County of San Diego

Low Impact Development Handbook

Stormwater Management Strategies

DECEMBER 31, 2007

Department of Planning and Land Use
5201 Ruffin Road, Suite B
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 first 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.

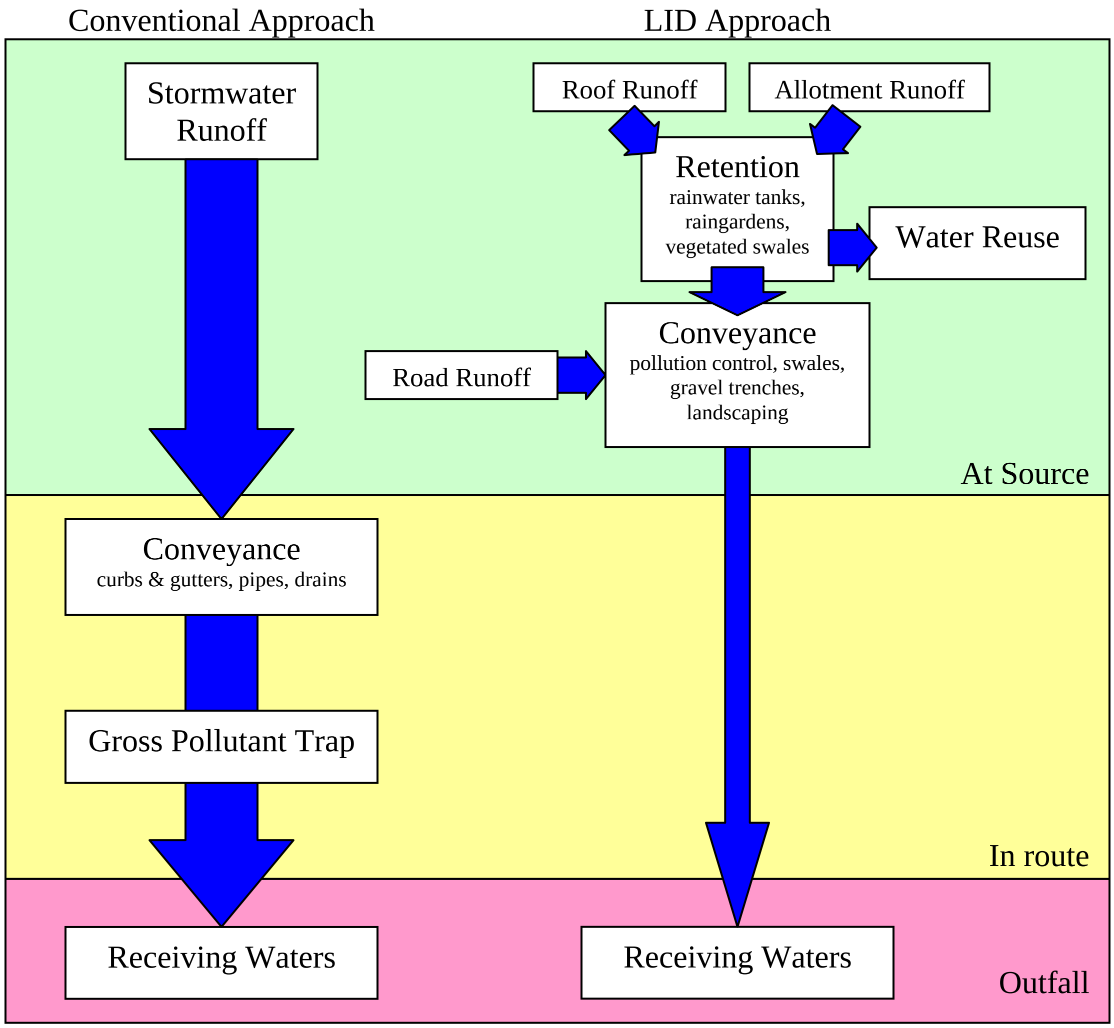
Change in Watershed Condition	**Stream Response**
Increased drainage density due to road networks, road crossing and stormwater outfalls	Increased storm flow volume and frequency
	Channel erosion
	Increased fine sediment and urban water pollutant loads
	Increased fish passage barriers
Increased fine 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]:

Principles of LID

- 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].

Goals of LID

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]:

Benefits of LID

- 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.

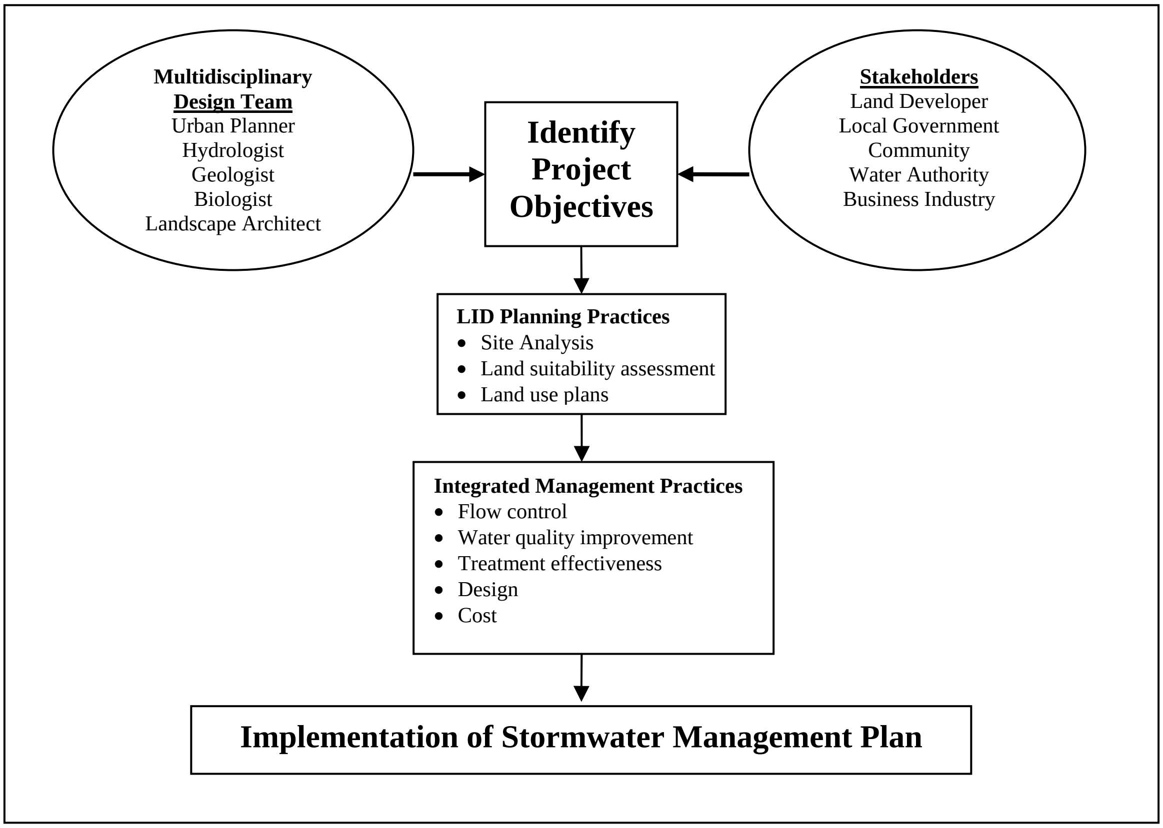
Important Note: Proposed stormwater "Infiltration BMPs", including permeable pavements, shall be reviewed by a qualified, licensed professional to provide a professional opinion regarding the potential adverse geotechnical conditions created by the implementation of the plans. Geotechnical conditions 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.

IMP	Effect or Function						
	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

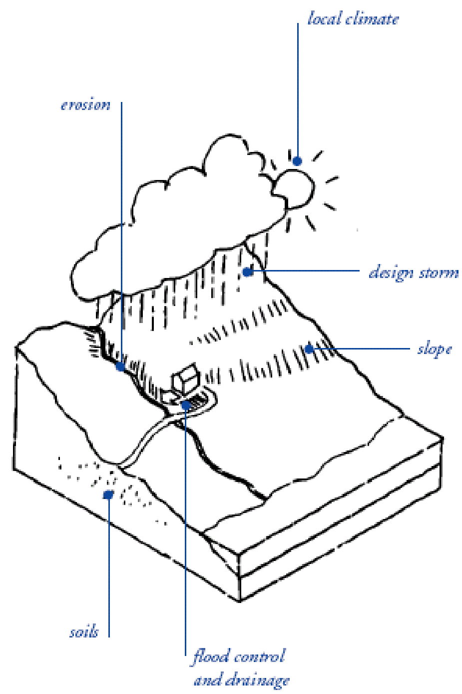
The County of San Diego is incredibly diverse. With approximately 4,260 square miles of land [14], the County includes a large variety of geologic and topographic conditions, land uses, and climate types, all of which influence stormwater runoff planning strategies. Key physical factors in San Diego 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.

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.

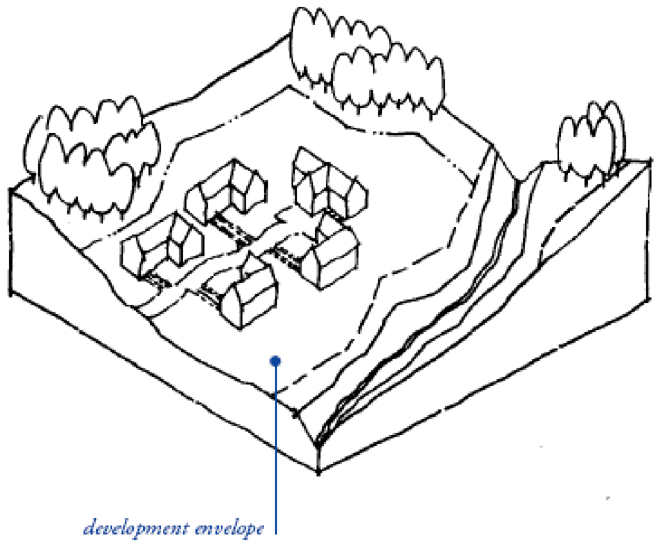
To reduce directly connected impervious areas and promote filtration and infiltration, the site planning principles below shall be considered to guide the layout and orientation of development projects. As required by the California Regional Water Quality Control Board, San Diego Region, Order Number 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

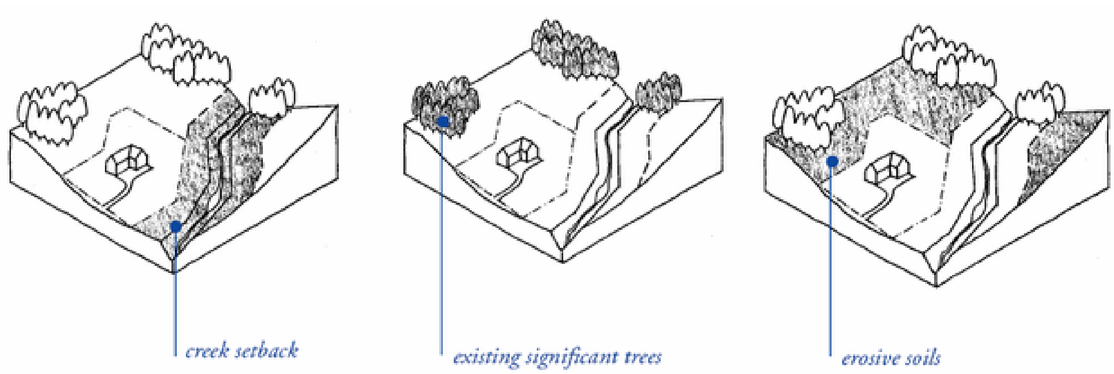
The following sections define these LID site planning principles and how to apply them while designing the LID project site plan.

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.

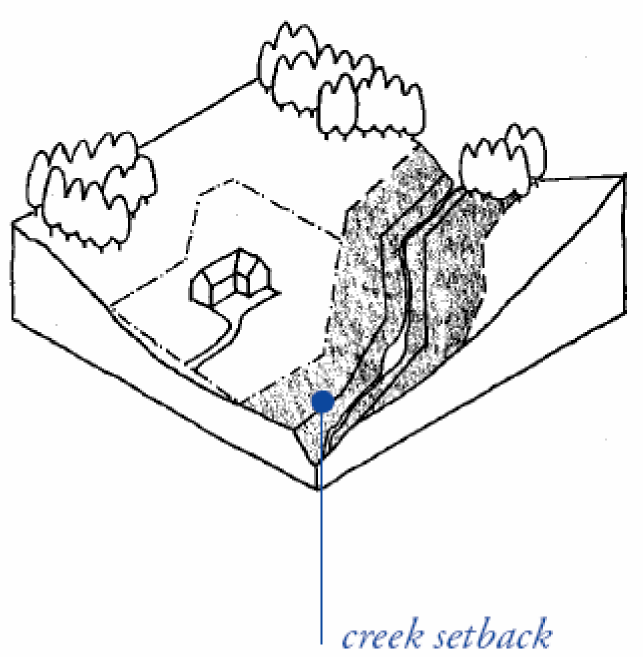


The upper soil layers of a natural area contain organic material, soil biota, vegetation, and a configuration favorable for storing and slowly conveying stormwater. The canopy of existing native trees and shrubs also provide a water conservation benefit by intercepting rain water before it hits the ground. 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]

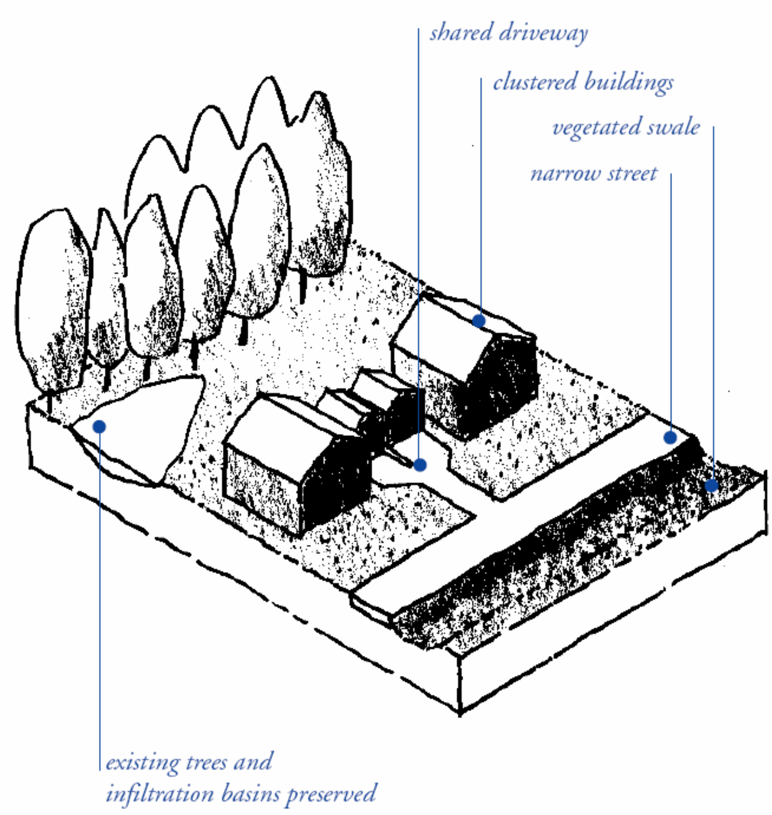


The next site planning strategy is to minimize impacts to natural drainages (natural swales, topographic depressions, etc.). During the site assessment, natural drainages must be identified along with their connection to creeks and/or streams, if any. Natural drainages offer a benefit to stormwater management 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].

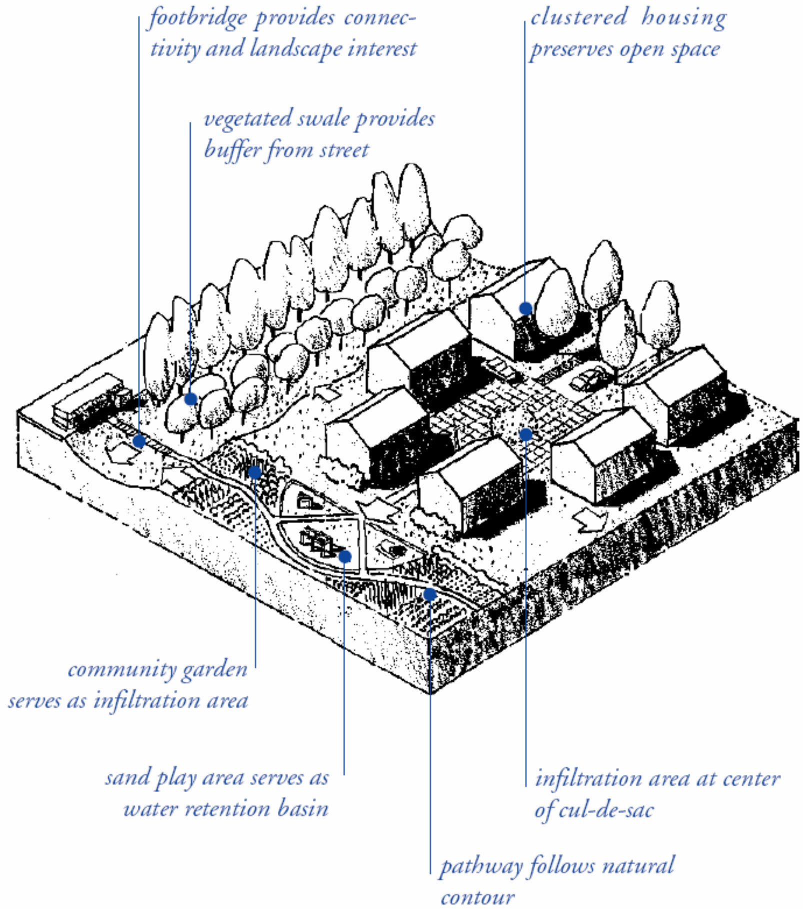
2.2.4. Minimize Soil Compaction[4]

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.

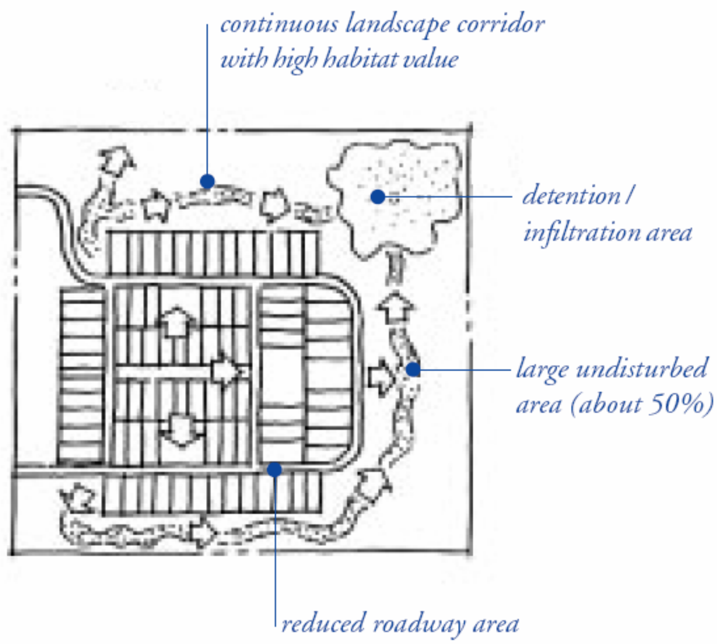
Photograph Courtesy of EOA, Inc.

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

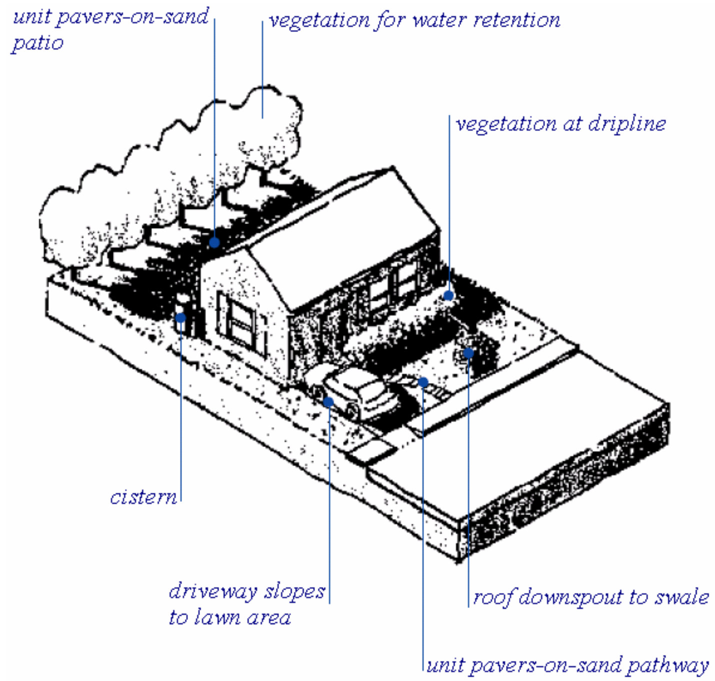


Cluster development, a site planning technique in use for several decades, considers not only individual lots, but larger site boundaries. It concentrates development on one portion of a site, and maintains more of the site in open space. Cluster designs include strategies such as smaller lot sizes, 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.

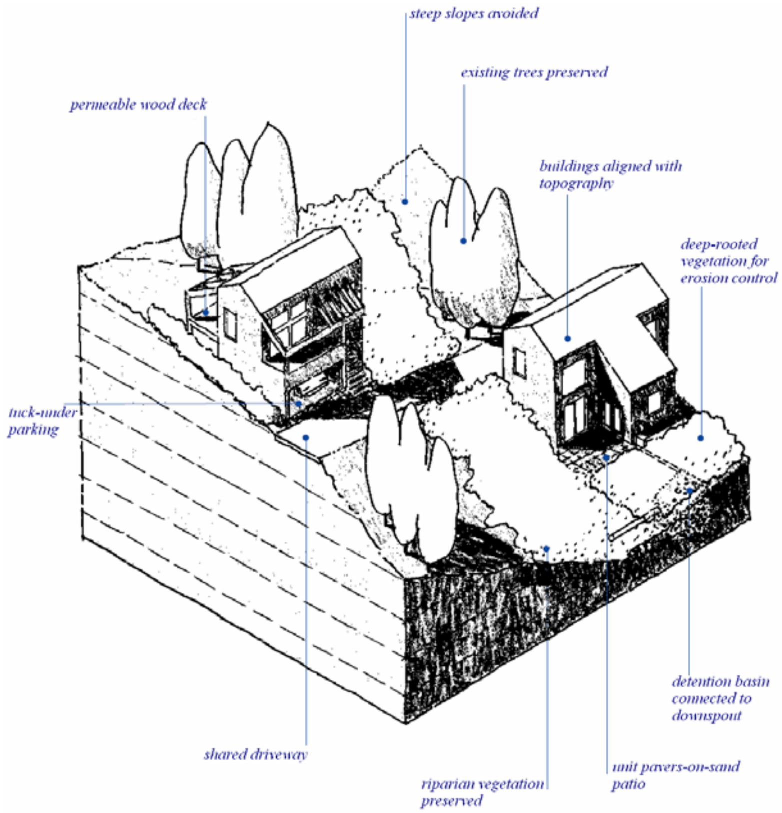
Opportunities for on-site stormwater management still exist, even in the most densely developed infill site, though they will require greater creativity or multiple use of space. For instance, an underground/under pavement storage reservoir may be created to promote filtration and stormwater storage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



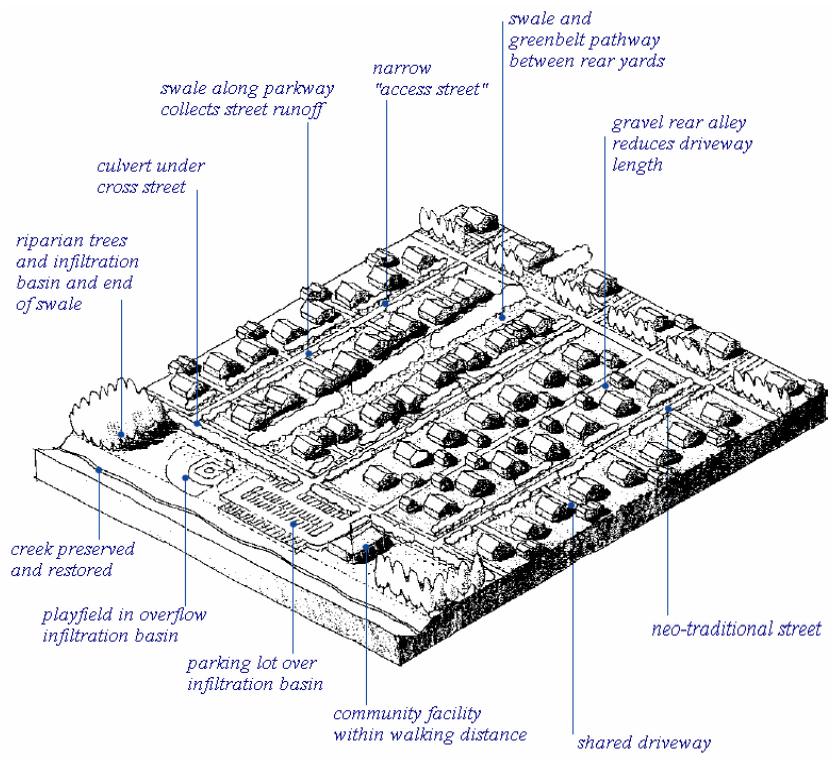
Hillside sites, large and small, present particular challenges for stormwater management. Because slopes are often pronounced, some infiltration strategies that are best suited to more level sites, such as dry wells, infiltration basins, or trenches, are impractical and can cause landslides or severe 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:

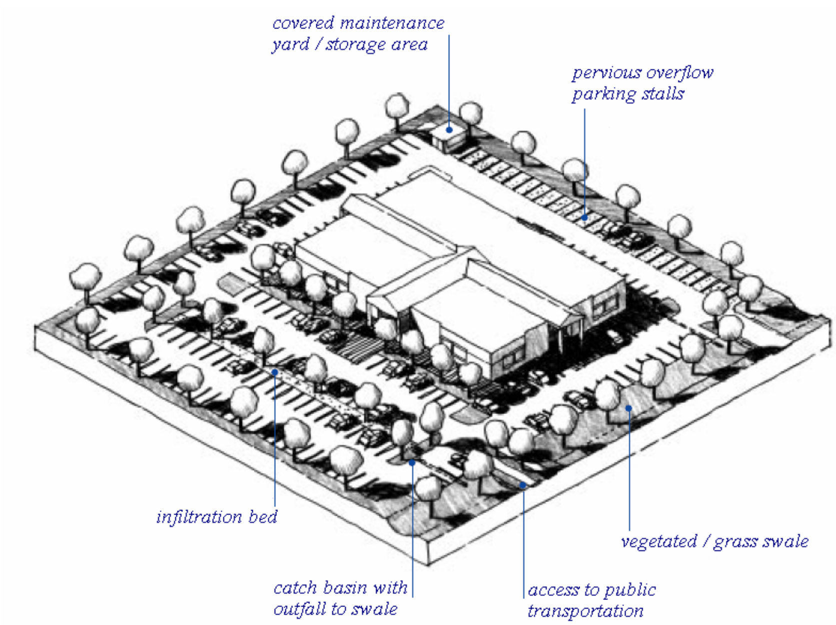
- Minimal street widths
- Permeable rear alley & shared driveways to reduce pavement
- Community facility within walking distance
- Parking lot over infiltration basin[1]
- Depressed playfield with multiple use as infiltration basin[1]
- Swale along parkway collects street runoff (with appropriate slopes)
- 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.

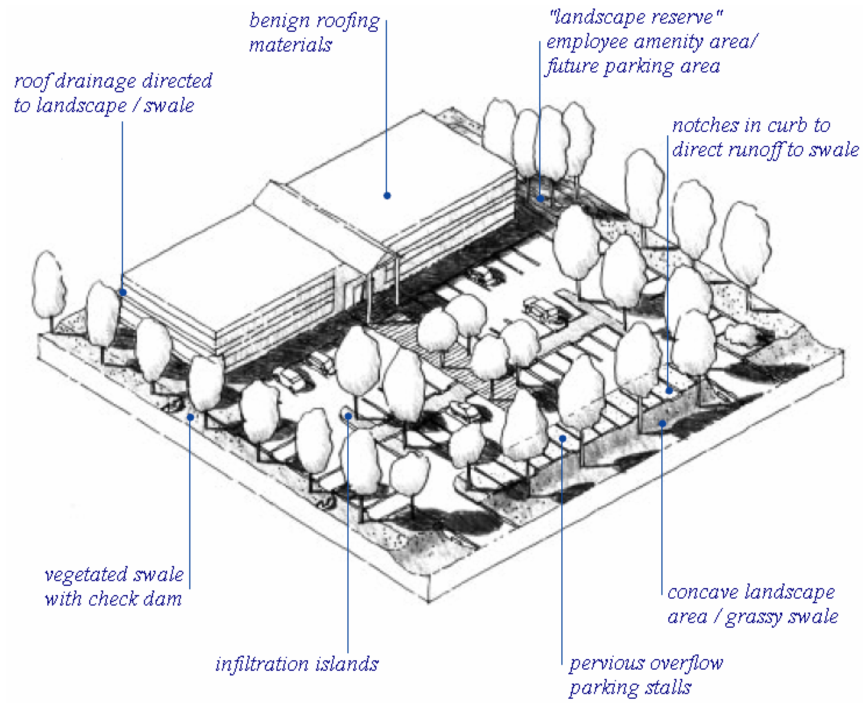
If well designed, correctly installed, and properly maintained, stormwater management techniques can enhance the aesthetic character of a shopping center and improve its marketability.

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.

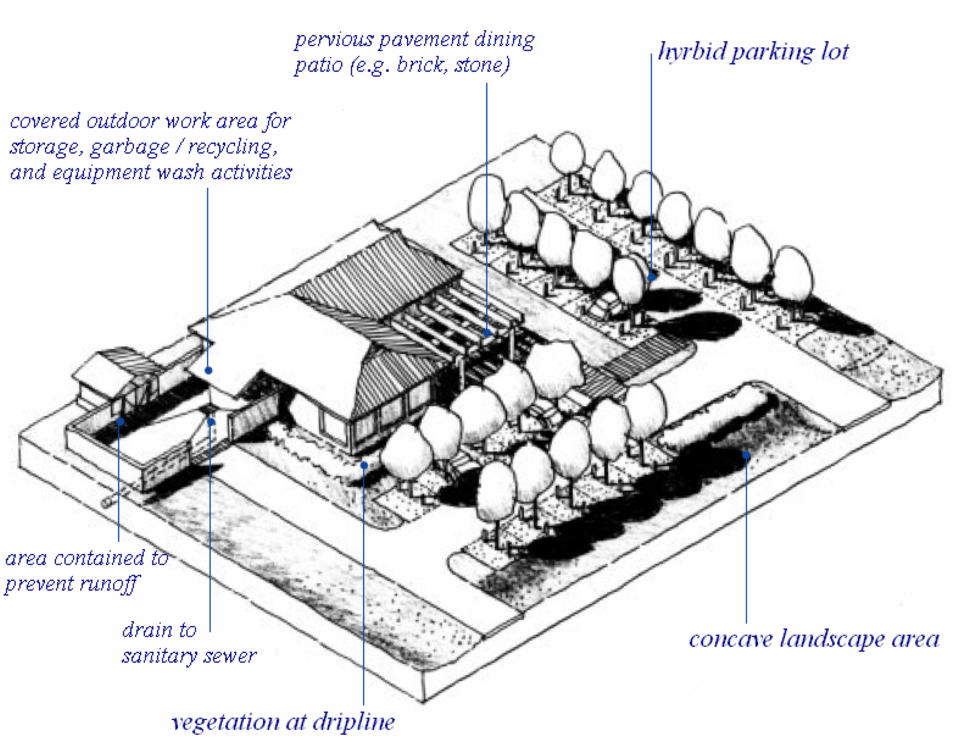
A portion of the required parking may be allowed to be held in "landscape reserve," until a need for the full parking supply is established. This means that the original construction only builds parking to meet anticipated staff needs. If the parking demand increases, the area held in landscape reserve 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.

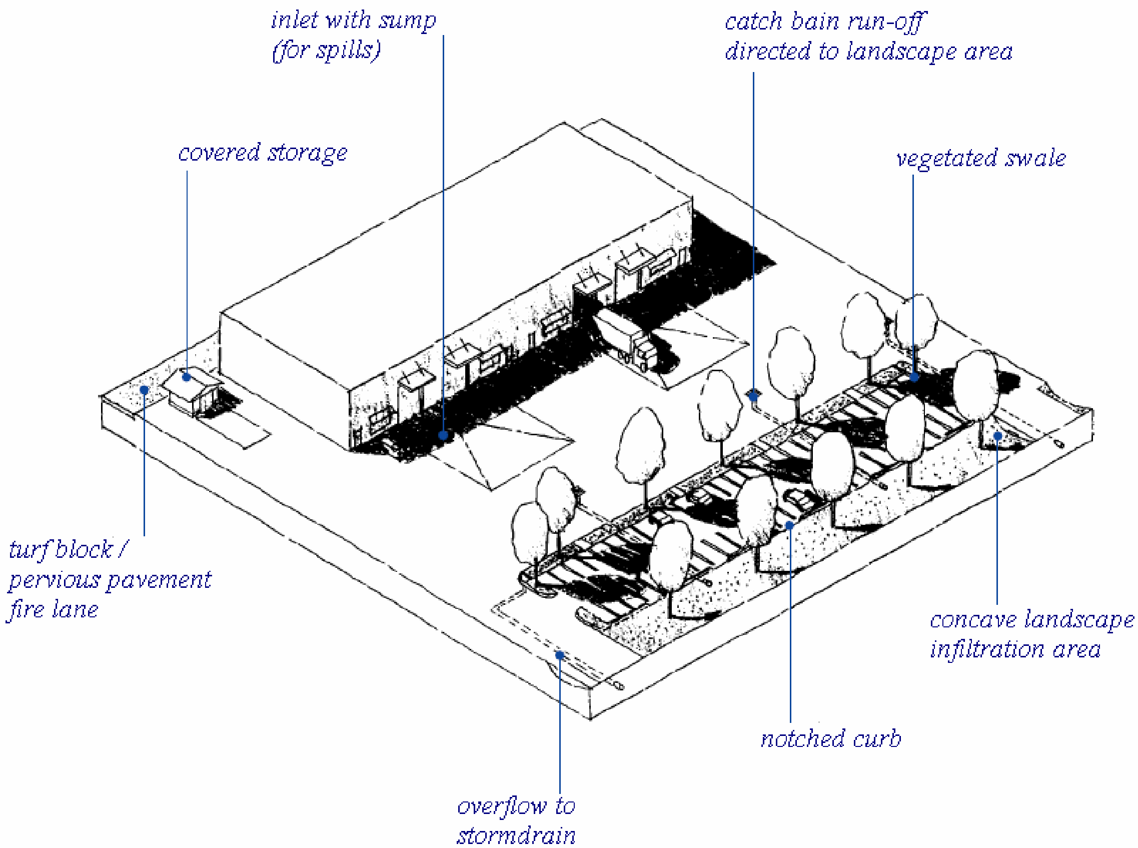
The techniques illustrated in this example are:

- 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.***

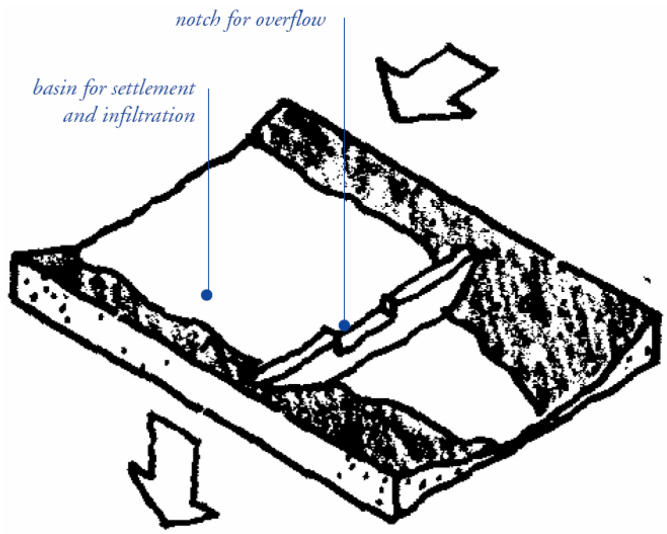
Before specific LID solutions can be developed for a particular project, the project designer must determine the appropriate development category for the project (e.g., multifamily residential). Once the designer has determined the appropriate development category for the project a multitude of specific 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.

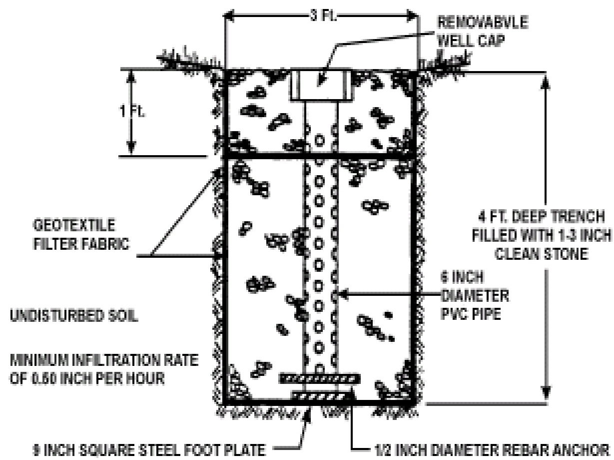
Site soil conditions generally determine if infiltration is feasible. In Soil Groups A and B (see Appendix 3, Section B.1) infiltration is usually acceptable, but it is severely limited in Soil Groups C and D. It is also limited where high groundwater, steep slopes, or shallow bedrock is present. The 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.

Photograph: City of Encinitas, Detention/Infiltration Area

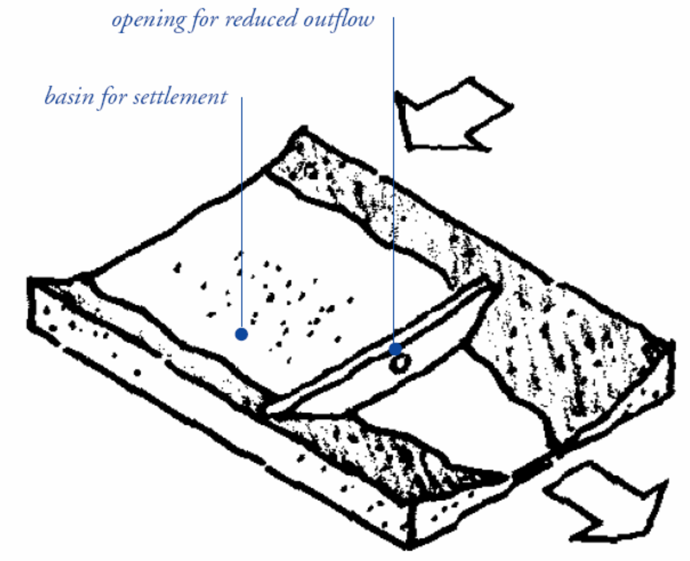
For more information on Infiltration Trenches please see **<u>Fact Sheet 1</u>** in Appendix 4.

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.

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

3.1.2. Retention and Detention



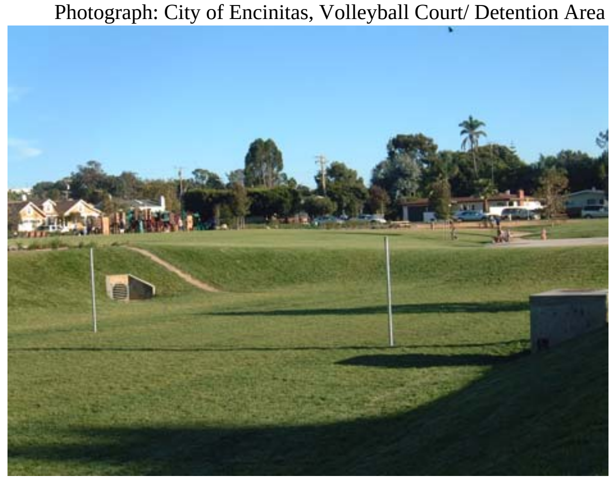
Retention and detention systems differ from infiltration systems primarily in intent. While infiltration systems are intended to percolate water into the soil, retention and detention systems are designed primarily to store runoff for gradual release or reuse. Detention systems store runoff for up to 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.

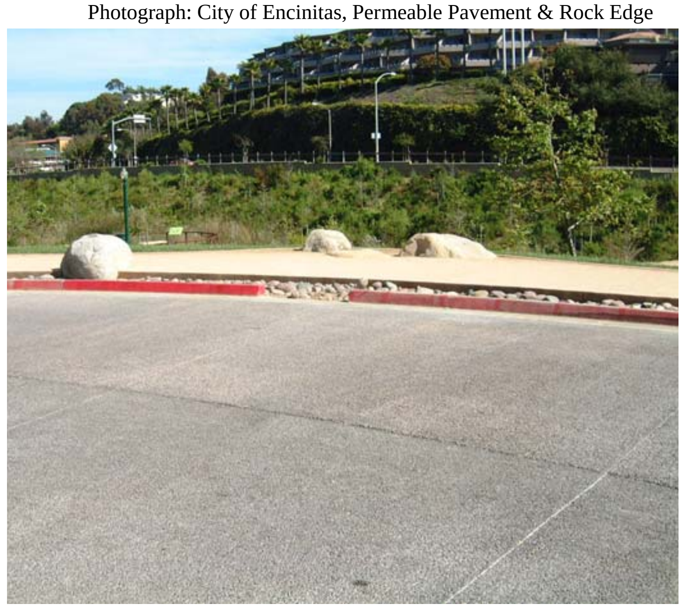
For more information on Bioretention please see **Fact Sheet 7** in Appendix 4.

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 <u>impervious</u> 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 **<u>Fact Sheet 8</u>** 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

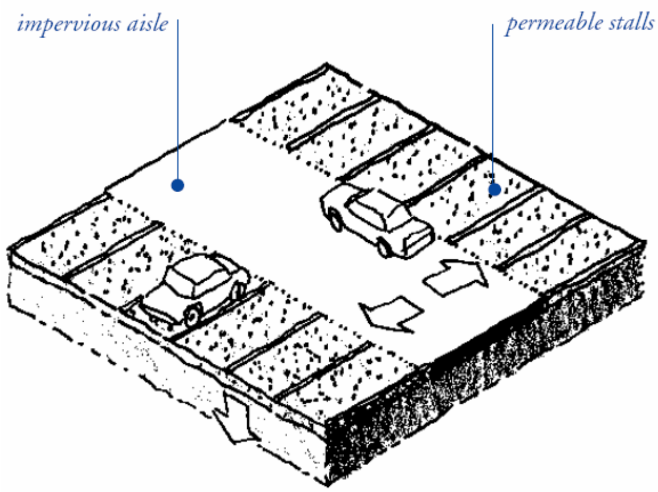
Cul-de-sac streets present special opportunities and challenges. Because cul-de-sac streets terminate, they require a turn-around area large enough to accommodate large trucks. County Fire code requires a minimum paved radius width of 36 feet in residential areas. If an entire 36 foot radius turnaround 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.

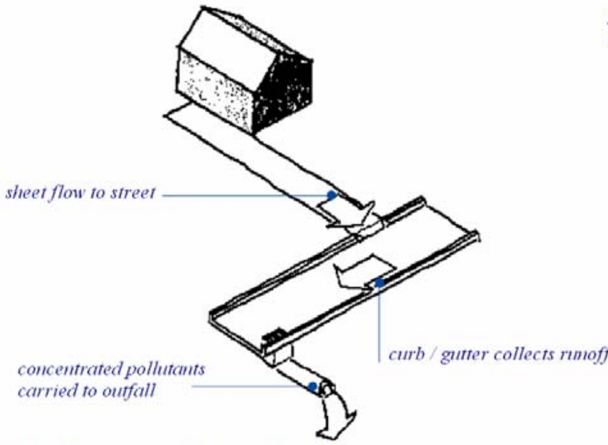
Photograph Courtesy of EOA, Inc.

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.

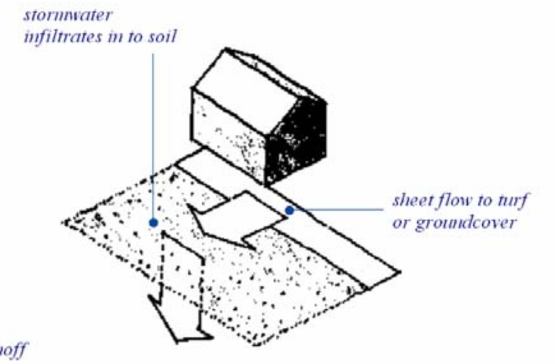
For more information on Hybrid Parking, Lots Parking Groves, and Overflow Parking please see **Fact Sheets 21-23** in Appendix 4.

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.

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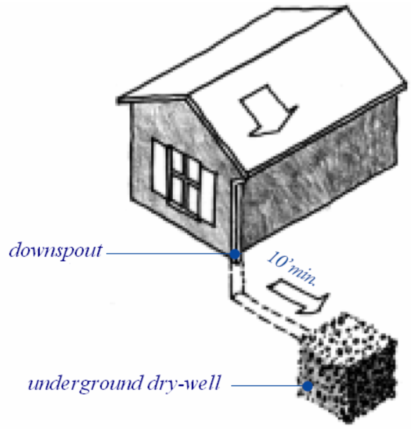
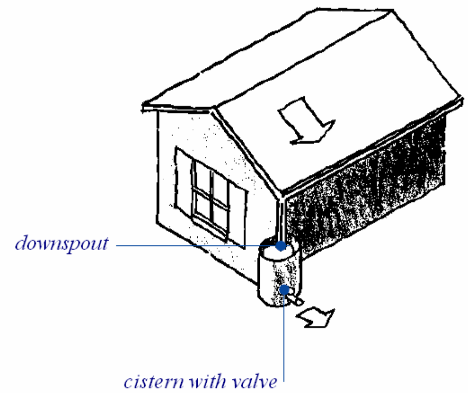
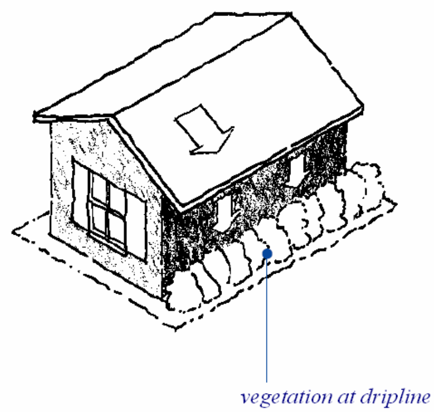
3.6. LID Building Design



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.

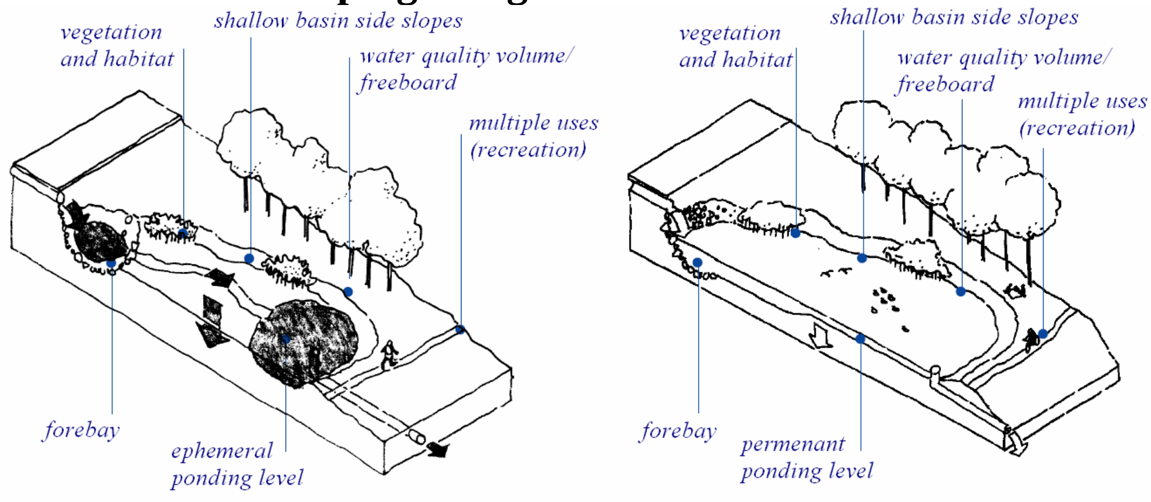
3.6.5. Vegetated Roofs

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 **Fact Sheet 30** 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.