact parking spaces
- Analyze parking lot layout to evaluate the applicability of narrowed traffic lanes and slanted parking stalls
- If appropriate, minimize impervious parking area by using overflow parking areas constructed of pervious paving materials

Lot Level

- Use maximum lot coverage requirements to manage the amount of impervious surfaces
- Reduce front yard setbacks to allow for shorter driveways
- Use alternative materials for patios, sidewalks, driveways, as appropriate

Benefits

- Directly reduce runoff volumes and peak rates
- Reduces development and maintenance costs
- Enhances aesthetics and habitat

Limitations

- Must comply with local private road ordinances
- Must comply with vehicular safety standards

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	High
Commercial	Yes	Groundwater Recharge	High
Ultra Urban	Limited	Peak Rate	High
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Limited	TSS	Medium
Highway / Road	Yes	TP	Low
		NO3	Low
Recreational	Yes	Temperature	Medium
Additional Considerations			
Cost		Low	
Maintenance		Low	
Winter Performance		High	

Residential cul-de-sac with vegetation
Source: SEMCOG

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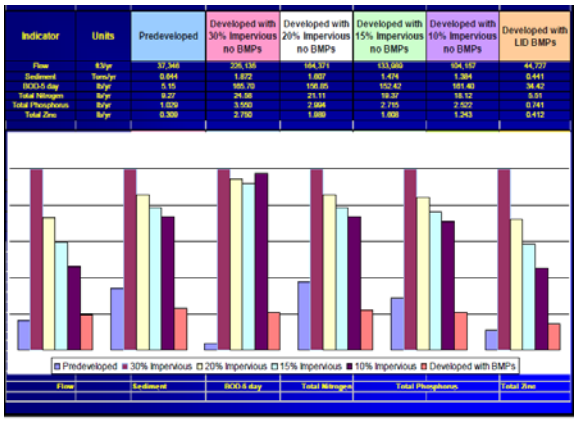
Reduce Impervious Surfaces

Reducing street imperviousness performs valuable stormwater functions:

- Increases infiltration
- Decreases runoff volumes
- Improves water quality by decreasing nonpoint source pollutant loading
- Decreases the concentration and energy of stormwater.



Indicator	Units	Predeveloped	Developed with 30% Impervious no BMPs	Developed with 20% Impervious no BMPs	Developed with 15% Impervious no BMPs	Developed with 10% Impervious no BMPs	Developed with LID BMPs
Flow	ft3/yr	37,348	226,136	164,371	133,989	104,157	44,727
Sediment	Tons/yr	0.844	1.872	1.607	1.474	1.384	0.441
BOD-5 day	lb/yr	5.15	165.70	116.85	152.42	181.48	34.42
Total Nitrogen	lb/yr	9.27	24.58	21.11	19.37	18.12	5.51
Total Phosphorus	lb/yr	1.529	3.550	2.984	2.715	2.522	0.741
Total Zinc	lb/yr	0.308	2.750	1.889	1.466	1.243	0.412

Source: Texaslid - Coffman

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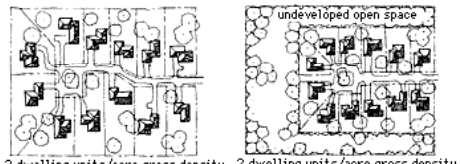
Reduce Impervious Surfaces

Design Considerations

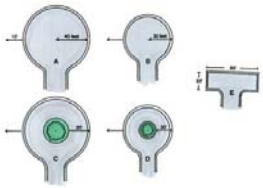
Street width

Street length



Source: University of Minnisota

Cul-de-sacs



Source: Center for Watershed Protection

Parking

- Lot Layout
- Stall Geometry
  - Ex: percentage of compact parking spaces
- Parking ratios
  - Ex: Shared parking with operating hours arrangements

Reduce Impervious Surfaces

Maintenance
Decreased maintenance, ex: repair, snow removal, winter maintenance

Source: Contech

Cost
<u>Street Width</u>
Less grading
Less infrastructure
Less paving

<u>Street Length</u>
Less curb
Less gutter
Less stormwater management controls

<u>Parking</u>
Reducing parking ratio

Site Fingerprinting

Key Design Features

- Reduce paving and compaction of highly permeable soils.
- Minimize the size of construction easements and stockpile areas
- Avoid existing tree removal where possible
- Flag to delineate the smallest site disturbance area possible
- Maintain existing topography and associated drainage divides

Benefits

- Preserves infiltration capacity
- Preserves existing, valued vegetation
- Minimizes the hydrologic impacts

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low/Med
Commercial	Yes	Groundwater Recharge	Low/Med
Ultra Urban	Limited	Peak Rate	Low/Med
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	High
Highway/Road	Limited	TP	High
		NO3	Medium
Recreational	Yes	Temperature	High
Additional Considerations			
Cost		Low/Medium	
Maintenance		Low/Medium	
Winter Performance		High	

Protection of Vegetation on a Construction Site
(Source: SEMCOG, 2008)

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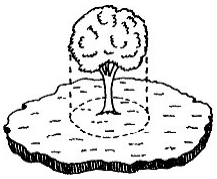
Site Fingerprinting

Drip Line



Incorrect fencing techniques

Correct fencing techniques

Source: Growing Earth TreeCare

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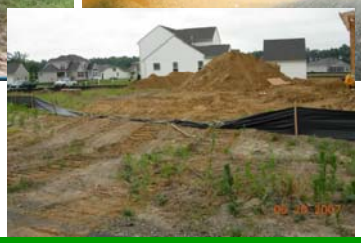
Site Fingerprinting

Construction Stormwater – Poor BMPs



Source: EPA 2012

Bad, very bad

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Site Fingerprinting

Construction Stormwater – Upgrade BMPs

Source: EPA 2012

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Special Land Uses

Army training lands are **unique, intensive land uses** with critical impacts to stormwater. Examples:

- Bivouac
- Maneuver Corridors
- Secondary Roads
- Small Weapons Firing Ranges
- Tank Trail
- Drop Zones

PWTB 200-1-62: Low Impact Development for Sustainable Installations: Stormwater Design and Planning Guidance for Development within Army Training Areas

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Bivouac

Hardened bivouac site

Temporary bivouac site

Environmental Impacts

- Compaction
- Increased runoff
- Erosion
- Increased heat locally due to loss of vegetative cover
- Loss of habitat for plants and animals
- Loss of ground layer of plants

Solution

- Site fingerprinting
- Selective grading

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Maneuver Corridors

Tank maneuver area is permanently non-vegetated. Runoff from these areas must be managed through LID IMPs surrounding the area.

Environmental Impacts

- Compaction
- Increased runoff
- Erosion
- Increased heat locally due to loss of vegetative cover
- Loss of habitat for plants and animals

Solution

- Site fingerprinting

Secondary Roads

Example improved secondary roads at Fort Benning, GA

Environmental Impacts

- Compaction
- Increased runoff
- Erosion
- Increased heat locally due to loss of vegetative cover
- Loss of habitat for plants and animals

Solution

- Site fingerprinting
- Selective grading

Small Weapons Firing Ranges

Environmental Impacts

- Compaction
- Increased runoff
- Erosion
- Increased heat locally due to loss of vegetative cover
- Loss of habitat for plants and animals
- Heavy metal build up in soils
- Dust from impacts repeatedly in the same place

Solution

- Site fingerprinting

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Tank Trails

Environmental Impacts

- Compaction
- Increased runoff
- Erosion – Wind and water
- Increased heat locally due to loss of vegetative cover
- Loss of habitat for plants and animals
- Stream siltation at crossing points
- Erosion at heavily trafficked intersections
- Noise

Solution

- Site fingerprinting

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Learning Objective 4.2

- **Review Structural Low Impact Development (LID) Best Management Practices (BMPs).**

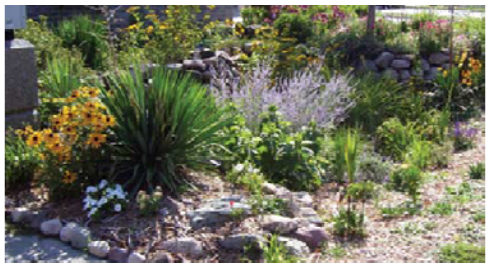
Structural LID BMPs

The structural BMPs are:

- Bioretention
- Vegetated Swale
- Vegetated Filter Strip
- Permeable Pavement
- Rainwater Harvesting
- Green Roofs
- Infiltration Practices
- Level Spreaders
- Constructed Filter
- Soil Restoration
- Reforestation and Afforestation
- Riparian Buffer Restoration

Bioretention

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Med/High
Commercial	Yes	Groundwater Recharge	Med/High
Ultra Urban	Limited	Peak Rate	Medium
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	High
Highway/Road	Yes	TP	Medium
Recreational	Yes	TN	Medium
		Temperature	High
Additional Considerations			
Cost		Medium	
Maintenance		Medium	
Winter Performance		Medium	



Variations
- Subsurface storage/ infiltration bed
- Use of underdrain
- Use of impervious liner

Key Design Features
- Flexible in size and infiltration
- Ponding depths 6-18 inches for drawdown within 48 hours
- Native plants
- Amend soil as needed
- Provide positive overflow for extreme storm events

Site Factors
- Water table/bedrock separation two-foot minimum, four foot recommended
- Soils: HSG A and B preferred: C & D may require an under-drain) see Infiltration BMP)
- Feasibility on steeper slopes: Medium
- Potential hotspots: Yes with pretreatment and/or impervious liner
- Max. drainage area: 5:1, not more than 1 acre to one area

Benefits
- Volume Control and groundwater recharge, Moderate peak rate control, filtration
- Versatile with broad applicability
- Enhance site aesthetics, habitat
- Potential air quality and climate benefits

Limitations
- Higher maintenance until vegetation is established
- Limited impervious drainage area
- Required careful selection and establishment of plants

Photo on left of Formal Rain Garden, Traverse City, MI and data, source SEMCOG

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BUILDING STRONG

Bioretention

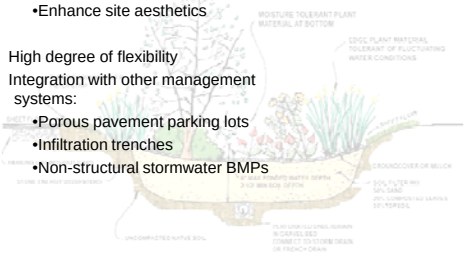
sra1

Method of managing stormwater by :
- pooling water with a planting area
- allowing the water to infiltrate the garden

Accomplishments:
- Reduce runoff volume
- Filter pollutants
- Provide habitat
- Recharge groundwater
- Reduce stormwater temperature impacts
- Enhance site aesthetics

High degree of flexibility

Integration with other management systems:
- Porous pavement parking lots
- Infiltration trenches
- Non-structural stormwater BMPs



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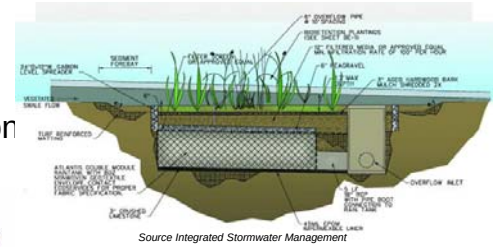
Slide 4

sra1 discuss differences in bioretention sizes and the respective names:
1) bioretention cells - 1/2 -5 acres
2) microbioretention -
3) raingardens - <
M2PERSRA, 12/6/2011

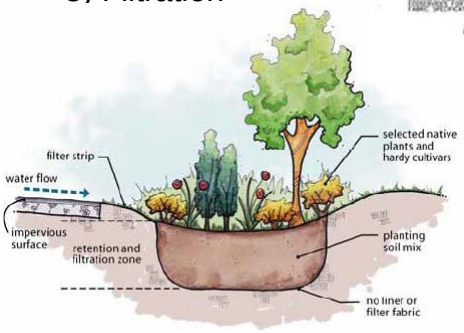
Bioretention

Performance Types:

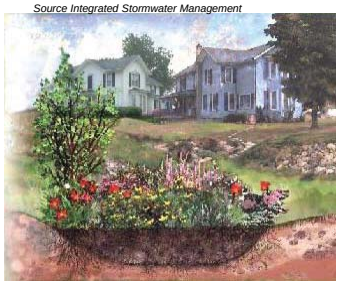
1) Infiltration
2) Infiltration-Filtration
3) Filtration



Source Integrated Stormwater Management



Source Integrated Stormwater Management



US ARMY CORPS OF ENGINEERS
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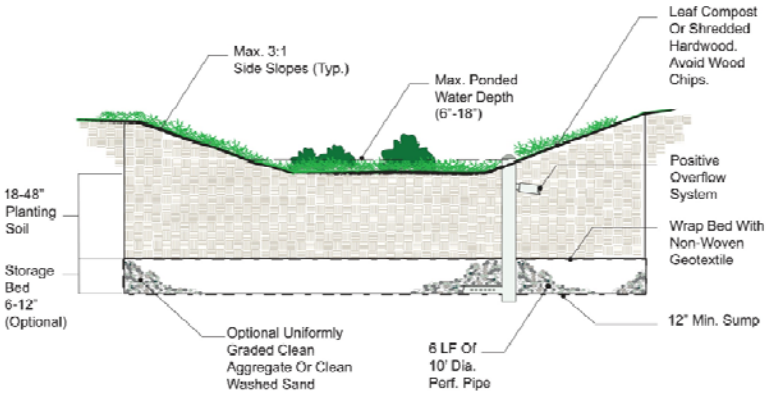
Bioretention



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Bioretention

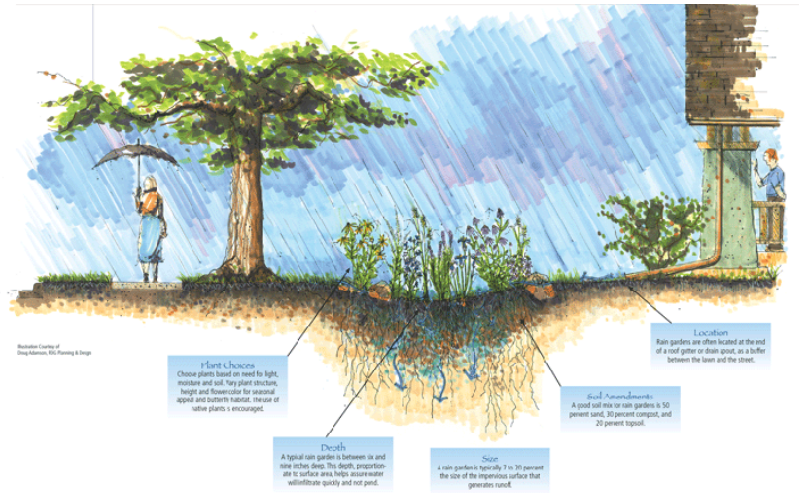

Image courtesy of 'Rain Garden Fact Sheet" USDA Natural Resources Conservation Service, 2009

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Bioretention

Variations in flow inlet:

Trench Drain

Curb Cuts

Positive Overflow Device

Applications:

Linear Bioretention Area along Roadway

Bioretention Area within Parking Lot -Raleigh USARC

Standard inlet to allow for overlow

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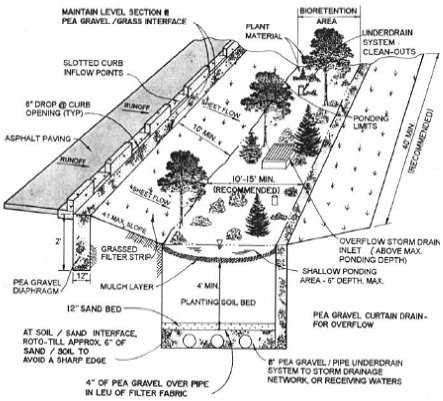
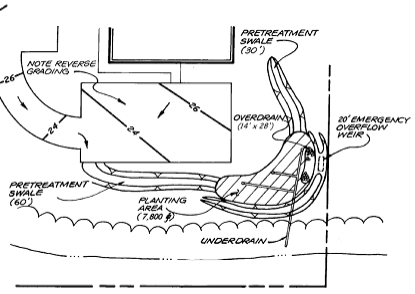
Bioretention

Design Considerations

Flow-through



Off-line



Sources: Right source: University of Iowa

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Bioretention

Design Considerations

- Soil mixture
- Depth of standing water
- Infiltration/filtration rates
- Duration of standing water

Source: NAVFAC

Source: NAVFAC

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Bioretention

Rain garden in a turning circle

First year after planting

Five years after planting

Maintenance Considerations:

- Newly established plants should receive irrigation throughout first season
- Little seasonal pruning
- Remove organic material if needed
- Inspect biannually for sediment buildup, erosion, and plant health

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Bioretention

Cost Considerations

Source: Texas lid - Coffman

US ARMY CORPS OF ENGINEERS
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Bioretention

Cost Considerations

Source: Texas lid - Coffman

US ARMY CORPS OF ENGINEERS
BUILDING STRONG

Bioretention

Source: NAVFAC

US ARMY CORPS OF ENGINEERS
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Bioretention

Source: NAVFAC

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Swales

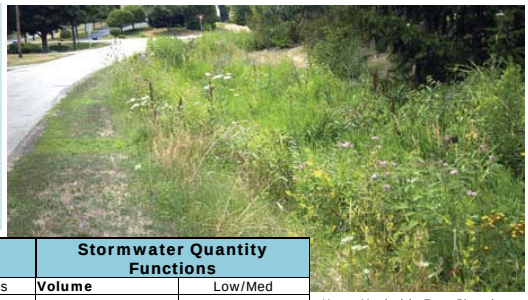
Variations
- Vegetated swale with infiltration trench
- Linear wetland swale Grass swale

Key Design Features
- Handles the 10-year storm event with some freeboard
- Two-year storm flows do not cause erosion
- Maximum size is five acres
- Bottom width of two to eight feet
- Side slopes from 3:1 (H:V) to 5:1
- Longitudinal slope from one to six percent
- Check dams can provide additional storage and infiltration

Site Factors
- Water table to bedrock depth two–foot minimum
- Soils – A,B preferred; C & D may require an underdrain (see infiltration BMP)
- Slope-one to six percent (<one percent can be used w/ infiltration)
- Potential hotspots – No
- Maximum drainage area – five acres

Benefits
- Can replace curb and gutter for site drainage and provide significant cost savings
- Water quality
- Peak and volume control with infiltration

Limitations
- Limited application in areas where space is a concern
- Unless designed for infiltration, there is limited peak and volume control



Upper : Meadowlake Farms Bioswale
Source: SEMCOG

Applications		Stormwater Quantity Functions	
Residential	Yes	**Volume**	Low/Med
Commercial	Yes	**Groundwater Recharge**	Low/Med
Ultra Urban	Limited	**Peak Rate**	Low/Med
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Limited	**TSS**	Med/High
Highway/Road	Yes	**TP**	Low/High
Recreational	Yes	**TN**	Medium
		Temperature	Medium
Additional Considerations			
Cost		Low/Med	
Maintenance		Low/Med	
Winter Performance		Medium	

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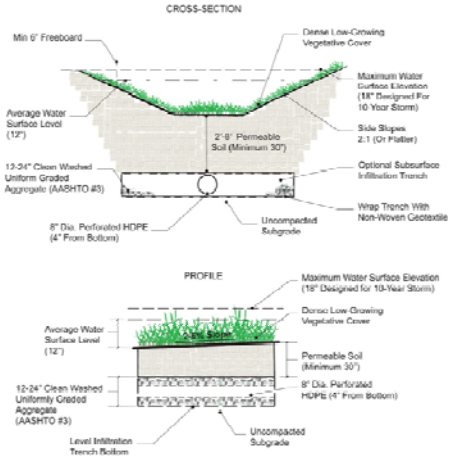
Vegetated Swale

Schematics of Vegetated Swale with an underlying aggregate layer



Source: Pennsylvania Stormwater BMP Manual, 2006

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Vegetated Swale

Variations

Vegetated swale with infiltration trench

Wet swale
Source: Hubbell, Roth & Clark, Inc.

Grass Swale
Source: Pennsylvania Stormwater BMP Manual, 2006.

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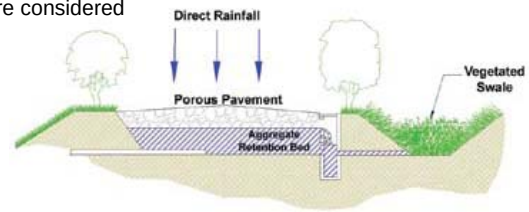
Vegetated Swale

Maintenance

- Irrigation during plant establishment and in periods of little rain or drought.
- Stabilize with erosion control matting or blankets during plant establishment
- Annually inspect,
- Annually mow and trim vegetation

Cost

- Cost-effective alternative to traditional curbs and gutters when all construction, operation, and maintenance activities are considered



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Vegetated Filter Strip

Variations

- Turf grasses Prairie grasses, shrubs, and groundcover vegetation, including trees
- Indigenous woods and dense vegetation

Key Design Features

- Use with level spreaders to promote sheet flow across strips
- Longitudinal slope from 1-6 percent
- Maintain dense vegetation
- See Appendix for recommended filter strip native vegetation

Site Factors

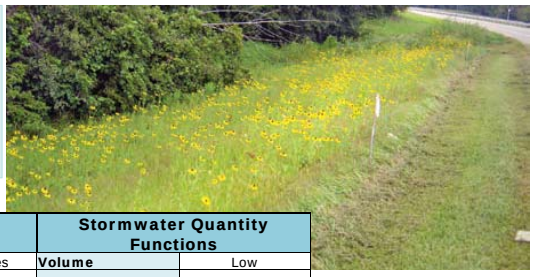
- Water table to bedrock depth – N/A
- Soils – N/A for permeability
- Slope – 25 percent preferred (1 – 10 percent if soils/vegetation allow)
- Potential hotspot – Yes with special design considerations
- Max. drainage area – 100 feet impervious or 150 feet pervious upgradient

Benefits

- Low Cost
- Good water quality performance
- Aesthetic and habitat benefits

Limitations

- Generally should be coupled with other BMPs for comprehensive stormwater management



Vegetated filter strip along roadway
Source: SEMCOG

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	Limited	Peak Rate	Low
Industrial	Limited	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	Med/High
Highway/Road	Yes	TP	Med/High
Recreational	Yes	NO3	Med/High
		Temperature	Med/High
Additional Considerations			
Cost		Low	
Maintenance		Low Varies dependent on type of vegetation	
Winter Performance		High	

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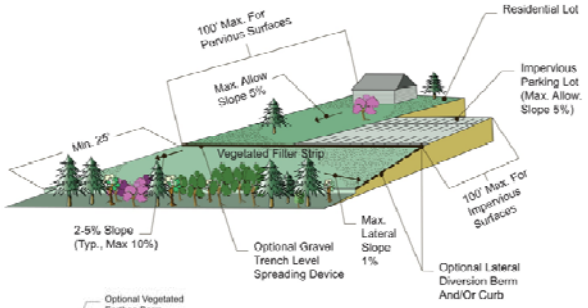
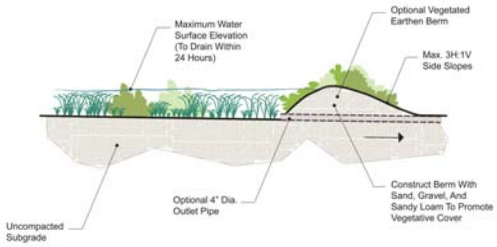
Vegetated Filter Strip





Top: Diagram showing elements of a vegetated filter strip
Source: SEMCOG

Left: Optional earthen berm at bottom of vegetated filter strip
Source: SEMCOG

Vegetated Filter Strip

Maintenance

- Adequate design
- Proper vegetative cover.
- Minimal maintenance efforts, many of which may overlap with standard landscaping demands.

Cost

- Grading,
- Sodding (when applicable),
- Installing vegetation,
- Constructing a level spreader,
- Constructing a pervious berm (if proposed)
- Depending on design, construction costs may range anywhere from no cost to expensive
- Maintenance costs are highly variable, as they are a function of frequency and local labor rates.

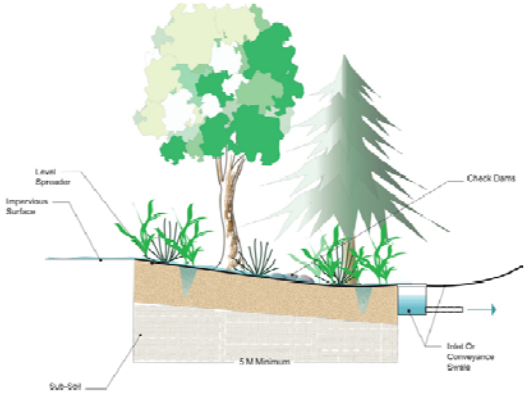


Figure 2-10
Vegetated Filter Strip
(Source: Landmark Design Group)

Pervious Pavement

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	No	Peak Rate	Low
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	Low
Highway/Road	Yes	TP	Low
Recreational	Yes	NO3	Low
		Temperature	Low
Additional Considerations			
Cost		Low	
Maintenance		Low	
Winter Performance		High	

Left: Porous concrete
Source: Green Infrastructure Digest.
Right: Pervious pavement with infiltration schematic
Source: SEMCOG

Variations

- Porous asphalt
- Pervious concrete
- Permeable paver blocks
- Reinforced turf/gravel

Key Design Features

- Follow soil infiltration testing protocol (Appendix E) and infiltration BMP guidelines
- Do not infiltrate on compacted soil
- Level storage bed bottoms
- Provide positive stormwater overflow from bed
- Surface permeability >20"/hr

Site Factors

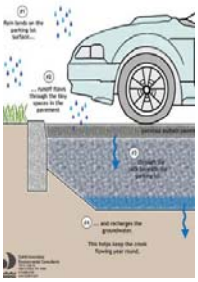
- Water table/Bedrock separation: two-foot min.
- Feasibility on steeper slopes: Low
- Potential hot spots: Not without design of pretreatment system

Benefits

- Volume control and groundwater recharge, moderate peak rate control
- Dual use for pavement structure and stormwater management

Limitations

- Pervious pavement not suitable for all uses
- High maintenance needs



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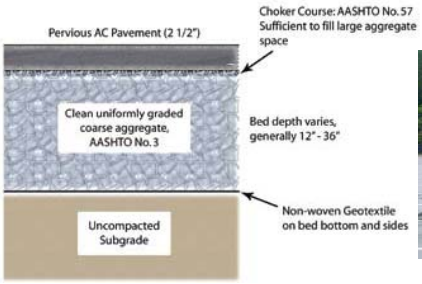
Pervious Pavement



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Pervious Pavement

Variations

Porous asphalt on open-graded stone subbase
Source: SEMCOG

Permeable paver blocks
Source: SEMCOG

Permeable paver lot
Source: SEMCOG

Pervious and impervious concrete
Source: Michigan Department of Environmental Quality

Colored pervious concrete
Source: SEMCOG

Reinforced Turf used as overflow parking
Source: SEMCOG

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Pervious Pavement

Applications

Porous parking lot and rain gardens
Source: Green Infrastructure Digest

Permeable pavers
Source: Green Infrastructure Digest

Permeable paver street in Dowagiac, MI
Source: SEMCOG

Porous asphalt pathway at Grey Towers National Historic Site, Milford, PA
Source: SEMCOG

Mill Creek Basketball Court Pervious Pavement
Source: City of Philadelphia

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Pervious Pavement

Porous Asphalt on top of regular pavement

Water drains through the asphalt instead of across it

- Reduces splash and spray
- Reduces hydroplaning tendencies
- Improves visibility
- Improves traction
- Quieter
- Cleaner runoff than conventional pavement
- Retrofit existing roads for water quality
- Extends the life of existing roads

Porous asphalt. Source: Texaslid - Barrett

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Pervious Pavement

Porous Asphalt on top of regular pavement

Conventional Asphalt

Porous Asphalt

Porous asphalt. Source: Texaslid - Barrett

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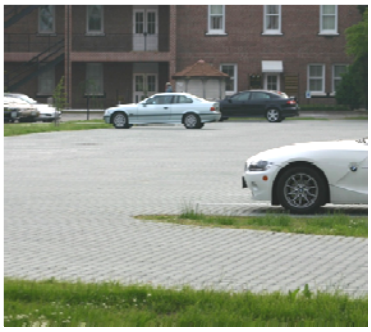
Pervious Pavement

Maintenance

- Asphalt is flexible and often does not gain potholes.
- Vacuuming pavement is controversial. Some say vacuum pavement twice a year. Others say that clogging issues arise about the lifetime expectancy of roads.
- Do not allow construction staging, soil/mulch storage, etc., on unprotected pavement surface

Cost

- Deeper subgrade
- Requires experienced contractors
- Cost offset by the significant reduction in the required number of inlets and pipes.
- Less earthwork and/or deep excavations involved.
- Pavement areas with subsurface infiltration beds often eliminate the need (and associated costs, space, etc.) for detention basins.



Pavers at Fort Monroe

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Rain Water Harvesting

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	High
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	Yes	Peak Rate	Low
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	High
Highway/Road	No	TP	Medium
		NO3	Medium
Recreational	Yes	Temperature	High

Additional Considerations	
Cost - Rain barrel - Cistern - Manufactured product	 Low Medium Varies
Maintenance	Medium
Winter Performance	Medium

Variation

- Rain barrels
- Cisterns, both underground and above ground
- Tanks
- Storage beneath a surface (using manufactured products)

Key Design Features

- Small storm events are captured with most structures
- Provide overflow for large storm events
- Discharge water before next storm event
- Consider site topography, placing structure up-gradient in order to eliminate pumping needs

Site Factors

- Water table to bedrock depth – N/A (although must be considered for subsurface systems)
- Soils – N/A
- Slope – N/A
- Potential hotspots – Yea with treatment
- Max. drainage area – N/A

Benefits

- Provides supplemental water supply
- Wide Applicability
- Reduces potable water use
- Related cost savings and environmental benefits

Limitations

- Manages only relatively small events which requires additional management and use for the stored water

Photo on left of Formal Rain Garden, Traverse City, MI and data, source SEMCOG

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Rain Water Harvesting

Variations in flow inlet:

Rain Barrel
Fort Bragg Rain Barrel System

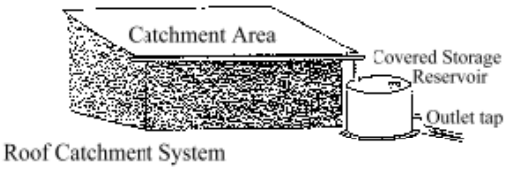
Cistern

Vertical Storage for vegetated roof plaza

Rainstore™ cistern beneath brick pavers on a vegetated rooftop plaza at University of North Carolina – Chapel Hill

Rain Water Harvesting

In the most basic form of this technology, rainwater is collected in simple vessels at the edge of the roof.



Rain Water Harvesting

Maximum Annual Gallons of Rain Capture = Annual Rainfall x Square Footage of Roof x .623 Gallons

Estimated efficiency ratings are:

- For a tile/metal roof assume a 95% runoff efficiency
- For a concrete/asphalt roof assume a 95% runoff efficiency
- For a gravel roof assume a 70% runoff efficiency
- For a bare soil roof assume a 75% runoff efficiency
- For a grass roof assume a 17% runoff efficiency

Rain Water Harvesting

Maintenance

<u>Rain barrels</u>

- Inspect rain barrels four times per year, and after major storm events.
- Remove debris from screen as needed.
- Replace screens, spigots, downspouts, and leaders as needed.
- To avoid damage, drain container prior to winter, so that water is not allowed to freeze in devices.

<u>Cisterns</u>

- Flush cisterns annually to remove sediment.
- Brush the inside surfaces and thoroughly disinfect twice per year.
- To avoid damage, drain container prior to winter, so that water is not allowed to freeze in devices.

Vegetated Roof

Variations
- Intensive
- Semi-intensive
- Extensive

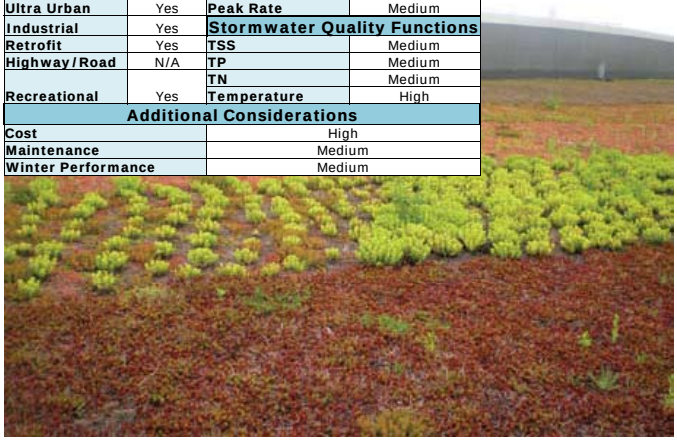
Key Design Feature
- Extensive roofs are most commonly used for rainfall runoff mitigation
- Roofs with pitches steeper than 2:12 (9.5 degrees) much incorporate supplemental measures

Benefits
- Good stormwater volume control
- Heating and cooling energy benefits
- Increased lifespan of roof
- Heat island reduction
- Enhance habitat value

Limitations
- Cost (intensive systems)
- Careful design and construction required
- Maintenance requirements until plants established
- Can't store or treat stormwater from other parts of the property

Applications		Stormwater Quantity Functions	
Residential	Limited	Volume	Med/High
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	Yes	Peak Rate	Medium
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	Medium
Highway/Road	N/A	TP	Medium
Recreational	Yes	TN	Medium
		Temperature	High
Additional Considerations			
Cost		High	
Maintenance		Medium	
Winter Performance		Medium	

Green roof with sedum at Lawrence Technological University's Taubman Student Services Center
Source: Lawrence Technological University



US ARMY CORPS OF ENGINEERS
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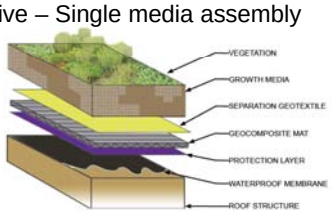
Vegetated Roof

Vegetated roof types

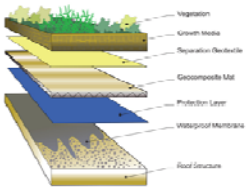
	Extensive Vegetated Roof	Semi-Intensive Vegetated Roof	Intensive Vegetated Roof
Maintenance	Low	Periodically	High
Irrigation (after plants are established)*	No	Periodically	Regularly
Plant Communities	Moss, Sedum, Herbs, and Grasses	Grass, Herbs, and Shrubs	Perennials, Shrubs, and Trees
System build-up height	60-200 mm	120-250 mm	150-400 mm Underground garages = > 1000 mm
Weight	60 - 150 kg/m2 13-30 lbs/sqft	120 - 200 kg/m2 25-40 lbs/sqft	180 - 500 kg/m2 35-100 lbs/sqft
Construction costs	Low	Medium	High
Desired use	Ecological protection layer	Designed vegetated roof	Park-like garden

*Irrigation is required regularly to establish plant communities, especially during the first season.

Extensive – Single media assembly



Extensive – Dual media assembly



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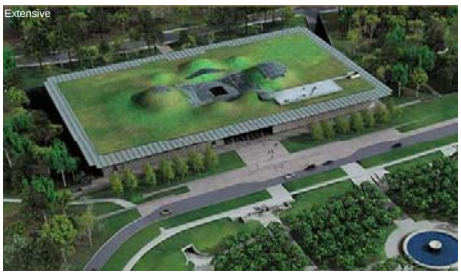
Vegetated Roof



Top left: California Academy of Sciences green roof
Top right: Nanyang Art School in Singapore
Source: Inhabitat
Bottom left: Australian home
Source: Treehugger, A Discovery Company
Bottom right: Green Roof
Source: Phipps

Vegetated Roof

Maintenance
- Irrigation and inspections during plant establishment period and in times of drought.

Cost
- The construction cost of vegetated roof covers varies greatly, depending on factors such as:
- Height of the building
- Accessibility to the structure by large equipment such as cranes and trailers
- Depth and complexity of the assembly
- Remoteness of the project from sources of material supply
- Size of the project
- Reduce their life-cycle costs.

Pentagon Remote Delivery Facility (RDF)
One of the largest "green roofs" in the east.

Vegetated Roof

Traditional Approach – Washington State

- Membrane and ballast
- Downspouts to Storm water

LID Approach – Pentagon Annex

- Membrane and vegetation
- Disconnect downspouts

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Infiltration Practices

	Applications						
	Residential	Commercial	Ultra Urban	Industrial	Retrofit	Highway / Road	Recreational
Dry Well	Yes	Yes	Yes	Limited	Yes	No	No
Infiltration Basin	Yes	Yes	Limited	Yes	Limited	Limited	No
Infiltration Berm	Yes	Yes	Limited	Yes	Yes	Yes	No
Infiltration Trench	Yes	Yes	Yes	Yes	Yes	Yes	No
Subsurface Infiltration Bed	Yes	Yes	Yes	Yes	Yes	Limited	No

Variations:

- Dry wells
- Infiltration basins
- Infiltration berms
- Infiltration trenches
- Subsurface infiltration beds
- Level spreaders

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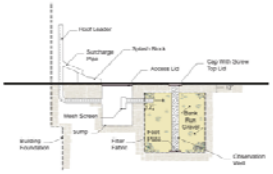
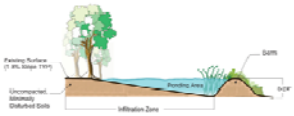
Infiltration Practices

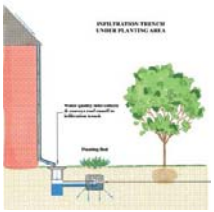


Dry Well

Infiltration Basin



Infiltration Berm



Infiltration Trench

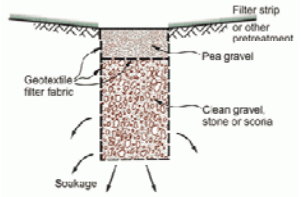
Subsurface infiltration bed

Infiltration Practices

Maintenance
There are a few general maintenance practices that should be followed for all infiltration BMPs. These include:

- Inspected and cleaned at least twice per year.
- The overlying vegetation of subsurface infiltration features should be maintained in good condition, and any bare spots revegetated as soon as possible.
- Vehicular access on subsurface infiltration areas should be prohibited (unless designed to allow vehicles), and care should be taken to avoid excessive compaction by mowers.

Cost
Varies greatly depending on the configuration, location, site conditions, maintenance etc.



Level Spreaders

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	No	Peak Rate	Low
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	Low
Highway/Road	Yes	TP	Low
Recreational	Yes	NO3	Low
		Temperature	Low
Additional Considerations			
Cost		Low	
Maintenance		Low	
Winter Performance		High	

Level Spreader into wetland *Source: Lee R. Skabelund, Kansas State University*

Variations
- Inflow
- Outflow

Key Design Features
- Ultimate outlet from structural BMPs
- Roof downspout connections (roof area > 500sf)
- Inlet connections (impervious area > 500sf)
- Inflow to structural BMP, such as filter strip, infiltration basin, vegetated swale

Site Factors
- Water table to bedrock depth – N/A
- Soils – Permeability not critical but should be considered for erodibility
- Slope – 1-8 percent max.
- Potential hotspots – Yes
- Maximum drainage area – Varies (five acres max.)

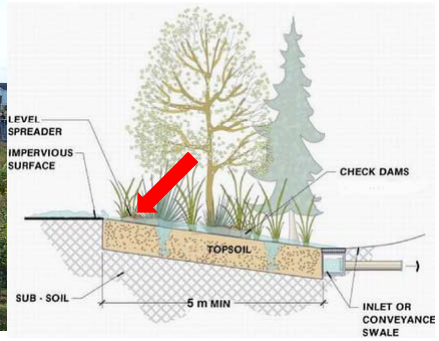
Benefits
- Low Cost
- Wide applicability
- Ability to work with other BMPs in a treatment train
- Avoids concentrated discharges and their associated potential erosion

Limitations
- Low stormwater benefits by itself
- Careful design and construction required to function properly

Level Spreaders

Wetland Swale with Level Spreader and Limestone Lines

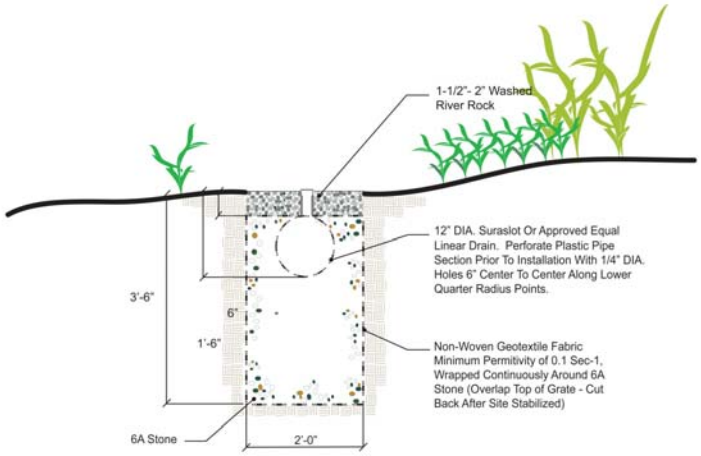
Source: asla.org



Wetland Swale with Level Spreader and Limestone Lines

Source: asla.org

Level Spreaders



Detail of Level Spreader
Source: InSite Design Studio

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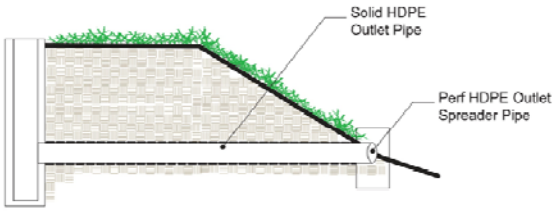
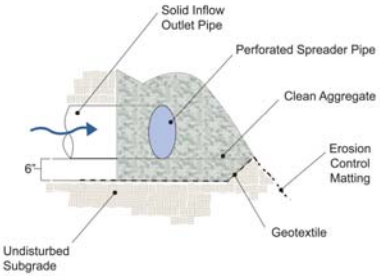
Level Spreaders



SIDE VIEW



Top Right: Level Spreader with a Perforated Outflow Pipe
Source: SEMCOG.org
Bottom Left: Level Spreader with an Inflow Pipe
Source: SEMCOG.org

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Level Spreaders

Maintenance
Compared with other BMPs, level spreaders require only minimal maintenance efforts, many of which may overlap with standard landscaping demands. Minimum routine inspection maintenance effort for level spreaders:

- Once a month and after every heavy rainfall (greater than two inches) for clogging, repairs, and inspection.
- Once a year to remove any weeds or shrubs growing on level spreader or in swale.

Washtenaw County West Service Center level spreader
Source: SEMCOG.org

Cost
Level spreaders are relatively inexpensive and easy to construct and vary on the type of level spreaders.

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Constructed Filter

Applications		Stormwater Quantity Functions	
Residential	Limited	Volume	Low/High
Commercial	Yes	Groundwater Recharge	Low/High
Ultra Urban	Yes	Peak Rate	Low/High
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	High
Highway/Road	Yes	TP	Medium
		TN	Medium
Recreational	Yes	Temperature	Low
Additional Considerations			
Cost		Med/High	
Maintenance		High	
Winter Performance		Medium	

Variations
- Surface non-vegetated
- Vegetated
- Infiltration
- Contained
- Linear Perimeter
- Small subsurface
- Large subsurface
- Manufactured filtration systems

Key Design Features
- Depth of filtering medium 18-30"
- Surface ponding should drain down within 72 hours (3-6" ponding depth)
- May be designed to infiltrate
- May require pretreatment for debris and sediment
- Some system require sufficient head (2-6 feet)
- Flow splitter or positive overflow required to bypass large storms
- Requires minimum permeability of filtration medium
- Underdrains may be needed if infiltration is infeasible

Site Factors
- Water table to bedrock depth – N/A
- Soils – N/A
- Slope – N/A
- Potential hotspots – Yes
- Max. drainage area – 5 acres

Benefits
- Good water quality performance
- Lot a of variations for a variety of applications
- Can be used effectively as pretreatment for other BMPs

Limitations
- Limited water quantity benefits
- Relatively high cost
- High maintenance needs

Photo on left ofFormal Rain Garden, Traverse City, MI and data, source SEMCOG

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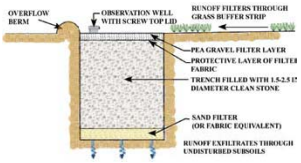
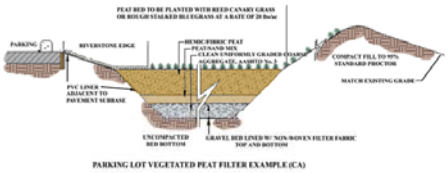
Constructed Filter

Variations in flow inlet:





Vegetated peat filter

Surface non-vegetated filter

Surface container filter

Linear perimeter filter

Constructed Filter

Maintenance Considerations:

- Standing water
- Film or discoloration of any surface filter material .
- Remove trash and debris as necessary
- Scrape silt with rakes, if collected on top of the filter
- Till and aerate filter area
- Replenish filtering medium if scraping/removal has reduced depth of filtering media
- Repair leaks from the sedimentation chamber or deterioration of structural components
- Clean out accumulated sediment from filter bed chamber and/or sedimentation chamber
- Clean out accumulated sediment from underdrains

Cost

Varies according to the filtering media (sand, peat, compost), land clearing, excavation, grading, inlet and outlet structures, perforated pipes, encasing structure (if used), and maintenance cost.

Can represent significant cost savings in reduced land consumption in ultra-urban areas where land costs are high. Can be placed under roads or parking lots.

Soil Restoration

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Medium
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	Yes	Peak Rate	Medium
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Limited	TSS	High*
Highway/Road	Yes	TP	High*
Recreational	Yes	NO_3	Medium
		Temperature	Medium

Additional Considerations	
Cost	Medium
Maintenance	Low
Winter Performance	High

*Newly amended soils are susceptible to erosion and release of TSS and phosphorus until stabilized with mulch, erosion blanket, sod, or some other covering.

Key Design Features

- Follow nonstructural BMP to minimize soil compaction
- Evaluate existing soil conditions using methods referenced in Soil Infiltration Testing Protocol (Appendix E) before creating a soil restorations strategy
- Soil media used in restoration is either organic or inorganic (man-made) and is mixed into existing soil

Benefits

Widely applicable

- Relatively low cost
- Additional benefits such as improved plant health and reduced erosion

Limitations

- Relatively limited stormwater benefits on a unit area basis

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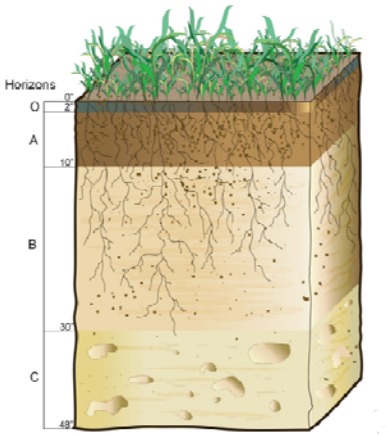
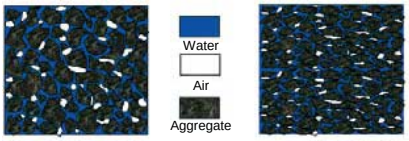
Soil Restoration

Healthy Soil Profile



Source: USDA NRCS

Compacted soil constrains movement of air and water



Good physical condition

Poor physical condition (compacted)

Soil restoration can occur anywhere to alleviate soil compaction. It can be specifically addressed in the following examples:

- New development (residential, commercial,
- industrial)
- Detention basin
- Golf courses

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Soil Restoration

Soil Type	Infiltration Rate (inches/hour)
Sand	>1.5
Sandy Loam	1-1.5
Loam	0.5-1
Clay loam	.25-0.5
Clay	<.25

Source: Texaslid - Simmons

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Native Revegetation

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low/Med/High
Commercial	Yes	Groundwater Recharge	Low/Med/High
Ultra Urban	Limited	Peak Rate	Low/Med/High
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	High
Highway/Road	Limited	TP	High
Recreational	Yes	NO3	Med/High
		Temperature	Med/High
Additional Considerations			
Cost		Low/Med	
Maintenance		Low	
Winter Performance		Medium	

Left: Bennett Arboretum Wildflower Grow Zone Project, Wayne County, MI
Source: Wayne County Department of Environment

Right: Sanguinaria canadensis - "Bloodroot"
Source: ANR State

Variations
- Prairie
- No-mow lawn area
- Woodland
- Constructed wetlands
- Buffer areas
- Replacement lawn area

Key Design Features
- Minimize traditional turf lawn area
- Develop landscape plan using native material, determining the most appropriate
- Use integrated pest management (IPM) approach

Site Factors:
- Water table to bedrock depth: N/A
- Soils: Vegetation should match soil types
- Slope: Applicable on most slopes (up to 1H:1V)
- Potential hotspots: No
- Max. drainage area: Optimal is five times (max. 20 times) the revegetated area

Benefits
- Low long-term maintenance needs
- Improves water quality
- Reduces volume

Limitations
- Establishment period requires more intensive maintenance, such as weeding and watering

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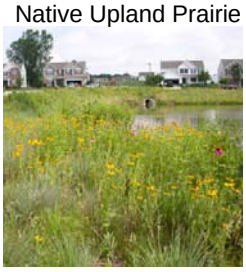
Native Revegetation

Types:

- Riparian Buffer Restoration
- Reforestation
- Native Prairie Restoration
- And others…

Native Upland Prairie



Native Plants

Source: Turf Magazine

Native Grasses - Seeded

Source: Raven's Next

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Native Revegetation

Little Darby Creek, West Jefferson, Ohio

source: Target Company

Native vegetation in a parking lot at Harborside Office Center, City of Port Huron, MI
Source: St. Clair County Health Department

Native plantings surrounding detention facilities
Source: InSite Design Studio, Inc.

Native revegetation along a walkway
Source: City of Bangor, MI

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Native Revegetation

Maintenance
Local land conservancies are excellent resources when considering the long-term stewardship of the area. Consult local land conservancies as resources.

- Reduces over the long term
- Significantly less mowing than conventional lawns
- Significantly less irrigation

Cost

- Reduction in long term operating and maintenance costs
- Included as part of the "infrastructure" of water quality design and protection.

Above: Katy Trail, Dallas.
Below source: Halff. Onyx Drive.

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Riparian Buffer Restoration

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low/Med
Commercial	Yes	Groundwater Recharge	Low/Med
Ultra Urban	Yes	Peak Rate	Low/Med
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	Med/High
Highway/Road	Limited	TP	Med/High
Recreational	Yes	NO3	Med/High
		Temperature	Med/High
Additional Considerations			
Cost		Low/Med	
Maintenance		Low	
Winter Performance		High	

Key Design Features

Riparian buffers consist of three distinct zones:

- **Zone 1**: Streamside zone extends a minimum distance of 25 feet.
- **Zone 2**: Middle zone extends immediately from the outer edge of Zone 1 for a minimum distance of 55 feet.
- **Zone 3**: Outer zone extends a minimum of 20 feet immediately from outer edge of Zone 2.

Site Factors

- Water table to bedrock depth: N/A
- Soils: Match vegetation to soils to maximize long-term viability of plantings.
- Scope: N/A
- Potential hotspots: No
- Max. drainage area: 5-20 times the buffer area

Benefits

- Water quality
- Ecological and aesthetic value
- Low Cost

Limitations

- Reduced Volume and peak rate control

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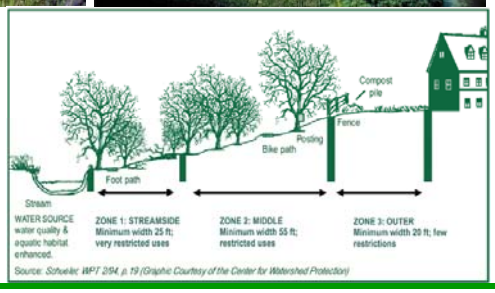
Riparian Buffer Restoration

Top left: Native pond edge
Source: JFNew

Top right: Riparian Buffer Zones
Source: Macalester College

Bottom right: Schematic of a three-zone buffer
Source: Schueler, Watershed Protection Techniques



Riparian Buffer Restoration

Applications

Restoring riparian buffers can be applied in many settings:

1. Adjacent to permanent or intermittent streams,
2. At the margins of lakes or ponds,
3. At the margin of intermittent or permanently flooded, environmentally sensitive, open water wetlands,
4. On karst formations at the margin of sinkholes and other small groundwater recharge areas, and
5. Between manicured lawns, cultivated areas or hardscape and swales, streams or rivers to help dissipate and treat runoff and help stabilize the tops of channel banks.

Check Dams

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Medium
Commercial	Yes	Groundwater Recharge	Medium
Ultra Urban	No	Peak Rate	Medium
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	High
Highway/Road	Yes	TP	Medium
		NO3	Medium
Recreational	Yes	Temperature	Low
Additional Considerations			
Cost		Low	
Maintenance		Low	
Winter Performance		High	

Grassed swale with cobble check dams

Source: Lake Superior Streams

Grassed swale with grassy check dams

Source: Lake Superior Streams

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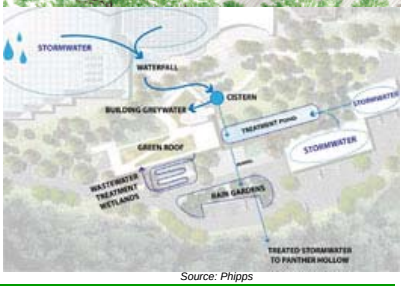
Treatment Trains

LIDs controls are best when distributed throughout the site as a "treatment train."

A treatment train is a series of LID applications which replicate the natural hydrologic function of the predevelopment landscape.

Examples:
- Permeable pavement drains to bioretention
- Green Roof drains infiltration trench
- Bioretention overflows into vegetated swale



Source: Phipps

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Rain garden + Grass swale

Typical ditch application
Pre-construction

Rain garden + Grass swale
Post-construction

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Case Study: Fort Meade

Design Considerations:

- Reduce Impervious surface
- Water Quality – Chesapeake Bay TMDL for nitrogen, phosphorus and sediments

LID Approach:

- Remove curb
- Impervious disconnection
- Infiltration trench

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Case Study: Fort Meade

HOSPITAL PARKING AREA/TRAPEZOIDAL CHANNEL - DESIGN CONCEPT

OACSIM LID Demonstration Project (Design Only)

LID Approach:

- Permeable paving
  - Bioretention
    - Bioswale
- Reduce impervious surface
- Water Quality benefits

HOSPITAL PARKING AREA/TRAPEZOIDAL CHANNEL

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Case Study: Fort Meade

OACSIM LID Demonstration Project (Design and Construction)

LID Approach:

- Pipe removal
- Revegetation
- Water Quality benefits
- Environmental benefits

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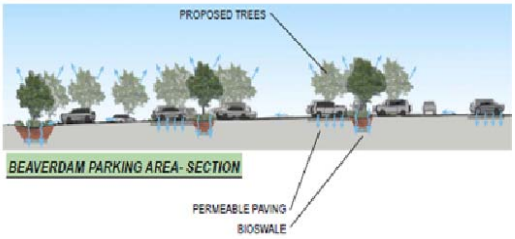
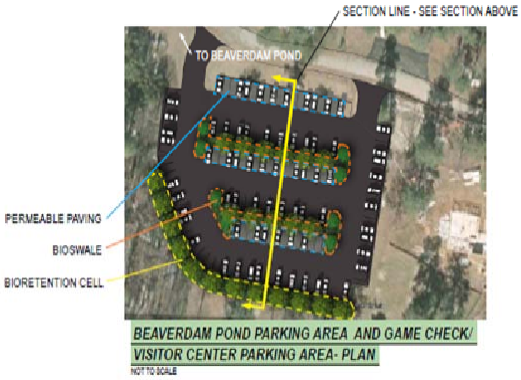
Case Study: Fort A.P. Hill



OACSIM LID Demonstration Project (Design and Construction)

LID Approach:

- Permeable paving
  - Bioswale
    - Bioretention
- Reduce impervious surface
- Reduce heat island
- Water Quality benefits



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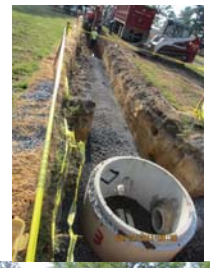
Case Study: Fort A.P. Hill



Case Study: Tobyhanna Army Depot

Green Roof Retrofit

- Two warehouse buildings retrofitted with modular vegetated trays, covering 165,000 ft^2 roof area
- Tray depth 4" soil media planted with succulents
- System added 15-17 lbs/ft^2 to roof

Results

- Reduced impervious area and urban heat island effect
- During summer months, air intake temperature readings from roof decreased from 125°F to 87°F
- Roof runoff temperature decreased to 75°F, which benefits nearby surface waters
- Contract cost $4M = $24 / ft^2 installed

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Nonstructural and Structural LID BMPs

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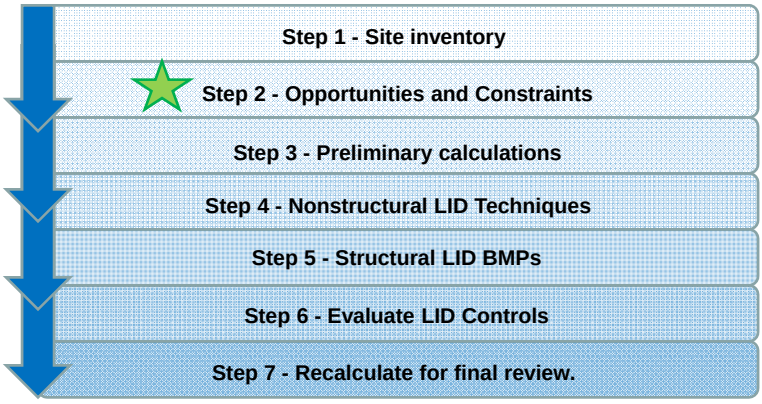
Site Planning for LID



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Plan Proposed Sites

Continue group exercise:

- Introduce HQ and VMF project site development requirements.
- Each group given building footprints.
- Lay out proposed site (buildings, roads, parking lots etc.) on survey plan.
- Brainstorm nonstructural and structural BMP opportunities.
- Each group present site plan.

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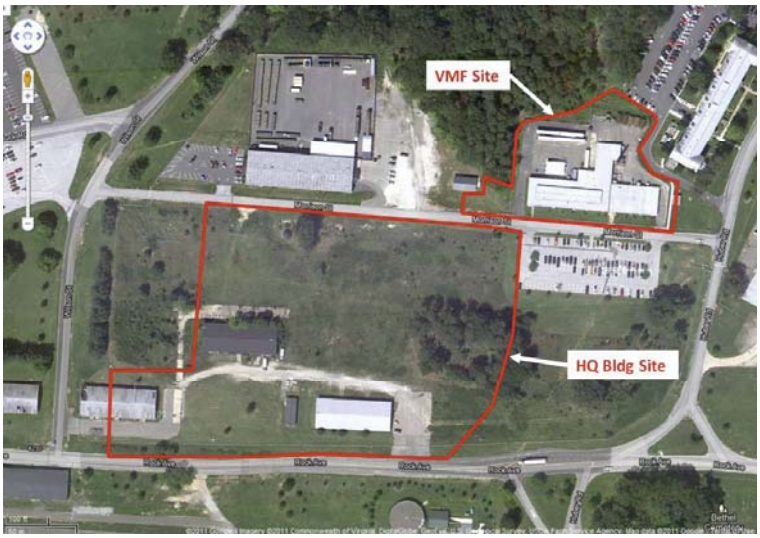
HQ Complex – Fort Meade



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HQ Proposed Site

- Headquarters Building = 47,000 sf
- Visitor Control Center (VCC) = 2,900 sf
- Site Requirements:
  - Main entrance to site off Rock Ave.
  - 20 visitor parking spaces for VCC
  - 125 POV parking spaces for HQ Building
  - Loading dock and maintenance drive behind HQ
  - Drop off circle at front entrance of HQ Building

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VMF Proposed Site

- Vehicle Maintenance Building = 14,000 sf
- Site Requirements:
  - Main entrance to site off Morrison St.
  - User requires large paved area behind building for vehicle and supply storage
  - No new POV parking requirement
  - Provide sidewalk along Morrison St. to link VMF with existing pavilion and HQ site