County of San Diego

Low Impact Development Handbook

Stormwater Management Strategies

DECEMBER 31, 2007

Department of Planning and Land Use
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San Diego, California 92123

APPROVAL

I hereby certify that this **Low Impact Development Handbook** was considered by the Director of Planning and Land Use, in coordination with the Director of Public Works on the 9th day of January, 2008.

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I hereby certify that this **Low Impact Development Handbook** has hereby been approved by the Deputy Chief Administrative Officer (DCAO) of the Land Use and Environment Group on the 9TH day of JANUARY, 2008. The Director of Planning and Land Use is hereby authorized to approve any updates or revisions to this manual.

Approved, JANUARY 9, 2008

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HANDBOOK DEVELOPMENT

This document was prepared by the County of San Diego, Department of Planning and Land Use (DPLU), MSCP Watershed Planning Program, in coordination with the staff of several departments within the County. The LID Handbook Project Team consisted of the following:

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Executive Summary

Urban runoff pollution is commonly considered the nation's number one water quality problem [2, 3]. Stormwater issues have increasingly become a key consideration in land use planning and development over the last several years in San Diego County. The San Diego Regional Water Quality Control Board (Board) first approved San Diego's Municipal Stormwater Permit in 1990 (Order No. 90-42) and renewed the permit in 2001 (Order No. 2001-01), which required all jurisdictions to develop and implement a stormwater program. On January 24, 2007, the Board adopted the revised Municipal Stormwater Permit (Regional Water Quality Control Board (RWQCB) Order No. R9-2007-0001) [4]. The revised permit contains standards and requirements which are intended to further reduce the pollution that enters local streams, creeks, bays and beaches. San Diego County jurisdictions are mandated by the permit to regulate new and existing development and redevelopments (that add or increase impervious cover by 5,000 sq. ft.) to comply with stormwater requirements.

As part of the revised Municipal Stormwater Permit [4], San Diego jurisdictions must initially encourage developments to incorporate minimal Low Impact Development (LID) techniques into Priority Development Projects by January 2008. During this initial phase the LID Handbook will serve as the guidance structure for these LID techniques and the initial LID projects that will be monitored as LID standards and criteria are being developed in the region. San Diego jurisdictions will collectively establish feasibility and applicability criteria and develop specific LID requirements over the next couple years. Once these specific criteria and requirements have been established and accepted by the Board, the jurisdictions will have one year to incorporate the new LID requirements into their local codes and ordinances. Therefore, by the year 2010, the County and other local jurisdictions will each have an updated stormwater program with a comprehensive list of BMPs, including the new LID standards and criteria.

The Permit is a product of the federal Clean Water Act (CWA) [5]. The CWA passed in 1972 and was expanded to include stormwater regulation in 1990, making it illegal to discharge pollutants into waterways. The Board is responsible for ensuring that federal and state water regulations are implemented at the local level.

Stormwater runoff (also known as "urban runoff" in populated areas) is defined as rainwater that flows over land, roofs & pavements and then enters our stormwater infrastructure, i.e. our gutters and storm drains. It is important to note here, that all public storm drains in San Diego (west of the Tecate Divide) drain directly to our beaches without any wastewater treatment. As stormwater runoff flows over various structures and pavement, the water picks up and carries sediments and pollutants such as pesticides, fertilizers, oils, metals, bacteria, and animal feces down to our streams, lagoons, bays and beaches.

For the above reasons, on-site stormwater management has become one of the critical elements for preventing pollution from entering our storm drains. The County of San Diego is required to reduce the discharge of pollutants in urban runoff to the maximum extent practicable by requiring development to use stormwater best management practices (BMPs) and Low Impact Development techniques in new and redesigned developments.

LID uses decentralized, site-based planning and design strategies to manage the quantity and quality of stormwater runoff. LID attempts to reduce the amount of runoff by mimicking the natural hydrologic function of the site. LID focuses on minimizing impervious surfaces and promoting infiltration and evaporation of runoff before it can leave the location of origination. Using small, economical landscape features, LID techniques work as a system to filter, slow, evaporate, and infiltrate surface runoff at the source [6].

The LID Handbook is designed to assist public and private land developers with the selection of various design features. LID planning techniques include: minimizing paved areas, minimizing soil compaction, preservation of natural open space including trees and natural drainage channels, clustering of development on compacted soils, and locating open space areas to absorb overflows. In addition to planning, the LID Handbook discusses a broad range of LID Integrated Management Practices (IMPs) to help developers mimic the site's natural hydrological function. IMPs may include directing runoff to natural and landscaped areas, man-made filtration devices such as small vegetated swales, rain gardens, and permeable pavements and pavers. Other basic principals include dividing and sectioning impervious surfaces (no large continuously paved areas), eliminating runoff pathways and re-dispersing runoff (no downspouts connected to stormdrains), and, where feasible, harvesting of rain water in rain barrels or cisterns and using runoff as an irrigation source. These LID techniques can be applied to areas of residential, commercial, industrial, and municipal development.

The LID Handbook has been initially designed to complement the existing County of San Diego Stormwater Standards Manual [7] and the Landscape Water Conservation Design Manual [8]. Once the County updates its local Standard Urban Stormwater Mitigation Plan (SUSMP) [9] with revised BMPs, the LID Handbook will be incorporated into the updated Stormwater Standards Manual.

Section 1 Introduction

1.1. Purpose and Organization of the LID Handbook

The Goal of the County of San Diego's LID Program is to protect water quality by preserving and mimicking nature through the use of stormwater planning and management techniques on a project site. The Purpose of the LID Handbook is to provide a comprehensive list of LID planning and stormwater management techniques for developers, builders, contractors, planners, landscape architects, engineers, and government employees to reference as guidance prior to developing a project site. The LID Handbook has been developed for the County of San Diego under the guidance of the LID Technical Advisory Committee.

The LID Handbook is designed to assist planners, developers, architects, landscape professionals, city and county development services, including planning and public works staff, and others with engineering solutions and site planning practices that attempt to mimic natural hydrologic functions for development sites. Some examples of engineering solutions include diversion, infiltration and filtration of runoff into and through vegetated swales and landscaped areas, permeable surfaces and soils, evapotranspiration by vegetation, biodegradation of pollutants by soil bacteria, and infiltration for groundwater recharge. Conventional development and storm drain system design typically inhibit natural hydrologic functions by creating large impermeable surfaces that prevent infiltration and groundwater recharge, increase runoff, and discharge polluted runoff offsite and eventually into streams, rivers, lakes, lagoons, bays, and ultimately the Pacific Ocean [10]. Some examples of LID practices that mimic natural hydrologic functions include vegetated rock swales, bioretention basins and permeable pavement. In addition to providing water quality benefits, LID practices reduce the quantity of runoff from developed areas and can assist with water conservation.

The LID Handbook is intended to complement the County of San Diego Stormwater Standards Manual [7] (Appendix A of the County's "Watershed Protection, Stormwater Management and Discharge Control Ordinance"), the Standard Urban Stormwater Mitigation Plan (SUSMP) [9], the County's Hydrology Manual [11], and the Landscape Water Conservation Design Manual [8]. Local design engineers, architects, landscape professionals and contractors should use the current version of the Stormwater Standards Manual and Landscape Water Conservation Design Manual for specific information related to the performance, design, operation, inspection and maintenance of structural treatment controls and LID practices such as vegetated swales, bioretention basins and permeable pavement. The LID Handbook provides guidance for new development and redevelopment to incorporate these practices and other techniques that reduce runoff, increase groundwater recharge, and improve water quality. However, the current Stormwater Standards Manual will be updated to reflect the new LID solutions that are implemented as a result of the new Regional Permit. Certain standards contained in the current Stormwater Standards Manual will need to be amended to properly implement these LID solutions. For example, the current manual states that LID infiltration areas must not be located within 100 feet of a building foundation or drinking water well as required by the Stormwater Standards Manual. This standard would preclude the use of LID on most sites and therefore it will need to be changed to allow for new LID solutions, including those identified in this manual. Any and all specific LID solutions must be designed and reviewed by a qualified and licensed professional before they can be incorporated into a development project.

The LID Handbook should be the <u>first</u> guidance document referenced during the development planning process. This includes new development or redevelopment (net addition of less than 5,000 square feet of impervious surface, and/or less than 1 acre of land disturbance) of residential, commercial, industrial, civic (e.g. parks and churches), or public works projects. The LID Handbook should be used to reference LID planning policies and procedures and general site designs for reducing stormwater quality impacts from new development and redevelopment projects. Once a conceptual LID site plan is developed, stormwater treatment, storm drainage and flood control facilities should be designed based on the design criteria presented in the current version of the Stormwater Standards Manual. During the construction phase, Best Management Practices (BMPs) should be employed to comply with the San Diego County Watershed Protection, Stormwater Management and Discharge Control Ordinance (WPO) [7].

The LID Handbook is organized as follows:

Section 1 Provides an overview of Stormwater Regulations and Management, LID Background, LID Benefits, and Goals of LID.

Section 2 Contains LID planning practices, including land use planning, site assessment, and site design examples.

Section 3 Provides a brief discussion of LID Integrated Management Practices (on-site LID techniques).

Appendix 1 Is a **Glossary** of relevant LID terms.

Appendix 2 Contains a **Bibliography** of references cited in the manual.

Appendix 3 Discusses primary considerations for implementing LID in the County of San Diego.

Appendix 4 Contains important **Fact Sheets** for specific design considerations for each LID technique.

1.2. Stormwater Management

1.2.1. Background

Historically urban development and storm drain system design have consisted of streets, driveways, sidewalks and structures constructed out of impervious materials that directly convey runoff to curb and gutter systems, storm drain inlets and a network of underground storm drain pipes. They have been designed to convey stormwater away from developed areas as quickly and efficiently as possible [10]. Conventional storm drainage systems can include detention basins designed to reduce peak flows. However, they typically do not address stormwater quality or improvement of groundwater recharge. This has been the engineering standard for approximately the last 50 years.

When natural vegetated pervious ground cover is converted to impervious surfaces such as paved highways, streets, rooftops, and parking lots, the natural absorption and infiltration abilities of the land are lost. This typically results in post-development runoff with greater volume, velocity, and peak flow rate than pre-development runoff from the same area [4].

Runoff durations can also increase as a result of flood control and other efforts to control peak flow rates. Increased volume, velocity, rate, and duration of runoff accelerate the erosion of downstream natural channels. Significant declines in the biological integrity and physical habitat of streams and other receiving waters have been found to occur with a 10% conversion from natural to impervious surfaces [4]. Furthermore, ephemeral and intermittent streams as found in the semi-arid regions in southern California have been shown to be even more sensitive, where an increase of 2-3% total-impervious-area can have impacts to stream morphology [12].

Table 1. Degradation of watershed conditions and stream response.

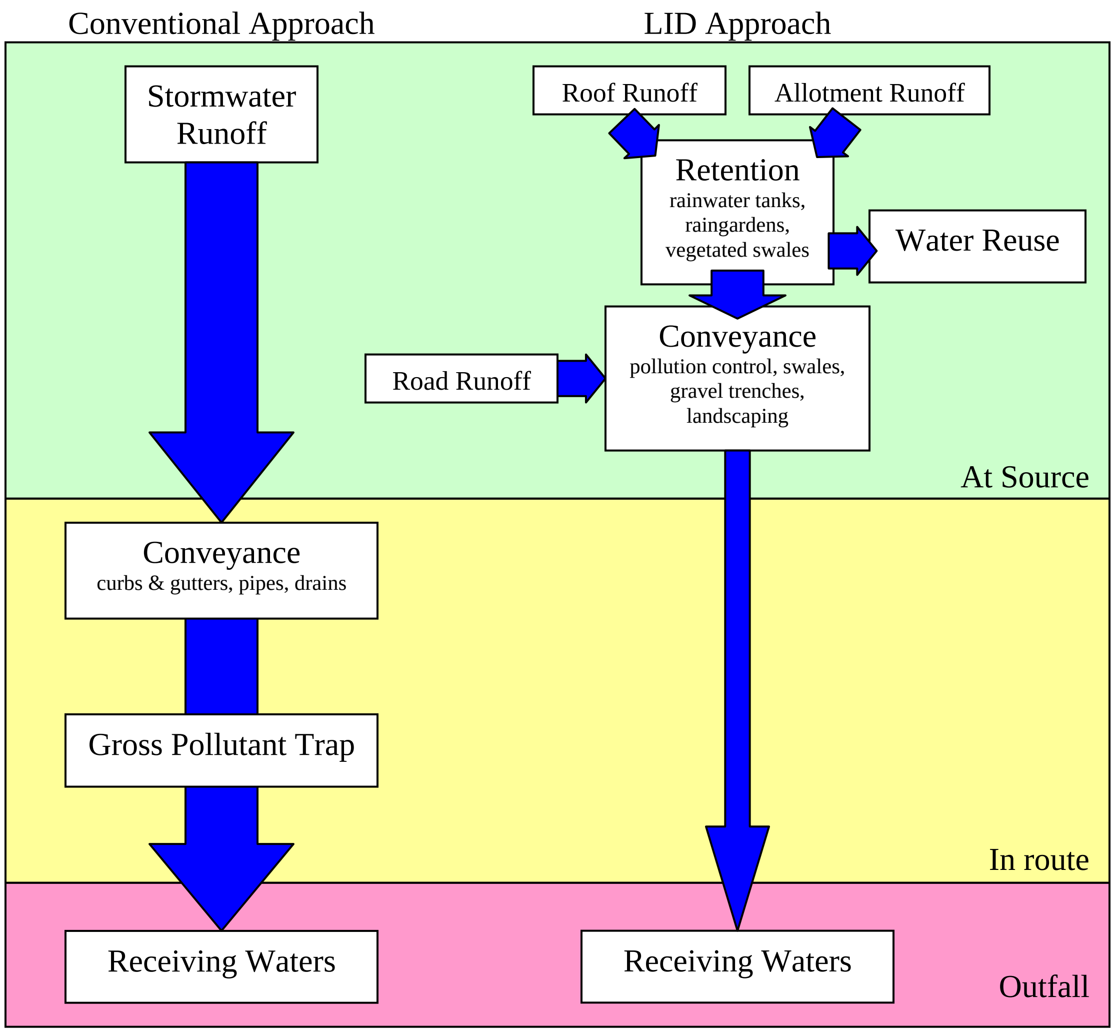
Change in Watershed Condition	**Stream Response**
Increased drainage density due to road networks, road crossing and stormwater outfalls	Increased storm flow volume and frequency
	Channel erosion
	Increased fine sediment and urban water pollutant loads
	Increased fish passage barriers
Increased fine sediment deposition	Reduced intergravel dissolved oxygen levels in streambed
	Loss of macroinvertebrate habitat
Loss or fragmentation of riparian areas	Reduced delivery of woody debris
	Reduced bank stability and loss of bank habitat structure and complexity
	Reduced shading and temperature control
Reduced quantity and quality of woody debris	Reduced channel stability, sediment storage, in stream cover for fish and insects, loss of pool quality and quantity

Change in Watershed Condition	Stream Response
Increased pollutant loads	Synthetic organic compounds and trace elements: some acutely toxic; negative health effects in fish; altered spawning and migration of fish in presence of metals.
	Nutrients: excessive aquatic plant growth; excessive diurnal oxygen fluctuations
	Synergistic influence of multiple pollutants unknown

Around the country conventional development has resulted in increased runoff rates, volumes, and increased flooding potential. Additionally, conventional development, together with previous storm drain system design methods which did not provide storm water quality treatment, resulted in the direct transport of pollutants to local streams, rivers, lakes, lagoons, bays, and the Pacific Ocean. Urban development creates new pollution sources as human population density increases and brings with it proportionately higher levels of vehicle emissions and maintenance waste, municipal sewage, pesticides, household hazardous waste, pet waste, trash, etc. which is either washed or directly dumped into the storm drains [4]. Individually, residential homes and businesses typically contribute relatively small amounts of runoff and pollutants. However, numerous studies have shown that the collective discharge of untreated runoff from large areas of conventional residential, commercial, industrial, and municipal development often results in significant environmental impacts to local water resources [13].

The volume and rate of runoff and the potential to transport pollutants to local water bodies depends on a variety of factors, including developed and proposed land use and management practices, and existing climatic, hydrologic and geologic conditions within a drainage area. Numerous studies have shown that small storms, which occur more frequently than relatively large storms, typically transport the greatest load of pollutants to local water bodies [13]. In addition, the majority of pollutants are typically transported during the "first flush" portion of a runoff event, which is often considered to be the first half-inch of a storm event. Therefore, the sizing of structural treatment controls and LID practices is most efficient and cost effective when they are designed to capture and treat the most frequently occurring storm events as well as the "first flush" portion of runoff producing storm events.

Figure 1. Conventional vs. LID Stormwater Approach



Improvements in stormwater management have been made in the County of San Diego since 2001 with the passing of the first Stormwater Municipal Permit. Additional stormwater improvements are now required as defined in the revised Stormwater Municipal Permit in 2007 [4]. With the addition of almost one million new residents in the San Diego region by 2030 [14], new development and redevelopment in San Diego County will continue to present challenges for stormwater treatment and management. In addition to the NPDES stormwater permit requirements discussed in Section 1.2.2; effective management of both the quantity and quality of stormwater is vital to the long-term economic growth and quality of life in the County of San Diego. With the current knowledge that conventional storm drainage systems are responsible for the degradation of many of the nation's water bodies, stormwater quality management must now also be considered in the design of storm drainage for new development and redevelopment.

1.2.2. State and Federal Stormwater Regulations

The California Regional Water Quality Control Board (RWQCB), a division of the State of California Environmental Protection Agency, requires all local jurisdictions to implement a stormwater program to address stormwater concerns. The RWQCB issued the region's first Municipal Stormwater Permit, or NPDES permit, in 1990 (Order No. 90-42) and renewed the permit in 2001 (Order No. 2001-01) [15] permitting San Diego County jurisdictions to discharge stormwater runoff via storm drains into natural water bodies. Requirements under the permit mandate that the jurisdictions regulate development and existing establishments to comply with stormwater requirements.

The Permit is a product of the federal Clean Water Act (CWA). The CWA was passed by Congress in 1972 and was extended to stormwater concerns in 1990; thus making it illegal to release pollutants into waterways. The RWQCB is responsible for ensuring that federal and state water regulations are implemented at the local level.

On January 24, 2007, the RWQCB adopted a revised Municipal Stormwater Permit (Order No. R9-2007-0001) [4]. The revised Permit intends to further reduce the pollution that runs down storm drains into local waterways. As part of the Permit, San Diego jurisdictions must initially encourage developments to incorporate minimal LID techniques into Priority Development Projects by January 2008. During this initial phase the LID Handbook will serve as the guidance structure for these LID techniques and initial LID projects will be monitored as LID standards and criteria are being developed in the region. San Diego jurisdictions will collectively establish feasibility and applicability criteria; develop specific LID requirements within the next couple of years. Once these specific criteria and requirements have been established and accepted by the Board, the jurisdictions will have one year to incorporate the new LID requirements into their local codes and ordinances. By the year 2010, the County and other local jurisdictions will each have an updated stormwater program with a comprehensive list of BMPs, including the new LID standards and criteria.

Additional detailed information about stormwater requirements can be found on the Regional Water Quality Control Board Region 9 website at: http://www.swrcb.ca.gov/rwqcb9/

1.2.3. Stormwater Management Plans and BMPs

To meet the goals of the NPDES permit renewed in 2001, the County of San Diego established a "Watershed Protection, Stormwater Management and Discharge Control Ordinance" (WPO) with Appendix A: Stormwater Standards Manual (SSM) [7] for developers. The WPO, including the SSM, defines the requirements that are legally enforceable by the County. The County also established a Standard Urban Storm Water Mitigation Plan (SUSMP) for Land Development and Public Improvement Projects. The SUSMP addresses land development and capital improvement projects. It is focused on project design requirements and related post-construction requirements, but not on the construction process itself. The SUSMP also addresses the WPO requirements.

In order to comply with the CWA, the state Water Code, and the above mentioned County Ordinances, the County requires that property owners complete a Stormwater Management Plan (SWMP) prior to issuance of any permit. The purpose of a SWMP is to document Best Management Practices (BMPs) that will be implemented to prevent pollutants from entering stormwater conveyances and receiving waters.

Construction projects with a disturbed area of greater than 1-acre, must also prepare a Storm Water Pollution Prevention Plan (SWPPP) in order to receive a construction permit. In a typical project, a SWPPP is a document consisting of narrative and a separate sheet within the construction document set, usually in the Civil Engineering or Landscape series, that outlines both a plan to control stormwater pollution during construction (temporary controls) and after construction is completed (the permanent constructed stormwater pollution prevention elements). The permanent controls are usually found on the sheet within the construction documents.

The most economical and effective stormwater treatment and management strategies arise in site planning and design. This document emphasizes ways to reduce the creation of new runoff, and to infiltrate or detain runoff in the landscape.

LID Integrated Management Practices (IMPs) go beyond the previous set of stormwater BMPs by requiring a new way of thinking about impervious land coverage and stormwater management. They are a collection of proven methods and techniques that “integrate” stormwater management into planning and design; reducing the overall runoff, managing stormwater as a resource, and focusing filtration at the source.

LID practices are ecological structural controls and are therefore considered BMPs. Planning and implementation of BMPs to protect surface water quality is required under the National Pollutant Discharge Elimination System (NPDES) stormwater permit issued to the unincorporated County of San Diego, incorporated cities, Port of San Diego and Regional Airport Authority [4]. These permits require the county and cities to control pollutants in stormwater discharges to the Maximum Extent Practicable (MEP) and to reduce pollutants to a level compatible with the beneficial uses designated for the receiving waters.

1.3. Overview of Low Impact Development (LID)

Low Impact Development is an innovative stormwater management approach with the basic principle that is modeled after nature: manage rainfall runoff at the source using uniformly distributed decentralized micro-scale controls. It was pioneered in Prince Georges County, Maryland and has been applied successfully across the country. LID's goal is to mimic a site's predevelopment hydrology by using design practices and techniques that effectively capture, filter, store, evaporate, detain and infiltrate runoff close to its source [15]. This can be accomplished by creating site design features that; direct runoff to vegetated areas containing permeable/amended soils, protect native vegetation and open space, and reduce the amount of hard surfaces and compaction of soil. LID practices are based on the premise that stormwater management should not be seen as merely stormwater disposal. Rather than conveying the runoff from small frequent storm events directly into underground pipes and drainage systems for discharge offsite, LID IMP's dissipate and infiltrate stormwater runoff with landscape features and, where practical, permeable surfaces located onsite, thereby reducing runoff volumes and filtering runoff before it leaves the site. Most forms of development have the ability to incorporate some level of LID design techniques and practices. However higher density infill and vertical development is more limited in feasible LID solutions whereas low-density residential development has more flexibility to incorporate LID design techniques.

LID design techniques and practices need to look at the major development features of a project, including project green space areas and landscaping, rooftops, streetscapes, parking lots, sidewalks, and medians. LID is a versatile approach that can be applied to new development, urban retrofits, redevelopment, and revitalization projects [15].

The Principles of LID can be characterized by the following five elements [6]:

<u>Principles of LID</u>

- Conserve natural resources that provide valuable natural functions associated with controlling and filtering stormwater
- Minimize & disconnect impervious surfaces
- Direct runoff to natural and landscaped areas conducive to infiltration
- Use distributed small-scale controls or Integrated Management Practices (IMPs) to mimic the site's pre-project hydrology
- Stormwater education leads to pollution prevention

LID is a stormwater management and design strategy that is integrated into design of the development project. LID complements other urban planning techniques such as "Smart Growth" "Green Building" and "Sustainable Development" by focusing on alternative approaches to stormwater runoff management and treatment. Smart Growth and Sustainable Development are land use planning terms that describe the efforts of communities across the country to manage and direct growth in a way that reduces damage to the environment and builds livable towns and cities. A sustainable community preserves and enhances the quality of life of residents both within and between communities, while minimizing local impact on the natural environment. Green or sustainable building is the practice of creating healthier and more resource-efficient models of construction, renovation, operation, maintenance, and demolition [15]. By focusing on the watershed protection aspect of smart growth and sustainable development, LID can be incorporated into Smart Growth, Green Building and Sustainable Development practices. LID does not replace local land use planning; rather, it is a complementary set of planning tools applied at the project level to better manage stormwater in areas appropriately designated for growth.

1.3.1. Goals of Low Impact Development

LID's approach to urban planning and design aims to minimize the hydrological impacts of urban development on the surrounding environment. Both stormwater management and LID are directed at providing flood control, flow management, and water quality improvements. LID recognizes that opportunities for urban design, landscape architecture and stormwater management infrastructure are intrinsically linked.

The goal of LID site design is to reduce the generation of stormwater runoff and to treat pollutant loads where they are generated. This is accomplished first with appropriate site planning and then by directing stormwater towards small-scale systems that are dispersed throughout the site with the purpose of managing water in an evenly distributed manner. These distributed systems allow for downsizing or elimination of stormwater ponds, curbs, and gutters. Because LID embraces a variety of useful techniques for controlling runoff, designs can be customized according to local management requirements and site constraints. Designers and developers can select the LID technologies that are appropriate to the site's topographic and climatic conditions that are appropriate to meet stormwater control requirements and specific project constraints and opportunities. New projects, redevelopment projects, and capital improvement projects are all candidates for implementation of LID [16].

<u>Goals of LID</u>

Protect Water Quality
Reduce Runoff
Reduce Impervious Surfaces
Encourage Open Space
Protect Significant Vegetation
Reduce Land Disturbance
Decrease Infrastructure Costs

1.3.2. Benefits of LID

LID has numerous benefits and advantages over the conventional approach. In short, LID is a more environmentally sound technology. By addressing runoff close to the source through intelligent site design, LID can enhance the local environment and protect public health. LID protects environmental assets, protects water quality, and builds community livability. Other benefits include [17]:

<u>Benefits of LID</u>

- Protects surface and ground water resources
- Reduces non-point source pollution
- Reduces habitat degradation
- Applicable to greenfield, brownfields, and urban developments
- Multiple benefits beyond stormwater (aesthetics, quality-of-life, air quality, water conservation, property values)
- Groundwater recharge (where needed)
- Meets Total Maximum Daily Loads (TMDL) and other stormwater requirements

As new development increases over time, increased impervious area will result, effecting hydrologic functions such as infiltration, groundwater recharge, and the frequency and volume of discharges. These natural functions can be maintained with the use of LID practices, which includes reduced impervious surfaces, functional grading, open channel sections, disconnection of hydrologic flowpaths, and the use of bioretention/filtration landscape areas.

In areas where groundwater recharge is desired, LID is beneficial because these practices facilitate rainwater infiltration. Rainwater infiltration is needed for adequate groundwater recharge, especially to provide adequate recharge to endure extended drought periods. Groundwater recharge directly influences local water tables. Local water tables are often connected to reservoirs as well as streams, providing seepage to streams during dry periods and maintaining base flow essential to the biological and habitat integrity of streams. A significant reduction or loss of groundwater recharge can lead to a lowering of the water table and a reduction of base flow in receiving streams during extended dry weather periods. Increased impervious area can reduce rainfall infiltration, which can lead to increased risk of potential impacts from drought. LID practices increase natural rainfall penetration and natural groundwater recharge, thus reducing potential impacts to biological habitat and reduced base flow into reservoirs from extended drought periods. However, in a few San Diego County areas served with municipal drinking water, the potential for high groundwater exists due to the artificial introduction of imported water into the groundwater system from septic system and/or irrigation return flows. The artificial recharge from these sources in some cases may exceed natural pre-development groundwater recharge. This in turn has caused some natural pre-development ephemeral streams to develop year-round perennial flows. Infiltration devices would not be feasible in such areas as it could potentially exacerbate already high groundwater conditions and in some cases contribute to artificial perennial stream flows. In this type of situation, rain water harvesting in appropriately designed barrels or cisterns would be an appropriate LID alternative to infiltration.

LID techniques can facilitate and remove stormwater pollutants. The natural processes employed by LID practices allow pollutants to be filtered or biologically or chemically degraded before stormwater reaches the water bodies. Section 303(d) of the Clean Water Act [5] requires each state to set a Total Maximum Daily Load (TMDL) for all impaired waterbodies. A TMDL is the maximum amount of pollution that a waterbody can receive without violating state water quality standards. For example, Chollas Creek is impaired for the pesticide Diazinon. Jurisdictions in this watershed must implement BMPs to reduce Diazinon concentrations that discharge to the creek. To do so, these jurisdictions plan to use LID practices to reduce impervious area, reduce impacts, and achieve TMDL goals. The combination of runoff reduction and pollutant removal in LID practices is an effective means of reducing pollution released to the environment and meeting Clean Water Act requirements.

1.3.3. Challenges and Limitations of LID Practices

Not all sites can effectively utilize some of the LID techniques. Soil permeability, soil contamination, slope, and water table characteristics may limit the potential for local infiltration. Urban areas planned for multifamily and mixed use development or high rise construction and locations with existing high contaminant levels in the soil may be severely limited or precluded from using LID infiltration techniques onsite. A more community-level approach to LID rather than a site by site approach may be warranted. Other non-infiltration LID techniques such as street trees, permeable pavements with an under drain, raised sidewalks, rain water harvesting with appropriately designed barrels or cisterns, vegetated roofs/modules/walls are still an option for projects in the urban setting, however these techniques must be carefully integrated into projects with thorough consideration of engineering and geotechnical limitations.

Another limiting factor to LID is the lack of research and pilot projects in an arid environment. There are existing examples of LID in Los Angeles County, Orange County, and San Diego County [18]. However access to project information, success stories and lessons learned are limited. The County of San Diego is striving to encourage LID pilot projects in the region and will provide access to research as it becomes available. An extensive **Literature Index** on related LID topics around the world can be accessed on the County of San Diego's website at:
http://www.sdcdplu.org/dplu/docs/LID/LIT-INDEX.pdf

Established practices can be difficult to modify and negative perceptions and lack of information must be alleviated. Even though the public may welcome naturalistic features prescribed by LID, some may prefer the conventional and familiar method of treating stormwater. As experience and demonstration of infiltration and filtration practices increase in the region and our knowledge of the techniques that are most appropriate for the San Diego region develops, fears and misunderstanding should diminish. Education, careful planning and professional consultation and experience will alleviate LID misperceptions over time.

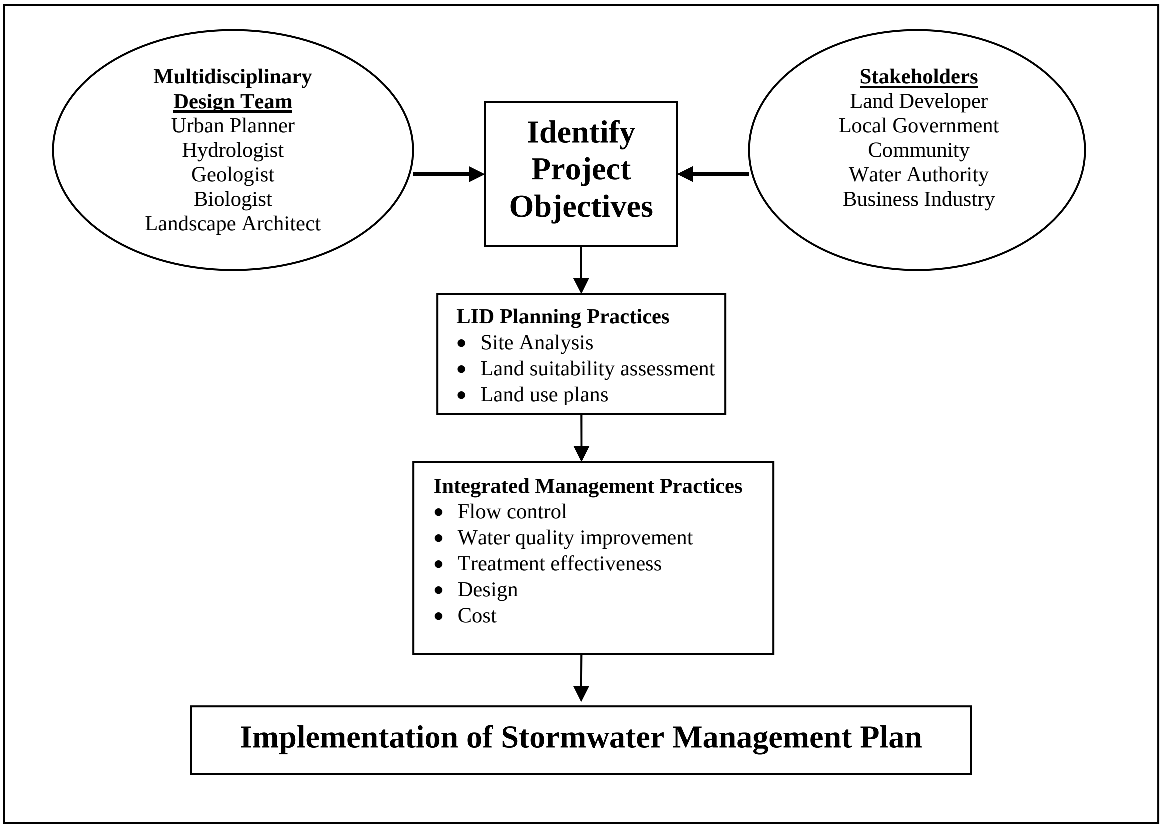
Important Note: Proposed stormwater "Infiltration BMPs", including permeable pavements, shall be reviewed by a qualified, licensed professional to provide a professional opinion regarding the potential adverse geotechnical conditions created by the implementation of the plans. Geotechnical conditions such as: slope stability, expansive soils, compressible soils, seepage, groundwater level, and loss of foundation or pavement subgrade strength should be addressed, and where appropriate, mitigation recommendations should be provided. The impact on existing, proposed, and future improvements including buildings, roads, and manufactured slopes, must be included in the review.

For further LID challenges and considerations in San Diego, please see Appendix 3.

1.3.4. LID and Stormwater Management Planning

A broad approach to the development of a stormwater management scheme is outlined in the County of San Diego's WPO Appendix A "Stormwater Standards Manual" (SSM) [7]. The guidelines in the manual provide strategies to meet stormwater management objectives involving integration of site design with catchment-wide use of non-structural BMPs and structural BMPs. Consideration of these strategies during the planning phase of a stormwater management scheme helps guide the decision making process when selecting and designing BMPs to manage stormwater. The construction activities involved in translating a design concept for a stormwater management scheme into on-the-ground solutions will vary depending on what BMPs are included.

Figure 2. Planning, design, assessment and implementation stages, and associated activities involved in applying LID principles and practices to urban stormwater management.



LID uses the same strategies as the stormwater standards manual. Strategies fall under the two broad categories of Planning Practices and Integrated Management Practices (IMPs).

Common LID Planning Practices include site design planning based on natural land contours and decreasing the impervious surface. These methods may include:

- Reducing Impervious Surfaces
- Disconnected Impervious Areas
- Natural Resource Conservation
- Cluster / consolidate development
- Xeriscaping and water conservation

The basic LID strategy for handling runoff is to reduce the volume and decentralize flows. This is usually best accomplished by creating a series of smaller retention/detention areas that allow localized filtration instead of carrying runoff to a remote collection area to be treated [19]. These are known as LID Integrated Management Practices (IMPs). Common LID IMPs include:

- Bioretention
- Vegetated / Rock Swales
- Filter Strips
- Vegetative Roof Systems
- Rain Collection Systems
- Permeable pavement and materials

Table 2. [20] Presents the variety of runoff management functions provided by the LID IMPs. A more detailed description is provided in Section 3 and technical Fact Sheets are provided in Appendix 4.

	Effect or Function						
IMP	Slow Runoff	Filtration	Infiltration	Retention	Detention	Evaporation	Water Quality Control
Soil Amendments		X	X				X
Bioretention		X	X	X	X	X	X
Vegetated Filter Strips / Buffers	X	X				X	X
Grassed Swales	X	X				X	X
Rock Swales	X	X				X	X
Rain Harvesting				X			
Street Trees							X
Vegetated Roofs	X				X	X	X
Permeable Materials		X	X			X	X
Rock Beds		X			X	X	X

1.3.5. LID and the Water Conservation in Landscaping Act

The State of California's Department of Water Resources is updating their Water Conservation Landscape Ordinance to establish specific standards for landscape design and irrigation design to assure efficient and responsible use of all available water resources for all citizens within the State. The Ordinance is also intended to implement the water efficiency/drought tolerant landscape design requirements of California Assembly Bill 1881, (Water Conservation in Landscaping Act) which apply to new development. These design requirements will support landscapes that are essential to the quality of life here in San Diego County as well as reducing the use of our limited water supplies for irrigation and landscaping. The requirements will also be compatible with a variety of other landscaping objectives, including erosion control, brush management, and invasive plant species control as well as filtering, treating, and utilizing storm water run-off in landscaped areas. Landscape design, installation, maintenance, and management can and should be water efficient. The right to use water is limited to the amount reasonably required for the beneficial use to be served and the right does not and shall not extend to waste or unreasonable methods of use.

1.3.6. LID and the Multiple Species Conservation Program

The Multiple Species Conservation Program (MSCP) is a comprehensive habitat conservation program that addresses multiple species habitat needs and the preservation of native vegetation communities in San Diego. The MSCP targets thousands of acres of open space for conservation within the planning area, including over half of all remaining natural habitat areas and other open spaces (such as disturbed and agricultural lands) that can contribute to conservation objectives. The MSCP does not place a moratorium on development, rather, in these areas an ordinance for addressing biological mitigation provides incentives to develop in the less sensitive habitat areas and mitigate in the areas that have been identified for preservation.

One of LID's planning strategies is to "conserve natural areas, soils, and vegetation". This strategy is in alignment with the goals of MSCP. Developments occurring within the MSCP may already be meeting a fundamental LID objective by applying this planning strategy of preserving sensitive lands and drainages. LID techniques specific to the development project's footprint may still be necessary to achieve the other LID objectives. On a landscape level, the creation of large preserve areas through implementation of MSCP and other programs will serve as the foundation for watershed protection in the San Diego region. Other LID/MSCP scenarios are expected to develop as the MSCP and LID programs are implemented together and grow to compliment each other.

1.4. Summary of LID Considerations in San Diego

The County of San Diego is incredibly diverse. With approximately 4,260 square miles of land [14], the County includes a large variety of geologic and topographic conditions, land uses, and climate types, all of which influence stormwater runoff planning strategies. Key physical factors in San Diego that affect the function, design and performance of LID measures include climate (precipitation, temperature, evapotranspiration), geology (slopes & soils), hydrology (rain distribution and runoff,), groundwater, surface water quality objectives and land use planning and constraints. More information is provided on these physical factors in Appendix 3 of this manual and corresponding County manuals/documents are referenced in those pages.

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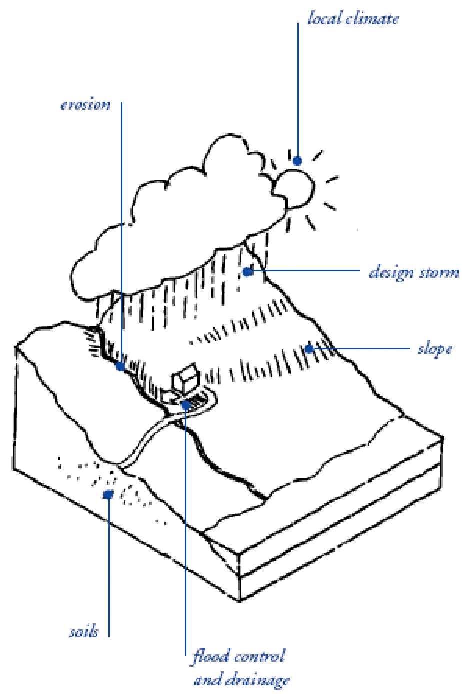
Section 2 Site Planning Practices

2.1. Site Assessment

A comprehensive inventory and assessment of site conditions is the crucial initial step for implementing LID. Site assessment, site planning, and site design are iterative processes.

The site assessment process should evaluate existing conditions such as hydrology, topography, soils, vegetation, and water features to identify how stormwater moves through the site prior to development. Next, the assessment must consider the land use requirements such as the underlying General Plan, zoning requirements, Multiple Species Conservation Program (MSCP) requirements (if applicable), road design standards, sidewalks and parking requirements, driveways, and regulations regarding the use of cluster developments. Utilizing this information, site planning and design should consider how road design, lot configuration and construction practices can utilize existing natural features on the site in order to retain beneficial natural hydrologic functions. In instances where these features do not exist or can not be retained, LID Site Design IMPs should be utilized to mimic the pre-existing hydrological function of the site.



Site designers and municipal planners must understand site conditions and use these as the basis for selecting appropriate stormwater quality controls. Site analyses should indicate how each of the following constraints and opportunities (where applicable) affect the site (WSUD Sydney Region Practice note 2) [21]. Use the following inventory check list to assist with the identification and evaluation of a potential site for LID:

Site Assessment Checklist

Landform
- ☐ Contours / Top of slope
- ☐ Steep slopes (>25%)
- ☐ Orientation of site (North arrow)
- ☐ Natural Features (cliffs, rock outcrops, drainages)

Water
- ☐ Water flow
- ☐ Water quality
- ☐ Drainage patterns
- ☐ Riparian Zones
- ☐ ESA
- ☐ Flood Hazards
- ☐ Depth to Groundwater
- ☐ Seeps and Springs

Soils
- ☐ Soil Type
- ☐ Permeability of soils
- ☐ Expansive soils
- ☐ Collapsible soils
- ☐ Landslides
- ☐ Depth to topsoil and subsoil
- ☐ Erosion potential
- ☐ Geotechnical Hazards

Plants & Habitat
- ☐ Vegetation type
- ☐ Evapotranspiration
- ☐ Existing trees and shrubs
- ☐ Weed species
- ☐ Sensitive species
- ☐ Vegetation to be removed
- ☐ MSCP lands
- ☐ Biological Open Space
- ☐ Park lands, BLM, preserves

Climate
- ☐ Avg. Temperature
- ☐ Avg. Precipitation
- ☐ Prevailing winds
- ☐ Areas of full or partial shade
- ☐ Wildfire Hazard

Site Features
- ☐ Existing structures noted to be removed or retained
- ☐ Location and height of walls/fences
- ☐ Archeological sites
- ☐ Easements
- ☐ Aesthetics of and around the site
- ☐ Aesthetic qualities on site

Land Use Planning
- ☐ General Plan & Zoning
- ☐ Setbacks
- ☐ Parking lot requirements
- ☐ Landscaping requirements
- ☐ Building restrictions

Adjacent lands
- ☐ Location of adjacent structures
- ☐ Rooftop and floor levels of adjacent buildings
- ☐ Form and character of adjacent buildings

Services
- ☐ Location of existing overhead / underground utilities
- ☐ Street requirements
- ☐ Fire Safety requirements

2.2. Site Planning

For a particular site, assessment of the existing environment and land use constraints outlined in the previous section and checklist above can be used to produce a series of maps identifying setbacks, streams, lakes, wetlands, steep slopes, hazard areas, significant habitat areas, buffers (fire, wetland, open space, slopes), and soils. Permeable soils or soils offering the best available infiltration potential should also be noted and utilized. When infiltration practices are not desirable, filtration practices such as swales running to the municipal stormwater system or temporary on-site water retention should be considered in site planning. Map layers showing different aspects of a site (soils map, slopes map, hydrology map, zoning, etc.) can be combined to delineate the best areas for development to occur on the site. Building sites, road layout, and stormwater infrastructures should be configured within these development areas to reduce soil, significant vegetation, and drainage disturbance and take advantage of a site's natural stormwater processing capabilities.

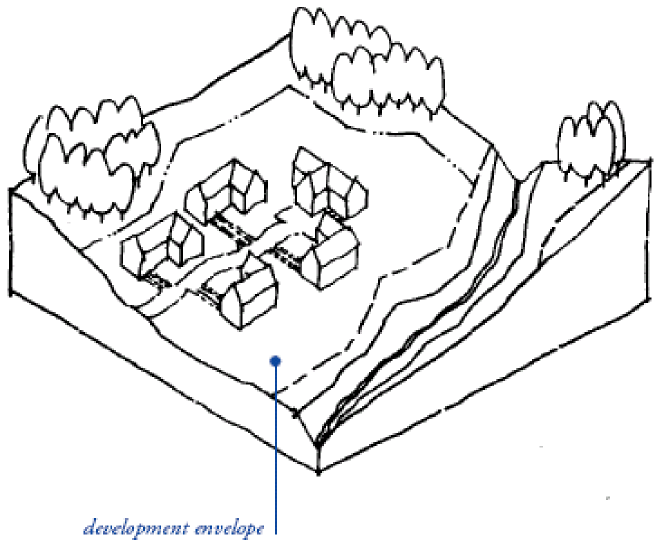
To reduce directly connected impervious areas and promote filtration and infiltration, the site planning principles below shall be considered to guide the layout and orientation of development projects. As required by the California Regional Water Quality Control Board, San Diego Region, Order Number R9-2007-0001, the following site design strategies shall be implemented where applicable and feasible:

- Conserve natural areas, soils, and vegetation
- Minimize disturbances to natural drainages
- Minimize & disconnect impervious surfaces
- Minimize soil compaction
- Drain runoff from impervious surfaces to pervious areas

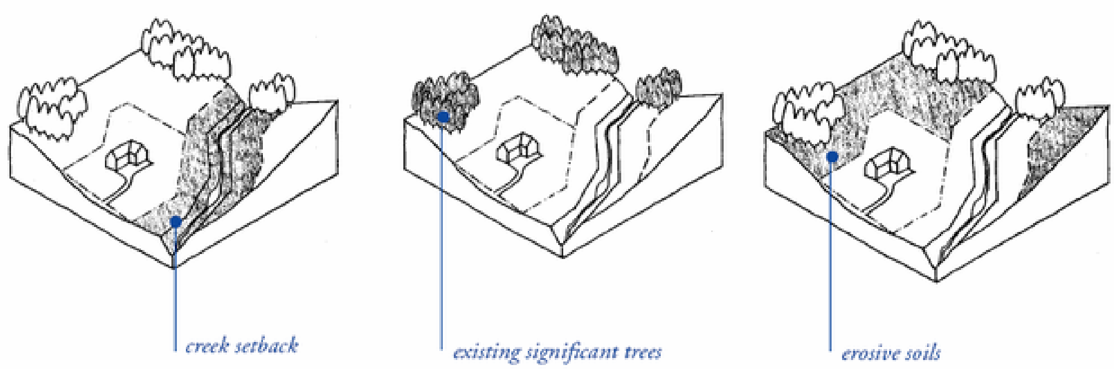
The following sections define these LID site planning principles and how to apply them while designing the LID project site plan.

2.2.1. Conserve Natural Areas, Soils, and Vegetation[1]

Consistent with the County's Conservation Element of the General Plan the first site planning strategy is to conserve natural resources on site. Assess the site for significant trees (see definition), shrubs, sensitive vegetation, and permeable soils and refer to applicable local codes, standards, easements, setbacks, etc., to define the development envelope and create the draft plan.

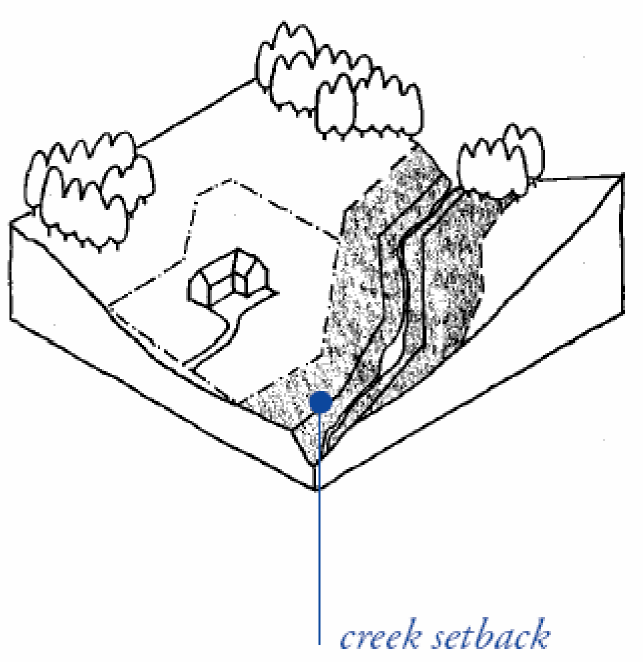


The upper soil layers of a natural area contain organic material, soil biota, vegetation, and a configuration favorable for storing and slowly conveying stormwater. The canopy of existing native trees and shrubs also provide a water conservation benefit by intercepting rain water before it hits the ground. By minimizing disturbances in these areas natural processes are able to intercept stormwater, providing a water quality benefit. By keeping the development envelope concentrated to the least environmentally sensitive areas of the site and set back from natural areas, stormwater runoff is reduced, water quality can be improved, environmental impacts can be decreased, and many of the site's most attractive native landscape features can be retained. Retaining these natural landscape features may also count toward landscaping credit for development's requiring landscape plans. In some situations, site constraints, regulations, economics, and/or other factors may not allow avoidance of all sensitive areas on a project site. The standard California Environmental Quality Act (CEQA) review process will ensure that projects impacting biological resources onsite shall offset those impacts with mitigation elsewhere onsite or through offsite preserve creation to comply with CEQA, the Biological Mitigation Ordinance (BMO), MSCP objectives (if applicable) and other County requirements.



[1] Order No. R9-2007-0001, Pg19. Section: D.1.d.(4)(b)i.

2.2.2. Minimize Disturbances to Natural Drainages[2]

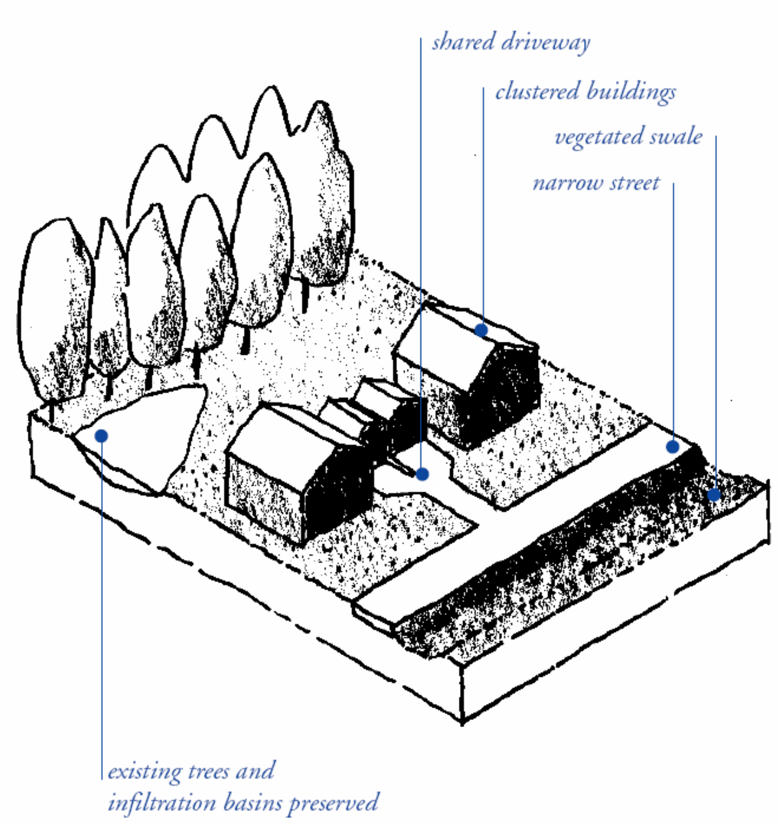


The next site planning strategy is to minimize impacts to natural drainages (natural swales, topographic depressions, etc.). During the site assessment, natural drainages must be identified along with their connection to creeks and/or streams, if any. Natural drainages offer a benefit to stormwater management as the soils and habitat already function as a natural filtering/infiltrating swale. When determining the development footprint of the site, natural drainages should be avoided. By keeping the development envelope set back from natural drainages, the drainage can retain its water quality benefit to the watershed. Implementing "treatment train" IMPs, such as filter strips and bioretention, further protect the natural swale from runoff and help to increase the site's stormwater benefit by reducing stormwater runoff, improving water quality, decreasing environmental impacts, retaining sensitive habitat areas and attractive landscape features. In some situations, site constraints, regulations, economics, or other factors may not allow avoidance of drainages and sensitive areas. The standard CEQA review process will ensure that projects impacting drainages onsite shall offset those impacts with mitigation in order to comply with CEQA, the BMO, the Resource Protection Ordinance (RPO), MSCP objectives (if applicable) and other County requirements.

[2] Order No. R9-2007-0001, Pg19. Section: D.1.d.(4)(b)v.

2.2.3. Minimize and Disconnect Impervious Surfaces[3]

Development typically increases impervious surfaces on formerly undeveloped or less developed landscapes and reduces the capacity of remaining pervious surfaces to capture and infiltrate rainfall [22]. In traditional development, the runoff from these impervious surfaces is captured by pipes and is directly connected to the municipal storm drain. Impervious areas directly connected to the storm drain system have been identified as contributing to non-point source pollution.



Minimize Impervious Surfaces

Reducing impervious surfaces retains the permeability of the project site, allowing natural processes to filter and reduce non-point sources of pollution. Many opportunities are available within the development envelope to increase the permeability of the site by minimizing impervious surfaces. For instance, transportation related surfaces such as streets, sidewalks, and parking lot aisles should be constructed to the minimum width necessary, provided that public safety, circulation, and pedestrian access are not compromised.[3] In addition, walkways, trails, overflow parking lots, alleys and other low traffic areas are required to be constructed with permeable materials where underlying site conditions allow.[3] Other ways of reducing impervious surfaces can be accomplished by concentrating development to specific areas on the site, building vertically instead of horizontally, incorporating landscaping in the center of cul-de-sacs, and designing for shared parking lots and driveways. In addition, in areas where the ground has been properly tilled, gravel, mulch, and water conserving lawns are permeable ground covers suitable for a wide variety of uses.

Pavement surfaces should be selected for permeability. A patio of permeable unit pavers, for example, is more permeable than a large concrete slab. Pervious concrete and

[3] Order No. R9-2007-0001, Pg19. Section: D.1.d.(4)(a)iii., (b)ii., iii.

permeable asphalt-concrete (AC) are alternative materials that can preserve permeability where a larger, more intensely used paved area is needed.

Pervious concrete and permeable AC designs can allow for very slow infiltration in areas with low permeability by adding stone reservoirs under the permeable surfaces. In areas where infiltration is not appropriate, these reservoirs can be fitted with an under drain to allow filtration, storage, and evaporation, prior to drainage into the municipal stormwater system. Urban and infill developments may have limited opportunities to reduce impervious surfaces, in which case LID techniques such as the application of permeable pavements with underdrains, raised sidewalks, rain water harvesting with appropriately designed barrels or cisterns, vegetated roofs/modules/walls, street trees, etc., may be more appropriate. When applying the strategies above, they must be reflected at all levels of a project, from site planning to material application in order to ensure proper implementation and the desired water quality benefit.

Disconnect Impervious Surfaces

Creating permeable surfaces between impermeable surfaces is an effective way to intercept urban runoff and reduce runoff volumes. This technique can be achieved by disconnecting continuously paved areas with landscaping and/or permeable materials and by directing roof runoff into similarly permeable areas, vegetation, soils, and permeable materials. This technique results in reduced stormwater peak flows and filtration of the water before it drains to the municipal stormwater system and/or natural watercourses. It also reduces the amount of runoff which enters the stormdrain or leaves the site as some of the runoff is infiltrated into the site's permeable areas.

Any impervious surface which drains into a catch basin, drain, or other impermeable conveyance structure is considered a "Directly Connected Impervious Area" (DCIA). The DCIA is measured by adding together the square footage of all impervious surfaces (see definition "impervious surface area") that flow directly into a conveyance stormwater system. These impervious surfaces are principally comprised of rooftops and conventional pavements. Impervious surfaces that flow into a pervious area are not directly connected to a conveyance system are not included in the calculation. However, the pervious area receiving the impervious surface runoff must be of appropriate width, location, slope, and design to effectively treat the runoff [23].

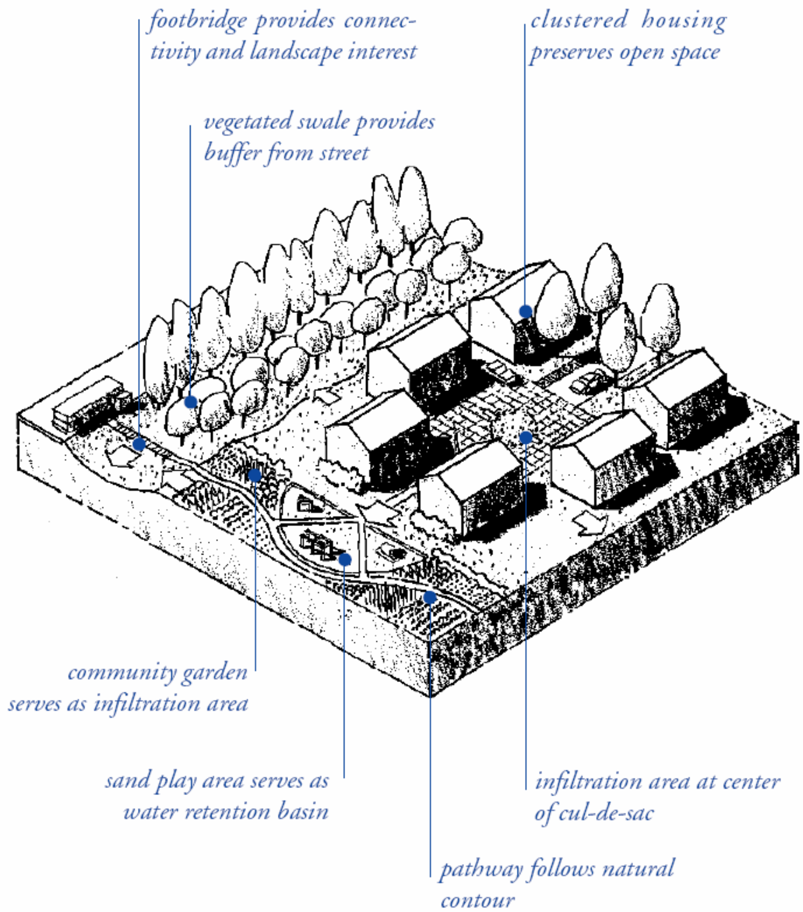
2.2.4. Minimize Soil Compaction[4]

The fourth site planning strategy is to minimize soil compaction in planned pervious areas (infiltration areas, landscaping, lawns, green space etc.) and reduce the overall area of soil disturbance. The upper soil layers contain organic material, soil biota, and a configuration favorable for storing and slowly conducting stormwater down gradient. By protecting native soils and vegetation in appropriate areas during the clearing and grading phase of development the site can retain some of its existing beneficial hydrologic function. It is important to recognize that areas adjacent to and under building foundations, roads and manufactured slopes must be compacted with minimum soil density requirements [24] in compliance with the Grading Ordinance. Clearing and grading exposes and compacts the underlying subsoil, producing a site with significantly different hydrologic characteristics. For this reason, disturbance should be avoided in planned green space and proposed landscaped areas where feasible. These areas that are planned for retaining their beneficial hydrological function should be restricted during the grading/construction phase so that vehicles and construction equipment do not intrude and inadvertently compact the area. Protecting native soil and vegetation to retain the beneficial hydrologic function during the clearing and grading phase can present a significant yet important challenge within the development process.

In urban sites, it may not be possible to avoid soil disturbance. In areas planned for landscaping where compaction could not be avoided, re-tilling of the soil surface should be performed to allow for better infiltration capacity. Soil amendments are recommended and may be necessary to increase permeability and organic content. Soil stability, density requirements, and other geotechnical considerations associated with soil compaction must be reviewed by a qualified, licensed geotechnical, civil or other professional engineer.

[4] Order No. R9-2007-0001, Pg19. Section: D.1.d.(4)(b)iv.

2.2.5. Drain Runoff from Impervious Surfaces to Pervious Areas[5]



When planning for stormwater management and designing the project to meet stormwater requirements, the permeability of the project site should be retained or improved. Projects planned with landscaped areas or other pervious areas (lawns) are required to be designed and constructed to receive stormwater runoff (from rooftops, parking lots, sidewalks, walkways, patios, etc.)[5]. These pervious areas help slow, retain, filter, and treat runoff in the first few inches of the soil before discharging into the municipal stormwater system. In rural situations these pervious areas should be designed to infiltrate and/or percolate stormwater on site where appropriate. In areas that have stormwater infrastructure, pervious areas must receive runoff before it drains into the municipal stormwater system. As required, the amount of runoff directed from impervious areas shall correspond with the pervious area's capacity to treat that runoff[5]. When directly infiltrating into the ground using pure infiltration BMPs (infiltration trench, infiltration basin, dry wells, permeable pavements without an under-drain) the soil conditions, slope and other pertinent factors must be addressed by a qualified licensed geotechnical, civil or professional engineer.

Urban and infill developments may have limited opportunities to maximize permeability, in which case LID techniques such as the application of permeable pavements, vegetated roofs/modules/walls, raised sidewalks, street trees, etc., may be more appropriate.

LID techniques for stormwater infiltration and/or filtration attempt to work with land uses and natural land features to become a major design element of the development plan. By applying LID techniques early in the site plan development, these stormwater techniques can be utilized more efficiently. When applying LID strategies in the stormwater management plan and the drainage plan, the project can include optimal pathway alignment, optimum locations for usable open space, pocket parks and play areas, and building sites. In this way, the stormwater management plan helps the project convey a

[5] Order No. R9-2007-0001, Pg19. Section: D.1.d.(4)(a)i., ii.

more aesthetically pleasing and integrated relationship to the natural features of the site and the project's surroundings. In redevelopment and other site-constrained projects where the opportunities for surface drainage and surface infiltration systems are limited, it may be possible to create underground storage systems to promote retention and/or slow infiltration (e.g. permeable pavements, recharge bed, etc.) prior to releasing runoff into the municipal stormwater system.

Important Note: Proposed stormwater "Infiltration BMPs", including permeable pavements, shall be reviewed by a qualified, licensed professional to provide a professional opinion regarding the potential adverse geotechnical conditions created by the implementation of the plans. Geotechnical conditions such as slope stability, expansive soils, compressible soils, seepage, groundwater, and loss of foundation or pavement subgrade strength should be addressed, and where appropriate, mitigation recommendations should be provided. The impact on existing, proposed, and future improvements should be included in the review.

Mission Valley Library Photograph Courtesy of C.Sloan

2.3. LID Site Design Examples

LID site designs use planning and design strategies to reduce the quantity and improve the quality of stormwater from new development and redevelopment. LID site design attempts to mimic the site's pre-developed (natural) hydrologic function. Site techniques involve reducing impervious surfaces, disconnecting impervious surfaces from storm drains and other impervious surfaces to allow natural infiltration and treatment of stormwater runoff, increasing opportunities for infiltration and conveyance through vegetated and landscaped features near roads and structures, reducing soil compaction during development, reducing road and driveway widths in exchange for additional landscaping and green space, protecting sensitive natural areas, habitats and important drainages, and linking greenways, parks, wilderness, and conservation land.

In addition to laying out LID planning concepts, this section also provides guidance on how LID water quality goals can be addressed within the three basic types of land use development: Residential, Commercial, and Industrial.

The site planning principles and design concepts described in the following pages are integrated in a series of design examples based on topography and land use. The design examples are illustrative only. They are not intended to be hard and fast requirements for all development but instead examples of LID solutions which can be employed. They show an approach to site planning and design that integrates stormwater management as an organizing element. Real sites and real projects will require various combinations and engineering ingenuity to suit unique conditions.

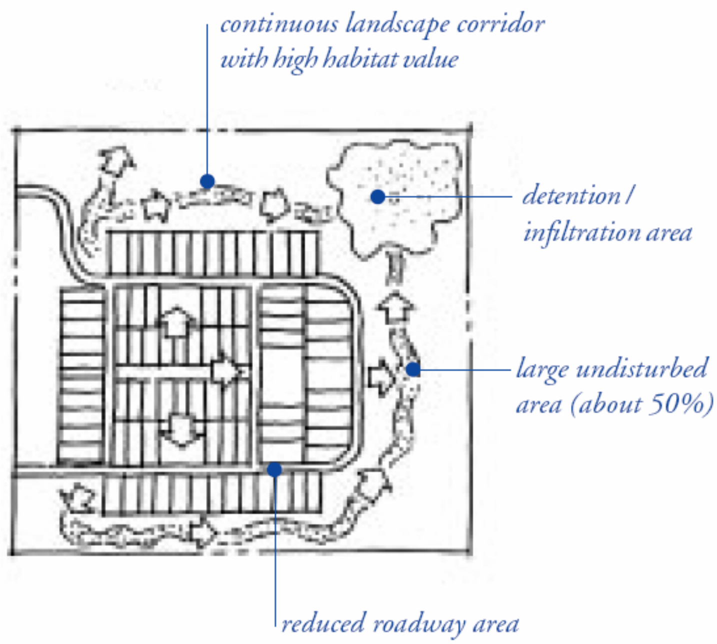

Photograph Courtesy of EOA, Inc.

As shown here, a "treatment train" approach should be used to provide multiple opportunities for stormwater treatment to maximize the effectiveness of LID design. This multi-technique approach will increase temporary storage and retention of stormwater during short intense storms, as well as increase filtration, infiltration, percolation, and recharge to ensure water quality standards [13]. Using multiple LID techniques will decrease the need for additional traditional stormwater control methods, and help stormwater to be naturally treated through filtration, infiltration, and percolation (in compliance with the Hydrology Manual). For example, a site can be designed by combining LID methods such as implementing a grass swale with permeable pavers as overflow areas and a landscaped bioretention cell. The following pages show examples of sites utilizing a “treatment train” approach to LID site-specific design.

Site planning is a complex and demanding process. Proper planning will involve balancing IMP needs with site constraints as well as other development concerns. To be successful, a new development must meet marketing, economic, regulatory, engineering, environmental, construction, and design criteria. The following design examples attempt to show that by recognizing stormwater as a resource, and making it a primary consideration in site design, communities can be built to reward the investment, enhance the natural environment, and create an ideal place for people to live and work.

2.3.1. Residential

2.3.1.1. Clustered Low-Density Residential Design

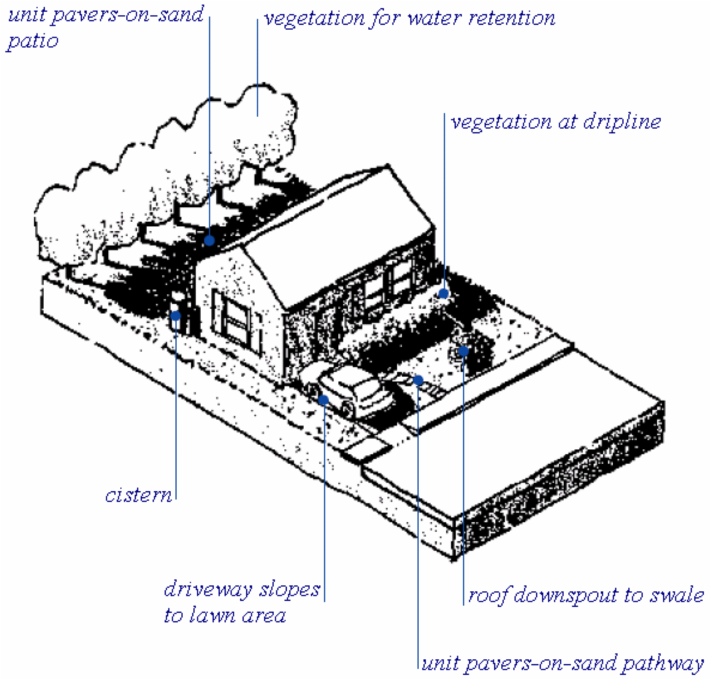


Cluster development, a site planning technique in use for several decades, considers not only individual lots, but larger site boundaries. It concentrates development on one portion of a site, and maintains more of the site in open space. Cluster designs include strategies such as smaller lot sizes, reduced setbacks and frontages, alternative street layouts to reduce road networks (see Appendix 4, Fact Sheet 14), and alternative driveway, sidewalk, and bike path designs (see Appendix 4, Fact Sheet 24). When choosing the development envelope for a site, features such as drainages and creeks, sensitive habitat areas, steep slopes, and highly erosive or permeable soils should be protected.

A focal point of clustered development is to reduce the actual footprint of the development project and the footprint of the roadway network internal to the project. Clustered development can provide increased area for passive recreation, when usable open space is concentrated in a public or semi-public place, rather than divided in many large, private yards. However, clustered developments can face resistance in the marketplace, because home buyers sometimes prefer the larger lot sizes and wider streets of conventional development patterns. Rural communities may also resist clustered development because they appear as an unconventional development pattern which differs from the large conventional rural lot pattern. Watershed education and clustered development benefits must be clearly communicated as a benefit to the community. Clustered development should include appropriate landscaping (native/Xeriscape) in order to blend with the surrounding environment. These landscaping areas can also be used in conjunction with LID treatment solutions.

In a watershed plan that employs clustered, dense development to preserve open space, on-site treatment in the more densely developed portion of the watershed may not be necessary. Dense or clustered development allows for significant areas to be preserved and remain undeveloped, reducing the need to mitigate throughout the entire watershed.

2.3.1.2. Single Residential Lot



A single-family residential lot may provide significant opportunities for stormwater management. Because they occur at the garden level, LID solutions can add aesthetic richness that will directly benefit the project and the surrounding community. When the ratio of impervious cover relative to land area is low, landscape area can accommodate a variety of subtle filtration strategies. Stormwater management techniques can also provide habitat for wildlife, create shade, improve character, provide supplemental irrigation water, and promote growth of landscape planting. When planning a subdivision of small single family lots, the determination of whether lot-by-lot LID infiltration solutions are appropriate must be carefully weighed. Consider all physical, engineering, geotechnical and public health and safety constraints as well as the long term maintenance and practicality of approaching infiltration at this level. Conserving natural resources, disconnecting impervious surfaces by pitching driveways towards yards and allowing roof runoff to run over the lawn before entering the stormdrain, are infiltration techniques more appropriate for subdivision planning.

Homeowner education is a crucial component of successful stormwater management techniques at all levels, but especially at the single lot scale. Residents need to be educated on the purpose, operation, and proper care of various design elements, particularly those requiring routine maintenance like cisterns which must periodically be emptied and cleaned. If drywells are used, residents must also understand that they are for rainwater only – never as a place to dump oil, pesticides, paint thinner, solvents, degreasers, household cleaners or other unwanted wastes.

The techniques for this type of development might include:

- Unit pavers-on-sand patio
- Not directly connected impervious driveway
- Unit pavers-on-sand pathway
- Roof downspout to swale
- Vegetation for water retention (deep rooted trees)
- Herbaceous vegetation at dripline of roof

2.3.1.3. Multi-Family Residential Site

Photograph Courtesy of EOA, Inc.

In urban areas, many of the sites for new construction are infill or redevelopment sites. These sites usually have higher densities (typically from 12 to 100 units per acre) which demand a greater proportion of pavement and roof coverage.

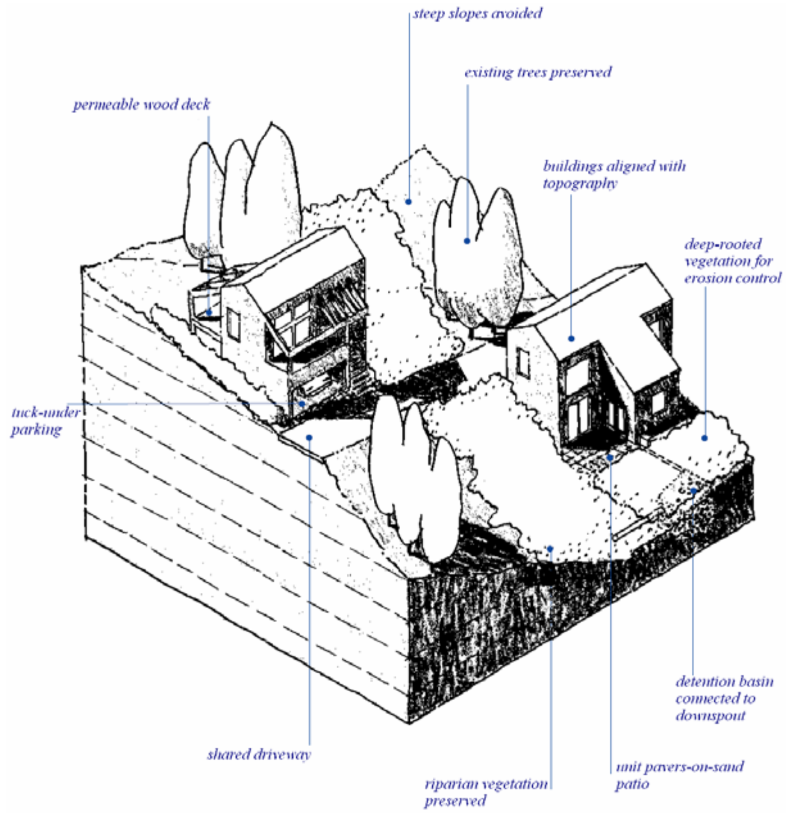
Opportunities for on-site stormwater management still exist, even in the most densely developed infill site, though they will require greater creativity or multiple use of space. For instance, an underground/under pavement storage reservoir may be created to promote filtration and stormwater storage prior to release into the municipal stormwater system.

Urban high rise densities often result in the entire site being covered by buildings with a minimal amount of landscaping. Although these sites present limited opportunities to incorporate LID solutions, they are a highly efficient way to develop land and reduce pressure on rural and undeveloped land. By allowing high density in urban cores (often referred to as Smart Growth), rural lands can be preserved more effectively allowing a watershed benefit by reducing impacts to water quality and encouraging groundwater recharge and habitat conservation.

The techniques illustrated in this example are:

- Not directly connected impervious driveway (pitched to lawn)
- Turf block fire access road (with fire sign)
- Multiuse lawn play area, fire access, and biofiltration
- Roof downspout to landscaping
- Rain harvesting
- Vegetation for water retention (deep rooted trees)
- Herbaceous vegetation at dripline of roof

2.3.1.4. Residential Hillside Site



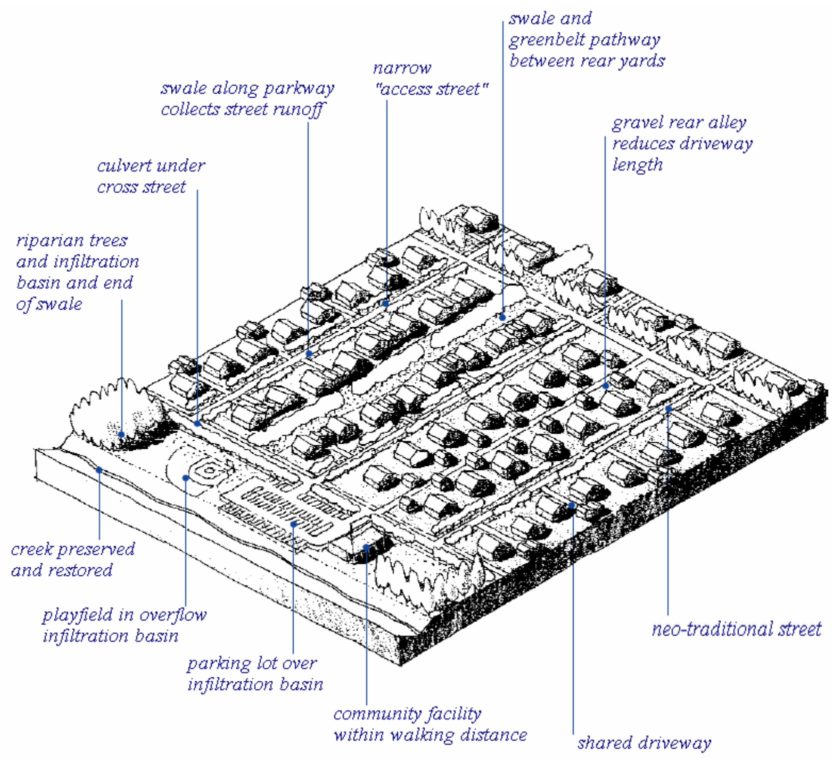
Hillside sites, large and small, present particular challenges for stormwater management. Because slopes are often pronounced, some infiltration strategies that are best suited to more level sites, such as dry wells, infiltration basins, or trenches, are impractical and can cause landslides or severe damage. Erosion must be prevented through siting with contours to reduce grading and careful stabilization of disturbed slopes. Finally, drainage systems, pure infiltration techniques and detention devices must be located so that water does not compromise the integrity of building foundations and other structures.

The techniques illustrated in this example are:

- Avoidance of steep slopes
- Buildings aligned with topography to reduce grading
- Preservation of existing trees and indigenous vegetation
- Preservation of riparian vegetation (drainages with native plants/soils)
- Deep rooted vegetation for erosion control
- Narrow rural roads
- Shared driveway
- Combination parking and driveway area
- Tuck-under parking utilizing pervious materials
- Permeable wood deck for outdoor use area
- Unit pavers-on-sand patio (with qualified, licensed professional's approval)
- Detention basin connected to roof downspout (down slope from building)
- Swale with check dams flows to creek

2.3.1.5. Large Residential Flat Site

Larger flat sites present some of the greatest opportunities for stormwater management. If soils have adequate percolation rates, infiltration swales and basins are easily incorporated. In more poorly drained soils, flat sites allow for detention and retention systems to slow the speed of runoff and hold it for later release. This allows sediments to settle and minimizes stream bank erosion from high velocity flows, meeting important hydro-modification objectives.



This example applies the site planning and design principles discussed earlier at the neighborhood scale. For the purposes of illustration, two different street access systems are shown: driveways from the street or rear alley access. Each has different planning implications, but both can be integrated with appropriate stormwater management.

Each cluster of buildings could also contain the finer grain elements like those illustrated for the small single lot, large single lot and infill site.

The techniques illustrated in this example are:

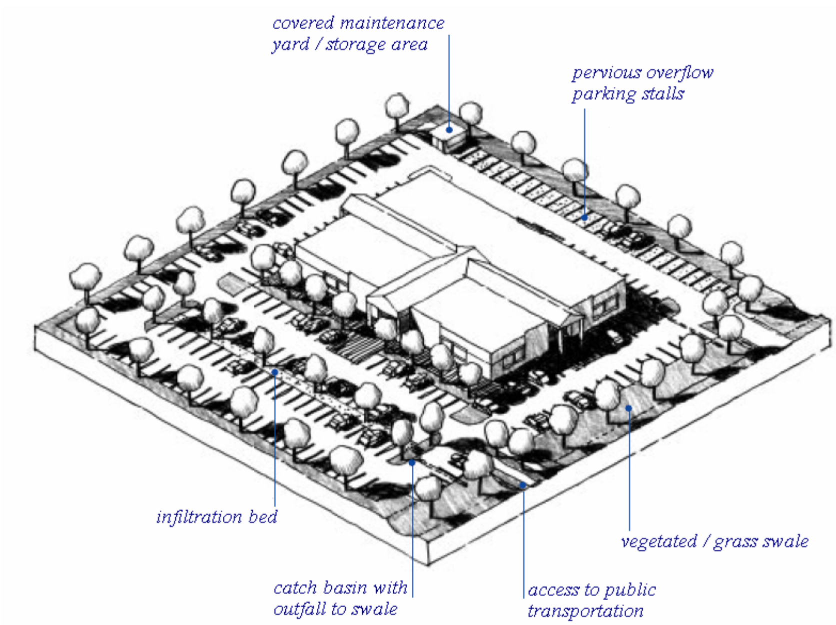
- Minimal street widths
- Permeable rear alley & shared driveways to reduce pavement
- Community facility within walking distance
- Parking lot over infiltration basin[1]
- Depressed playfield with multiple use as infiltration basin[1]
- Swale along parkway collects street runoff (with appropriate slopes)
- Culvert to carry parkway swale under cross street
- Trees and infiltration basin at end of swale[1]
- Swale and greenbelt pathway between rear yards

[1] Technique requires Qualified, licensed professional's approval.

2.3.2. Commercial

2.3.2.1. Commercial Shopping Center

Shopping centers present many opportunities for stormwater management, especially in the parking areas. Infiltration swales and extended dry detention basins can be incorporated into space between parking aisles. Recognizing that much of the parking is only necessary during peak times, such as the holiday season, a proportion of outlying stalls may be paved with permeable materials.



The utility functions inherent in any shopping center also need attention, such as restaurant wash-down areas, trash collection areas, and service yards. These outdoor work areas require specific techniques to prevent polluted runoff from entering the storm drain system or local water bodies. Similarly, potential hazardous materials use within the shopping center, i.e. dry cleaning establishments, requires special attention and treatment. Finally, trash and other storage areas can be properly designed and constructed to prevent pollutants from running off these areas into the storm drain system.

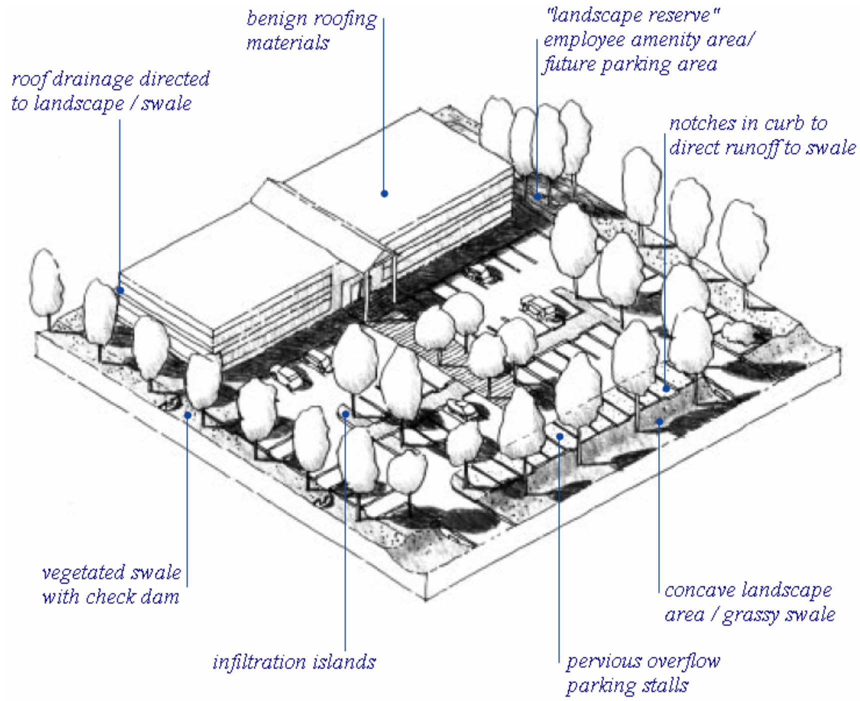
If well designed, correctly installed, and properly maintained, stormwater management techniques can enhance the aesthetic character of a shopping center and improve its marketability.

The techniques illustrated in this example are:

- Vegetated/rock swale along perimeter
- Infiltration bed to divide parking aisles[1]
- Permeable pavement parking stalls[1]
- Notched curb to direct runoff from parking area into swale
- Catch basin runoff directed to infiltration area[1]
- Covered maintenance yard/service areas
- Rain harvesting

[1] Technique requires Qualified, licensed professional's approval.

2.3.2.2. Commercial Office buildings



Office buildings can integrate stormwater management techniques in many ways.

Landscape areas for employee use and perimeter screening can be designed as extended dry detention basins or biofilters (swales) to infiltrate and detain runoff, while drying up shortly after a rain event. These areas can also be designed as fountains or entry statements to add aesthetic enhancement.

Parking can be treated in a variety of ways with the use of permeable materials. Impervious parking stalls can be designed to drain onto landscape infiltration areas.

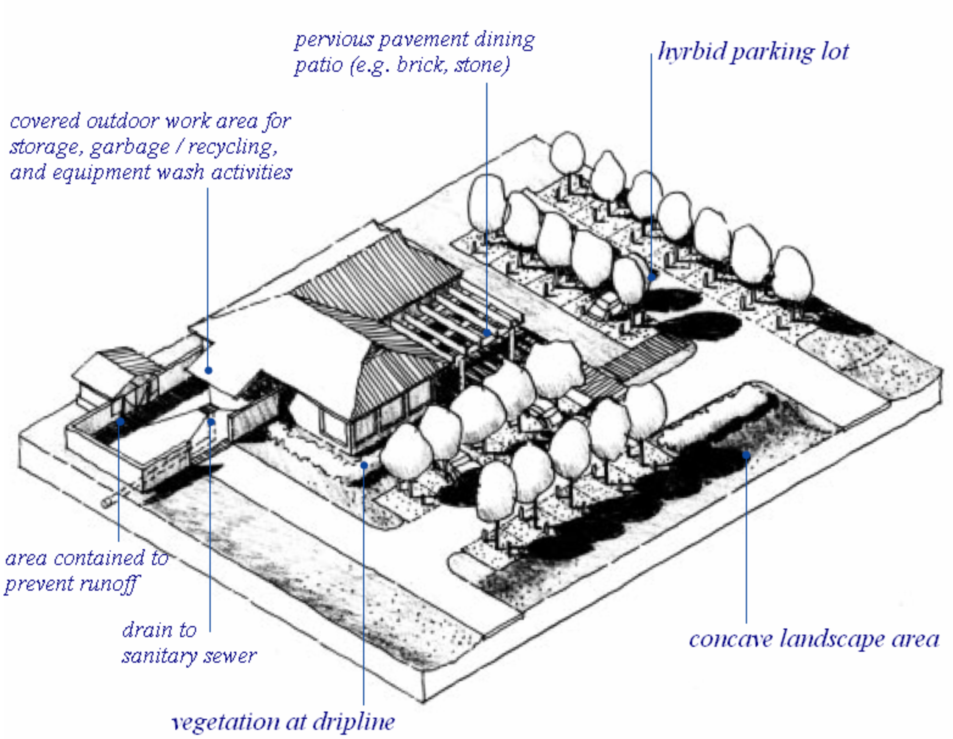
A portion of the required parking may be allowed to be held in "landscape reserve," until a need for the full parking supply is established. This means that the original construction only builds parking to meet anticipated staff needs. If the parking demand increases, the area held in landscape reserve can be modified to accommodate parking. In this way, parking is held to a minimum based on actual use, rather than by a zoning formula that may not apply to the office building's actual parking need.

The techniques illustrated in this example are:

- Catch basin runoff directed to infiltration area[1]
- Vegetated swale with check dams
- Landscaped "parking reserve"
- Concave landscape areas to infiltrate runoff[1]
- Pervious overflow parking stalls[1]
- Roof drainage directed to landscape
- Rain harvesting

[1] Technique requires Qualified, licensed professional's approval.

2.3.2.3. Commercial Restaurant



Restaurants offer a strong contrast between infiltration opportunities and special activity areas. Careful selection of materials such as brick or stone paving for outdoor patios can enhance the restaurant's aesthetic appeal while allowing for infiltration as appropriate. Landscape plantings can also be selected for stormwater infiltration.

Parking can be provided in a variety of ways, with hybrid parking lots for staff, who stay for long shifts, or with landscaped infiltration islands in lots with conventional paving for patrons, who stay for shorter periods.

In contrast to these infiltration opportunities, restaurants have special activity areas that need to be isolated from the storm drain system. Grease, stored items, trash, and other food waste must be kept in properly designed and maintained special activity areas. Local ordinances may have design guidelines for allowable square footage of covered and uncovered areas.

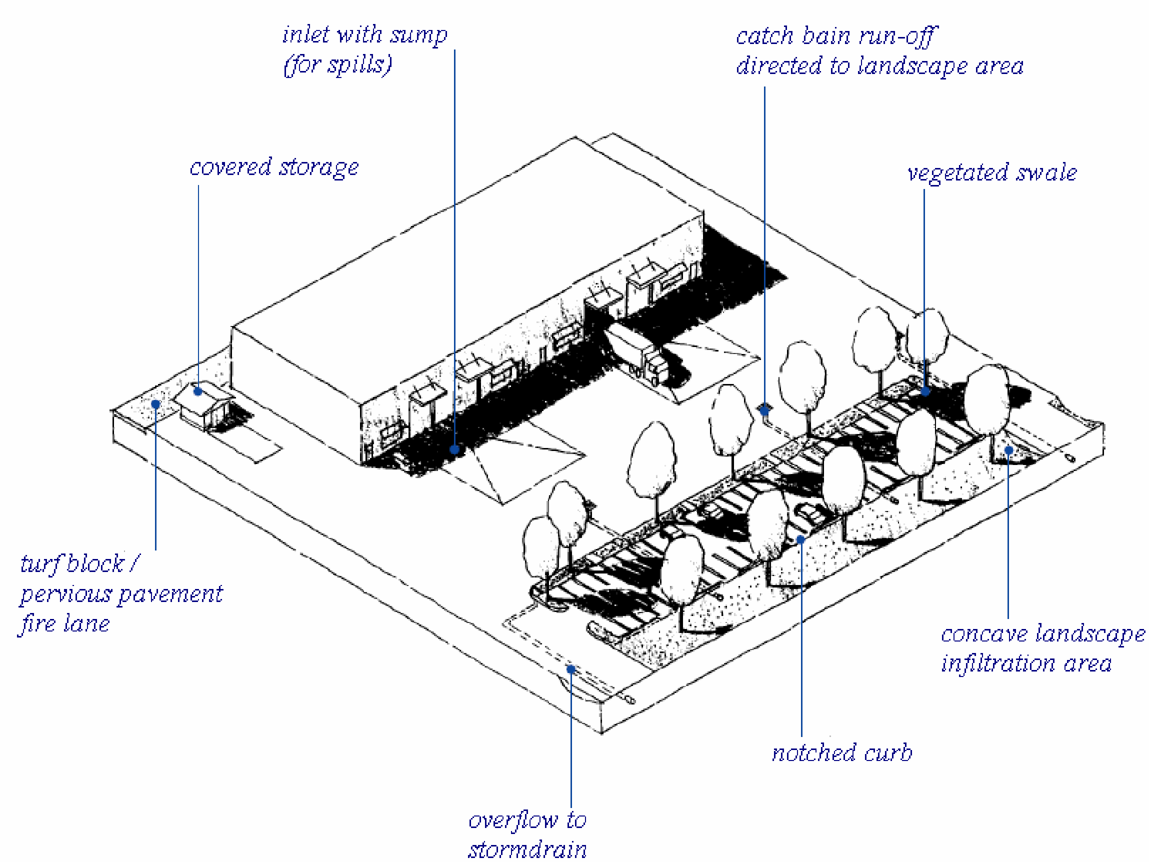
The techniques illustrated in this example are:

- Permeable pavement patio[1]
- Catch basin runoff directed to infiltration area[1]
- Hybrid parking lot
- Vegetation at drip line
- Concave landscape areas to infiltrate runoff[1]
- Rain harvesting
- Covered outdoor work area (trash, food waste, storage, equipment wash)

[1] Technique requires Qualified, licensed professional's approval.

2.3.3. Industrial

2.3.3.1. Industrial Park



Industrial parks present special challenges when designing for stormwater management. They usually require large paved areas for truck access and employee parking, and space is usually limited. They also often have chemical storage and other special activity areas that require that infiltration techniques are avoided.

Still, there are opportunities to incorporate design details to protect stormwater quality. These include minimizing impervious surface area through the use of permeable pavements, infiltration areas to collect runoff, and proper treatment of special activity areas.

The techniques illustrated in this example are:

- Vegetated/rock swale along perimeter
- Catch basin runoff directed to infiltration area[1]
- Permeable pavement fire lane
- Notched curb to direct runoff from parking area into swale
- Rain harvesting
- Proper loading dock design
- Covered maintenance yard/service areas

[1] Technique requires Qualified, licensed professional's approval.

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Section 3 Integrated Management Practices

A variety of Low Impact Development (LID) design concepts and specific engineering solutions are presented in this chapter and are further detailed as Fact Sheets in Appendix 4. Each Fact Sheet illustrates an approach to design and construction of developed areas for increasing stormwater infiltration, providing stormwater retention, slowing runoff, and/or reducing impervious developed areas. The techniques presented here are not all-inclusive, and are not appropriate for every site or condition, but it is anticipated that, once the intent and utility of these design concepts and engineering solutions are understood, planners and designers will use their ingenuity to develop the appropriate “treatment train” of LID strategies consistent with water quality goals.

The various categories or types of development listed in Section 2 present unique challenges which make certain LID solutions appropriate for some types of development but not for others. For example, permeable pavement may be an effective and appropriate solution for a low-rise office building, however, in a high-rise residential or office building with virtually no part of the site left undeveloped and with parking provided underground, permeable pavement would not be an effective or appropriate solution. Additionally, downstream conditions on neighboring properties, manufactured slopes, the location of structures and utilities among many other design aspects of a project will present unique challenges for designers and engineers and may make what are otherwise effective LID solutions inappropriate for the specific site. ***All LID “infiltration BMPs” proposed for a specific project shall be reviewed and approved for use in the project by the project’s geotechnical engineer, civil engineer, or other qualified licensed professional to avoid the potential for slope failure, water seepage or migration under structures or on to neighboring property, conflicts with underground utilities, or other potential conflicts with engineering and design objectives. Project plans must be designed in accordance with local zoning regulations, ordinances, and community plans.***

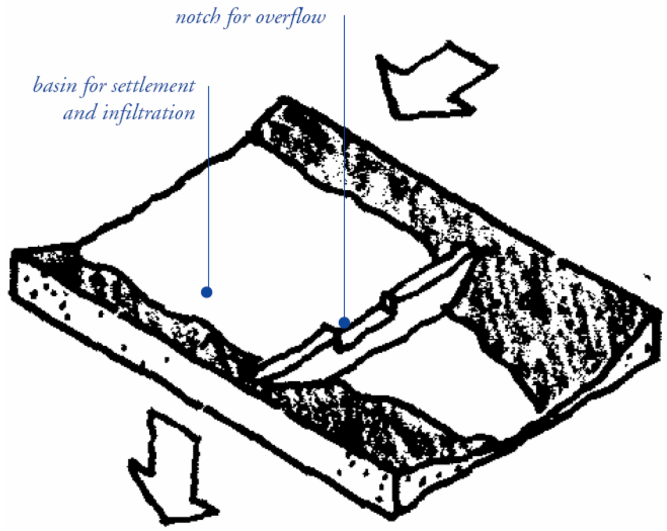
Before specific LID solutions can be developed for a particular project, the project designer must determine the appropriate development category for the project (e.g., multifamily residential). Once the designer has determined the appropriate development category for the project a multitude of specific design considerations must be taken into account when determining the project’s runoff and hydrology conditions. These design considerations include grading and the creation of slopes, selection of paving materials, collection and channeling of roof, driveway, parking, and road surface runoff, grading, soil conditions and the creation of slopes, and many other design aspects of the project.

The individual design aspect of a project may make little difference to the overall hydrological characteristics of the project, but taken together, these design aspects create significant changes to the natural hydrology of the project site and, likewise, significant challenges in meeting stormwater quality goals. Consistent with the concept of starting at the source, a combination of individual LID solutions may be required for a particular project which taken collectively effectively mitigate the project’s water quality impacts.

3.1. Hydrologic Design

Drainage systems can achieve stormwater management goals by using one of three basic elements: infiltration, retention/detention, and biofiltration. These elements can be implemented either alone or in combination, depending on site and other conditions.

3.1.1. Infiltration



Infiltration is the process where water enters the ground and moves downward through the unsaturated soil zone. Infiltration is ideal for management and conservation of runoff because it filters pollutants through the soil and restores natural flows to groundwater and downstream water bodies. Attenuating flow through infiltration, while allowing evaporation and evapotranspiration is an effective stormwater management practice in blocking the transport of pollutants to receiving waters. An infiltration system is designed to match pre-development condition infiltration rates and to infiltrate the majority of runoff from small storms into the soil rather than discharging it into a surface water body. Infiltration basins can range from a single shallow depression in a lawn, to an integrated swale, pond, and underground storage basin network.

Site soil conditions generally determine if infiltration is feasible. In Soil Groups A and B (see Appendix 3, Section B.1) infiltration is usually acceptable, but it is severely limited in Soil Groups C and D. It is also limited where high groundwater, steep slopes, or shallow bedrock is present. The base of an infiltration system must have a vertical distance of at least 10 feet from the seasonal high groundwater mark (water table). Infiltration is also not appropriate in or directly above manufactured slopes, where infiltrated flows could cause slope failures, near building foundations, or where downstream neighboring properties would be adversely affected.

Infiltration basins can be either open or closed. Open infiltration basins, which include ponds, swales, and other landscape features, are usually vegetated – the vegetation maintains the porous soil structure, reduces erosion, and utilizes water through evapotranspiration. In arid regions, Xeriscaped rock-lined basins are common. Closed infiltration basins can be constructed under the land surface with open graded crushed stone, leaving the surface to be used for parking or other uses (see Fact Sheet 11). Subsurface, closed basins are generally more difficult to maintain and more expensive than surface systems, and are used primarily where high land costs demand that the land surface be used for economic use.

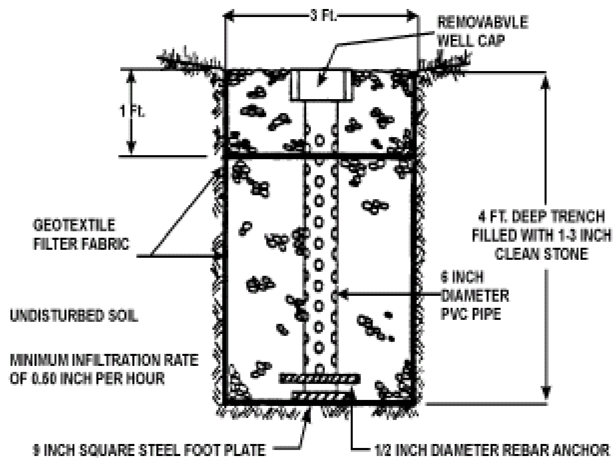
Other design considerations include clogging that may occur in very fine or poorly drained soils and impacts on slope stability if located uphill from hillside sites. Infiltration basins are best installed at the end of construction, after the site is fully stabilized. If possible, flows should be bypassed until the site is stabilized, as construction-related runoff may contain a high proportion of silts that can clog the basin floor.

Infiltration systems have been used by CALTRANS and local jurisdictions in California for about three decades [25], though heavy clay soils sometimes limit their local application. The basic design goal of infiltration systems is to provide opportunities for rainwater to enter the soil. This is generally accomplished by retarding the flow of runoff, and by bringing it into contact with the soil, either by holding it in ponds or subsurface reservoirs or moving it slowly along the ground surface. Infiltration basins are most economical if placed near the source of runoff, but they should be avoided on steep, unstable slopes, near building foundations, within 100 feet of water wells, or other structures.

Infiltration Practices are discussed below:

3.1.1.1. Infiltration Trench

Infiltration trenches temporarily hold stormwater runoff within a sub-surface trench prior to infiltration into the surrounding soils. An infiltration trench is similar in function to an infiltration basin except that an infiltration basin's stored volume is held above ground, while an infiltration trench's stored volume is held below ground.



For more information on Infiltration Trenches please see **Fact Sheet 1** in Appendix 4.

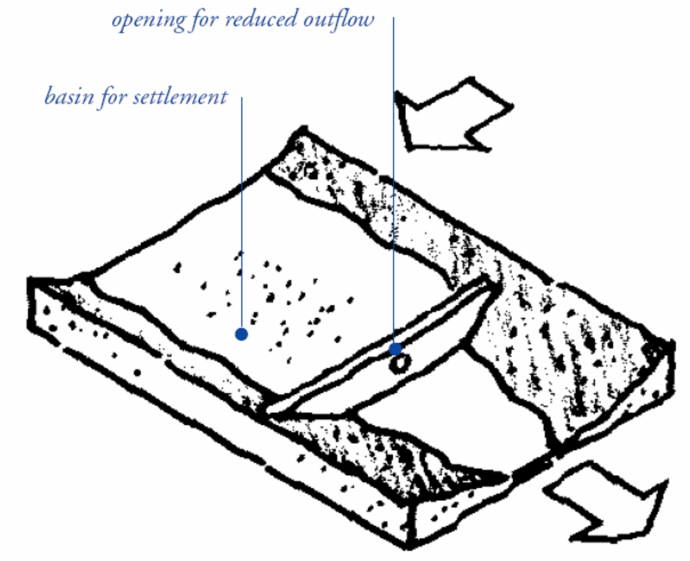
3.1.1.2. Infiltration Basin

Infiltration basins are sited in either natural or excavated open areas and are designed to temporarily hold stormwater runoff prior to evaporation and infiltration through the basin floor. They are similar in function to infiltration trenches except that an infiltration basin's stored volume is held above ground, while an infiltration trench's stored volume is held below ground.

Photograph: City of Encinitas, Detention/Infiltration Area

For more information on Infiltration Basins please see **Fact Sheet 2** in Appendix 4.

3.1.2. Retention and Detention



Retention and detention systems differ from infiltration systems primarily in intent. While infiltration systems are intended to percolate water into the soil, retention and detention systems are designed primarily to store runoff for gradual release or reuse. Detention systems store runoff for up to 72 hours after a storm and are dry until the next storm event. Detention facilities provide pollutant removal by temporarily capturing runoff and allowing particulate matter to settle prior to release to surface waters. Retention facilities are used to capture runoff, which is subsequently withdrawn or evaporated [13]. Properly designed retention and detention systems release runoff slowly enough to reduce downstream peak flows to their pre-development levels, allow fine sediments to settle, and uptake dissolved nutrients in the runoff where vegetation is included. Retention and detention systems are most appropriate for areas where water percolates poorly through the soil.

Detention and retention facilities and other practices that temporarily store runoff also evaporate it and allow for plant evapotranspiration. Evaporation from runoff detention and retention areas, including rooftops, streets, basins, and ponds can be an important mechanism for runoff management within San Diego's warm, dry climate [13].

Outlets of detention systems may clog easily if not properly designed and maintained. Retention system outlets must both maintain the permanent pool and release the remainder of runoff at a controlled rate during each storm. Common outlet designs are orifices, perforated risers, and V-notch weirs, with an emergency spillway provided to safely convey storms larger than the stormwater quality design storm [11].

3.1.2.1. Extended Detention (dry) Ponds

Photograph: City of Encinitas, Volleyball Court/ Detention Area

Extended detention (dry) ponds can be used for both pollutant removal and flood control. These ponds store water during storms anywhere from a day 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. Most importantly, detention basin side slopes should be constructed at 3:1 or flatter. This prevents people from accidentally falling into deep water.

For more information on Dry Ponds please see **Fact Sheet 3** in Appendix 4.

3.1.3. Biofilters

Biofilters can include rock and vegetated swales, filter strips or buffers, sand filters, and bioretention. Biofilters are effective if flows are slow and depths are shallow. Shallow and low-velocity flows are generally achieved by grading the site and sloping pavement in a way that promotes sheet flow of runoff. The slow movement of runoff through vegetation provides an opportunity for sediments and particulates to be filtered and degraded through biological activity [25]. In draining soils, the biofilter also provides an opportunity for stormwater infiltration, which further removes pollutants and reduces runoff volumes. Furthermore, biofiltration devices can be designed with soil amendments to allow for some flow attenuation.

Photograph Courtesy of EOA, Inc.

Slow, shallow sheet flow is maintained in the biofilter by constructing it with gently sloping sides based on slope stability. The key concept is to move water slowly through the vegetation at a shallow depth for a minimum critical time. Biofilters should be vegetated (and/or rock-lined) with appropriate plant material such as Xeriscape plants and/or salt grass to match the climatic/soil conditions and relevant landscaping requirements. In the dry arid regions of the County, rock swales and Xeriscaping are appropriate to meet State water conservation goals.

Biofilters are especially applicable to parking lots, parkways, and along highways as the long aisles can be sloped into linear grass or rock swales to collect and treat runoff from pavement surfaces. Adjacent pavement elevations should be set slightly higher than the adjacent biofilter. If water enters at concentrated points, as opposed to sheet flow, erosion control should be included at inlets and outlets [26].

3.1.3.1. Vegetated Swales / Rock Swales

Photograph Courtesy of EOA, Inc.

Vegetated or rock swales can be a particularly effective design strategy in large conventionally paved parking lots. Parking lot drainage can be integrated with landscaping to provide filtration, evaporation, infiltration and detention of stormwater. Swales provide low maintenance and act as linear biofilters along the perimeter of the lot or along internal islands. Stormwater is directed to these linear landscaped spaces and travels slowly over rocks and vegetated surfaces, allowing pollutants to settle and slow runoff velocities. Check dams or gravel weirs can also be added to swales to further slow and spread concentrated flows.

For more information on Swales please see **<u>Fact Sheet 4</u>** in Appendix 4.

3.1.3.2. Vegetated Filter Strips

Filter strips are areas of either planted or native vegetation, situated between a potential, pollutant-source area and a surface-water body that receives runoff. The term 'buffer strip' is sometimes used interchangeably with filter strip. Vegetated filter strips are broad sloped open vegetated areas that accept shallow runoff from surrounding areas as distributed or sheet flow.

For more information on Vegetated Filter Strips please see **<u>Fact Sheet 5</u>** in Appendix 4.

3.1.3.3. Sand Filters

Sand filters have proven effective in removing several common pollutants from storm water runoff. Sand filters generally control storm water quality, providing very limited flow rate control [27]. The purpose of sand filters is to manage the first flush, which typically contains the highest concentration of pollutants.

For more information on Sand Filters please see **<u>Fact Sheet 6</u>** in Appendix 4.

3.1.3.4. Bioretention

Bioretention systems are essentially a surface and sub-surface water filtration system. In function they are similar to sand filters. However, whereas sand filters provide water quality treatment via passage of stormwater through a sand medium, Bioretention systems incorporate both plants and underlying filter soils for removal of contaminants.

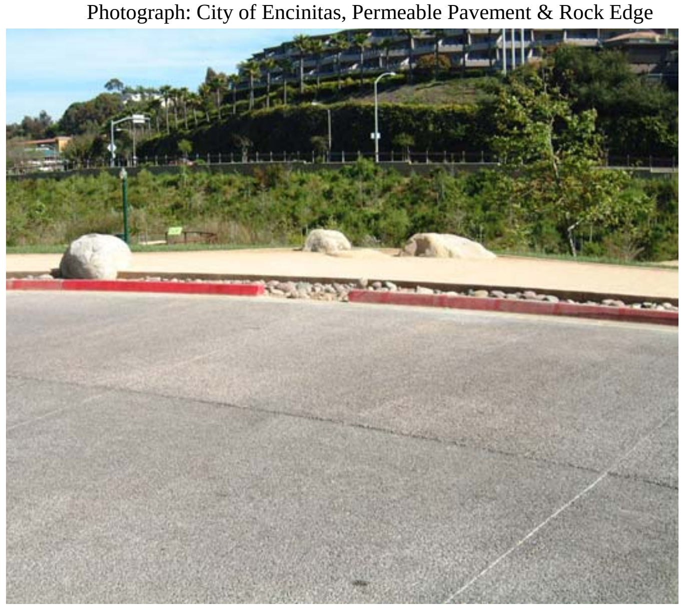
For more information on Bioretention please see **Fact Sheet 7** in Appendix 4.

Photograph Courtesy of EOA, Inc.

3.2. Permeable Pavement Design

Permeable pavements can be used for 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.

Photograph: City of Encinitas, Permeable Pavement & Rock Edge



There are four main categories of permeable pavements: poured in-place pervious concrete, permeable asphalt concrete, unit pavers, 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 [28].

- 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 pertains to applications subject to heavy vehicle loads, but is also important for large areas where settling could result in unwanted puddling on surfaces such as pedestrian walkways.

When used properly, permeable pavement can facilitate biodegradation of the oils from cars and trucks, help rainwater infiltrate soil, decrease urban heating, replenish groundwater, allow tree roots to breathe, and reduce total runoff [29].

Pervious concrete and permeable 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 permeable Asphaltic Concrete share similar design considerations.

Conventional 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 pervious areas instead of into directly-connected collection structures will reduce their negative impact on water resources.

3.2.1. 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 has a surface-void content of 15-25%, allowing water and air to pass through the pavement.

Pervious concrete, like other concretes, acts as a rigid slab. It has an open, rough appearance and provides a walking or riding surface similar to aggregate concrete. 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 [30]. Because of its porosity, pervious concrete pavements usually do not require curbs and gutters for primary drainage control.

Pervious concrete may be suitable for light to medium duty applications such as residential access roads, residential street parking lanes, parking lots, overflow parking areas, utility access, sidewalks, bike paths, maintenance walkways/trails, residential driveways, stopping lanes on divided highways, and patios.

For more information on Pervious Concrete please see **Fact Sheet 8** in Appendix 4.

3.2.2. Permeable Asphalt Concrete (AC)

Permeable AC consists of an open-graded asphalt concrete over an open-graded aggregate base, over a draining soil. Unlike traditional asphalt concretes, permeable AC contains very little fine aggregate (dust or sand), and is comprised almost entirely of stone aggregate and asphalt binder. Without fine sediment filling the voids between larger particles, permeable AC has a void content of 12-20% which makes it very permeable.

In installations where permeable AC has been used over a permeable base, the pavement becomes an infiltration system which allows water to pass through the surface and collect in the open-graded aggregate base. This will achieve stormwater management without curb or gutter systems. In these sites which mostly consist of parking lots and light duty roads in the eastern United States, permeability has been maintained over long periods without special maintenance. On light duty streets built of permeable AC, 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 [31]. Permeable AC is widely 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 [32]

Permeable AC may be suitable for light to medium duty applications such as residential access roads, residential street parking lanes, parking lots, overflow parking areas, utility access, sidewalks, bike paths, maintenance walkways/trails, residential driveways, stopping lanes on divided highways, and patios. Permeable AC has also been used in heavy application such as airport runways and highways because its porosity creates a favorable driving surface in rainy weather [32]. It increases vehicle capacity of the highways without the expense of widening. As such, interstate highways in Georgia and Oregon have been repaved with permeable AC for safety reasons. Permeable AC allows better drainage, traction, and visibility [29].

For more information on Permeable AC please see **Fact Sheet 9** in Appendix 4.

3.2.3. Permeable Pavers

Permeable pavers are an alternative to conventional pavement and can create an opportunity for infiltration of stormwater runoff and groundwater recharge. For areas that are not heavily trafficked, permeable pavers are also an alternative to conventional asphalt and concrete. Permeable pavers are modular systems with pervious openings that allow water to seep through. Runoff that permeates through is either detained in an underlying gravel bed, infiltrated into the underlying soil, or both. Types of permeable pavers include open-celled unit pavers or modular blocks made of concrete or brick with pervious openings.

Open-celled unit pavers are pre-assembled, flexible plastic grid networks that utilize soil and turf/salt grass or gravel backfill to fill the blocks and create a flat surface. 3.2.3.1 demonstrates one type of open-celled unit paver. The grid systems have a solid support structure surrounding an open cell where the grass or gravel is placed. Some systems have hollow rings or honeycombs with a base, while others have open cells without bases. The plastic grids are flexible, allowing for use on uneven surfaces. These systems work well in overflow parking areas, driveways and sidewalks. Open-celled unit pavers can also be made out of concrete.

Concrete block pavers and brick pavers are designed to set on sand or fine gravel and form an interlocking pavement surface. Modular block pavers are designed to bear heavy loads and are well suited for industrial and commercial parking lots, utility access, residential access roads, driveways, and walkways.

For more information on Unit Pavers please see **Fact Sheet 10** in Appendix 4

3.2.3.1. Open Cell Unit Paver

Photograph Courtesy of EOA, Inc.

Open celled unit pavers are available in either precast concrete or plastic and are filled with soil and typically 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 [31].

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. Open-celled unit pavers can also be filled with alternatives to turf which includes either inert gravel or a lower maintenance groundcover such as chamomile. These alternatives can absorb some traffic and may be more appropriate to meet the State Water Conservation goals in San Diego. 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.

3.2.3.2. Brick Pavers

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. This increased to between 0.66 and 0.76

at intensities between 0.06 and 0.12 inches per half hour [31]. The larger the joints, the greater the permeability.

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 the last 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 the price.

3.2.3.3. Natural Stone Pavers

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 which makes an impervious pavement. Some natural stone materials, such as flagstone and granite, are available in thicker slabs suitable for placing 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 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.

3.2.3.4. Concrete Unit Pavers

Solid, pre-cast 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. A monitored demonstration site of Ecostone concrete pavers at the San Diego County Operations Center detected no runoff from the pavers during the 2005-2006 and 2006-2007 wet seasons.

For more information on Unit Pavers please see **Fact Sheet 10** in Appendix 4

3.2.4. Subsurface Reservoir Bed

In some cases parking lots can be designed to perform more complex stormwater management functions. Subsurface stormwater storage and/or 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 require 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 [31]. As emphasis on stormwater management increases, the economic viability of these solutions will increase.

Based on the infiltration rate of the underlying soils, additional storage may be required in the granular sub-base layer of a porous pavement section. The required storage may be based on a comparison of the rate of infiltration of the sub-soils and the design storm hydrograph. However, sites with low permeability soils (type D) may require underdrains and/or liners to prevent seepage from damaging existing structures or slopes. For further information on infiltration considerations, please see Appendix 3.G "LID Treatment BMPs Design Considerations".

For more information on Recharge Beds please see **Fact Sheet 11** in Appendix 4.

3.2.5. 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" [31].

If laid on a slope, and subjected to moderate traffic or concentrated runoff, loose gravel can be displaced and require periodic regrading. Weed abatement may be required periodically, though this can be reduced by laying permeable landscape fabric between the gravel and subgrade. Organic materials such as bark or wood chips decompose over time and must be replenished. Some mulches meet federal requirements for playground fall surfaces and can be inexpensive, permeable pavements for outdoor play areas. 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.

For more information on Granular Materials please see **Fact Sheet 12** in Appendix 4.

3.3. LID Road Design

GENERAL DESCRIPTION

Roads include a significant portion of impervious coverage in a community and are among of the largest contributors of stormwater flows and pollutant loads. LID road design is a strategy to reduce this impact by minimizing impervious coverage and maximizing stormwater infiltration and pollutant uptake.

Road Design Standards

More than any other single element, road design has a powerful impact on stormwater quality. Roads are at the nexus of a wide variety of land use and environmental issues. Considered a number of ways, the road is a large design element. In a typical neighborhood, the public right-of-way (i.e. the road or street) comprises approximately 20 to 25% of total land area, making it the single most important determinant of neighborhood character. Roads also can comprise up to 70% of a residential community's total impervious land coverage with the remainder of impervious land coverage coming from rooftops and other structures. This can make road design one of the greatest factors in a development's impact on stormwater quality. Roads are subject to municipal ordinances, standards, and management which allow local jurisdictions a great deal of control over their design. For these reasons, the road is one of the most important design elements in site planning and an element that can be most directly affected by local ordinances and policies.

Elements of LID Road Design:

- Road layout – Consider alternatives that reduce impervious coverage such as reducing the length of the road network by exploring alternative road layouts. Clustering homes and narrowing lot frontages can reduce road length by reducing the overall development area. Another approach is to lengthen street blocks and reduce cross roads by providing pedestrian and bicycle paths mid-block to increase access,
- Road width – Road width is a function of land use, density, road type, average daily traffic, traffic speeds, street layout, lot characteristics and parking, drainage, emergency access, and underground utilities.
- Cul-de-sac design – Cul-de-sacs create large areas of impervious coverage in neighborhoods. Alternatives to the traditional cul-de-sac can reduce impervious coverage. Examples of alternatives which reduce impervious surfaces are; a T-shaped hammerhead turnaround, standard radius cul-de-sac with landscaped center-island [33] for bioretention (see Section 3.3.6), grid street systems and a loop road network.
- Right-of-way – Reflect the minimum required to accommodate the travel lane, parking, sidewalk, and, if present, vegetation in right of ways.
- Permeable materials – Use permeable materials in alleys and on-street parking where feasible (less than 5% slope).

- Increased access – Create paths to open space and other opportunities for pedestrians and bicyclists in subdivisions where alternative street layouts such as loop networks and cul-de-sacs are utilized.
- Traffic calming features – Traffic circles, chicanes, chokers, and center islands, offer the opportunity for stormwater management through the use of bioretention areas or infiltration within these areas while providing pedestrian safety [34]. (For definitions and examples of chicanes and chokers, see "Traffic Calming: Roadway Design to Reduce Traffic Speeds and Volumes" [34])
- Drainage options:
  Maintain drainage – Preserve natural drainage patterns to the extent feasible and avoid locating streets in low areas or highly permeable soils.
  Uncurbed roads – Build uncurbed roads using vegetated swales where feasible.
  Urban curb/swale system – Runoff runs along a curb and enters a surface swale via a curb cut, instead of entering a catch basin to the storm drain system.
  Concave medians – Depress median below the adjacent pavement and design to receive runoff by curb inlets or sheet flow. This can be designed as a landscaped swale or a biofilter.

The overall objectives for LID road designs are:

- Reduce directly connected impervious area (DCIA) by reducing the overall road network coverage.
- Minimize or eliminate effective impervious area (EIA) and concentrated surface flows on impervious surfaces by reducing or eliminating hardened conveyance structures (pipes or curbs and gutters).
- Infiltrate and slowly convey storm flows in roadside bioretention cells and swales, and through permeable paving and aggregate storage systems under the pavement.
- Design the road network to reduce site disturbance, avoid sensitive areas, and reduce fragmentation of landscape.
- Create connected street patterns and open space areas to promote walking, biking and access to transit and services.
- Maintain efficient fire, safety, and emergency vehicle access.

Driveway, private road and public (non- circulation element) road design is influenced at the individual parcel and subdivision scale and is the focus of this section. Road design is site specific; accordingly, this section does not recommend specific road designs. Instead, the strengths and weaknesses of different road layouts are examined in the context of LID to assist designers in the process of providing adequate transportation systems while reducing impervious surface coverage.

Road Width Considerations. Reduced pavement width is a goal of LID, however the following concerns should be considered during project design:

- On roads where bicycle traffic is especially high, such as designated bike routes wider roads may be advisable to provide adequate space.
- Typical Fire Department standards require greater paved width for emergency vehicle access. A principal concern is that emergency access may be blocked if a

vehicle becomes stalled in the lane. Grid street systems and loop road systems provide multiple alternate emergency access routes to address this concern, though there may be a marginal increase in response times.
- Hillside sites have special access concerns and fire risks. Because of the potential for 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.

Road Drainage. Concrete curb and gutters are commonly required along both sides of a residential road, 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 also 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. Note that both of these alternatives are discussed and recommended in the County's SUSMP.

Private Roads (see [1], and [9]):

1. Rural swale system: road sheet flows to vegetated swale or gravel shoulder, curbs at street corners, culverts under driveways and road crossings;
2. Urban curb/swale system: road slopes to curb, periodic swale inlets drain to vegetated swale biofilter.

Driveways and parking areas:

1. Design residential driveways with shared access, flared (single lane at street) or wheelstrips (paving only under tires); or, drain into landscaping prior to discharging to the stromwater conveyance system.
2. Uncovered parking on private residential lots may be: paved with a permeable surface; or, designed to drain into landscaping prior to discharging to the stormwater conveyance system;
3. Where landscaping is proposed in parking areas, incorporate landscape areas into the drainage design.
4. Overflow parking may be constructed with permeable paving.
5. Reduce overall imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions, incorporate efficient parking lanes.

Public (non-circulation element) roads - The design of public roads shall use at least one of the following LID features [9]:

- Reduce sidewalk widths as long as ADA requirements are met
- Incorporate landscape buffer areas between sidewalks and streets

- Design non-circulation element streets for the minimum required pavement widths
- Minimize the number of residential street cul-de-sacs and incorporate landscaped areas to reduce impervious cover
- Urban curb/swale system: street slopes to curb, periodic swale inlets drain to vegetated swale biofilter

For more information on LID Street Design please see **Fact Sheet 14** in Appendix 4.

3.3.1. Public Road Standards

Current Public and Private Road standards mandate 60-80% impervious land coverage in the public right-of-way and/or the Private road easement. Runoff from these impervious surfaces is a principal concern regarding stormwater quality objectives unless the directly connected impervious areas are sufficiently reduced. Road standards that allow a hierarchy of road sizes according to average daily traffic volumes yields a wide variety of benefits: improved aesthetics from street trees and green parkways, reduced impervious land coverage, and reduced heat island effect. If the reduction in road width is accompanied by a drainage system that allows for infiltration of runoff, the impact of roads on stormwater quality can be effectively mitigated.

Public roads may utilize curbs and gutters, though the gutter may be tied to a biofilter or swale rather than an underground storm drain. Sidewalks may be provided on one side of the road, though usually preferable on both sides [35].

For more information on Public Road Standards please see **Fact Sheet 15** in Appendix 4.

3.3.2. Private Road Standards

A Private Road is used where required by Subdivision and Zoning Ordinance requirements. Curbs and gutters are replaced by gravel shoulders that are graded to form a drainage way, with opportunities for biofiltration and landscaping. Road sheet flow drains to a vegetated swale or gravel shoulder. Other characteristics of a private road standard include, curbs at street corners, and the placement of culverts under driveways and road crossings.

Typically, a narrow two-lane paved roadway is provided at approximately 24' wide. Most of the time single vehicles use the center of the paved roadway. Protection of the roadway edge and organization of parking are two significant issues in rural street design. Roadway edge protection can be achieved by flush concrete bands, steel edge, or wood headers. Upon recommendation of the local Fire Authority parking can be restricted by use of signage and/or striping.

For more information on Private Road Standards please see **Fact Sheet 16** in Appendix 4.

3.3.3. Curb-Cuts

Photograph courtesy of Mike Campbell (RBF consulting)

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 lined with vegetation or gravel/rock and gently sloped, these swales function as biofilters. 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.

For more information on Curb-Cuts please see **Fact Sheet 17** in Appendix 4.

3.3.4. 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 (with appropriate slopes), permitting infiltration of stormwater along its entire length. Because runoff from the street is not concentrated, but dispersed along its entire length, the buildup of pollutants in the soil is reduced. If parking is not desired on the shoulder, signage or striping 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 reduces impact on stormwater quality and that captures the most attractive elements of traditional neighborhood design. [9]

For more information on Rural Swale Systems please see **Fact Sheet 18** in Appendix 4.

Road 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)

- A cobble or rip-rap bottom combined with plantings
- Proper plant selection so that weeds are easily maintained

Maintenance practices for surface systems are different than most urban Public Works Department practices, and some employee retraining may be required to facilitate maintenance of road 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.

3.3.5. Concave Median

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.

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/rock 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.

For more information on Concave Medians please see **Fact Sheet 19** in Appendix 4.

3.3.6. Cul-de-sac Design

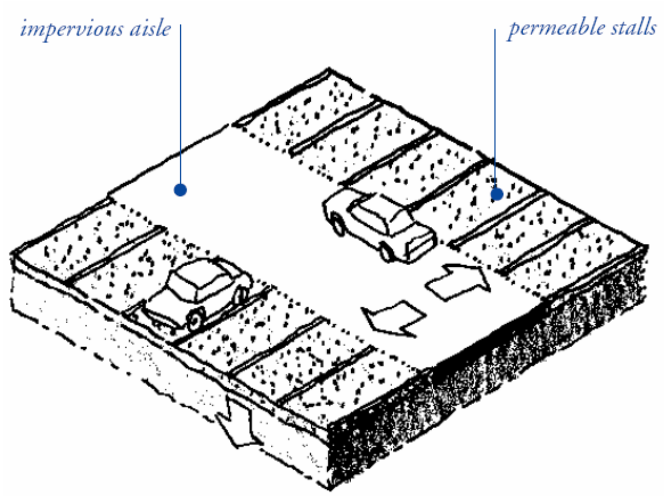
Cul-de-sac streets present special opportunities and challenges. Because cul-de-sac streets terminate, they require a turn-around area large enough to accommodate large trucks. County Fire code requires a minimum paved radius width of 36 feet in residential areas. If an entire 36 foot radius turnaround is paved, it creates a 4,071 square foot impervious circle. Aside from the implications for stormwater quality, this is especially unfortunate as a design element, because it creates a heat island at the front of several homes. A turnaround with a central concave landscaped area can create an opportunity for stormwater infiltration and/or detention. A landscaped area in the center of a cul-de-sac can reduce impervious land coverage 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 [36].

For more information on Cul-de-sacs please see **Fact Sheet 20** in Appendix 4.

3.4. LID Parking Lot Design

GENERAL DESCRIPTION

Parking lots contribute a sizeable area of impervious coverage to a community, and are significant sources of stormwater runoff and the discharge of associated pollutants to the storm drain system and local surface waters. Several strategies can be implemented to mitigate this impact, including reducing impervious surfaces, using permeable materials in overflow parking areas and bioretention basins in parking lot islands and perimeter landscaping.



Parking is the greatest single land use in most industrial, office, and commercial development. A 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 which make them a significant contributor to environmental degradation. 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.

Stormwater management in parking lots can mimic natural hydrologic functions by incorporating design features that capture, treat, and infiltrate or detain stormwater runoff rather than conveying it directly into the storm drain system. Management options include:

- Landscaped detention areas (see Fact Sheet 3) can be installed within and/or at the perimeter of parking lots to capture and infiltrate or detain runoff.
- Parking groves, which include permeable landscaped areas designed with grades several inches below the impervious parking surface can delineated by flat concrete curbs, shrubs, trees and bollards (see Fact Sheet 22).
- Permeable surfaces can be installed in down gradient parking stalls and in overflow parking areas. Permeable materials that can be utilized include permeable pavers, permeable AC, and pervious concrete. In some circumstances, gravel or wood chips can also be used.
- Stormwater runoff from the top floor of parking garages can be drained to planter boxes located at the perimeter of the parking lot or at street level.

Reducing Impervious Surfaces

Research has shown that zoning regulations typically require more parking spaces than are needed. Parking lot size is usually based on peak demand rather than average usage.

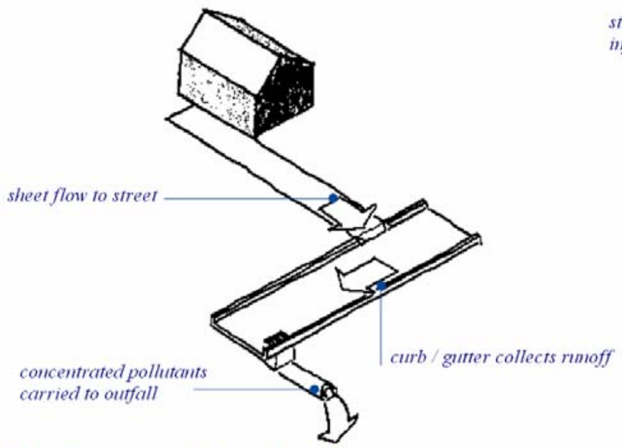
Photograph Courtesy of EOA, Inc.

Parking codes should be reviewed and revised to either reduce parking minimums or require reduction in directly connected impervious areas. Parking codes should also be revised to allow shared parking for businesses with different hours of peak demand. Bus and shuttle services can be provided between commercial centers that experience peak demands only during holidays and parking areas such as government facilities and schools that are typically vacant over holidays. Other strategies that can also be implemented to reduce the total parking area include compact parking spaces and determining the most space-efficient design for parking spaces (e.g. angled or perpendicular). Consideration should be given to design options such as underground parking or multi-storied garages. As noted above, vegetation and landscaping can be designed to intercept rainfall and capture stormwater. Including trees in parking lot landscaping should also be considered. In addition to reducing impervious coverage, trees reduce the urban heat island effect of parking lots by shading heat-adsorbing surfaces.

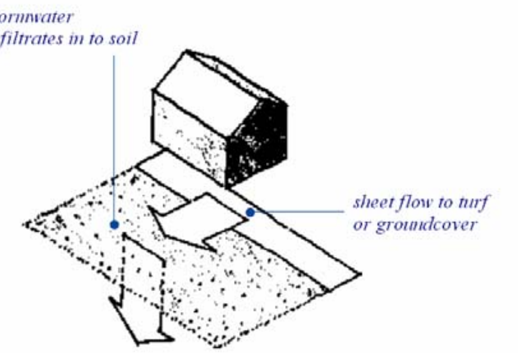
For more information on Hybrid Parking, Lots Parking Groves, and Overflow Parking please see **Fact Sheets 21-23** in Appendix 4.

Photograph: City of Encinitas, Roadside GrassCrete parking

3.5. LID Driveway, Sidewalk, and Bike Path Design



Directly-connected impervious driveway



Not directly-connected impervious driveway

Driveways, sidewalks, and bike paths add a significant amount of impervious coverage to a community and are an element of a site's design that can be altered to minimize directly connected impervious areas. Driveways often slope directly to the street and storm drain system and contribute significantly to stormwater pollution. There are three primary strategies that can be implemented to reduce these impacts, including:

- Reduce pavement widths.
- Direct surface flow from pavements to a permeable landscaped area.
- Utilize permeable paving materials

Driveways

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 reduce 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.

Not Directly-Connected Impervious Driveway

A conventional driveway that drains to the storm drain system is a "directly connected impervious area" which collects and concentrates 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.

Crushed Aggregate Driveway

Gravel and other granular materials can make a suitable permeable pavement for rural and other low-traffic driveways. Because it is lightly used by very slow moving vehicles, a well-constructed driveway of granular material can serve as a relatively smooth 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 Section 3.2: "Permeable Pavements").

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. Some unit pavers may also be installed on very fine gravel.

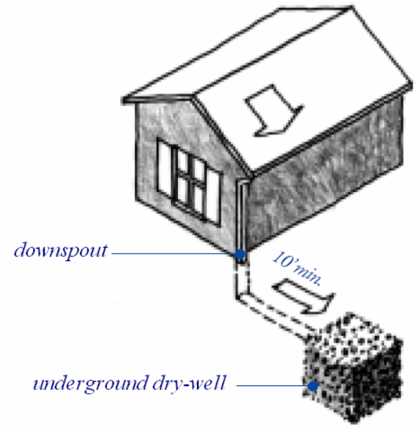
Paving only Under Wheels
Concrete paving only under the wheel tracks is a viable, inexpensive design if the driveway is straight between the garage and the street. By leaving the center strip open to be planted groundcover or filled with a permeable material such as gravel, a driveway of two concrete wheel tracks can significantly reduce impervious surface coverage compared with a single lane concrete driveway. Drainage, climate, and maintenance must be considered with the design of this technique so that the landscape can be planned appropriately.

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.

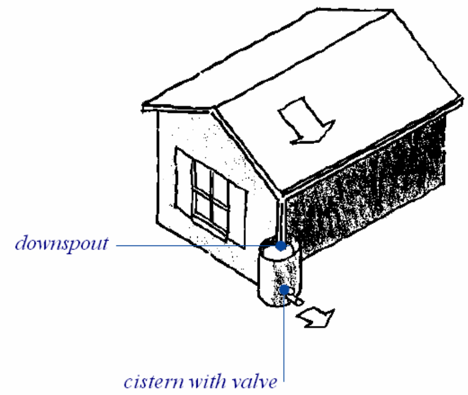
For more information on LID Driveway, Sidewalks, and Bike Path Design please see **Fact Sheet 24** in Appendix 4.

Photograph Courtesy of EOA, Inc.

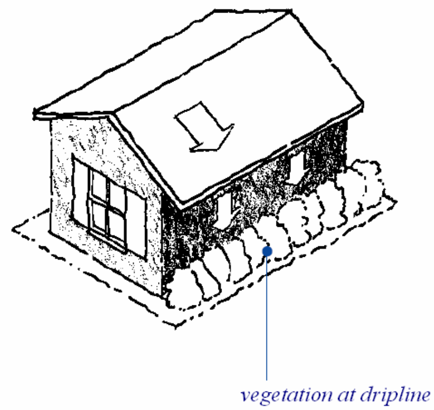
3.6. LID Building Design



Dry-well



Cistern



Foundation planting

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 the impervious land coverage. Therefore, multi-story buildings have less impact on stormwater quality than single-story building with the same square footage. 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.

3.6.1. 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 reduce 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 buildings as required based on soil type, and must follow local building codes. They must be installed in soils that accommodate infiltration. In poorly drained soils, dry-wells have very limited feasibility unless designed with an underdrain. Dry-wells must receive approval from a qualified, licensed professional.

For more information on Dry Wells please see **Fact Sheet 25** in Appendix 4.

3.6.2. Rain Water Harvesting

A key LID technique in a setting with soils relatively restrictive to infiltration is water harvesting, which can be applied at smaller residential scales using rain barrels or cisterns at larger scales in commercial and light industrial developments. Harvesting has been successful in reducing runoff discharged to the storm drain system and conserving water in applications at all scales.

3.6.2.1. Cisterns & Rain Barrels

Photograph Courtesy of Arid Solutions, Inc.

Cisterns and rain barrels capture roof runoff from the roof downspout and provide an effective way to store and slowly release runoff into the soil. 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 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 small storms. Cisterns can be incorporated into the aesthetics of the building and garden. The cistern must be designed and maintained to minimize clogging by leaves and other debris. In the dryer regions of the County, cisterns and rain barrels may only fill up a couple times a year and may be more practical when the system is supplemented with graywater from a County Permitted Graywater System.

3.6.2.2. Large Scale Harvesting

Examples exist around the world of harvesting water from much larger buildings than could be served by a rain barrel, including vertically elevated as well as horizontally spread harvesting structures. For example, in downtown Seattle the King County Government Center collects enough roof runoff to supply over 60 percent of the toilet flushing and plant irrigation water requirements, saving approximately 1.4 million gallons of potable water per year [42]. A smaller public building in Seattle, the Carkeek Environmental Learning Center, drains roof runoff into a 3500-gallon cistern to supply toilets [43]. The Natural Resources Defense Council office in Santa Monica is another example of a medium-scale rain harvesting application [44].

For more information on Rain Harvesting please see **Fact Sheet 26** in Appendix 4.

3.6.3. 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 but should not have large woody roots that can grow under and disturb building foundation. Unvegetated foundation swales utilizing cobble and gravel can also be used to protect foundations from potential water damage.

For more information on Foundation Planting please see **Fact Sheet 27** in Appendix 4.

3.6.4. Downspout to Swale

Discharging the roof downspout to landscaped areas via swales 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 into a swale or landscaped area. An energy dissipater such as rock or cobble is recommended at the outlet. The roof runoff is slowed by the rocks, absorbed by the soils and vegetation, and remaining runoff can then flow away from the building foundation towards the storm drain.

For more information on Downspout to Swale please see **Fact Sheet 28** in Appendix 4.

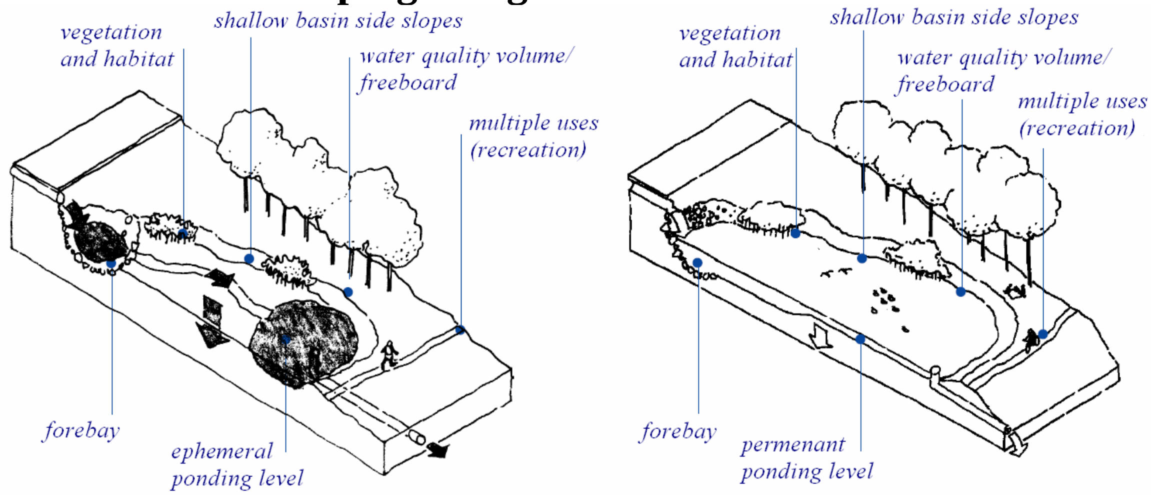
3.6.5. Vegetated Roofs

Vegetated roofs (also known as green roofs and eco-roofs) offer a number of benefits in the urban landscape including: increased energy efficiency, improved air quality, reduced temperatures in urban areas, noise reduction, improved aesthetics, extended life of the roof, and most importantly improved stormwater management. Stormwater benefits include: reduction of stormwater run-off, reduce quantity of industrial effluent, extend lifetime of infrastructure, reduce CSO events, and reduce flooding potential [37].

Vegetated roofs fall into two categories: intensive and extensive. Intensive roofs are designed with a relatively deep soil profile and are often planted with ground covers, shrubs, and trees. Intensive green roofs may be accessible to the public for walking or serve as a major landscaping element of the urban setting. Extensive vegetated roofs are designed with shallow, light-weight soil profiles and ground cover plants adapted to the harsh conditions of the roof top environment [38].

For more information on Vegetated Roofs please see **Fact Sheet 29** in Appendix 4.

3.7. LID Landscaping Design



Extended detention (dry) ponds **Wet ponds**

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 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 [39]. In the developed environment, 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. 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.

Aeration techniques such as drilling, scarifying, and roto-tilling can break up soil and enhance percolation. In addition, by properly amending the soil and increasing soil organic matter, water holding capacity can be significantly increased

Water Conservation in Landscaping Act of 1990

The State of California's Department of Water Resources is updating their Water Conservation Landscape Ordinance to establish specific standards for landscape design and irrigation design to assure efficient and responsible use of all available water resources for all citizens within the State. The Ordinance is also intended to implement the new development landscape design requirements of California Assembly Bill 1881, update to the Water Conservation in Landscaping Act [40]. These design requirements will support landscapes that are essential to the quality of life here in San Diego County. The requirements will also assure that we continue to meet a variety of landscaping objectives, including preventing erosion, filtering, treating, and utilizing storm water runoff. Landscape design, installation, maintenance, and management can and should be water efficient.

All landscape improvements shall conform to the County of San Diego's Landscape Water Conservation Design Manual. Where a local water agency serving a proposed project has adopted more stringent water conservation landscape requirements, the landscaping and irrigation design shall comply with the water agency's requirements.

Where appropriate for the site and the intended stormwater management technique, the landscaping may include natural features such as rock and stone.

Where service is available to the project site and appropriate for the intended use, recycled or reclaimed water shall be used for irrigation.

3.7.1. Soil Amendments

Development activities often remove, disturb and compact topsoil from construction sites. The outcome is a decrease in the infiltration and water storage capacity of post development soils, and an increase in stormwater runoff potential. In addition, soils in the arid climate of San Diego tend to lack organic matter and nutrients, and often have a high silt and/or clay content. Soils high in clay content have slow infiltration rates, resulting in a high runoff potential. By properly amending soils their hydrologic characteristics can be enhanced, leading to increased infiltration and water storage characteristics. Benefits accrued by incorporating soil amendments include decreased stormwater runoff, a decrease in polluted runoff from landscaping practices, and water conservation.

Organic soil amendments improve soils by increasing the water holding capacity in sandy soils, improving the physical characteristics of clay soils by altering the soil structure and percolation rates, and by providing a steady supply of nutrients and organics to help remediate ground water pollution. Properly prepared organic material can increase the microbial diversity in the soil and enhance plant health and immunity to disease. Composted products from licensed facilities are recommended, as these products have undergone a process to reduce pathogens and have a carbon: nitrogen ratio of less than 25:1. They can be tilled into the soil or can be applied as a top dressing to existing landscaped areas.

Landscaped areas that include decorative turf grass are a major contributor to stormwater runoff contaminated by fertilizers and pesticides. In landscaped areas where soils have been compacted and not amended, soils can behave like impervious areas, generating considerable amounts of runoff. By properly amending soils, the runoff potential can be reduced. This also reduces irrigation needs, as water is more easily infiltrated into the ground and retained in the soil matrix where it can be utilized by plants. Fertilizer needs can also be reduced by incorporating appropriate soil amendments, thereby reducing stormwater pollution.

For more information on Soil Amendments please see **<u>Fact Sheet 30</u>** in Appendix 4.

3.7.2. Street Trees

Trees can be used as a stormwater management tool in additions to providing more commonly recognized benefits such as energy conservation, air quality improvement, and aesthetic enhancement. Tree surfaces (roots, foliage, bark, and branches) intercept, evaporate, transpire, store or convey precipitation before it reaches surrounding impervious surfaces. In bioretention cells or swales, tree roots build soil structure that enhances infiltration capacity and reduces erosion [41].

- Local community planning areas often have specific guidelines for the type and location of trees planted along public streets or rights-of-way. The extent and growth pattern of the root structure must be considered when trees are planted in bioretention areas or other stormwater facilities with under-drain structures or near paved areas such as driveways, sidewalks, utilities or streets.

For more information on Street Trees please see **Fact Sheet 31** in Appendix 4.

3.7.3. 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 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 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. [38]. When designing landscapes for stormwater management, appropriate groundcover and plant species must be selected. Xeriscape plants, salt grass lawns, woody perennials, and cobbles can all be used, depending on the desired aesthetic effect.

Selection of appropriate plant material for LID projects is dependant on several factors These include:

- Micro-climatic conditions of planting area (i.e., sun exposure, temperature highs and lows, prevailing winds)
- Soil type (i.e., clay, sand, silt)
- Drought or temporary inundation tolerance
- Plants ability to aid in the removal of contaminants
- Visual characteristics of plants (texture, color, form)
- Maintenance requirements
- Non-invasive
- Disease resistance

Final selection of plant material needs to be made by a landscape architect experienced with LID improvement projects. Water retention areas and bio-swales need to have access for periodic maintenance activities.

For more information on Plant Species please see **Fact Sheet 32** in Appendix 4.

3.7.4. 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 less irrigation after 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 flow lines, 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. 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 [38]. 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 over watering. Over watering can be a significant contributor to run off and dry weather flows. Watering should only occur to accommodate plant health and should be adjusted at least four times a year. When ever practical, utilize Weather Based Irrigation Controllers and follow real time evapotranspiration (plant water use) data from the California Irrigation Management Information System (CIMIS) from the Department of Water Resources. Organic methods for fertilizers and pest control (including Integrated Pest Management) should be utilized. 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.

County of San Diego

Low Impact Development Appendices

San Diego Considerations and

LID Fact Sheets

DECEMBER 31, 2007

Department of Planning and Land Use
5201 Ruffin Road, Suite B
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Appendix 1 Glossary

Aquifer The underground layer of rock or soil in which groundwater resides. Aquifers are replenished or recharged by surface water percolating through soil. Wells are drilled into aquifers to extract water for human use.

Average Daily Traffic (ADT) The average total number of vehicles that traverse a road or highway on a typical day. Often used to classify and design roadway systems.

Biofilter Any of a number of devices used to control pollution using living materials to filter or chemically process pollutants.

Bioretention A technique that uses parking lot islands, planting strips, or swales to collect and filter urban stormwater, that includes grass and sand filters, loamy soils, mulch, shallow ponding and native trees and shrubs.

Buffer A zone created or sustained adjacent to a shoreline, wetland or stream where development is restricted or prohibited to minimize the negative effects of land development on animals and plants and their habitats.

Catchment The smallest watershed management unit, defined as the area of a development site to its first intersection with a stream, usually as a pipe or open channel outfall.

Check dam (a) A log or gabion structure placed perpendicular to a stream to enhance aquatic habitat. (b) An earthen or log structure, used in grass swales to reduce water velocities, promote sediment deposition, and enhance infiltration.

Cluster Development A development pattern for residential, commercial, industrial, institutional, or combination of uses, in which the uses are grouped or "clustered," rather than spread evenly throughout the parcel as in conventional lot-by-lot development. A local jurisdiction may authorize such development by permitting smaller lot sizes if a specified portion of the land is kept in permanent open space to provide natural habitat or open space uses through public or private dedication.

Constructed wetland An artificial wetland system designed to mitigate the impacts of urban runoff.

Contamination The impairment of water quality by waste to a degree that creates a hazard to public health through poisoning or through the spread of disease.

Cul-de-Sac A circular section located at the end of an access street that permits vehicles to turn around.

Curbs A concrete barrier on the margin of a road that separates vehicular and pedestrian traffic and is used to direct stormwater runoff to an inlet, protect pavement edges, and protect lawns and sidewalks from encroachment by vehicles.

Density The average number of families, persons, or housing units per unit of land. Usually density is expressed in "(number of) units per acre".

Design Storm A rainfall event of specified duration, intensity, and return frequency (e.g., a 2 year 6 hour event) that is used to calculate runoff volume and peak discharge rate.

Detention The temporary storage of storm runoff which is used to control discharge rates sufficiently to provide gravity settling of pollutants.

Detention Time The amount of time water actually is present in a basin. Theoretical detention time for a runoff event is determined from the period of release from the basin.

Disturbance The act of moving, grading, tilling, clearing, taking or repositioning the natural environment's soil surfaces and/or vegetation that was previously undisturbed by man.

Directly Connected Impervious Area (DCIA) The square footage of all impervious surfaces (see "Impervious Surface Area") that flow directly into a conveyance stormwater system.

Drainage Basin A land area bounded by high points, which drains all surface water into a single stream, other body of water, or storm drain infrastructure. (see Watershed)

Ephemeral Stream A stream or waterway that holds water only for a few hours or days, then evaporates (?) shortly after rain storms.

Erosion The wearing away of land surface by wind or water. Erosion occurs naturally from weather or runoff but can be intensified by land-clearing practices related to farming, residential, commercial or industrial development, road building, or timber cutting.

Evapotranspiration The combined loss of water from a given area, occurring during a specified period of time, by evaporation from the soil surface and transpiration from plants into the atmosphere.

Evaporation Practices Practices that temporarily store runoff and provide for its evaporation. (e.g.: retention, detention, reservoirs, etc.).

Excess Parking Parking spaces that are constructed over and above the number required or predicted based on the parking demand ratio for a particular land use or activity.

Feasible Capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, and technological factors. Infeasibility must be supported by substantial evidence developed through a good faith effort to investigate alternatives that would result in less adverse impacts. A substantial modification to the configuration of a development, or reduction in density or intensity, would not be considered infeasible unless supported by the above factors.

Filter Fabric A textile of relatively small mesh or pore size that is used to either allow water to pass through while keeping sediment out (permeable), or prevent both runoff and sediment from passing through (impermeable).

Filter Strips A vegetated area that treats sheetflow and/or interflow to remove sediment and other pollutants. Filter strips are used to treat shallow concentrated stormflows over very short contributing distances in urban areas.

First Flush The delivery of a disproportionately large load of pollutants during the early part of storms due to the rapid runoff of accumulated pollutants. The first flush of runoff can be defined in several ways (e.g., one-half inch per impervious acre).

Forebay An extra storage space provided near an inlet of a wet pond or constructed wetland to trap incoming sediments before they accumulate in the pond.

Green Space The proportion of open space in a cluster development that is retained in an undisturbed vegetative condition.

Groundwater Water stored underground that fills the spaces between soil particles or rock fractures. A zone underground with enough water to withdraw and use for drinking water or other purposes is called an aquifer.

Habitat The specific area or environment in which a particular type of plant or animal lives. An organism's habitat must provide the basic requirements for life and should be free of harmful contaminants.

Hammerhead A "T" shaped turnaround option for lightly traveled residential roads. This road type creates less impervious cover as compared to a circular cul-de-sac.

Heat Island Effect The increase in ambient temperatures generated by heat radiating from paved surfaces exposed to sunlight.

Hybrid Parking Lots A parking lot that uses multiple paving techniques to better utilize the area by combining impervious aisles with permeable stalls.

Hydrology The science of the behavior of water in the atmosphere (air), on the surface of the earth, and underground.

Impermeable Not able to be infiltrated by water.

Impervious Surface Any surface which cannot be effectively (easily) penetrated by water. Examples include conventional pavements, buildings, highly compacted soils, and rock outcrops.

Impervious surface area The ground area covered or sheltered by an impervious surface, measured in plan view (i.e., as if from directly above). For example, the "impervious surface area" for a pitched roof is equal to the ground area it shelters, rather than the surface area of the roof itself.

Imperviousness The level of (or percentage of) impervious surface within a development site or watershed.

Infill Developing vacant parcels or redeveloping existing property within urban or sub-urban areas.

Infiltration The downward entry of water into the surface of the soil, as contrasted with percolation which is movement of water through soil layers.

Infiltration Best Management Practice (BMP) Any treatment BMP designed primarily to percolate water into the subsurface. These include: infiltration trench, infiltration basin, dry wells, permeable pavements without an under-drain, and sub-surface reservoir beds without an under-drain. BMPs that have some incidental infiltration but which are designed primarily to retain water or to treat water, such as bioretention, filter strips, permeable pavements with an under-drain, or vegetated/rock swales, are not infiltration BMPs.

Infiltration Basin A concave vegetated surface (e.g., pond) designed to hold water so that it can gradually infiltrate into the soil.

Intermittent Stream A stream that flows mostly during the rainy or wet season and may not flow at all during other times of the year.

Management Practice A method, activity, maintenance procedure, or other management practice for reducing the amount of pollution entering a water body. The term originated from the rules & regulations developed pursuant to the federal Clean Water Act (40 CFR 1 30).

Natural Drainage A drainage consisting of native soils such as a natural swale or topographic depression which gathers and/or conveys runoff to a permanent or intermittent watercourse or waterbody.

Nonpoint Source Pollution Pollution that enters water from dispersed and uncontrolled sources, such as rainfall or snowmelt, moving over and through the ground rather than a single, identifiable source. A nonpoint source is any source of water pollution that does not meet the legal definition of point source in section 502(14) of the Clean Water Act (e.g., agricultural practices, on site sewage disposal, automobiles, and recreational boats). While individual sources may seem insignificant, they may contribute pathogens, suspended solids, and toxicants which result in significant cumulative effects.

National Pollutant Discharge Elimination System (NPDES) A provision of the Clean Water Act that prohibits discharge of pollutants into waters of the United States unless a special permit is issued by EPA, a state, or another delegated agency.

Open Space A portion of a cluster development that is set aside for public or private use and is not developed. The space may be used for active or passive recreation, or may be reserved to protect or buffer natural areas (see also Green Space).

Parking Groves A variation on the hybrid parking lot design, that uses a grid of trees and bollards to delineate parking stalls and create a shady environment. The permeable stalls reduce impervious land coverage while the trees reduce the heat island effect and improve soil permeability.

Perennial Stream A stream channel that has running water throughout the year.

Percolation The downward movement of water through soil layers, as contrasted with infiltration which is the entry of water into the surface of the soil.

Permeable A type of soil or other material that allows passage of water or other liquid.

Permeable Surfaces Surfaces made up of materials that allow stormwater to infiltrate the underlying soils (e.g., soil covered or vegetated areas).

Pervious A soil or material that allows the passage of water or other liquid.

Point Source Pollution A source of pollutants from a single point of conveyance, such as a pipe. For example, the discharge from a sewage treatment plant or a factory is a point source pollutant.

Pollutants A chemical or other additive that adversely alters the physical, chemical, or biological properties of the environment.

Permeable Pavement Asphalt or concrete paving material consisting of a coarse mixture cemented together with sufficient interconnected voids to provide a high rate of permeability.

Private Roads Considered the lowest order of road in the hierarchy of roads, private roads conduct traffic between individual dwelling units onto Public streets (such as Residential Collector Roads feeding onto local public roads or Circulation Element roads.). Private roads generally convey the lowest traffic volume, and are prime candidates for reduced street widths.

Public Roads A public corridor or right of way which enables vehicular, bicycle and pedestrian traffic. Roads are classified in a hierarchical order, according to their character and level of service they intend to provide. The County maintains standards for public roadways, including the Public Road Standards which primarily describe Circulation Element Road design and criteria.

Circulation Element Roads - Circulation Element roads are considered the regional backbone or skeleton road system. These roads provide for the vehicular movement of goods and services between various parts of the County. Traffic on Circulation Element roads are given preference at intersections, and some access control may be considered in order to maintain capacity to carry high volumes of traffic.

Non-Circulation Element - Non Circulation Element roads, or Local Public Roads, feed vehicular traffic into the Circulation Element system of roads. They provide access to residential neighborhoods, commercial and industrial areas. Of the two types of Public roads, non-Circulation Element roads are afforded the most flexibility with regards to implementing LID concepts.

Receiving Waters Water bodies such as lakes, rivers, wetlands, bays, and coastal waters that receive runoff.

Recharge Area A land area in which surface water infiltrates soil and reaches to the zone of saturation, such as where rainwater soaks through the earth to reach an aquifer.

Recharge Infiltration of surface water to groundwater.

Retrofit To provide or add new equipment, parts, structures, or techniques made available after the time of original construction or manufacture.

Riparian Area Habitat found along the bank of a natural and freshwater waterway, such as a river, stream, or creek, that provides for a high density, diversity, and productivity of plant and animal species.

Runoff Water from sources such as rain, melted snow, agricultural or landscape irrigation that flows over the land surface.

Runoff Coefficient The runoff coefficient measures permeability and determines the portion of rainfall that will run off the watershed. The runoff coefficient value, expressed as ‘C’, can vary from close to zero to as high as 1.0. A low ‘C’ value indicates that most of the water is retained for a time at the site, by soaking into the ground or forming puddles, whereas a high ‘C’ value means that the majority of the rain is runoff.

Sand Filter A small scale sand filter consists of a preliminary sediment trap chamber with a secondary filtration chamber and are usually located in below-ground concrete pits (as residential/lot level). Larger scale sand filters may be comprised of a preliminary sedimentation basin with a downstream sand filter basin-type arrangement.

Setback A required, specified distance between a building or structure and a lot line or lines. A setback can be used as a tool to protect sensitive areas from negative impacts associated with development.

Shared Parking A strategy designed to reduce the total number of parking spaces needed within an area, by allowing adjacent users to share parking areas during non competing hours of operation (e.g., a shared lot for a theater and an office building).

Sheetflow A flow condition during a storm where the depth of stormwater runoff is very shallow in depth and spread uniformly over the land surface. A sheet flow can quickly change into a concentrated channel flow within several hundred feet.

Significant Tree Any tree which is more than 12 inches in diameter as measured four and one-half feet (4'-6") above the root crown; or any tree with a diameter of any two trunks of at least 16 inches as measured four and one-half feet (4'-6") above the root crown. Any 'Oak tree' of the quercus genus more than 6 inches in diameter as measured four and one-half feet (4'-6") above the root crown; or any such tree with a total diameter of any two trunks of at least 8 inches as measured four and one-half feet (4'-6") above the root crown.

Steep Slope An area of land that has a slope angle of 25% or greater.

Stormwater Conveyance	A system of gutters, pipes, or ditches used to carry stormwater from surrounding land areas to constructed or natural drainage systems.
Stormwater Runoff	Rain that flows over the surface of the land without penetrating the soil.
Structural Control	A practice that involves design and construction of a facility to mitigate the adverse impact of urban runoff and often requires maintenance.
Subdivision	The process (and result) of dividing a parcel of land into smaller buildable sites, streets, open spaces, public areas, and the designation of utilities and other improvements. State and local regulations govern the density and design of new subdivisions.
Surface Water	Water on the surface of the land that has not infiltrated the soil including streams, lakes, rivers, and ponds.
Standard Urban Stormwater Mitigation Plan (SUSMP)	A mitigation plan for land development projects and public improvement projects.
Swale	An open drainage channel that has been explicitly designed to detain, evaporate, and/or infiltrate the runoff associated with a storm event.
Treatment Control BMP	Any engineered system designed to removed pollutants by a variety of methods such as simple gravity to settle particulate pollutants, filtration, biological uptake, media absorption or any other physical, biological, or chemical process.
Treatment Train	A stormwater technique in which several treatment types (filtration, infiltration, retention, evaporation) are used in conjunction with one another and are integrated into a comprehensive runoff management system.
Unit Pavers	Concrete grid and modular pavement whose spaces are filled with pervious materials such as sod, sand, or gravel.
Vector	Any insect (e.g.: mosquitoes) or other organism that is capable of harboring or transmitting a causative agent of human disease (e.g.: virus, bacterium, fungus, etc.).
Water Table	The upper surface of groundwater or the level below which the soil is saturated with water. The water table indicates the uppermost extent of ground water.
Watercourse	A permanent or intermittent stream or other body of water, either natural or improved, which gathers or carries surface water.

Watershed (see Drainage Basin) The geographic region within which water drains into a particular river, stream or body of water. A watershed includes hills, lowlands, and the body of water into which the land drains. Watershed boundaries are defined by the ridges of separating watersheds.

Zoning A mapped area to which a uniform set of regulations apply. Zoning may govern the use, placement, spacing, and size of land and buildings within a specific area (zone).

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An extensive LID Literature Index can be found on the County of San Diego Department of Planning and Land Use website: www.sdcounty.ca.gov/dplu

Appendix 3 San Diego LID Considerations

San Diego County is located between Orange and Riverside Counties on the north, the United States/Mexico International Border on the south, Imperial County on the east, and the Pacific Ocean on the west. San Diego County encompasses approximately 4,260 square miles and includes a variety of topography, soil types, land uses, and climate, all of which have impacts to runoff during rainfall and storm events.

San Diego is an area of great climatic variation. The map of San Diego County, Figure A.1, shows the major rivers and the divide that separates the western and eastern watersheds. This divide follows the mountain ridgeline with elevations that vary from 3,000 to 5,000 feet above sea level. Precipitation that falls east of the divide flows to the Salton Sea Basin, while runoff from precipitation west of the divide flows down the western slope to the Pacific Ocean. The western side of the divide is designated as Region 9 by the Regional Water Quality Control Board and is regulated by the Municipal Stormwater Permit (Order No. R9-2007-0001).

The key physical factors that affect the function, design and performance of LID measures in San Diego are: climate; geology; hydrology; groundwater; fire safety; and vector management.

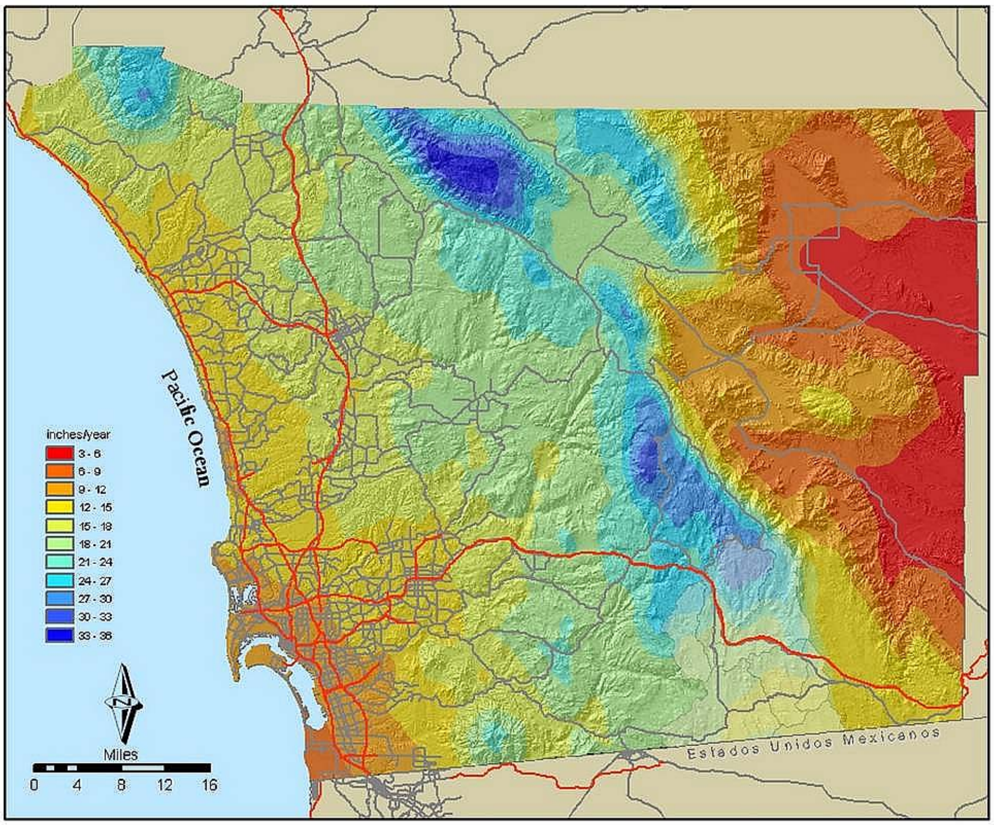
A. Climate

One of the key physical factors in San Diego that can affect the function, design and performance of LID measures is climate (precipitation, temperature, evapotranspiration). San Diego County has a mild, equable climate characterized by warm dry summers and mild winters. However there is considerable variation between the coastal, mountain, and desert areas. The major influences on San Diego's climate are the topography, the sea-surface temperature of the coastal waters, and the orientation of the coastline. In general the coastal area has a very small temperature range; temperature variations are greater in the mountains and greatest in the desert. The county generally has abundant sunshine. Winds are generally light and variable in direction except for persistent westerly winds during summer afternoons along the coast. Humidity remains moderate throughout the year in the western and middle portions of the County and quite low in the desert area during summer afternoons. Rainfall is variable across the region based primarily on season, location, and elevation.

Precipitation

Rainfall across San Diego County is variable, with most rain falling from November to April. The average rainfall is highest in the mountains and least along the coast and in the desert. Most of the county experiences light rainfall, although some of the central mountain areas receive more than 30 inches per year. Seasonal precipitation along the coast averages 10 inches. The amount increases with elevation as moist air is lifted over the mountains. Some reporting points in the Cuyamaca and Vulcan Mountains measure more than 35 inches per year with areas on Mt. Palomar receiving up to 45 inches. Totals diminish rapidly with decreasing elevation on the eastern slopes of the mountains with some desert stations reporting as low as 2.5 inches per season. The average annual precipitation across San Diego is represented in map below (Figure A.1). The average monthly distribution of rainfall across the year within San Diego is summarized in Table A.1 below.

Figure A.1 Average Annual Precipitation



Average Annual Precipitation for San Diego County

Source: California Irrigation Management Information System (1999) (see below)

Table A.1 Average Monthly Rainfall in San Diego County (inches)

Location	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Escondido (1931-1979)	2.79	2.85	2.54	1.30	0.37	0.09	0.02	0.15	0.28	0.66	1.58	2.94	15.57
San Pasqual (1979-2005)	2.70	3.37	2.79	1.08	0.28	0.11	0.14	0.06	0.22	0.68	1.21	1.63	14.26
Ramona (1974-2005)	3.42	3.51	3.37	1.23	0.39	0.08	0.13	0.18	0.36	0.71	1.40	1.73	16.49
El Capitan Dam (1948-2005)	3.09	2.88	3.23	1.29	0.51	0.12	0.06	0.15	0.28	0.63	1.58	2.01	15.82
El Cajon (1979-2005)	2.48	2.74	2.45	0.80	0.14	0.09	0.09	0.02	0.17	0.61	1.33	1.24	12.16
La Mesa (1948-2005)	2.62	2.17	2.42	1.05	0.31	0.08	0.05	0.08	0.21	0.54	1.42	1.55	12.50
San Diego Airport (1914-2005)	2.06	2.00	1.70	0.79	0.21	0.06	0.02	0.06	0.18	0.50	0.95	1.74	10.26
Chula Vista (1948-2005)	1.91	1.73	1.75	0.75	0.15	0.06	0.02	0.06	0.16	0.40	1.13	1.17	9.30
Alpine (1952-2005)	3.00	3.15	3.18	1.39	0.48	0.15	0.12	0.18	0.32	0.75	1.72	1.93	16.36
Campo (1948-2005)	3.03	2.69	2.43	1.09	0.33	0.07	0.35	0.52	0.37	0.67	1.29	1.83	14.68
Oceanside (1953-2005)	2.11	2.14	1.73	0.97	0.20	0.08	0.03	0.07	0.27	0.40	1.06	1.26	10.31
Vista (1957-2005)	2.80	2.55	2.43	1.04	0.22	0.12	0.06	0.08	0.28	0.55	1.43	1.66	13.22
Palomar Mountain (1948-2005)	5.65	5.42	5.31	2.18	0.61	0.13	0.40	0.66	0.56	1.04	2.78	3.78	28.52
Henshaw Dam (1948-2005)	5.00	4.82	4.71	2.01	0.62	0.11	0.30	0.47	0.50	0.94	2.37	3.20	25.06
Warner Springs (1948-1977)	2.48	1.92	2.14	1.37	0.45	0.06	0.37	0.88	0.46	0.60	1.22	1.91	13.86
Borrego (1948-2005)	1.10	1.13	0.75	0.24	0.07	0.02	0.31	0.55	0.34	0.30	0.48	0.75	6.04
Julian (1949-1988)	4.68	4.09	4.51	2.41	0.97	0.14	0.39	0.74	0.83	0.98	2.86	3.27	25.89
Cuyamaca (1948-2005)	5.94	5.88	6.02	2.90	1.11	0.19	0.49	0.72	0.84	1.28	3.31	4.56	33.25

Temperature

Moderate temperatures are found year round near the coast while the interior part of the county has generally warm summers and cool winters. The average annual temperature is in the low 60s (Fahrenheit) on the coastal plain and in the coastal valleys it drops into the mid-50s at higher elevations in the mountains, and increases to values around 70 degrees in the desert areas at the eastern edge of the county. During the winter the mean minimum temperature drops to the mid-40s along the immediate coast, below 30 degrees in the mountains, and is in the mid-30s over the desert. July maximum temperatures average in the 70s along the coast, increasing to around 90 degrees in the foothills, and can exceed 100 degrees in the desert area. The average monthly distribution of temperature within San Diego is summarized in Table A.2 below.

Table A.2 Average Monthly Temperature in San Diego County (^oF)

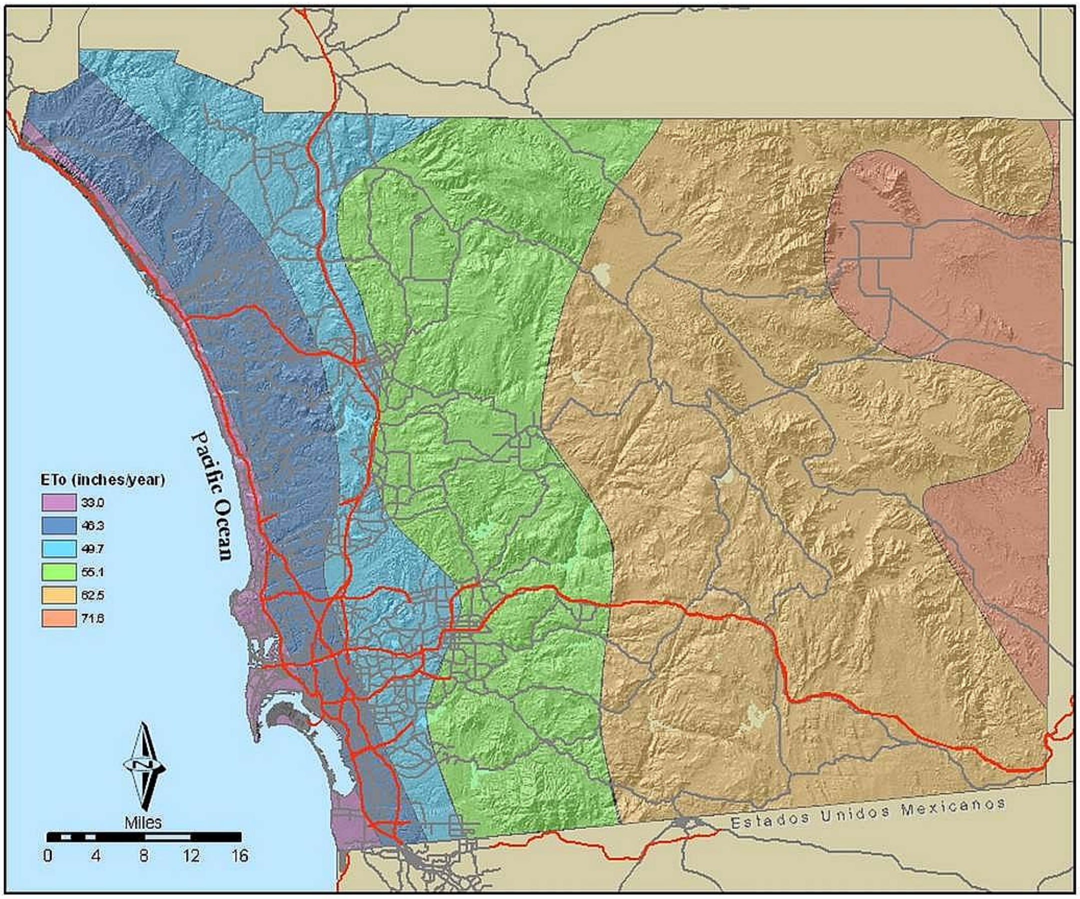
Location		J	F	M	A	M	J	J	A	S	O	N	D	Annual
	max.	66.0	66.9	68.9	72.3	75.7	80.8	87.6	88.0	85.7	79.4	73.4	67.5	76.0
Escondido (1931-1979)	min.	37.7	39.8	42.4	46.4	50.9	54.4	58.7	59.6	56.7	50.0	41.9	38.3	48.1
	max.	71.0	71.2	72.5	76.7	79.4	84.3	90.2	91.8	90.2	83.6	76.5	71.2	79.9
San Pasqual (1979-2005)	min.	39.8	42.5	44.9	47.5	52.2	55.7	59.0	60.0	57.5	51.3	42.7	38.0	49.3
	max.	66.8	67.3	68.1	72.5	76.7	84.0	90.0	91.0	88.0	80.6	72.9	67.4	77.1
Ramona (1974-2005)	min.	38.3	39.0	4.0	43.0	48.2	51.5	55.9	57.0	55.1	48.0	41.6	36.9	46.3
	max.	68.6	70.4	70.6	75.5	78.8	86.3	93.0	93.6	91.4	84.4	76.6	70.2	80.0
El Capitan Dam (1948-2005)	min.	41.2	42.9	44.5	47.5	50.9	54.3	58.1	59.2	58.1	52.9	46.4	41.8	49.8
	max.	69.4	69.9	71.3	75.4	77.4	81.5	87.4	88.9	87.1	81.2	74.3	69.5	77.8
El Cajon (1979-2005)	min.	42.5	44.3	47.3	50.5	55.4	58.4	62.7	64.1	61.3	54.9	45.8	41.2	52.4
	max.	67.0	68.4	68.8	71.6	73.3	77.5	82.8	84.3	83.3	78.8	73.1	68.3	74.8
La Mesa (1948-2005)	min.	44.5	46.0	47.6	50.6	54.3	57.7	61.5	62.8	61.0	55.9	49.2	44.8	53.0
	max.	64.7	65.2	65.9	67.5	68.6	70.9	74.8	76.3	75.7	72.9	70.0	65.9	69.9
San Diego Airport (1914-2005)	min.	48.0	49.6	51.8	54.6	58.0	60.8	64.3	65.6	63.8	59.2	52.8	48.6	56.4
	max.	65.0	65.6	65.3	66.8	67.9	69.8	73.4	75.2	75.4	73.1	69.5	65.5	69.4
Chula Vista (1948-2005)	min.	44.8	46.4	49.1	52.0	56.4	59.6	63.5	64.7	62.6	56.8	49.5	44.6	54.2
	max.	65.2	66.6	67.9	72.4	76.5	83.7	90.4	90.7	88.1	80.7	71.5	65.5	76.6
Alpine (1952-2005)	min.	42.3	42.9	43.8	46.4	50.0	54.7	60.1	61.3	59.3	53.4	46.6	42.1	50.1
	max.	62.1	63.7	66.0	71.2	77.6	86.4	93.7	93.6	89.2	79.7	69.1	62.7	76.2
Campo (1948-2005)	min.	33.6	33.8	35.1	36.9	40.8	44.6	52.2	52.9	48.7	41.9	36.2	32.7	40.8
	max.	63.9	63.8	63.8	65.1	66.6	68.5	72.1	74.3	73.7	71.5	68.2	64.9	68.0
Oceanside (1953-2005)	min.	44.6	45.7	47.6	50.4	54.8	58.4	62.2	63.4	60.9	55.9	48.9	44.5	53.1
	max.	67.3	67.9	68.1	70.9	72.9	76.3	81.4	83.1	82.0	78.0	72.4	67.6	74.0
Vista (1957-2005)	min.	44.0	45.0	46.3	48.6	53.3	56.6	60.1	61.5	59.9	55.0	48.3	44.0	51.9
	max.	51.1	52.6	55.4	61.3	68.3	77.9	84.3	83.8	79.7	69.7	59.0	62.3	66.3
Palomar Mountain (1948-2005)	min.	34.0	34.5	35.7	39.5	45.7	54.3	61.6	61.9	57.0	48.6	39.9	34.8	45.6
	max.	59.7	61.9	63.7	68.5	74.3	83.9	92.3	92.8	88.4	79.0	68.0	61.2	74.5
Henshaw Dam (1948-2005)	min.	29.2	31.2	33.9	37.0	41.7	45.8	52.1	52.6	47.3	39.4	32.7	28.5	39.3
	max.	59.5	62.6	64.1	69.6	76.8	85.8	94.1	93.5	88.9	78.9	68.1	61.7	75.3
Warner Springs (1948-1977)	min.	28.7	29.7	31.9	35.3	39.7	44.8	52.7	52.4	47.5	40.2	34.1	29.7	38.9
	max.	69.3	72.5	77.6	84.5	93.1	102.7	107.3	105.9	100.7	89.8	77.8	69.1	87.5
Borrego (1948-2005)	min.	44.1	46.7	50.0	53.8	60.7	68.2	75.4	75.3	69.9	60.6	52.3	43.4	58.2
	max.	55.6	58.2	59.3	64.8	71.3	81.4	90.1	89.6	84.6	74.2	63.4	57.4	70.8
Julian (1949-1988)	min.	34.5	34.7	34.8	37.0	40.6	45.8	53.0	53.7	49.3	43.3	38.1	35.6	41.7
	max.	50.8	52.8	55.3	60.7	67.8	77.1	84.7	84.8	80.3	70.3	59.3	52.4	66.3
Cuyamaca (1948-2005)	min.	29.2	30.5	32.9	36.2	41.3	48.2	55.0	55.1	48.3	39.4	33.4	29.1	39.8

Evapotranspiration

The term "evapotranspiration" refers to the total transfer of moisture to the atmosphere from the soil, water bodies, vegetation canopy (evaporation) and plants (transpiration). Evapotranspiration can represent a significant water loss from a watershed. Types of vegetation and land use significantly affect evapotranspiration and therefore, the amount of water leaving a watershed. Factors that affect evapotranspiration include the plant type (root structure and depth), the plant's growth stage or level of maturity, percentage of soil cover, solar radiation, humidity, temperature, and wind.

Monthly reference evapotranspiration (ETo), which is a measure of potential evapotranspiration from a known surface, such as grass or alfalfa, has been estimated for San Diego County by the California Irrigation Management Information System (CIMIS) and is represented in the map below (Figure A.2):

Figure A.2. Evapotranspiration.



Evapotranspiration for San Diego County

Source: California Irrigation Management Information System (1999) (see below)

References:

- California Department of Water Resources, Water Use Efficiency Office, (1999). *California Irrigation Management Information System (CIMIS).* State of California. http://wwwcimis.water.ca.gov/cimis/welcome.jsp

B. Geology and Soils

San Diego County can be divided into three distinct geomorphic provinces: (1) the Coastal Plain, (2) the Peninsular Range, and (3) the Salton Trough. The Coastal Plain is largely covered in sedimentary formational units. The Peninsular Range generally consists of granitic and other hard rock. The Salton Trough represents a relatively small, remote portion of the County, and has a limited extent of pervious sandy deposits. Unlike many other areas of California, San Diego County has relatively little in the way of pervious soils, such as alluvium-filled valleys and dune deposits. Thus, stormwater infiltration devices (lacking under drains) may not be appropriate for many portions of the County.

Proposed stormwater "Infiltration BMPs", including permeable pavements, shall be reviewed by a qualified, licensed professional to provide a professional opinion regarding the potential adverse geotechnical conditions created by the implementation of the plans. Geotechnical conditions such as: slope stability, expansive soils, compressible soils, seepage, groundwater, and loss of foundation or pavement subgrade strength should be addressed, and where appropriate, mitigation recommendations should be provided. The impact on existing, proposed, and future improvements should be included in the review.
The United Sates Department of Agriculture National Resources Conservation Services (NRCS), formerly the Soil Conservation Services, has classified San Diego Area soils with respect to: (1) Their ability to accept and absorb water, (2) their tendency to produce runoff, and (3) their erodibility. Their results are presented in Soil Survey, San Diego Area, California (1973). For more information on infiltration site selection please see the CALTRANs Infiltration Study (2003).

The ability of soils to accept and absorb water was originally evaluated for the purpose of sewage effluent disposal; but, applications in low impact development are closely related. According to the Survey:

> *In general, the entire Area has severe limitations for sewage effluent disposal. There are, however, some exceptions worth mentioning. Along the major streams of the Coastal Plains and the Foothills are soils that have slight limitations. The Lake Henshaw drainage and the tributary drainage basin to the east comprise a large area where limitations are moderate. This area extends northwest and east along valleys floors. In the valleys of the southern part of the Mountain zone are scattered areas of soils that have slight limitations. In the Desert zone are extensive areas of soils that formed in alluvium and have slight limitations.*
>
> *Widespread severe limitations indicate the need for caution in locating and constructing sewage disposal systems. Nevertheless, some areas where limitations are severe have been developed for homesites served by individual systems. In these areas, other factors may have outweighed the soil limitations, the limitations may not have been considered when selecting the sites, or the limitations were compensated for through the use of larger filter fields or other design features.*

The Survey classified soil runoff potential into four Hydrologic Soil Groups labeled A through D. Group A and B soils exhibit the greatest percolation rates (unless soils are compacted during construction) and are generally best suited to stormwater percolation. However, the San Diego Area has a relatively high concentration of Group C and D soils, which exhibit lower percolation rates that generally limit the use of infiltration-based stormwater management systems.

The hydrologic soil groups are defined as follows:
Group A soils have a high rate of percolation and a low runoff potential. The rate of water transmission is high, thus, runoff potential is low.

Group B soils have moderate percolation rates when thoroughly wet. These are chiefly soils that are moderately deep to deep, moderately well drained to well drained, and moderately coarse textured. Rate of water transmission is moderate.

Group C soils have a slow percolation rate when thoroughly wet. They are chiefly soils that have a layer impeding the downward movement of water, or they are moderately fine to fine textured soils that have a slow infiltration rate. The rate of water transmission is slow.

Group D soils have very slow percolation rates when thoroughly wet. They are clays that have a high shrink-swell potential, soils that have a high permanent water table, soils that have a claypan or clay layer at or near the surface, or soils that are shallow over nearly impervious material. The rate of water transmission for group D soils is very slow.

The Survey also evaluated erodibility. The great majority of soils in the San Diego Area exhibit moderate or severe erosion potential.

Data for a specific site, preliminary infiltration, runoff, and erodbility can be obtained by referring to the Survey and consulting the complete national listing provided by the NRCS, or by performing an on-site investigation. Retaining a licensed professional engineer and advancing exploratory excavations at the site are highly recommended. Consideration should be given to the effects of urbanization on the natural hydrologic soil group. If heavy equipment can be expected to compact the soil during construction or if grading will mix the surface and subsurface soils, appropriate changes should be made in the soil group selected (SD County Hydrology Manual, 2003).

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C. Hydrology

Hydrology is the scientific study of the waters of the Earth and its atmosphere, their occurrence, circulation, distribution, chemical and physical properties, and their reaction with their environment, including the relation to living things. While the science of hydrology includes many aspects such as groundwater movement, oceanography, meteorology, and other aspects, the purpose of this Section is to examine surface runoff.

This Section will describe the type of storm runoff events occurring in San Diego County as a result of the region's climate (discussed in Section 2.A) combined with geology (discussed in Section 2.B), topography, predominant soils, land use, and other factors. It will further describe how these factors impact engineering design of storm water conveyance features, including design of LID features. The practices described in this LID Handbook are designed to address surface runoff resulting from direct precipitation, with a goal of mimicking natural conditions as closely as possible to reduce surface runoff from developed areas. The LID Handbook describes LID features that can be incorporated on project sites to achieve this goal. The inclusion of native vegetation into landscaping is a complementary, beneficial practice to LID, which minimizes excess surface runoff and subsurface flow of irrigation water that is not representative of natural site conditions by reducing the need for or amount of irrigation.

The factors influencing the amount of surface runoff generated during a storm event include: the total area contributing to the point of interest (the drainage area), rainfall intensity, and the ability of the watershed to capture or attenuate runoff. The latter is dependent on the land cover and soil type, slope, antecedent moisture conditions, and existing drainage infrastructure within the watershed. Runoff is directly related to rainfall intensity. The higher the rainfall intensity, the higher the resulting peak flow rate of surface runoff. Runoff is also directly related to the land cover and soil type, slope, and antecedent moisture conditions within the watershed. These factors affect both the volume and peak flow rate of runoff. More impervious land cover, steeper slopes, more impermeable soil types, and saturated soil conditions result in greater runoff volumes and greater peak flow rates. Rainfall intensity depends on climate, which is a factor that cannot be controlled in engineering design. Slopes and soil types are also somewhat predetermined based on existing geology. Fill practices will significantly alter existing slopes and soil properties, but typically in a manner that increases surface runoff. Antecedent moisture conditions depend on climate, but may be altered by irrigation practices in localized areas. Although some of these factors are predetermined for engineering design, engineers and site designers do have the ability to enhance land cover practices to maximize the watershed's ability to intercept and store runoff.

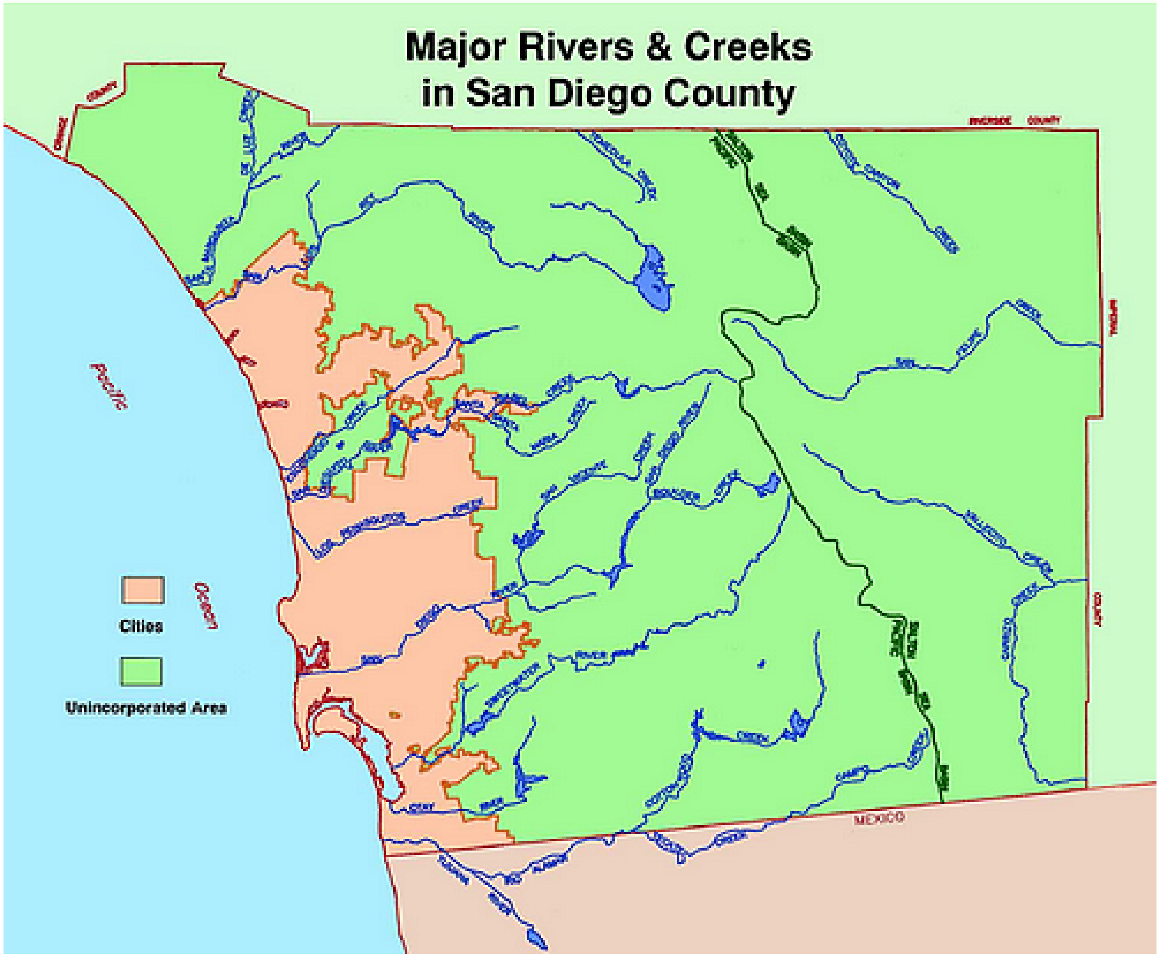


Figure A.3 Major Rivers and Creeks in San Diego

Source: County of San Diego (2003, June). *San Diego County Hydrology Manual*. Department of Public Works, Flood Control Section

Storm Intensity

Due to the convective winter weather pattern and relative proximity to the jet stream, San Diego typically has high intensity, short duration storm events. Regardless of the amount of total rainfall delivered (measured in inches), the intensity with which it is delivered (measured in inches per hour) often results in flashy, high peak flow rates of storm runoff. The design of LID features used in San Diego must account for the high intensity storms in order to provide for conveyance or bypass, and appropriate erosion prevention. The engineer must assess how the design storm event that governs the design of storm water conveyance systems for flood control (e.g., the 100-year storm event) will affect the LID features, which are typically designed for more frequent (1, 2, and 5-year) storm events. The engineer must determine whether the 100-year storm event should bypass the LID feature, or be conveyed through the LID feature, accounting for proper energy dissipation, scour prevention, and capacity. It may be necessary to provide for overflow from the LID feature or provide bypass if safe overflow (that would not result in erosion or directing flow to undesirable location) is not practical or achievable.

Land Cover, Slope, and Soil Type

Land cover, slope, and soil type influence the ability of the watershed to capture or attenuate runoff. Within a development project, land cover is almost entirely determined by engineering design (site design). The intent of LID features is to enhance the land cover to mimic the project site's natural ability to intercept, store, and route runoff in the pre-development condition. This can be achieved by a combination of reducing the development features that act to reduce absorption and infiltration, replacing absorption and infiltration areas, and preserving natural drainage routes where possible. Section 3 of the LID Handbook discusses seven site planning strategies to meet these goals.

The design of LID features must respect hydrologic constraints presented by slopes (natural and engineered), soil types (natural and engineered/compacted), and the historical development of the area in order to provide a safe development. The naturally steep slopes and clayey soils that are predominant in San Diego County present unique challenges to achieving the goals stated above, and their hydrologic effects must be considered in the design of LID features. Steep slopes and clayey soils are not conducive to infiltration. Instead, they result in high peak flow rates and volumes of surface runoff. LID features that replace infiltration lost to impermeable surfaces should not exceed pre-development conditions or concentrate infiltration volumes that were previously dispersed throughout the site in the pre-development condition without consideration of subsurface geology and flow paths. Furthermore, knowledge of how tributary and downstream areas were developed in the past (i.e. whether underdrains were used in existing fill areas) is vital to help determine how increased infiltration could affect the project site as well as down gradient properties.

The existing soil types in the majority of developable area in San Diego typically have low infiltration rates. Furthermore, steep slopes in San Diego County present a challenge to minimizing fill, as fill is often constructed in order to maximize buildable area. In order to protect them from erosion or failure, fill slopes are designed to drain runoff safely from the land surface to an engineered system to minimize intrusion of water into the fill. Based on these factors, neither the natural nor the engineered/compacted soils are conducive to infiltrating excess runoff on or above steep slopes. Potential increased seepage conditions could develop from increased infiltration of surface water to the subsurface, which could potentially present problems to properties adjacent and down gradient from infiltration projects. Therefore, it will be essential to work closely with the a qualified, licensed professional on the design of Infiltration BMPs to evaluate the site constraints as well as the potential impacts to downstream property owners.

Because of the difficulty of replacing infiltration to convey runoff safely from fill areas and slopes, site design LID techniques can be utilized to reduce impervious areas. In order to maximize buildable area techniques such as constructing streets, sidewalks, and parking lot aisles to the minimum width necessary, increasing building density (number of stories above or below ground), and minimizing the use of impervious surfaces, such as decorative concrete, in the landscape design can be utilized. Absorption areas can be mimicked by maximizing canopy interception in the site landscaping, minimizing soil compaction, and replacing soil absorption in controlled locations where underdrain systems can be included to protect against increased seepage conditions, such as in engineered open drainage channels, planters, tree wells, biofiltration areas, and other landscaped areas with controlled drainage.

D. Groundwater Infiltration

Aquifer Characteristics in San Diego County

San Diego County has a variety of aquifer types and geologic environments, which have different associated groundwater issues. The coastal zone is mostly supplied with imported potable water from the member agencies of the San Diego County Water Authority (CWA). The remaining portion of the County (approximately 65% by area) is totally dependent on groundwater resources. For all lands to the east of the San Diego CWA boundary, water resources are limited to naturally-occurring surface and groundwater resources. In this area, no imported water is, or will likely become, available in the foreseeable future. This is due to the lack of infrastructure, the limited availability of water within the desert southwest, the cost of providing these services, and the political approval needed to extend the CWA boundaries.

Groundwater resources in the County which lie east of the CWAs service area are limited due to the amount of rainfall and resulting infiltration, or groundwater recharge, as well as limited groundwater storage. The majority of this area is underlain by fractured rock aquifers, which restricts development due to very limited groundwater storage. There are also relatively shallow, alluvial aquifers which are typically found in river and stream valleys and intermountain valleys adjacent and in many cases overlying fractured rock aquifers. Some of these aquifers have a relatively thin saturated thickness and therefore limited storage. Desert basins in the extreme eastern portion of the County have relatively large storage capacity, but extremely limited groundwater recharge. Because of the limited groundwater recharge, desert basins are particularly prone to groundwater overdraft, where groundwater extraction exceeds long-term groundwater recharge. High groundwater demand in Borrego Springs has resulted in an overdraft condition.

High Groundwater Conditions

In areas served by municipal drinking water, the potential for high groundwater exists in some areas due to the artificial introduction of imported water into the groundwater system mainly from septic system and/or irrigation return flows. Parts of Valley Center, Rainbow, Ramona, and a few areas east of Escondido have historic records of high groundwater. These areas have had recorded septic tank failures which has led to bacteria and nitrate contamination of groundwater. A technical septic system failure is when conditions are such that the water table rises to within five feet of the bottom of a septic system disposal field. A minimum 10-foot separation is required to prevent the underlying groundwater and nearby surface waters from being contaminated by bacteria, nitrates, and possible virus strains in the wastewater. Stormwater infiltration devices may not be feasible in areas with septic systems which are served by municipal drinking water.

In general, perennially high groundwater conditions are uncommon in the groundwater dependent areas of the County east of the CWA line with a few exceptions such as parts of Jacumba and a few other sporadic instances largely within alluvial aquifer environments.

Groundwater Contamination Concerns
Some pollutants, such as nitrates, bacteria, total dissolved solids, petroleum products, and solvents, can migrate to depths that can ultimately threaten water supply wells. Illegal dumping of waste oil, pesticides, herbicides, paint, paint thinner and other chemical products into any type of infiltration device presents additional risk to groundwater contamination. Local water districts and other agencies generally have policies and strategies to protect groundwater supplies from these threats. These policies are an attempt to balance the environmental benefits of infiltration with the compelling need to protect soil and groundwater supplies.

Groundwater infiltration concerns:
A case study by the USGS of a groundwater recharge basin in Fresno showed that a wide variety of urban runoff pollutants were removed by absorption within the top 1.5 inches of sediment in the basin, but no pollutants were found in the sediment at a depth greater than six inches. This shows that the pollutants did not travel more than six inches deep – typically well above the level of groundwater wells. In the County of San Diego, a ten foot separation is recommended between infiltration practices and the top of the groundwater table in order to allow sufficient biological activity and filtration to occur.

With proper maintenance of stormwater management systems, pollutants infiltrating into the soil do not usually pose a risk of contaminated soil or groundwater. Risk is greater when there is a concentrated source of pollutants, such as in a heavy industrial site or in the case of illegal disposal.

References

- Additional information on groundwater may be found in the Groundwater section of the San Diego County LID Literature Index.
- Schroeder, Roy A. (1995) Potential for Chemical Transport Beneath a Storm-runoff Recharge (Retention) Basin for an Industrial Catchment in Fresno. U.S. Geological Survey Water Resources Investigations Report 93-4140, prepared in cooperation with the Fresno Metropolitan Flood Control District. Sacramento.

E. Fire Safety Considerations

There are a multitude of approaches to reducing the impact of stormwater runoff in developed areas. Paramount in choosing optimal design methods is public safety.

Fire safety demands accessibility to structures by fire apparatus (trucks and other emergency vehicles) and allows residents to relocate in a safe manner in advance of an oncoming fire, flood, or other catastrophe. State and County Fire Codes specify how fire access roads are to be designed to provide emergency vehicle access within recognized operational parameters. Dead end roads must meet the CCR Title 14 and County Fire Code requirements for secondary access and emergency vehicle turnarounds.

Vegetation management ("fuel modification") must be maintained in compliance with fire codes, particularly adjacent to buildings and to grass surfaced fire lanes. Landscaping restrictions limit the amount and type of native and ornamental vegetation within 100 feet or more of structures. Landscaping in proximity to specially designed roadways with grass covering is particularly important in that it not interfere with fire apparatus access, or with firefighter perception of vehicle accessibility

Any design that allows water to travel through surfaces designed for travel by fire apparatus must meet accepted County of San Diego design criteria to allow all weather safe passage by heavy fire equipment. Areas designed for fire engine access that appear to be lawns or meadows (e.g. "turf block") must be clearly marked as fire lanes and have an irrevocable easement which prohibits the installation of anything that could obstruct or appear to obstruct its use by fire engines. Fire officials have concern that responding apparatus operators are able to recognize designated fire lanes (fire access roadways) that appear to be lawns, and have confidence in the area's capability of safely supporting 50,000 – 75,000 pound engines and ladder trucks. Fire apparatus can only utilize such surfaces in wet situations if the surface is virtually flat. Any grade makes traction and control very difficult.

Developments must be designed to permit testing of fire protection systems. Discharge of potable water from fire hydrants and sprinkler system test valves must be directed to permeable areas.

References

- Section 902.2.2.4 County of San Diego Consolidated Fire Code (2001, October 17) Ord. No. 9397. County Code of Regulatory Ordinances. Title 3, Div 5, Ch3.

F. Vector Control

A vector is any insect, arthropod, rodent or other animal that is capable of harboring or transmitting a causative agent of human disease. In the County of San Diego, the most significant vector population related to stormwater is mosquitoes.

Mosquitoes and Disease

Figure 1. The Mosquito Life Cycle

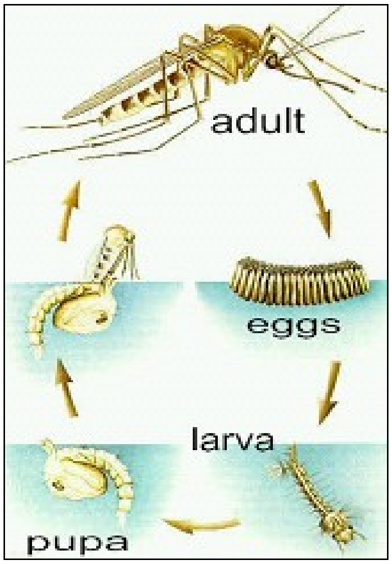


Figure from County of San Diego, Department of Environmental Health, Vector Control Program website

The mosquito has four stages of life (Figure 1, The Mosquito Life Cycle). The life cycle begins when a female lays an egg raft on top of water that can contain up to 100 eggs. Total development from egg to adult can be less than one week during periods of warm weather and the average adult mosquito usually lives for about two weeks. Almost all mosquitoes need standing water to complete their life cycle. For this reason, mosquitoes are usually found in areas of standing water including wetlands, irrigation ponds, detention basins, percolation and infiltration basins, and other stormwater conveyance systems. Only female mosquitoes bite. They need the protein and nutrients from blood for their developing eggs.

There are approximately 24 species of mosquitoes found in San Diego County and of these; there are at least four that are known to carry diseases that can be passed to humans. The recent spread of West Nile virus (WNV) has increased the health risk of mosquito contact and increased the importance of designing and maintaining measures to prevent mosquito breeding. Prevention and remedial measures can also protect or prevent (1) the individuals who are allergic to bites of various mosquitoes and other vector species; (2) numerous bites or stings from vectors which can destroy the pleasure of patio or garden use in suburban areas; (3) large numbers of biting or stinging vectors in recreational areas; and (4) secondary infections which can result from bites and stings.

San Diego County's Vector Control Program (VCP) has developed a comprehensive early detection, surveillance, and response plan to control the spread of WNV. For more information visit the VCP website at www.sdfightthebite.com.

Vector Sources

Vector sources occur where conditions provide habitat suitable for breeding. Backyard residential sources of standing water are common mosquito breeding sources. These sources include unmaintained swimming pools and buckets, toys, and other common items that can hold even small amounts of water. Ponds and reservoirs are another major source of mosquitoes.

Any source of standing water, including but not limited to natural and constructed wetlands, irrigation ponds, detention basins, percolation and infiltration basins, and other stormwater conveyance systems (even those below ground) can be breeding grounds for mosquitoes and other vectors resulting in adverse public health effects related to vectors and disease transmission.

Stormwater Management

A standard requirement for new development is the incorporation of Best Management Practices (BMPs) to reduce stormwater flow rates, allowing stormwater to infiltrate into the ground, and to reduce constituent concentrations in runoff. Unfortunately, BMPs for managing runoff often provide aquatic habitats suitable for mosquitoes and other vector species as an unintended consequence of their implementation.

An often overlooked aspect of treatment BMP implementation is the long-term commitment of funds necessary for proper maintenance of structures. Routine and timely maintenance is critical for suppressing mosquito breeding as well as for meeting local water quality goals. If maintenance is neglected or inappropriate for a given site, even structures designed to be the least “mosquito friendly” may become significant breeding sites.

Every possible effort should be made to “design the bugs out” early in the project design phases. Vectors should be considered during the preparation of stormwater management and maintenance plans and during preconstruction planning to avoid creating possible public health hazards. The County of San Diego includes guidance in the Standard Urban Stormwater Mitigation Plan (SUSMP) to minimize the mosquito production potential of treatment BMPs. The County of San Diego requires that stormwater management facilities be designed so that water will drain within 72 hours to prevent mosquito breeding.

Standard Mitigation and Project Design Considerations

Minimizing mosquito production potential requires that standing water not be available for sufficient time to permit eggs to develop to adult mosquitoes. For stormwater BMP’s, this can be achieved in one of three ways: 1) discharge of all captured water within 72 hours, 2) deny mosquitoes access to standing water, or 3) make the habitat less suitable for mosquito breeding. The most effective design strategy to exclude vectors from Low Impact Development (LID) Integrated Management Practices (IMPs) is to design the system to ensure that water is discharged within 72 hours, thereby eliminating the potential vector breeding source. The below recommendations are adapted from the document, “Managing Mosquitoes in Stormwater Treatment Devices” prepared by the University of California, Agriculture and Natural Resources, UC Mosquito Research Program. Management of standing water to eliminate the potential for vector breeding sources associated with stormwater treatment facilities must be addressed in the project’s Stormwater Management Plan (SWMP).

Design Measures to promote rapid discharge of captured water in BMP's

- Select or design an alternative stormwater device that provides adequate constituent removal and complete drainage within 72 hours. Special attention to groundwater depth is essential to determining water residence times.
- Incorporate features that prevent or reduce the possibility of clogged discharge orifices (e.g., debris screens). The use of weep holes is not recommended due to rapid clogging.
- Use the hydraulic grade line of the site to select a treatment BMP that allows water to flow by gravity through the structure. Pumps are not recommended because they are subject to failure and often require sumps that hold water.
- Design distribution piping and containment basins with adequate slopes to drain fully and prevent standing water. The design slope should take into consideration buildup of sediment between maintenance periods.
- Avoid the use of loose riprap or concrete depressions that may hold standing water.
- Avoid barriers, diversions, or flow spreaders that may retain standing water.

REFERENCES

- Metzger, Marco E. (2004). *Managing Mosquitoes in Stormwater Treatment Devices* California Department of Health Services, Vector-Borne Disease Section. University of California, Division of Agriculture and Natural Resources http://www.ucmrp.ucdavis.edu/publications/managingmosquitoesstormwater8125.pdf

- Additional information on mosquitoes and other vectors in San Diego may be found in the Vector section of the San Diego County LID Literature Index.

G. LID Treatment BMPs Design Considerations

LID site design BMPs are more readily applied to new development where the implementation of these methods can begin as part of the planning phase. LID BMPs applied to retro-fit and in-fill projects in most cases need to consider to a greater extent existing site conditions. These site conditions as discussed below may limit the application of LID BMPs and need to be considered in the design approach.

Design considerations for LID site development BMPs include increasing travel time to maintain the time of concentration and provide storage to control both peak flows and total runoff volume to address hydro-modification issues. As discussed previously, the design approach to LID site design BMPs with regard to storm water quantity requirements should be based on the design criteria presented in the updated Hydraulic Design Manual, updates to the SUSMP and the Hydro-modification Plan that is under development.

LID BMPs may also function in new development, in-fill development and retro-fits to address urban runoff water quality issues. For most in-fill and retro-fit projects in built-out and urbanized areas of the County, LID site design techniques are often limited. However, LID BMPs that also address water quality issues may be applicable where site conditions are favorable. Per the Municipal Stormwater Permit for San Diego County (January 2007), LID BMPs that are correctly designed to effectively infiltrate, filter, or treat runoff can be considered treatment control BMPs. Where LID BMPs are used as "Treatment BMPs", the design approach needs to consider both water quantity and quality requirements. LID BMPs applied to retro-fit projects may be integrated into an overall watershed program to reduce the overall volume of impacted runoff entering the receiving waters.

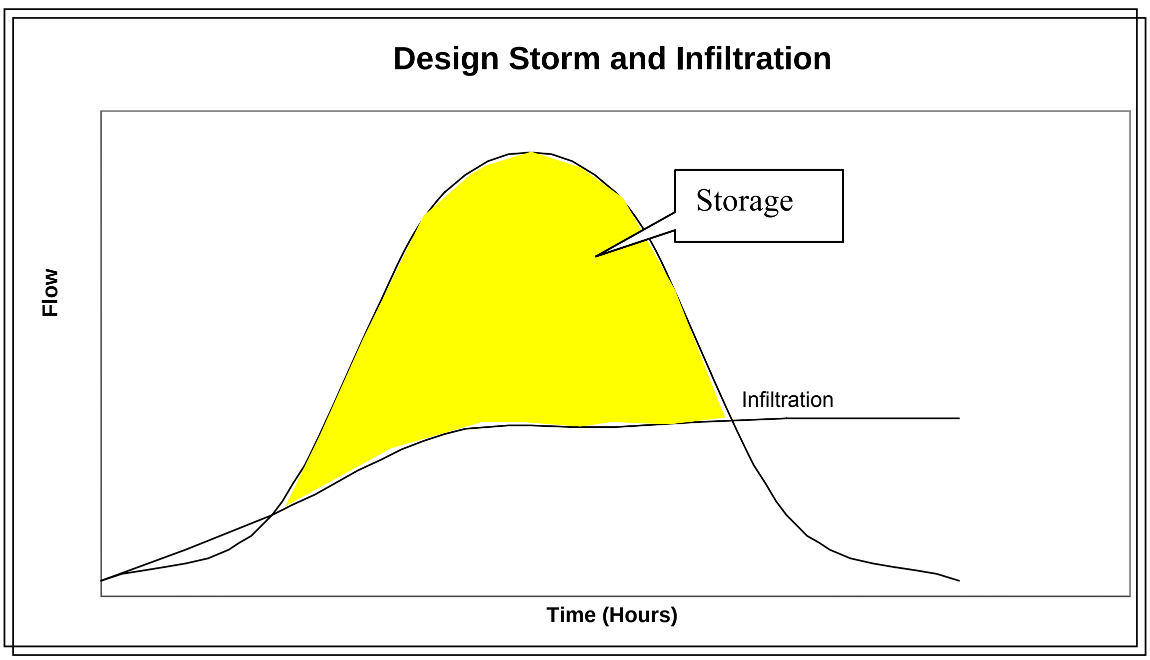
LID BMPs that use infiltration as a primary or secondary function need to consider both sub-surface vertical and horizontal hydraulic conductivity and the design volume or flow of runoff to be "treated" by the BMP. LID BMPs include permeable pavement, biorentention, bioswales, stormwater planters, wetlands and turf replacement which all have a secondary infiltration function. "Infiltration BMPs" such as infiltration trenches, infiltration basins, permeable pavements without under-drains and infiltration devices are examples of LID BMPs where infiltration is the primary function.

The determination of infiltration rates within the sub-soils is one of a number of site conditions that need to be assessed as part of the design of LID BMPs. As recommended throughout this document, these site conditions should be conducted and reported by a geotechnical engineer or other qualified, licensed professional. Generally, there are less of these site issues for new development compared to in-fill and retro-fit projects. The site conditions that should be assessed include:

- Infiltration Rate - Vertical and horizontal hydraulic conductivity of the sub-surface soils below the bottom elevation of the BMP

- Depth to Groundwater – Distance to the groundwater table and the potential for groundwater mounding, short circuiting through higher permeability pathways, and increased down-gradient seepage
- Existing Structures – Distance to existing structure and the potential of damage from increased infiltration
- Existing Infrastructure/ Utilities - Distance to existing infrastructure and utilities and the potential of damage from increased infiltration
- Slope Stability – Potential for increase in pore water pressures leading to instability of down-gradient slopes and damage to property
- Expansive Soils – Presence of expansive clays that are adjacent to or under existing structures that may result in damage

Based on the infiltration rate of the underlying soils, additional storage may be required as part of the LID BMP depending on the treatment volume or rate required. Storage can be provided, for example, in the granular sub-base layer of a porous pavement section or in the amended soil and/or granular layers in a bio-retention BMP. As shown in the figure below, the required storage may be based on a comparison of the rate of infiltration of the sub-soils and the design storm hydrograph. If the design requirement is to capture the entire flow of the design storm represented by the hydrograph, then the required storage volume would be the area under the hydrograph and above the infiltration line.



The determination of the required storage volume will depend on the design treatment volume or flow. This selection of the design treatment sizing criteria will depend on the specific applicable and relevant regulatory drivers. The regulatory requirements will depend on the location of the site and water quality issues within the associated watershed and jurisdiction.

The design criteria for sizing of site design LID BMPs will be developed as part of the SUSMP and Hydrology Manual updates. LID BMPs may also be designed as treatment or pollution control BMPs. Where LID BMPs have a treatment or pollution reduction function, the sizing of the LID storage and treatment components may consider additional regulatory drivers. For example, the San Diego Region Municipal Stormwater Permit (Order No. R9-2007-0001) requires for all treatment control BMPs on Priority Development Projects (see D.d.(1) of the Permit) to meet the following design criteria:

- Volume-based BMPs – 24-hr 85th percentile storm event
- Flow-based BMPs – maximum flow rate from 0.2 inch per hour rainfall or max. flow rate from 85th percentile hourly rainfall intensity

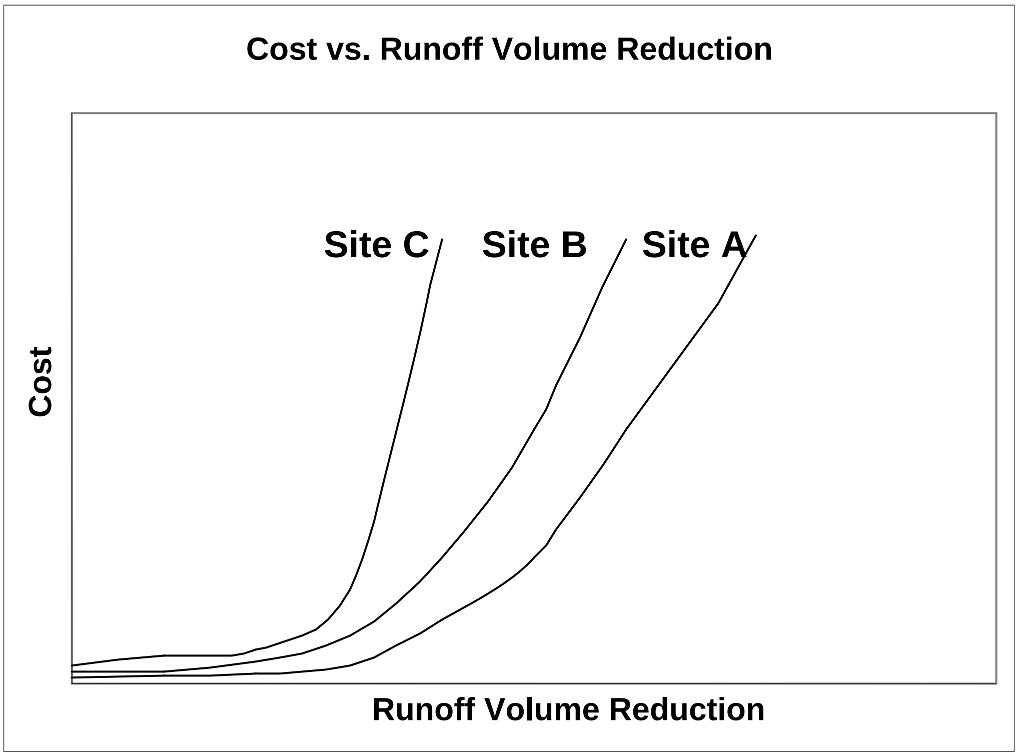
The Permit allows for LID BMPs that are correctly designed to effectively infiltrate, filter or treat runoff to be considered treatment control BMPs. LID treatment/pollution control BMPs located in jurisdictions that need to consider additional pollution reduction goals as part of a TMDL program may also include design approaches that consider design storms based on pollutagraph data and specific pollutant reduction goals of the watershed. These design approaches will be further developed in the next phase and will depend on the specific watershed and jurisdiction regulatory drivers.

The application of these regulatory driven approaches to the LID BMP design needs also to consider the specific site conditions as listed above. Sites with a greater number of constraints to increased infiltration and storage requirements will require additional engineered system components. For example, site with low permeability soils will require additional storage above the sub-soils (where appropriate). The application of LID treatment control BMPs to sites that are characterized as least favorable for infiltration BMPs, may not suitable from a cost benefit perspective when compared to other BMPs. The table below presents a possible range of site types from more (Site A) to least favorable (Site C) based on site conditions. Possible engineering solutions are listed in the table to address these constraints. The design approach to LID treatment BMPs needs to consider possible engineering solutions, however, a cost benefit analysis should be performed to compare with other possible BMPs to address water quality goals.

Site Constraints	Example Site A	Example Site B	Example Site C	Possible Engineering Components
Low Permeability Soils	√	√	√	Increase storage by increasing depth and porosity of sub-base layers and amending sub-soils (or line and drain)
Shallow Groundwater			√	Evaluate potential mounding and migration of constituents to verify BMP will not impact groundwater
Adjacent to Existing Structures		√	√	Provide underdrains and/or liners to prevent seepage from damaging existing structures
Space is Limited		√	√	Evaluate the potential to provide greater storage below ground or provide storage through green roofs, rain barrels or other rain collection techniques
Adjacent to Existing Infrastructure / Utilities	√	√	√	Provide underdrains and/or liners to prevent seepage from damaging existing structures
Proximity to Foundations			√	Provide underdrains and/or liners to prevent seepage from damaging existing structures
Potential Slope Stability Issues		√		Evaluate the potential for increased pore water pressure from increased infiltration
Presence of Expansive Soils			√	Provide underdrains and/or liners to prevent seepage from damaging existing structures. Rely on evapo-transpiration as primary function rather than infiltration.

The approach to evaluating a site for the application of LID treatment BMPs should therefore include first identifying the desired level of treatment based on the regulatory drivers. The regulatory drivers can then be used to assign a design volume or flow. Site conditions should then be assessed to determine the constraints to achieve the treatment goal. Based on the site constraints, a cost benefit analysis should then be conducted compared to other approaches to meet water quality goals. This cost benefit analysis should evaluate the increased costs to achieve higher infiltration or overall treatment volume based on site constraints. At higher treatment volumes and flows costs are likely to increase sharply at a point where significant additional engineering components are required to address existing site constraints. As shown in the figure below, this point of sharp cost increase should then be compared to other water quality treatment options where required by the specific regulatory drivers. Site with less favorable conditions (Site C) will have sharp increased costs at lower infiltration/treatment volume compared to more favorable sites (Site A). The application of LID treatment BMPs to these less favorable sites may therefore not be cost effective.

These design considerations for the application of LID BMPs should be compared to the applicable watershed and jurisdictional urban runoff management program goals and design guidelines.



Appendix 4 Technical Fact Sheets

LID site design uses planning and design strategies to minimize the quantity and improve the quality of stormwater from new development and redevelopment. The following fact sheets suggest techniques to reduce impervious surfaces, directly disconnect impervious areas from storm drains, maximize on-lot infiltration through vegetated and landscaped features, maximize multi-use open space, and minimize disturbance. Any particular design detail can make a small difference in the overall impact of a development, but when implemented with other IMPs, these details can exert a profound influence on the ability of a development to meet stormwater quality goals. These details will hopefully encourage planners, developers, engineers, and builders to utilize these opportunities to manage small quantities of runoff at many diverse locations throughout a site.

The techniques presented here are not all-inclusive, and may not be appropriate for every site or condition. The intent of these fact sheets is to encourage the use of and foster the development of alternative strategies where appropriate to reach water quality goals.

For further information regarding the techniques described below, refer to the Additional Literature Index. The sections titled Best Management Practices and Economics cover each of the techniques. The other sections in which information about a particular technique can be found are listed at the end of each fact sheet.

Please Note
All figures and illustrations are courtesy of Patric Dawe from BASMAA's "Start as the Source" Manual (1999) unless otherwise noted.

	Detention	Infiltration Practices			Filtration Practices						Reuse
Site Features and Design Objectives	Extended Detention Pond	Infil-tration Trench	Infil-tration Basin	Dry Well	Vegetated/ Rock Swale	Filter Strip	Sand Filter	Bio-retention system	Down-spout to Swale	Vegetated Roof and Walls	Cisterns and Rain Barrels
Clayey native soils	✓				✓	✓	✓	✓	✓	✓	✓
Permeable native soils	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Very steep slopes									✓	✓	
Shallow groundwater	✓				✓	✓	✓	✓	✓	✓	✓
Avoid saturation subsurface soils									✓	✓	
Connect to roof downspouts				✓	✓				✓		✓
Parking lots/ island medians					✓	✓	✓	✓			
Sites with extensive landscaping	✓		✓		✓	✓		✓			✓
Densely developed sites with limited space/landscape		✓		✓		✓	✓		✓	✓	✓
Fit BMPs into landscape and setback areas		✓			✓	✓	✓	✓			✓
Make drainage a design feature					✓	✓		✓			✓
Convey as well as treat stormwater					✓	✓			✓		

Adapted from Contra Costa's Stormwater C.3 Guidebook (2006).

Fact Sheet 1. Infiltration Trench

Infiltration trenches temporarily hold stormwater runoff within a sub-surface trench prior to infiltration into the surrounding soils. An infiltration trench is similar in function to an infiltration basin except that an infiltration basin's stored volume is held above ground, while an infiltration trench's stored volume is held below ground.

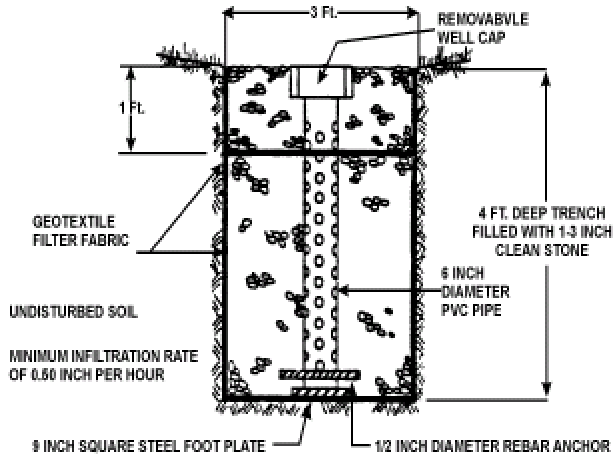


Photo: Southeastern Wisconsin Regional Planning Commission, 1991.

CHARACTERISITICS

- Runoff entering the system is stored in the void space of the aggregate material or modular cells prior to percolating into the surrounding soils
- Removes sediments and attached pollutants by infiltration through the sub-soils, reduces runoff volumes by infiltration into the sub-soils, delays runoff peaks by providing detention storage capacity and reducing flow velocities
- Surface area above the trench to be used for planting, gardens, temporary parking lots, etc.

APPLICATION

- Best suited to small residential, commercial and industrial developments with high percentages of impervious areas.
- Commonly used in conjunction with overlying permeable pavements as an effective treatment train.

DESIGN

- Typically constructed as a shallow trench filled with reservoir storage aggregate of gravel or cobbles, but can also comprise of modular plastic cells.
- The maximum contributing area to an individual infiltration trench should be less than 5 acres.
- The base of the trench must be ripped/tyned before placement of the overlying aggregate
- Soils analysis required to determine anticipated percolation rate through the sub-soil layer
- Construction phase runoff must not be allowed to enter and clog these facilities.

MAINTENANCE

- Careful site evaluation and inspection prior to construction is important for the effectiveness and longevity of the device
- Regular maintenance, including the replacement of clogged aggregate, will also increase the effectiveness and life of the trench.

- Generally, the maintenance needs of infiltration trenches is minimal, however, inadequate maintenance frequencies can result in the underlying surface soils becoming clogged.

LIMITATIONS

- Extensive geotechnical site evaluation must occur before construction to ensure that the infiltration trench will function properly without compromising groundwater, slopes, etc.
- "Infiltration BMPs" are not appropriate when:
  - The seasonal high groundwater table is within 10 feet of the base of the BMP
  - At locations where surrounding soil stratum is unstable
- exceptions to the 10 foot separation can be made when:
  - The BMP is designed with an under-drain and approved by a qualified licensed professional, or when:
  - Written approval of a separation within the interval of 4-10 feet has been obtained by the Regional Water Quality Control Board and the Department of Environmental Health.
- Generally, infiltration trenches are not suitable for: areas with heavy clay soils, exposed bedrock or shallow soils over rock or shale, steep terrain, locations with a high water table, potential salinity hazard areas, non-engineered fill or contaminated land and areas adjacent to building foundations or fill slopes.
- Upstream pre-treatment of litter and coarse sediments must be available to reduce clogging of the underlying infiltration surface (treatment train).

ECONOMICS

- Infiltration trenches are somewhat expensive, when compared to other stormwater practices, in terms of cost per area treated.
- One cost concern associated with infiltration practices is the maintenance burden and longevity. If improperly sited or maintained, infiltration trenches have a high failure rate. In general, maintenance costs for infiltration trenches are estimated at between 5 percent and 20 percent of the construction cost. More realistic values are probably closer to the 20-percent range, to ensure long-term functionality of the practice.

REFERENCES

- For more information on infiltration site selection please see the CALTRANs Infiltration Study (2003) at : http://www.dot.ca.gov/hq/env/stormwater/special/newsetup/_pdfs/new_technology/CTSW-RT-03-025/IFB_Final_Report.pdf
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- URS Australia Pty Ltd, (2004, May), Water Sensitive Urban Design: Technical Guidelines for Western Sydney, Upper Parramatta River Catchment Trust. Section 3
- US EPA (1999, September) BMP Fact Sheet 832-F-99-019. http://www.epa.gov/owm/mtb/infltrenc.pdf
- For additional information pertaining to Infiltration Trenches, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 2. Infiltration Basins

Infiltration basins are sited in either natural or excavated open areas and are designed to temporarily hold stormwater runoff prior to infiltration through the basin floor. They are similar in function to infiltration trenches except that an infiltration basin's stored volume is held above ground, while an infiltration trench's stored volume is held below ground.

CHARACTERISTICS
- Use the natural filtering ability of the soil to remove pollutants in stormwater runoff.
- Infiltration through the sub-soils serves to remove sediments and attached pollutants, reduce runoff volumes, and reduce downstream peak flows and velocities.

APPLICATION
- Most effective in removing coarse to fine sediments and attached pollutants
- Best suited to medium to large residential, commercial and industrial developments with high percentages of impervious areas.
- Best located within natural surface depressions or gullies within relatively large open areas.
- Best used in conjunction with passive recreation/green space.

DESIGN
- Can be constructed as either small or large scale devices. Small scale units are usually excavated pits or ponds, while larger scale units are typically located within natural surface depressions or gullies within the site occupying a large open area (i.e. playing field or parkland)
- Extensive site evaluation should take place to ensure that a particular site is suitable for an infiltration basin before one is constructed.
- Construction phase runoff must not be allowed to enter and clog these facilities.
- Infiltration basins typically consume about 2 to 3% of the site draining to them, which is relatively small. Additional space may be required for buffer, landscaping, access road, and fencing.
- Soils analysis required to determine the anticipated percolation rate through sub-soil layer.
- Should be constructed as part of a stormwater treatment train, with upstream pre-treatment of litter and coarse sediments
- Water quality volume determined by local requirements.
- Basin sized so that the entire water quality volume is infiltrated within 48 hours.
- Vegetation establishment on the basin floor may help reduce the clogging rate.

- Build the basin without driving heavy equipment over the infiltration surface. Any equipment driven on the surface should have extra-wide (“low pressure”) tires. Prior to any construction, rope off the infiltration area to stop entrance by unwanted equipment.
- After final grading, the infiltration surface should be tilled deeply to maximize infiltration.

MAINTENANCE

- Regular maintenance is critical to the sustained operation of infiltration basins
- Inspection and maintenance must ensure that water infiltrates into the subsurface completely and that the desired drain time is preserved.
- Drain time and vegetation must be monitored to prevent mosquito and vector habitat.
- Semiannual inspections are required to identify potential problems such as erosion of the basin side slopes and invert, standing water, trash and debris, and sediment accumulation.
- Remove accumulated sediment and regrade when the accumulated sediment volume exceeds 10% of the basin.
- If erosion is occurring within the basin, revegetate immediately and stabilize with an erosion control mulch or mat until vegetation cover is established.

LIMITATIONS

- Extensive geotechnical site evaluation must occur before construction to ensure that the infiltration basin will function properly without compromising groundwater, etc.
- “Infiltration BMPs” are not appropriate when:
  - The seasonal high groundwater table is within 10 feet of the base of the BMP
  - At locations where surrounding soil stratum is unstable
- exceptions to the 10 foot separation can be made when:
  - The BMP is designed with an under-drain and approved by a qualified licensed professional, <u>or</u> when:
  - Written approval of a separation within the interval of 4-10 feet has been obtained by the Regional Water Quality Control Board and the Department of Environmental Health.
- Generally, infiltration basins are not suitable for: areas with heavy clay soils, exposed bedrock or shallow soils over rock or shale, steep terrain, locations with a high water table, potential salinity hazard areas, non-engineered fill or contaminated land and areas adjacent to building foundations or fill slopes.
- Upstream pre-treatment of litter and coarse sediments must be available to reduce clogging of the underlying infiltration surface.

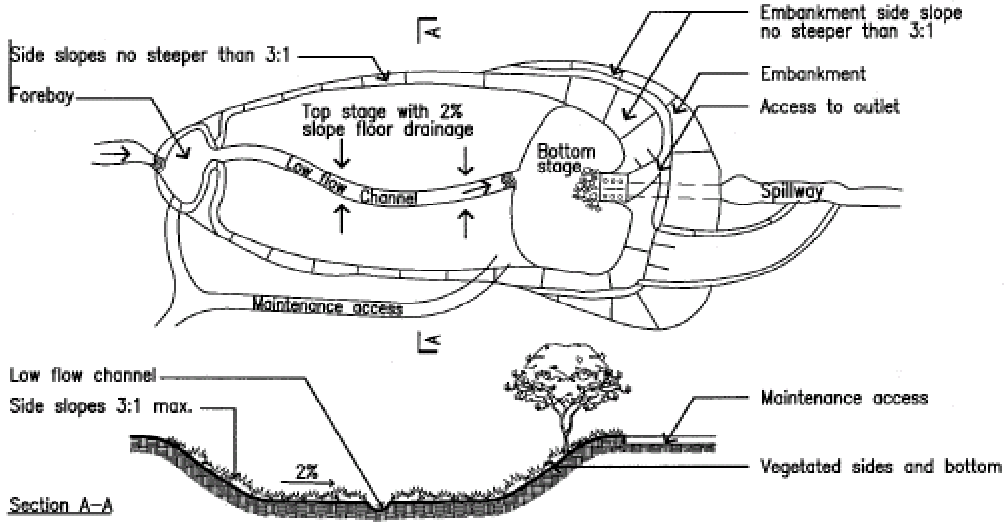
ECONOMICS

- Relatively cost-effective due to low infrastructure cost during construction.
- Land availability and cost should be taken into consideration.
- Maintenance costs are estimated at 5 to 10% of construction costs.
- If improperly maintained, infiltration basins have a high failure rate. Thus, it may be necessary to replace the basin with a different technology after a relatively short period of time.

REFERENCES

- For more information on infiltration site selection please see the CALTRANs Infiltration Study (2003) at : http://www.dot.ca.gov/hq/env/stormwater/special/newsetup/_pdfs/new_technology/CTSW-RT-03-025/IFB_Final_Report.pdf
- California Stormwater Quality Association. (2003, January) California Stormwater BMP Handbook: New Development and Redevelopment. Section TC-11
- URS Australia Pty Ltd, (2004, May), Water Sensitive Urban Design: Technical Guidelines for Western Sydney, Upper Parramatta River Catchment Trust. Section 3.
- Southeastern Wisconsin Regional Planning Commission (1991). Costs of Urban Nonpoint Source Water Pollution Control Measures. Technical Report No. 31. Southeastern Wisconsin Regional Planning Commission, Waukesha, WI.
- For additional information pertaining to Infiltration Basins, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 3. Extended detention (dry) ponds



Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Extended detention (dry) ponds store water during storms for a short period of time (from a few hours up to three days), and discharge water to adjacent surface waters. Stormwater design volumes are designed to be stored in such basins for more than 1 day to provide adequate settling time and maximize pollutant removal. The basins are dry between storms, and do not have a permanent pool of water. This tool is best suited for use as part of a treatment train in conjunction with other LID techniques.

CHARACTERISTICS

- If properly designed, ponds can have a lifetime of 50 years.
- Clay or impervious soils should not affect pollutant removal effectiveness, as the main removal mechanism is settling.
- Pollutants removed primarily through gravitational settling of suspended solids, though a small portion of the dissolved pollutant load may be removed by contact with the pond bottom sediments and/or vegetation, and through infiltration.
- Moderate removal of suspended solids (sediment) and heavy metals.
- Low to moderate removal of nutrients and Biological Oxygen Demand (B.O.D.).
- Pollutant removal can be maximized by increasing residence time; two-stage pond design, with the addition of wetland vegetation to lower stages of the pond; sediment trapping forebay to allow efficient maintenance; regular maintenance and sediment cleanout; installing adjustable gate valves to achieve target detention times; designing pond outlet to detain smaller treatment volumes (less than two-year storm event).

APPLICATION

- May be initially used as construction settling basins, but must be re-graded and cleaned out before used as a post-construction pond.
- May be designed for both pollutant removal and flood control.
- May be appropriate for developments of 10 acres or larger.

- Potential for multiple uses including flood control basins; parks, playing fields, and tennis courts; open space; overflow parking lots.

DESIGN

- Coordinate pond design, location, and use with local municipal public works department and/or county flood control department to reduce potential downstream flooding.
- Default conditions for safety have been to fence basins with chain link. Consider aesthetic design elements with safety analyst to address pond barriers, such as fencing and/or vegetation, and shallow side slopes (8:1 to 12:1).
- See County of San Diego Drainage Design Manual

MAINTENANCE

- Regular inspection during wet season for sediment buildup and clogging of inlets and outlets (designing a forebay to trap sediment can decrease frequency of required maintenance, as maintenance efforts are concentrated towards a smaller area of the basin and less disruptive than complete basin cleaning).
- Clean inlet trash rack and outlet standpipe as necessary.
- Clean out basin sediment approximately once per year (this may vary depending on pond depth and design, and if forebay is used).
- Mow and maintain pond vegetation, replant or reseed as necessary to control erosion.

LIMITATIONS

- Limitation of available space.
- Dry detention ponds have only moderate pollutant removal when compared to some other structural treatment controls and are relatively ineffective at removing soluble pollutants.
- Basins must be designed with vector control (max 72 hour residence time), sediment and vegetation removal/maintenance considerations in mind.
- Not suitable on sites with steep slopes.

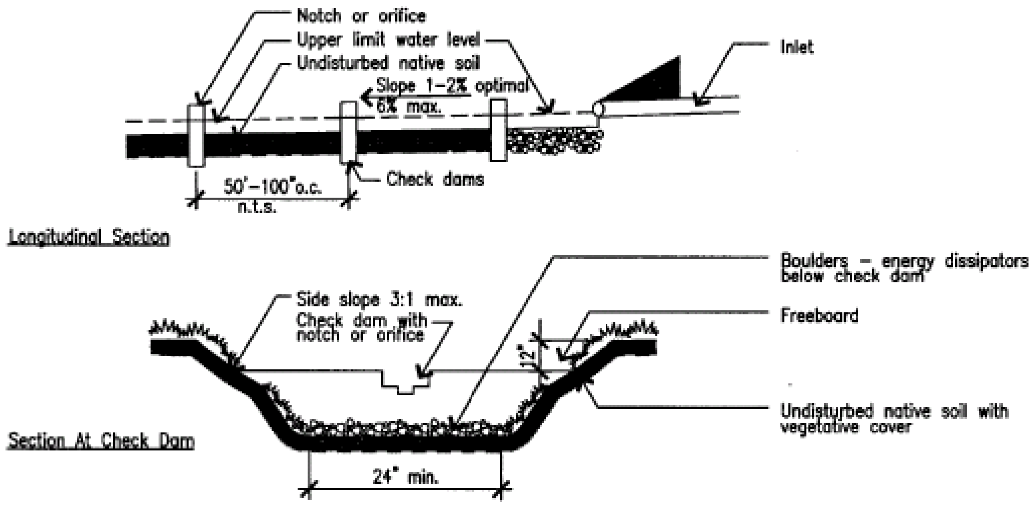
ECONOMICS

- Least expensive stormwater quality pond option available. 0-25% additional cost when added to conventional stormwater detention facilities.
- Construction cost $0.10-$5.00 per cubic foot of storage (savings from preparing silt basins used during construction for use as extended detention ponds).
- Maintenance cost 3-5% of construction cost annually.

REFERENCES

- California Stormwater Quality Association. (2003, January) California Stormwater BMP Handbook: New Development and Redevelopment.
- For additional information pertaining to extended detention ponds, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 4. Vegetated Swale / Rock Swale



Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Vegetated / rock swales are vegetated or rock lined earthen channels that collect, convey, and filter site water runoff and remove pollutants. Swales are an alternative to lined channels and pipes; configuration and setting are unique to each site.

CHARACTERISTICS

- If properly designed and maintained, swales can last for at least 50 years.
- Can be used in all soil types, natural or amended.
- When swales are not holding water, they appear as a typical landscaped area.
- Water is filtered by vegetation/rocks and pollutants are removed by infiltration into the subsurface of the soil.
- Swales also serve to delay runoff peaks by reducing flow velocities.

APPLICATION

- Swales are most effective in removing coarse to medium sized sediments.
- Parking lot medians, perimeters of impervious pavements.
- Street and highway medians, edges (in lieu of curb and gutter, where appropriate).
- In combination with constructed treatment systems or sand filters.

DESIGN

- Vegetation of each swale is unique to the setting, function, climate, geology, and character of each site and climatic condition.
- Can be designed with natural or amended soils, depending on the infiltration rate provided by the natural condition versus the rate needed to reduce surface runoff .
- Grass swales move water more quickly than vegetated swales. A grass swale is planted with salt grass; a vegetated swale is planted with bunch grass, shrubs or trees.
- Rocks, gravel, boulders, and/or cobbles help slow peak velocity, allow sedimentation, and add aesthetic value.

- Pollutant removal effectiveness can be maximized by increasing residence time of water in swale using weirs or check dams.
- Swales are often used as an alternative to curbs and gutters along roadways, but can also be used to convey stormwater flows in recreation areas and parking lots.
- Calculations should also be provided proving the swale capable of safely conveying the 100-year flow to the swale without flooding adjacent property or infrastructure.
- See County of San Diego Drainage Design Manual for design criteria. (section 5.5) http://www.sdcounty.ca.gov/dpw/docs/hydrologymanual.pdf

MAINTENANCE

- Swale maintenance includes mowing and removing clippings and litter. Vegetated swales may require additional maintenance of plants.
- Periodically remove sediment accumulation at top of bank, in swale bed, or behind check dams.
- Monitor for erosion and reseed grass or replace plants, erosion control netting and mulch as necessary. Fertilize and replace vegetation well in advance of rainy season to minimize water quality degradation.
- Regular inspections and maintenance is required during the establishment period.

LIMITATIONS

- Only suitable for grades between 1% and 6%; when greater than 2.5% should be paired with weir or check dam.
- “Turf” swales will commonly require irrigation and may not meet State water conservation goals.
- Irrigated vegetation is not appropriate in certain sites. Xeriscape techniques, natural stone and rock linings should be used as an alternative to turf.
- Wider road corridors may be required to incorporate swales.
- Contributing drainage areas should be sized to meet the stormwater management objective given the amount of flow that will be produced.
- When contributing flow could cause formation of low-flow channel, channel dividers must be constructed to direct flow and prevent erosion.

ECONOMICS

- Estimated grass swale construction cost per linear foot $4.50-$8.50 (from seed) to $15-20 (from sod), compare to $2 per inch of diameter underground pipe e.g., a 12” pipe would cost $24 per linear foot).
- $0.75 annual maintenance cost per linear foot

REFERENCES

- CALTRANS – Storm Water Handbook (cabmphandbooks.com)
- For additional information pertaining to Swales, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 5. Vegetated Filter Strips

A filter strip (or "buffer strip") is an area of either planted or native vegetation, situated between a potential, pollutant-source area and a surface-water body that receives runoff. Vegetated filter strips are broad sloped open vegetated areas that accept shallow runoff from surrounding areas as distributed sheet flow.

CHARACTERISICS

- Can serve to remove sediments by filtration through the vegetation, reducing runoff volumes, and delaying runoff peaks by reducing flow velocities.
- A properly designed and operating filter strip provides water-quality protection by reducing the amount of sediment, organic matter, nutrients and pesticides in the runoff at the edge of the field, and before the runoff enters the surface-water body.
- Filter strips also provide localized erosion protection since the vegetation covers an area of soil that otherwise might have a high erosion potential.
- Often constructed along road, parking-lot, stream, lake, pond or sinkhole boundaries, filter strips installed on cropland not only help remove pollutants from runoff, but also serve as habitat for wildlife.

APPLICATION

- Most effective in removing coarse to medium sediments and attached pollutants (such as nutrients, free oils/grease and metals).
- Typically used in conjunction with swales as an alternative to curb and gutter and can form part of a multi-use corridor.
- Typically used as a pre-treatment for other stormwater treatment devices (treatment train).

DESIGN

- The proper application of a filter strip should consider the type and quantity of the potential pollutant (sediment, nutrient, pesticide, organic matter, etc.), soil characteristics (clay and organic matter content, infiltration rate, permeability, etc.), slope steepness, shape and area of the field draining into the filter.
- Can be designed with natural or amended soils, depending on the infiltration rate provided by the natural condition versus the rate needed to reduce surface runoff .
- Most effective when used on gradually sloping areas
- The type of vegetation most suitable for the site should be decided based on soil type, potential pollutant sources/types, infiltration needs, etc.
- Once the type of vegetation is selected, soil fertility should be evaluated, and the seeding method selected.

MAINTENANCE

- Filter strips must be inspected after intense rainfall events and runoff events of long duration because small breaks in the sod and small erosion channels quickly become large problems.

- Minimize the development of erosion channels within the filter. Even small channels may allow much of the runoff from the field to bypass the filter. These areas should be repaired and reseeded immediately to help ensure proper flow of runoff through the filter.
- Periodic soil testing should occur and soil amendments should be applied as needed.
- Weeding may be necessary to reduce or eliminate weeds that could compromise the filter strip's effectiveness.

LIMITATIONS

- "Turf" buffer strips will commonly require irrigation and may not meet State water conservation goals.
- Irrigated vegetation may not be appropriate in certain sites. Xeriscape techniques, natural stone and rock linings can be used as an alternative to turf.
- Requires adequate sunlight for plant growth
- Effectiveness is dependant on soil characteristics, slope steepness, landscape shape, the ratio of the filter area to the area generating the runoff, filter width, and the type and quality of the vegetation in the filter.
- Regular inspections and maintenance is required, particularly during the establishment period.
- Requires sufficient space and designed large enough to meet the stormwater management objective given the amount of flow that will be produced.

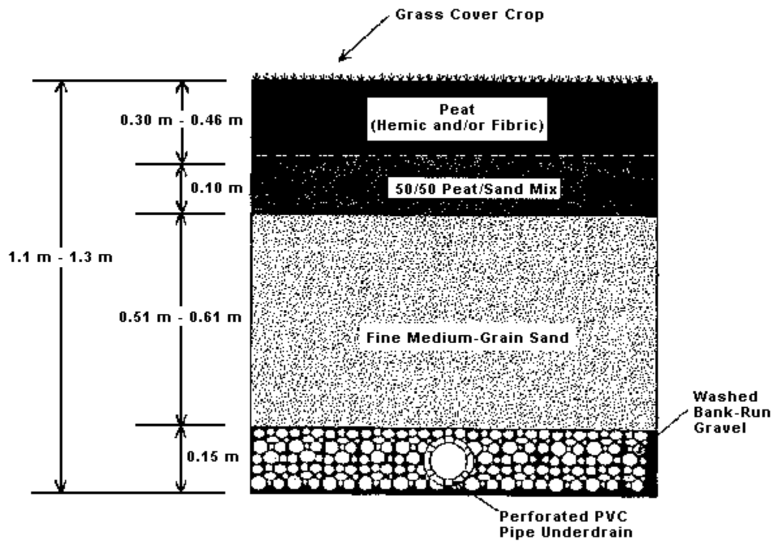
ECONOMICS

- Installation costs for filter strips may be estimated by considering the amount of grading, seeding, and establishment required for the site. Filter strip installation costs are similar to those of vegetative swales, and typically lower than costs for bioretention swales with soil amendment or sand media filtration devices (2003 CASQA Development Handbook Tables 5-4 and 5-5).

REFERENCES

- California Stormwater Quality Association. (2003, January) California Stormwater BMP Handbook: New Development and Redevelopment.
- Leeds, R., Brown, L. C., Sulc, M. R., VanLieshout, L, (n. d.) Vegetated Filter Strips: Application, Installation, and Maintenance. *Food, Agriculture and Biological Engineering*. Ohio State University Extension. http://ohioline.osu.edu/aex-fact/0467.html0
- URS Australia Pty Ltd, (2004, May), Water Sensitive Urban Design: Technical Guidelines for Western Sydney, Upper Parramatta River Catchment Trust. Section 3.
- Southeastern Wisconsin Regional Planning Commission (1991). Costs of Urban Nonpoint Source Water Pollution Control Measures. Technical Report No. 31. Southeastern Wisconsin Regional Planning Commission, Waukesha, WI.
- For additional information pertaining to Filter Strips, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 6. Sand Filters



Typical peat-sand filter cross section, Young et al., (1996)

Sand filters have proven effective in removing several common pollutants from storm water runoff. Sand filters generally control storm water quality, providing very limited flow rate control (EPA). The purpose of sand filters is to manage the first flush, which typically contains the highest concentration of pollutants. There are two basic types of Sand Filters: the "Austin" design, which receives flow from a collection point, and the "Delaware" type, which takes dispersed sheet flow. Sand filters can be constructed either open to the surface or fully underground and can have a hard bottom or be open to the soil for infiltration of the treated runoff.

CHARACTERISICS

- Effective means of filtering
- Swales and sand filters remove suspended solids, pollutants that have been adsorbed into the solids, oil and grease
- Decrease flow rate and flow velocity by retaining stormwater as it filters through.

APPLICATION

- Most effective in removing medium to fine sized sediments and attached pollutants (such as nutrients, frees/grease and metals, especially when the sand is mixed with organic mulch)
- Best suited as near source treatment measures with small catchments (<50 acres) for residential commercial and industrial developments with high percentages of impervious areas, such as parking lots, service stations, high density residential housing and roadways.
- Sand filters are appropriate for retrofitting sites with space limitations and underground installations.
- Applicable in areas where underlying soils alone cannot treat runoff adequately - or where ground water tables are high.

DESIGN

- Can be constructed as either small or large scale devices.
- Small scale sand filter units are usually located in below ground concrete pits (as residential/lot level) comprising of a preliminary sediment trap chamber with a secondary filtration chamber.
- Larger scale sand filters may comprise of a preliminary sedimentation basin with a downstream sand filter basin-type arrangement.

MAINTENANCE

- Sand filters require frequent inspection and maintenance
- Annual removal and replacement of surface filter sand
- If upstream pre-treatment of litter and coarse sediments does not occur then filter clogging could become a major maintenance issue.

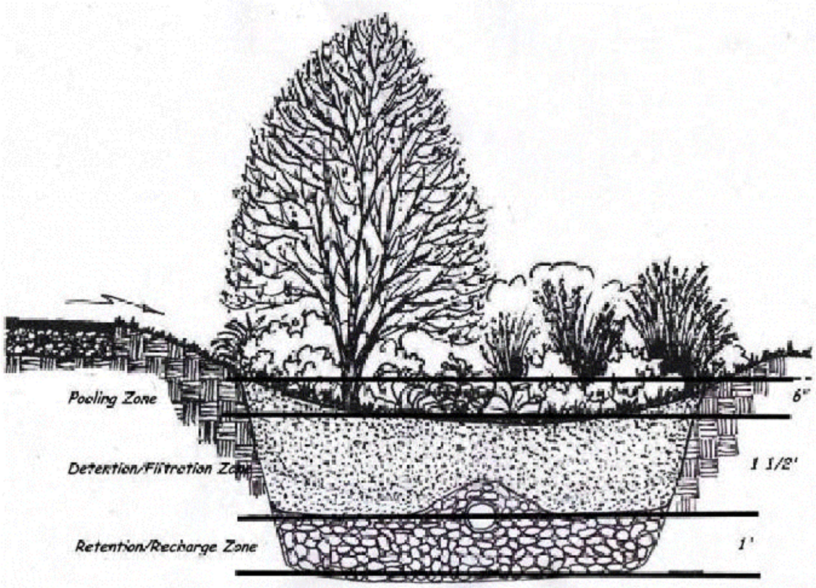
ECONOMICS

- Underground filters are generally considered to be a high-cost BMP option for water quality management. The cost of surface facilities using organic media filters is comparable to the cost of filtration facilities that use sand medium. For conceptual costing a price $3,400 to $16,000 per impervious acre served can be used to estimate the construction cost of a proposed facility, excluding real estate, design, and contingency costs (Schueler, 1994).

REFERENCES

- Young, G.K., Stein, S., Cole, P., Kammer, T., Graziano, F., Bank, F.. (1996). *Evaluation and Management of Highway Runoff Water Quality*. FHWA-PD-96-032. Federal Highway Administration, Office of Environment and Planning
- U.S. Department of Transportation, Federal Highway Administration http://www.fhwa.dot.gov/environment/ultraurb/3fs9.htm
- US EPA (1999, September) BMP Fact Sheet 832-F-99-007. http://www.epa.gov/owm/mtb/sandfltr.pdf
- Schueler, Thomas R. 1994. The importance of imperviousness. Watershed Protection Techniques 1:100-11
- For additional information pertaining to Sand Filters, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 7. Bioretention Systems



Typical Bioretention cross section, *Anatomy of a Rain Garden,* n.d.

Bioretention systems are essentially a surface and sub-surface water filtration system. In function they are similar to sand filters. Bioretention systems incorporate both plants and underlying filter soils for removal of contaminants. These facilities normally consist of a treatment train approach: filter strip, sand bed, ponding area, organic layer, planting soil, and plants.

CHARACTERISICS

- Effective in removing sediments and attached pollutants by filtration through surface vegetation, ground cover and underlying filter media layer
- Delay runoff peaks by providing retention capacity and reducing flow velocities.
- Vegetation increases aesthetic value while also enhancing filtration capacity and helping to maintain the porosity of the filter media.
- Can be constructed as either large or small scale devices, with native or amended soils.
- Small scale units are usually located in a residential planter box that filters collected stormwater through the filter media and to an outlet.
- Larger scale devices work on the same methodology, however are generally located along the streetscapes and retarding basins over large open areas.
- In addition, there are two main types of bioretention system: Non-conveyance systems, which generally pond runoff volume, and Conveyance, which generally convey minor storm events along longitudinal channels. Such conveyance systems generally include an amended soil layer under the surface for additional storage and filtration

APPLICATION

- Effective in removing medium to fine size sediments and attached pollutants (such as nutrients, free oils/grease and metals), but typically have higher pollutant

removal efficiencies for a wider range of contaminants due to enhanced filtration/biological processes associated with the surface vegetation.
- Best suited to small residential, commercial, and industrial developments with high percentages of impervious areas, including parking lots, high density residential housing, and roadways.
- Aesthetic benefits due to the surface vegetation make bioretention systems appealing for incorporation into streetscape and general landscape features.

DESIGN
- Provide a gentle slope for overland flow and adequate water storage. No water should be allowed to pond in the bioretention system for longer than 72 hours.
- Usually designed in conjunction with swales and other devices upstream so as to reduce filter clogging and provide water treatment (treatment train).
- Filter media employed is usually the plant growing material, which may comprise soil, sand and peat mixtures.
- "Planting box" type systems should be restricted to very small catchment areas.
- A subdrain system should be included in urban areas along with associated cleanout to facilitate maintenance.
- For more precise design techniques, see: CASQA (2003, January) California Stormwater BMP Handbook: New Development and Redevelopment

MAINTENANCE
- Generally, only routine periodic maintenance typical of any landscaped area (mulching, plant replacement, pruning, weeding) is necessary.
- Regular inspections and maintenance are particularly important during the vegetation establishment period.
- Routine maintenance should include a biannual health evaluation of the trees and shrubs and subsequent removal of any dead or diseased vegetation.
- Other potential tasks include soil pH regulation, erosion repair at inflow points, mulch replenishment, unclogging the under-drain, and repairing overflow structures.

LIMITATIONS
- Adequate sunlight is required for vegetation growth.
- The use of irrigation may not meet State water conservation goals. Appropriate drought-tolerant plants should be considered.
- Placement may be limited by the need for upstream pre-treatment so as to avoid filter clogging (treatment train).
- Contributing drainage area should be less than 1 acre for small-scale, on-lot devices
- Bioretention (a BMP with incidental infiltration) is not an appropriate BMP when:
    - the seasonal high groundwater table is within 6 feet of the ground surface (US EPA 1999)
    - at locations where or where surrounding soil stratum is unstable
- exceptions to the 6 foot separation can be made when:
    - the BMP is designed with an under-drain and approved by a qualified licensed professional, <u>or</u> when:

  - written approval of a separation in the interval of 4-6 feet has been obtained by the Regional Water Quality Control Board and the Department of Environmental Health.
- Site must contain sufficient elevation relief so that subdrain system may discharge to receiving swale, curb or storm drain system.

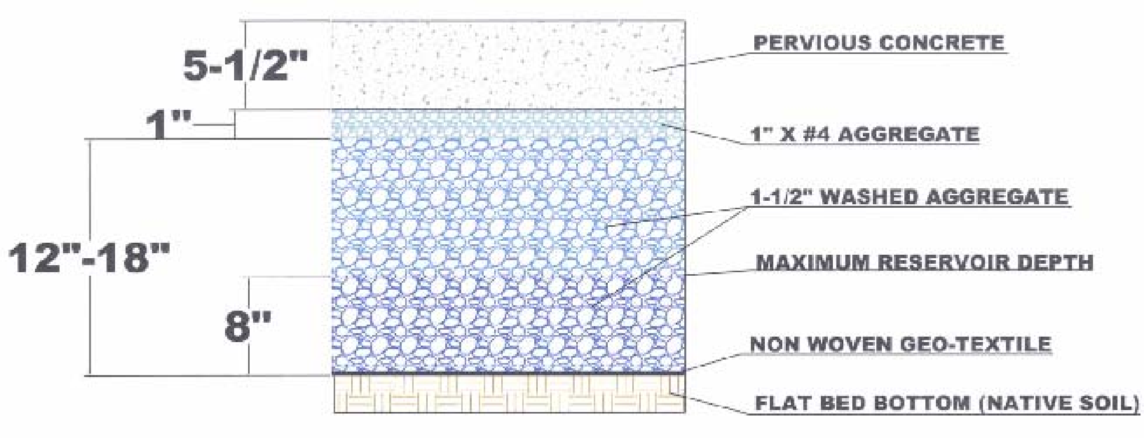
ECONOMICS

- Construction cost estimates for a bioretention area are slightly greater than those for the required landscaping for a new development (EPA, 1999).
- The operation and maintenance costs for a bioretention facility will be comparable to those of typical landscaping required for a site. (CASQA, 2003)
- Maintenance costs are projected at 5-7% of the construction cost annually.

REFERENCES

- California Stormwater Quality Association. (2003, January) California Stormwater BMP Handbook: New Development and Redevelopment.
- URS Australia Pty Ltd, (2004, May), Water Sensitive Urban Design: Technical Guidelines for Western Sydney, Upper Parramatta River Catchment Trust.
- US EPA (1999, September) BMP Fact Sheet 832-F-99-012. http://www.epa.gov/owm/mtb/biortn.pdf
- US EPA (1999, August) Preliminary Studies: Preliminary Data Summary of Urban Stormwater Best Management Practices. EPA-821-R-99-012 Part D.
- For additional information pertaining to Bioretention Systems, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 8. Pervious Concrete



From the County of San Diego, Department of General Services, Permeable Pavement Study.

Pervious concrete is suitable for light to medium duty applications such as residential access roads, residential street parking lanes, parking lots, overflow parking areas, utility access, sidewalks, bike paths, maintenance walkways/trails, residential driveways, stopping lanes on divided highways, and patios.

CHARACTERISTICS

- Rigid, poured-in-place slab.
- Appearance similar to exposed aggregate.
- Texture will vary depending on the type of screed used during installation.
- An open-graded crushed aggregate base reservoirs for water storage is a critical component of a pervious concrete installation, especially in areas with low permeability soils.
- Curb and gutter system may not be necessary to control low flow.
- Runoff coefficient: very low to nil (can infiltrate up to 140cm/hr [56"/h])
- Reduces impervious land coverage

APPLICATION

- Flat sites (slope <5%) with uniform, permeable subgrade (or appropriate depth to construct deep base).
- Terraced, flat-bottomed stone reservoirs may be used to facilitate use of pervious concrete on steeper slopes.
- Low traffic volume bikeways, streets, travel lanes, parking stalls, residential driveways, patios.
- Not appropriate for gas stations, truck stops, areas with high concentrations of hydrocarbon leaching.
- Required pre-construction fire access roads must be constructed of conventional pavements due to construction sediments/fines.

DESIGN

- Install during a late phase of construction so that runoff will not enter and clog pavement pores.

- A thin (1-2") choker course of uniformly-graded 1/2" gravel material on top of the larger 2-3"stone reservoir stone facilitates placement of the pervious concrete.
- A maximum of one hour between on-site mixing and placing pervious concrete is recommended.
- Subgrade to be moistened before concrete is placed.
- The thickness of pervious concrete installations should be determined by a civil engineer based on analyses of hydraulic and structural requirements (typically 6").
- A geotechnical engineer or other qualified, licensed professional should verify the location of a pervious concrete installation as appropriate for infiltration.
- Subgrade and base rock design must be determined by a qualified professional according to soil conditions and intended use or anticipated loads.
- Base of open-graded crushed aggregate with no fine sands. Must be designed to support surface uses, allow water to flow through, and prevent migration of subbase soils.
- Avoid usage in high traffic areas.
- Slopes should be flat or very gentle.
- Filter fabric should be placed on the bottom and sides of the subbase reservoir.
- Erosion and sediment introduction from surrounding areas must be strictly controlled during and after construction to prevent clogging of void spaces in base material and permeable surface.
- Install pervious concrete towards the end of construction activities to minimize sediment transport and clogging of pores.
- During construction, do not allow construction or heavy vehicles to traverse excavated recharge beds or areas of newly completed permeable pavement.
- During emplacement of pervious concrete, boards should be used to separate individual pours and to produce uniform seams between adjacent pours.
- The surface of each pour should be finished as soon as possible because pervious concrete can set up very rapidly in our local arid environment.
- If surface permeability becomes ineffective due to clogging or accidental paving, water directed to a rock-edge drain will allow for infiltration into subbase when designed correctly (pages 41-42 in Porous Pavements by Bruce Ferguson).
- In areas with low permeability soil, an under-drain system may be needed.

MAINTENANCE

- The overall maintenance goal is to avoid clogging of the void spaces.
- Inspect permeable asphalt and concrete several times during the first few storms to insure proper infiltration and drainage. After the first year, inspect at least one time per year.
- Permeable pavements and materials should be cleaned with a vacuum-type street cleaner a minimum of twice a year.
- Hand held pressure washers can be effective for cleaning the void spaces of small areas.
- Maintenance personnel must be educated and instructed not to seal or pave with non-porous materials.

- Damaged pervious concrete can be removed and replaced with new pervious concrete. Small areas can be replaced with conventional concrete if drained to adjacent pervious material.

LIMITATIONS

- Appropriate construction techniques are necessary to ensure performance.
- Consistent mixes are critical in multi-pour projects.
- Proper hydration is critical in San Diego region because temperatures can vary considerably during multi-pour projects that may span several days.
- Curing with secure plastic sheeting must start immediately after placement and should continue for at least seven days.
- Typically not to be applied on street where speeds exceed 30mph or streets that experience high-traffic loads.
- Not applicable where the seasonal high groundwater table is closer than 10 feet below the bottom of the gravel subbase unless designed with an under-drain.
- Pervious concrete may experience raveling if not properly hydrated and installed.
- Pervious concrete may become clogged if not protected from nearby sediment sources or when not maintained.
- Applications with under-drain systems are typically more expensive than conventional concrete.
- Pervious concrete should be avoided in drainage areas with activities that generate highly contaminated runoff.
- Avoid using pervious concrete in close proximity to underground utilities. If it is necessary to use pervious concrete in these areas, care must be taken to keep infiltrated water form migrating into utility trench bedding.

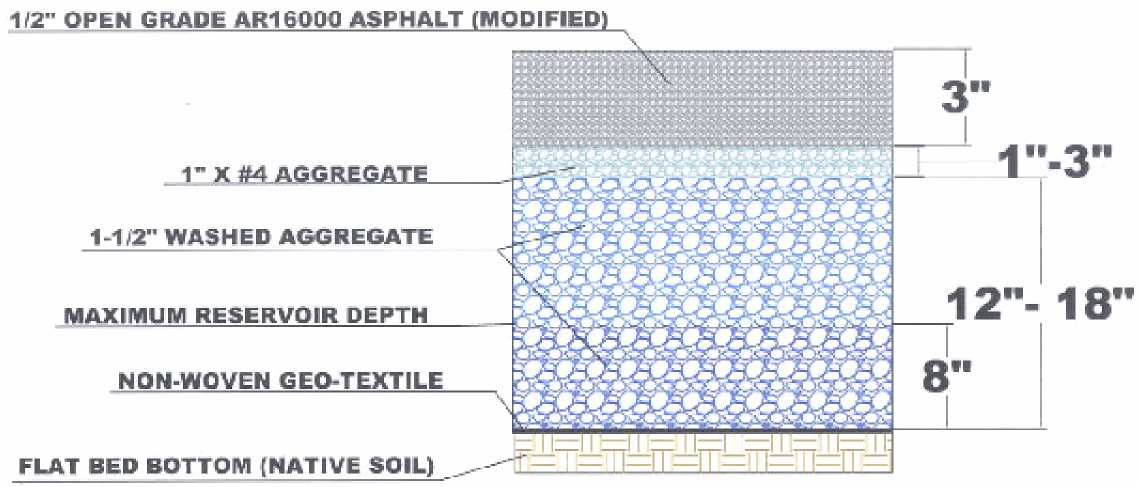
ECONOMICS

- Installation costs up to 50% greater than conventional concrete.
- Costs can be offset by savings in not installing curb and gutter drainage system.
- Maintenance cost up to 1-2% of construction cost annually.

REFERENCES

- Ferguson, Bruce K. (2005). Porous Pavements: Integrative studies in water management and land development. CRC Press, Boca Raton, Florida.
- For additional information pertaining to Pervious Concrete, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 9. Permeable Asphalt-Concrete (AC)



From the County of San Diego, Department of General Services, Permeable Pavement Study.

Permeable AC may be suitable for light to medium duty applications such as residential access roads, residential street parking lanes, parking lots, overflow parking areas, utility access, sidewalks, bike paths, maintenance walkways/trails, residential driveways, stopping lanes on divided highways, and patios.

CHARACTERISTICS

- Flexible, poured-in-place slab
- Appearance similar to conventional asphalt, though rougher surface.
- Rough, coarse surface improves traction in wet conditions, but may result in a rough ride.
- An open-graded crushed aggregate base reservoir for water storage is a critical component of a permeable AC installation, especially in areas with low permeability soils.
- Curb and gutter system may not be necessary to control low flow.
- Runoff coefficient: very low to nil (can infiltrate 50-150 cm/h [20-60"/h])
- Reduces impervious land coverage

APPLICATION

- For use in areas with mid-low traffic use, such as travel lanes, parking stalls, and especially well suited in parking lots.
- Flat sites (slope < 5%) with uniform, permeable subgrade.
- Not appropriate for gas stations, truck stops, or other areas in which hydrocarbon leaching occurs.
- Required pre-construction fire access roads must be constructed of conventional pavements due to construction sediments/fines.

DESIGN

- Install during a late phase of construction so that runoff will not enter and clog pavement pores.

- Subgrade and base rock design must be determined by a qualified professional according to soil conditions and intended use or anticipated loads.
- Base of open-graded crushed aggregate with no fine sands. Must be designed to support surface uses, allow water to flow through, and prevent migration of subbase soils.
- AC mix void content of 12-20%
- Filter fabric may be required below base course.
- Special tools are required for installation.
- Use a single size grading to provide open voids in the gravel subbase
- Erosion and sediment from surrounding areas must be strictly controlled during and after construction to prevent clogging of void spaces.
- Install permeable AC towards the end of construction activities to minimize sediment transport and clogging of pores
- During construction, do not allow construction or heavy vehicles to traverse excavated recharge beds or areas of newly completed permeable pavement.
- A qualified, licensed professional should verify the location of a permeable AC installation and subgrade preparation as appropriate for infiltration.
- Subgrade and base rock design must be determined by a qualified professional according to soil conditions and intended use or anticipated loads.
- During emplacement of permeable AC, boards should be used to separate individual pours and to produce uniform seams between adjacent pours.
- Permeable AC is stickier than conventional asphalt and a citron based releasing agent should be used to clean asphalt buildup from the supply truck bed.
- The surface of each pour should be finished as soon as possible as permeable AC can set up very rapidly in our local arid environment.
- In areas with low permeability soil, an under-drain system may be needed.

MAINTENANCE

- The overall maintenance goal is to avoid clogging of the void spaces.
- Inspect permeable AC several times during the first few storms to insure proper infiltration and drainage. After the first year, inspect at least one time per year.
- Permeable pavements and materials should be cleaned with a vacuum-type street cleaner a minimum of twice a year.
- Hand held pressure washers can be effective for cleaning the void spaces of small areas.
- Failures have been reported when pavements have been located down slope from an erosive soil and sediment is allowed to wash over the pavement. Caution must be taken during construction phase.
- Maintenance personnel must be educated and instructed not to seal or pave with non-porous materials.
- Small areas of damaged or removed permeable pavement can be repaired with conventional asphalt if drained to adjacent permeable AC.

LIMITATIONS

- Not applicable where the seasonal high groundwater table is closer than 10 feet below the bottom of the gravel subbase unless designed with an under-drain.
- Avoid using permeable pavements in close proximity to underground utilities. If it is necessary to use permeable pavements in these areas, care must be taken to keep infiltrated water form migrating into utility trench bedding.
- Permeable AC may become clogged if not protected from sediment, or when not maintained.
- Applications with under-drain systems are typically more expensive than conventional asphalt
- Permeable AC should be avoided in drainage areas with activities that generate highly contaminated runoff.

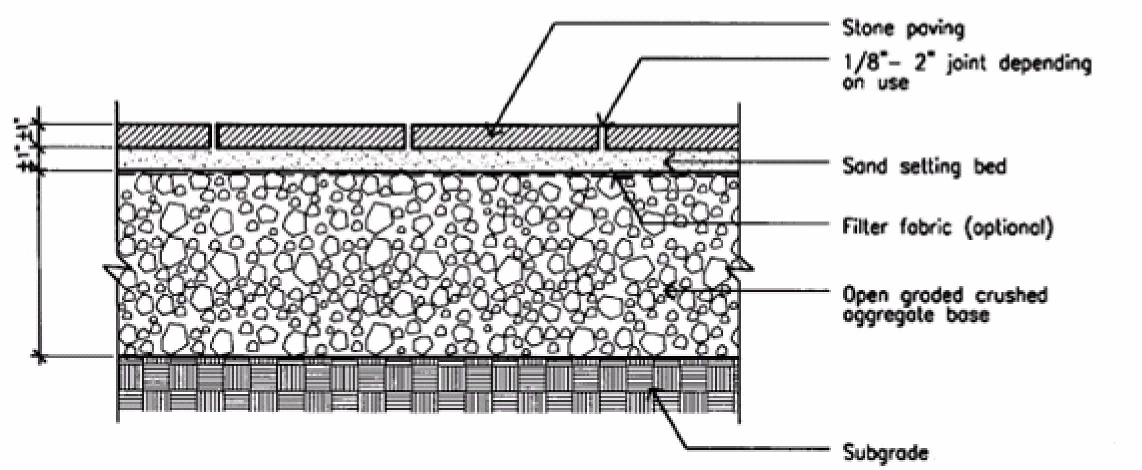
ECONOMICS

- Up to 50% more than conventional asphalt pavement.
- Costs can be offset by savings in reducing or eliminating curb and gutter drainage system.
- Maintenance cost up to 1-2% of construction cost annually.

REFERENCES

- Cahill Associates – East Whiteland Township, Chester County, PA
- Ferguson, Bruce K. (2005). Porous Pavements: Integrative studies in water management and land development. CRC Press, Boca Raton, Florida.
- For additional information pertaining to Pervious Asphalt Concrete, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 10. Unit Pavers



There are a variety of unit paver types that provide a pervious ground surface suitable for a variety of applications. Open celled unit pavers (turf block), brick paving, natural stone pavers, and solid pre-cast concrete unit pavers are all examples of unit pavers that can provide an attractive pavement with the added benefit of decreasing a development's impervious area.

CHARACTERISTICS

- Units vary in size, weight, surface characteristics, strength, durability, proportion of open area, interlocking capability, runoff characteristics, and cost.
- Units can be filled with gravel, stone, or salt grass turf.
- Turf units require deep-rooted grass species that can penetrate reservoir base course.
- Curbs and gutters are generally not necessary to control low flow.
- Runoff coefficient is generally between 0.13 and 0.8, but varies depending on rainfall intensity, joint spacing and paver type.
- Permeability is directly related to the permeability of the subgrade.
- Reduces impervious land coverage.
- Pavers are available in a variety of materials of varying colors, textures, shapes and finishes.
- Load bearing capacity is dependant upon the type of paver used.

APPLICATION

- Application varies based upon paver type.
- Areas of low flow traffic and infrequent parking such as residential driveways, overflow parking areas, fire/ emergency access roads, utility roads, pedestrian paths and jogging trails, and street shoulders are appropriate locations for turf block.

- Brick pavers, concrete pavers and natural stone pavers are generally suitable for driveways, walkways, patios, public sidewalks, parking lots, plazas, and low volume streets.

DESIGN

- Flat sites (slope < 5%) with uniform, permeable subgrade.
- To maximize permeability, use an open-graded crushed rock base course in reservoir design (not rounded pea gravels or fines).
- Subgrade must be designed for anticipated loads.
- Provide under drain system where there are no deep permeable soils.
- Avoid using permeable pavers in areas with underground utilities. If it is necessary to use permeable pavers in these areas, care must be taken to keep infiltrated water form migrating into utility trench bedding.
- Because bricks and natural stone are laid loose, the field for these pavers must be enclosed by a rigid frame. Concrete, mortared brick on a concrete grade beam, redwood header, and metal edging are commonly used.
- Erosion and sediment introduction from surrounding areas must be strictly controlled during and after construction to prevent clogging of void spaces in base material and permeable surface.
- Runoff should enter the system after pre-treatment through other treatment train controls (i.e. buffer strips, drainage swales, etc.).
- Filter fabric should be placed on the bottom and sides of the subbase layer.
- Permeable pavers should be the last element installed during construction or redevelopment.
- Utilization of correct design specifications is essential for adequate infiltration, storage, and structural integrity of permeable paving systems.
- Contractors should be trained and have experience with installation.

MAINTENANCE

- Longevity ensured by locating in low erosion conditions, quality construction, and installation of good base layer.
- Easy to repair, since units are easily lifted and reset.
- Periodically add joint material (i.e. sand) to replace material that has been moved or worn by traffic or weather.
- Occasional weed suppression may be required.
- Turf units may need occasional reseeding and have similar maintenance of a regular lawn, requiring mowing, fertilization, and irrigation.
- Concrete pavers should not be washed to remove debris and sediment in the openings between pavers, rather sweeping with suction should be utilized.
- Pavers can be removed individually and replaced when utility work is needed.
- Top course aggregate can be removed or replaced in open-celled unit paving systems if they become clogged or contaminated.
- In open-celled unit pavers, grid segments should be replaced when three or more adjacent rings are broken or damaged.
- Must not be sealed with non-porous materials.

LIMITATIONS

- Concrete block is bulkier with smaller openings for soil and infiltration. The concrete draws the moisture out of the soil which tends to dry out the grass in hot, dry weather.
- Turf swales will commonly require irrigation and may not meet State water conservation goals.
- Irrigated vegetation is not appropriate in certain sites. Gravel/rock fill may be necessary in these sites.
- Permeability is directly related to the permeability of the subgrade.
- Some paver types are not suitable for all day parking, heavy use or areas with turning movements because grass gets insufficient sun for optimal growth or is suppressed by constant abrasion.
- Avoid using permeable pavements in close proximity to underground utilities. If it is necessary to use permeable pavements in these areas, care must be taken to keep infiltrated water form migrating into utility trench bedding.
- Due to the irregular surface area that can occur with permeable pavers, permeable pavers shouldn't be considered for disabled parking spaces and walkways.
- Areas with high water tables, impermeable soil layers, or shallow depth to bedrock may not be suitable as infiltration areas with an open-graded base.
- Not recommended in areas with high grease or oil loads, such as near restaurant waste disposal areas, gas stations and truck stops.
- Not recommended in areas where high sediment loads are deposited on the surface, such as downslope of steep, erosion-prone areas.
- Modular blocks are not recommended for slopes exceeding 10 percent.

ECONOMICS

- $4-$25 per square foot, installed, depending on paver type used.
- Generally more expensive than concrete or asphalt pavements.
- 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.

REFERENCES

- Guadalupe River Project, San José, CA. Emergency access/fire lane.
- University of Miami Orange Bowl Stadium, Miami, FL. Parking lot with asphalt aisles, and turf block stalls,
- Ferguson, Bruce K. (2005). Porous Pavements: Integrative studies in water management and land development. CRC Press, Boca Raton, Florida.
- For additional information pertaining to Unit Pavers, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 11. Subsurface Reservoir Bed

From the County of San Diego, Department of General Services, Permeable Pavement Study.

Stone reservoir recharge beds underneath parking lots are beds of open-graded crushed stone that receive and store water for infiltration.

CHARACTERISTICS

- Underground system eliminates the possibilities of mud, mosquitoes and safety hazards sometimes associated with ephemeral surface drainage.
- Provides for storage of large volumes of runoff, which is directed underground by means of permeable pavements or perforated distribution pipes.
- Plastic domed stormwater chambers can be used to increase the capacity of a recharge bed.
- Constraints include soil infiltration rates, depth to water table and bedrock, and traffic type and volume.

APPLICATION

- Underneath parking lots generally in areas where land values are high and the need to control runoff is great.

DESIGN

- Recharge and storage basin of clean open-graded crushed stone with 40% void space.
- Filter fabric placed on floor and sides of recharge bed following excavation allows water to pass readily, but prevents soil fines from migrating up into rock basin, reducing effective storage area of recharge bed.
- Water can be directed to recharge beds via permeable pavement and/or a storm drain system discharging through perforated pipes.
- Soil layer of 4 feet or more with percolation rate of 0.5 inches per hour or more required; must be field tested.
- Direct all sediment-laden runoff from impervious surfaces (e.g., roof tops, roads, parking areas, walkways, etc) away from permeable pavement/recharge bed or pretreat to eliminate sedimentation.
- Prevent failures by implementing strict erosion/sediment control during construction.

MAINTENANCE

- Vacuum sweeping or pressure hosing recommended.

LIMITATIONS

- Avoid using permeable pavements in close proximity to underground utilities. If it is necessary to use permeable pavements in these areas, care must be taken to keep infiltrated water form migrating into utility trench bedding.
- Not applicable where the seasonal high groundwater table is closer than 10 feet below the bottom of the gravel subbase unless designed with an under-drain.

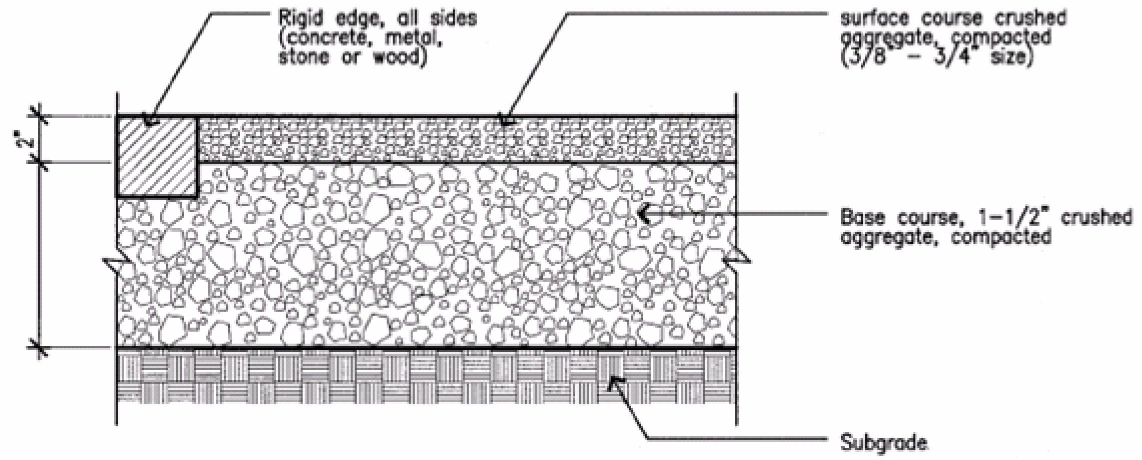
ECONOMICS

- Accurate economic data pertaining to the use of subsurface reservoir beds is currently unavailable, however, site specific cost records can be found in the LID Literature Index.

REFERENCES

- Morris Arboretum, Philadelphia, PA.
- Automatic Data Processing corporate offices, Philadelphia, PA.
- Ferguson, Bruce K. (2005). Porous Pavements: Integrative studies in water management and land development. CRC Press, Boca Raton, Florida.
- For additional information pertaining to Permeable Pavement Recharge Beds, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 12. Crushed Aggregate (gravel)



A variety of crushed aggregates, generally known as gravel, can be used to form a permeable pavement. Found in a variety of settings ranging from Parisian cafes to Japanese ceremonial gardens to rural roadways, crushed aggregate is a versatile, economical permeable pavement material with a long history of use.

CHARACTERISTICS

- A granular material, crushed aggregate can be laid in any shape field or configuration.
- Runoff coefficient: 0.10 – 0.40". Pavements of fine crushed stone (e.g. decomposed granite fines) are relatively impermeable. Permeability increases with larger aggregate sizes. Open-graded mixes are more permeable than mixes that include fines.
- Easy to install.
- Reduces impervious land coverage.

APPLICATION

- Low volume and low speed vehicle traffic areas.
- Parking stalls, private driveways, walkways, and patios.
- Areas of low erosion.
- Not appropriate for ADA-compliant accessible paths of travel.
- Flat sites (slope < 5%) with uniform, permeable subgrade.

DESIGN

- Because the aggregate is laid loose, the field must be enclosed by a rigid frame in most applications. Concrete, mortared brick on a concrete grade beam, redwood header, and metal edging are commonly used.
- To maximize permeability, use an open-graded crushed rock base course (not rounded pea gravels or fines).
- In areas with pedestrian traffic, use smaller aggregate (3/8" size). Larger aggregate (3/4" size) makes a better driving surface.

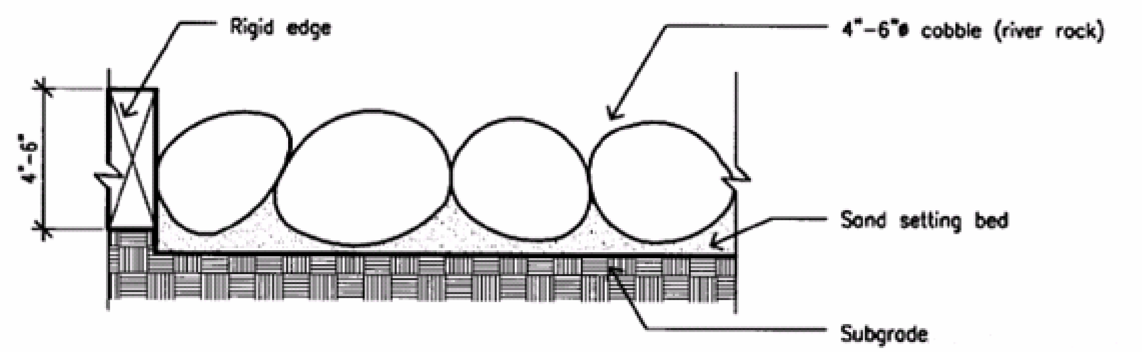
MAINTENANCE
- Longevity ensured by locating in low erosion conditions, quality construction, and installation of good base layer.
- Easy to repair since aggregate is easily re-graded and replenished.
- Occasional weed suppression may be required.
- To maximize permeability, minimize compaction of subgrade.
- Periodic and/or replenishing, raking of displaced gravel may be required.

LIMITATIONS
- Dust Control
- Not appropriate for ADA-compliant accessible paths of travel.
- Restrict heavy vehicle and equipment loading to prevent compaction of underlying soils when not used in conjunction with the recommended base course.
- Because the aggregate is laid loose, the field must be enclosed by a rigid frame in most applications.
- Avoid using permeable pavements in close proximity to underground utilities. If it is necessary to use permeable pavements in these areas, care must be taken to keep infiltrated water form migrating into utility trench bedding.

ECONOMICS
- Less expensive than conventional asphalt or concrete pavement.
- Least expensive of all pavements, ranging from $1 to $3 per square foot.
- Reduced impervious land coverage reduces or eliminates need for catch basins/ underground storm drain system.

REFERENCES
- Ferguson, Bruce K. (2005). Porous Pavements: Integrative studies in water management and land development. CRC Press, Boca Raton, Florida.
- For additional information pertaining to Crushed Aggregate, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 13. Cobbles



Larger granular materials are known as cobbles. 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.

CHARACTERISTICS

- Can be laid in a field of any shape or configuration with or without base.
- Material varies in color, shape, and size.
- Runoff coefficient: 0.60 – 0.90"; higher for larger sizes.
- Easy to install.
- Reduces impervious land coverage.

APPLICATION

- Commonly used around bases of trees in lawn areas and garden areas
- Commonly used in parkway planter strips and median islands.
- Commonly used with decorative mulch in landscaped areas.

DESIGN

- Rigid edges such as concrete, brick, wood or metal band is useful to keep cobbles in place.
- To maximize permeability, use an open-graded crushed rock base course (not rounded pea gravels or fines).
- Diameters range from 4" to 8".
- A permeable filter fabric may be provided under the cobbles to suppress weeds and minimize migration of soil.

MAINTENANCE

- Periodic weed suppression may be required.
- Resetting or replacement of cobbles may be required periodically.

LIMITATIONS

- Not suitable for walkway surface or vehicular traffic

- Labor intensive to install because they have to be set individually
- Resetting or replacement of cobbles may be required
- Weed growth and sediment accumulation can impede permeability

ECONOMICS

- Easy to remove/reinstall
- Cost varies widely depending on material. Washed river rock is less costly than angular granite cobbles.

REFERENCES

- Ferguson, Bruce K. (2005). Porous Pavements: Integrative studies in water management and land development. CRC Press, Boca Raton, Florida.
- For additional information pertaining to Cobbles, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 14. LID Street Design

Streets and roads account for a significant portion of the impervious coverage in a given area and are one of the largest contributors to stormwater and pollutant runoff. LID techniques strive to reduce this impact by reducing impervious coverage and maximizing storm water infiltration and pollutant uptake.

CHARACTERISITCS

- Employs alternatives that reduce impervious coverage, such as reducing the length of the road network by exploring alternative street layouts.

APPLICATION

- Multiple techniques with a variety of applications can be utilized to achieve the goal of reducing impervious coverage and reducing pollutant runoff.
- Both city and rural streets have the potential for application of multiple LID techniques.
- Some possible applications include changes to road layout, street width, cul-de-sac design, use of permeable materials, utilization of traffic calming features as sites for LID components, curb-cuts, street-side swales, concave medians, as well as a number of others.

DESIGN

- Reduce the length of residential streets by reviewing minimum lot widths and exploring alternative street layouts
- Clustering homes and narrowing lot frontages can reduce road length by reducing the overall development area.
- Another approach is to lengthen street blocks and reduce cross streets, providing pedestrian and bicycle paths mid-block to increase access.
- When siting streets, consider natural drainage patterns and soil permeability.
- Consider access for large vehicles, equipment, and emergency vehicles when designing alternative street layouts, widths, and cul-de-sacs.
- Consider emergency access requirements and curve and sight distance requirements

MAINTENANCE

- Narrower streets should cost less to maintain than wider streets as they present less surface area to maintain and repair.
- Landscaped and bioretention cul-de-sacs and traffic calming areas will require routine maintenance associated with these areas.

LIMITATIONS

- Local zoning standards may require wide streets, sidewalks on one or both sides of streets, and curbed roads.

- Local zoning standards will also determine what other techniques may or may not be applicable.
- Arterial, collector and other street types with greater traffic volumes are not candidates for narrower streets.
- Street width and turnaround design need to accommodate emergency vehicles.

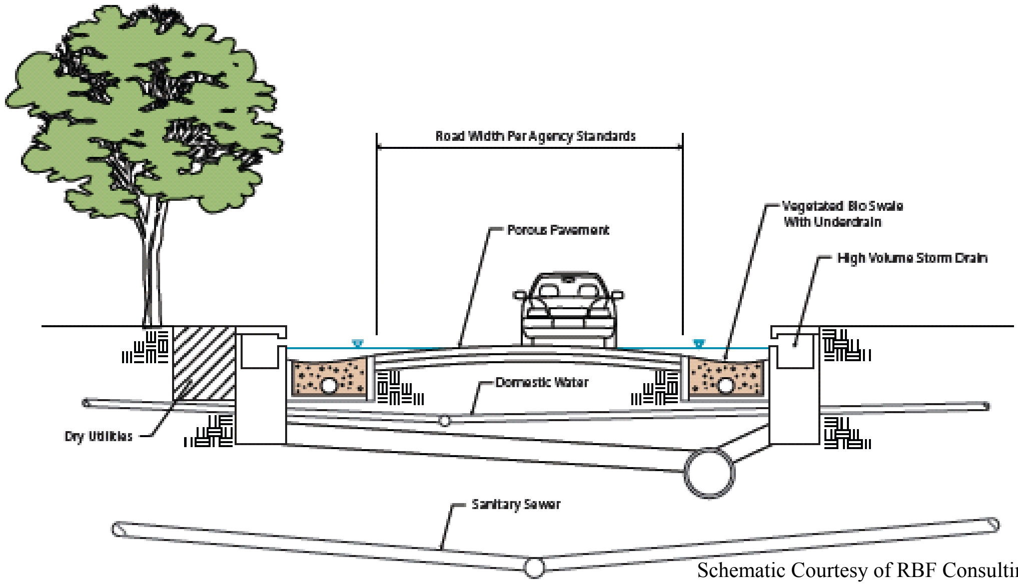
ECONOMICS

- Costs will vary based upon the techniques applied at each given location.
- Costs are also dependant on whether the application is a retro-fit or new construction.

REFERENCES

- Kennedy/Jenks Consultants (2005, August) Truckee Meadows, NV Low Impact Development Handbook: Guidance on LID Practices for New Development and Redevelopment http://www.cityofreno.com/gov/pub_works/stormwater/management/land_use/
- City of Seattle street natural drainage systems: http://www.seattle.gov/util/About_SPU/Drainage_&_Sewer_System/Natural_Drainage_Systems/index.asp
- For additional information pertaining to LID Street Design, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 15. Public Road Standard



Schematic Courtesy of RBF Consulting

CHARACTERISTICS

- Sidewalks are provided on one or both sides of the street depending on adjacent land uses, pedestrian needs.
- Parkway on one or both sides can be used for planting and surface drainage (for flat slopes).
- Road is crowned to the gravel shoulders or swale on each side before flowing into underground storm drain.
- Reduces sediment, oil and grease, and hydrocarbons when combined with biofilters and swales.

APPLICATION

- Appropriate for areas where traffic volumes are at or between 750-2,500 ADT.
- Grid street systems and loop road are most appropriate for non-circulation element roads.
- May not be appropriate for long cul-de- sac streets or hillside sites with high fire risks.

DESIGN

- Construction detailing same as typical street standard.
- Coordinate with local and regional zoning ordinances and public works standards.
- Streets with special uses, such as bike routes, may require additional pavement width.
- Depending on topography, parkway strip can be designed as a linear swale/ biofilter with curb openings directly into swale.

MAINTENANCE

- Standard street maintenance practices required.
- Parkway strip between curb and sidewalk requires mowing, tree care. This can be the responsibility of the local jurisdiction or the adjacent property owner depending on local codes and ordinances.

LIMITATIONS

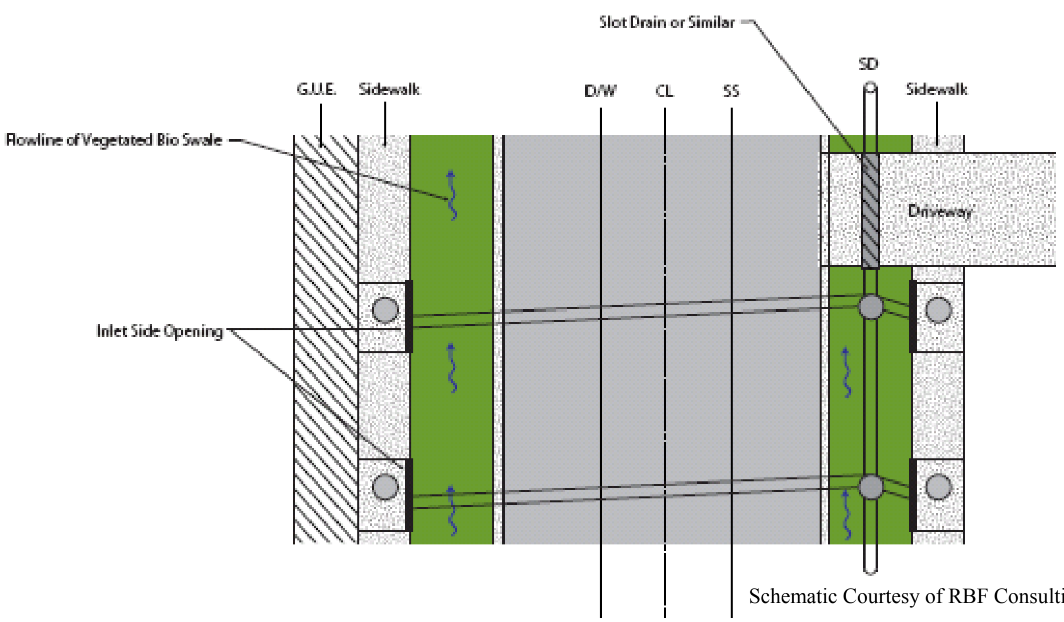
- Feasibility and amount of application is dependant upon local zoning standards
- May not be appropriate for long cul-de- sac streets or hillside sites with high fire risks (because of the potential of shared moving space to be blocked by a single vehicle, with no alternate emergency route).

ECONOMICS

- Narrower street section reduces initial construction costs.
- Increased parkway adds additional landscape maintenance cost, especially compared with conventional street section without a parkway strip.
- Properties on narrower streets with tree-lined landscaped parkways typically command higher values than those on wider treeless streets.

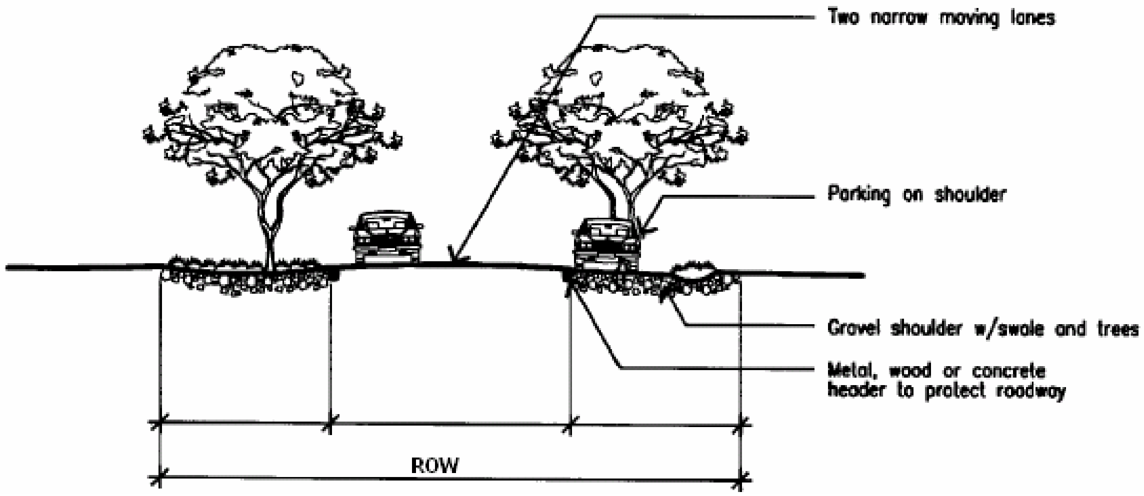
REFERENCES

- Spielberg, F., Chellman, C. E., (1997, June) *Traditional Neighborhood Development Street Design Guidelines*. Institute of Transportation Engineers (ITE) Transportation Planning Council Committee 5P-8. http://findarticles.com/p/articles/mi_qa3734/is_199706/ai_n8770782
- Skinny Streets program, Portland, OR.., Velarde, Loreto Streets, Mountain View, CA.
- For additional information pertaining to Public Road Standards, see the works cited in the San Diego County LID Literature Index and the County of San Diego Department of Public Works Public Road Standards.



Schematic Courtesy of RBF Consulting

Fact Sheet 16. Private Road Standard



Standard Private Roads have 24' two-lane paved roadway with no curb or gutters. Gravel or crushed aggregate shoulders act as a drainage way and parking area.

CHARACTERISTICS

- Vehicles tend use the center of the narrow paved roadway.
- Permeability: Road is crowned to the gravel shoulders on each side. Pavement width allows for shoulder on one or both sides that can be used for planting and surface drainage (for flat slopes).
- Reduces impervious land coverage.
- Reduces sediment, oil and grease, and hydrocarbons when combined with biofilters and swales.

APPLICATION

- Appropriate for areas where traffic volumes are at or below 500-750 ADT and speeds between 15 to 25 mph.
- May not be appropriate for long cul-de- sac streets or hillside sites with high fire risks.
- Rural standard presents a more informal aesthetic and is suitable for less urban locations.

DESIGN

- Roadway edge protection can be achieved by flush concrete bands, steel edge, or wood headers.
- Depending on topography, gravel shoulder can be designed as a linear swale/biofilter with water sheet flowing directly into swale.
- Parking can be allowed only on one side to preserve a wider moving space for emergency vehicles. Parking restrictions may be required by the local fire authority.
- If catch basins are used, provide settlement basin before inlet or raise inlet above bottom of swale, to prevent sediment from filling catch basin.

MAINTENANCE

- Gravel shoulders require periodic regrading and replenishing.
- Elimination of curb means that conventional street sweeper machinery cannot be used.
- Landscaped shoulder with surface storm drain elements requires maintenance. This is the responsibility of the property owner.

LIMITATIONS

- Only appropriate where traffic volumes are low and speeds slow.
- May not be appropriate for long cul-de- sac streets or hillside sites with high fire risks

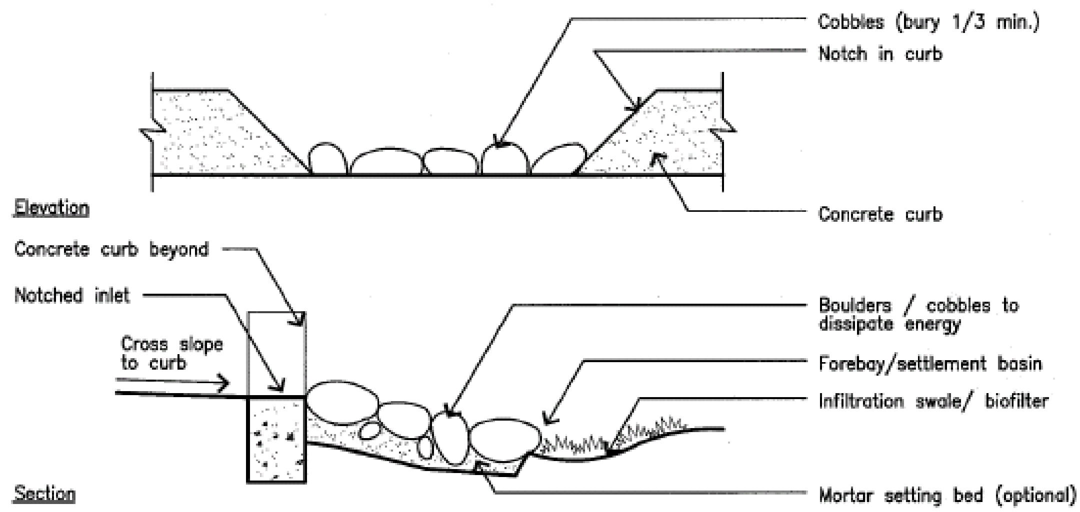
ECONOMICS

- Narrower street section and elimination of curb and gutter reduces initial street construction costs significantly.
- Landscaped shoulder with surface storm drain elements adds moderate landscape maintenance cost.
- Properties on narrower streets with tree-lined landscaped parkways typically command higher values than those on wider treeless streets.

REFERENCES

- Spielberg, F., Chellman, C. E., (1997, June) *Traditional Neighborhood Development Street Design Guidelines.* Institute of Transportation Engineers (ITE) Transportation Planning Council Committee 5P-8. http://findarticles.com/p/articles/mi_qa3734/is_199706/ai_n8770782
- Skinny Streets program, Portland, OR.
- Residential streets, Atherton, CA.
- For additional information pertaining to Private Road Standards, see the works cited in the San Diego County LID Literature Index and the San Diego County Standards for Private Roads (DPW).

Fact Sheet 17. Curb-cuts



Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

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 lined with ground cover or gravel/rock and gently sloped, these swales function as biofilters. 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.

<u>Urban curb/swale</u> systems are a hybrid of standard urban curb and gutter with a more rural or suburban swale drainage system. It provides a rigid pavement edge for vehicle control, street sweeping, and pavement protection, while still allowing surface flow in landscaped areas for stormwater quality protection.

CHARACTERISTICS

- Runoff travels along the gutter, but instead of being emptied directly into catch basins and underground pipes, it flows into surface swales.
- Stormwater can be directed into swales either through conventional catch basins with outfall to the swale or notches in the curb with flow line leading to the swale.
- Swales remove dissolved pollutants, suspended solids (including heavy metals, nutrients), oil and grease by infiltration.

APPLICATION

- Can be created in existing and new residential developments, commercial office parks, arterial streets, concave median islands.

- Swale system can run either parallel to roadway or perpendicular to it, depending on topography and adjacent land uses.

DESIGN
- Size curb-openings or catch basins for design storm.
- Multiple curb openings closely spaced are better than fewer openings widely spaced because it allows for greater dissipation of flow and pollutants.
- Provide energy dissipaters at curb notches or catch basin outfall into swale.
- Provide settlement basin at bottom of energy dissipater to allow for sedimentation before water enters swale.
- Curb cuts should be at least 12 inches wide to prevent clogging.
- Curb cuts should have a vertical drop in addition to sufficient width to prevent clogging.

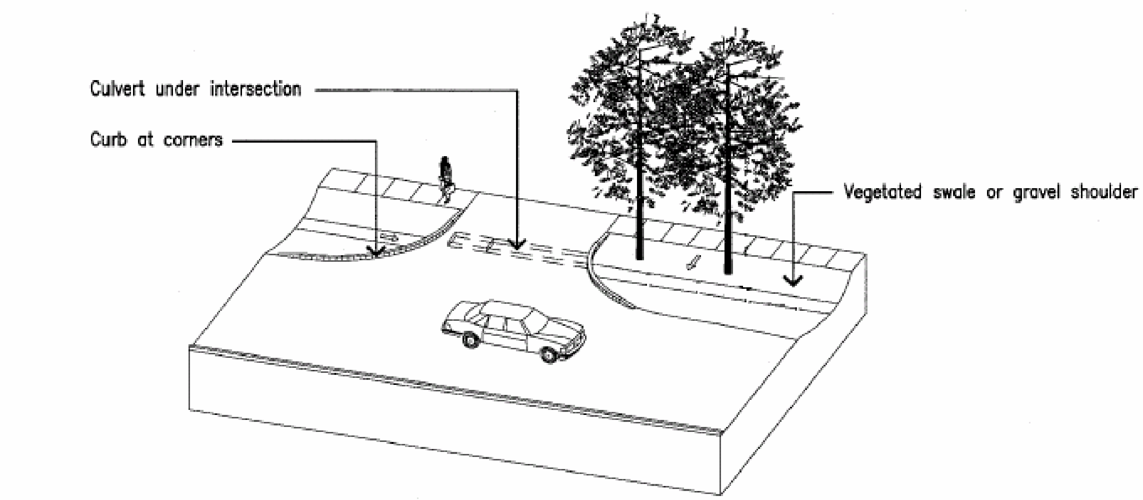
MAINTENANCE
- Annual removal of built-up sediment in settlement basin may be required.
- Catch basins require periodic cleaning.
- Inspect system prior to rainy season and during or after large storms.

LIMITATIONS
- Parking requirements and codes

ECONOMICS
- Cobble-lined curb opening may add marginal cost compared to standard catch basin.
- Swale system requires periodic landscape maintenance.

REFERENCES
- Village Homes subdivision, Davis, CA. Residential street network,
- Folsom, CA. Dual-drainage system,
- For additional information pertaining to Curb-cuts, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 18. Rural Swale Systems



Rural swale systems are a combination of street design elements that allow for surface drainage while simultaneously protecting the roadway edge, organizing parking, and allowing for driveway access and pedestrian circulation. Generally consist of street sheet flows being directed to a vegetated swale or gravel shoulder, curbs only at street corners, and culverts under driveways and street crossings

CHARACTERISTICS

- Shoulder can be designed to accommodate parking or to serve as a linear swale, permitting infiltration of stormwater along its entire length.
- Runoff from the street is not concentrated, but dispersed along its entire length, and build-up of pollutants in the soil is minimized.

APPLICATION

- Differing systems can be applied depending on the local characteristics, needs and zoning standards.

DESIGN

- Concrete curb and gutter not required.
- Ensure that culverts under intersections drain, to avoid standing water and resulting septic condition.
- For steeper slopes, roadside swales should be protected to minimize erosion.
- Provide concrete curb at intersection radii to protect roadway edge and landscape area from turning movements.
- Crown street to direct runoff to shoulders. If drainage is provided on one side only, then provide cross-slope towards swale.
- Protect pavement edge with rigid header of steel, wood or a concrete band poured flush with the street surface.

- If parking is not desired on the shoulder, no parking signs and striping can be used.
- Central medians can be used to divide traffic for safety or aesthetics.

MAINTENANCE

- Surface systems require periodic maintenance and inspection.
- Maintenance for surface systems is different than most urban Public Works Departments currently practice, and employee retraining may be required.
- Surface drainage systems are easier to monitor and clear than underground systems, because problems, when they occur, are visible and on the surface. This eliminates the need for subsurface inspection or street excavation.

LIMITATIONS

- Design and scope is dependant upon local conditions and zoning standards.

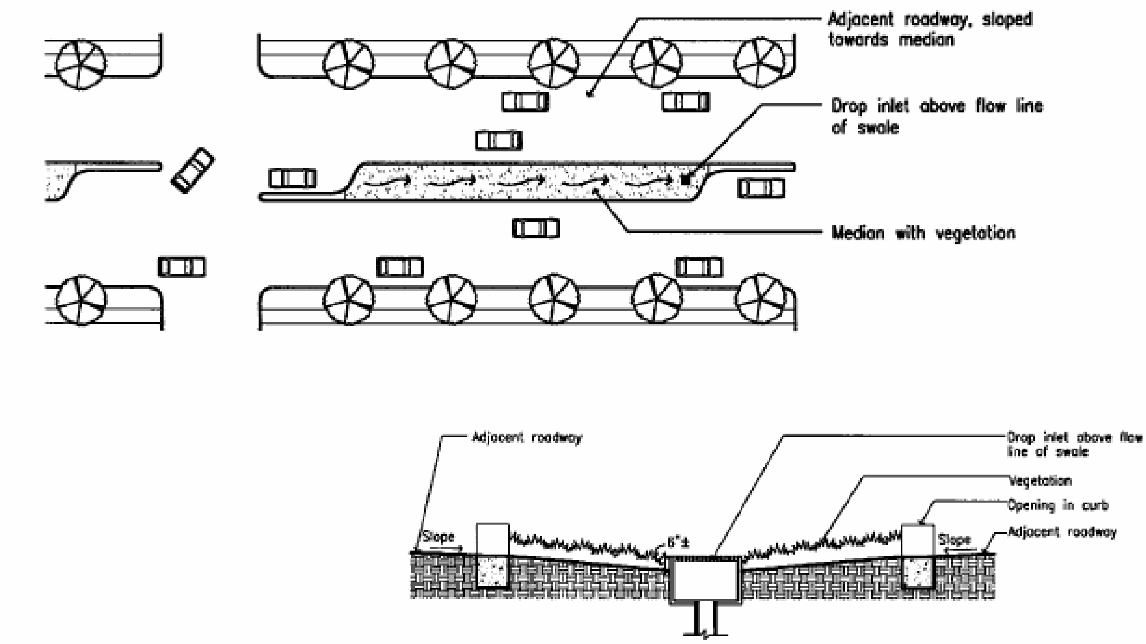
ECONOMICS

- Surface swales are less costly to install than underground pipe systems, but may have higher on-going maintenance costs.

REFERENCES

- City of Folsom, CA.
- For additional information pertaining to Rural Swale Systems, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 19. Concave Median



Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Conventional medians are normally designed as a convex surface to shed water onto adjacent pavement and into a curb and gutter system. Concave medians reverse this relationship by depressing the median surface slightly depressed below the adjacent pavement section and designing the median to receive runoff.

CHARACTERISTICS

- Provides safety and aesthetic functions of traditional convex medians while accommodating stormwater infiltration.
- Helps to disconnect impervious street surface from storm drain system by directing street runoff into landscaped or aggregate-filled median for infiltration.
- Can be designed as a landscaped swale or turf-lined biofilter to treat first-flush runoff, which carries a high concentration of oils and other pollutants off the street.

APPLICATION

- Can be applied where new roads are being constructed or current roads can be retrofitted.
- Applicable on roadways where a traditional median might normally occur

DESIGN

- Adjacent roadway design must provide cross-slope into medians.
- Runoff from street can be directed into swale by sheet flow or curb inlets.
- Concave medians must be sized to accommodate the water quality volume, and planting must be designed to withstand periodic inundation.
- For steeper slopes, concave medians should be protected to minimize erosion.

- Catch basin and underground storm drain system may be required for high flows, depending on the available area for infiltration and retention.
- Set catch basin rim elevations just below the pavement elevation, but above the flow line of the infiltration area so that the water quality volume will collect in the swale before overflowing into the underground system.
- Can be constructed in either natural or amended soils, depending on the infiltration rate provided by the natural condition versus the rate needed to reduce surface runoff sufficiently.

MAINTENANCE

- Landscaped concave medians have maintenance requirements similar to landscaped convex medians.
- Some maintenance staff retraining may be required to facilitate maintenance of swales or other stormwater detention elements.

LIMITATIONS

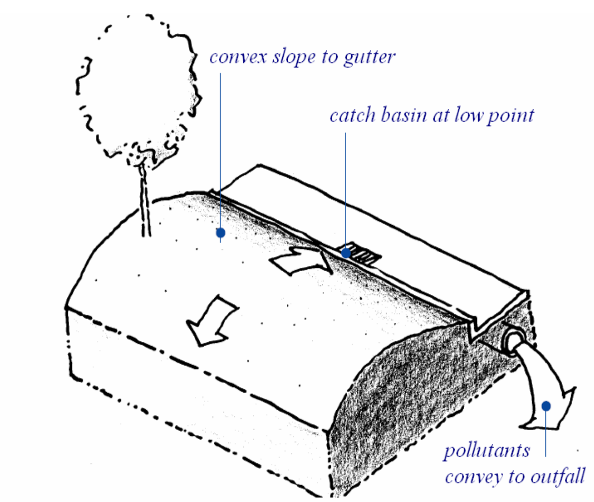
- Plant species suited for concave medians depends upon water availability and frequency of rainfall and tend to be similar to those used for other vegetated swales.
- Irrigated vegetation may not be appropriate in certain sites. Xeriscape techniques, natural stone and rock linings can be used as an alternative to turf.

ECONOMICS

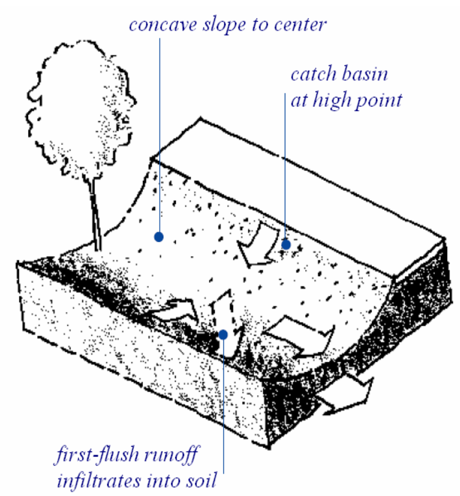
- Costs are similar to convex landscaped medians.

REFERENCES

- For additional information pertaining to Concave Medians, see the works cited in the San Diego County LID Literature Index.



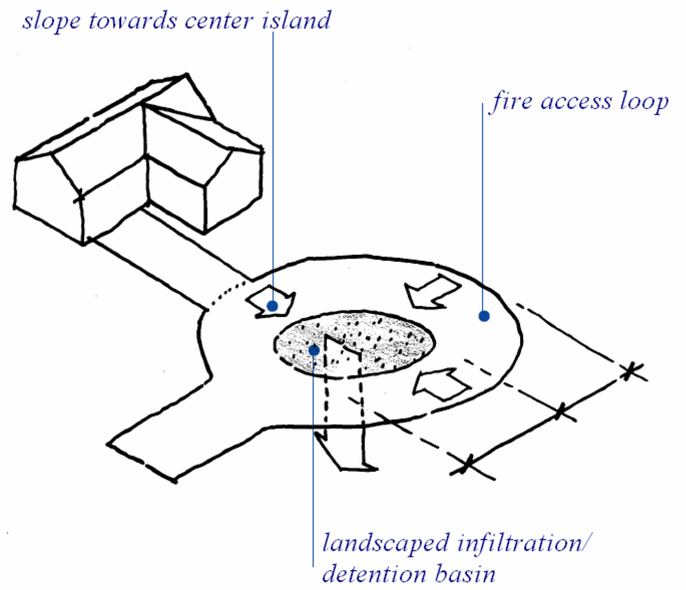
Conventional median design: convex surface



Concave median

Fact Sheet 20. Cul-de-sac Design

A landscaped area in the center of a cul-de-sac can reduce the impervious land coverage and can reduce and treat runoff through the use of bioretention and/or well draining soils. Design of a landscaped cul-de-sac must be coordinated with fire department personnel to accommodate turning radii and other operational needs (County of San Diego Consolidated Fire Code).



CHARACTERISTICS

- Conventional cul-de-sacs are paved across their entire diameter. This large impervious area increases runoff and creates a heat island at the front of adjacent land uses.
- A turnaround with a central concave landscaped space or other pervious surface can meet fire department access requirements and create an opportunity for stormwater infiltration or detention.
- A landscaped area in the center of a cul-de-sac can reduce impervious land coverage, while maintaining the required turning radius.

APPLICATION

- Appropriate for cul-de-sac streets in residential, commercial, and institutional settings.

DESIGN

- Street termination requires turnaround area large enough to accommodate large trucks.
- Some local fire departments may require the center landscaped area to accommodate fire trucks. This can be achieved by providing a permeable load bearing surface.
- Asymmetrical cul-de-sac design is more rural than conventional round cul-de-sac design.
- Curb with slots may be needed to allow run-on from the street while keeping vehicles off landscaping.

MAINTENANCE

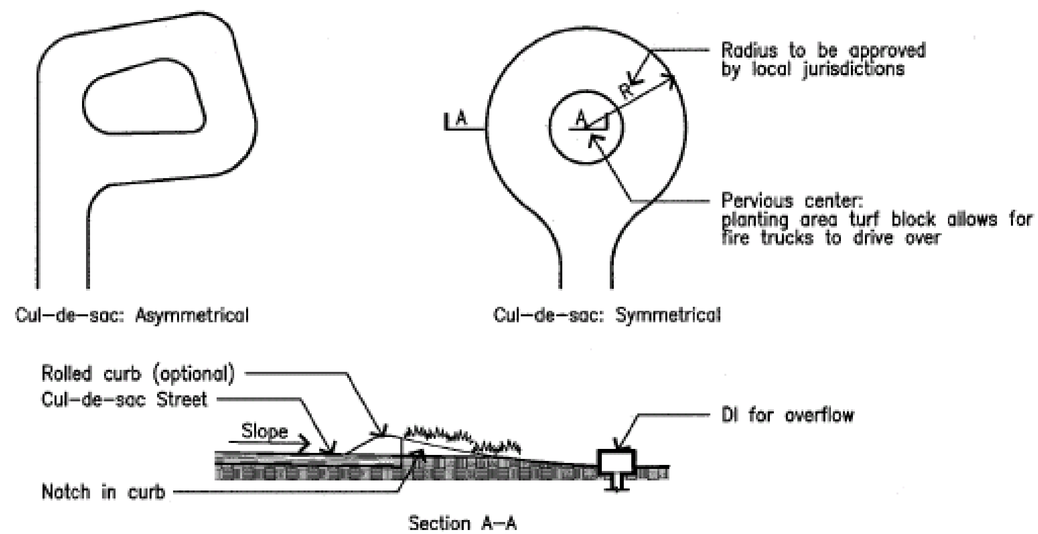
- Similar to other planted medians.

LIMITATIONS

- Practicality and design are dependant upon local zoning standards and the specific characteristics of any given proposed site.
- Must be large enough to meet fire and other emergency standards

ECONOMICS

- Cost of extending storm drain the length of the cul-de-sac may outweigh the savings gained from reduction of paved area.
- Landscaping in center island may add costs for planting, and periodic maintenance.

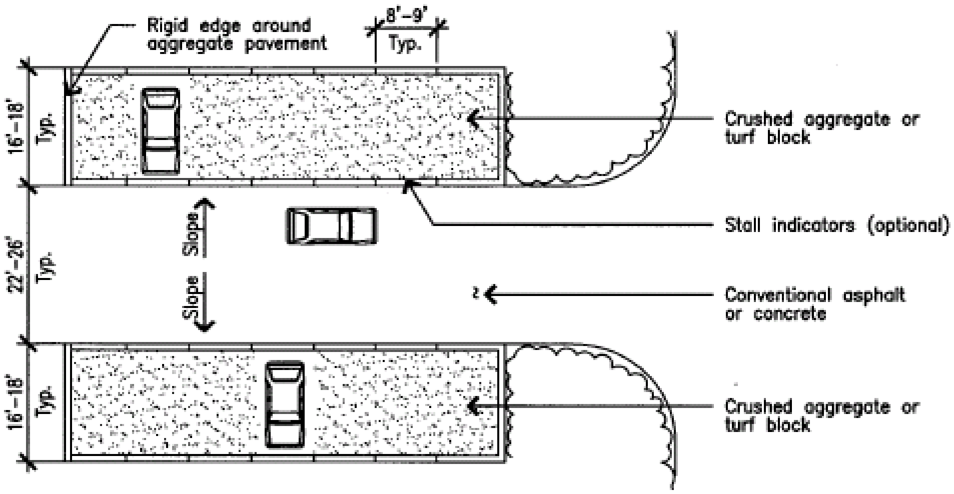


Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

REFERENCES

- For additional information pertaining to Cul-de-sac Design, see the works cited in the San Diego County LID Literature Index.
- Section 902.2.2.4 County of San Diego Consolidated Fire Code (2001, October 17) Ord. No. 9397. County Code of Regulatory Ordinances. Title 3, Div 5, Ch3.

Fact Sheet 21. Hybrid Parking Lot



Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Hybrid parking lots differentiate paving, combining impervious aisles with permeable stalls. Impervious aisles are designed to carry moving vehicle traffic and accommodate turning movements. Permeable stalls are designed for stationary or very slow moving cars. There are many possible combinations of materials.

CHARACTERISTICS

- Hybrid lots can reduce the overall impervious surface coverage of a typical double-loaded parking lot by 60%, and reduce the need for an underground drainage system.
- Differentiation between aisles and stalls can mitigate the overall visual impact of the parking lot.

APPLICATION

- Commercial areas, offices, multi-family housing, hotels, restaurants.
- Selection of permeable pavement material depends on use. Permeable asphalt, pervious concrete or unit pavers are recommended for stalls in areas with high turnover, such as restaurants. Areas with low turnover, such as hotels, office buildings, and housing can use crushed aggregate for stalls.
- Variable permeability, depending on pavements chosen.
- High ground water or lack of deep, permeable soils may limit applications.

DESIGN

- Keep permeable pavement areas relatively flat (slope ≤ 5%)
- Aisles are constructed of conventional asphalt or concrete suitable for heavier traffic use, speeds between 10 and 20 mph, and designed to support the concentrated traffic of all vehicles using the lot.
- Stalls are constructed of a permeable pavement, such as open-graded crushed aggregate, open-celled unit pavers, turf block, permeable asphalt, or pervious concrete.

- Avoid using permeable pavement in areas with underground utilities. If it is necessary to use permeable pavement in these areas, care must be taken to keep infiltrated water form migrating into utility trench bedding.
- Slope aisles into adjacent permeable stalls.
- Subdrain or overflow drainage may be required depending on design storm and underlying soils.
- Stall markings can be indicated with wood headers laid in field of permeable pavement, change in unit paver color, concrete bands or pavement markers ("Botts dots"), depending on the material used.
- Designated handicapped stalls must be made of an ADA compliant pavement.

MAINTENANCE

- Periodic weed control, sweeping, and regrading required for gravel stalls.
- Irrigation, fertilizer, weed control, and mowing required for turf block stalls. Pressure hosing or vacuum sweeping may be required for pervious concrete or permeable asphalt stalls.

LIMITATIONS

- Limitations are related to the materials used (for example, if stalls are constructed of crushed aggregate, the limitations associated with crushed aggregate would apply to the hybrid parking lot).
- Space limitations and soil type might affect the types of pavements that can be used.

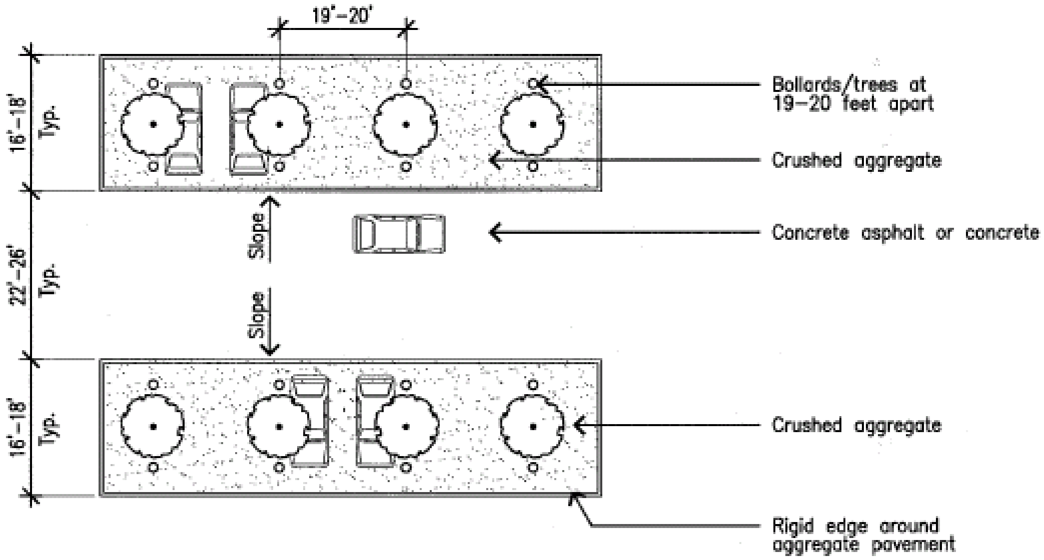
ECONOMICS

- Reduction of overall impervious surface coverage may eliminate or reduce need for underground drainage system.
- Construction cost will depend on materials chosen. A hybrid lot of conventional asphalt aisles with crushed aggregate stalls will be lower cost than a lot entirely paved in asphalt. A hybrid lot of conventional asphalt aisles with unit pavers stalls will be higher cost than a lot entirely paved in asphalt.

REFERENCES

- Parking lot. Medford Village, NJ.
- For additional information pertaining to Hybrid Parking Lots, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 22. Parking Grove



Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

<u>Parking groves</u>, a variation on the hybrid parking lot design, use a grid of trees and bollards to delineate parking stalls and create a shady environment. The permeable stalls reduce impervious land coverage while the trees reduce heat island effect and improve soil permeability.

CHARACTERISTICS

- Parking grove not only shades parked cars, but presents an attractive open space when cars are absent.
- Permeability depends on the type of pavement used.
- Reduces impervious land coverage.

APPLICATION

- Best in locations where the users of the parking lot are a consistent group of people (such as multi-family housing or an office building) who become familiar with parking between the trees.
- Best in situations where vehicles park for long periods of time, such as hotels, housing, offices.
- Not recommended for high turnover lots, such as restaurants and commercial areas because of additional care needed to navigate around trees.

DESIGN

- Parking stalls must be oversized to accommodate thickness of bollards and trees.
- Set trees/bollards at least three feet in from end of stall to allow for turning movements into and out of stall.
- Trees should be protected during the establishment period. Align stakes along implied stall line.
- Bollards may be omitted if proper tree staking is provided during establishment period.

- Metal tree cages are not recommended because they are easily damaged and can scratch cars.
- Trees should be selected for high, horizontal branching structure, and should not be prone to limb breakage or insects that secrete honeydew.
- Provide irrigation to trees as required.

MAINTENANCE

- Requires tree pruning and maintenance to ensure clearance of vehicles.
- Trees may occasionally be damaged by cars. They should recover after pruning, but may require replacement.

LIMITATIONS

- Limitations are related to the materials used (for example, if stalls are constructed of crushed aggregate, the limitations associated with crushed aggregate would apply to the hybrid parking lot).
- Space limitations and soil type might affect the types of pavements that can be used.

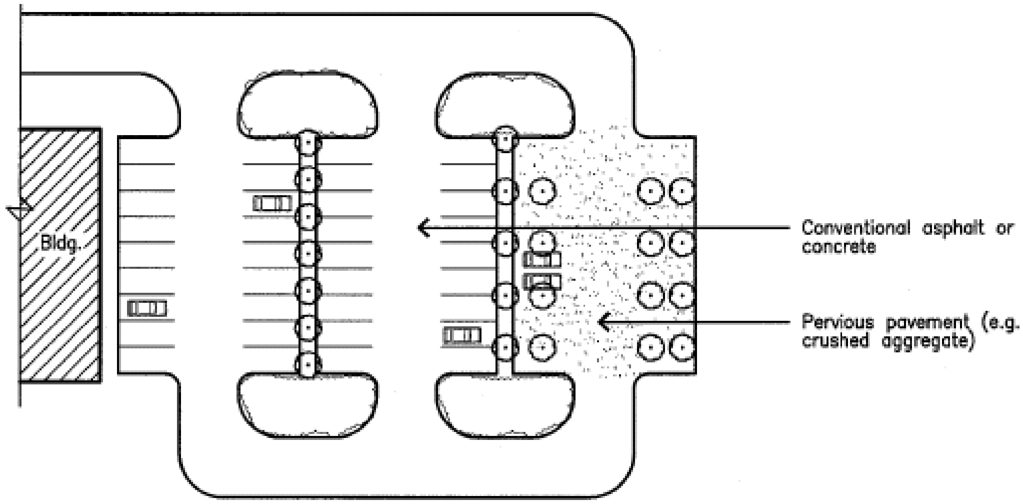
ECONOMICS

- More expensive to construct and maintain than standard parking lots.

REFERENCES

- Seaside Motel Auto Court, Seaside, FL.
- City of LA, Bureau of Street Services – Street Tree Division http://lacity.org/boss/streettree/treeguide.htm
- Street Trees Recommended for Southern California, Second Edition (1999). Street Tree Seminar, Inc.
- For additional information pertaining to Parking Groves, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 23. Overflow Parking



Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Overflow parking design differentiates between regular and peak parking demands, constructing the regular demand parking stalls with traditional impervious materials and constructing peak parking stalls of a different, more permeable, material.

CHARACTERISTICS

- Overflow area can be pervious materials such as turf block, crushed stone, unit pavers on sand, and can be designed to break up an expanse of continuous parking lot.
- Permeability depends on pavement used.

APPLICATION

- Large parking lots with variable capacity needs such as shopping malls, conference centers, office complexes, amusement parks, sport facilities.
- Visitor parking areas in multifamily residential developments or office complexes.
- Facilities with infrequent but extensive peak parking needs, such as churches, sports arenas, and conference centers.

DESIGN

- Must be designed to accommodate volume of overflow parking.
- In many uses, regular parking demand accounts for approximately two-thirds of total, with one-third accommodated as overflow.
- Irrigation may be necessary if overflow parking is turf block.

MAINTENANCE

- Maintenance depends on pavement selected.

LIMITATIONS

- Limitations are related to the materials used (for example, if stalls are constructed of crushed aggregate, the limitations associated with crushed aggregate would apply to the hybrid parking lot).
- Space limitations and soil type might affect the types of pavements that can be used.

ECONOMICS

- Cost depends on pavement selected and overall design.

REFERENCES

- Gravel overflow parking at Nordstrom parking lot. Corte Madera, CA.
- Orange Bowl parking lot, FL.
- For additional information pertaining to Overflow Parking, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 24. LID Driveway, Sidewalk, and Bike Path Design

CHARACTERISTICS

Driveways, sidewalks and bike paths are another source of impervious coverage that can adversely affect water quality by the runoff generated from their surface. Several management opportunities and strategies are available to reduce this impact, including:

- Reducing sidewalks to one side of the street.
- Utilize shared driveways to provide access to several homes.
- Disconnect bike paths from streets. Bike paths separated from roadways by vegetated strips reduce runoff and traffic hazards.
- Utilizing pervious materials to infiltrate or increase time of concentration of storm flows.
- Reducing driveway and sidewalk width when possible.
- Directing driveway and sidewalk runoff to adjacent vegetation to capture, infiltrate, and treat runoff.
- Installing a bioretention area or swale between the street and sidewalk and grading runoff from the sidewalk to these areas.
- Planting trees between the sidewalk and streets to capture and infiltrate runoff.
- Installing grated infiltration systems in sidewalks and bike paths to receive runoff as sheet flow. These can be installed to protect trees or can provide off-line stormwater management via a grate over an infiltration trench.

APPLICATION

- Residential Subdivisions, single family and multi-family homes.
- Commercial Development
- Public Parks

DESIGN

- Grade driveways, sidewalks, and bike paths at a two percent slope to direct runoff to an adjacent vegetated area.
- Pervious materials such as permeable pavers, permeable concrete or asphalt, gravel, or mulch can be utilized for sidewalk surfaces.
- In some cases, sidewalks and bike paths can be placed between rows of homes to increase access and decrease overall effective imperviousness.
- Grated infiltration systems should include removable grates to allow for maintenance, and must be capable of bearing the weight of pedestrians.

LIMITATIONS

- Ordinances may require sidewalks on both sides of the street.
- Groundwater table must not be within 10 feet of the bottom of infiltration trenches.

MAINTENANCE CONSIDERATIONS

- Maintenance necessary is related to the techniques applied (permeable materials, bioretention, swales).
- Vector breeding may occur in bioretention and swales if not properly designed or maintained.

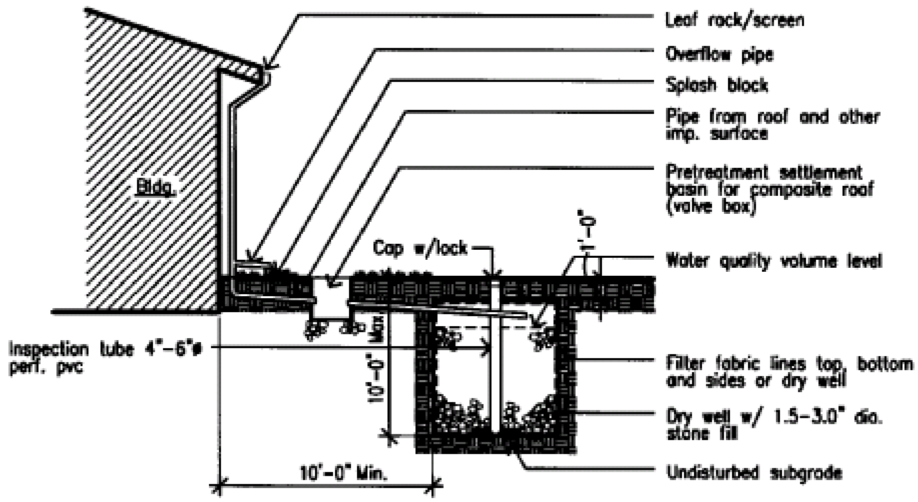
ECONOMICS

- Costs are related to the number, type and size of the techniques applied.

REFERENCES

- For additional information pertaining to LID Driveway, Sidewalk, and Bike Path Design see the works cited in the San Diego County LID Literature Index.

Fact Sheet 25. Dry-well



Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

A dry-well is a subsurface basin to which runoff is diverted for infiltration. The roof downspout is connected to the dry-well, allowing runoff to be stored and slowly infiltrated.

CHARACTERISTICS
- Compact.
- Hidden from view, has no effect on aesthetics.

APPLICATION
- Can be used to control stormwater runoff for new residential development, or new additions to existing buildings

DESIGN
- Confirm requirements with local municipal ordinances and receive approval from a qualified, licensed professional. These may include overall depth, as well as setbacks from structures, property lines, water supply wells, groundwater level, septic drainfields, and sensitive areas.
- Subgrade must be relatively permeable (not appropriate for clay).
- Requires excavation filled with drain rock and wrapped top, sides and bottom with filter fabric. Excavation is sized to accommodate water quality volume storm, accounting for 38-40% void space of gravel fill.
- A buried catch basin (concrete, plastic, or metal) or large diameter pipe with open bottom set on end can be used to contain drain rock.
- Roof downspouts are attached to the dry well, an overflow pipe is provided for runoff in excess of water quality volume.
- Provide perforated observation pipe (such as a 6" diameter PVC) to allow for inspection and maintenance.
- Provide pre-treatment sedimentation basin for composite roofs. This can be a small plastic valve box with open bottom.

MAINTENANCE

- Requires inspection at beginning of rainy season.
- Remove sediment from sedimentation basin prior to rainy season.

LIMITATIONS

- Not appropriate for slopes >40% or
- Not appropriate for areas with expansive soils.
- “Infiltration BMPs” are not appropriate when:
  - the seasonal high groundwater table is within 10 feet of the base of the BMP
  - at locations where surrounding soil stratum is unstable
- exceptions to the 10 foot separation can be made when:
  - the BMP is designed with an under-drain and approved by a qualified licensed professional, or when:
  - written approval of a separation within the interval of 4-10 feet has been obtained by the Regional Water Quality Control Board and the Department of Environmental Health.
- Subgrade must be relatively permeable (not appropriate for clay).
- Applicability dependant upon local regulations, zoning standards and site characteristics (slope, soil type, amount of rainfall, drainage area, space available, etc).

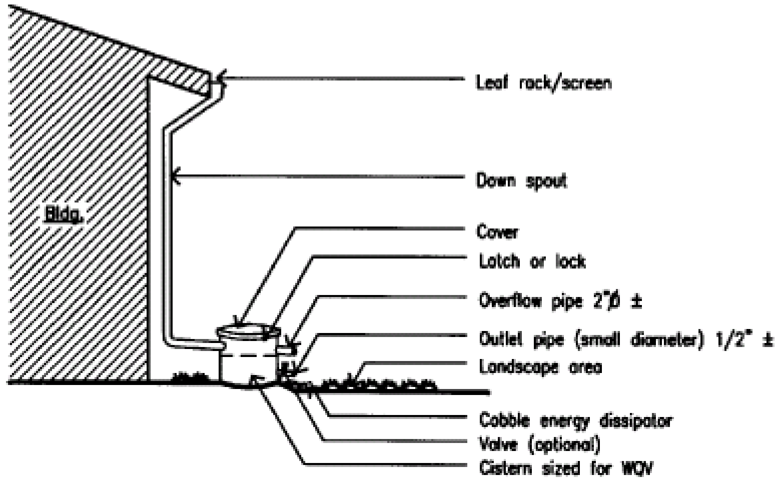
ECONOMICS

- Relatively inexpensive to construct and maintain.

REFERENCES

- For more information on infiltration site selection please see the CALTRANs Infiltration Study (2003) at: http://www.dot.ca.gov/hq/env/stormwater/special/newsetup/_pdfs/new_technology/CTSW-RT-03-025/IFB_Final_Report.pdf
- Washington Department of Ecology’s Stormwater Management Manual for Western Washington (http://www.ecy.wa.gov/pubs/0510033.pdf), BMP T5.10 Downspout Dispersion in Volume V, page 5-3.
- For additional information pertaining to Dry-wells, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 26. Rain Harvesting



Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Rain harvesting reduces runoff discharged to the storm drain system and can help conserve water in applications at all scales. Rain barrels and cisterns are storage vessels that are directly connected with the roof downspout. Water is slowly released with either a manually operated valve or a permanently open outlet.

CHARACTERISTICS

- Can be incorporated into the aesthetics of the building and garden.
- Reduces peak runoff and allows sediment to settle.
- Provides more infiltration benefits than connecting directly to storm drain.

APPLICATION

- New and existing residential buildings
- New and existing commercial buildings

DESIGN

- Manually operated valve can be closed to store stormwater for irrigation use or infiltration between storms.
- Must be covered to prevent mosquitoes from breeding.
- Permanently open outlet must be sized appropriately.
- Size cistern for water quality volume, provide overflow for larger storms.
- For safety reasons provide secure cover or ≤ 4” top opening if holding more than 6” depth of water.
- Provide screen on gutter and intake of outlet pipe to minimize clogging by leaves and other debris.

MAINTENANCE

- System requires regular monitoring and cleaning.
- Ensure system is not clogged by leaves or other debris.

LIMITATIONS

- Due to San Diego's arid climate and depending on location, rain barrels and cisterns may fill with rain only a few times per year.

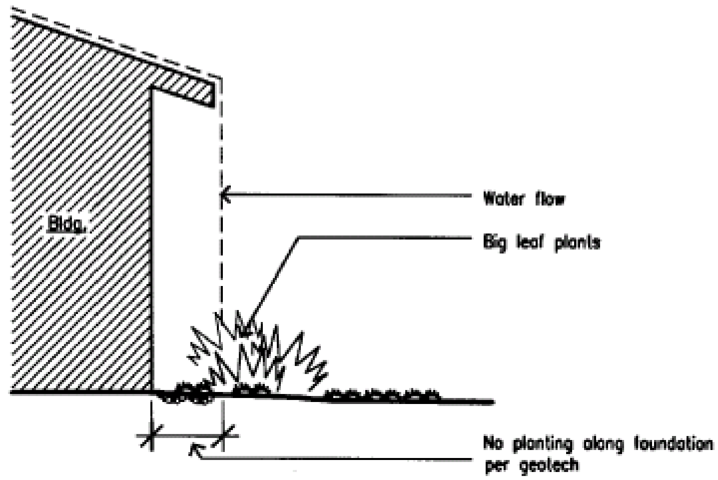
ECONOMICS

- Low installation cost.

REFERENCES

- For additional information pertaining to Cisterns and Rain Barrels, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 27. Foundation Planting



Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Landscape planting around the base of the eaves can reduce the physical impact of water on the soil and provide a subsurface matrix of roots that encourage infiltration.

CHARACTERISTICS

- Foundation planting provides increased opportunities for stormwater infiltration.
- Planting protects the soil from erosion caused by concentrated sheet flow coming off the roof, reducing the amount of sediment in urban runoff.

APPLICATION

- For buildings that do not use a gutter system.

DESIGN

- Locate plants at the roof drip-line.
- Select plants with high capacity for vertical water storage.
- Select plants with leaf architecture that intercepts rainwater and traps it for eventual evaporation.
- Select plants sturdy enough to tolerate the heavy runoff sheet flows, and periodic soil saturation.
- Provide mulch cover in planting bed to protect soil from impact of falling rainwater and to increase soil water-holding potential.
- Protect perimeter of foundation as required by local soil conditions.

MAINTENANCE

- Regular garden maintenance.
- Gardening must occur to ensure compliance with fire codes.

LIMITATIONS

- Particularly considering the frequency and ferocity of fires in San Diego County, care must be taken to ensure that any foundation planting does not pose a potential fire hazard for the building.
- Water infiltration near the building presents the danger of water damage to the foundation. Depending on soil type, protect foundation with moisture barriers and grade foundation to move water a safe distance from the building. Contact a qualified, licensed professional before this LID technique is applied.

ECONOMICS

- Costs vary based upon plant choice, but generally can be expected to be relatively low if planted and maintained correctly.

REFERENCES

- For additional information pertaining to Foundation Planting, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 28. Downspout to Swale

Discharging a roof downspout to landscaped areas via swales allows for polishing and infiltration of the runoff.

Photograph Courtesy of EOA, Inc.

CHARACTERISTICS

- Runoff from the roof is directed into a rocky or vegetated swale area.
- The water flows through swale with overflow continuing to the storm drain.

APPLICATIONS

- Appropriate for most buildings with landscaped areas adjacent to the building where soil drainage is appropriate and water infiltration does not pose a risk to the foundation.

DESIGN

- The downspout can be directly connected to a pipe which daylights some distance from the building foundation, releasing the roof runoff into a rock lined swale towards a landscaped area.
- The roof runoff is slowed by the rocks, absorbed by the soils and vegetation, and remaining runoff flows away from the building foundation into the storm drain.
- Xeriscape techniques, natural stone and rock linings should be used as an alternative to turf.

MAINTENANCE

- Maintenance is similar to that necessary for other swale areas and will depend on the specific style chosen.

LIMITATIONS

- Only suitable for grades between 1% and 6%
- When a vegetated swale is used, the site requires adequate sunlight for vegetation growth
- Avoid infiltrating too close to foundations and underground utilities.

ECONOMICS

- Costs are similar to those associated with other swale devices.

REFERENCES

- For additional information pertaining to the Downspout to Swale technique, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 29. Vegetated Roofs

Vegetated roofs serve to treat stormwater pollutants, reduce runoff volumes, provide additional landscape amenity, provide acoustical control, air filtration and create urban wildlife habitat. Vegetated roofs also provide oxygen production, carbon storage, increase insulation and extend the expected lifetime of the roof compared to conventional roofing.

Photograph Courtesy of EOA, Inc.

CHARACTERISTICS

- Roofs can be either extensive or intensive or vegetation can be placed in modules.
- Extensive: Consists of shallow (1”-6”), lightweight substrate and a few types of low-profile, low-maintenance, drought-tolerant plants
- Intensive: Consists of thicker (8”-48”) substrate can support a richer variety of plant material and a more garden-like appearance
- Vegetated walls are facades of steel cables that hold climbing plants away from the surface of the building.

APPLICATION

- Can be installed on almost any building with slopes up to 40 degrees
- Vegetated roofs are effective strategies for managing stormwater in highly urbanized settings where rooftops comprise a large percentage of the total impervious surface.
- Can be an effective way of reducing energy costs in a conservation-conscious way

DESIGN

- Construction should be performed by an experienced vegetated roof specialist.
- Extensive roofs utilize light-weight soil mixes to reduce loads. Native soils are usually too heavy when wet for roof usage.
- Structural capacity of the roof must be designed to support up the anticipated additional loads.
- A living non-irrigated vegetated roof in San Diego is possible to maintain and will perform a stormwater benefit; however irrigation may be required during Xeriscape plant establishment. Consult an experienced vegetated roof specialist.
- Extensive green roof systems contain several layers of protective materials to convey water away from the roof deck. These generally include (from the bottom up) a waterproof membrane, a root barrier, a layer of insulation, a drainage layer, a filter fabric for fine soils, the engineered growing medium or soil substrate, and the plant material.
- Sedums, a common vegetated roof plant, have fleshy water-storing leaves that do not burn easily, even in near drought conditions.

MAINTENANCE

- Installations require regular inspection and maintenance to guarantee proper functioning of any drainage or irrigation components as well as for removal of dead or diseased vegetation
- As needed, pruning and weeding must occur in order to maintain the appearance of the roof. Weeding and removal of dead material should be scheduled to coincide with important horticulture cycles.
- Intensive vegetated roofing may require more frequent inspection and maintenance.
- Intensive installations may also require irrigation as needed. Extensive installations should not be irrigated unless deemed absolutely necessary.
- Soils may also need to be tested for pH periodically and neutralizing agents may need to be employed as needed.

LIMITATIONS

- Installing a vegetated roof with a pitch of greater than 20 percent increases project complexity and requires supplemental anchoring.
- A slight pitch is preferable for efficient drainage but may not be as necessary in the arid environment.
- Sun exposure must be considered as both pitch and neighboring buildings may limit the amount of sunlight the vegetation receives, which can inhibit growth and the other beneficial effects of a vegetated roof.
- The site must have sufficient structural strength the hold the load of the vegetated roof at its most water saturated.
- Fire safety provisions must be abided by and may affect the location and the extent of vegetated roofing that is allowed.

ECONOMICS

- Costs vary based upon system implemented.
- Vegetated roof savings have been reported to offset annual energy costs.

REFERENCES

- Environmental Affairs Department: City of Los Angeles (2006), *Green Roofs-Cooling Los Angeles: A Resource Guide*, III-9 http://www.fypower.org/pdf/LA_GreenRoofsResourceGuide.pdf
- Miller, (2003). *Extensive Green Roofs*. Whole Building Design Guide. http://www.wbdg.org/design/resource.php?cn=0&cx=1&rp=41.
- Breuning, Jorg (Spring 2007) Fire & Wind on Extensive Green Roofs. *Green Roof Infrastructure Monitor*. Vol. 9., No.1. pg 12-13.
- Sharp, R. (2007). Green Walls 101: Introduction to Systems and Design. *Green Roof Infrastructure Monitor*. Vol. 9, No.1. pg 16-17.
- For additional information pertaining to Vegetated Roofs, see the works cited in the Green Roofs Section of the San Diego County LID Literature Index.

Fact Sheet 30. Soil Amendments

Soils in the arid climate of San Diego tend to lack organic matter and nutrients, and often have a high silt and/or clay content. Soils high in clay content have slow infiltration rates, resulting in high runoff potential. The infiltration and water storage capacity of such areas can be amended by improving the organic content of the soil. This is achieved by tilling amendments including organic materials into the native soil or by importing topsoil.

CHARACTERISITICS

- Serves to reduce stormwater runoff volumes
- Improves water quality through filtration
- Improves plant growth and overall aesthetics
- Reduces or even eliminates the need for fertilizing
- Reduces net erosion
- Results in reduced total maintenance costs for landscaping
- In order to be effective, slopes must be less than 33%

APPLICATION

- Soil amendments are advisable for many vegetated areas and should be designed to address soil characteristics, plant types, drainage, and plant water use requirements.
- Existing lawn or landscaped areas with poor plant growth due to compaction and low-organic content soils and sites with poor drainage characteristics are prime candidates for soil amendments and/or lawn alternatives.
- May be especially important in new construction where the existing topsoil is poor, has been removed or has been compacted
- Retrofitting of existing landscape with minimal disturbance
- Soil amendments may not be required under certain circumstances when utilizing low water use and low nutrient demand plant material such as some California native species.
- If appropriate, where no amendments are required soil can be ripped, tilled or otherwise treated to reduce compaction and encourage percolation.
- Soil amendments can improve water storage and infiltration characteristics in applications such as swales, filter strips, and bioretention.

DESIGN

- A licensed landscape architect or other qualified licensed professional should be consulted.
- The most cost-effective strategy is to save and reuse native topsoil, and to protect areas of native vegetation wherever possible.
- Soils should be analyzed by a lab to determine the specific soil amendments needed.
- To optimize water holding capacity and plant health, organic material including leaf compost, peat moss or composted manure should be included in the soil amendments.

- Incorporate amendments during conclusion of site development.
- Care must be taken around existing trees and shrubs to prevent root damage during construction and soil amendment application.

MAINTENANCE

- For areas that incorporate turf, annual soil aeration should be conducted
- Organic topdressing mulch may need to be supplemented at certain intervals.

LIMITATIONS

- On steep slopes, increasing soil moisture could potentially cause soil instability, therefore soil amendments may not be suitable for certain slopes and care must be taken in the timing of the amending.
- Areas with grades steeper than 33% are not effective locations for soil amendments.
- Soil amendments may not be necessary under certain circumstances when utilizing low water use and low nutrient demand plant material such as some California native specifies.

ECONOMICS

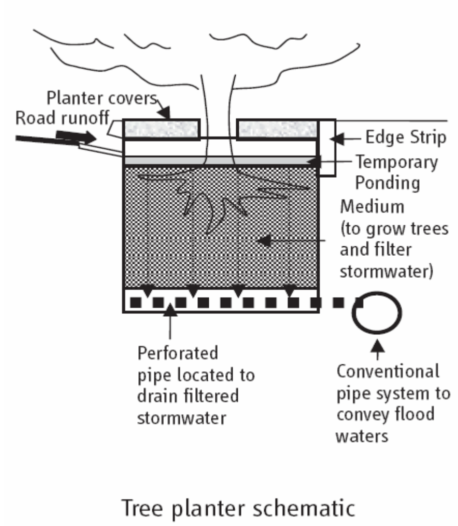
- Costs will vary according to site specific conditions, but have previous been estimated at $1.00 to $3.00 per square foot of soil amended (this does not include the cost of revegetating the area after amendments are made).

REFERENCES

- Low Impact Development Center, Inc. (n.d.). *Soil Amendments Costs.* http://www.lid-stormwater.net/soilamend/soilamend_costs.htm
- For additional information pertaining to Soil Amendments, see the works cited in the San Diego County LID Literature Index.

Fact Sheet 31. Street Trees


Photograph Courtesy of EOA, Inc.



Photograph from Water Sensitive Urban Design Guidelines, Melbourne, Australia (2005)

Trees can be used as a stormwater management tool in addition to providing the more commonly recognized benefits of energy conservation, air quality improvement, and aesthetic enhancement.

CHARACTERISTICS

- Tree surfaces (roots, foliage, bark, and branches) intercept, evaporate, store or convey precipitation to the soil before it reaches surrounding impervious surfaces.
- In bioretention cells or swales, tree roots build soil structure that enhances infiltration capacity and reduces erosion.

APPLICATION

- Using modified planter boxes as opposed to the tradition approach can provide stormwater filtration in an otherwise impervious urban environment.
- Modified street tree planters are appropriate for use along streets, sidewalks, driveways and other urban settings.
- Medians and traffic calming bays can also be utilized as bioretention systems using systems such as street trees.

DESIGN

- Appropriate placement and selection of tree species is important to achieve desired benefits and reduce potential problems such as pavement damage by surface roots and poor growth performance.
- Check with local community planning guidelines for the type and location of trees planted along public streets or rights-of-way.
- The extent and growth pattern of the root structure must be considered when trees are planted in bioretention areas or other stormwater facilities with under-drain structures or near paved areas such as driveways, sidewalks or streets. Root barrier devices can be utilized where applicable.

- Available growing space must also be considered in site planning.
- Soil type and water availability must be considered in species choice and placement.
- Underground utilities and overhead wires must be circumvented.
- Additional functions desired, such as shade, aesthetics, windbreak, privacy screening, should impact species choice and placement as well
- Other important tree characteristics to consider when making a selection include: Longevity or life-span, Tolerance for urban pollutants, Growth Rate, Tolerance to drought, seasonally saturated soils, and poor soils, Canopy spread and density, Foliage texture and persistence

MAINTENANCE

- In general, maintenance includes annual routine inspection and maintenance activities.
- These would include removal of trash, debris and sediment, replenishment of the mulch, and care or replacement of plants.
- During extreme droughts the plants may need to be watered in the same manner as any other landscape material.

LIMITATIONS

- Local planning guidelines and zoning provisions for the permissible species and placement of trees along public streets or rights-of-way must be consulted.
- Vehicle and pedestrian sight lines; proximity to paved areas and underground utilities; proximity to neighbors, buildings, and other vegetation; prevailing wind direction; and sun exposure all must be considered in street tree placement.
- Species appropriate is dependant upon the available space for root and foliage growth, location of utilities such as water pipes and power lines, available water (irrigation should be limited as much as possible) and tolerance to pollutants.

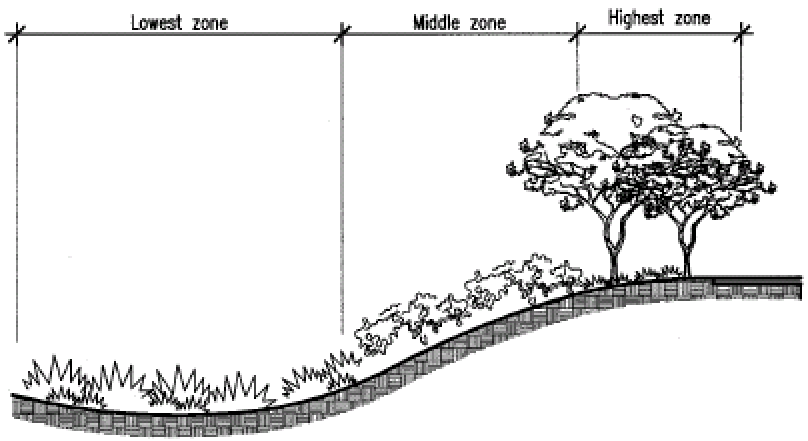
ECONOMICS

- Accurate economic data pertaining to the use of subsurface reservoir beds is currently unavailable, however, site specific cost records can be found in the LID Literature Index.

REFRENCES

- City of LA, Bureau of Street Services, Street Tree Division http://lacity.org/boss/streettree/treeguide.htm
- Street Tree Seminar, Inc. (1999), *Street Trees Recommended for Southern California*. Anaheim, California.
- Low Impact Development Center, Inc. (n.d.). *Maintenance of Tree Box Filters.* http://www.lid-stormwater.net/treebox/treeboxfilter_maintain.htm
- For additional information pertaining to Street Trees see the works cited in the San Diego County LID Literature Index.
- City of Melbourne, Australia. (2005). *Water Sensitive Urban Design Guidelines.* http://www.melbourne.vic.gov.au/rsrc/PDFs/Water/WSUD_part1.pdf

Fact Sheet 32. Plant species selection for infiltration areas



Conditions, dimensions, and materials shown are typical. Modifications may be required for proper application, consult qualified professional.

Plant species selection for infiltration areas can improve the infiltration potential of landscape areas as well as improve the aesthetics of design.

CHARACTERISTICS

- Deep rooted plants help to build soil porosity.
- Certain plant species and applications provide bio-remediation effects by improving water quality.
- Leaf surface-area helps collect rainwater before it lands on the soil, especially in light rains, increasing the overall water holding potential of the landscape.
- Select species that are tolerant of moist soils or periodic inundation, as well as drought if planted without supplemental irrigation.

APPLICATION

- Applicable to all treatment devices that incorporate plant materials.

DESIGN

- Select appropriate plant species depending on zone of inundation: lowest, middle, and highest.
  - Lowest: Depending on size, location and drainage watershed, this area may encounter frequent inundation, wet dry cycles or high moisture conditions.
  - Middle: Depending on size, location and drainage watershed, this area may encounter occasional inundation and wet dry cycles.
  - Highest: Depending on size, location and drainage watershed, this area may encounter very rare inundation.
- Select the appropriate plant for the use, anticipated water inundation, habitat and aesthetic goals.
- Consider sight-line and other requirements for parking lots and street-side plantings.
- Include mulch cover in planting areas.

MAINTENANCE

- Maintenance can have a significant impact on soil permeability and its ability to support plant growth. Proper mulching of the soil surface improves water retention and infiltration, while protecting the surface root zone from temperature extremes.
- Slightly more attention to maintenance and care of plant material may be required than in non-infiltration areas.

LIMITATIONS

- Cool season turf grasses utilized in vegetated swales require irrigation and may not meet state and local water conservation goals.
- Irrigated vegetation may not be appropriate in certain sites. Xeriscape techniques, natural stone and rock linings and other inert groundcovers can be used as an alternative to living vegetation.

ECONOMICS

- Varies based on landscaping needs.

REFERENCES

- For additional information pertaining to Species Selection for Infiltration Areas, see the works cited section titled “Landscaping” in the San Diego County LID Literature Index.