Appendix B—Low Impact Development Techniques

Appendix B – Low Impact Development

Introduction

Low Impact Development (LID) is an innovative approach that uses state-of-the-art science and technology to manage urban stormwater by working with the hydrological cycle and its associated natural processes. The goal of LID is to design new development or redevelopment in a way that minimizes the impacts of the new impervious surfaces, its surface water runoff, and its non-point sources of pollution sources, in a way that that is consistent with the natural hydrological cycle for the site and the watershed. Using LID, stormwater is managed in a series of small, cost-effective landscape features, similar to existing natural systems, located on each lot rather than being conveyed and managed in larger pond facilities, located at the bottom of the basin.

Applicability to Mason County

Much of the Mason County Area is largely undeveloped. Due to the site-specific nature of LID designs, it is difficult to propose LID site planning on such a large planning level, without conceptual drawings of the proposed development(s). Therefore, the intent of this appendix is to introduce general LID concepts, strategies, and case studies in the form of a brief literature review that may be applied within Mason County. LID designs for surface water management generally do not replace needed surface water management detention and water quality treatment facilities; however, they can be used to reduce the size of these facilities. They are also often used to achieve infiltration, water quality enhancement, aquifer recharge, low flow augmentation, and other natural functions that most conventional surface water management facilities are not normally designed to achieve.

LID Goals

The primary goal of LID is to mimic the predevelopment site hydrology by using site specific design techniques to store, treat, infiltrate, evaporate, and detain runoff. Using these techniques helps to reduce off-site runoff, enhance groundwater recharge, and provide opportunities for improving water quality (Prince George's County, Maryland, 1999). Reported water quality benefits of LID practices are summarized in Table B.1. In general, LID strategies are most effective at removing total suspended solids and metals, followed by biological oxygen demand and bacteria, and finally by the removal of total phosphorous and nitrogen.

Table B.1 Reported Pollutant Removal Efficiency of LID Practices							
LID Practice	***TSS***	***Total P***	***Total N***	***Zinc***	***Lead***	***BOD***	***Bacteria***
Bio-retention	-	81	43	99	99	-	-
Dry Well	80-100	40-40	40-60	80-100	80-100	60-80	60-80
Infiltration Trench	80-100	40-60	40-60	80-100	80-100	60-80	60-80
Filter/Buffer Strip	20-100	0-60	0-60	20-100	20-100	0-80	-
Vegetated Swale	30-65	10-25	0-15	20-50	20-50	-	-
Infiltration Swale	90	65	50	80-90	80-90	-	-
Wet Swale	80	20	40	40-70	40-70	-	-

Reference #4 and #7

By attempting to maintain the pre-development hydrological balance, LID designs often contribute to other environmental benefits. For example, many LID practices incorporate landscape plantings which create habitat features. Landscaping can also be used to attenuate heating-island effects common in many urban areas.

Comparison of Conventional and LID Stormwater Management Approaches

The fundamental concept of LID design is to treat rainfall on-site through site and building specific designs. One LID design objective is to capture as much rainfall on site as possible, and then return it to its natural hydrologic pathways (i.e. infiltration and evapotranspiration) or reuse it at the source. On the other hand, conventional stormwater management typically routes water to a pond or infiltration area, often located off site.

Table B.2 summarizes how conventional stormwater management and LID can be used to alter or preserve the natural hydrologic regime.

Table B.2 Comparison of Conventional and LID Stormwater Management Impacts on the Hydrologic Cycle		
Hydrologic Parameter	***Conventional***	***LID***
Vegetation/Natural Cover	typically not incorporated into drainage designs.	used to maintain pre-development hydrology
Time of Concentration	shortened, reduced as a by-product of drainage efficiency	increased where possible to approximate predevelopment conditions
Runoff Volume	increases in runoff volume	controlled to predevelopment conditions
Peak Discharge	controlled to predeveloped design criteria	controlled to predeveloped conditions for all storms
Runoff Frequency	increased, especially for small, more frequent storms	controlled to predeveloped conditions for all storms
Rainfall Abstractions (Interception, Infiltration, Depression Storage)	large reduction in all elements	maintained to predevelopment conditions
Groundwater Recharge	reduction in recharge	maintained to predevelopment conditions

Reference#1.

LID Designs and Practices

LID practices to maintain hydrologic functions can include the following:

- *Impervious Surface Control Devices*—alternative pavers, green roof, etc.
- *Infiltration Facilities*—dry well, infiltration trench, etc.
- *Semi-natural Conveyance System*—bioretention, grass swale, bioswale, etc.
- *Storage* – cistern, rain barrel
- *Landscaping* – effective grading, installation of plants for water quality and quantity control.

Each of these LID practices is briefly described below.

Impervious Surface Control Devices

Runoff from new impervious surfaces is the primary cause of flooding and stream degradation. Reducing the amount of new impervious surface area in development is one of the most effective methods to achieve a reduction in the total volume of runoff. For example, most residential streets can be as narrow as 22 to 26 feet wide without sacrificing emergency access, on-street parking, or vehicular and pedestrian safety. A shift to narrower streets can result in a 5 to 20 percent overall reduction in impervious area. Reducing road area also reduces paving costs.

Examples of narrow residential street widths from different regions of the country are listed in Table B.3.

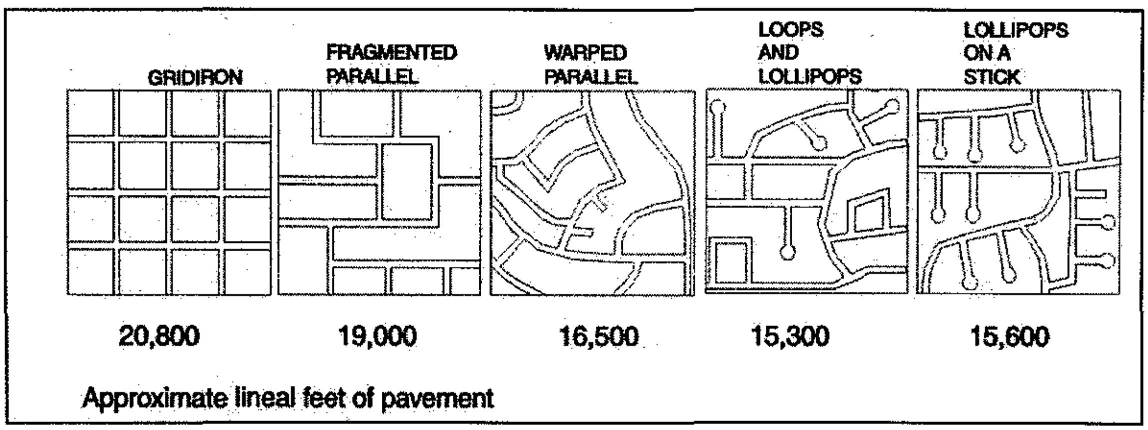
Table B.3
Examples of Narrow Residential Street Widths

State	***Jurisdiction***	***Standard***
Arizona	City of Phoenix	28 feet(parking on both sides)
California	City of Novato	24 feet (both sides, 2 to 4 du) 28 feet (both sides, 5 to 15 du)
Colorado	City of Boulder	20 feet (150 ADT) 20 feet (no parking, 350 – 1000 ADT) 22 feet (one side, 350 ADT) 26 feet (both sides, 350 ADT) 26 feet (one side, 500 – 1000 ADT)
Delaware	Delaware DOT	21 feet (one side)
Florida	City of Orlando	28 feet (both sides, res. lots <55 feet wide) 22 feet (both sides, res. lots >55 feet wide)
Maine	City of Portland	24 feet (one side)
Maryland	Howard County	24 feet (1000 ADT)
Michigan	City of Birmingham	26 feet (both sides) 20 feet (one side)
Montana	City of Missoula	26 feet (both sides, 3 – 80 du) 32 feet (both sides, 81 – 200 du) 12 feet (alley)
New Mexico	Albuquerque	28 feet (one side)
New Jersey		20 feet (no parking, 0 – 3500 ADT) 28 feet (one side, 0 – 3500 ADT)
Oregon	City of Portland	26 feet (both sides) 20 feet (one side)
Pennsylvania	Bucks County	12 feet (alley) 16 – 18 feet (no parking, 200 ADT) 20-22 feet (no parking, 200 – 1000 ADT) 26 feet (one side, 200 ADT) 28 feet (one side, 200 – 1000 ADT)
Tennessee	City of Johnson City	22 feet (<240 ADT) 24 feet – 28 feet (240 – 1500 ADT) 28 feet (>1500 ADT)

Table B.3 (cont.) Examples of Narrow Residential Street Widths		
State	***Jurisdiction***	***Standard***
Vermont	City of Burlington	30 feet (both sides)
Washington	City of Kirkland	12 feet (alley) 20 feet (one side) 24 feet (both sides, low density only) 28 feet (both sides)
W. Virginia	Morgantown	22 feet (one side)
Wisconsin	City of Madison	27 feet (both sides, <3 du/ac) 28 feet (both sides, 3 – 10 du/ac)
ADT = average daily traffic du = dwelling unit		

Reference #2 and #3

Other typical LID approaches include alternative roadway layout (Figure B.1) and reduced parking standards (Table B.4). The potential results of impervious surface reduction, or on the overall effective impervious area, are listed in Table B.5. Note how small reductions in the total impervious area can have a relatively large reduction of the amount of on-site impacts and resulting effective impervious area within the watersheds.



Reference #11

Figure B.1 – Length of pavement of various roadway layout options.

Table B.4 Conventional Minimum Parking Ratios			
Land Use	***Parking Requirement***		***Actual Average Parking Demand***
	Parking Ratio	***Typical Range***	
Single-family homes	2 spaces per dwelling unit	1.5 – 2.5	1.11 spaces per dwelling unit
Shopping center	5 spaces per 1000 ft^2 GFA	4.0 – 6.5	3.97 per 1000 ft^2 GFA
Convenience store	3.3 spaces per 1000 ft^2 GFA	2.0 – 10.0	—
Industrial	1 space per 1000 ft^2 GFA	0.5 – 2.0	1.48 per 1000 ft^2 GFA
Medical/dental office	5.7 spaces per 1000 ft^2 GFA	4.5 – 10.0	4.11 per 1000 ft^2 GFA
GFA = Gross floor area of a building without storage or utility spaces.			

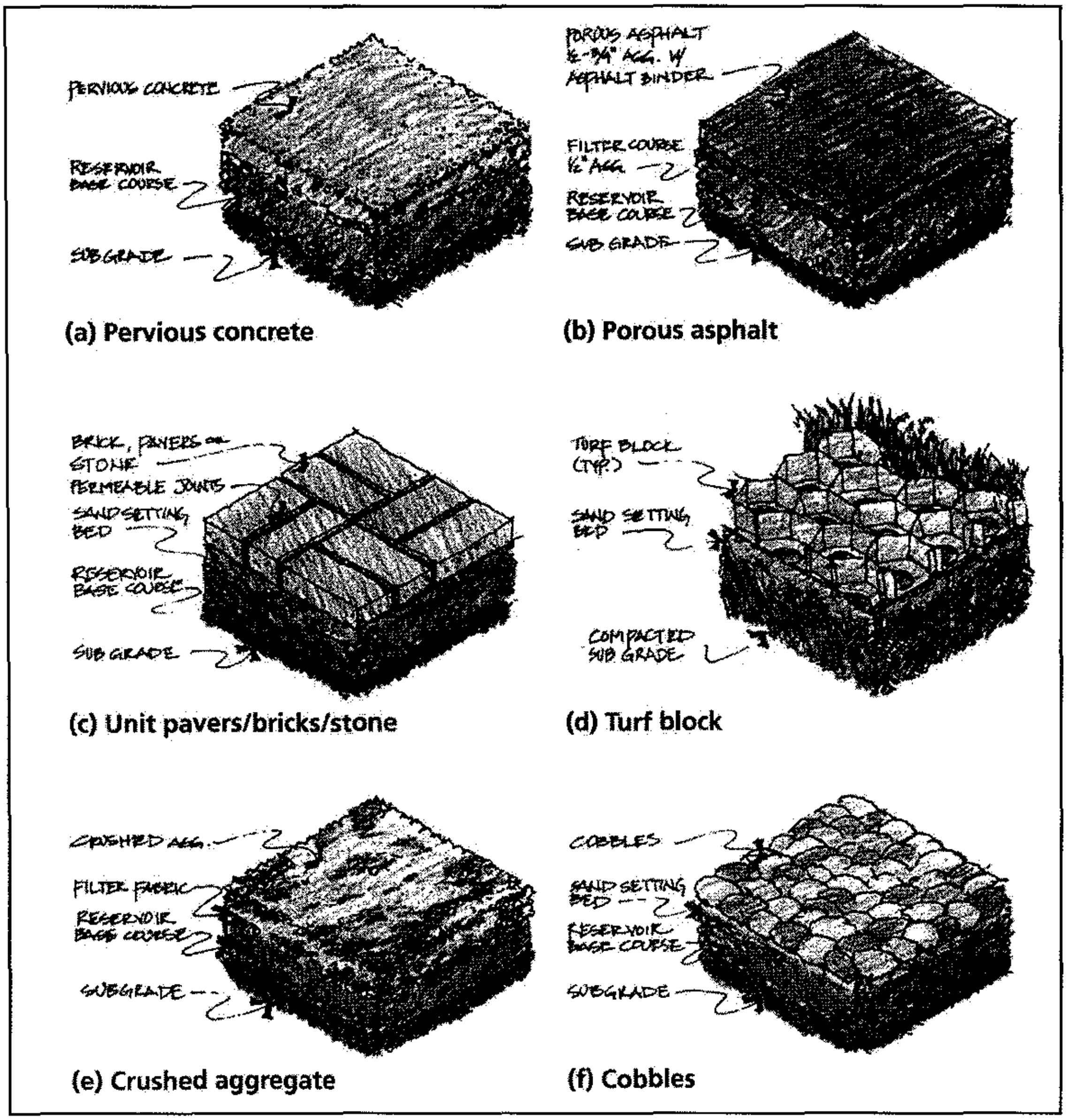
Reference # 11, #14, and #15

Table B.5 Basin and Site Coverage Assessment Reduction Analysis Results						
Potential Strategy			***Impervious Surface Reduction Percentages (%)***			
			Site-Specific		Basinwide	
			Total	Effective	Total	Effective
1.		Reduce residential sidewalks by 50 percent by installing the walks on one side of the street only.	1.33	1.00	1.59	0.83
2.		Reduce residential sidewalks from 5 feet width to 4 feet width.	0.53	0.40	0.64	0.33
3.	a.	Reduce local access street widths from 32 feet to 27 feet.	2.50	2.00	2.98	3.12
	b.	Reduce local access street widths from 32 feet to 25 feet.	3.50	2.80	4.17	4.37
	c.	Reduce local access street widths from 32 feet to 20 feet.	6.00	4.80	7.15	7.49
4.	a.	Reduce commercial parking by 5 percent.	2.67	2.67	1.04	1.37
	b.	Reduce commercial parking by 10 percent.	5.33	5.33	2.09	2.74
	c.	Reduce commercial parking by 20 percent.	10.67	10.67	4.18	5.47
5.	a.	Reduce multifamily parking by 5 percent.	0.74	0.74	0.16	0.21
	b.	Reduce multifamily parking by 10 percent.	1.48	1.48	0.32	0.42
	c.	Reduce multifamily parking by 20 percent.	2.95	2.95	0.64	0.84
6.	a.	Reduce commercial, industrial, and multifamily roof areas by 10 percent.	4.25	4.25	1.38	.094
	b.	Reduce commercial, industrial, and multifamily roof areas by 20 percent.	8.50	8.50	2.76	1.89

Reference #15

Alternative Pavers

Alternative pavers are permeable or semi-permeable surfaces that can be used for driveways, parking lots, and walkways. Figure B.2 shows typical alternative pavers. The effectiveness of alternative pavers will vary depending on the soil layer underneath. Underlying soils need to have a permeability between 0.5 and 3.0 inches per hour. The City of Seattle gives credit for porous pavement (Table B.6) in computing runoff rates from a developed site.



Reference #17

Figure B.2 – Alternative Pavers

Table B.6 Porous Pavement Impervious Surface Reduction Credit				
	SCS Hydrologic Soil Group			
	A	***B***	***C***	***D***
Curve Number (without credit)	98	98	98	98
Curve Number (with credit)	78	85	89	91

Reference #16

Due to the permeability of porous pavers, there is some risk of contaminating groundwater, although most paving alternatives have some pollutant removal effects through the infiltration process. Therefore, they should be located at least two to five feet above the seasonally high groundwater table and at least 100 feet away from drinking water wells[1]. Other design considerations for alternative pavers are listed as Table B.7.

Table B.7 Design Criteria for Alternative Pavers	
Design Criterion	***Guidelines***
Site Evaluation	Take soil boring to a depth of at least 4 feet below bottom of pavers to check for soil permeability, porosity, depth of seasonally high water table, and depth to bedrock.
	Not recommended on slopes greater than 5%. Best with slopes as flat as possible.
	Minimum infiltration rate 3 feet below bottom of pavers: 0.5 inches per hour.
	Minimum depth to bedrock and seasonally high water table: 4 feet.
	Minimum setback from water supply wells: 100 feet.
	Minimum setback from building foundations: 10 feet downgradient, 30 meters (100 feet) upgradient.
	Not recommended in areas where wind erosion supplies significant amounts of windblown sediment.
	Drainage area should be less than 15 acres.
Traffic Conditions	Use for low-volume automobile parking areas and lightly used access roads.
	Avoid moderate to high traffic areas and significant truck traffic.
	Avoid snow removal operation. Post with signs to restrict the use of sand, salt, and other deicing chemicals typically associated with snow cleaning activities.

[1]Please refer to the new draft State Underground Injection Control Rule, 2005.

Table B.7 (cont.) Design Criteria for Alternative Pavers	
Design Criterion	***Guidelines***
Design Storm Storage Volume	Highly variable; depends upon regulatory requirements. Typically design for storm water runoff volume produced in the tributary watershed by the 6-month, 24-hour duration storm event.
Drainage Time for Design Storm	Minimum: 12 hours.
	Maximum: 72 hours.
	Recommended: 24 hours.
Construction	Excavate and grade with light equipment with tracks or oversized tires to prevent soil compaction.
	As needed, divert storm water runoff away from planned pavement area before and during construction.
	A typical porous pavement cross-section consists of the following layers: 1) porous asphalt course, 2-4 inches thick; 2) filter aggregate course; 3) reservoir course of 1.5-3-inches of washed rock; and 4) filter fabric
Porous Pavement Placement	Paving temperature: 240° - 260° F.
	Minimum air temperature: 50° F.
	Compact with one or two passes of a 10-ton roller.
	Prevent any vehicular traffic on pavement for at least two days.
Pretreatment	Pretreatment recommended to treat runoff from off-site areas. For example, place a 25-foot wide vegetative filter strip around the perimeter of the porous pavement where drainage flows onto the pavement surface.

Reference #18

Green Roofs

Green roof applications can be appropriate for some commercial and multi-family residential lots where the buildings occupy a large portion of the site. A layer of absorbent soil on the top of building retains rainfall and allows it to evaporate or transpire from the rooftop vegetation. The runoff from a green roof passes through the absorbent soil layer to an underdrain layer (there is no surface runoff), and therefore, peak runoff rates are attenuated. Green roofs provide multiple benefits such as attenuation of heat island effects which help to save on the energy cost of the building and sound reduction.

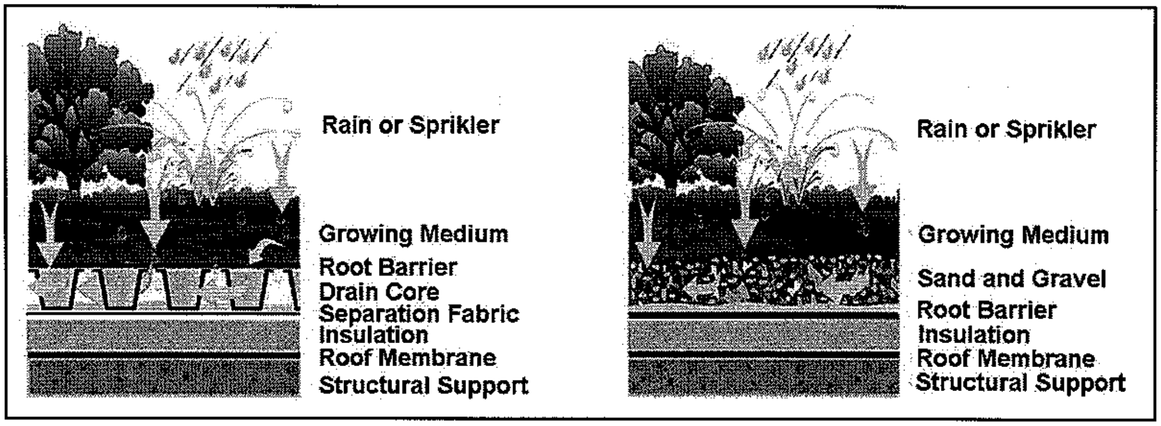
Green roofs are classed into two categories:

- extensive green roofs; shallow soil layer of 3 to 7-inch
  20-34 lb/square feet weight

- intensive green roofs; thick soil layer of 8-inch to 8-foot

80-150 lb/square feet weight

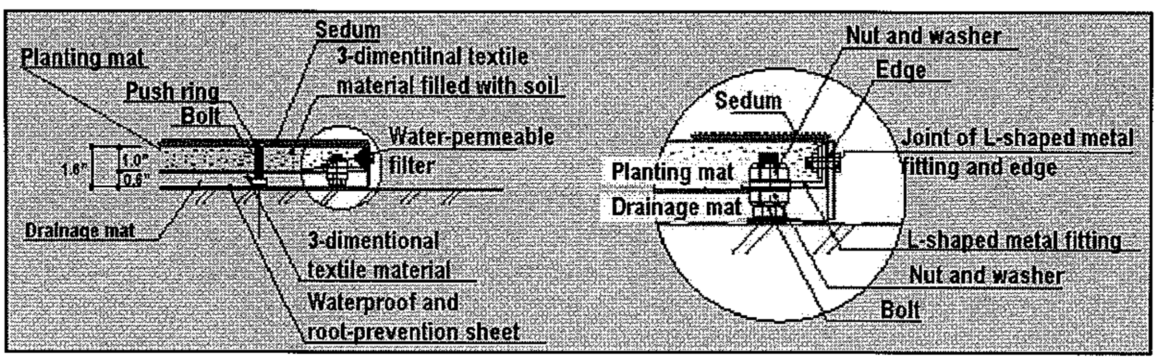
Recently, new technologies have made green roofs lighter to reduce the additional cost of supporting structure of the building. Figure B.3 shows typical green roof profiles.



Reference #19

Figure B.3 – Green Roof Profile

As the least weight green roof, sedum roof has been tested at many locations. Sedum is dry-tolerant plant that can grow with a thin soil layer (one to two-inch). It reduces the weight of green roof five to eight lb/square feet, eliminating the need for additional structural support. Figure B.4 shows sedum roof profiles and details.



Reference #20

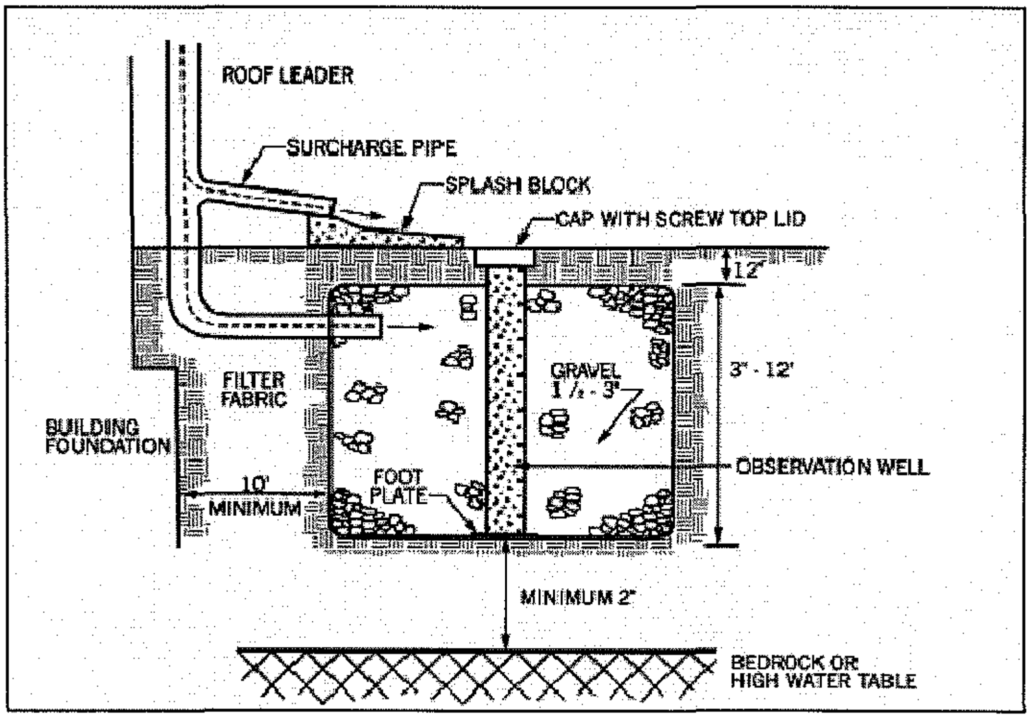
Figure B.4 – Sedum Roof Profile and Detail

Studies show that about one-foot of soil depth is needed to achieve the maximum reduction in runoff rate from prolonged winter storms. However, significant reduction in runoff rates from short intense storms that occur during dry weather periods can be achieved with as little as four inches of soil depth.

The City of Portland gives new green roofs the same credit as forest cover, allowing a curve number of 48 for roof gardens (intensive green roof) and a curve number of 61 for Eco-Roof (extensive green roof). In Germany, 3-inch green roofs have been found to be cost effective, and appreciable runoff will not begin until rainfall amounts exceed 0.6 inch.

Infiltration Facilities – Dry Well

Dry wells are small, excavated trenches backfilled with aggregate. They function as infiltration systems and are often used to control runoff from building rooftops. Dry well designs can be modified to act as catch basins, where they both collect and infiltrate direct surface runoff. Figure B.5 shows a typical detail of a dry well.

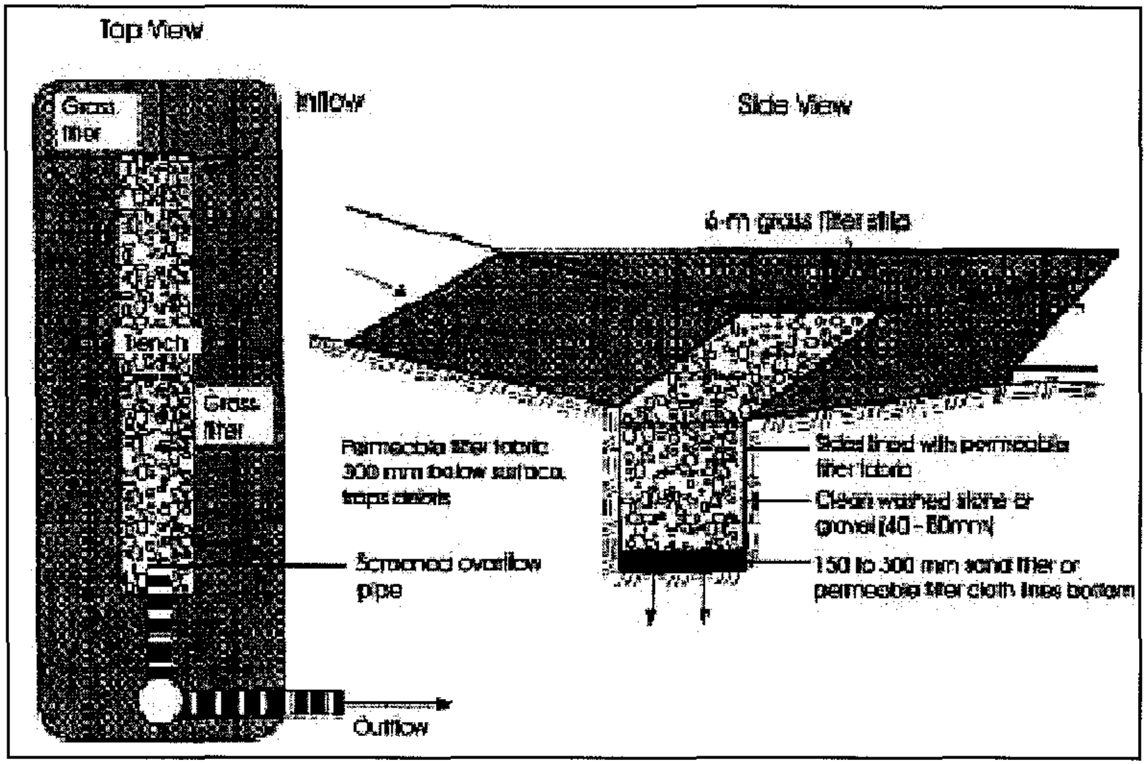


Reference #7

Figure B.5 – Typical Dry Well Section

Infiltration Facilities – Infiltration Trench

An infiltration trench is a shallow excavated trench that has been backfilled with coarse stone aggregate. It can be an underground reservoir or subsurface basin (Figures B.6 and B.7). Stormwater runoff is diverted into the trench and is stored until it can be infiltrated into the soil, usually over a period of several days. Infiltration trenches are a good design option in sandy soils where the depth to the maximum wet-season water table or hardpan is greater than three to six-feet. (Note: The new draft of the Washington State Underground Injection Control Rule has specific design recommendations for dry wells based on soil types and risk of aquifer contamination.)



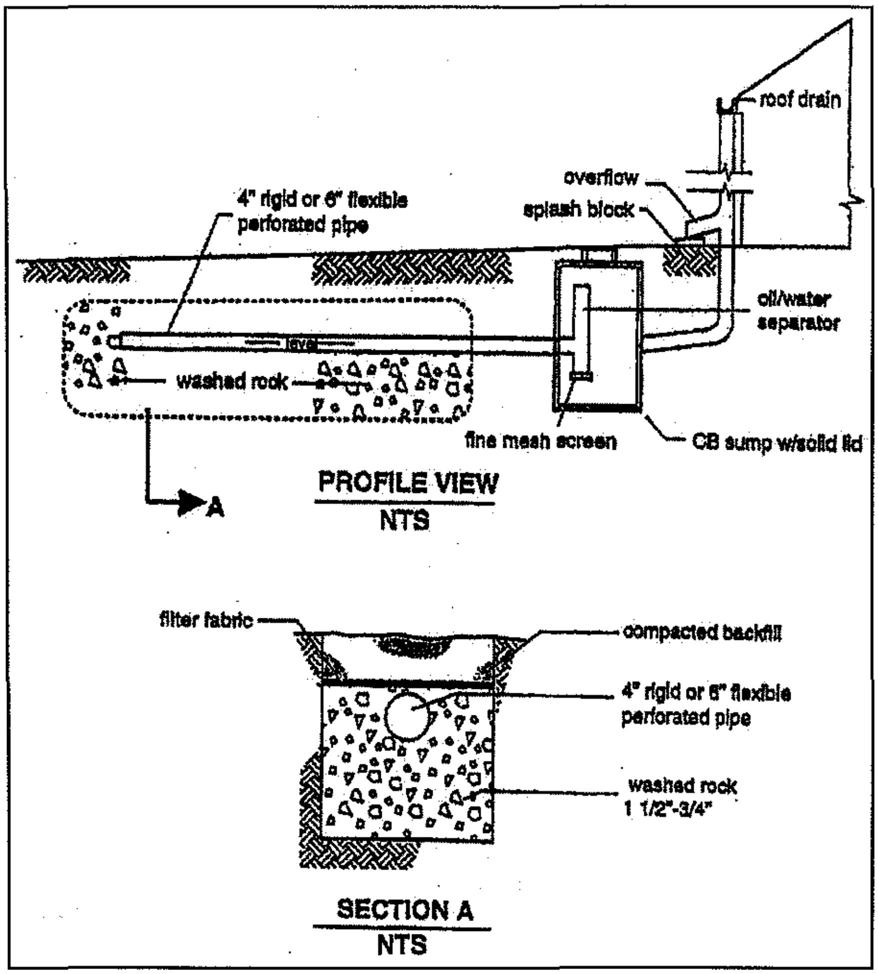
Reference #21

Figure B.6 – Subsurface Infiltration Trench

Bioretention

Bioretention is a water quality and water quantity control practice. It uses the chemical, biological, and physical properties of plants, microbes, and soils for removal of pollutants from stormwater runoff. Bioretention typically is used to treat small (0.25-1.0 acre), highly impervious surfaces such as parking lots and commercial areas. It is designed to contain an average annual storm event of about 0.5 – 0.7 inches of rainfall (Reference #21).

Bioretention consists of grass buffer strips (pretreatment area), ponded area, planting soil, sand bed, organic layer (mulch), and vegetation. A conceptual illustration for a bioretention area is presented in Figure B.8. The bioretention area design provides infiltration and water storage for uptake by vegetation.



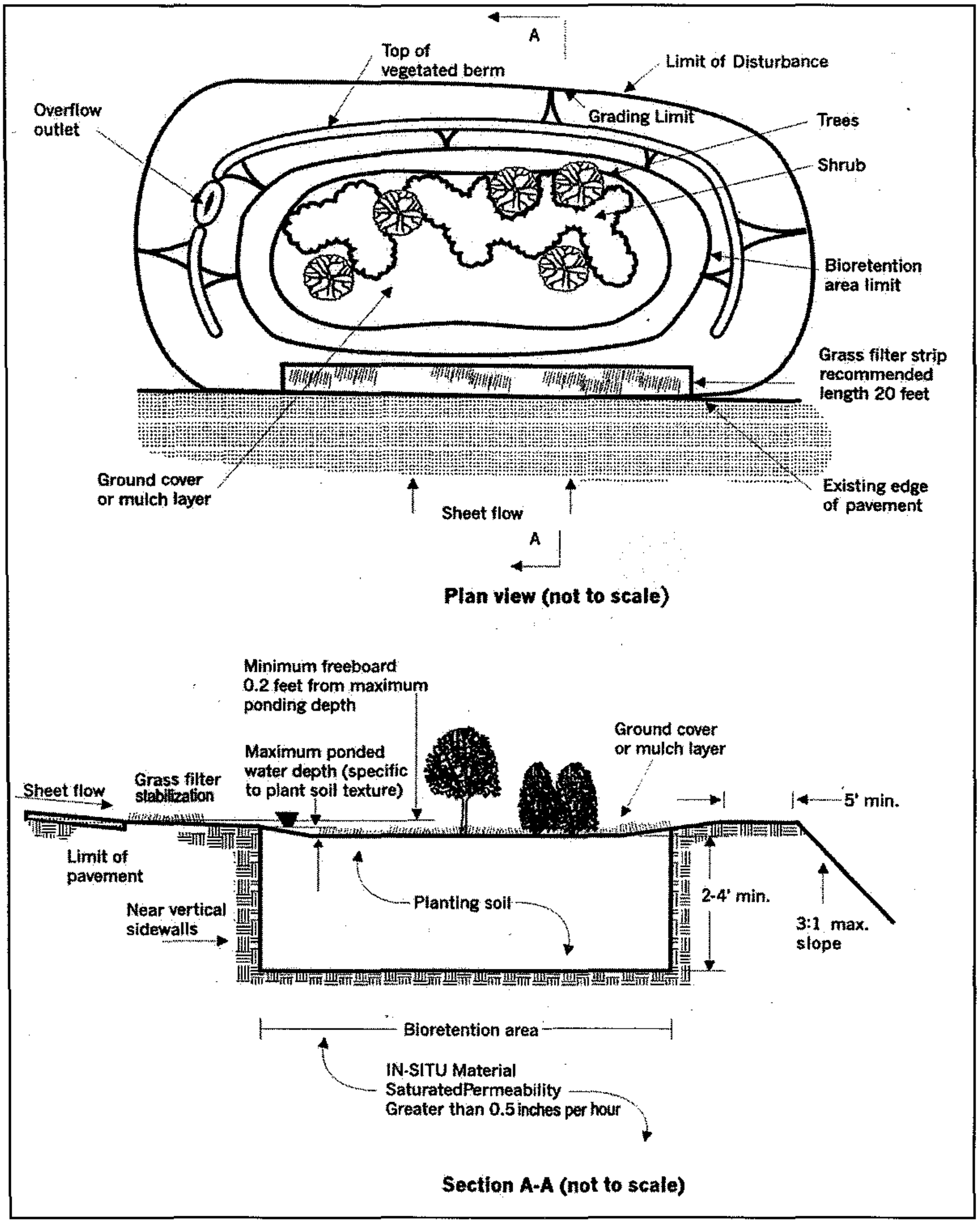
Reference #16

Figure B.7 – Underground Infiltration Trench

The surface of the planting soil is depressed to allow for ponding of runoff. Collected runoff is infiltrated through a surface organic layer of mulch and/or a ground cover to the planting soil. The runoff is stored in the planting soil where it is discharged over a period of days to the native soil underlying the bioretention area.

Bioretention areas should be designed as an off-line treatment system. In off-line systems, the "first flush", which is the most contaminated sheet flow, is retained, and larger flows are bypassed into the normal storm drain system. Such a design prevents the first flush from being washed out by higher discharges associated with on-line systems.

Bioretention has many potential side benefits other than water quality treatment. Plantings can improve the aesthetic value of the site as well as providing ecological value, such as improved habitat for small animals, shade, privacy screens, and wind breaks.



Reference #7

Figure B.8 – Plan View and Section of Bioretention Area

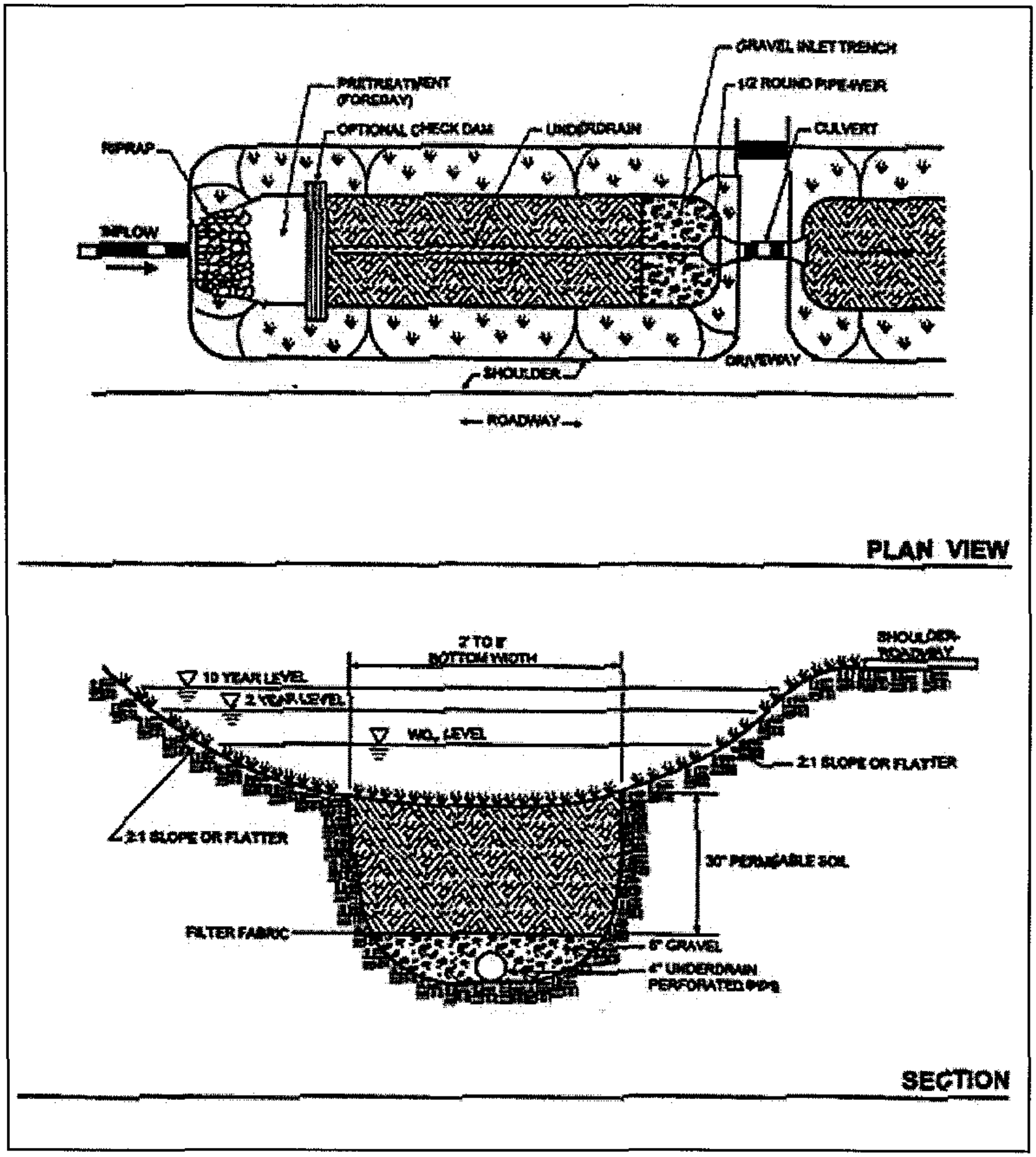
Cost reduction is another benefit of bioretention facilities. In Prince George's County, Maryland, a case study demonstrated that bioretention can be an economical alternative for providing treatment for the first half-inch of runoff from commercial and residential sites. For example, the total estimated cost of a water quality treatment facility for an office building was reduced from $174,000 with oil-grit separators to $111,600 with a bioretention area. For other office building sites, evaluated, bioretention practices reduced the amount of storm drainpipe from 800 to 230 feet.

Grass Swale
Grass swales provide a series of vegetated open channels that are designed specifically to treat and attenuate stormwater runoff. They are best applied on a relatively small scale (generally less than five acres of impervious surface). There are many design variations including dry swales, wet swales, and biofiltration swales. These systems work well along roadways, driveways, and parking lots.

Dry swales are similar in design to bioretention areas. They typically have a sand/soil mix layer that meets minimum permeability required at the bottom of the channel. An underdrain system is also installed under the soil bed. Typically, the underdrain system is created by a gravel layer which encases a perforated pipe. Stormwater treated by the soil bed flows into the underdrain, which conveys treated stormwater back to the storm conveyance system (Figure B.9).

Wet swales intersect the groundwater and behave like a linear wetland cell. This design variation incorporates a shallow permanent pool and wetland vegetation to provide stormwater treatment. One disadvantage to the wet swale is that shallow standing water in the swale can cause public nuisance by providing mosquito breeding habitat.

A biofiltration swale is similar to a dry swale. It is more specifically designed for the treatment of stormwater. The primary pollutant removal mechanisms are filtration by grass blades which enhance sedimentation, trapping, and adhesion of pollutants to the grass and thatch. Biofiltration swales generally do not effectively remove dissolved pollutants. Maintaining dense vegetation is the key to its effectiveness. Therefore, a swale should receive a minimum of six-hours of sunlight daily during the summer months for healthy grass growth. A swale must dry between storms to maintain vegetation in good condition. For permanent saturated soil conditions, a wet biofiltration swale should be installed. Because typical grass dies when soil saturation exceeds two weeks, vegetation specifically adapted to saturated soil conditions should be used.



Reference #1

Figure B.9 – Plan View and Section of Dry Swale

Grass filter strips are vegetated areas intended to treat sheet flow from adjacent impervious areas. Filter strips function by reducing runoff velocities and filtering sediment and other pollutants. With proper maintenance, filter strips can provide relatively high pollutant removal. Grass filter strips require a relatively large amount of space, typically equal to the impervious area they treat. The land requirements for this practice can be a critical drawback in urban environments, where land prices are high. (Reference #1)

Storage

Rain barrels and cisterns are low-cost, effective, and easily maintainable storage units applicable to both residential and commercial/industrial site. Rain barrels operate by retaining a predetermined volume of rooftop runoff. In general, cisterns have a larger capacity and are installed either on rooftop or underground. Washington State Department of Ecology's stormwater design manual suggests that cisterns should provide at least 1,000 gallons of storage to have any significant hydrologic effect.

Costs and Benefits

Conventional and LID stormwater management costs are difficult to compare, because "marginal costs" are rarely defined for either approach. Some case studies and pilot programs show at least a 25 to 30 percent reduction in costs associated with site development, stormwater fees, and maintenance for residential developments that use LID strategies. These savings are achieved by reductions in clearing, grading, pipes, ponds, inlets, curbs, and paving. However, many LID projects have not been fully assessed in the long run due to its early stage in implementation. Some of this basic information is also lacking for conventional stormwater management as well. For instance, the costs to retrofit and repair an entire pipe system after 50 or 60 years are rarely estimated for conventional management. (Reference #8)

In addition, costs are site specific. Each project will be unique based on the site's soil conditions, topography, existing vegetation, land availability, etc. Some commonly seen cost benefits of LID projects include the following:

1. Multi-functionality—In many projects, LID was originally designed as a landscaped feature before its functionality as a stormwater control was introduced. In these situations, the landscaping and construction costs for stormwater have not been included and financially appear to be free. Additionally, the cost of maintaining the landscaped areas is typically included in the project cost and not in the cost of the stormwater system.
2. Lower lifecycle costs—It is important to take into account not just the initial capital costs but also those over the structure's lifetime, which can include operation, repair, maintenance, and decommissioning. Many LID techniques are self-perpetuating, easily repairable, or can be left as natural areas at the end of their functional lifetime, while conventional facilities may require high costs to take out of commission, repair, maintain, and/or replace.
3. Reduced off-site costs—Since LID addresses stormwater trunkline conveyance at its source, it is unlikely to incur major off-site costs in the form of conveyance network or outfalls. Most conventional techniques will require an off-site conveyance network to collect the stormwater from the on-site system, resulting

in additional project costs for the enhancement of downstream systems as urban areas expand.

4. Functional use of open space land—LID practices, such as bioretention, can usually be designed as part of the development's open space. Unlike large detention ponds, if these multifunctional LID practices are distributed throughout set-aside open space or previously designated landscaped land, they can contribute to a more park-like and community-friendly setting without incurring any additional costs for land allocation to the drainage system.

LID techniques will become less expensive over time, as a growing number of competing LID practitioners drive down prices and the technology becomes standard. Roofscapes Inc. expects that overall cost of green roof systems to decline by about 25 percent over the next couple of years (Reference #12).

Currently, costs of each LID technique are estimated as follows:

- Green roof; $5.6 to $14 /square feet[2]
- Absorbent landscaping/Bioretention; $2.3 to $6.5 /square feet[3]
- Dry swale (80 percent bioretention area): $1.8/square feet to $5.2/square feet (Reference #1)
- Porous pavement: $2 to $3 /square feet (conventional asphalt costs $0.5 to $1/square feet)
- Infiltration facilities : $2.8/square feet to $16/square feet
- Manually constructed cisterns (reinforced concrete, size of 3,000 gallons): $1,000

Summary: Applicability of LID to Mason County

Due to its natural setting, there will be many opportunities to use LID designs for the management of surface water runoff as the land within Mason County continue to develope. Table B.8 summarizes the applicability of the five major practices of LID design briefly discussed in the above literature review.

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[2] Extensive roofs are in the lower range, and intensive roofs are in the higher range. A pilot project in the City of White Rock, BC, which has a four-inch deep soil layer, costs about $8.4/square feet than a conventional impervious roof. (Reference #5)

[3] Sites with six-inch deep absorbent soil layer are in the lower range, and sites with 1.5-foot deep absorbent soil layer in the higher range.

Table B.8
Potential Applicability of LID Practices within Mason County

LID Practice	***Examples***	***Applicability to Mason County***
Impervious Surface Control	Porous Pavement Green Roofs	- Could be incorporated into any building design. - Could be incorporated into any building design.
Infiltration Facilities	Dry Well Infiltration Trench	- Recommended for rooftop runoff, provides some attenuation of storms and some infiltration. - Recommended for conveyance, provides infiltration and some detention
Semi-Natural Conveyance System	Bioretention Grass Swale/Bioswale Filter Strips	- Include with landscaping where possible. - Good for small site attenuation and treatment. - Good for parking lots.
Storage	Cistern Rain Barrel	- Of limited use (unless of a large scale). - Could be used for some dry season watering
Landscaping	Effective Grading Use of Plants	- Of limited stormwater benefit unless of a large scale. - Recommend incorporating LID into landscape and green space areas to save costs and provide natural aesthetic look to the site.

In general, LID strategies can be beneficial and are recommended for future development within Mason County. The greatest attraction of the LID in surface water management design is the ability to better mimic some of the naturally occurring drainage systems. As development occurs, LID strategies could be used to simulate these natural systems.

The challenge for the Mason County land owners is to determine which LID strategies should be used and where should they be located. LID designs typically require land, and typically are more costly than conventional drainage designs. Unless they can be incorporated into required landscape and open-space areas, the use of the conventional regional detention and treatment systems may still be the best way for a land owners or developers to optimize the amount of land available for new construction. Clearly a reasonable tradeoff will need to be made between costs, availability of land, and the cost and ability to mitigate environmental impacts as development within Mason County continues.

References

1. Better Site Design Fact Sheet homepage, http://www.stormwatercenter.net

2. Center for Watershed Protection. 1998. *Better Site Design: A Handbook for Changing Development Rules in Your Community*. Ellicott City, MD

3. Cohen, A. *Narrow Streets Database.* Congress for the New Urbanism. Available online at: www.sonic.net/abcaia/narrow.htm

4. CRC, 1996; Davis et al. 1997; MWCG, 1987; Urbonas and Stahre, 1993; Yousef et al., 1985; Yu et al., 1992; Yu et al., 1993.

5. *Effectiveness of Stormwater Source Control,* Greater Vancouver Sewerage & Drainage District, 2002

6. Introduction to LID, Low Impact Development Center Inc., http://www.lid-stormwater.net/intro/background.htm#1

7. *Low-Impact Development Design Strategies, An Integrated Design Approach,* Prince George's County, Maryland, 1999

8. Low-Impact Development, Mary Catherine Hager, Stormwater January/February 2003

9. *Municipal Guide to Low Impact Development,* Low Impact Development Center Inc., http://www.lowimpactdevelopment.org/lid%20articles/Municipal_LID.pdf

10. *Natural Approach to Stormwater Management,* Puget Sound Action Team, March 2003

11. *Parking Generation, 2nd edition.* Institute of Transportation Engineers, Washington, DC. 1987.

12. Roofscape Inc., homepage, http://www.roofmeadow.com/

13. SEA Street homepage, Seattle Public Utility, http://www.seattle.gov/util/SEAStreets/default.htm

14. Smith, Thomas. *Flexible Parking Requirements.* Planning Advisory Service Report No. 377. American Planning Association, Chicago, IL. 40 pp. 1984

15. Wells, Cedar. *Impervious Surface Reduction Technical Study.* Draft Report. City of Olympia Public Works Department. Washington Department of Ecology, Olympia, WA. 1994.

16. City of Seattle. *Flow Control Technical Guidance Manual,* November, 2000.

17. *Green Streets. Innovative Solutions for Stormwater and Stream Crossings,* Metro June 2002.

18. Stormwater Technology Fact Sheet, Porous Pavement, EPA, September, 1999.

19. Amergreen Roof Garden System, http://www.americanwick.com/pdf/amergreen.pdf.

20. Thin-Layer Roof Top Greening System Using Sedum Carpet, http://www.takenaka.co.jp/takenaka-e/techno/lolo-sedum/.

21. Schueler, T.R., *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practice,* Metropolitan Washington Council of Governments. 1987.

22. *The Bioretention Manual.* Programs and Planning Division, Department of Environmental Resources, Price George's County, Maryland, November 2001.

Low Impact Development (LID) Screening Matrix

LID Technique*	Description	Applicability	Comments
1. Site assessment	The site assessment process evaluates the hydrology, topography, soils, vegetation, and water features of the site to identify how stormwater moves through the site prior to development. Wetlands, riparian management areas and floodplains are considered in the assessment process.	All subbasins	Mason Co. GIS includes information such as topography, soils, and water features (including wetlands and floodplains) that can be shared with property owners. Provide contact information in a brochure distributed to the public.
2. Site planning and design	Site planning and design addresses road, driveway, and parking layouts, road crossings, street trees, site layout, and building design. LID practices applicable to a given site influence the planning and design of these elements for the site.	All subbasins	Provide information and examples in a brochure distributed to the public.
3. Site phasing and fingerprinting	Site construction phase planning is performed to minimize impacts on LID elements. Site fingerprinting refers to placing development away from environmentally sensitive areas (wetlands, steep slopes, etc.), future open spaces, tree save areas, future restoration areas, and temporary and permanent vegetative buffer zones. It also confines ground disturbance to areas where structures, roads and rights-of-way will exist after construction is complete.	All subbasins	Mason Co. GIS includes information such as topography, soils, and water features (including wetlands and floodplains) that can be shared with property owners. Provide information and examples in a brochure distributed to the public.
4. Preserving native soils and vegetation	This technique addresses preservation of native soils and vegetation as a primary LID objective to limit impacts on aquatic systems. This is done through reduction of total impervious surface coverage; providing areas for infiltration of project runoff; and maintaining or closely mimicking the natural hydrologic function of the site.	Basins EF090, EF100, EF010, EF020, and other sites with wetlands, and/or streams	Mason Co. GIS includes information such as topography, soils, and water features (including wetlands and floodplains) that can be shared with property owners. Provide information and examples in a brochure distributed to the public.

*Basic Source: Puget Sound Action Team • Washington State University Pierce County Extension, *Low Impact Development Guidance Manual for Puget Sound*, January 2005 (Revised May 2005)

Low Impact Development (LID) Screening Matrix

LID Technique	Description	Applicability	Comments
5. Clearing and grading	For project clearing and grading, the primary LID technique is to minimize site disturbance through reducing the extent of grading and retaining vegetative cover. This technique seeks to minimize hydrologic modifications and control sediment yield from the site.	All subbasins	Mason County proposed zoning currently limits the structure size and the maximum allowable lot coverage of many of the proposed zones.
6. Bioretention cells	Bioretention cells (also known as "rain gardens") provide for on-site retention of stormwater through the use of vegetated depressions engineered to collect, store and infiltrate runoff.	All subbasins	Provide information and examples in a brochure distributed to the public. Good for small (0.25 – 1 ac), highly impervious sites such as parking lots and commercial areas.
7. Sloped biodetention	The sloped biodetention technique uses grassy vegetative barriers such as hedgerows on contours to detain stormwater and reduce pollutant loads.	BP, R-3	
8. Bioretention swales	Bioretention swales function to collect, store and infiltrate runoff on a linear basis such as in landscaped swales in roadway medians.	All basins	May be used instead of curb and gutter infrastructure.
9. Tree box filters	Tree box filters are a mini bioretnention areas installed beneath trees. With this technique, runoff is directed to the tree box where it is cleaned by vegetation and soil before being discharged to a catch basin. The runoff also helps to irrigate the tree.	BP, R-3, POS, VC, VR	
10. Maintenance	On-going maintenance and long term protection of native vegetation and soils associated with LID stormwater facilities are necessary to their successful performance. Clearly written maintenance procedures and LID area protection plans are important to this element.	POS	County to provide maintenance of their right of way. Provide information and examples in a brochure distributed to the public.

Low Impact Development (LID) Screening Matrix

LID Technique	Description	Applicability	Comments
11. Amending construction site soils	With this technique, disturbed site soils are amended to enhance their hydrologic attributes and environmental benefits in landscaped areas. Soil amendment specifications include organic matter content, pH, depth of amendment and subsoil preparation.	All basins	Provide information and examples in a brochure distributed to the public.
12. Permeable pavement	Permeable pavement surfaces accommodate pedestrian, bicycle and vehicular traffic while allowing the infiltration, treatment and storage of stormwater. The general categories of this technique relate to the pavement wearing material and include: • Permeable asphalt concrete • Permeable concrete • Permeable gravel • Permeable pavers Permeable pavement sections consist of: (1) a permeable wearing course or surface area designed to provide the strength needed for traffic loads; (2) an aggregate base below the surface section for support, vertical and lateral dispersion of water, and temporary storage of runoff; (3) and separation layer using non-woven geotextile fabric below the aggregate base to prevent upward migration of fine soil particles; and (4) where required, a water quality treatment layer to filter pollutants and protect the ground water.	All basins	(+) Provides groundwater recharge, no space requirements, and high removal efficiency (US GBC) (-) Requires permeable soils, not suitable for high traffic or high speed areas, high potential for failure, requires maintenance (US GBC)

Low Impact Development (LID) Screening Matrix

LID Technique	Description	Applicability	Comments
13. Vegetated roof	Vegetated roofs are also known as green roofs and eco-roofs. They are categorized as either intensive (deeper soil layer, intensive plantings, higher maintenance) and extensive (shallower soil layer, lower cost, lower maintenance). Benefits identified for vegetated roofs include energy efficiency and air quality, temperature and noise reduction in urban areas, improved aesthetics, extended roof life, and reduction in stormwater flows. The typical vegetated roof section includes from top to bottom: vegetation layer; growth medium (soil) layer; separation layer; drainage, aeration, water storage and root barrier layer; water proof membrane; and roof structure section.	All basins	Provide information and examples in a brochure distributed to the public.
14. Minimal excavation foundations	This LID technique seeks to limit soil disturbance during construction by the use of minimal excavation systems. The objective is to limit compaction of site soils from heavy equipment operations which would result in degradation of the infiltration and storage capacities of the site soils.	All basins	Provide information and examples in a brochure distributed to the public.
15. Homeowner education	Homeowner education is an important component of a successful LID maintenance program and LID area protection plan. Clearly written operations and maintenance procedures and protection management plans should be a part of any homeowner education program.	All basins	Provide information and examples in a brochure distributed to the public.
16. Downspout dispersion	Downspout dispersion provides for the dispersion and infiltration of roof runoff onsite. Several dispersion methods are available including splash blocks, gravel trenches and sheet flow.	Low density Residential zoning areas	Basins with well draining soil and low % impervious

Low Impact Development (LID) Screening Matrix

LID Technique	Description	Applicability	Comments
17. Roof stormwater harvesting systems	Roof stormwater harvesting (also know as "rainwater harvesting") is the collection and storage of roof runoff for domestic or irrigation purposes. Harvesting systems include a collection (roof) area, a filter, a storage device (tank or vault) and an outflow device.	Subbasins requiring rate control EF010, EF015, SF010, SF020, and SF030	Helps reduce the size of regional facilities subbasins requiring rate control.
18. Filter strips	Filter strips are grassy slopes located adjacent to an impervious area subject to vehicular traffic. Pollutants are removed by the action of grass blades which enhance sedimentation and trapping and adhesion of pollutants to the grass. Filter strips are graded to provide for sheet flow over the entire filter area.	Roads in residential areas (<10 units per acre?)	This low maintenance water quality feature is economical and even provides some habitat (US Green Building Council). Filter strips work best with low velocity flows.
19. Media filtration	Media filtration includes sand filter units or patented units using leaf compost material or other media such as perlite, zeolite and others. Pollutants are removed through filtration in sand filters and filtration, adsorption, ion exchange and microbial degradation in the patented units.	Near outfalls without enough open space to provide another WQ facility	
20. Constructed Wetland	Constructed Wetlands are engineered systems that are designed to mimic natural wetland treatment properties. Advanced designs incorporate a wide variety of wetland trees, shrubs, and plants while basic systems only include a limited number of vegetation types (US GBC).	Upstream of outfalls and/or at shared use public open space	Good for large developments, or regional facilities, peak volume control, high removal efficiency, and aesthetic value. Requires significant space, some maintenance, and is not economical for small developments.