Cluster developments have many benefits compared with conventional commercial developments or residential subdivisions. They can reduce impervious cover, stormwater pollution, construction costs, and the need for excessive grading and landscaping, while providing for the conservation of natural areas. Figure 3-4.7 shows a simple example of cluster development.

Along with reduced impervious areas, open space designs provide a host of other environmental benefits lacking in most conventional designs. These developments reduce the potential to encroach on conservation and buffer areas since enough open space is usually reserved to accommodate these protected areas. Further, less land is cleared during the construction process and therefore alteration of the natural hydrology and the potential for soil erosion are also greatly diminished.

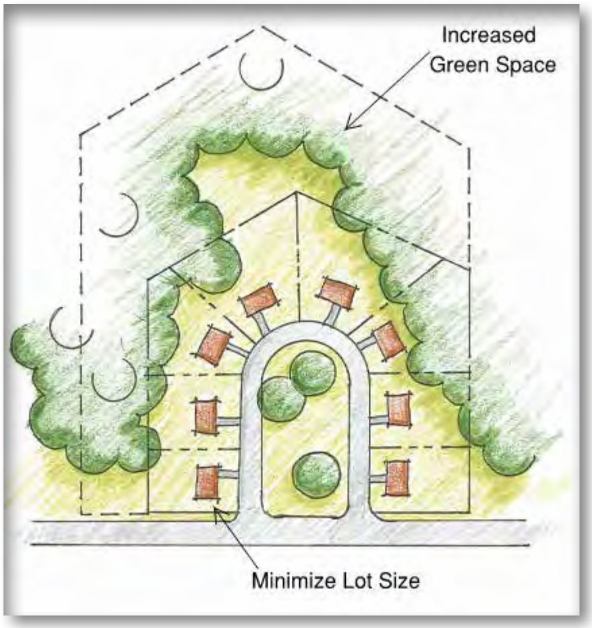


Figure 3-4.7
Example of Simple Cluster Development

3.4.3 Reduction of Impervious Cover/Impervious Cover Management

A technique potentially having the largest stormwater impact is simply reducing the total amount of impervious area necessary for a project. Reducing impervious area gives immediate benefits by improving water quality, reducing runoff volumes and peak flow rates, reducing runoff temperature and minimizing runoff velocity. Multiple techniques exist to accomplish this task.

A. Use Fewer or Alternative Cul-de-sacs: Alternative turnarounds are designs for end-of-street vehicle turnarounds that replace cul-de-sacs and reduce the amount of impervious cover created in developments. Cul-de-sacs are local access streets with a closed circular end that allows for vehicle turnarounds. Many of these cul-de-sacs can have a diameter of more than 80 feet. From a stormwater perspective, cul-de-sacs create a large area of impervious cover, increasing the amount of runoff. For this reason, reducing the size of cul-de-sacs through the use of alternative turnarounds or eliminating them all together through the use of loop streets can reduce the amount of impervious area created at a site. It is important to coordinate alternative cul-de-sacs with the City to maintain adequate access for emergency vehicles.

Numerous alternatives exist to create less impervious cover than the traditional 80-foot cul-de-sac. These alternatives include: reducing cul-de-sacs to a 60-foot diameter and creating hammerheads, loop roads, and pervious landscaped islands in the cul-de-sac center, see Figure 3-4.8.

Figure 3-4.8
Looped Turn-Around with Bioretention in Center

- **Cul-de-sac Design:** Though cul-de-sacs and 'dead ends' are not encouraged in urban street design, they do exist within urban areas. Where cul-de-sacs are unavoidable, they can be designed with central landscaped islands that reduce impervious area and to allow for infiltration of stormwater runoff.

  The goal is to provide ample room for vehicles, while also reducing impervious area and managing stormwater from the street and adjacent properties. The street should be graded to the central island to the extent that surrounding topography allows. Figure 3-4.9 demonstrates a bioretention facility. In this design, runoff can enter the island through curb openings or a curbless design. Other alternatives to traditional cul-de-sac's are shown in Figure 3-4.10.

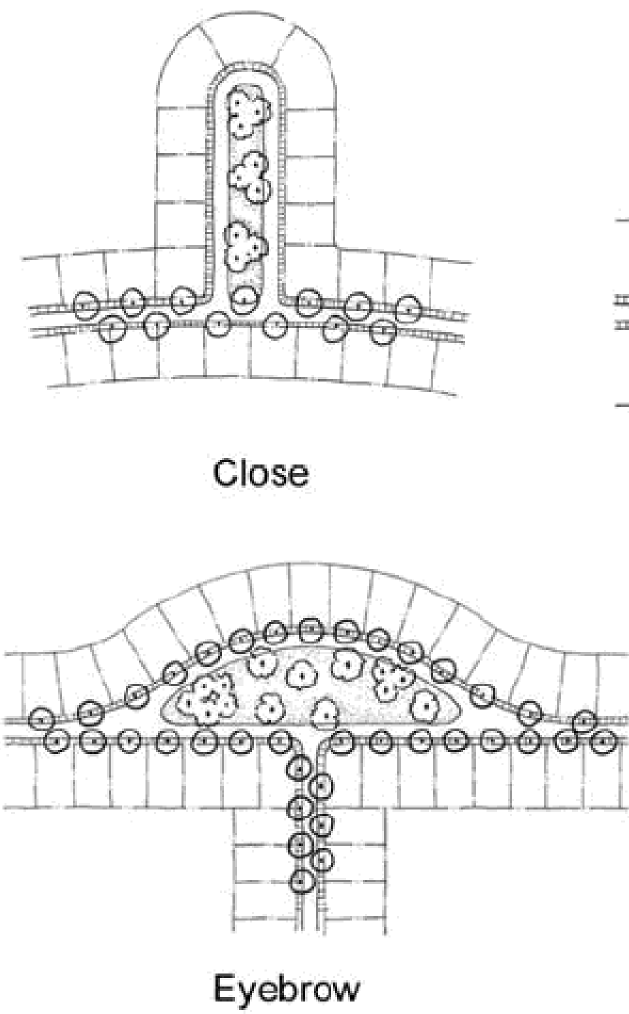


Figure 3-4.10
Alternative Designs

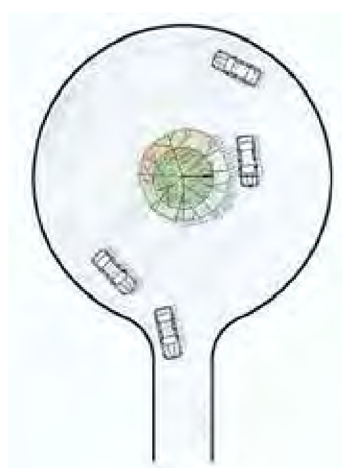


Figure 3-4.9
Looped Turn-Around with Bioretention in Center

B. Create Parking Lot Stormwater "Islands": Parking lots should be designed with landscaped stormwater management "islands" which reduce the overall impervious cover of the lot, as well as provide for runoff treatment and control in stormwater facilities. Having a few large islands will sustain healthy trees more effectively than several small islands. The most effective solutions in designing for tree roots in parking lots is to use a long planting strip at least 8 feet wide, constructed with sub-surface drainage and compaction resistant soil.

Structural control, such as filter strips, vegetated swales and bioretention areas can be incorporated into parking lot islands. Stormwater is directed into these landscaped areas and temporarily detained. The runoff then flows through or filters down through the bed of the structure and is infiltrated into the subsurface or collected for discharge at a controlled rate into a stream or another stormwater facility. These structures can be attractively integrated into landscaped areas and can be easily maintained by commercial landscaping firms.

- Parking Lot Design: The requirements of peak flow management and stormwater volume reduction can often be met by rethinking parking lot design. Effective use of the minimum parking space and aisle dimensions allows the number of parking spaces to remain the same, while reducing impervious surface, providing stormwater management, and adding valuable green space to a parking lot.
- Parking Lot Design Overview: An important goal in sustainable parking lot design is to attempt to eliminate or minimize pipes and inlets. In this case, sheet flow from the parking lot is directed toward shallow bioretention gardens. The runoff is then temporarily detained and infiltrated into the subsurface of the bioretention garden. Bioretention gardens can replace the need for other conventional stormwater management techniques. Sites can benefit from distributed bioretention gardens placed along the edges of the parking lot as well as in islands and medians, such as that shown in Figure 3-4.11.

Figure 3-4.11
Parking lot Biorentention Garden

By utilizing this design technique, traditional stormwater infrastructure can be reduced, and parking lot aesthetics are improved. The use of large trees helps to improve the air quality and provide shade for the cars in the parking lot.

It is important to note that it is important to have flow controls, such as level spreaders or stabilized filter strips, to reduce sheet flow velocity to a non-erosive level.

C. **Minimize Impervious Area:** In this case, the goal is to thoughtfully consider reducing the total impervious cover. This can be achieved by objectively looking at the site and what impervious areas are necessary versus what is a convenience. Reduction of impervious areas reduces stormwater volume and peak flow rates, as well as a reduction of urban "heat island" effects.

- Reducing Paving Surfaces: Two options for reduction of paved surfaces include: use of narrower sidewalks or street lanes based on anticipated use (i.e. using 10' wide travel lanes instead of 12' wide on low traffic roadways), and eliminating excessive parking designed for infrequent events by considering the use of pervious "overflow" parking to handle infrequent events. This can be accomplished with "geogrids" or "geo-webs" incorporated into the top layer of soil prior to planting turf.
- Using Pervious Paving Materials: Multiple technologies such as sand swept brick pavers, porous concrete, and turf pavers, illustrated in Figure 3-4.12, promote infiltration while still providing a stable surface. Anticipated frequency of use, soil type, and weight of vehicles must be considered to determine the appropriate surface.

Figure 3-4.12
Parking area paved with turf block paver

- Porous/Permeable Pavement: The use of porous or permeable pavement creates a parking lot that distributes stormwater evenly into subsurface infiltration bed. These systems can be designed to infiltrate even the large storms. To ensure continued function, seasonal maintenance is required for most porous pavement systems.

The City will proactively consider use of alternative materials on a case by case basis. Technologies such as porous concrete must be swept and maintained frequently, placed on a well drained subgrade with suitable soils located outside of graded fill areas. Turf reinforced pavers may require occasional fertilizer and replanting. Effective maintenance of these materials determines long term success.

- Use of Multiple Story Structures: This approach would reduce the project footprint by constructing a structure two or more stories high instead of constructing a larger single story building. Many developers are also placing parking beneath structures to minimize the total impervious footprint (see Figure 3-4.13).

- Use of "Green Roof": Technologies have increased substantially over the past two decades with respect to the functional use of a growing and living roof system. A green roof at West Virginia University, illustrated in Figure 3-4.14, provides rainfall attenuation by collecting water in the planting soil and promoting evapotranspiration. The initial cost of a green roof system installation is typically more expensive than a traditional roof system since it must be structurally designed to handle the weight of soil and anticipated water impoundment, however, a green roof can reduce costs of heating and cooling during the lifespan of a building. There are costs related to plant maintenance with respect to a green roof system, but if it is maintained properly, a green roof can have a longer life expectancy than a conventional roof system.

D. Disconnect Impervious Cover: Impervious area is considered either connected or disconnected depending on where the stormwater runoff is discharged. Disconnected impervious cover is defined as impervious cover that does not contribute directly to stormwater runoff from a site. Stormwater runoff is directed to existing or constructed on-site pervious areas to infiltrate into the soil or be filtered by overland flow. Typically the net rate and volume of the

Figure 3-4.13
Building in Charleston with a Reduced Impervious Footprint Due to Parking Beneath Building

Figure 3-4.14
Green roof at West Virginia University

runoff from the disconnected impervious cover is substantially reduced. Figure 3-4.15 shows a constructed detention area / rain garden where sidewalk and rooftop runoff was conveyed instead of being connected to a pipe system.

Courtesy of Philadelphia Stormwater Manual V 2.0

Figure 3-4-15
Example of Detention Garden use to slow water discharge

- Surface Runoff Disconnection: Is a practice that can be applied to almost any location, whether it is implemented during the construction phase or even modifying a post-construction site. Because disconnecting impervious cover requires minimal construction and material, it is very cost effective. Further, there are reduced maintenance costs associated with disconnection practices compared to traditional BMPs. Annual inspections are required in order to ensure that stormwater properly conveyed to the desired location, and infiltration is occurring as originally planned. These inspections should be scheduled during annual grounds maintenance. Figure 3-4.16 shows a retrofit to the Berkeley County Courthouse parking lot where runoff was disconnected from storm sewer and was diverted to a new rain garden.

Figure 3-4.16
Rain Garden at Berkeley County Courthouse

- Rooftop Disconnection: Disconnecting rooftops from the system involves directing flow from downspouts to vegetated areas where the runoff can infiltrate into the ground or be filtered by overland flow. Rooftop disconnection is dependent on several site conditions to function properly; such as permeable flow path area, soils, slopes and soil compaction.

  In the past, roof drains were routinely directed to streets or city drainage structures. It is important to note the proximity to basements, utility vaults and pedestrian walkways so disconnection of rooftops does not create other problems on site.

  Stormwater runoff can be collected in storage devices such as rain barrels or cisterns so it can be reused as a non-potable water source. Rain barrels are most commonly used in residential applications. Stormwater that is collected in rain barrels can be used to irrigate lawns and gardens, and as wash water. This water is not suitable for human consumption, as it has not been properly treated. A series of rain barrels can be installed at one location to provide larger capacity. An overflow pipe must be installed and screens should be used to discourage mosquito breeding.

  Cisterns are generally larger than rain barrels (see Figure 3-4.17) and can be installed above or below ground. Cisterns may include pumps and filtration devices to reuse the water. The larger storage capacity allows for greater reuse opportunities and can accommodate more than one residence.

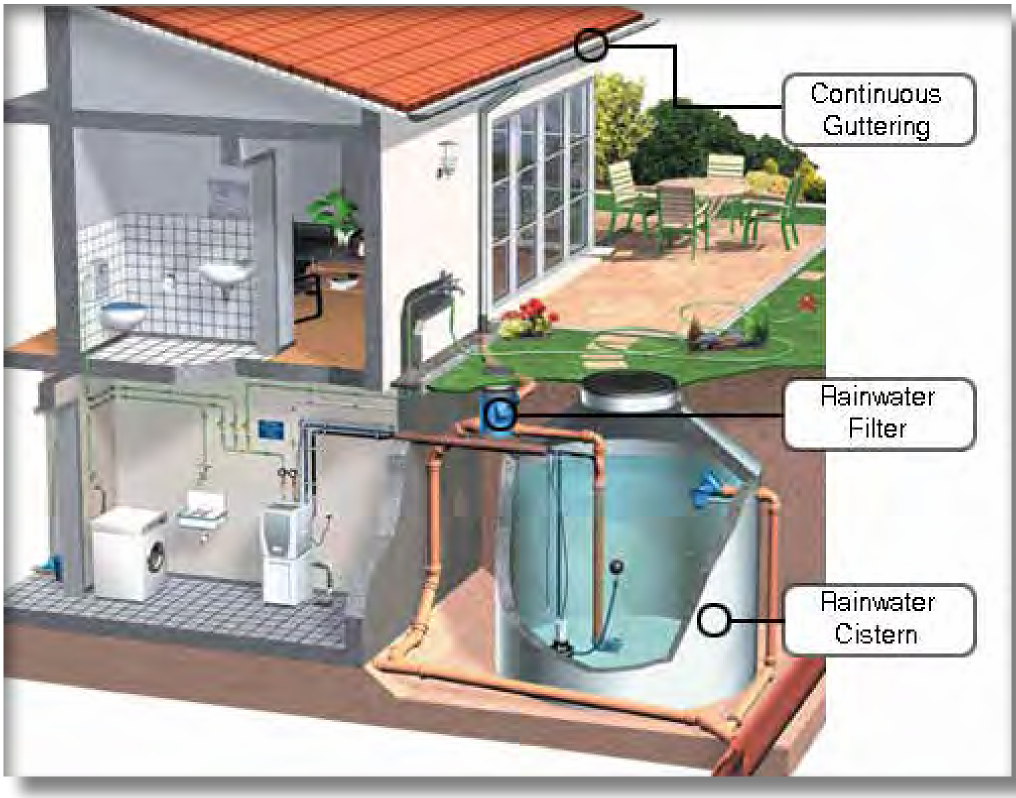


Figure 3-4.17
Rainwater Cistern Schematic

Impervious disconnection is appropriate for homes, businesses, pavement structures (such as sidewalks and driveways), pathways, parking lots and low-traffic alleys or side streets. The rain garden at the Charleston Habitat ReStore shop collects stormwater from the entire parking area, see Figure 3-4.18. Large roadways and parking areas require additional considerations.

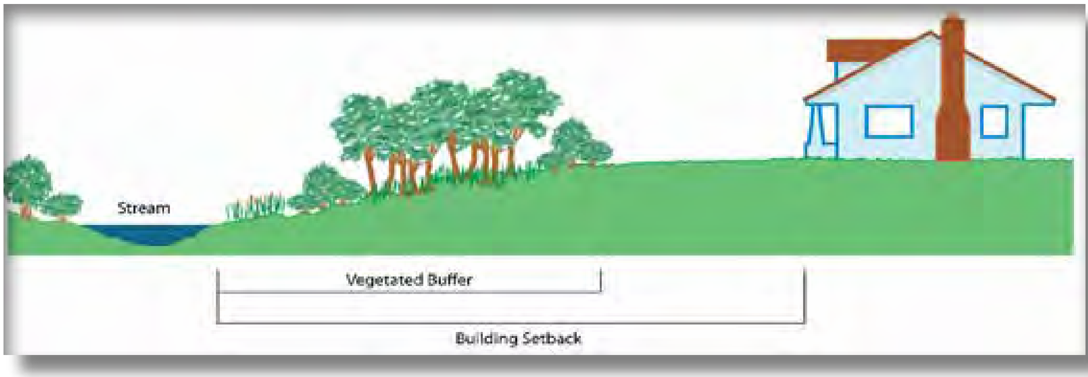
Figure 3-4.18
Parking lot collection Rain Garden

3.4.4 Utilization of Natural Features for Stormwater Management

A. **Use Buffers and Undisturbed Areas:** Stormwater runoff can be directed towards riparian buffers and other undisturbed natural areas delineated in the initial stages of site planning to infiltrate runoff, reduce runoff velocity and remove pollutants, see Figure 3-4.19. Natural depressions can be used to temporarily store (detain) and infiltrate water, particularly in areas with permeable (hydrologic soil group A and B) soils.

The objective in utilizing natural areas for stormwater infiltration is to intercept runoff before it has become concentrated and then distribute this flow evenly (as sheet flow) to the buffer or natural area.

Carefully constructed berms can be placed around natural depressions and below undisturbed vegetated areas with pervious soils to provide for additional runoff storage and/or infiltration of flows.



Courtesy of mtaudubon.org

Figure 3-4.19
Example of a natural buffer zone

B. Use Natural Drainageways Instead of Storm Sewers: The use of natural open channels allows for more storage of stormwater flows on-site, lower stormwater peak flows, a reduction in erosive runoff velocities, infiltration of a portion of the runoff volume, and the capture and treatment of stormwater pollutants, see Figure 3-4.20. It is critical that natural drainageways be protected from higher post-development flows by applying downstream streambank protection methods to prevent erosion and degradation.

Figure 3-4.20
Natural Drainageway

C. Use Vegetated Swales and Medians Instead of Curb and Gutter: Unlike curb and gutter systems which move water without treatment, open vegetated channels along a roadway remove pollutants by allowing infiltration and filtering to occur. Older roadside ditches that have not been maintained suffer from erosion, standing water, and road edge deterioration. Grass channels and enhanced dry swales are two alternatives that, when properly installed and maintained, are excellent methods for treating stormwater. In addition, open vegetated channels can be less expensive to install than curb and gutter systems.

Medians that are retrofitted to provide stormwater control are effective elements of traffic calming and stormwater management while enhancing the visual quality of the streetscape, see Figure 3-4.21. There are different ways to help prevent stormwater runoff pollution from reaching rivers. Bioinfiltration swales and concave designs are just a few examples of effective stormwater control (see Section 6.6 for details). These provide for an attractive and healthier appearance, and still deliver the necessary benefits to our natural resources.

Figure 3-4.21
Retrofitted Median

D. Maximize Tree Canopy over Impervious Cover: Trees have several stormwater control functions. Trees intercept precipitation by holding water in the leaves and branches allowing it to evaporate, thereby retaining flow and dissipating the runoff energy. This function typically suits storm events measuring less than 0.5 inches within a 24 hour period. Generally, large trees with small leaves are most efficient in capturing precipitation. Deciduous trees are less effective during winter months, whereas evergreens function year-round. Tree facilitate stormwater infiltration and groundwater recharge.

Trees provide cover for paved surfaces which reduces the amount of heat the surface absorbs. This reduces the impacts of the "Urban Heat Island Effect". The less heat absorbed through pavement, the less heat is conveyed to stormwater runoff; decreasing the likelihood that heated stormwater reaches receiving waters. Trees regulate air temperature, unlike where paved surfaces are prevalent. Normally temperatures run higher in the vicinity of large areas of paved surfaces that do not have trees present. Substantial tree canopy provides cover and it can act as a form of disconnection to reduce stormwater temperature. Figure 3-4.22 displays how a dense tree canopy along Capitol Street in Charleston provides shade and some disconnection for rainfall.

Figure 3-4.22
Capitol Street Tree Canopy

E. Altering Time of Concentration: "Time of concentration" is defined as the time it takes a drop of water to travel from the most distant point of drainage area to the outlet of that area once precipitation begins. To minimize stormwater flows, the time should be as long as possible. Natural drainage areas have tree canopies, brush, leaf litter and winding streams that work together to slow the runoff of water. Paved areas remove these components and direct runoff through pipes and ditches increasing the water velocity and reducing the time of concentration.

3.5 LID Case Study

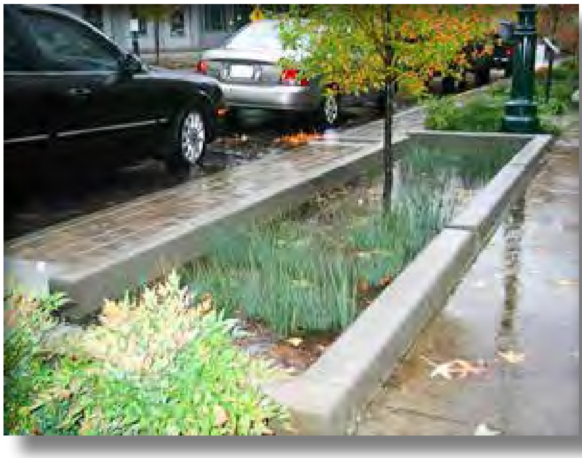
Case Study: SW 12th Avenue Green Street, Portland, Oregon

The SW 12th Avenue Green Street project at SW 12th and Montgomery on the Portland State University campus utilizes a series of landscaped stormwater planters designed to capture and infiltrate approximately 8,000 sf of street runoff.

This innovative streetscape project effectively manages street runoff while still maintaining efficient pedestrian travel and on-street parking.

Built in summer 2005, this street retrofit project demonstrates how both new and existing streets in downtown or highly urbanized areas can be designed to provide direct environmental benefits and be aesthetically integrated into the urban streetscape.

This project is effective, functional, and also successfully integrates landscaped stormwater planters into the urban fabric.



Courtesy of Portlandonline.com

Figure 3-5.1
Retrofitted Median

How It Works

The 12th Avenue Green Street project disconnects street stormwater runoff from a storm sewer that drains directly into the Willamette River and manages it on-site using a landscape approach. Stormwater runoff from SW 12th Avenue flows downhill along the existing curb until it reaches the first of four stormwater planters.

The street runoff is channeled into the first stormwater planter through a 12 inch curb cut. Once inside the planter, the water is allowed to collect until it reaches a depth of six (6) inches. The landscape media within each planter allows the water to infiltrate in the soil at a rate of four (4) inches per hour (Figures 3-5.1 and 3-5.2).

If a rain event is intense, water will exit through the planter's second curb cut, flow back out into the street and eventually enter the next downstream stormwater planter.

Depending on how intense a particular storm is, runoff will continue downhill from planter to planter until all of the stormwater planters are at capacity. Once the system exceeds capacity, the water exits the last stormwater planter and enters the storm sewer.

Courtesy of Portlandonline.com

Figure 3-5.2
Retrofitted Median

With the new stormwater facilities now in place, nearly all of SW 12th Avenue's annual street runoff, estimated at 180,000 gallons, is managed by the landscape system.

Design Challenges

The main challenge for retrofitting SW 12th Avenue was finding enough space for pedestrians, on-street parking, street trees, landscaping, street lighting, signage, and stormwater planters within an eight (8) foot wide space.

A three (3) foot wide parking egress zone was dedicated for people to access their vehicles without being impeded by the storm water planters. Perpendicular pathways were located between each stormwater planter so that a pedestrian would have several access points to their cars or the sidewalk.

For pedestrian safety, a four (4) inch curb exposure at each planter indicates a drop in grade (Figure 3-5.3). Each curb cut that allows the street runoff to enter the storm water planters has an Americans with Disabilities Act (ADA) accessible grate to allow for uninterrupted pedestrian flow along the parking egress zone (Figure 3-5.4).

Courtesy of Portlandonline.com

Figure 3-5.3
Four (4) Inch Curb Exposure

An Award Winning Design

The SW 12th Avenue Green Street Project has received a national award of honor from the American Society of Landscape Architects (ASLA). The city completed the construction of the $30,000 demonstration project in June 2005 and has continually monitored its performance.

Courtesy of Portlandonline.com

Figure 3-5.4
ADA Accessible Grate Over 12 inch Curb Cut Channel

Reference

"SW 12th Avenue Green Street Fact Sheet." City of Portland, Oregon. 2010. Web. 21 Sept. 2010. <http://www.portlandonline.com/bes/index.cfm?c=45386&a=123776>.