Alternative Turnarounds

Practice Description

Alternative turnarounds are designs for end-of-street vehicle turnaround that replace cul-de-sacs and reduce the amount of impervious cover created in residential neighborhoods. 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 radius of more than 40 feet. From a stormwater perspective, this creates a huge bulb of impervious cover, increasing the amount of stormwater runoff. For this reason, reducing the size of cul-de-sacs through the use of alternative turnarounds or eliminating them altogether can reduce the amount of impervious cover created at a site.

There are numerous alternatives to the traditional 40-foot cul-de-sac that create less impervious cover. These include reducing cul-de-sacs to 30-foot radius, hammerheads, loop roads, and creating pervious islands in the center.

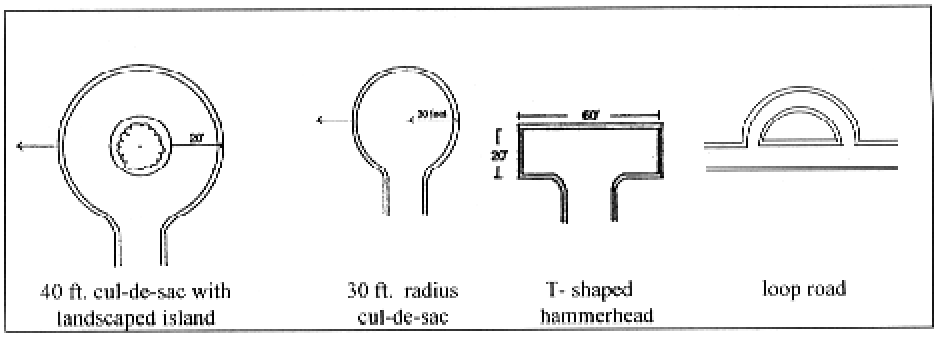


Figure 1: Four turnaround options for residential streets

Figure 1: Alternative turnaround options (CWP, 1998)

Planning Considerations

Alternative turnarounds can be applied in the design of residential, commercial, and mixed use developments. Combined with alternative pavers, green parking, curb elimination and other techniques, the total reduction to site impervious cover can be dramatic, reducing the amount of stormwater runoff from the site. With proper designs, much of the remaining stormwater can be treated on-site.

Sufficient turn-around area is a significant factor to consider in the design of cul-de-sacs. In particular, the types of vehicles entering into the cul-de-sac should be considered. Fire trucks, service vehicles, and school buses are often cited as examples for increased turning radii. However, research shows that some fire trucks are designed for smaller turning radii. In addition, many new larger service vehicles are designed using a tri-axle, and schools buses usually do not enter individual cul-de-sacs.

Implementation of alternative turnarounds will also have to address local regulations and marketing issues. Communities may have specific design criteria for cul-de-sacs and other alternative turnarounds. Also, cul-de-sacs are often featured as highly marketable and, while alternative turnarounds can still capture the end of the street appeal, actual research on market preference is not widely known. Local regulations often dictate requirements for turnaround radii, and some of the alternatives may not be allowed by local codes. In addition, marketing perceptions may also dictate designs, particularly in residential areas. While changing local codes is no small effort, by initiating a local site planning roundtable, communities can change some of these regulations through a cluster ordinance or through a collective effort to review local codes to promote better site design.

Since alternative turnarounds reduce the amount of impervious cover created, construction savings can be an incentive (asphalt costs \$0.50–\$1.00 per square foot in materials alone). Bioretention is estimated at \$6.40 per cubic foot and, while it costs more than providing a naturally vegetated area, it can help reduce overall stormwater costs.

Design Criteria

The primary goals of the alternative turnaround BMP is to reduce impervious surface. This can be achieved through reducing the size of cul-de-sacs or eliminating cul-de-sacs from roadway design. The designs in Figure 1 above show four options for achieving this goal, which range from placing a planter in the center of a traditional cul-de-sac to creating a small loop in the road to route traffic effectively while using less pavement.

Maintenance

If islands are constructed as part of a turnaround, these areas will need to be maintained. Kept as a natural area, the costs could be minimal. Bioretention areas will also require maintenance. The other options create less asphalt to repave, and maintenance will remain the same and cost less (“Alternative Turnarounds,” USEPA 2006).

Eliminating Curbs and Gutters

07/07/2009

Practice Description

This practice promotes grass swales as an alternative to curbs and gutters along residential streets. Curbs and gutters are designed to quickly convey runoff from the street to the storm drain and, ultimately, to a local receiving water. Consequently, they provide little or no removal of stormwater pollutants. Indeed, curbs often act as traps where deposited pollutants remain until the next storm washes them away. Many communities require curbs and gutters as standard elements of road sections. In fact, many communities discourage the use of grass swales. Revisions to current local road and drainage regulations are needed to promote greater use of grass swales along residential streets.

Planning Considerations

The use of engineered swales in place of curbs and gutters should be encouraged in low- and medium-density residential zones where soils, slope, and housing density permit. However, eliminating curbs and gutters is generally not feasible for streets with high traffic volume or extensive on-street parking demand (i.e., commercial and industrial roads). Nor is it a viable option in arid and semi-arid climates where grass cannot grow without irrigation.

Removal of curbs and gutters decreases the peak flow discharge to receiving waters. Furthermore, under the proper design conditions, grass swales can be effective in removing pollutants from urban stormwater (Schueler, 1996).

Engineered swales are a much less expensive option for stormwater conveyance than the curb and gutter systems they replace. Curbs and gutters and the associated underground storm sewers have been documented to cost as much as $36 per linear foot, which is roughly twice the cost of a grass swale (Schueler, 1995). Consequently, when curbs and gutters are eliminated, the cost savings can be considerable.

Design Criteria

A series of site factors must be evaluated to determine whether a grass swale is a viable replacement for curbs and gutters at a particular site.

Contributing drainage area

Most individual swales cannot accept runoff from more than 5 acres of contributing drainage area. Typically, they serve 1-2 acres each.

Soils

The effectiveness of swales is greatest when the underlying soils are permeable (hydrologic soil groups A and B). The swale may need more engineering if soils are less permeable.

Slope

Swales generally require a minimum slope of 1 % and a maximum slope of 5 %.

Water Table

For most designs, swales should be avoided if the seasonally high water table is within 2 feet of the proposed bottom of the swale.

Development Density

The use of swales is often difficult when development density becomes more intense than four dwelling units per acre, simply because the number of driveway culverts increases to the point where the swale essentially becomes a broken-pipe system. Typically, grass swales are designed with a capacity to handle the peak flow rate from a 10-year storm, and fall below erosive velocities for a 2-year storm.

Construction and Installation

Although there are different design variations of the grassed swale, some design considerations are common to all. An overriding similarity is the cross-sectional geometry. Swales often have a trapezoidal or parabolic cross section with relatively flat side slopes (flatter than 3:1 horizontal: vertical), though rectangular and triangular channels can also be used. Designing the channel with flat side slopes increases the wetted perimeter. The wetted perimeter is the length along the edge of the swale cross section where runoff flowing through the swale contacts the vegetated sides and bottom. Increasing the wetted perimeter slows runoff velocities and provides more contact with vegetation to encourage sorption, filtering, and infiltration. Another advantage to flat side slopes is that runoff entering the grassed swale from the side receives some pretreatment along the side slope.

Another similarity among designs is the type of pretreatment needed. In all design options, a small forebay should be used at the front of the swale to trap incoming sediments. A pea gravel diaphragm, a small trench filled with river-run gravel, should be constructed along the length of the swale and used as pretreatment for runoff entering the sides of the swale. Other features designed to enhance the performance of grassed swales are a flat longitudinal slope (generally between 1 percent and 2 percent) and a dense vegetative cover in the channel. The flat slope helps to reduce the flow velocity within the channel. The dense vegetation also helps reduce velocities, protects the channel from erosion, and acts as a filter to treat stormwater runoff. During construction, it is important to stabilize the channel while the vegetation is becoming established, either with a temporary grass cover or with natural or synthetic erosion control products. In addition to treating runoff for water quality, grassed swales must convey runoff from larger storms safely. Typical designs allow the runoff from the 2-year storm (i.e., the storm that occurs, on average, once every two years) to flow through the swale without causing erosion. Swales should also have the capacity to pass larger storms such as a 10-year storm safely.

The following discussion identifies design and construction practices for three variations of open-channel practices: the grassed channel, the dry swale, and wet swale. For a detailed discussion of *Grass Swales*, see *Volume 1 – Chapter 4.*

Grassed Channels

Of the three grassed swale designs, grassed channels are the most similar to a conventional drainage ditch, with the major differences being flatter side slopes and longitudinal slopes, and a slower design velocity for water quality treatment of small storm events. Of all of the options, grassed channels are the least expensive but also provide the least reliable pollutant removal. An excellent application of a grassed channel is as pretreatment to other structural stormwater practices. A major difference between the grassed channel and many other structural practices is the method used to size the practice. Most stormwater-management water quality practices are sized by volume. This method sets the volume available in the practice equal to the water quality volume, or the volume of water to be treated in the practice. The grassed channel is a flow rate-based design. Based on the peak flow from the water quality storm (this varies regionally, but a typical value is the 1 inch/24-hr storm), the channel should be designed so that runoff takes, on average, 10 minutes to flow from the top to the bottom of the channel. A procedure for this design can be found in Design of Stormwater Filtering Systems (CWP, 1996).

Dry Swales

Dry swales are similar in design to bioretention areas. These designs incorporate a fabricated soil bed into their design. The native soil is replaced with a sand/soil mix that meets minimum permeability requirements. An underdrain system is installed at the bottom of the soil bed. This underdrain is a gravel layer that encases a perforated pipe. Stormwater treated in the soil bed flows into the underdrain, which routes this treated stormwater to the storm drain system or receiving waters. Dry swales are a relatively new design, but studies of swales with a native soil similar to the man-made soil bed of dry swales suggest high pollutant removal.

Wet Swales

Wet swales intersect the groundwater and behave similarly to a linear wetland cell (see *Constructed Stormwater Wetland Practice*). This design variation incorporates a shallow permanent pool and wetland vegetation to provide stormwater treatment. This design also has potentially high pollutant removal. Wet swales are not commonly used in residential or commercial settings because the shallow standing water may be a potential mosquito-breeding area ("Grassed Swales," USEPA 2006).

Common Problems

A number of real and perceived limitations hinder the use of grass swales as an alternative to curb and gutters:

The pavement edge along the swale can experience more cracking and structural failure, increasing maintenance costs. The potential for pavement failure at the road/grass interface can be alleviated by "hardening" the interface with grass pavers or geo-synthetics placed beneath the grass. Other options include placing a low-rising concrete strip along the pavement edge.

The shoulder and open channel will require more maintenance. In reality, maintenance requirements for grass channels are generally comparable to those of curb and gutter systems. The major requirements involve turf mowing, debris removal, and periodic inspections.

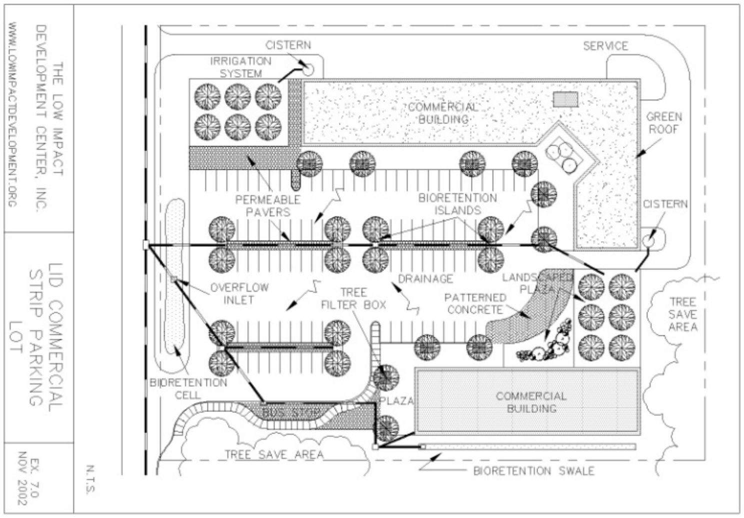
Some grass swales can have standing water, which make them difficult to mow, and can cause nuisance problems such as odors, discoloration, and mosquitoes. In reality, grass channels are not designed to retain water for any appreciable period of time.

Other concerns involve fears about utility installation and worries that the grass edge along the pavement will be torn up by traffic and parking. While utilities will need to be installed below the paved road surface instead of in the right-of-way, most other concerns can frequently be alleviated through the careful design and integration of the open channels along the residential street.

Maintenance

The major maintenance requirement for grass swales is mowing during the growing season, a task usually performed by homeowners. In addition, sediment deposits may need to be removed from the bottom of the swale every ten years or so, and the swale may need to be tilled and re-seeded periodically. Occasionally, erosion of swale side slopes may need to be stabilized. The overall maintenance burden of grass swales is low in relation to other stormwater practices, and it is usually within the competence of the individual homeowner. The only major maintenance problem that might arise pertains to "problem" swales that have standing water and are too wet to mow. This particular problem is often alleviated by amending the soil with rocks and well-drained soils to promote drainage.

Green Parking



Practice Description

Green parking uses a combination of techniques to decrease the parking lot's impact on surrounding drainage patterns. Applied correctly, this can dramatically reduce impervious cover and, consequently, the amount of stormwater runoff. Some techniques include setting maximums for the number of parking spaces created, minimizing the dimensions of parking lot spaces, using permeable pavers in overflow parking areas, using bioretention areas to treat stormwater, encouraging shared parking, and providing economic incentives for structured parking. Green parking strategies can be used in both new developments and redevelopment ("Green Parking," USEPA 2006).

Planning Considerations

Applied together, green parking techniques can effectively reduce the amount of impervious cover, protect local streams, save expenses on stormwater management, and visually enhance a site. Proper bioretention area design can help meet stormwater management and landscaping requirements while keeping maintenance costs at a minimum. Some limitations to applying green parking techniques include applicability, cost, and maintenance. For example, shared parking is practical only in mixed-use areas, and structured parking may be limited by the cost of land versus construction.

The pressure to provide parking spaces can come from fear of complaints as well as bank loan requirements. This may pressure developers to construct more parking than necessary and to be a barrier to providing the greenest parking lot possible. Green parking lots, however, can dramatically reduce the amount of impervious cover created. The level of effectiveness depends on how much impervious cover is reduced as well as the combination of techniques used to provide the greenest parking lot. While the pollutant removal rates of bioretention areas have not been directly measured, their capability is considered comparable to a dry swale, which removes 91% of total suspended solids, 67% of total phosphorous, 92% of total nitrogen, and 80-90% of metals (Schueler, 1996).

Implementation

Minimize Dimensions of Parking Spaces

Minimizing the dimensions of parking spaces is another green parking lot technique. Besides reducing the length and width of all spaces, parking stall dimensions can be reduced by providing compact vehicle spaces. While large sport utility vehicles (SUVs) are often cited as barriers to stall minimization techniques, most local parking codes require stall widths wider than the widest SUVs ("Green Parking," USEPA 2006).

Amend Parking Ratios

Many commercial areas require excessively high parking ratios based upon the highest hourly parking demand during peak seasons. Changing the calculation method to account for actual average parking demand instead can help jurisdictions set a maximum number of parking spaces. The table below provides examples of conventional parking requirements and compares them to average parking demand.

Conventional Minimum Parking Ratios
(Source: ITE, 1987; Smith, 1984; and Wells, 1994)

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.			

Alternative Pavers

Utilizing alternative pavers is also an effective green parking technique. These can replace conventional asphalt or concrete in both new developments and redevelopment projects. Alternative pavers can range from medium to relatively high effectiveness in meeting stormwater quality goals.

The different types of alternative pavers include gravel, cobbles, wood mulch, brick, grass pavers, turf blocks, natural stone, pervious concrete, and porous asphalt.

Bioretention Areas

Bioretention areas can effectively treat stormwater in a parking lot. Stormwater is directed into a shallow, landscaped area and temporarily detained. The runoff then filters down through the bed of the storage area and is infiltrated into the subsurface or collected into an underdrain pipe for discharge into a stream or another stormwater facility. Bioretention areas can be attractively integrated into landscaped areas and can be maintained by commercial landscaping firms. For detailed design specifications of bioretention areas, refer to the *Bioretention (Rain Gardens) Practice*.

Shared & Structured Parking

Shared parking in mixed-use areas and structured parking are also green parking techniques that can further reduce the conversion of land to impervious cover. A shared parking arrangement could include usage of the same parking lot by an office space that experiences peak parking demand during the weekday with a church that experiences parking demands during the weekends and evenings. Costs may dictate the usage of structure parking, but building upwards or downwards can help minimize surface parking.

Common Problems

As referenced above, cost and maintenance are the major limitations on green parking techniques. Alternative pavers are currently recommended only for overflow parking because of the considerable cost of maintenance, and bioretention areas can be costly to construct. Strategies like setting maximums for parking spaces, minimizing stall dimensions, and encouraging shared parking can result in considerable construction cost savings, however, and all of the green parking techniques can also reduce stormwater management costs.

Alternate Pavers

Alternative pavers require proper installation and more maintenance than conventional asphalt or concrete. Accessibility, climate, soil type, traffic volume, and long-term performance should be considered along with costs and stormwater quality controls when choosing paving materials. Use of alternative pavers in cold climates will require special consideration since snow shovels are not practical for many of these surfaces. Sand is particularly troublesome if used with paving blocks since the sand that ends up in between the blocks cannot effectively wash away or be removed. In addition, salt used to de-ice can infiltrate directly into the soil and cause potential groundwater pollution.

Soil types will affect the infiltration rates and should also be considered when using alternative pavers. Clayey soils (D soils) will limit the infiltration on a site. If groundwater pollution is a concern, use of alternative pavers with porous soils should be carefully considered.

Maintenance

Alternate Pavers

The durability and maintenance cost of alternative pavers also limits use to low traffic-volume areas. For the reasons cited above, alternative pavers for parking are recommended for light-use residential areas that do not require accessibility and for parking overflow areas. At the same time, alternative pavers can abate stormwater management costs. Used in combination with other better site design techniques, the cumulative effect on stormwater can be dramatic.

Bioretention

Bioretention requires regular landscaping maintenance, including measures to ensure that the area is functioning properly. In many cases, bioretention areas require intense maintenance initially, but less is needed over time. Many tasks can be completed by a landscaping contractor, who may already be hired at the site. Landscaping maintenance requirements can be less resource intensive than traditional landscaping practices such as elevated landscaped islands in parking areas.

Typical Maintenance Activities for Bioretention Areas ("Green Parking," USEPA 2006)

Activity	Schedule
Remulch void areas Treat diseased trees and shrubs Mow turf areas	As needed
Water plants daily for 2 weeks	At project completion
Inspect soil and repair eroded areas Remove litter and debris	Monthly
Remove and replace dead and diseased vegetation	Twice per year
Add mulch Replace tree stakes and wires	Once per year

Green Roofs

Practice Description

There are two primary strategies for constructing green roofs (vegetated roof covers and roof gardens): to detain rainfall and to promote evapotranspiration of runoff. Some innovative projects even capture larger quantities of water for management with strategies such as roof ponding areas and cisterns. The vegetated roof blankets the roof area with a layer of living vegetation. These are particularly effective when applied to extensive roofs, such as those commonly used on commercial, multifamily, and institutional buildings. However, they can be applied to virtually any building, including single-family residences. Vegetated roof covers are an effective means of retarding runoff from roof surfaces. Initially during a rainfall event, nearly all precipitation striking the foliage is intercepted. As rain continues, water percolates into and begins to saturate the growth media and root zone of the cover. Significant quantities of water do not begin to drain from the roof until the field capacity of the medium is filled. For small rainfall events, little runoff occurs and most of the precipitation eventually returns to the atmosphere.

Roof gardens (which are also called “intensive green roofs”) are landscaped environments that may include planters and potted shrubs and trees. Roof gardens can be custom-made naturalized areas, designed for outdoor recreation, and perched above congested city streets. Because of the special requirements for access, structural support, and drainage, roof gardens are found most frequently in new construction. The services of a professional engineer are required to evaluate the structural and drainage constraints associated with roof garden design. For larger storms, both types of green roofs can delay and slow the peak runoff significantly.

Planning Considerations

Green roofs are useful for a wide range of construction types. They provide very effective stormwater management for small- to mid-size events. By employing a green roof, developers can often conserve space on-site that would otherwise be required for detention or retention facilities. Experts believe this strategy may even extend the life expectancies of roofs, primarily by shielding from ultraviolet light (UV and temperature extremes. It reduces heat island effects caused by impervious surfaces, and can even bring down heating and cooling costs in the building. It adds aesthetic value to residential and commercial property; provides attractive textures and colors; and creates habitat for birds and insects. There are some disadvantages to this BMP, however. It often requires additional structural strengthening to hold the weight of the structure. Although roof gardens require only normal garden maintenance, the location may make it more difficult to inspect and correct problems. The vegetated roof cover style of green roof cannot be walked on, although a roof garden can handle foot traffic. Buildings that employ rooftop detention strategies may experience leaks. These are also among the most expensive practices per square foot of treated area.

Design Criteria

When preparing a design for a green roof, whether it is a vegetated roof or a roof garden, there are several requirements that must be met. The project must begin with a vegetation plan prepared by a horticulturalist versed in green roofs. The design and implementation will also require the participation of a structural engineer to verify that the roof structure and structure strength are adequate to accommodate these BMPs. The design must include access to the roof for regular inspection and maintenance. If roof slopes are greater than 20 degrees, support systems must be installed to avoid slippage of the growing medium and plants. Specific design criteria for these two primary types of green roofs are detailed below.

Vegetated Roof Covers

Because of recent advances in synthetic drainage materials, vegetated roof covers are now feasible on most conventional flat and gently sloping roofs. A lightweight, efficient drainage layer is placed between the growth medium and the impermeable membrane protecting the roof surface. This layer rapidly conveys water off the roof surface and prevents it from ponding. Vegetated roof covers also serve to protect roof materials and prolong their life, primarily by shielding from UV and temperature extremes. European data show that green roofs can double the life span of a roof.

Although vegetative roof covers are most effective during the growing season, they are also beneficial during the winter months if the vegetative matter from the dead or dormant plants is left in place and intact.

The emphasis of the design should be to promote rapid roof drainage and minimize the weight of the system. It is advisable to obtain the services of specialized installers because of the many factors that may influence the design.

Waterproof Roof Liner

In some instances, the impermeable lining can be the watertight tar surface, which is conventional in flat-roof construction. However, where added protection is desired, a layer of plastic or a rubber membrane can be installed immediately beneath the drainage net or sheet drain.

Drainage Net or Sheet Drain

The drainage net or sheet drain is a continuous layer that underlies the entire cover system. A variety of lightweight, high-performance, drainage products function well in this environment. The product selected should be capable of conveying the discharge associated with the design storm without ponding water on top of the roof cover. The drainage layer must have a good hydraulic connection to the roof gutters, drains, and downspouts. To prevent the growth medium from clogging the drainage layer and to prevent roots from penetrating the roof surface, a geotextile should be installed immediately over the drainage net or sheet drain. Some products have the geotextile bonded to the upper surface of the drainage material. A root retardant (such as copper sulfate) is typically included in this geotextile.

Lightweight Growth Medium

The depth of the growth medium should be as small as the cover vegetation will allow, which is typically 3 to 6 inches. Low-density substrate materials with good water-retention capacity (e.g., mixtures containing expanded slate, expanded shale, expanded clay, and terra cotta) should be specified. Media appropriate for this application will retain 40 to 60 percent water by weight and have bulk dry densities between 35 and 50 lb/ft^3. The makeup of the media will vary depending on the types of plants used, but an example media makeup would be 55% expanded slate, 30% root zone sand, and 15% compost. Care should be taken when specifying compost because it will break down over time, and the depth of the media will therefore decrease. A photograph of expanded slate is provided as Figure 1. Earth and topsoil are too heavy for most applications, as well as being too wet for succulent and other recommended vegetation, and too dry for grasses.

Figure 1
Expanded Slate

Vegetation

A limited number of plants can thrive in the roof environment where periodic rainfall alternates with periods that are hot and dry. Effective plant species must tolerate mildly acidic conditions and poor soil; prefer very well-drained conditions and full sun; tolerate dry soil; and be vigorous colonizers. It should also be noted that conditions can be much wetter for longer periods near a gutter or drain and drier near the peaks. Succulents have shown to be very successful in vegetative roof covers, and are preferred to grasses. Both annual and perennial plants can be used. Vegetative roof covers may need provisions for occasional watering (e.g., conventional lawn sprinklers) during extended dry periods. A vegetation plan prepared by a horticulturalist versed in green roof vegetation is required.

Hydraulics

Vegetative roof covers influence runoff in two ways: intercepting rainfall during the early part of a storm, and limiting the release rate. Hydrologic properties are specific to the growth medium. If information is not provided by the supplier, prospective media should be laboratory-tested to establish:

- Porosity
- Moisture content at field capacity
- Moisture content at the wilting point
- Saturated hydraulic conductivity

Rainfall retention properties are related to field capacity and wilting point. Appropriate media for this application should be capable of retaining water at the rate of 40 percent by weight, or greater. The medium must be uniformly screened and blended to achieve its rainfall retention potential. During the early phases of a storm, the media and root systems of the cover intercept and retain most of the rainfall, up to the retention capacity. For instance, a 3-inch cover with 40 percent retention potential effectively controls the first 1.2 inch of rainfall. Although some water percolates through the cover during this period, this quantity is generally negligible compared with the direct runoff rate without the cover in place. Capture rates are dependent on rainfall intensity, antecedent rainfall, time of year, evapotranspiration, and roof pitch. Green roofs on pitches steeper than 1:12 do not function as well as for water quality and quantity control. Vegetated roof covers should be kept on slopes of 8 percent or less, if they are being used to mitigate water quality or quantity.

Once the field capacity of the cover is attained, water drains freely through the medium at a rate that is approximately equal to the saturated hydraulic conductivity of the medium. The maximum release rate from the roof can be controlled by selecting the appropriate medium. The medium is a mechanism for “buffering” or attenuating the peak runoff rates from roofed areas. The attenuation can be important even for large storms. By using specific information about the hydraulic properties of the cover medium, the effect of the roof cover system on the runoff hydrograph can be approximated with numerical modeling techniques. As appropriate, the predicted hydrographs can be added into site-wide runoff models to evaluate the effect of the vegetative roof covers on site runoff. The hydraulic analysis of roof covers requires the services of a properly licensed design professional experienced in this type of drainage design.

Drainage nets or sheet drains with transmissivities of 15 gallons per minute per foot or higher are recommended. When assessing a drainage layer design, designers should evaluate the roof topography to establish the longest travel distances to a roof gutter, drain, or downspout. If flow converges near drains and gutters, the design unit flow rate should be increased accordingly. The drainage layer should be able to convey the design unit flow rate at the roof grade without water ponding on top of the cover medium.

For storms larger than the design storm, direct roof runoff will occur. The design flow rates should be based on the largest runoff peak attenuation considered in the design of the vegetated roof cover.

Weight Considerations

Roof designs are dictated by state and local building codes and standards. They must account for maximum design loads contributed by dead loads, live loads, and snow or water accumulation. The design of a vegetative roof cover can alter the dead loads to the system, and it should therefore be closely coordinated with the structural design of the building. Dead loads for vegetated roof covers include the planting medium, vegetation, drainage system, and water in the pore space. However, the additional weight is partly offset by the removal of the gravel ballast.

By using appropriate materials, the total weight of fully saturated vegetated roof covers can readily be maintained below 35 pounds per square foot (psf). It is also possible that the minimum weight design focus for the vegetated roof cover might be too light to satisfy the ballast requirements for flat tar roofs. As required, deepening the medium can increase the weight of the cover system.

Roof Gardens

Roof gardens generally are designed to achieve specific architectural objectives. The load and hydraulic requirements for roof gardens vary according to the intended use of the space. Intensive roof gardens typically include design elements such as planters filled with topsoil, decorative gravel or stone, and containers for trees and shrubs. Complete designs also may detain runoff ponding in the form of water gardens or storage in gravel beds. A wide range of hydrologic principles may be used to achieve stormwater-management objectives, including runoff peak attenuation and runoff volume control.

Effective designs ensure that all direct rainfall is cycled through one or more devices before being discharged to downspouts as runoff. For instance, rainfall collected on a raised tile patio can be directed to a medium-filled planter where some water is retained in the root zone and some is detained and gradually discharged through an overflow to the downspout.

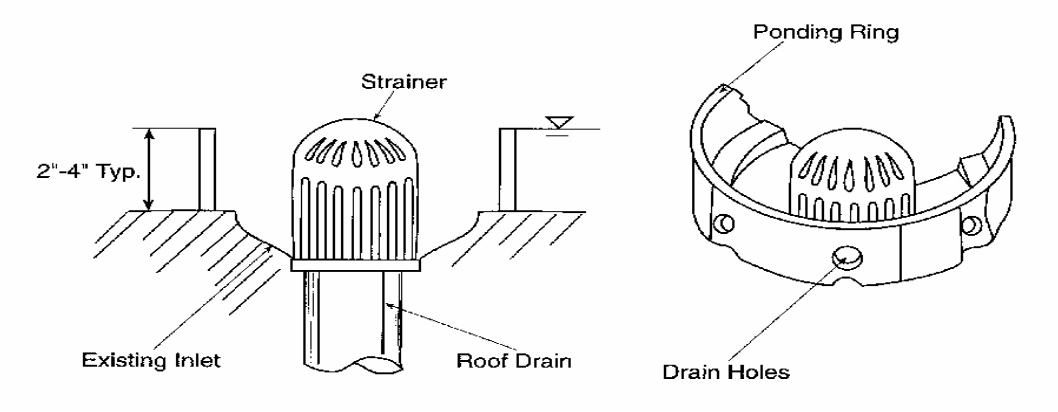
Roof Ponding Areas

Roof ponding measures can be designed for rainfall events of all sizes. However, the structural loads associated with the impounded runoff may impose limitations on their use. This is especially true if ponding areas must also accommodate runoff derived from adjacent roof surfaces.

Flat roofs can be converted to ponding areas by restricting the flow to downspouts. Figure 2 shows a simple device that can be used to modify downspout inlets. The device features drain holes that retard outflow as the water level rises and a weir ring that allows free drainage once the design ponding level is attained. It is essential that a structural engineer verify that the existing roof can carry this extra weight. Some form of emergency overflow is advisable and can be as simple as a free overflow through a notch in the roof parapet wall.

Figure 2

Modification of Downspout Inlet (Adapted from Tourbier, 1974)



The inputs needed for analysis of roof ponding systems are similar to those needed for design of dry ponds and other runoff peak attenuation facilities. These are:

- Input hydrograph
- Depth-storage function
- Depth-discharge function

Because the roof is impermeable, the runoff hydrograph is simply the rainfall distribution for the design storm multiplied by the area of the roof.

The depth to storage relationship can be computed from the topography of the roof. For perfectly flat roofs, the storage volume of a ponding level is equal to the roof area times the ponding level.

The depth-discharge relationship is unique to the outlet device used. For simple ponding rings, the following discharge equation can be used:

$$O = 3.141\ CD(d - H)3/2$$

where:

O = outflow rate (cfs)
C = discharge coefficient (typically 3.0 but may vary depending on the shape the flow device)
D = diameter of the ring (ft)
d = depth of ponding (ft)
H = height of the ring (ft)

With this information, the attenuation effectiveness of the roof ponding system can be predicted by using the Modified Puls or other storage-routing procedure. The performance of the ponding area can be adjusted by changing the height or diameter of the ponding ring.

Cisterns

Cisterns, or rainbarrels, are a method of collecting and storing rainwater for future use. Uses include irrigation, vehicle washing, toilet flushing, and laundry operation. Cisterns are effective for reducing runoff if they are used correctly. Cisterns must be designed to capture an appropriate volume of water that will be re-used onsite on a regular basis. Cisterns that are not used regularly will remain full, not collect rainfall from future storms, and not reduce runoff. Cistern pumps can be included in a design where an increase in water pressure is needed. Pumps should be designed to accommodate the necessary pressure and flow for the system.

Construction and Installation

The main construction guideline is to engage professionals who are experienced with rooftop runoff management BMP installation. Preferably, the same team can undertake all phases of the project from waterproofing to planting to ensure continuity from the design to construction process.

Additional Roof Loading

Additional loading is one of the main factors controlling the feasibility and cost of a rooftop runoff management BMP. New extensive green roofs can be accommodated in building design for a minor additional cost. Rooftop runoff management BMPs on an existing building need to consider the bearing capacity of the structure. It is also possible to use roof areas where point loading can be increased over columns or along a bearing wall, to allow areas for deeper growing medium and larger plants. A structural engineer must be consulted to verify roof and structure strength.

Access to the Roof

Access to the roof is required for inspection and maintenance. For example, materials need to be carried to the roof for soil and plant replacements. Suitable exterior or interior access or elevator stops need to be provided to allow this access. For 1- to 3-story structures, blower trucks or shingle lifts may be used.

Waterproof Membrane

A waterproof membrane is an essential component of a rooftop runoff management BMP. It is recommended that a membrane be installed at the same time the rooftop runoff management BMP is deployed. In addition, good drainage must be provided to prevent extended contact with water and reduce the possibility for leaks and for plant mortality due to drowning or rotting. Roof appurtenances such as parapets, skylights, mechanical systems, and vents should be well protected with a gravel skirt, and when necessary, weep drains.

If the waterproof membrane contains organic material (e.g., bitumen) plant roots may penetrate it. Also, the chemical composition of the membrane should be compatible with the surfaces with which it will be in contact. Membranes developed specifically for rooftop runoff management BMPs contain a root-deterring chemical or metal foil at the seams to prevent root damage (Peck and Kuhn, 2004).

Horizontal Strapping

On a roof slope greater than 20 degrees, horizontal strapping or other support systems must be installed to avoid slippage and slumping of the growing medium and plants.

Timing of Roof Planting

The timing of planting depends on the local climate and season. Planting in the summer may require additional irrigation. Fall planting depends on the availability of plants and whether there is sufficient time to allow for the plants to become established before late winter. Mid-spring planting (February–April) is recommended for much of Mississippi.

Common Problems

Consult with qualified design professional if any of the following occur:

- Weeds are present
- Vegetation is dead or diseased
- The structure is clogged
- The structure is damaged
- Clogging has occurred
- Other damage has occurred

Maintenance

Two to three yearly inspections are recommended to check for weeds and damage. After installation, weekly visits may be needed to ascertain the need for irrigation.

Both regular plant maintenance and maintenance of the waterproofing membrane are required. All rooftop runoff management measures must be maintained periodically. Furthermore, the vegetative measures require routine care and maintenance typical of any planted area. The maintenance includes attention to plant nutritional needs, irrigation as required during dry periods, and occasional weeding. The cost of maintenance can be significantly reduced by judiciously selecting hardy plants that will out-compete weeds. In general, fertilizers must be applied periodically. Fertilizing usually is not a problem on flat or gently sloping roofs where access is unimpeded and fertilizers can be uniformly broadcast. However, fertilization is not recommended if the roof is to be used for water quality improvement. Treading on the cover system should not damage properly designed vegetated roof covers. Maintenance contracts for routine care of the vegetative cover frequently can be negotiated with the installer.

Retrofits of existing roofs must incorporate easy access to gutters, drains, spouts, and other components of the roof drainage system. Foreign matter, including leaves and litter, should be removed promptly.

Narrower Residential Streets

Practice Description

This better site design practice promotes reducing the width of streets to lower the level of impervious cover associated with new residential development. By doing so, stormwater runoff and associated pollutant loads may also be reduced. Currently, many communities require residential street widths of 32, 36, and even 40 feet. Wide streets provide two parking lanes and two moving lanes, but they often provide more parking than is necessary. Narrowing street widths requires a more efficient use of the public realm and individual lots to match community needs. In many residential settings, street widths can be as narrow as 22 to 26 feet without sacrificing emergency access, on-street parking, or vehicular and pedestrian safety. Even narrower access streets can be used when only a handful of homes need to be served. Driveways make up an average of 20% of a subdivision’s impervious surface, a figure which jurisdictions can reduce by allowing the use of alternative paving, shorter driveways, or even shared driveways (Schueler, 1995). Currently, developers often have little flexibility to design narrower streets because most communities require wide residential streets as a standard element of their local road and zoning standards. Revisions to current local road standards are often needed to promote greater use of narrower residential streets.

Planning Considerations

Narrower streets can be used in residential developments generating less than 500 or fewer average daily trips (ADT). Such developments generally consist of 50 single family homes. Narrower streets may also be feasible for streets generating 500 to 1,000 ADT. However, they will not work for arterials, collectors, streets that carry greater traffic volumes, and those streets on which traffic volume varies over time.

In most communities, existing local road standards will need to be modified to allow the use of narrower streets. Several communities have successfully implemented narrower streets, including Portland, Oregon; Bucks County, Pennsylvania; and Boulder, Colorado. In addition, there are numerous examples of communities where developers have successfully narrowed private streets within innovative subdivisions. Local communities may lack the authority to change road standards when state agencies retain the review of public roads, however. In these cases, street narrowing can be accomplished only on private streets that are maintained by residents rather than by a local or state agency.

Cities interested in adopting a narrow streets policy will benefit from consulting with a broad cross section of city officials and affected stakeholders, including public works departments, emergency personnel, residential communities, and business owners, among others. Outreach and local research can help correct misperceptions about the effects of narrow streets and can gain broader acceptance for their environmental, safety and aesthetic benefits (NSPS, 2000).

Design Criteria

Residential street design requires a balancing of competing objectives: design, speed, traffic volume, emergency access, parking, and safety. These objectives can be met in a much narrower roadway than that required by the traditional subdivision.

Safety

Roadway widths in residential areas with 50 homes or fewer can safely be as narrow as 22 feet, according to many national engineering organizations (CWP, 1998). Narrowing streets actually lowers traffic speeds, making streets safer (USDOT, 1997). By dedicating more of the right-of-way to pedestrians and bicyclists, street planners can also make these alternative forms of travel more attractive, further reducing the number of automobile trips and relieving traffic pressure on the roadway.

Emergency Access

Although emergency vehicle access is often given as the reason for wide roadway requirements in a subdivision, this may not be necessary. The U.S. Fire Administration indicates that a street width of 18 to 20 feet is adequate for accommodating a fire vehicle (CWP, 1998).

Parking

The right-of-way associated with parking provides a great deal of design flexibility for reducing impermeable surface. There are some cases where on-street parking may not be desirable at all. Where the street provides space for parking, however, alternative paving surfaces, like pervious pavers, can reduce the overall impervious cover. Extending the curb and devoting some existing parking spots to stormwater management is another design alternative. Streets with angled parking accommodate this strategy well. By taking in just one or two spaces, street designers can incorporate a rain garden within the curbline at the corner or the midblock (ICF, 2009).

Common Problems

Real and perceived barriers hinder wider acceptance of narrower streets at local levels. Advocates for narrower streets need to respond to the concerns of local agencies and the general public. Some of the more frequent concerns about narrower streets are listed below.

Inadequate On-Street Parking. Recent research and local experience have demonstrated that narrow streets can adequately accommodate residential parking demand. A single-family home typically requires 2 to 2.5 parking spaces. In most residential zones, this parking demand can be satisfied by one parking lane on the street and a driveway.

Car and Pedestrian Safety. Recent research indicates that narrow streets have lower accident rates than wide streets. Narrow streets tend to lower vehicle speeds and act as traffic-calming devices. Furthermore, sidewalk access can be provided if needed. Although this might add additional impervious area, net impervious area can be decreased due to greater reductions in street width.

Emergency Access. When designed properly, narrower streets can easily accommodate fire trucks, ambulances, and other emergency vehicles.

Large Vehicles. Field tests have shown that school buses, garbage trucks, moving vans, and other large vehicles can generally safely negotiate narrower streets, even with cars parked on both sides.

Utility Corridors. It is often necessary to place utilities underneath the street rather than in the right-of-way.

Maintenance

Narrower streets should slightly reduce road maintenance costs for local communities, since they present a smaller surface area to maintain and repair.

Riparian/Forested Buffer

Photo Source:
NRCS

Practice Description

Riparian buffers are natural or constructed ecosystems along a shoreline, wetland, or stream where trees, grasses, shrubs, and herbaceous plants filter pollutants from stormwater runoff and shallow groundwater flow prior to discharge to receiving waters. Buffers are designed to remove sediment and other insoluble contaminants from runoff, to allow increased time for infiltration of soluble nutrients and pesticides, and to protect aquatic habitat by providing shade to watercourses to help maintain temperature norms and sound barriers to or from outside areas. Buffer zones also provide natural visual aesthetics for all land disturbance activities. Where natural buffer zones are not present or are inadequate, artificial buffer zones may be engineered using silt fences, diversions, vegetative practices and other BMPs. For additional information on Stream Protection, review the final section of Chapter 4 of Volume 1.

There are three primary types of buffers: water pollution hazard setbacks, vegetated buffers, and engineered buffers. Water pollution hazard setbacks are areas separating potential pollution hazards from waterways. Vegetated buffers are natural areas that divide land uses or provide landscape relief. Engineered buffers are specifically designed to treat stormwater before it enters streams, lakes, or wetlands.

Planning Considerations

Buffers can be applied to new development through the establishment of specific preservation areas and by sustaining management through easements or community associations. For existing developed areas, an easement may be needed from adjoining landowners. A local ordinance can help set specific criteria for buffers to achieve stormwater management goals.

Buffer zones will vary depending on location and application. In some cases, their water quality objectives may be combined with a screening function for the noise and visual pollution of construction activities. Separate criteria will apply for various forms of land-disturbing activities:

1. Activities adjacent to a perennial stream or permanent water body
2. Silvicultural operations
3. Construction or other land-disturbing activities
4. Agricultural activities

The State of Mississippi does not require formal designs or plans for buffers except in the case of activities adjacent to a permanent water body, in which case a description of the water body, slope of adjacent land, and erodibility of soils in the area will be provided to support buffer zone width selection. If an artificial buffer zone is required, pertinent design information will be provided.

Design Criteria

For optimal stormwater treatment, the following buffer designs are recommended. The buffer should consist of three lateral zones: a stormwater depression area leading to a grass filter strip that, in turn, leads to a forested buffer. The stormwater depression is designed to capture and store stormwater during smaller storm events and bypass larger storm flows directly into a channel. Runoff captured within the stormwater depression can then be spread across a grass filter designed for sheet flow conditions. The grass filter then discharges into a wider forest buffer designed to have zero discharge of surface runoff to the stream or full infiltration of sheet flow.

In general, a minimum width of at least 150 feet is recommended to provide adequate stream protection. The three-zone buffer system, consisting of inner, middle, and outer zones, is an effective technique for establishing a buffer. The zones are distinguished by function, width, vegetative target, and allowable uses.

- The inner zone protects physical and ecological integrity. It consists of a minimum of 25 feet plus wetland and critical habitats. The vegetative target consists of mature forest. Its allowable uses are restricted to flood controls, utility rights-of-way, footpaths, etc.
- The middle zone provides distance between upland development and the inner zone. It is typically 50 to 100 feet depending on stream order, slope, and 100-year floodplain. The vegetative target for this zone is managed forest. Usage is restricted to some recreational activities, some stormwater BMPs, and bike paths.

- The outer zone is the first zone to encounter runoff. It functions to prevent encroachment while slowing and filtering backyard runoff. The outer zone's width is at least 25 feet and, while forest is encouraged, turf-grass can be a vegetative target. The outer zone's uses are unrestricted. They can include lawn, garden, compost, yard wastes, and most stormwater BMPs ("Riparian Buffer," USEPA 2006).

Construction and Installation

General

Runoff from the disturbed areas should not be channeled into the buffer zone, but rather allowed to spread out over the entire buffer zone length. For concentrated flows, a level spreader may be required to allow for the proper functioning of the buffer zone.

Where a natural buffer zone is not available, or the required zone width is not attainable, provide flow barriers such as diversions, sediment traps, vegetative planting, and silt fences as needed.

Construction or Other Land-Disturbing Activities Adjacent to a Perennial Stream or Permanent Water Body

This represents the most stringent requirement that applies to buffer zones. At a minimum, a 150′ buffer zone will be left between the land disturbance activity and a water body. The buffer zone width may be greater than 150′ depending upon the soil type and slope of adjacent land.

Buffer Zones Adjacent to Permanent Water Bodies

Soil Erosion Hazard	Recommended Buffer Zone Width (Ft) (% Slope)		
	30	40	50
Slight			155
Moderate		170	200
Severe	170	210	250

**** Refer to County Soil survey for erosion hazard. MS Forestry Commission's Mississippi BMPs Handbook states that distances should be doubled for disturbed areas in municipal watersheds.**

Silvicultural Operations

Buffer zone requirements will adhere to the guidance provided by the Mississippi Forestry Commission (MFC) for silvicultural Best Management Practices including Streamside Management Zone and Filter Strip. For areas not adjacent to a permanent water body, a buffer zone of 15′ will be maintained on the perimeter of all silvicultural operations adjacent to property boundaries and public rights-of-way.

Construction or other Land-Disturbing Activities

For areas not adjacent to a permanent water body, a buffer zone of 15′ will be maintained on the perimeter of the construction site. This buffer zone will:

1. Reduce runoff velocities.
2. Filter sediment from runoff.
3. Act as a screen for "vision pollution."

4. Reduce construction and adjacent noise levels.
5. Reduce dust problems.
6. Improve the aesthetics of the area.

This type of buffer zone may be crossed by construction entrances, utilities construction, etc., but where natural vegetation is removed for these purposes, artificial buffer zone measures should be installed (e.g. construction entrance BMP, silt fence, diversion, etc.).

These post-construction measures should be incorporated into the design of the final post-construction landscape providing a permanent green strip on the perimeter of the completed project.

Common Problems

The table below describes some common obstacles to the best performance of riparian buffers at removing pollutants from stormwater and the design factors that can enhance their performance.

Factors that Enhance/Reduce Buffer Pollutant Removal Performance
("Riparian Buffers," USEPA 2006)

Factors that Enhance Performance	Factors that Reduce Performance
Slopes less than 5%	Slopes greater than 5%
Contributing flow lengths <150 feet.	Overland flow paths over 300 feet
Water table close to surface	Ground water far below surface
Check dams/level spreaders	Contact times less than 5 minutes
Permeable but not sandy soils	Compacted soils
Growing season	Non-growing season
Long length of buffer or swale	Buffers less than 10 feet
Organic matter, humus, or mulch layer	Snowmelt conditions, ice cover
Small runoff events	Runoff events >2 year event.
Entry runoff velocity less than 1.5 feet/sec	Entry runoff velocity more than 5 feet/sec
Swales that are routinely mowed	Sediment buildup at top of swale
Poorly drained soils, deep roots	Trees with shallow root systems
Dense grass cover, 6 inches tall	Tall grass, sparse vegetative cover

Maintenance

An effective buffer-management plan offers many aesthetic, environmental, and recreational benefits but must be adequately managed to function properly. The initial design should include establishment, management, and distinctions of allowable and prohibited uses in the buffer zones. Buffer boundaries should be well defined and visible before, during, and after construction. Without clear signs or markers defining the buffer, its boundaries can become invisible to local governments, contractors, and residents. In some cases, these sites may even be used as dumping grounds for those unaware of their purpose of protecting water quality. Regular clean-up and landscape maintenance will ensure that riparian buffers remain an asset to the community and build public support for the continued use of riparian buffers as a stormwater management practice (NCDENR, 2007). Particular attention must be paid to buffers designed to capture urban stormwater runoff. These sites will require more maintenance if the first zone is designated as a bioretention or other engineered depression area ("Riparian Buffer," USEPA 2006).