6 Site Design and Landscape Details

Once a site plan is generated, a multitude of small design decisions must be made, each of which will affect the hydrology of a development. These design decisions include selection of paving materials, collection of roof runoff, grading of landscaped areas, and many other details.

Any particular detail may make little difference in the overall impact of a development, but taken together, these details exert a profound influence on the ability of a development to meet stormwater quality goals. Consistent with the concept of starting at the source, these details look for opportunities to manage small quantities of runoff at many diverse locations throughout a site.

A variety of design techniques and details are presented in this chapter. Each illustrates an approach to design and construction for maximizing infiltration, providing retention, slowing runoff, and minimizing impervious land coverage. The techniques presented here are not all-inclusive, and may not be appropriate for every site or condition, but it is hoped that, once the intent of these details is understood, designers and builders will use their ingenuity to develop additional strategies consistent with water quality goals.

Site Design and Landscape Details

Look for opportunities throughout the site.

• For more information about these design details, see Chapter 8.

Design Details Matrix

This matrix summarizes the details described on the following pages by their initial construction cost, maintenance cost, relative effectiveness at meeting stormwater quality goals, and their suitability for use in expansive, clay soils. Conventional approaches are also evaluated for comparison.

Legend ❍ (Least) ◗ (Most)

	Cost (initial)	Cost (maint.)	Effectiveness	OK in clay†
6.1 Permeable pavements				
Conventional asphalt/concrete	◗	❍	❍	
6.1a Pervious concrete				❍
6.1b Porous asphalt				❍
6.1c Turf block	◗●			◗
6.1d Brick	●◗		◗	◗
6.1e Natural stone	●◗		◗	◗
6.1f Concrete unit pavers	●◗		◗	◗
6.1g Crushed aggregate	❍	◗		
6.1h Cobbles	❍	◗	◗	
6.2 Streets				
Conventional street standards	●❍		❍	
6.2a Access street: urban neo-traditional standard	❍	❍		
6.2b Access street: rural standard	❍	◗		
6.2c Urban curb/swale system	◗	◗		◗
6.2d Rural swale system	❍	◗		◗
6.2e Dual drainage system				
6.2f Concave median	❍	❍		◗
6.2g Cul-de-sac	❍	❍		◗
6.3 Parking lots				
6.3a Hybrid parking lot	❍	◗		
6.3b Parking grove	◗	❍		
6.3c Overflow parking	❍	◗		
6.3d Porous pavement recharge bed				

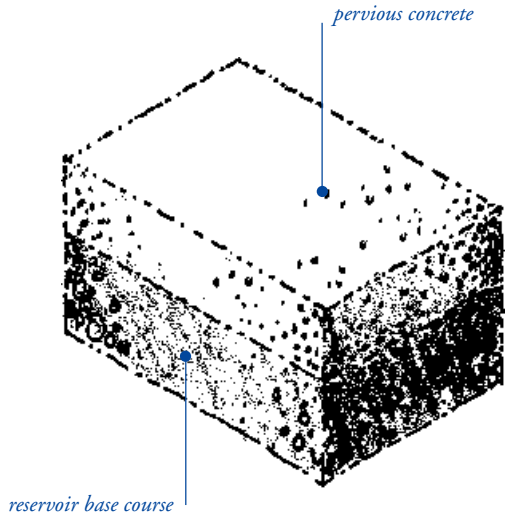
	Cost (initial)	Cost (maint.)	Effectiveness	OK in clay†
6.4 Driveways				
Conventional driveway	❍	◗	❍	
6.4a Not directly-connected impervious driveway	❍	❍		◗
6.4b Crushed aggregate	❍	◗		
6.4c Unit pavers on sand	●◗		◗	◗
6.4d Paving only under wheels	❍	◗		
6.4e Flared driveways	❍	❍		
6.4f Temporary parking	❍	◗		
6.5 Buildings				
Conventional pipe system	●◗		❍	
6.5a Dry-well	❍	◗		◗
6.5b Cistern	●◗		◗	
6.5c Foundation planting	❍	❍		◗
6.5d Pop-up emitters	❍	◗		❍
6.5e Building materials	◗	◗		
6.6 Landscape				
Conventional pipe system	●◗		❍	
6.6a Grass/vegetated swales	❍	◗		
6.6b Extended detention (dry) ponds	❍	◗		
6.6c Wet ponds	❍●			
6.6d Plant species selection for infiltration areas	❍	◗		
6.6e Landscape maintenance for stormwater systems	◗	◗		

† Details are indicated suitable for clay if they either reduce DCIA or can be designed as retention/detention systems.

• For more information about these design details, see Chapter 8.

Details

6.1 *Permeable pavements*



6.1a Pervious concrete

6.1 Permeable pavements. Permeable pavements are a method of infiltrating stormwater while simultaneously providing a stable load-bearing surface. While forming a surface suitable for walking and driving, permeable pavements also contain sufficient void space to infiltrate runoff into the underlying reservoir base course and soil. In this way they can dramatically reduce impervious surface coverage without sacrificing intensity of use.

There are three main categories of permeable pavements: poured-in-place pervious concrete and porous asphalt, unit pavers-on-sand, and granular materials.

All of these permeable pavements (except turf block) have in common a reservoir base course. This base course provides a stable load-bearing surface as well as an underground reservoir for water storage. The base course must meet two critical requirements:

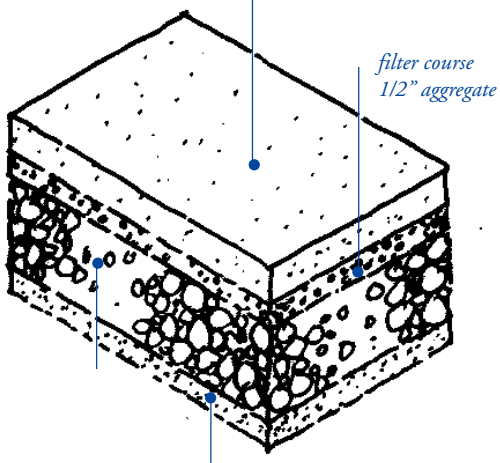
- it must be *open graded*, meaning that the particles are of a limited size range, so that small particles do not choke the voids between large particles. Open-graded crushed stone of all sizes has a 38 to 40% void space, allowing for substantial subsurface water storage.[31]
- it must be *crushed stone*, not rounded river gravel. Rounded river gravel will rotate under pressure, causing the surface structure to deform. The angular sides of a crushed stone base will form an interlocking matrix, allowing the surface to remain stable.

Depending on the use of the surface, a permeable, engineered base section may need to be added to support the intended load. This applies to areas subject to heavy vehicle loads, but is also important for large areas where settling could result in unwanted puddles in areas such as pedestrian walkways.

Pervious concrete and porous asphalt are two emerging paving materials with similar properties. Like their impervious, conventional counterparts, both make a continuous, smooth paving surface. They differ from their conventional counterparts in that they allow water to pass through the surface course to the rock base course that serves as a reservoir and infiltration basin for stormwater. Both pervious concrete and porous asphalt share similar design considerations.

6.1a Pervious concrete. Pervious concrete, also known as Portland cement pervious pavement, is most commonly used in Florida, where it was developed in the 1970s. Pervious concrete is a discontinuous mixture of coarse aggregate, hydraulic cement and other cementitious materials, admixtures, and water, which forms a permeable pavement.

Permeable pavements, continued



6.1b Porous asphalt

(adapted from City of Rockville, MD. specifications)

Pervious concrete, like other concretes, acts as a rigid slab. It has an appearance very similar to exposed aggregate concrete, and provides a similar walking or riding surface. An aggregate base course can be added to increase total pavement thickness or hydraulic storage. Pervious concrete is an extremely permeable material: in tests by the Florida Concrete and Products Association, permeability of new surfaces has been measured as high as 56 inches per hour. With improper installation or mix, permeability can be reduced to 12 inches per hour. Even after attempts to clog the surface with soil by pressure washing, the material retained some permeability.[32] Because of its porosity, pervious concrete pavements usually do not require curbs and gutters for primary drainage control.

6.1b Porous asphalt. Porous asphalt consists of an open-graded asphalt concrete over an open-graded aggregate base, over a draining soil. Unlike traditional asphalt concretes, porous asphalt contains very little fine aggregate (dust or sand), and is comprised almost entirely of stone aggregate and asphalt binder, giving it the common name "popcorn mix." Without fines filling the voids between larger particles, porous asphalt has a void content of 12-20%, making it very permeable.

Porous asphalt is used by Caltrans as a wearing course on freeways because its porosity creates a superior driving surface in rainy weather. These installations are always over an impermeable asphalt layer and are not permeable pavements.[33]

In installations where porous asphalt has been used over a permeable base, the pavement becomes an infiltration system, allowing water to pass through the surface and collect in the open-graded aggregate base, achieving stormwater management without curb or gutter systems. In these sites, mostly parking lots and light duty roads in the eastern United States, permeability has been maintained over long periods without special maintenance. The oldest porous asphalt pavement in the United States, at the University of Delaware Visitors' Center, was built in 1973, and is still permeable and structurally sound after 23 years.[34]

On light duty streets built of porous asphalt, some loss of porosity occurs in localized areas due to sedimentation or scuffing at intersections due to repeated wheel turning, but the overall performance of the pavement is not significantly compromised.[35]

Pervious concrete and porous asphalt design considerations: Sealing and clogging of the pavement surface is possible, even with maintenance and high power vacuuming. Most successful installations are in Florida and other coastal areas where slopes are

flat, soils sandy, and winter sanding/salting minimal. Avoid installation in high traffic areas, and stabilize surrounding land to minimize sediment deposition on the pavement.

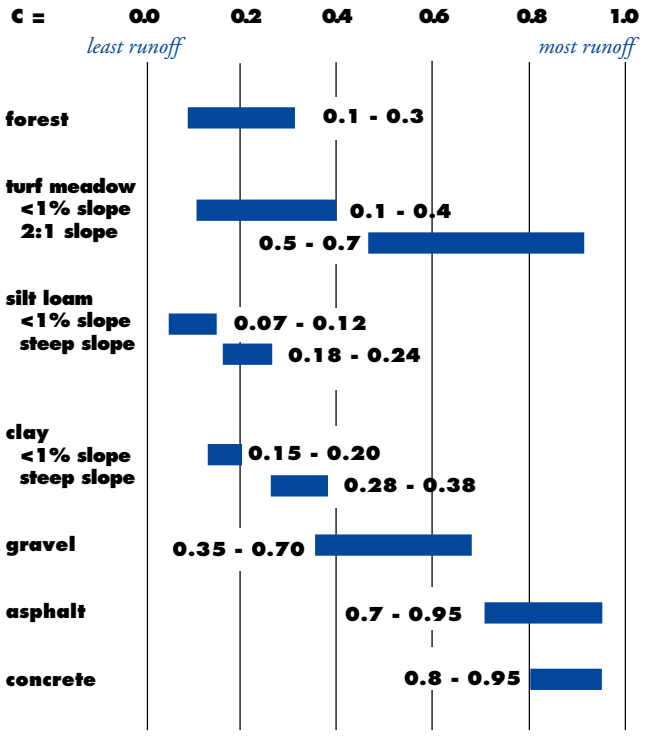
Installation must meet special requirements. Subgrade uniformity is essential, and slopes over a few percent are not recommended because of potential subgrade erosion. A permeable base and an infiltration rate of at least 0.5 inches/hour in the native soil is required (i.e. a HSG A or B soil).

Installation of pervious concrete and porous asphalt requires special tools and has narrower tolerances than traditional concretes or asphalts. Finally, lack of independent testing (especially in the case of pervious concrete) limits the ability to make judgements about long-term performance.

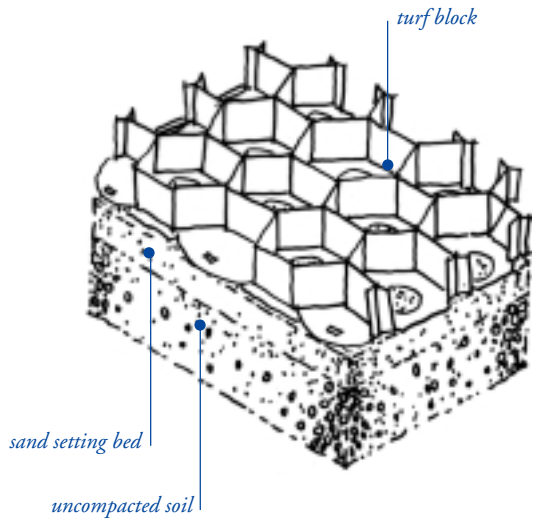
Unit costs of these permeable pavements are greater than traditional concrete and asphalt, though this cost can be offset by not building a curb and gutter drainage system. Potentially a valuable means of reducing impervious land coverage in areas requiring a large, smooth pavement, their relative unfamiliarity, special requirements and lack of conclusive testing have made pervious concrete and porous asphalt little used in the San Francisco Bay Area to date. If these materials begin to gain wider local acceptance, their relative costs will likely go down.

Coefficients of Runoff

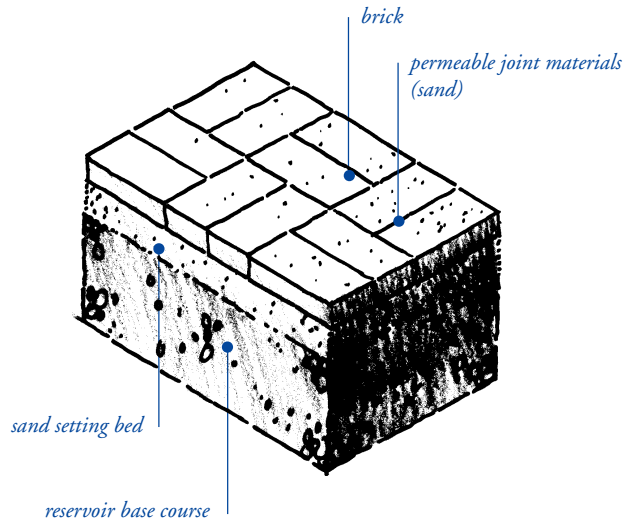
The chart below illustrates typical ranges for the coeficient of runoff (C) for various materials.[36]



Details 6.1 *Permeable pavements, continued*



6.1c Turf block



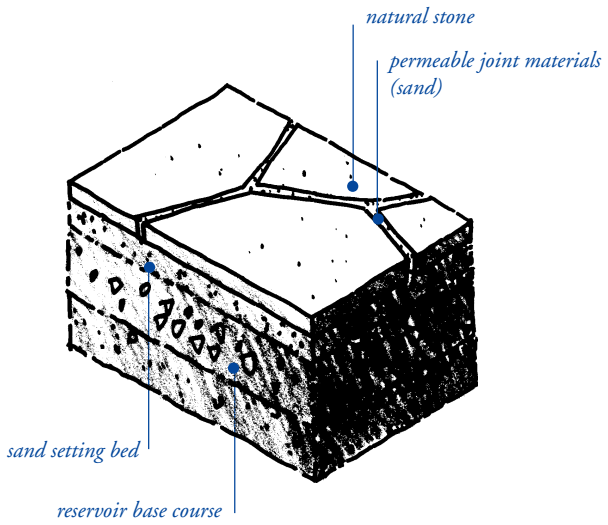
6.1d Brick

Unit pavers-on-sand. A wide variety of unit pavers are available for use in outdoor applications. Unlike poured-in-place concretes or asphalts, which create one continuous surface, unit pavers are discrete units that are set in a pattern on a prepared base. This gives unit pavers great flexibility in design, construction, and maintenance. *Open-celled unit pavers* are designed to create a permeable pavement surface, allowing water to pass through precast voids. *Solid unit pavers,* made of impermeable materials, can produce permeable pavement surfaces if they are spaced to expose a permeable joint and set on a permeable base. Unit pavers are available in many colors, shapes, and textures. Sometimes colored concrete is stamped to appear like unit pavers, but this pavement surface performs both hydrologically and structurally like a poured concrete slab, and does not provide the stormwater infiltration opportunities of unit pavers-on-sand.

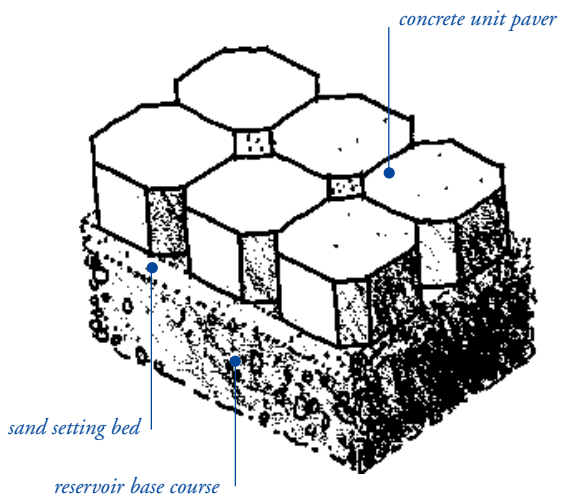
6.1c Turf block. Turf block is one example of an open celled unit paver. These open celled unit pavers are available in both precast concrete or plastic, and are filled with soil and planted with turf. They were developed in Germany in the 1960s to reduce the "heat island" effect of large parking areas and are now used throughout the world. The products vary in size, weight, surface characteristics, strength, durability, interlocking capabilities, proportion of open area per grid, runoff characteristics, and cost. Laboratory tests have shown that open celled units have runoff coefficients of from 0.05 to 0.35, depending on slope, and surface configuration.[37]

When planted with turf, they are generally most successful in overflow parking areas, driveways, or emergency access roads. If installed in heavily used parking areas the turf often does not get adequate sunlight, and on heavily traveled roadways it can be worn away from tire abrasion. Occasionally open celled unit pavers are filled with alternatives to turf, either an inert gravel or a lower maintenance groundcover such as chamomile, that can absorb some traffic. Because of their irregular surface, open celled unit pavers generally do not provide comfortable walking surfaces, though the degree of comfort varies depending on design.

6.1d Brick. Clay fired brick is an ancient, solid paving material of great durability and flexibility. When laid on a permeable base with sand joints, brick paving provides an opportunity for a limited amount of stormwater infiltration, especially at low rainfall intensities. One experiment found coefficient of runoff volume to rainfall volume between 0.13 and 0.51 at half hour rainfall intensities up to 0.03 inches, increasing to between 0.66 and 0.76 at intensities between 0.06 and 0.12 inches per half hour.[38] The larger the joints, the greater the permeability.



6.1e Natural stone



6.1f Concrete unit pavers

Brick is available in a wide range of colors and finishes, and can be set in a variety of patterns. When laid on sand, it creates a very suitable walking or riding surface. Though it was widely used for roads in the early part of this century, it is today generally used for driveways, pathways, plazas, and patios.

Because brick is a relatively soft material, brick pavements can develop a rich character over time as the surface becomes slightly worn with use and the natural colors and textures are exposed. Brick is generally comparable in cost with other solid unit pavers, though shipping costs and special finishes or colors can affect price significantly.

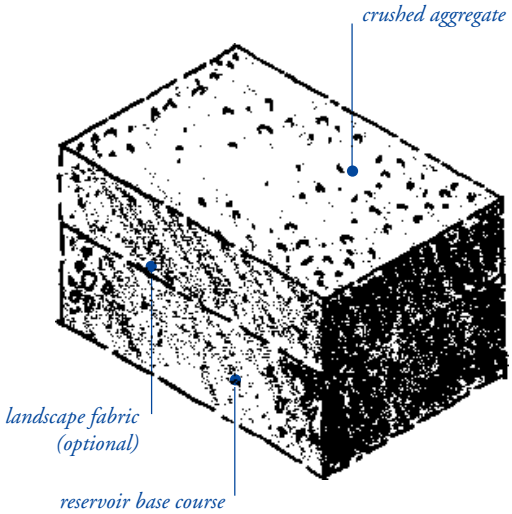
6.1e Natural stone. Natural stone paving materials are available in a wide variety of shapes and colors. Because of their high cost and relative brittleness, they are usually laid in thin pieces on a mortar bed over concrete, making an impervious pavement. Some natural stone materials, such as flagstone and granite, are available in thicker slabs suitable for laying on sand. When laid in a random pattern with wide sand, gravel, or soil joints (from 1/2 to 4 inches) random cut stone can create a highly permeable pavement. The joints can be planted with small groundcovers or left bare. Smaller, square cut stones can also be made into permeable pavements. The cobblestone walks of older European cities are a familiar example of natural stone pavement. Stones set in these tighter sand joints can be expected to have a permeability similar to brick-on-sand.

Because of their high cost natural stone pavements are generally limited to patio areas or walkways, where they can be attractive accents. Some stone materials, such as flagstone and slate, are relatively brittle and suitable for pedestrian areas only. Paving made of harder stone, such as granite, can bear vehicular loads.

6.1f Concrete unit pavers. Solid precast concrete unit pavers are available in a wide variety of colors, shapes, sizes, and textures. They are designed to be set on sand, and form an interlocking pavement surface that can bear heavy traffic loads. Their permeability and performance is similar to brick-on-sand. Some manufacturers are now producing concrete unit pavers with small voids to increase permeability (e.g. "Ecostone"). The cost of concrete unit pavers is generally the lowest of all unit pavers, though it can vary depending on shipping, special colors or finishes.

Unit pavers-on-sand considerations. Installation costs for unit pavers on sand are higher than traditional asphalt or concrete paving. Unit pavers-on-sand, however, are generally less expensive to install than mortar-set unit pavers on a rigid concrete base, especially considering the added cost of drainage struc-

Permeable pavements, continued



6.1g Crushed aggregate

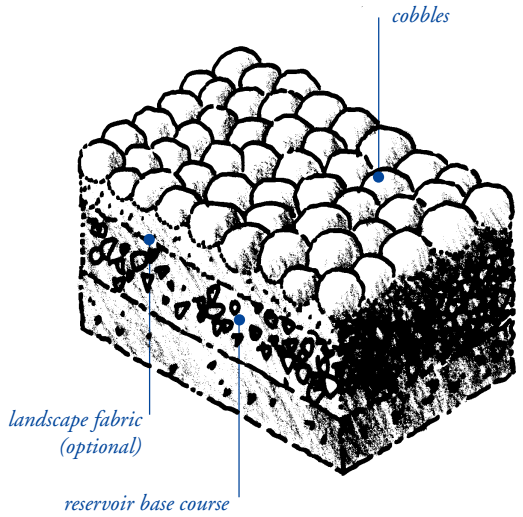
tures required for the mortared design. Solid unit pavers require no special maintenance, though the joints between units may require occasional weed supression, depending on the size of the joints, the subgrade, and other conditions. Grassed open-celled unit pavers require the same maintenance as lawns. Open-celled pavers filled with gravel require periodic "topping off" of the voids to replace gravel picked up by tire tread and pedestrians.

Unit pavers are especially valuable for walkable surfaces around trees, as they allow infiltration of water and air. If root growth causes the pavement surface to become uneven, the unit pavers can be removed and reset smoothly. Differential settlement can occur in a pavement made of unit pavers on sand, creating tripping hazard. This most often occurs if the base is improperly prepared, but can be remedied by recompacting the base and relaying the pavers. Penetration of mineral and organic particles into narrow sand joints of solid unit pavers-on-sand can severely limit permeability over time.

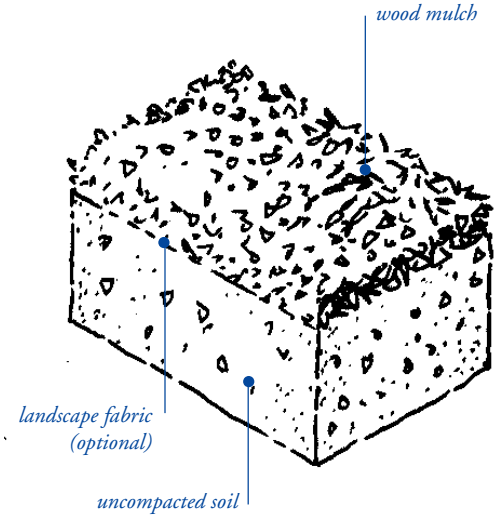
Granular materials. A wide variety of loose aggregates can be made to form permeable pavements suitable for walking, jogging, biking, or light vehicular traffic. The size of these granular materials ranges from fine aggregates to large stones, and can be divided into two general categories: gravels and cobbles. Depending on the aggregate size, these granular pavements have a runoff coefficient of 0.20 to 0.40.[39]

6.1g Crushed aggregate (gravel). A variety of crushed aggregates, generally known as gravel, can be used to form a permeable pavement. Aggregates are available in many sizes, ranging from approximately 2" to sand sized grains known as "fines." Relatively inexpensive to purchase and easy to install, gravel can be laid in any shape or configuration. To keep aggregates confined to its desired area, it is laid in a field that is bounded by some rigid frame such as wood header, metal edging or concrete band. Many colors, grades, and types of parent material are available, including crushed decomposed granite, base rock, and pea gravel. In selecting gravel pavements for pedestrian or vehicular traffic, crushed stones provide the most suitable surface, as the angled facets of the aggregate form an interlocking, semi-rigid matrix. Naturally worn small stones, such as pea gravel, have smooth round surfaces which rotate under pressure, making for a less firm footing. For surfaces subject to vehicular use, crushed gravel sizes between 3/8" and 3/4" make a stable surface that is also easy to walk on.

Found in a variety of settings ranging from Parisian cafes to Japanese ceremonial gardens to rural roadways, crushed aggre-



6.1h Cobbles



6.1i Wood mulch

gate is a versatile, economical permeable pavement material with a long history of use.

6.1h Cobbles. Larger granular materials are known as cobbles. Cobble sizes generally range from approximately 6" to 24" diameter and are available in a variety of stones and colors. Cobbles do not make a suitable surface for walking or vehicular traffic, but are useful as a permeable pavement in areas where little traffic is desired, such as under large trees, or in hard to maintain areas such as median islands. Cobbles have similar construction characteristics as gravel, except they are somewhat more labor intensive to install because each cobble must generally be set individually.

6.1i Wood mulch. Wood mulches and wood chips are among organic granular materials that can be used as permeable surfaces suitable for light pedestrian use. Some of these mulches meet federal requirements for playground fall surfaces, and can be inexpensive, permeable pavements for outdoor play areas.

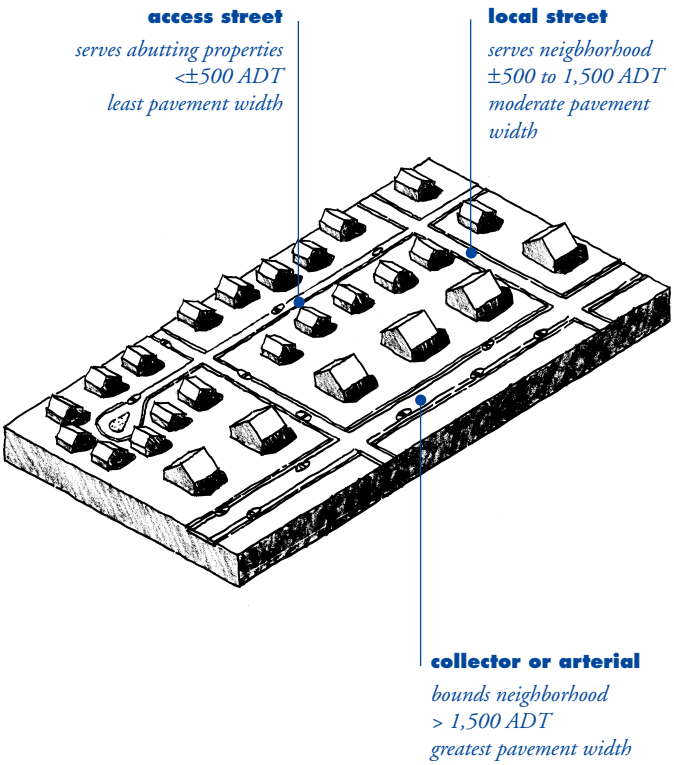
Granular materials considerations. If laid on a slope, and subjected to moderate traffic or concentrated runoff, loose gravel can be displaced and require periodic regrading. Organic materials such as bark or wood chips decompose over time and must be replenished. Weed abatement may be required periodically, though this can be minimized by laying permeable landscape fabric between the gravel and subgrade. Installation costs for gravel and other granular materials are generally the least of all permeable pavements, but require a degree of periodic maintenance to preserve the integrity of the pavement surface.

Concrete and asphalt. Conventional concrete and asphalt (technically known as **portland cement concrete** and **asphaltic concrete**, respectively) are impervious pavements widely used in site development. Because of their ease of installation, flexibility, durability, economy, and load bearing capabilities, concrete and asphalt are the most commonly used pavement materials. With a runoff coefficient of near 1.0, conventional concrete and asphalt pavements are principal contributors to impervious land coverage in most development.

In site design for stormwater quality, these materials are best used sparingly. If more permeable pavement materials cannot be used, minimizing the area of concrete and asphalt surfaces through clustering and other techniques will reduce the resulting impervious land coverage. For remaining area, designing asphalt and concrete pavement surfaces to slope towards infiltration basins instead of into directly-connected collection structures will minimize their negative impact on water resources.

Details

6.2 *Streets*



More than any other single element, street design has a powerful impact on stormwater quality. Streets and other transport-related structures typically can comprise between 60 and 70% of the total impervious area, and, unlike rooftops, streets are almost always directly connected to an underground stormwater system.[40]

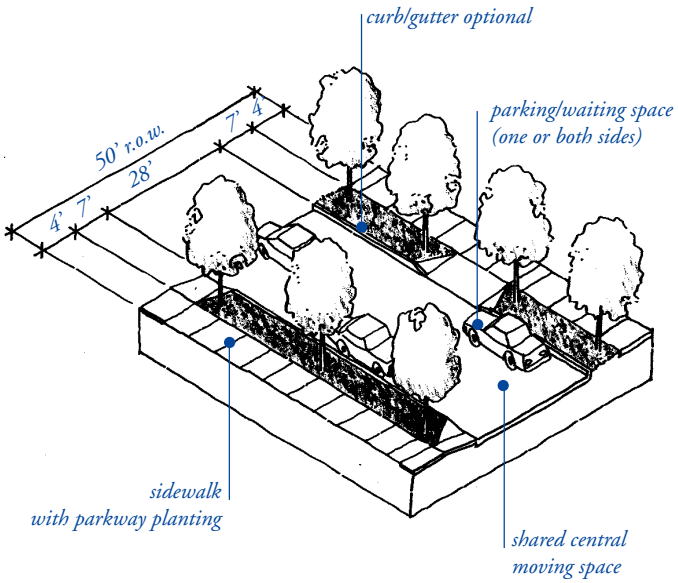
The combination of large, directly connected impervious areas, together with the pollutants generated by automobiles, makes the street network a principal contributor to nonpoint source pollution. Locally, the Santa Clara Valley Urban Runoff Program estimated that automobiles were the source of half or more of the copper, cadmium and zinc in its waterways.[41]

Street design is usually mandated by local municipal standards. These standards have been developed since World War II to facilitate efficient automobile traffic and maximize parking. Most require large impervious land coverage, with a typical Bay Area local street standard mandating that 85% or more of the public right-of-way be covered with impervious pavement.

In recent years new street standards have been gaining acceptance that meet the access requirements of local residential streets while reducing impervious land coverage. These standards generally create a new class of street that is smaller than the current local street standard, called an "access" street. An access street is at the lowest end of the street hierarchy and is intended only to provide access to a limited number of residences.

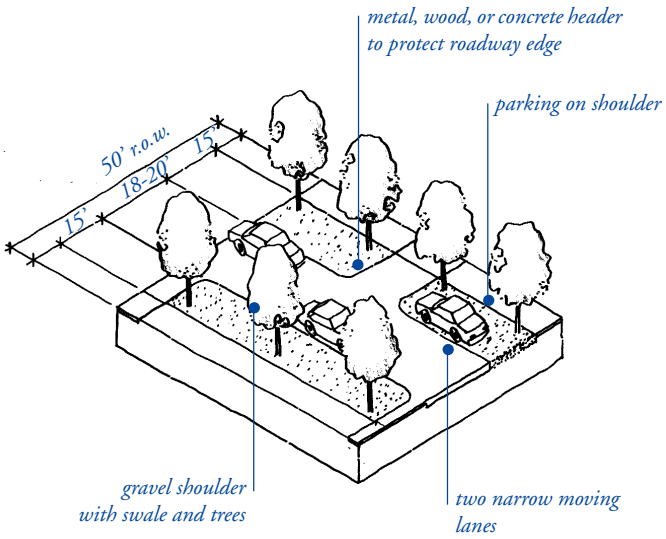
Two approaches in particular have been implemented with success in various American communities: "neo-traditional design" and "headwaters streets."[42] Neo-traditional design seeks to emulate the tree-lined, compact streets found in pre-war, traditional residential neighborhoods. The headwaters streets concept suggests that streets be scaled to traffic volume just as stream size increases with water volume. Both strategies allot street space according to anticipated traffic levels rather than mandating a predetermined number of vehicle lanes.

Recognizing that street design is the greatest factor in a development's impact on stormwater quality, it is important that designers, municipalities and developers employ street standards that reduce impervious land coverage.



6.2a Access street: urban neo-traditional standard

74± % impervious land coverage



6.2b Access street: rural standard

36± % impervious land coverage

Two types of access streets can be built using neo-traditional standards: urban or rural.

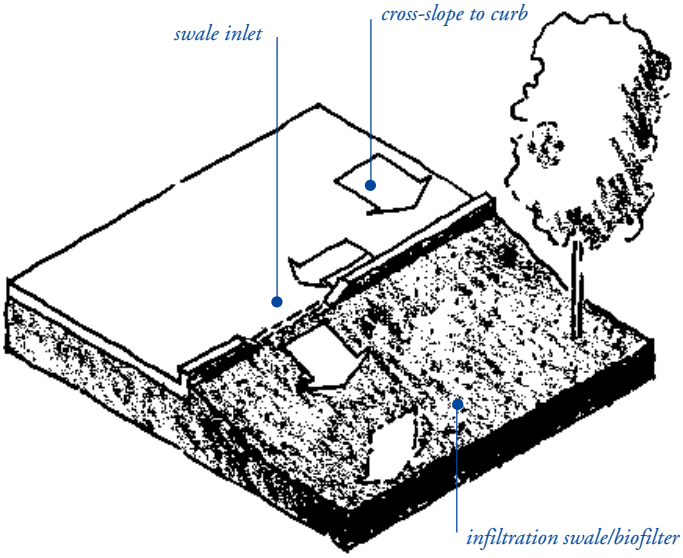
6.2a Urban neo-traditional standard. An urban standard will utilize curbs and gutters, though the gutter may be tied to a biofilter or swale rather than an underground storm drain. According to an informational report published by the Institute of Transportation Engineers (ITE), pavement widths for neo-traditional urban streets are typically from 26 to 30' wide with a shared central moving lane, and parking permitted on one or both sides. Sidewalks are provided on at least one side of the street, though usually preferable on both sides.[43]

6.2b Rural Standard. A rural standard can be used where aesthetics and other factors permit, with curbs and gutters replaced by gravel shoulders, further reducing construction costs and improving opportunities for stormwater infiltration. The gravel shoulders are graded to form a drainage way, with opportunities for infiltration basins, ponding and landscaping. A narrow two-lane paved roadway is provided, approximately 18 to 22 feet wide. Most of the time single vehicles use the center of the paved roadway. When two cars are present moving in opposite directions, drivers reduce speeds and move towards the right hand shoulder. Protection of the roadway edge and organization of parking are two issues in rural street design. Roadway edge protection can be achieved by flush concrete bands, steel edge, or wood headers. Parking can be organized by bollards, trees, or allowed to be informal. On very low volume, low speed, access streets, sidewalks may not be required, as pedestrians walk in the street or on the shoulder.

The current typical municipal street standards that mandate 80 to 100% impervious land coverage in the public right-of-way are a principal contributor to the environmental degradation caused by development. A street standard that allows a hierarchy of streets sized according to average daily traffic volumes yields a wide variety of benefits: improved safety from lower speeds and volumes, improved aesthetics from street trees and green parkways, reduced impervious land coverage, less heat island effect, and lower development costs. If the reduction in street width is accompanied by a drainage system that allows for infiltration of runoff, the impact of streets on stormwater quality can be greatly mitigated.

Street width considerations. The experience of both the pre-war traditional streets and newer subdivisions of neo-traditional design has shown that low volume streets with shared moving lanes can be safe, often safer than wider streets, because drivers are

Streets, continued



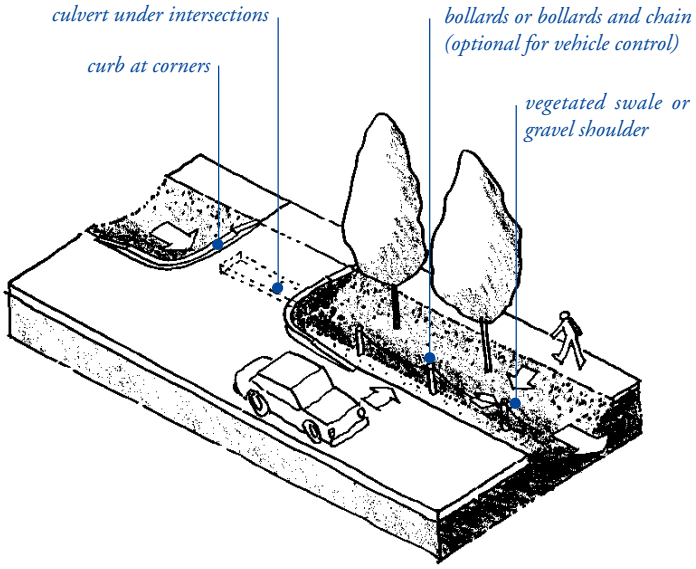
6.2c Urban curb/swale system

more cautious. These neo-traditional streets are designed for traffic speeds between 15 to 25 mph, compared to a design speed of 30 mph for most current municipal standards.[44] This reduced design speed increases safety, particularly for pedestrians. Nevertheless, shared moving space may promote unsafe conditions or high incidences of driver inconvenience if traffic volumes are much above 500-750 ADT. On access streets where bicycle traffic is especially high, such as designated bike routes or in university towns, wider streets may be advisable to provide adequate space.

Emergency service providers often raise objections to reduced street widths. Typical Fire Department standards require greater moving space for emergency access than accommodated by neo-traditional designs. A principal concern is that emergency access may be blocked if a vehicle becomes stalled in the single moving lane. Grid street systems provide multiple alternate emergency access routes to address this concern, though there may be a marginal increase in response times. Documenting the number of instances where delay has occurred in existing pre-war neighborhoods with street widths below current Fire Department standards may be a suitable way to asses the risk of this situation arising in new neighborhoods with neo-traditional street design, and to balance it with the demonstrated increased risk from higher traffic speeds on wider streets.

Inlet detail for urban curb/swale system

Just as a drop inlet collects runoff into an underground pipe system, a swale inlet collects runoff into a surface infiltration system. This swale inlet includes boulders set in soil to dissipate flow velocities and minimize erosion.



6.2d Rural swale system

Emergency service access is one factor of many that form a general assessment of neighborhood safety. One way to balance emergency service access with the benefits of access streets is to allow parking on one side only to preserve a wider moving space.

Hillside sites have special access concerns and fire risks. Because of the potential of shared moving lanes to be blocked by a single vehicle, with no comparable alternate route, reduced street widths may not be advisable on long cul-de-sac streets or narrow hillside sites.

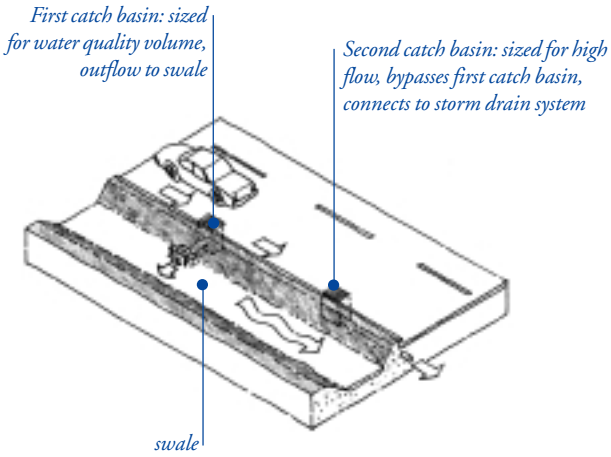
Street drainage. Current Bay Area municipal standards generally require concrete curb and gutter along both sides of a residential street, regardless of number of houses served. The curb and gutter serves several purposes: it collects stormwater and directs it to underground conveyance drainage systems, it protects the pavement edge, it prevents vehicle trespass onto the pedestrian space, it provides an edge against which street sweepers can operate, and it helps to organize on-street parking.

Curb and gutter systems provide a directly connected conduit to natural water bodies and may act to collect and concentrate pollutants. There are two alternatives to typical curb and gutter systems that meet functional requirements while lessening the street's impact on stormwater quality.

6.2c Urban curb/swale system. On streets where a more urban character is desired, or where a rigid pavement edge is required, curb and gutter systems can be designed to empty into drainage swales. These swales can run parallel to the street, in the parkway between the curb and the sidewalk, or can intersect the street at cross angles, and run between residences, depending on topography. Runoff travels along the gutter, but instead of being emptied into a catch basin and underground pipe, multiple openings in the curb direct runoff into surface swales or infiltration/detention basins. If planted with turfgrass and gently sloped, these swales function as biofilters (see Drainage systems 5.5c). Because concentration of flow will be highest at the curb opening, erosion control must be provided, which may include a settlement basin for ease of debris removal.

6.2d Rural swale systems. On streets where a more rural character is desired, concrete curb and gutter need not be required. Since there is no hard edge to the street, the pavement margins can be protected by a rigid header of steel, wood or a concrete band poured flush with the street surface. Parking can be permitted on a gravel shoulder. If the street is crowned in the middle, this gravel shoulder also can serve as a linear swale, permitting infiltration of stormwater along its entire length. Because runoff from the street is not concentrated, but dispersed

Streets, continued



6.2e Dual drainage system

along its entire length, the buildup of pollutants in the soil is minimized. If parking is not desired on the shoulder, or if it needs to be organized, bollards, trees or groundcovers can be installed along the shoulder to prevent vehicle trespass.

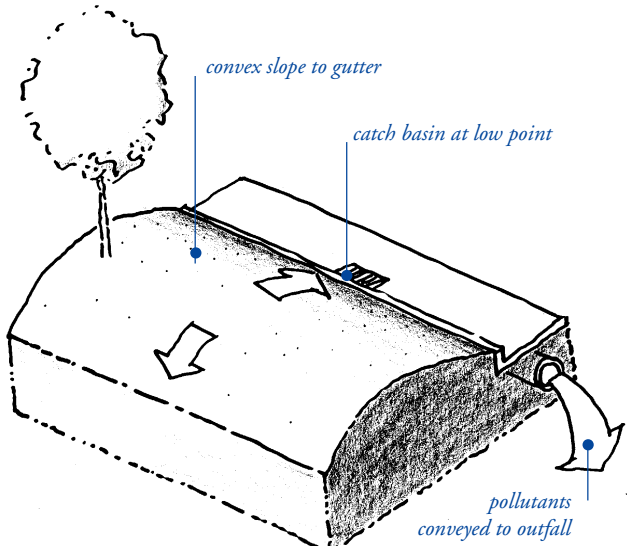
In these ways edge treatments other than continuous concrete curb and gutters with underground drainage systems can be integrated into street design to create a headwaters street system that minimizes impact on stormwater quality and that captures the most attractive elements of traditional neighborhood design.

6.2e Dual drainage system. A dual drainage system is one that captures the first flush of rainfall from the 2-year storm event in a catch basin that outflows to a grass swale with small check dams. Consituents are filtered as water passes through the swale, to the outlet that directs flow back into the main storm drainage system. Runoff in excess of the 2-year storm event is captured by a second catch basin that is directly connected to the storm drain. This system can work effectively at treating the small storms while making provisions for the large storms.

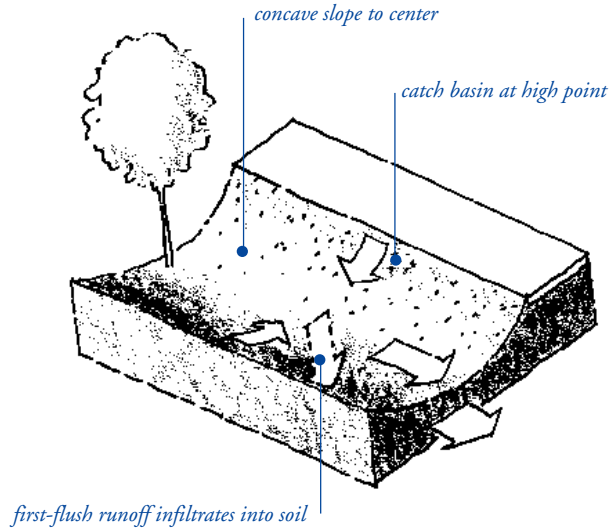
Street drainage considerations. The perception that surface swale systems require a great deal of maintenance is a barrier to their acceptance. In practice, maintenance is required for all drainage systems, and surface systems can require comparable or less maintenance than underground systems. Design factors for low maintenance include:

- erosion control at curb openings
- shallow side slopes and flat bottoms (as opposed to ditches which erode)
- planting with easily maintained groundcover such as turf
- minimizing weeds through proper plant selection or installation of permeable landscape fabric.

Maintenance practices for surface systems are different than most urban Public Works Departments currently practice, and some employee retraining may be required to facilitate maintenance of street systems using surface swales instead of concrete curbs and underground pipes. One advantage of surface drainage systems is that problems, when they occur, are easy to fix because they are visible and on the surface.



Conventional median design: convex surface



6.2f Concave median

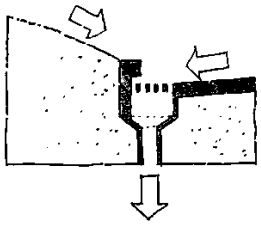
Medians. Sometimes streets are designed with central medians to divide traffic for safety or aesthetics.

Conventional median design includes a convex surface rising above the pavement section, with drainage directed towards a curb and gutter system. Runoff is conveyed rapidly off the median and the street directly into a catch basin/underground pipe system, concentrating pollutants and carrying them to water bodies.

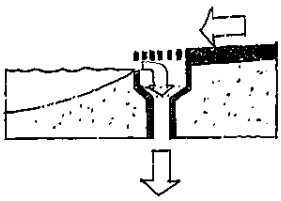
6.2f Concave median. If the soil level in the median is designed as a concave surface slightly depressed below the pavement section, water is directed from the street into the median.

Concave medians are especially valuable at treating the first-flush runoff, which carries a high concentration of oils and other pollutants off the street, especially if the median is designed as a landscaped swale or turf lined biofilter. Because of the relatively small area provided by the median for stormwater infiltration and retention, a catch basin and underground storm drain system may be required. By setting catch basin rim elevations just below the pavement elevation, but above the flow line of the infiltration swale, a few inches of water will collect in the swale before overflowing into the underground system.

Catch-basin design for medians.

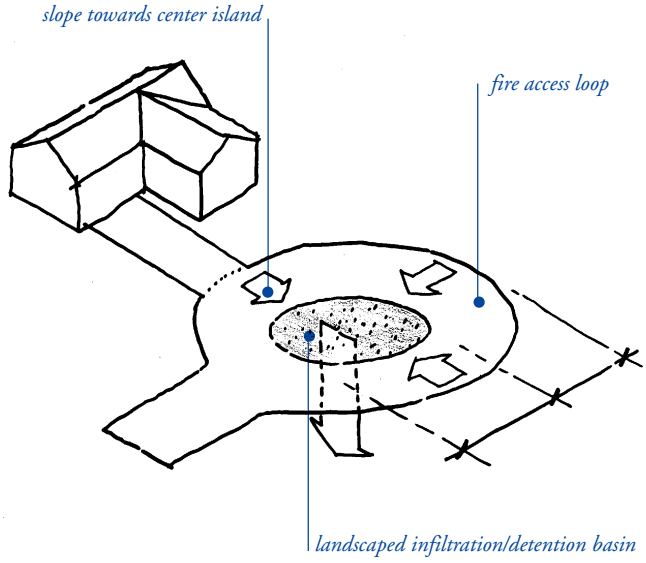


A catch basin located at the low point of a ***conventional convex median*** and gutter collects all runoff – including the first flush.



Like an overflow drain in a bathtub, a catch basin located just below the pavement surface, and a few inches above the flow line of a ***concave median***, provides an opportunity to pond runoff while also providing drainage for larger storms.

Details 6.2 *Streets, continued*



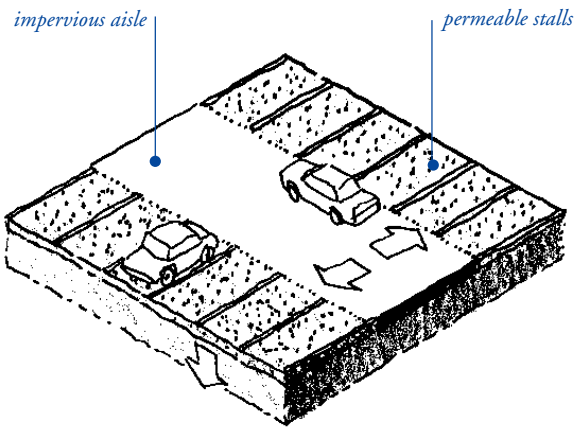
6.2g Cul-de-sac

6.2g Cul-de-sac. Cul-de-sac streets present special opportunities and challenges. Because cul-de-sac streets terminate, they require a turn-around area large enough to accommodate large trucks, such as occasional moving vans and emergency access vehicles. Fire departments, in particular, often require 60 feet or greater diameter turnarounds. If an entire 60 foot diameter turnaround is paved, it creates an 11,000 square foot impervious circle, or $^1/_4$ acre of impervious land coverage. Aside from the implications for stormwater quality, this is especially unfortunate as a design element, because it creates an unattractive heat island at the front of several homes.

A turnaround with a central concave landscaped area can create an opportunity for stormwater infiltration or detention. A landscaped area in the center of a cul-de-sac can reduce impervious land coverage 30 to 40%, depending on configuration. Design of a landscaped cul-de-sac must be coordinated with fire department personnel to accommodate turning radii and other operational needs.

Details

6.3 *Parking lots*



6.3a Hybrid parking lot

6.3 Parking lots. In any development, storage space for stationary automobiles can consume many acres of land area, often greater than the area covered by streets or rooftops. In a neighborhood of single family homes, this parking area is generally located on private driveways or along the street. In higher density residential developments, parking is often consolidated in parking lots.

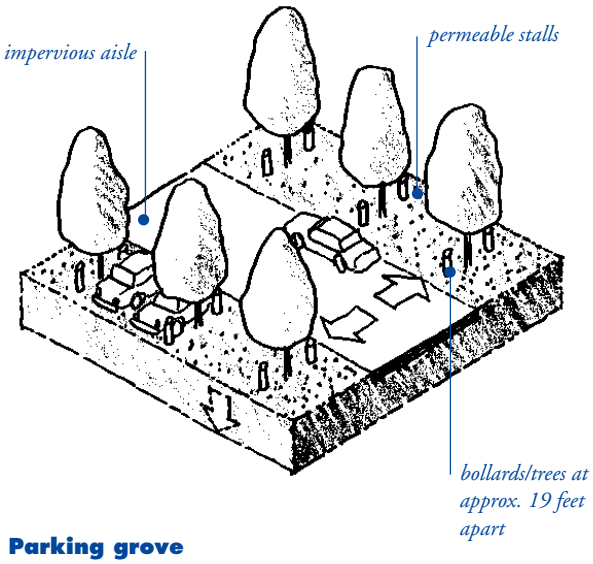
The space for storage of the automobile, the standard parking stall, occupies only 160 square feet, but when combined with aisles, driveways, curbs, overhang space, and median islands, a parking lot can require up to 400 square feet per vehicle, or nearly one acre per 100 cars. Since parking is usually accommodated on an asphalt or concrete surface with conventional underground storm drain systems, parking lots typically generate a great deal of directly-connected impervious area.

There are many ways to both reduce the impervious land coverage of parking areas and to filter runoff before it reaches the storm drain system.

6.3a Hybrid parking lot. Hybrid lots work on the principle that pavement use differs between aisles and stalls. Aisles must be designed for speeds between 10 and 20 mph, and durable enough to support the concentrated traffic of all vehicles using the lot. The stalls, on the other hand, need only be designed for the 2 or 3 mph speed of vehicles maneuvering into place. Most of the time the stalls are in use, vehicles are stationary. Hybrid

Hybrid parking lot.
This hybrid lot in a mixed-use development in Medford Village, N.J. uses crushed aggregate parking stalls and a conventional asphalt aisle.
(photo: Bruce Ferguson)

Parking lots, continued



6.3b Parking grove

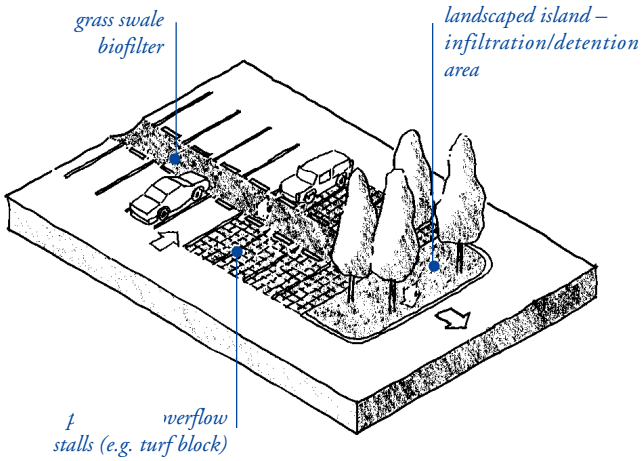
lots reduce impervious surface coverage in parking areas by differentiating the paving between aisles and stalls, combining impervious aisles with permeable stalls.

If the aisles are constructed of a more conventional, impermeable material suitable for heavier vehicle use, such as asphalt, the stalls can be constructed of a permeable pavement. This can reduce the overall impervious surface coverage of a typical double-loaded parking lot by 60%, and avoid the need for an underground drainage system.

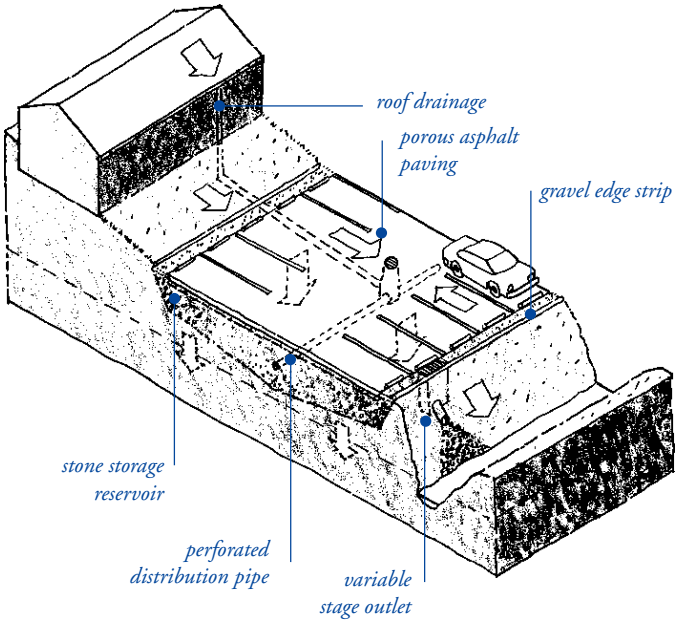
Permeable stalls can be constructed of a number of materials, including crushed aggregate, open-celled unit pavers, porous asphalt, or pervious concrete (see Permeable Pavements, 6.1). A hybrid lot of crushed aggregate stalls and conventional asphalt aisles is a low-cost, practical design that is easily constructed from standard materials (see photo, previous page). In most cases, stall markings are not required, as the geometry of the edges promotes orderly parking. If desired, stalls can be indicated with wood headers, change in unit paver color, or pavement markers ("botts dots").

6.3b Parking Grove. A variation on the permeable stall design, a grid of trees and bollards can be used to delineate parking stalls and create a "parking grove." If the bollard and tree grid is spaced approximately 19 feet apart, two vehicles can park between each row of the grid. This 9.5 foot stall spacing is slightly more generous than the standard 8.5 to 9 foot stall, and allows for the added width of the tree trunks and bollards. A benefit of this design is that the parking grove not only shades parked

Parking Grove.
This parking grove at a Seaside, FL. hotel uses bollards and trees at approximately 10 ft. on center to create a shady courtyard that accommodates parking. The crushed oyster shell pavement is permeable and stable for walking and driving.



6.3c Overflow parking



6.3d Porous pavement recharge bed
(adapted from Prince Georges Co., MD)

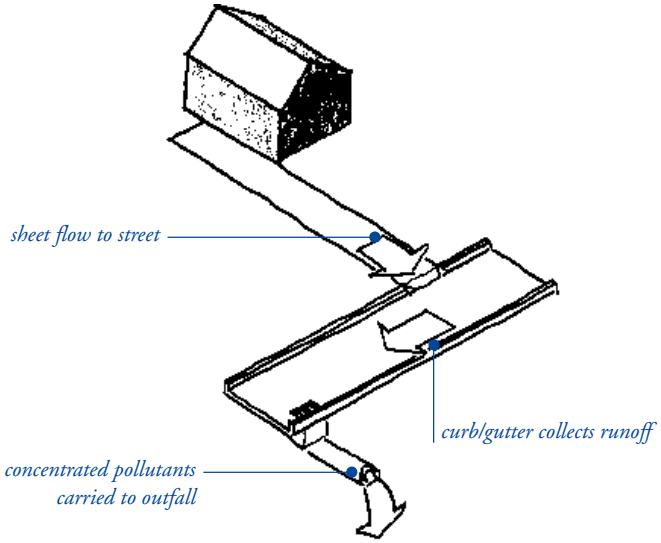
cars, but presents an attractive open space when cars are absent.

6.3c Overflow parking. In some locations daily parking needs fluctuate, often with peak use occurring only for special events or seasons. Typically, parking lots must be constructed to accommodate the peak demand, generating a high proportion of impervious land coverage of very limited usefulness.

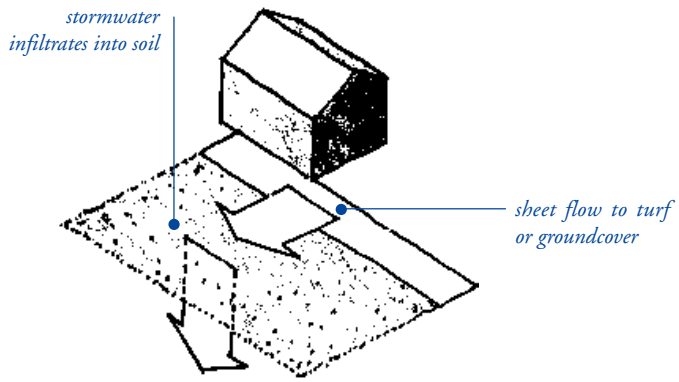
An alternative is to differentiate between regular and peak parking demands, and to construct the peak parking stalls of a different, more permeable, material. This "overflow parking" area can be made of a turf block, which appears as a green lawn when not occupied by vehicles, or crushed stone. The same concept can be applied to areas with temporary parking needs, such as emergency access routes or, in residential applications, RV or trailer parking (see 6.4f Temporary parking).

6.3d Porous pavement recharge bed. In some cases parking lots can be designed to perform more complex stormwater management functions. Subsurface stormwater storage and infiltration can be achieved by constructing a stone-filled reservoir below the pavement surface and directing runoff underground by means of perforated distribution pipes. Subsurface infiltration basins eliminate the possibilities of mud, mosquitoes and safety hazards sometimes perceived to be associated with ephemeral surface drainage. They also can provide for storage of large volumes of runoff, and can be incorporated with roof runoff collection systems. These underground infiltration and storage systems are relatively expensive, and required extensive engineering, but have been used in a variety of locations in the eastern United States where land values are high and the need to control runoff is great.[45] Similar high land values are found throughout the Bay Area, and as emphasis on stormwater management increases, the economic viability of these solutions will increase.

Details 6.4 *Driveways*



Directly-connected impervious driveway



6.4a Not directly-connected impervious driveway

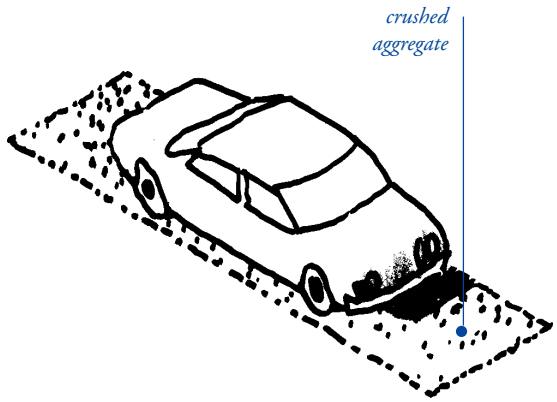
6.4 Driveways. Driveways can comprise up to 40% of the total transportation network in a conventional development, with streets, turn-arounds and sidewalks comprising the remaining 60%.

Driveway length is generally determined by garage setback requirements, and width is usually mandated by municipal codes and ordinances. If garages are set back from the street, long driveways are required, unless a rear alley system is included to provide garage access. If parking for two vehicles side-by-side is required, a 20 foot minimum width is required. Thus, if a 20 foot setback and a two-car wide driveway are required, a minimum of 400 square feet of driveway will result, or 4% of a typical 10,000 square foot residential lot. If the house itself is compact, and the driveway is long, wide, and paved with an impervious material such as asphalt or concrete, it can become the largest component of impervious land coverage on the lot.

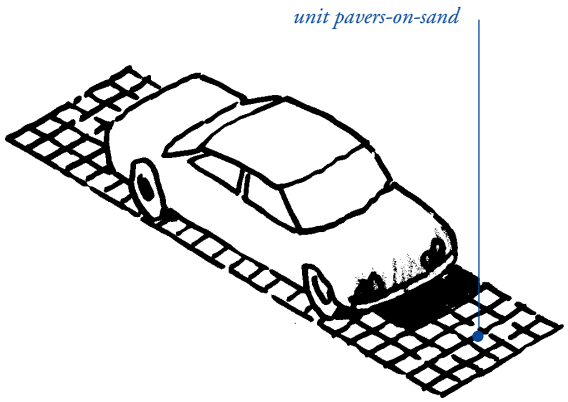
Municipalities can reduce the area dedicated to driveways by allowing for tandem parking (one car in front of the other). Also, if shared driveways are permitted, then two or more garages can be accessed by a single driveway, further reducing required land area. Rear alley access to the garage can reduce driveway length, but overall impervious surface coverage may not be reduced if the alleys are paved with impervious materials and the access streets remain designed to conventional municipal standards.

6.4a Not directly-connected impervious driveway. A conventional driveway that is a "directly connected impervious area" drains directly to the storm drain system – collecting and concentrating pollutants. The easiest way to reduce the impact of a conventional impervious driveway on water quality is to slope it to drain onto an adjacent turf or groundcover area. By passing driveway runoff through a permeable landscaped area, pollutants can be dispersed and cleansed in the soil. A conventional impervious driveway directly connected to the storm drain network collects and concentrates pollutants.

6.4b Crushed aggregate driveway. Gravel and other granular materials can make a suitable permeable pavement for driveways especially those that serve single family homes. Because it is lightly used by very slow moving vehicles, a well-constructed driveway of granular material can serve as a relatively smooth



6.4b Crushed aggregate driveway

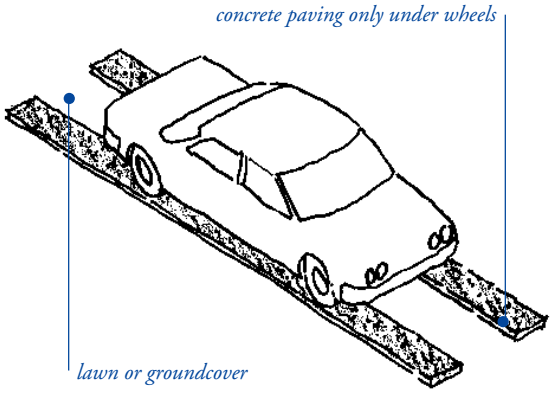


6.4c Unit pavers on sand

pavement with minimal maintenance. In choosing a granular material for a gravel driveway, use crushed stone aggregate. For proper infiltration and stormwater storage, the aggregate must be open-graded (see 6.1 Permeable pavements).

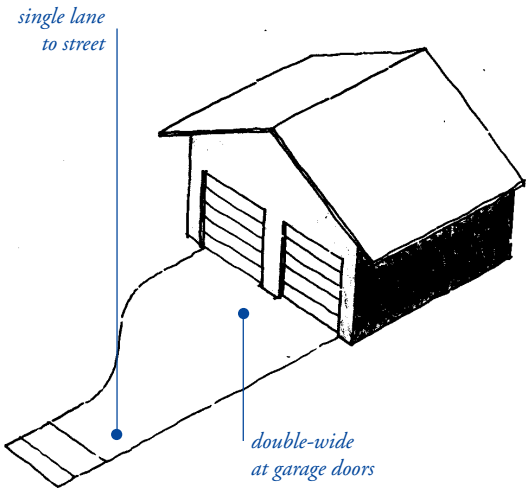
6.4c Unit pavers on sand. Unit pavers on sand can make a permeable, attractive driveway. A pavement of brick-on-sand or turf-block can make the driveway more integrated with the garden rather than an extension of the street penetrating deep into the garden space. For parking, a permeable, engineered base structural section may be required in addition to the sand setting bed.

6.4d Paving only under wheels. Concrete paving only under the wheel tracks is a viable, inexpensive design if the driveway is straight between the garage and the street. By leaving the center strip open to be planted with grass, groundcover or filled with a permeable material such as gravel, a driveway of two concrete wheel tracks can reduce impervious surface coverage by 60 to 70% compared with a single lane concrete driveway.

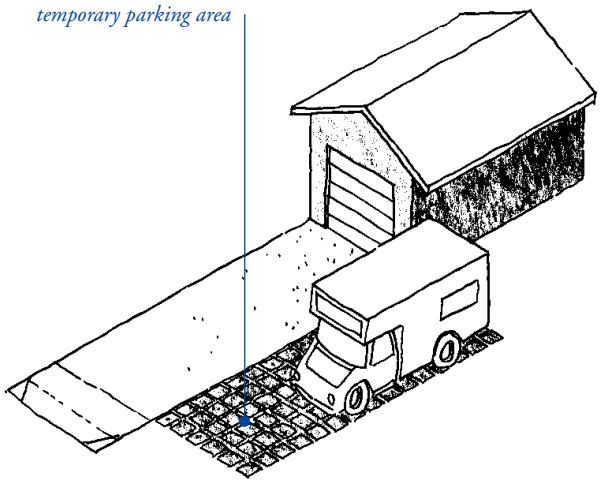


6.4d Paving only under wheels

Details 6.4 *Driveways (continued)*



6.4e Flared driveways



6.4f Temporary parking

6.4e Flared driveways. Long driveways or driveways that serve multi-car garages do not require the full multi-lane width along their entire length. The approach to the garage can be a single lane, adequate to accommodate the relatively infrequent vehicle trips, while the front of the garage can be flared to provide access to all garage doors. This strategy can reduce overall pavement cost and land coverage while maintaining adequate access for all parking spaces.

6.4f Temporary parking. In some areas, parking or access is required infrequently. These areas can be paved with a permeable turf-block or similar paver, and maintained as a landscaped surface. For the majority of the time when it is not used for parking, it appears and functions as a green space. When needed for parking or access, the surface supports vehicle loads. This is an especially valuable strategy for emergency access routes or overflow parking.

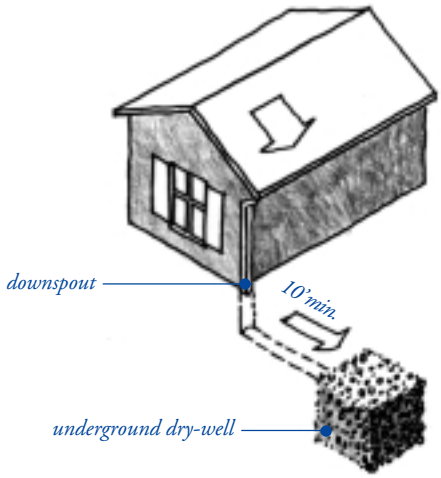
Driveway considerations. Driveways offer a relatively simple opportunity to improve both the aesthetics and permeability of residential developments.

By allowing tandem parking, shared driveways, or rear alley access, municipalities can minimize mandated driveway requirements.

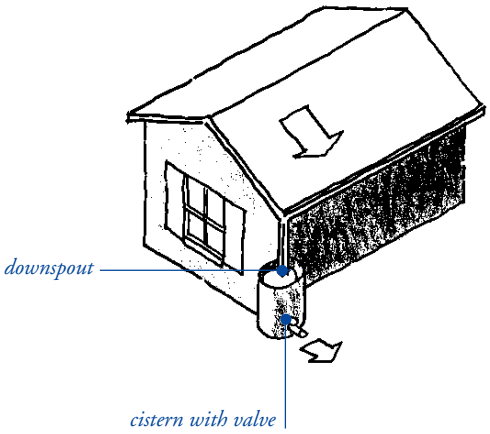
For designers and developers, the driveway's intimate relationship with the residence, and its relative freedom from government regulation, make it an element that can be designed to increase permeability and market appeal.

Some treatments, such as turf-block or gravel, require greater maintenance than poured-in-place asphalt or concrete designs. Other materials, such as brick or unit pavers, require a greater initial expense. Both the maintenance and cost implications of these designs can be balanced by the improved aesthetic and market appeal of driveways made from more attractive, more permeable pavements.

Details 6.5 *Buildings*



6.5a Dry-well



6.5b Cistern

6.5 Buildings. By definition, buildings create impervious land coverage. An important planning consideration is the site coverage and floor area ratio (F.A.R.). Buildings of equal floor area ratio can have widely different impervious coverage. For example, a two story building with 1,000 square feet of floor area will create 500 square feet of impervious area, while a one story building of the same floor area will create twice as much impervious land coverage. Therefore, tall skinny buildings have less impact on stormwater quality than low, spreading ones.

Once the building size and coverage is determined, there are a limited number of techniques for managing runoff from individual buildings to collect rooftop runoff and allow it to infiltrate into the soil.

6.5a Dry-well. If a gutter and downspout system is used to collect rainwater that falls on a roof, runoff becomes highly concentrated. If the downspout is connected to a dry-well, this runoff can be stored and slowly infiltrated into the soil.

A dry-well is constructed by digging a hole in the ground and filling it with an open graded aggregate. An underground connection from the downspout conveys water into the dry well, allowing it to be stored in the voids. To minimize sedimentation from lateral soil movement, the sides and top of the stone storage matrix can be wrapped in a permeable filter fabric, though the bottom may remain open. A perforated observation pipe can be inserted vertically into the dry-well to allow for inspection and maintenance.

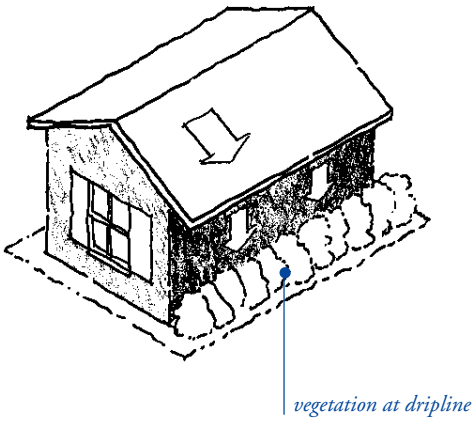
In practice, dry-wells receiving runoff from single roof downspouts have been successful over long periods because they contain very little sediment. They must be sized according to the amount of rooftop runoff received, but are typically 4 to 5 feet square, and 2 to 3 feet deep, with a minimum of 1 foot soil cover over the top (maximum depth of 10 feet).

To protect the foundation, dry-wells must be set away from the building at least 10 feet. They must be installed in soils that accommodate infiltration. In poorly drained soils, dry-wells have very limited feasibility.

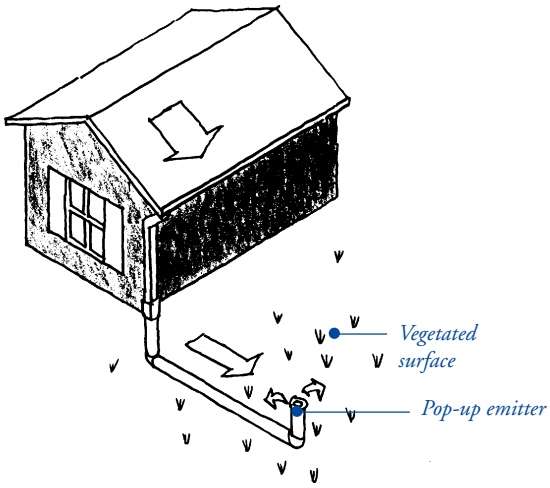
6.5b Cistern. Another way to store and slowly release roof runoff into the soil is to empty the downspout into a cistern. A cistern is an above ground storage vessel with either a manually operated valve or a permanently open outlet.

If the cistern has an operable valve, the valve can be closed to store stormwater for irrigation or infiltration between storms. This system requires continual monitoring by the resident or

Buildings, continued



6.5c Foundation planting



6.5d Pop-up drainage emitter

grounds crews, but provides greater flexibility in water storage and metering. If a cistern is provided with an operable valve and water is stored inside for long periods, the cistern must be covered to prevent mosquitoes from breeding.

A cistern system with a permanently open outlet can also provide for metering stormwater runoff. If the cistern outlet is significantly smaller than the size of the downspout inlet (say 1/4 to 1/2 inch diameter), runoff will build up inside the cistern during storms, and will empty out slowly after peak intensities subside. This is a feasible way to mitigate the peak flow increases caused by rooftop impervious land coverage, especially for the frequent, small storms.

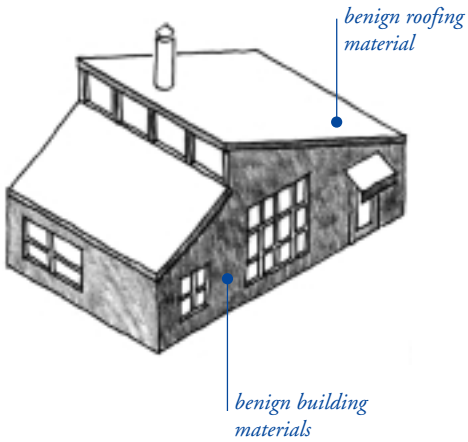
Cisterns can be incorporated into the aesthetics of the building and garden. Japanese, Mediterranean and American Southwest architecture provide many examples of attractive cisterns made of a variety of materials.

If a cistern holds more than 6" depth of water, it must be covered securely or have a top opening of 4" or less to prevent small children from gaining access to the standing water. The cistern must be designed and maintained to minimize clogging by leaves and other debris.

6.5c Foundation planting. For buildings that do not use a gutter system, landscape planting around the base of the eaves can provide increased opportunities for stormwater infiltration and protect the soil from erosion caused by concentrated sheet flow coming off the roof.

Foundation plantings can reduce the physical impact of water on the soil and provide a subsurface matrix of roots that encourage infiltration. These plantings must be sturdy enough to tolerate the heavy runoff sheet flows, and periodic soil saturation.

6.5d Pop-up drainage emitter. Discharging the downspout to landscaped areas allows for polishing and infiltration of the runoff. The downspout can be directly connected to a pipe which daylights some distance from the building foundation, releasing the roof runoff through a pop-up emitter. Similar to a pop-up irrigation head, the emitter only opens when there is flow from the roof. The emitter remains flush to the ground during dry periods, for ease of lawn or landscape maintenance.



6.5e Building materials

6.5e Building materials. Selection of building materials and construction practices has an affect on stormwater quality. Some building materials contribute to stormwater degradation as they age or combine with rainwater and air. Some construction practices use materials that pollute runoff. Other materials and practices are more benign. Examples of considerations in materials selection and building practices include:

Concrete. Check the contents and source of the concrete mixture for impurities. Avoid form separators such as diesel fuel or petroleum based oil. Vegetable oil can be used as a non-toxic alternate (though plaster and stucco may not adhere effectively to an oiled concrete substrate).

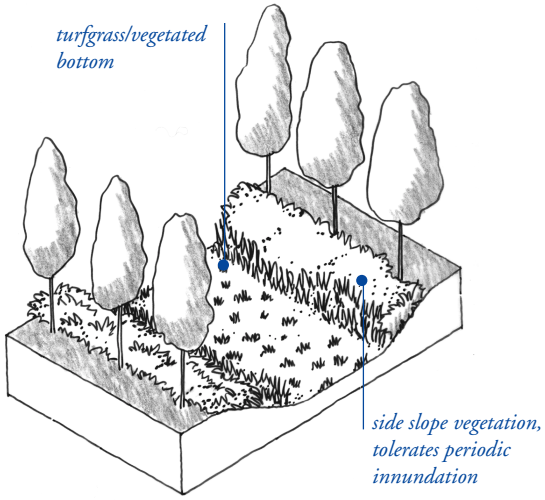
Wood. For landscape materials such as steps and walls, avoid using railroad ties and woods that have been pressure treated with creosote or penta wood preservatives. Many recycled plastic products are becoming more commonly available and are often suitable wood substitutes for decking, headers and other landscape uses. Steel studs and frames are also becoming a cost-effective substitute for wood framing.

Roofing. Materials that can generate polluted runoff under some conditions include copper sheeting (trace metal), asphalt shingles (by-product of oil refining process), zinc (trace metal; lead used in zincing process). Some alternative roofing materials include: slate, steel, stone, and terra cotta tiles. These materials are durable and fireproof. They may also require design attention to accommodate the added weight load.

Paints and coatings. Lead-based paints have been commonly used in building. White lead was used on wood siding, door and window frames, and casings. Red lead was used as a primer for steel window frames on commercial and industrial buildings When renovating old buildings, test for lead in the existing paint before proceeding with removal practices such as sanding or water blasting to avoid paint chips landing on and leaching into the soil.

Details

6.6 *Landscape*



6.6a Grass/vegetated swales

6.6 Landscape. In the natural landscape, most soils infiltrate a high percentage of rainwater through a complex web of organic and biological activities that build soil porosity and permeability. Roots reach into the soil and separate particles of clay, insects excavate voids in the soil mass, roots decay leaving networks of macropores, leaves fall and form a mulch over the soil surface, and earthworms burrow and ingest organic detritus to create richer, more porous soil. These are just a few examples of the natural processes that occur within the soil.[46]

In development, a certain amount of soil must be covered with impervious surface, but the remaining landscape can be designed and maintained to maximize its natural permeability and infiltration capacity.

One simple strategy to improve infiltration is to use the grading of landscape surfaces. Landscape surfaces are conventionally graded to have a slight convex slope. This causes water to run off a central high point into a surrounding drainage system, creating increased runoff. If a landscape surface is graded to have a slightly concave slope, it will hold water. The infiltration value of concave vegetated surfaces is greater in permeable soils. Soils of heavy clay or underlain with hardpan provide less infiltration value. In these cases concave vegetated surfaces must be designed as retention/detention basins, with proper outlets or underdrains to an interconnected system.

Multiple small basins. Biofilters, infiltration, retention/detention basins are the basic elements of a landscape designed for stormwater management (see Drainage system elements 5.5). The challenge for designers is to integrate these elements creatively and attractively in the landscape – either within a conventional landscape aesthetic, or by presenting a different landscape image that emphasizes the role of water and drainage.

Multiple small basins can provide a great deal of water storage and infiltration capacity. These small basins can fit into the parkway planting strip or shoulders of street rights-of-way. If connected by culverts under walks and driveways, they can create a continuous linear infiltration system. Infiltration and retention/detention basins can be placed under wood decks, in parking lot planter islands, and at roof downspouts. Outdoor patios or seating areas can be sunken a few steps, paved with a permeable pavement such as flagstone or gravel, and designed to hold a few inches of water collected from surrounding rooftops or paved areas for a few hours after a rain.

All of these are examples of small basins that can store water for

An ordinary lawn.
This lawn presents a conventional landscape appearance – its role as an effective biofilter capable of holding a few inches of water is barely noticable.

A different landscape image.
This infiltration basin uses simple landscape materials to create a landscape of great diversity that accentuates its role in a surface drainage network.

Basins for every landscape type.

a brief period, allowing it to infiltrate into the soil, slowing its release into the drainage network, and filtering pollutants.

6.6a Grass/vegetated swales. Parking lot drainage can be integrated with landscaping to provide infiltration and retention/detention basins. Grass swales can be a particularly effective design strategy in large conventionally paved parking lots, by providing low maintenance, linear biofilters along the perimeter of the lot or along internal islands. Stormwater is directed to these linear landscaped spaces and travels slowly over turfgrass or other vegetated surfaces, allowing pollutants to settle and slowing runoff velocities (See chapter 8 for details).

6.6b Extended detention (dry) ponds. Extended detention (dry) ponds can be used for both pollutant removal and flood control. These ponds store water during storms anywhere from a few hours up to a few days, discharge it to adjacent surface waters, and are dry between storms. Clay or impervious soils should not affect pollutant removal effectiveness, as the main removal mechanism is settling.

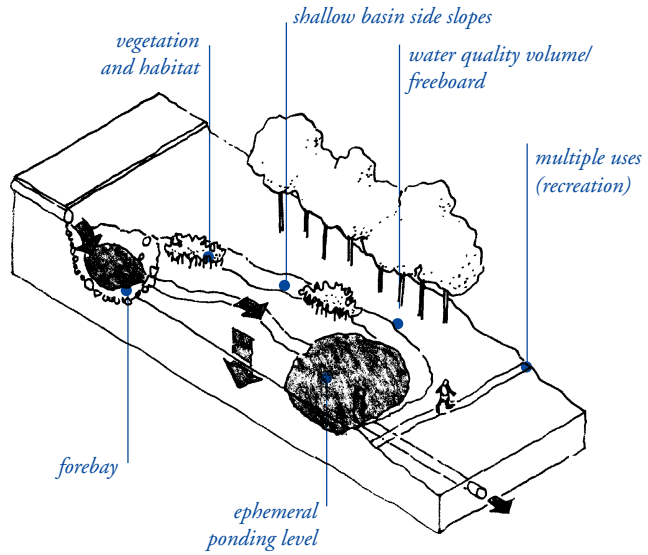
Extended detention ponds are generally appropriate for developments of ten acres or larger, and have the potential for multiple uses including flood control basins, parks, playing fields, tennis courts, open space, and overflow parking lots.

It is important to consider design elements to improve pond safety. The most important being shallow side slopes of no steeper than 3:1. This prevents people from accidentally falling into deep water. Barriers such as fencing and/or vegetation are also used, but they prevent access for recreational use, and also can present a hazardous situation if the side slopes are steep, because people drawn to the water can breach or climb the barrier and fall into deep water.

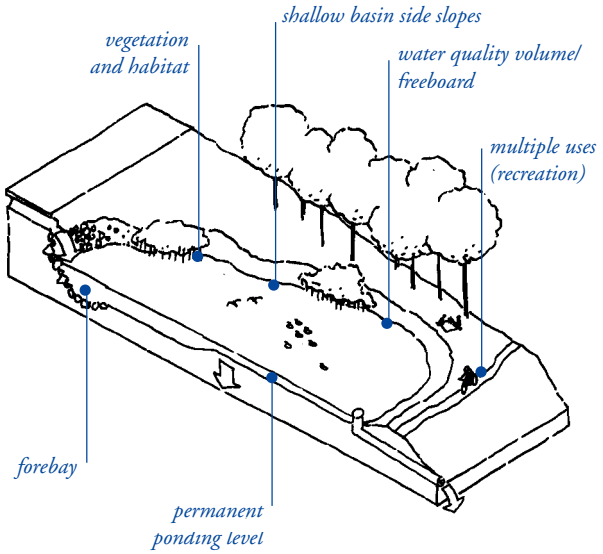
6.6c Wet ponds. Wet ponds are permanent pools of water that detain and treat stormwater runoff. These ponds, if designed with a fringe wetland at the pond edge, can increase property values by providing a significant landscape amenity with opportunities for passive recreation (e.g., birdwatching, fishing), and can be combined with pedestrian and bicycle circulation to provide active recreation. The fringe wetland is also an important factor in increasing pollutant removal.

6.6d Plant species selection for infiltration areas. The proper selection of plant materials can improve the infiltration potential of landscape areas. Deep rooted plants help to build soil porosity. Plant leaf-surface area helps to collect rainwater before it lands on the soil, especially in light rains, increasing the overall water-holding potential of the landscape. A single street tree can have a total leaf surface area of several hundred to

Landscape, continued



6.6b Extended detention (dry) ponds



6.6c Wet ponds

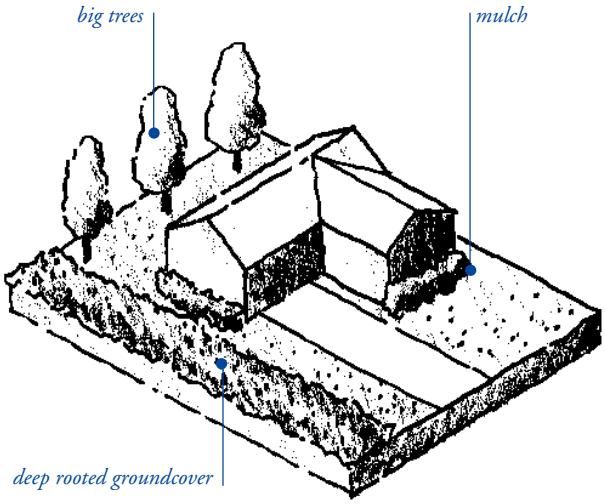
several thousand square feet, depending on species and size. This above ground surface area created by trees and other plants greatly contributes to the water-holding capacity of the land.

A large number of plant species will survive moist soils or periodic inundation. These plants provide a wide range of choices for planted infiltration/detention basins and drainage swales. Most inundated plants have a higher survival potential on well-drained alluvial soils than on fine-textured shallow soils or clays. Though oaks generally do not tolerate summer moisture, mature valley and blue oaks (*Quercus lobata* and *Q. douglasii*) in alluvial soils can survive winter inundation for up to 100 days annually.[47]

Landscape considerations. Landscape can perform a wide variety of stormwater management functions. In designing landscapes for stormwater management, appropriate groundcover must be selected. Turf grass lawns, woody perennials, and cobbles can all be used, depending on the desired aesthetic effect.

6.6e Landscape maintenance for stormwater systems. All landscape treatments require maintenance. Landscapes designed to perform stormwater management functions are not necessarily more maintenance intensive than highly manicured conventional landscapes. A concave lawn requires the same mowing, fertilizing and weeding as a convex one, and often less irrigation because more rain is filtered into the underlying soil. Sometimes infiltration basins may require a different kind of maintenance than conventionally practiced.

Typical maintenance activities include periodic inspection of surface drainage systems to ensure clear flowlines, repair of eroded surfaces, adjustment or repair of drainage structures, soil cultivation or aeration, care of plant materials, replacement of dead plants, replenishment of mulch cover, irrigation, fertilizing, pruning and mowing. Also, dead or stressed vegetation may indicate chemical dumping. Careful observation should be made of these areas to determine if such a problem exists.



6.6d/e Plant selection and landscape maintenance

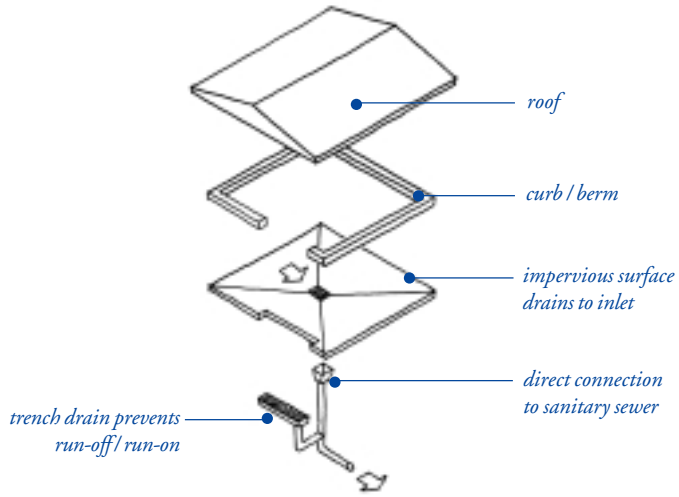
Landscape maintenance can have a significant impact on soil permeability and its ability to support plant growth. Most plants concentrate the majority of their small absorbing roots in the upper 6 inches of the soil surface if the surface is protected by a mulch or forest litter. If the soil is exposed or bare, it can become so hot that surface roots will not grow in the upper 8 to 10 inches. The common practice of removing all leaf litter and detritus with leaf blowers creates a hard crusted soil surface of low permeability and high heat conduction. Proper mulching of the soil surface improves water retention and infiltration, while protecting the surface root zone from temperature extremes.[47]

In addition to impacting permeability, landscape maintenance practices can have adverse effects on water quality. Because commonly used fertilizers and herbicides are a source of organic compounds, it is important to keep these practices to a minimum, and prevent overwatering.

When well-maintained and designed, landscaped concave surfaces, infiltration basins, swales and bio-retention areas can add aesthetic value while providing the framework for environmentally sound, comprehensive stormwater management systems.

Details

6.7 *Outdoor work areas*



6.7 Typical outdoor work area

6.7 Outdoor work areas. The site design and landscape details listed in previous chapters are appropriate for uses where low concentrations of pollutants can be mitigated through infiltration, retention and detention. Often in commercial and industrial sites, there are outdoor work areas in which a higher concentration of pollutants exists, and thus a higher potential of pollutants infiltrating the soil. These work areas often involve automobiles, equipment, machinery, or other commercial and industrial uses, and require special consideration.

Outdoor work areas are usually isolated elements in a larger development. Infiltration and detention strategies are still appropriate for and can be applied to other areas of the site, such as parking lots, landscape areas, employee use areas, and bicycle paths. It is only the outdoor work area within the development – such as the loading dock, fueling area, or equipment wash – that requires a different drainage approach. This drainage approach is often *precisely the opposite* from the infiltration/detention strategy– in other words, collect and convey.

In these outdoor work areas, infiltration is discouraged and runoff is often routed directly to the sanitary sewer, not the storm drain. Because this runoff is being added to the loads normally received by the water treatment plants (known as "publicly owned treatment works" or POTW), it raises several concerns that must be addressed in the planning and design stage. These include:

- higher flows (if area is exposed to rainfall) that could exceed the sewer system capacity,
- catastrophic spills that may cause harm to POTW operations, and,
- a general increase in pollutants.

These concerns can be addressed at policy, management, and site planning levels.

Policy. Piping runoff and process water from outdoor work areas directly to the sanitary sewer for treatment by a downstream POTW displaces the problem of reducing stormwater pollution. Municipal stormwater programs and/or private developers can work with the local POTW to develop solutions that minimize effects on the treatment facility.

Management. Commercial and industrial sites that host special activities need to implement a pollution prevention program, minimizing hazardous material use and waste. For example, if restaurant grease traps are directly connected to the sanitary sewer, proper management programs can mitigate the amount of grease that escapes from the trap. This grease, if released in large volumes, can clog sewer systems and cause overflows, or

Outdoor work areas

Outdoor work areas that may require structural treatment include:

Auto recycle facilities

Auto wrecking yards

Commercial nurseries

Corporation yards

Fueling stations

Fleet storage areas

Rooftop equipment

Marinas

Outdoor container storage

Outdoor loading/unloading facilities

Public works storage areas

Vehicle service and maintenance areas

Vehicle and equipment washing/steam cleaning facilities

All sites requiring a hazardous materials management plan (HMMP)

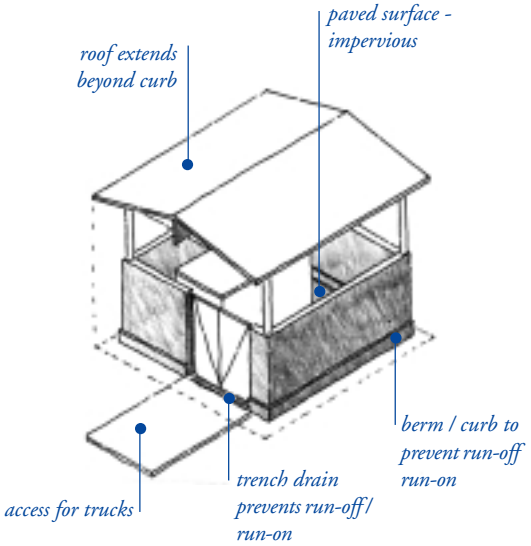
Source: Technical Note No. 87. *Watershed Protection Techniques.* Vol. 2, No. 2. February 1997.

damage the downstream treatment system.

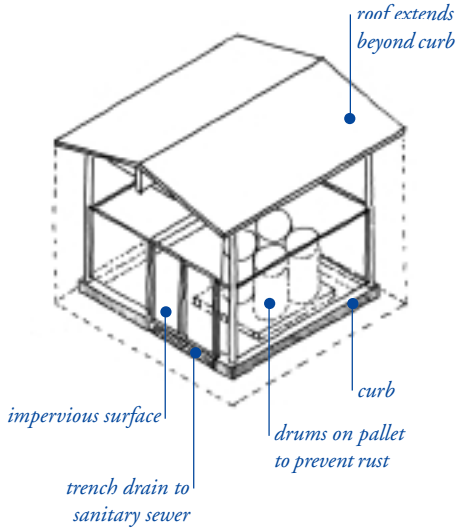
Site Planning. Outdoor work areas can be designed in particular ways to reduce their impacts on both stormwater quality and sewage treatment plants (if drainage system is connected):

- create an impermeable surface. This can be a conventional pavement, such as concrete or asphalt, or a prefabricated metal drip pan, depending on the use.
- cover the area with a roof. This prevents rain from falling on the work area and becoming polluted runoff.
- berm or mounding around the perimeter of the area to prevent water from adjacent areas to flow on to the surface of the work area. In this way, the amount of polluted runoff is minimized.
- directly connect runoff. Unlike other areas, runoff from these work areas is directly connected to the sanitary sewer or other specialized containment systems. This allows the more highly concentrated pollutants from these areas to receive special treatment that removes particular constituents. Approval for this connection must be obtained from the appropriate sanitary sewer agency.
- locate the work area away from storm drains or catch basins. If the work area is adjacent to or directly upstream from a storm drain or landscape drainage feature (e.g.

Details 6.7 *Outdoor work areas, continued*



6.7a Garbage and recycling area



6.7b Maintenance and storage area

bioswale), debris or liquids from the work area can migrate into the stormwater system.

These design elements are general considerations for work areas. In designing any outdoor work area, evaluate local ordinances affecting the use, as many local jurisdictions have specific requirements.

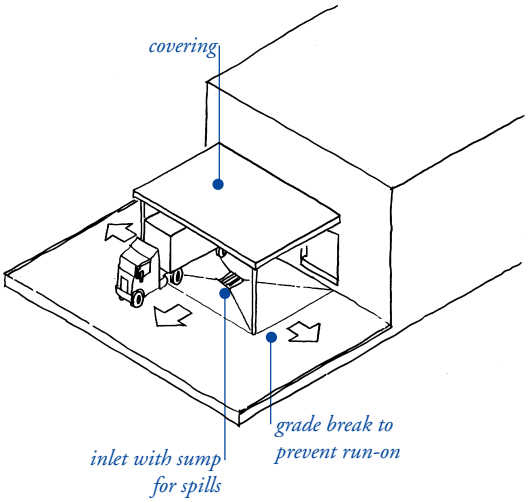
Some activities are common to many commercial and industrial sites. These include garbage and recycling, maintenance and storage, and loading. These activities can have a significant negative impact on stormwater quality, and require special attention to the siting and design of the activity area.

6.7a Garbage and recycling. Garbage and recycling areas must be designed to consider a wide range of factors. These include sizes of receptacles for both trash and a variety of recycled materials. They must be sited so that receptacles are accessible for collection by standard collection trucks, yet out of the way so as not to disturb the aesthetics of the site. Garbage and recycling areas should also be located away from drainage paths and waterways to prevent debris and spills from entering the drainage system.[49] Regular maintenance plans should be implemented for sweeping, litter control, and spill cleanup.

Protection from rainfall and "run-on" surface drainage can be achieved by designing a roof or covering for the enclosure, and a curb or berm around the perimeter to contain any leakage from trash containers and dumpsters. The dumpsters or trash containers need to sit on a paved area, not lawn or unpaved soil, to prevent infiltration of leakage. Plastic liners may also be used to contain liquid waste. In cases where water cannot be diverted from the areas (such as areas located within a low spot), a self-contained drainage system must be designed.

6.7b Maintenance and storage. To reduce the possibility of contact with stormwater runoff, maintenance and storage areas can be sited away from drainage paths and waterways.[50] Implementing a regular maintenance plan for sweeping, litter control, and spill cleanup, also helps prevent stormwater pollution.

Specifying impermeable surfaces for vehicle and equipment maintenance areas will reduce the chance of pollutant infiltration. A concrete surface will usually last much longer than an asphalt one, as vehicle fluids can either dissolve asphalt or can be absorbed by the asphalt and released later.[51]



6.7c Loading area

Vehicle and equipment washing. It is generally advisable to cover areas used for regular washing of vehicles, trucks, or equipment, surround them with a perimeter berm, and clearly mark them as a designated washing area. Sumps or drainlines can be installed to collect wash water, which may be treated for reuse or recycling, or for discharge to the sanitary sewer. The POTW may require some form of pretreatment, such as a trap, for these areas.

Fueling and maintenance activities must be isolated from the vehicle washing facilities. These activities have specific requirements (see below).

Storage of bulk materials, fuels, oils, solvents, other chemicals, and process equipment should be accommodated on an impervious surface covered with a roof. To reduce the chances of corrosion, materials should not be stored directly on the ground, but supported by a wire mesh or other flooring above the impervious pavement. In uncovered areas, drums or other containers can be stored at a slight angle to prevent ponding of rainwater from rusting the lids. Liquid containers should be stored in a designated impervious area that is roofed, fenced within a berm, to prevent spills from flowing into the storm drain.

If hazardous materials are being used or stored, additional specific local, state or federal requirements may apply.

6.7c Loading. Loading areas and docks can be designed with a roof or overhang, and a surrounding curb or berm. The area should be graded to direct flow toward an inlet with a shutoff valve or dead-end sump. The sump must be designed with enough capacity to hold a spill while the valve is closed. If the sump has a valve, it must be kept in the closed position and require an action to open it. All sumps must have a sealed bottom so they cannot infiltrate water. Contaminated accumulated waste and liquid must not be discharged to a stormdrain and may be discharged to the sanitary sewer only with the POTW's permission. If it does not receive approval for discharge to the sanitary sewer, it must be conveyed to a hazardous waste (or other offsite disposal) facility, and may require pretreatment.[52]

Details

6.7 *Outdoor work areas, continued*

Some specific uses have unique requirements.

Restaurants. Though special regulations and zoning ordinances address restaurant pollutants, there are still areas in which poor maintenance practices contribute to stormwater pollution. It is preferable that all cooking and cleaning activities occur inside the restaurant. If these activities are performed outside, there are some simple site design elements that can help reduce the potential for stormwater pollution (See case study 7.2f).

Containment curbs or berms can be designed around areas in which floor mat, container washing, exhaust filter and sink cleaning may take place. A covered, secondary containment area can be designed so that kitchen grease is contained, collected, and removed regularly by a recycling/disposal service, or disposed of through a grease trap with a sanitary sewer connection.[53]

Fueling areas. In all vehicle and equipment fueling areas, plans must be developed for cleaning near fuel dispensers, emergency spill cleanup, and routine inspections to prevent leaks and ensure properly functioning equipment.[54]

If the fueling activities are minor, fueling can be performed in a designated, covered and bermed area that will not allow run-on of stormwater or runoff of spills.[55]

Retail gasoline outlets and vehicle fueling areas have specific design guidelines (See case study 7.2g). These are described in a Best Management Practice Guide for retail gasoline outlets developed by the California Stormwater Quality Task Force, in cooperation with major gasoline corporations. The practice guide addresses standards for existing, new, or substantially remodeled facilities.

Fuel dispensing areas are defined as extending 6.5 feet from the corner of each fuel dispenser or the length at which the hose and nozzle assemble may be operated plus 1 foot, whichever is less. These areas must be paved with smooth impervious surface, such as Portland cement concrete, with a 2%-4% slope to prevent ponding, and must be covered. The cover must not drain onto the work area. The fuel dispensing area must be separated by the rest of the site by a grade break that prevents run-on of stormwater.

Within the gas station, the outdoor trash receptacle area (garbage and recycling), and the air/water supply area must be paved and graded to prevent stormwater run-on.