County of Los Angeles Low Impact Development Standards Manual

January 2009

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

Urbanization has the potential to impact the water resources in the County of Los Angeles. As land is developed, impervious area and surface runoff increase. Less water is percolated into the groundwater basins and runoff may collect and transport pollutants to the downstream receiving waters, including beaches, streams, and the flood control and water conservation systems of the County of Los Angeles. Low-Impact Development (LID) practices are one means to mitigate the impacts of development and urbanization.

WHAT IS LID?

LID is a new approach to managing rainfall and stormwater runoff. LID practices are designed to protect surface and groundwater quality, maintain the integrity of ecosystems, and preserve the physical integrity of receiving waters by controlling rainfall and stormwater runoff at or close to the source.

Use of these techniques helps reduce off-site runoff and ensure adequate groundwater recharge. LID techniques focus mainly on site-specific hydrology since every aspect of site development affects the hydrologic response of the site. Thus, the primary goal of LID methods is to mimic the undeveloped site hydrology using site-design techniques that store, infiltrate, evaporate, and detain runoff.

HOW DOES LID WORK?

The concept of LID is to distribute small, cost-effective landscape features throughout the project site. The source control concept is quite different from conventional regional treatment (pipe and large stormwater management basin design).

LID incorporates multifunctional site design elements or Best Management Practices (BMPs) for stormwater detention and water quality improvements. These multifunctional site design elements include the use of bioretention/filtration landscape areas, disconnected hydrologic flowpaths, reduced impervious surfaces, functional landscaping, and functional grading to maintain hydrologic functions that existed prior to development, such as infiltration, frequency and volume of discharges, and groundwater recharge.

BMPs are placed throughout the site in many small, discrete units and are distributed in a small portion of each lot or site near the source of impacts, virtually eliminating the need for a centralized facility, such as a regional stormwater management basin. By this process, a developed site can be designed as an integral part of the environment, maintaining undeveloped hydrologic functions through the careful use of LID BMPs. BMPs are defined and described in Chapter 5, Low-Impact Development Best Management Practices.

BMPs and the use of 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. Numerous studies have shown that small storms, which occur more frequently than relatively large storms in Southern California, typically transport the greatest load of pollutants to local water bodies. The majority of pollutants are typically transported during the first flush portion of a runoff event, which is often considered to be the first 3/4 inch of a storm event.

CHANGE TO IMPROVE QUALITY OF LIFE

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, the storm drain system, and downstream receiving waters. Until recently, conventional storm drainage and flood control systems have been designed to convey stormwater away from developed areas as quickly as possible without thoroughly addressing stormwater quality and/or groundwater recharge enhancement.

The natural absorption and infiltration abilities of the land are lost when natural vegetated pervious ground cover is converted to impervious surfaces, such as paved highways, streets, rooftops, and parking lots in conventional development. This can result in postdevelopment runoff with greater volume, velocity, and peak-flow rate than undeveloped runoff from the same area. Increased volume, velocity, rate, and duration of runoff can accelerate the erosion or sedimentation of downstream natural channels. Significant declines in the biological integrity and physical habitat of streams and other receiving waters may occur with a conversion from natural to impervious surfaces. Furthermore, ephemeral and intermittent streams, as found in the semiarid regions in Southern California, may be even more sensitive where a small increase of total impervious area can have impacts to stream morphology. Runoff durations can also increase as a result of flood control and other efforts to control peak-flow rates. See Table 1-1 for a listing of the potential impacts to a watershed due to conventional urban/suburban development.

Table 1-1 Degradation of watershed conditions and stream response.

Change in Watershed Condition	**Stream Response**
Increased pollutant loads	Metals, bacteria, and synthetic organic compounds: 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
Increased imperviousness	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 of 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

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. Until recently, conventional development has used existing storm drain system design methods that do not provide stormwater quality benefits.

Improvements in stormwater management have been made in the County of Los Angeles, but additional stormwater improvements are now required. With the addition of about 2.5 million new residents in the Los Angeles region by 2030, development in Los Angeles will continue to present challenges for stormwater treatment and management. Stormwater quality management techniques must be reconsidered in the design of new development and redevelopment. New and effective management through LID that improve the quantity and quality of stormwater is vital to the long-term economic growth and quality of life in the County of Los Angeles.

BENEFITS THROUGH THE USE OF LID

ENVIRONMENTAL BENEFITS

Pollution Abatement

LID practices can reduce both the volume of runoff and the pollutant loadings discharged into receiving waters. LID practices result in pollutant removal through settling, filtration, adsorption, and biological uptake. Reductions in pollutant loadings to receiving waters can improve habitat for aquatic and terrestrial wildlife and enhance recreational uses.

Protection of Downstream Water Resources

The use of LID practices can help prevent or reduce hydrologic impacts on receiving waters, reduce stream channel degradation from erosion and sedimentation, improve water quality, increase water supply, and enhance the recreational and aesthetic value of our natural resources. LID practices can be used to protect water resources that are downstream in the watershed. Other potential benefits include reduced incidence of illness from contact recreation activities, such as swimming and wading, more robust and safer seafood supplies, and reduced medical treatment costs.

Groundwater Recharge

LID practices can also be used to infiltrate runoff to recharge groundwater. Growing water shortages nationwide increasingly indicate the need for water resource management strategies designed to integrate stormwater, drinking water, and wastewater programs to maximize benefits and minimize costs. Development typically results in increases in the amount of impervious surface and volume of runoff.

Water Quality Improvements/Reduced Treatment Costs

It is almost always less expensive to keep water clean than it is to clean it up. A study of 27 water suppliers, conducted by the Trust for Public Land and the American Water Works Association, found a direct relationship between natural cover in a watershed and water supply treatment costs. In other words, communities with higher percentages of natural cover had lower treatment costs. According to the study approximately 50 to 55 percent of the variation in treatment costs can be explained by the percentage of forest cover in the source area.

Habitat Improvements

Innovative stormwater management techniques like LID or conservation design can be used to improve natural resources and wildlife habitat, maintain or increase land value, or avoid expensive mitigation costs.

LAND VALUE AND QUALITY OF LIFE BENEFITS

Reduced Downstream Flooding and Property Damage

LID practices can be used to reduce downstream impacts through the reduction of peak flows and the total volume of runoff. This can reduce property damage, the initial capital costs, and the operation and maintenance costs of flood control infrastructure. Strategies designed to manage runoff at the site, or as close as possible to its point of generation, can reduce erosion and sediment transport and reduce downstream impacts. As a result, the costs for clean ups and stream bank restoration can be reduced or avoided altogether. The use of LID techniques can also help protect or restore floodplains, which can be used as park space or wildlife habitat.

Real Estate Value/Property Tax Revenue

Various LID projects and smart growth studies have shown that people are willing to pay more for clustered homes than conventionally designed subdivisions. Clustered housing with open space is appreciated at a higher rate than conventionally designed subdivisions. The Environmental Protection Agency's *Economic Benefits of Runoff Controls* describes numerous examples where developers and subsequent homeowners have received premiums for proximity to attractive stormwater management practices. These designs should be visually attractive, safe for the residents, and should be considered an integral part of planning the development.

Aesthetic Value

LID techniques are usually attractive features because landscaping is an integral part of the designs. Designs that enhance a property's aesthetics using trees, shrubs, and flowering plants that complement other landscaping features can be selected. The use of these designs may increase property values or result in faster sale of the property due to the perceived value of the extra landscaping.

Quality of Life/Public Participation

Placing water quality practices on individual lots provides opportunities to involve homeowners in stormwater management and enhances public awareness of water quality issues. An American Lives, Inc., real estate study found that 77.7 percent of potential homeowners rated natural open space as essential or very important in planned communities.

LID GOALS

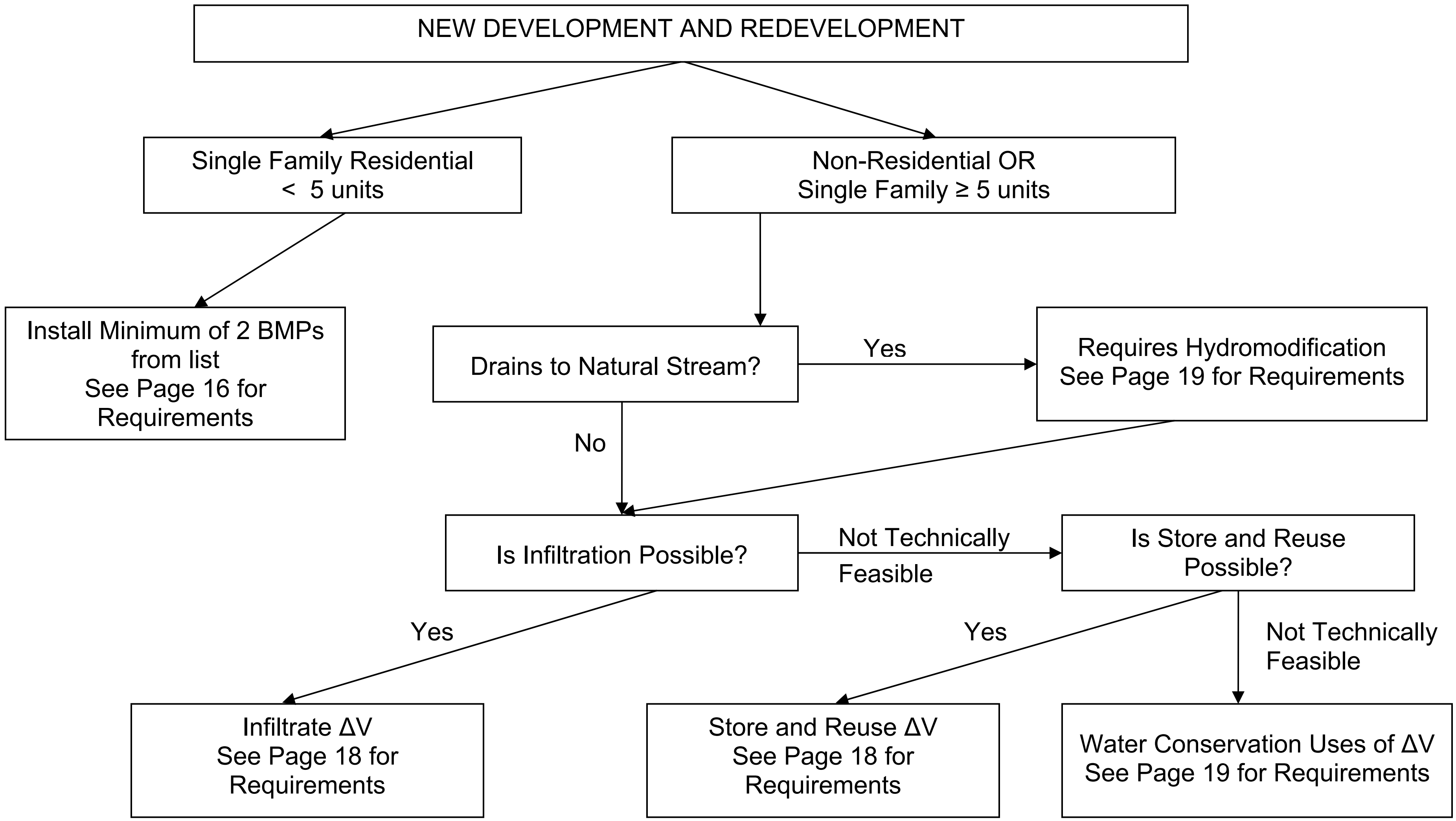
The goals of LID are discussed and demonstrated throughout the manual. The list below highlights some of the main goals and principles of LID:

- Provide an improved technology for water quality improvements of receiving waters and for additional groundwater recharge.
- Introduce new concepts, technologies, and objectives for stormwater management, such as micromanagement and multifunctional landscape features (bioretention areas, swales, and conservation areas), to mimic or replicate hydrologic functions and maintain the ecological/biological integrity of receiving streams.
- Encourage flexibility in regulations that allows innovative engineering and site planning to promote smart growth principles.
- Encourage environmentally sensitive development.
- Encourage public education and participation in environmental protection.

HOW TO USE THIS MANUAL

LID allows the site planner/engineer to use a wide array of simple cost-effective techniques that focus on site-level hydrologic control. This manual describes those techniques and provides examples and descriptions of how they work, and also contains BMP fact sheets. For ease of use and understanding, this document has been divided into 7 chapters. Figure 1-1 summarizes the major components of the LID approach. Compliance with the existing regulations is required by the County of Los Angeles Ordinance 22.52.2210.

LID DESIGN REQUIREMENTS



CHAPTER 2: SITE PLANNING AND SITE DESIGN

INTRODUCTION

A significant element in the implementation of LID, and one that should be incorporated at the earliest possible stage of a project, is the design and layout of the development site. Good LID site design takes advantage of the services provided by the site's natural systems. The natural systems that LID seeks to preserve and even restore are an undeveloped site's hydrologic functions, vegetation, and soils. LID site planning and design practices approach stormwater as a resource that should be conserved.

According to the National Association of Home Builders[1]:

> "LID (LID) strategies strive to allow natural infiltration to occur as close as possible to the original area of rainfall. By engineering terrain, vegetation, and soil features to perform this function, costly conveyance systems can be avoided, and the landscape can retain more of its natural hydrological function. LID practices dovetail with green building practices that incorporate environmental considerations into all phases of the development process. Builders can often use green building and LID to lower actual development costs. Although most effective when implemented on a community-wide basis, using LID practices on a smaller scale, i.e., on a small development, can also have an impact."

HYDROLOGIC FUNCTIONS

Natural hydrologic functions provide the following services in a watershed:

- Rainfall interception: In a vegetated watershed, the surfaces of trees, shrubs, and grasses catch initial light rainfall before it reaches the ground. Interception can delay the start and lower the volume of runoff.

- Shallow surface storage: The shallow pockets present in natural terrain store rainfall and runoff, filtering and allowing infiltration, and delaying the start of runoff.

- Evaporation and transpiration: Evaporation occurs when water changes from a liquid to a vapor and moves into the air. Transpiration occurs when vegetation releases water vapor into the atmosphere. Both processes reduce the volume of runoff, locally return moisture to the atmosphere, and provide local cooling effects. Collectively, this process is called evapotranspiration.

---

[1] National Association of Home Builders Research Center, *Low Impact Development (LID) Practices for Storm Water Management*, http://toolbase.org/Technology-Inventory/Sitework/low-impact-development, accessed April 7, 2008.

- Infiltration: Infiltration is the movement of surface water down through the soil into groundwater. Such movement filters and reduces the volume of runoff and replenishes groundwater supplies.

- Runoff: Runoff is the flow of water across the land surface that occurs after rainfall interception, surface storage, and infiltration reach capacity.

Hydrologic processes can be adversely impacted by land development through:

- Removing vegetation: The loss of vegetative canopy reduces the amount of rainfall intercepted. The loss of deep root systems allows soils to compress and lose storage and infiltration capacity. The loss of leaf litter and organic matter on the ground removes a number of beneficial physical, chemical, and biological processes that treat runoff.

- Covering porous soils with impervious surfaces: Rainfall that could have been stored or infiltrated is converted directly into runoff, carrying with it the pollution associated with the land use. Rainfall and runoff that could have recharged groundwater reservoirs for later reuse are lost.

- Replacing natural drainage paths with paved pathways, pipes, and channels: While efficiently removing water from a site, hardened conveyances collect the increased runoff with greater speed, causing higher flow rates, the loss of infiltration potential at the site, increased erosion in natural and soft-bottomed channels, and the loss of in-stream and streamside habitat.

VEGETATION

Vegetation provides the following services[2] in a watershed:

- Intercepts rainfall.

- Stores water in plant tissue.

- Filters air and water pollution.

- Provides erosion control.

- Keeps soil pore structure open for storage and infiltration of water.

- Pipes water along roots and into the soil.

- Provides water vapor through transpiration.

- Balances oxygen and carbon dioxide in the atmosphere by photosynthesis.

---

[2] American Society of Landscape Architects, et al., *Sustainable Sites Initiative, Preliminary Report on Standards & Guidelines*, November 1, 2007.

- Moderates the climate globally and locally by regulating greenhouse gasses and lowering heat island effects.

- Provides habitat for resident and migratory animals; provides connective habitat in urbanized areas.

Vegetation can be adversely impacted by land development through:

- Disturbance and removal: With the absence of vegetation, a site will lose its capacity to infiltrate, absorb, and filter runoff. Local heat island effects would be created. Soil health would suffer as soils become compacted. Erosion and sedimentation would increase.

- Inadequate space: Confined planting patterns, including cramped root zones, limit healthy plant growth, leading to increased maintenance and premature death of vegetation.

- Introduction of invasive plants: Some plants that are not native to the area can overtake the native or California friendly species, threatening native organisms.

SOILS

Healthy soils provide the following services[3] in a watershed:

- Regulate infiltration, runoff, erosion, sedimentation, and flooding.

- Increased capacity for the storage of water.

- Support growth of vegetation.

- Filter pollutants in runoff.

- Support production of food and raw materials.

- Support the nitrogen cycle.

- Lockup carbon.

- Provide biological habitats.

Soils can be adversely impacted by land development through:

- Compaction: Soil compaction disturbs native soil structure, reduces infiltration rates, and limits root growth and plant survivability. While soil compaction is necessary to provide structurally sound foundations, areas away from foundations are often excessively compacted by vehicle and foot traffic during construction.

[3] Ibid.

- Removal of vegetation: Removal of vegetation can expose soils to erosion and thus cause sedimentation and the modification of natural streams. Disturbance of soil can also release previously locked organic carbons into the atmosphere[4].

- Removal of topsoil: A common practice is the removal of topsoil before or during construction. This practice removes native seeds, removes soil organisms, impedes the reestablishment of healthy soils, and upsets the native soil structure even if the original soil is returned.

- Contamination: The application of pesticides and herbicides can introduce toxic organics and metals into the soil, which can bioaccumulate in higher organisms and possibly get into food sources. Broadly applied pesticides and herbicides could impact unintended species including those found in the soil. Such disruption can adversely affect resistance to pathogens, infiltration, and the filtering of pollutants.

SITE DESIGN PRACTICES[5] FOR LID

The goals of LID are to mimic undeveloped hydrology and control runoff at the source. These goals are accomplished with creative site planning and the incorporation of localized, naturally functioning BMPs into the site's design.

The first step in creating a LID design is site planning. The elements[6] that make up a successful low-impact site plan are:

1. Conserving natural areas, soils, and vegetation.
2. Minimizing disturbances to natural drainage patterns.
3. Minimizing and disconnecting impervious surfaces.
4. Minimizing soil compaction.
5. Directing runoff from impervious areas to pervious areas.

CONSERVING NATURAL AREAS, SOILS, AND VEGETATION

The conservation of natural areas, soils, and vegetation helps to retain numerous functions of predevelopment hydrology, including rainfall interception, infiltration, and evapotranspiration. Maximizing these functions will thereby reduce the amount of runoff that must be treated. Further, minimizing soil disturbance reduces the emission of

[4] Lal, R., "Soil Carbon Sequestration Impacts on Global Climate Change and Food Security," Science 304: 1623-7 (2004), in *Sustainable Sites Initiative*.
[5] American Society of Landscape Architects, et al., op cit.
[6] County of San Diego, *Low Impact Development Handbook*, December 31, 2007.

greenhouse gasses[7] and conserves natural habitat. For these reasons, site planning, design, and execution, where appropriate, should:

1. Conform to local watershed, conservation, and open space plans.

2. Preserve sensitive environmental areas.

3. Preserve historically undisturbed vegetated areas.

4. Build upon the least porous soils or limit construction activities and disturbances to areas with previously disturbed soils.

5. Protect healthy soils, reuse the top soils already on the site, and import soil only when on-site soils are exhausted.

6. Preserve the maximum surface area of undisturbed grades.

7. Preserve native trees and restrict disturbance of soils beneath tree canopies.

8. Avoid disturbing vegetation and soil on slopes and near surface waters.

9. Leave an undisturbed buffer along both sides of natural streams.

10. Avoid adding materials to the soil that decrease cation exchange capacity (CEC), such as sand, except where required for special water treatment needs.

    Examples of conserving natural areas, soils, and vegetation:

    - Avoid mass clearing and grading, and grade only those areas where structures are to be built.

    - Protect existing streamside areas and habitat.

    - Mulch tree and plant beds.

    - Incorporate plants to suit existing soil and drainage conditions rather than changing soil and drainage conditions to suit a desired plant list.

    - Create multilayered planting schemes that replicate natural sites with both canopy and vegetative ground cover.

    - Incorporate compost to increase water retention and soil moisture and reduce the need for fertilizer.

    - Use appropriate vegetative plantings and bioremediation techniques to remove or neutralize soil contaminants.

[7] Lal, R., op cit

- Cluster development to preserve porous soils, natural streams, and natural slopes.

MINIMIZING DISTURBANCES TO NATURAL DRAINAGE PATTERNS

Minimizing disturbances to natural drainage patterns preserves the predevelopment timing, rate, and duration of runoff as well as preserving streamside habitats. Preserving the predevelopment drainage characteristics will also minimize the physical impacts on a natural stream. For these reasons, site planning, design, and execution, where appropriate, should:

1. Maintain surface flow patterns of undeveloped sites.

2. Maintain existing water body alignments, sizes, and shapes.

3. Protect seasonal flooding patterns of wetlands.

4. Restore streams and drainage corridors to achieve the same characteristics of timing, flow, and habitat as the original drainage courses in the event that preservation of natural drainage patterns cannot be maintained.

   Examples of minimizing disturbances to natural drainage patterns:

   - Avoid burying, piping, or channelizing streams by carefully planning water crossings and considering alternatives to traditional culverts, even for small crossings.

   - Daylight piped stream systems and restore stream banks and channels to historic, healthy configurations.

   - Avoid the concentration of surface runoff.

   - Avoid large, shallow, and unshaded water features that can increase water temperatures in receiving waters.

   - Create or restore wetlands and riparian areas to absorb, filter, and attenuate runoff.

   - Restore organic matter levels in all root zones to levels consistent with similar soil types in undisturbed regional soils.

   - Minimize manicured lawns and annuals beds as the dominant site elements.

MINIMIZING AND DISCONNECTING IMPERVIOUS SURFACES

Minimizing and disconnecting impervious surfaces increase the chance for rainfall and runoff to infiltrate into the ground, thereby reducing, slowing, and filtering runoff, and increasing groundwater supplies. For these reasons site planning, design, and execution, where appropriate, should:

1. Reduce overall impervious areas by maximizing landscaping and using pervious pavements.

2. Reduce the amount of impervious areas that are hydraulically connected to impervious conveyances, such as driveways, walkways, culverts, swales, streets, or storm drains.

   Examples of minimizing and disconnecting impervious surfaces:

   - Use porous pavements on private property for sidewalks and less traveled surfaces, such as driveways, fire lanes, bike lanes, parking lanes, overflow parking, and parking stalls.
   - Install shared driveways, flared driveways, and residential driveways with center vegetated strips.
   - Provide for shared parking in commercial areas.
   - Direct roof downspouts to vegetated areas, rain gardens, or planter boxes.
   - Isolate paved areas with buffers.
   - Modify curb and gutter and route runoff in vegetated swales.
   - Reduce a building's footprint by building upward rather than outward.
   - Install rain barrels and cisterns below roof downspouts.
   - Install a green roof.

MINIMIZING SOIL COMPACTION

Soil compaction damages soil structure, reduces infiltration rates, limits root growth and plant survivability, and destroys soil organisms. Reduced infiltration creates increased runoff volume. Uncompacted soils support vegetation, support organisms, and store and infiltrate water. For these reasons site planning, design, and execution, where appropriate, should:

1. Restrict grading and compaction to those areas that will support structures.

2. Protect soils, especially porous soils, against compaction and rutting in areas where traffic is unavoidable.

3. Minimize the size of construction easements and material storage areas.

4. Site stockpiles within the development envelope during the construction phase of a project.

5. Prohibit working on wet soils with heavy equipment.

6. Restore compacted open space areas with tilling and soil amendments.

   Examples of minimizing soil compaction:

   - Incorporate a soil noncompaction and restoration plan into the project's construction phase Storm Water Pollution Prevention Plan.

   - Till into compacted soils 3 inches of well-aged organic mulch to a depth of 12 inches after grading.

DIRECTING RUNOFF FROM IMPERVIOUS AREAS TO INFILTRATION AREAS

Runoff across impervious areas will flow faster and carry pollutants accumulating on the impervious surfaces. The prevention of surface infiltration will also create more runoff volume. Directing runoff to infiltration areas will slow the velocity, filter out pollutants, and replenish groundwater. Infiltration has been found to be a reasonable and practical method for reducing pollutant load provided there is suitable pretreatment[8]. For these reasons site planning, design, and execution, where appropriate, should:

1. Grade surfaces to drain toward open space, swales, or bioretention cells with infiltration capability.

2. Grade surfaces to drain through suitable pretreatment trains toward porous pavements with infiltration capability.

3. Use grassed or vegetated swales with infiltration capability to convey runoff rather than using conduit and lined conveyances.

   Examples of directing runoff from impervious areas to infiltration areas:

   - Design streets to drain to grassed or vegetated swales or bioretention cells with infiltration capability.

   - Grade parking areas to drain to grassed or vegetated swales, bioretention cells, and/or pervious pavements with infiltration capability.

   - Grade driveways to drain sideways to adjacent pervious areas with infiltration capability rather than to the street.

[8] Los Angeles/San Gabriel Rivers Watershed Council, *L. A. Basin Water Augmentation Study*, www.lasgrwc.org/WAS.htm, accessed March 31, 2008.

- Direct roof runoff to vegetated swales, planter boxes, or bioretention cells with infiltration capability.

- Raise stormwater inlets in planting areas to allow water to soak into the soil where it can infiltrate.

CHAPTER 3: DESIGN REQUIREMENTS

All new development and redevelopment under the jurisdiction of the County of Los Angeles is required to meet LID requirements. The goals of LID are to increase groundwater recharge, enhance water quality, and prevent degradation to downstream natural drainage courses.

REQUIREMENTS FOR SMALL SCALE RESIDENTIAL PROJECTS

Residential development and redevelopment of four units or less, or remodels affecting more than 50 percent of the original home footprint are not required to complete hydrologic analysis for the project site, but must include at least two of the following items into the site design:

- Porous pavement

  Install porous pavement that allows rainwater to infiltrate through it. Porous pavement includes, but is not limited to, porous asphalt, porous concrete, ungrouted paving blocks, and gravel. At least 50 percent of the pavement on the lot shall be porous.

- Downspout routing

  Each roof downspout shall be directed to one of the following BMPs. The sum of the capacity of the downspout BMPs shall be at least 200 gallons.

  a. Cistern/rain barrel

     Direct roof downspouts to rain barrels or cisterns. The stored stormwater can then be used for irrigation or other nonpotable uses.

  b. Rain garden/planter box

     Direct roof downspouts to rain gardens or planter boxes that provide retention and treatment of stormwater.

- Disconnect impervious surfaces

  Slope driveways and other impervious surfaces to drain toward pervious surfaces. If possible, runoff should be directed toward vegetated areas or water quality BMPs. Limit the total area not directed toward vegetated areas or water quality BMPs to 10 percent or less of the area of the lot.

- Dry well

  Install a dry well to infiltrate stormwater. The dry well shall be sized to hold at least 200 gallons of stormwater.

- Landscaping and landscape irrigation

  Plant trees near impervious surfaces to intercept rainfall in their leaves. Trees planted adjacent to impervious surfaces can intercept water that otherwise would have become runoff. Two trees shall be planted on each parcel so that they overhang impervious surfaces. Install irrigation systems that minimize water usage and eliminate dry-weather urban runoff.

- Green roof

  Install a green roof to retain and treat stormwater on the rooftop. A green roof shall cover at least 50 percent of the total rooftop area.

REQUIREMENTS FOR LARGE SCALE DEVELOPMENT

All residential developments of five units or greater and all nonresidential developments shall follow the LID Hydrologic Analysis techniques outlined in the Hydrologic Analysis Section of this manual.

LID Requirements

Large scale residential and nonresidential development projects shall prioritize the selection of BMPs to treat stormwater pollutants, reduce stormwater runoff volume, and promote groundwater infiltration and stormwater reuse in an integrated approach to protecting water quality and managing water resources. BMPs shall be implemented in the following order of preference:

1. BMPs that promote infiltration.

2. BMPs that store and beneficially use stormwater runoff.

3. BMPs that utilize the runoff for other water conservation uses including, but not limited to, BMPs that incorporate vegetation to promote pollutant removal and runoff volume reduction and integrate multiple uses, and BMPs that percolate runoff through engineered soil and allow it to discharge downstream slowly.

4. If the Director of Public Works determines that compliance with the above (No. 3) LID requirements is technically infeasible, in whole or in part, in response to an applicant's submittal, the Director shall require the applicant to submit a proposal for approval by the Director that incorporates design features demonstrating compliance with the LID requirements to the maximum extent practicable.

The LID goals of increasing groundwater recharge, enhancing water quality, and preventing degradation to downstream natural drainage courses shall be used in the evaluation, approval, and implementation of LID BMPs, as well as any determination of infeasibility.

On-site Infiltration Requirements

The excess volume (ΔV) determined by the hydrologic analysis in Chapter 4 shall be infiltrated throughout the project site whenever possible. This can be accomplished on a lot-by-lot or on a subregional scale provided that equivalent benefit can be demonstrated. The following requirements apply:

- Infiltrate the ΔV from each lot at the lot level, or

- Infiltrate the ΔV from the entire project site including streets and public right of way in subregional facilities. The tributary area of a subregional facility shall generally be limited to 5 acres, but may be exceeded per the Director of Public Works.

Infiltration may not be possible in all development scenarios. Exceptions may include, but are not limited to, the following technical feasibility and implementation parameters:

- Locations where seasonal high groundwater is within 10 feet of the surface.

- Within 100 feet of a groundwater well used for drinking water.

- Brownfield development sites or other locations where pollutant mobilization is a documented concern.

- Locations with potential geotechnical hazards as outlined in a report prepared and stamped by a licensed geotechnical engineer.

- Locations with natural, undisturbed soil infiltration rates of less than 0.5 inches per hour that do not support infiltration-based BMPs.

- Locations where infiltration could cause adverse impacts to biological resources.

- Development projects in which the use of infiltration BMPs would conflict with local, State or Federal ordinances or building codes.

- Locations where infiltration would cause health and safety concerns

On-site Storage and Reuse Requirements

When infiltration is not possible, on-site storage and reuse of the ΔV is the next preferred LID BMP option. Storage and reuse of the ΔV may not be possible in all development scenarios. Exceptions may include, but are not limited to, the following technical feasibility and implementation parameters:

- Projects that would not provide sufficient irrigation or (where permitted) domestic grey water demand for use of stored runoff due to limited landscaping or extensive use of low water use plant palettes in landscaped areas.

- Projects that are required to use reclaimed water for irrigation of landscaping.

- Development projects in which the storage and reuse of stormwater runoff would conflict with local, State or Federal ordinances or building codes.

- Locations where storage facilities would cause potential geotechnical hazards as outlined in a report prepared and stamped by a licensed geotechnical engineer.

- Locations where storage facilities would cause health and safety concerns.

Water Conservation Requirements

When infiltration or storage and reuse of the ΔV is not possible, LID BMPs that incorporate vegetation to promote pollutant removal and runoff volume reduction, integrate multiple uses and/or BMPs that percolate runoff through engineered soil and allow it to discharge downstream slowly shall be implemented. These LID BMPs shall be sized to detain and treat the ΔV.

Infeasibility

Compliance with the LID requirements in this manual in whole or in part may not be feasible in all development scenarios. In these situations, the applicant shall demonstrate the infeasibility of compliance with the LID requirements and submit a proposal for approval by the Director that incorporates design features demonstrating compliance with the LID requirements to the maximum extent practicable.

Water Quality Treatment Requirements

The runoff from the water quality design storm event associated with the developed site hydrology described in Chapter 4 must be treated before discharge in compliance with the National Pollutant Discharge Elimination System Municipal Stormwater Permit for the County of Los Angeles.

Hydromodification Requirements

California Drainage Law is a complicated and complex area with respect to the rights of upper and lower landowners. Therefore, it is in everyone's best interest to require developments to analyze all the factors that may contribute to changed drainage characteristics, which may contribute to downstream drainage impacts (increased flooding and erosion). Below is an outline of the procedure required to analyze drainage impacts on off-site property.

1. All projects are required to conduct hydrology and hydraulic analysis for SUSMP, LID, 2-, 5-, 10-, 25-, and 50-year storm events per the Los Angeles County Department of Public Works Hydraulic and Hydrology manuals.

2. HEC-RAS is required as the standard for analyzing changes in flow velocity, flow volume, and depth/width of flow for all natural drainage courses.

3. Sediment transport analysis using HEC-RAS, SAMS, and HEC-6 is required to determine long-term impacts of streambed accretion and degradation for major drainage courses with Capital Storm flow rates (Q) greater than 5,000 cubic feet per second.

4. All projects are required to fully mitigate off-site drainage impacts caused by hydromodification and changes in water quality, flow velocity, flow volume, and depth/width of flow under all 7 hydrologic scenarios above.

5. If not fully mitigated, the developer is required to obtain Drainage Acceptance letters from impacted downstream property owners. If Drainage Acceptance letters cannot be obtained and mitigation is not feasible, the developer must recommend to Regional Planning that a Statement of Overriding Consideration be included in the California Environmental Quality Act document to disclose that there will be significant unmitigated downstream drainage impacts.

Hydromodification Exemptions

All projects that comply with one or more of the following conditions are exempt from conducting a full analysis for hydromodification impacts. Applicants must still demonstrate that the project mitigates for hydromodification impacts to the satisfaction of the Director of Public Works.

- Projects that disturb less than one acre.

- Less than 10,000 square feet of new impervious area.

- Projects that do not increase impervious area or decrease the infiltration capacity of pervious areas compared to preproject conditions.

- Projects that are replacement, maintenance, or repair of an existing permitted flood control facility.

- Projects within a watershed or subwatershed where a geomorphically-based watershed study has been prepared that establishes that the potential for hydromodification impacts is not present based on appropriate assessment and evaluation of relevant factors, including: runoff characteristics, soil conditions, watershed size and conditions, channel conditions, and proposed levels of development within the watershed.

- Projects that discharge directly or via a storm drain into concrete or significantly hardened channels, which in turn discharge into a sump area under tidal influence, or other receiving water that is not susceptible to hydromodification impacts.

- Projects that have hydrologic control measures that include sufficient subregional, regional, in-stream control measures, or a combination thereof such that hydromodification will not occur.

CHAPTER 4: LID HYDROLOGIC ANALYSIS

INTRODUCTION

Southern California has a relatively dry climate with long periods of very little rainfall often followed by intense storm events. The County of Los Angeles Department of Public Works uses the Modified Rational Method of hydrologic analysis. A detailed discussion of the methodology is included in the Los Angeles County Department of Public Works Hydrology Manual. The most recent version is available online at http://www.ladpw.org/wrd/publication/index.cfm.

LID GOALS

The primary benefits expected from implementation of LID are: (1) increased groundwater recharge, (2) enhanced water quality, and (3) stability of downstream natural reaches.

The main benefits of LID can be achieved with relatively simple analysis using tools that are currently available and consistent with approved methods, such as Los Angeles County's Tc calculator available online at http://www.ladpw.org/wrd/publication/Engineering/hydrology/tc_calculator_files.zip.

METHODOLOGY

<u>LID Hydrologic Analysis Steps</u>

Step 1: Determine hydrologic parameters

Determine drainage area of proposed development site (for sites larger than 40 acres use multiple subareas). Calculate slope and length of flow path and identify soil type.

Step 2 Identify design storm

There are several options for an LID design storm. This accounts for regional differences in rainfall and is consistent with existing SUSMP design criteria.

A. The 85th percentile 24-hour runoff event determined, as the maximized capture stormwater volume for the area, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/SCE Manual of Practice No. 87, (1998), or

B. The volume of annual runoff, based on unit basin storage water quality volume, to achieve 80 percent or more volume treatment by the method recommended in California Stormwater Best Management Practices Handbook – Industrial/Commercial, (1993), or

C. The volume of runoff produced from a 0.75-inch storm event prior to its discharge to a stormwater conveyance system, or

D. The volume of runoff produced from a historical record based reference 24-hour rainfall criterion for treatment 0.75 inch average for the County of Los Angeles area) that achieves approximately the same reduction in pollutant loads achieved by the 85th percentile 24-hour runoff event.

Step 3: Calculate undeveloped runoff volume

Using an approved hydrologic analysis tool consistent with the Los Angeles County Department of Public Works Hydrology Manual, determine the volume associated with the selected design storm assuming clear flows and undeveloped site conditions (0 percent impervious surfaces).

Step 4: Calculate developed runoff volume

Using the same design storm, determine the runoff volume associated with the proposed development. The impervious values shall be consistent with the hydrology manual recommendations based on land-use type.

Step 5: Calculate the excess volume (ΔV)

Subtract the undeveloped runoff volume from the developed runoff volume. This quantity is required to be infiltrated wherever possible at the site level and the BMPs used to accomplish this requirement shall be distributed throughout the project site.

Step 6: Determine water quality treatment volume or flow rate

The entire volume identified in Step 4 must be treated or infiltrated or one of the following flow rate based events can be used to determine the flow rate of runoff that must be treated:

A. The flow of runoff produced from a rain event equal to at least 0.2 inches per hour intensity; or

B. The flow of runoff produced from a rain event equal to at least 2 times the 85th percentile hourly rainfall intensity for the County of Los Angeles; or

C. The flow of runoff produced from a rain event that will result in treatment of the same portion of runoff as treated using volumetric standards above.

CHAPTER 5: LOW-IMPACT DEVELOPMENT BEST MANAGEMENT PRACTICES

BIORETENTION

POLLUTANT REMOVAL

Sediment	**High**
Nutrients	**High**
Trash	**High**
Metals	**High**
Bacteria	**High**
Oil and Grease	**High**
Organics	**High**

DESCRIPTION

Bioretention areas are vegetated shallow depressions that provide storage, infiltration, and evapotranspiration. Bioretention areas also remove pollutants by filtering stormwater through plants adapted to the local climate, soil moisture conditions, and an engineered soil mix. In bioretention areas, pore spaces, microbes, and organic material in the engineered soils help retain water in the form of soil moisture and promote the adsorption of pollutants (such as dissolved metals and petroleum hydrocarbons) into the soil matrix. Plants utilize soil moisture and promote the drying of the soil through transpiration. If no underdrain is provided, outflow of the device's stored water into the underlying soils occurs over a period of days. For areas with low permeability, native soils, or steep slopes, bioretention areas can be designed with an underdrain system that routes the treated runoff to a more suitable infiltration area, a cistern for later reuse, or to the storm drain system. In this situation, treatment is achieved mainly through filtration and adsorption in the vegetation and engineered soils.

ADVANTAGES	LIMITATIONS
• Provides shade and windbreaks, and improves aesthetics • Enhances water quality through treatment and gradual infiltration	• Not appropriate for industrial sites or locations where spills may occur • Not suitable for areas where water table is within 10 feet of ground and surface stratum unstable • Not recommended where tree removal would be required • May pose vector control problem

GENERAL CONSTRAINTS AND SITE CONCERNS

Implementation of bioretention for stormwater management is ideal for median strips, parking lot islands, and downstream of swales. Moreover, the runoff in these areas can be designed to either divert directly into the bioretention area or convey into the bioretention area by a curb and gutter collection system. The best location for bioretention areas is upland from inlets that receive sheet flow from graded areas and at areas that will be excavated. In order to maximize treatment effectiveness, the site must be graded in such a way that minimizes erosive conditions as sheet flow is conveyed to the treatment area. Locations where a bioretention area can be readily incorporated into the site plan without further environmental damage are preferred. Furthermore, to effectively minimize sediment loading in the treatment area, bioretention should only be used in stabilized drainage areas. Design considerations include:

- Native soil infiltration rate - Underdrain is required in low permeability soils.
- Vertical relief and proximity to storm drain - Site must have adequate relief between land surface and storm drain to permit vertical percolation through the soil media if collected and conveyed in underdrain to storm drain system.
- Depth to groundwater - Shallow groundwater table may not permit complete drawdown between storms.
- Availability of pervious area - Bioretention areas typically occupy between 2 to 10 percent of the drainage area.

MULTIUSE OPPORTUNITIES

Bioretention areas can be applied in various settings, including:

- Individual lots for rooftop, driveway, and other on-lot impervious surface infiltration.
- Shared facilities located in common areas for individual lots.
- Areas within loop roads or cul-de-sacs.
- Landscaped parking lot islands.

- Within parkways and other right of ways along roads.
- Common landscaped areas in apartment complexes or other multifamily housing designs.
- In parks and along open space edges.

Note: Please refer to the *County of Los Angeles Department of Public Works Stormwater Best Management Practice Design and Maintenance Manual* for the most up-to-date information on this BMP.

CISTERNS/RAIN BARRELS

POLLUTANT REMOVAL

Sediment	High
Nutrients	High
Trash	High
Metals	High
Bacteria	High
Oil and Grease	High
Organics	High

DESCRIPTION

Cisterns and rain barrels are containers, which capture stormwater runoff as it comes down through the roof gutter system. Rain barrels are placed outside of a building at roof downspouts to store rooftop runoff for later reuse in lawn and garden watering. Cisterns also collect rooftop runoff, but store the water in significantly larger volumes in manufactured tanks or built underground storage areas. Both cisterns and rain barrels can be implemented without the use of pumping devices, instead relying on gravity flow. The collection of this stormwater reduces the amount of stormwater runoff and assists in the reduction of potential pollutants entering the stormwater conveyance system. Reducing the water used from the municipal water system can reduce a site's water bill.

ADVANTAGES

- Low installation cost
- Requires little space for installation
- Reduces amount of stormwater runoff
- Conserves water usage
- Reduction in the discharge of pollutants due to reduction of overall off-site flow volume

LIMITATIONS

- Limited amount of stormwater runoff can be captured
- Restricted to structure runoff

GENERAL CONSTRAINTS AND SITE CONCERNS

The following rain barrel and cistern technical and operational features should be considered:

- Screens on gutters and downspouts to remove sediment and particles as the water enters the barrel or cistern.
- Removable child-resistant covers and mosquito screening on water entry holes.
- The option of draining the system completely for maintenance.
- Drain spigots that have garden hose threading, suitable for connection to a drip irrigation system.
- Aesthetic features that are compatible with the lot's landscaping plan or landscaping that provides visual screening.
- Private stormwater maintenance agreements met between the property owner and any potential second and third parties.
- Adequate storage capacity.
- Should be located for easy maintenance or replacement.

DESIGN SPECIFICATIONS

The required capacity of a cistern and rain barrel is a function of the rooftop surface area that drains to it, the inches of rainfall required to fill the vessel, and water losses due mainly to evaporation. Cisterns should be designed to prevent mosquito access.

OPERATIONS AND MAINTENANCE

Maintenance requirements for rain barrels are minimal and consist only of regular inspection of the unit as a whole and any of its constituent parts and accessories. All components should be inspected at least twice a year and repaired or replaced as needed. Cisterns, along with all their components and accessories, should undergo regular inspection at least twice a year. Replacement or repair of the unit as a whole and any of its constituent parts and accessories should be completed as necessary.

During the wet season, cisterns and rain barrels should be inspected periodically for mosquitos.

Note: For more information, please visit the American Rain Catchment Systems Association website at www.arcsa.org.

DRY PONDS

POLLUTANT REMOVAL	
Sediment	Medium
Nutrients	Low
Trash	High
Metals	Medium
Bacteria	Medium
Oil and Grease	Medium
Organics	Medium

DESCRIPTION

Dry extended detention (ED) basins are basins whose outlets have been designed to detain the runoff from a water quality design storm for 36 to 48 hours to allow sediment particles and associated pollutants to settle and be removed. Dry ED basins do not have a permanent pool; they are designed to drain completely between storm events. They can also be used to provide hydromodification and/or flood control by modifying the outlet control structure design and including additional detention storage. The slopes, bottom, and forebay of ED basins are typically vegetated.

Dry ED basins can be located either online or offline. For offline basins, a flow diversion structure is used to divert the design storm volume to the basin from the storm drain. For online basins, all storm drain flows are routed through the basin; storm events exceeding the water quality design capacity will pass through the basin and will discharge over a primary overflow untreated or, during extreme events, over an emergency spillway. In both types of basins, influent flows enter a sediment forebay. Here coarse solids are first removed prior to flowing into the main cell of the basin where finer sediment and associated pollutants settle as stormwater is detained and slowly released through a controlled outlet structure. Dry-weather flows and very low storm flows are often infiltrated within the basin.

ADVANTAGES

- Inexpensive and easy to construct and operate due to simplicity
- Provide significant removal of sediments and associated toxics
- Provides erosion control
- Provides flood control

LIMITATIONS

- Only moderate pollutant removal
- Ponded water may cause vector control problem

GENERAL CONSTRAINTS AND SITE CONCERNS

- Surface space availability - typically 0.5 to 2 percent of the total tributary development area required.
- Depth to groundwater - bottom of basin should be higher than the water table.
- Steep slopes - basins placed on slopes greater than 15 percent or within 200 feet from the top of a hazardous slope or landslide area require a geotechnical investigation.
- Compatibility with flood control - basins must not interfere with flood control functions of existing conveyance and detention structures.
- Dry ED basins shall never be placed within a blue-line stream.

MULTIUSE OPPORTUNITIES

A dry ED basin can sometimes be retrofitted into an existing flood control basin or integrated into the design of a park or playfield. Perforated risers, multiple orifice plate outlets, or similar multistage outlets are required for flood control retrofit applications to ensure adequate detention time for small storms while still providing peak-flow attenuation for the flood design storm. Recreational multiuse facilities must be inspected after every storm and may require a greater maintenance frequency than dedicated water quality basins to ensure aesthetics and public safety are not compromised. Any planned multiuse facility must obtain special approval by the County of Los Angeles Department of Public Works.

Note: Please refer to the *County of Los Angeles Department of Public Works Stormwater Best Management Practice Design and Maintenance Manual* for the most up-to-date information on this BMP.

DRY WELLS

POLLUTANT REMOVAL

Sediment	High
Nutrients	High
Trash	High
Metals	High
Bacteria	High
Oil and Grease	High
Organics	High

DESCRIPTION

Commonly known as sumps, french drains, drain fields, and shallow injection wells; dry wells simply use gravity to infiltrate stormwater into the subsurface. A dry well is constructed by digging a hole in the ground and filling it with an open graded aggregate or plastic infill devices. Stormwater runoff is diverted to the dry well for infiltration into the ground, allowing it to be stored in the voids. While it may seem harmless and cost-effective at first glance to use these dry wells to infiltrate stormwater into the ground, in reality, the impact to groundwater quality from these devices varies and is highly dependent upon many factors.

ADVANTAGES	LIMITATIONS
• Requires minimal space to install • Low installation costs • Reduces amount of runoff • Provides groundwater recharge • Can serve small impervious areas like rooftops • Helps to disconnect impervious surfaces	• Offers little pretreatment, which may cause clogging • Risk of groundwater contamination in very coarse soils may require groundwater monitoring • Dry wells service a limited drainage area, typically only rooftop runoff • Loss of infiltrative capacity and high maintenance cost in fine soils • Low removal of dissolved pollutants in very coarse soils • Not recommended for use with commercial rooftops unless adequacy of pretreatment is assured

GENERAL CONSTRAINTS AND SITE CONCERNS

Constraints for dry wells are similar to those associated with many infiltration BMPs:

- Soils must be permeable.
- Dry wells should not be installed where hazardous or toxic materials are used, handled, stored, or where a spill of such materials would drain into the dry well.
- Must have a minimum of 10 feet between the bottom of the dry well and the seasonal high-0water table.
- Dry wells must be located at least 10 feet away, on the down slope side of the structure, from building foundations to prevent seepage.
- Not suitable on fill sites or steep slopes.
- Generally, dry wells that are deeper than their widest surface dimension are classified as Class V Injection Wells and are regulated by the Environmental Protection Agency. These wells must comply with the requirements of the Federal Underground Injection Control Program.

Note: Please refer to the *County of Los Angeles Department of Public Works Stormwater Best Management Practice Design and Maintenance Manual* for the most up-to-date information on this BMP.

ENGINEERED WETLANDS

POLLUTANT REMOVAL

Sediment	High
Nutrients	Medium
Trash	High
Metals	High
Bacteria	High
Oil and Grease	High
Organics	High

DESCRIPTION

Constructed wetlands are constructed pools that retain water throughout the year. They are shallower than wet ponds, but have a greater vegetative cover. It is important to note that natural wetlands are not recommended for stormwater treatment as natural wetlands should be conserved.

Constructed wetlands are developed for the purpose of stormwater management. Additionally, constructed wetlands provide habitat and are aesthetically pleasing, making them widely accepted in communities. Treatment occurs through sedimentation and biological uptake. Many different designs for constructed wetlands exist, however, one of the most often used includes an initial detention pond for settling and increased storage capacity.

ADVANTAGES	LIMITATIONS
• Provides wildlife habitat • Provides removal of wide range of constituents • Provides erosion control • Provides flood control	• Safety concerns when constructed where there is public access • Not suitable for steep, unstable slopes • May have vector control problems • May need base flow to maintain water level • Requires fairly large open space • May require State Division of Safety of Dams approval depending on size

GENERAL CONSTRAINTS AND SITE CONCERNS

- Availability of base flows - stormwater wetlands require a regular source of water to support wetland biota.
- Slope stability - stormwater wetlands are not permitted near steep slope hazard areas.
- Surface space availability - large footprint required.
- Compatibility with flood control - basins must not interfere with flood control functions of existing conveyance and detention structures.

MULTIUSE OPPORTUNITIES

Provided adequate surcharge storage, a stormwater wetland may be combined with a flood control basin to provide both water quality control and peak-flow control. Wetlands can also be designed with wildlife viewing areas and walking trails around the perimeter to provide passive recreation. Any planned multiuse facility must obtain special approval by the County of Los Angeles Department of Public Works.

Note: Please refer to the *County of Los Angeles Department of Public Works Stormwater Best Management Practice Design and Maintenance Manual* for the most up-to-date information on this BMP.

GREEN ROOFS

POLLUTANT REMOVAL

Sediment	**High**
Nutrients	**Medium**
Trash	**High**
Metals	**High**
Bacteria	**High**
Oil and Grease	**High**
Organics	**High**

DESCRIPTION

A green roof is a heavy weight roof system of waterproofing material with a thick soil/vegetation protective cover. The green roof can be used in place of a traditional roof to limit impervious site area. The green roof captures and then evapotranspirates 50 to 100 percent of precipitation depending on the season. Green roofs attempt to mimic predeveloped hydrology, thereby reducing postdeveloped peak-runoff rates to near predeveloped rates. They help mitigate runoff temperatures by keeping roofs cool and retaining most of the runoff in warm seasons. Green roofs should not be used on slopes greater than 10 percent. A drain system and overflow to an approved conveyance and destination/disposal method will be required.

There are two types of green roofs: extensive and intensive systems. Intensive green roofs have larger depths of soil and require more maintenance and irrigation. Extensive green roofs feature very thin planting mediums and require little maintenance.

ADVANTAGES	LIMITATIONS
• Requires no additional space • Reduces overall volume of stormwater • Reduces pollutant discharge due to microbial processes and plant uptake	• Requires drought-tolerant vegetation • Increased roof loading • Requires maintenance to the same extent as any landscaped area • Need to be watered regularly in first year after construction until vegetation is established

GENERAL CONSTRAINTS AND SITE CONCERNS

Green roofs can be installed during initial construction or placed on buildings as part of a retrofit. The amount of stormwater that a green roof mitigates is directly proportional to the area it covers, the depth and type of the growing medium, slope, and the type of plants selected. The larger the green roof area, the more stormwater mitigated. Green roofs are appropriate for industrial and commercial facilities and large residential buildings such as condominiums or apartment complexes. Green roofs can also prove useful for small residential buildings under some circumstances. For instance, green roofs are commonly used on single-family residential structures in Germany and other European countries. Single-family residential structures, like all buildings with green roofs, must be able to support the loading from a saturated roof. Furthermore, the green roofs should be easily accessible; and residents should understand the maintenance requirements necessary to keep the roof functional.

A building must be able to support the loading of green roof materials under fully saturated conditions. These materials include a waterproofing layer, a soil or substrate layer, and a plant layer. Plants selected need to be suited for local climatic conditions and can range from sedums, grasses, and wildflowers on extensive roofs to shrubs and small trees on intensive roofs.

DESIGN SPECIFICATIONS

GENERAL SPECIFICATIONS

Proprietary green roof applications must comply with the vendor's guidelines for installation and maintenance. In the case of a conflict between vendor guidelines and County requirements, the stricter shall apply. Good quality waterproofing material must be used on the roof surface. Soil of adequate fertility and drainage capacity at depths of 2 to 6 inches and weight of 10 to 30 pounds per square foot shall be applied for an extensive green roof. For an intensive green roof, a minimum soil depth of 8 inches and weight of 60 pounds per square foot should be used. The building structure must be shown to be adequate to hold the additional weight. Vegetation shall be self-sustaining plants without the need for fertilizers or pesticides. Soil coverage to prevent erosion shall be established immediately upon installation by using mulch, vegetation mats, or other approved protection method. Ninety percent plant coverage shall be achieved within two years. Temporary irrigation to establish plants is recommended. A permanent irrigation system using potable water may be used, but an alternative means of irrigation such as air conditioning condensate or other nonpotable sources is recommended. Alternative sources should be analyzed to determine if the source has chemicals that might harm or kill the vegetation. Maximum roof slope shall be 10 percent, unless the applicant can provide documentation for runoff control on steeper slopes.

STRUCTURAL ROOF SUPPORT

The structural roof support must be sufficient to hold the additional weight of the green roof. For retrofit projects, check with an architect, structural engineer, or roof consultant to determine the condition of the existing building structure and what might be needed to support a green roof. This might include additional decking; roof trusses; joists, columns, and/or foundations. Generally, the building structure must be adequate to hold an additional 10 to 25 pounds per square foot (psf) saturated weight, depending on the vegetation and growth medium that will be used. (This is in addition to snow load requirements.) An existing rock ballast roof may be structurally sufficient to hold a 10 to 12 psf green roof. (Ballast typically weighs 10 to 12 psf.)

For new construction, the project architects and structural engineers shall address the structural requirements of the green roof during the design process. Greater flexibility and options are available for new buildings than for reroofing. The procedures for the remaining components are the same for both reroofing and new construction.

WATERPROOF MEMBRANE

Waterproof membranes are made of various materials, such as modified asphalts (bitumens), synthetic rubber ethylene propylene diene monomer (EPDM), hypolan chlorosulfonated polyethylene (CSPE), and reinforced polyvinyl chloride (PVC). Some of the materials come in sheets or rolls and some are in liquid form. They have different strengths and functional characteristics. Some of these products require root inhibitors and other materials to protect the membrane. Numerous companies manufacture waterproofing materials appropriate for green roofs.

PROTECTION BOARDS OR MATERIALS

These materials protect the waterproof membrane from damage during construction and over the life of the system, usually made of soft fibrous materials.

ROOF BARRIER

Root barriers are made of dense materials that inhibit root penetration. The need for a root barrier depends on the waterproof membrane selected. Modified asphalts usually require a root barrier while synthetic rubber (EPDM) and reinforced PVC generally do not. Check with the manufacturer to determine if a root barrier is required for a particular product. Membranes impregnated with pesticides are not allowed. Manufacturers must provide the County of Los Angeles Department of Public Works with evidence that membranes impregnated with copper will not leach out at concentrations of concern.

DRAINAGE LAYER

There are numerous ways to provide drainage. Products range from manufactured perforated plastic sheets to a thin layer of gravel. Some green roof designs do not require any drainage layer other than the growth medium itself, depending on roof slope and size (e.g., pitched roofs and small flat roofs).

GROWTH MEDIUM

The growth medium is generally 2 to 6 inches thick and well drained. It weighs from 10 to 25 pounds per square foot when saturated. A simple mix of 1/4 topsoil, 1/4 compost, and 1/2 pumice perlite may be sufficient for many applications. Some companies have their own growth medium specifications. Other components could include digested fiber, expanded clay or shale, or coir.

VEGETATION

Green roof vegetation should have the following attributes:

- Drought tolerant, requiring little or no irrigation after establishment.
- A growth pattern that allows the plant to thoroughly cover the soil. At least 90 percent of the overall surface shall be covered.
- Self-sustaining, without the need for fertilizers, pesticides, or herbicides.

  Able to withstand heat, cold, and high winds
- Very low maintenance, needing little or no mowing or trimming.
- Perennial or self-sowing.
- Fire resistant.

A mix of sedum/succulent plant communities is recommended because they possess many of these attributes. Herbs, forbs, grasses, and other low ground covers can also be used to provide additional benefits and aesthetics; however, these plants may need more watering and maintenance to survive and keep their appearance.

Installation: Four methods (or combinations of them) are generally used to install the vegetation; vegetation mats, plugs/potted plants, sprigs, and seeds.

1. Vegetation mats are sod-like, pregerminated mats that achieve immediate full-plant coverage. They provide immediate erosion control, do not need mulch, and minimize weed intrusion. They also need minimal maintenance during the establishment period and little ongoing watering and weeding.

2. Plugs or potted plants may provide more design flexibility than mats. However, they take longer to achieve full coverage, are more prone to erosion, need more watering during establishment, require mulching, and more weeding.

3. Sprigs are hand broadcast. They require more weeding, erosion control, and watering than mats.

4. Seeds can be either hand broadcast or hydraseeded. Like sprigs, they require more weeding, erosion control, and watering than mats.

GRAVEL BALLAST

Gravel ballast is sometimes placed along the perimeter of the roof and at air vents or other vertical elements. The need for ballast depends on operational and structural design issues. It is sometimes used to provide maintenance access, especially to vertical elements requiring periodic maintenance. In many cases very little, if any, ballast is needed. In some situations a header or separation board may be placed between the gravel ballast and adjacent elements (such as soil or drains). If a root barrier is used, it must extend under the gravel ballast and growth medium and up the side of the vertical elements.

DRAIN

As with a conventional roof, a green roof must safely drain runoff from the roof to an approved stormwater destination.

OPERATIONS AND MAINTENANCE

GENERAL REQUIREMENTS

- Soil Substrate/Growth Medium - soil shall be inspected for evidence of erosion from wind or water. If erosion channels are evident, they shall be stabilized with additional soil substrate/growth medium and covered with additional plants.

- Green Roof System Structural Components - Structural components shall be operated and maintained in accordance with manufacturers' requirements. Drain inlets shall be kept unrestricted. Inlet pipe shall be cleared when soil substrate, vegetation, debris, or other materials clog the drain inlet. Sources of sediment and debris shall be identified and corrected. Determine if drain inlet pipe is in good condition and correct as needed.

- Debris and Litter: Debris shall be removed to prevent clogging of inlet drains and interference with plant growth.

- Vegetation: Vegetation shall be maintained to provide 90 percent plant cover. During the establishment period, plants shall be replaced once per month as needed. During the long-term period, dead plants shall generally be replaced as needed. Fallen leaves and debris from deciduous plant foliage shall be removed. Nuisance and prohibited vegetation shall be removed when discovered. Dead vegetation shall be removed and replaced with new plants. Weeding shall be manual with no herbicides or pesticides used. Weeds shall be removed regularly and not allowed to accumulate. Fertilization is not necessary and fertilizers shall not be applied. During drought conditions, mulch or shade cloth may be applied to prevent excess solar damage and water loss. Mowing of grasses shall occur as needed. Clippings shall be removed.

- Irrigation can be accomplished either through hand watering or automatic sprinkler systems. If automatic sprinklers are used, manufacturers' instructions for operations and maintenance shall be followed. During the establishment period (1 to 3 years), water sufficient to assure plant establishment shall be applied. During the long-term period (3 plus years), water sufficient to maintain plant cover shall be applied.

- Spill prevention measures from mechanical systems located on roofs shall be exercised when handling substances that can contaminate stormwater. Releases of pollutants shall be corrected as soon as identified.

- Training and/or written guidance information for operating and maintaining green roofs shall be provided to all property owners and tenants. A copy of the operations and maintenance plan shall be provided to all property owners and tenants.

- Access and safety to the green roof shall be safe and efficient. Egress and ingress routes shall be maintained to design standards. Walkways shall be clear of obstructions and maintained to design standards.

- Aesthetics of the green roof shall be maintained as an asset to the property owner and community. Evidence of damage or vandalism shall be repaired and accumulation of trash or debris shall be removed upon discovery.

- Insects shall not be harbored at the green roof. Standing water creating an environment for development of insect larvae shall be eliminated by manual means. Chemical sprays shall not be used.

Note: Please visit www.greenroofs.org for more information on green roofs.

INFILTRATION BASIN

POLLUTANT REMOVAL

Sediment	High
Nutrients	High
Trash	High
Metals	High
Bacteria	High
Oil and Grease	High
Organics	High

DESCRIPTION

An infiltration basin is a shallow surface pond that is designed to infiltrate stormwater through permeable soils. Infiltration basins retain runoff until it gradually infiltrates through the soil and eventually into the groundwater. Vegetation is used to avoid erosion of the basin bottom and slopes. The vegetation provides pollutant removal efficiency and can also help recharge groundwater, thus helping to maintain low flows in stream systems. Pollutant removal takes place through a combination of filtration, adsorption, and biological processes.

Infiltration basins are effective in reducing the pollutants of concern listed above; however, coarser sediments can clog and render the basin ineffective. An evaluation of the soils at the site is required to determine if an infiltration basin is an appropriate BMP to use.

As opposed to infiltration trenches, an infiltration basin creates a visible surface pond because it is not backfilled with rocks or stones. Infiltration basins are generally used for drainage areas between 5 and 50 acres. For drainage areas less than 5 acres, an infiltration trench or other BMP may be more appropriate. For drainage areas greater than 50 acres, maintenance of an infiltration basin would be burdensome and an extended/dry detention basin or wet pond may be more appropriate.

Infiltration basins are generally dry except immediately following storms. A low-flow channel may be necessary if a constant base flow is present.

ADVANTAGES	LIMITATIONS
• Avoids discharge to surface waters • Good pollutant removal capabilities • Controls runoff volume • Provides erosion and flood control • Provides groundwater recharge • Provides more habitat value than other infiltration systems • It replicates pre-development hydrology • Can fulfill an area's landscape requirement	• Dependent upon soil and subsurface conditions • High failure rates due to clogging and high maintenance burden • Sediment forebay or pretreatment required • Not recommended to treat industrial sites or sites where hazardous spills may occur • Minimum soil infiltration rate of 0.5 inches/hour • Soil infiltration rates greater than 2.4 inches/hour require full treatment of water prior to infiltration, due to risk of groundwater contamination • Not appropriate for sites with Hydrologic Soil Types C and D • In coarse soil types there is risk of groundwater contamination • Requires complete stabilization of upstream drainage areas prior to construction • Not suitable for fill areas or steep slopes • Once basin becomes clogged it is difficult to restore function • Accumulation of metals and petroleum hydrocarbons may reach toxic level

GENERAL CONSTRAINTS AND SITE CONCERNS

The use of an infiltration basin may be limited by a number of factors, including type of native soils, climate, and location of groundwater table. Site characteristics such as excessive slope of the drainage area, fine-grained soil types, and proximate location of the water table and bedrock may preclude the use of an infiltration basin. Generally, infiltration basins are not suitable for areas with relatively impermeable soils containing clay and silt or in areas with fill.

As with any infiltration BMP, the potential for groundwater contamination must be carefully considered, especially if the groundwater is used for human consumption or agricultural purposes. The infiltration basin is not suitable for sites that use or store chemicals or hazardous materials unless hazardous and toxic materials are prevented from entering the basin. In these areas, other BMPs that do not allow interaction with the groundwater should be considered. In addition, an appropriate erosion-control seed mix needs to be used for the basin.

An infiltration basin needs to be built without driving heavy equipment over the infiltration surface. Any equipment driven on the surface should have extra-wide (low pressure) tires. Prior to any construction, the infiltration area needs to be enclosed with a top to stop entrance by unwanted equipment.

It is important to note that before construction begins, the entire drainage area needs to be stabilized. This can be done by implementing a temporary diversion berm around the perimeter of the construction site to prevent drainage and sediment buildup to this area. After construction is completed, the entire contributing drainage area needs to be stabilized and clean of construction material before runoff can be allowed into the infiltration basin.

It is also important to note that the use of treated wood or galvanized metal anywhere inside the facility is prohibited. The use of galvanized fencing is permitted only in accordance with County fencing requirements.

Evaluation of a particular site to determine if the use of an infiltration basin is appropriate includes:

- Determination of the soil type (ASTM D 3385-88 – Consider NRCS Soil Types A and B only) and consult USDA Soil Survey Tables to review other parameters such as the amount of silt and clay, presence of a restrictive layer or seasonal high water table, and estimated permeability. The soil should not have more than 30 percent clay or more than 40 percent of clay and silt combined. Eliminate sites that are clearly unsuitable for infiltration.

- Groundwater separation should be at least 10 feet from the basin invert to the measured groundwater elevation and 100 feet away from groundwater wells. There is concern at the State and regional levels of the impact on groundwater quality from infiltrated runoff, especially when the separation between groundwater and the surface is small.

- Placement should be away from buildings, slopes, and highway pavement (greater than 10 feet) and production wells and bridge structures (greater than 100 feet).

- Sites constructed of fill having a base flow or with a slope greater than 15 percent should not be considered.

- Ensure that adequate head is available to operate flow-splitter structures (to allow the basin to be off-line) without ponding in the splitter structure or creating backwater upstream of the splitter.

- Base flow should not be present in the tributary watershed.

Note: Please refer to the *County of Los Angeles Department of Public Works Stormwater Best Management Practice Design and Maintenance Manual* for the most up-to-date information on this BMP.

INFILTRATION TRENCHES

POLLUTANT REMOVAL

Sediment	High
Nutrients	High
Trash	High
Metals	High
Bacteria	High
Oil and Grease	High
Organics	High

DESCRIPTION

An infiltration trench is a long and narrow excavated ditch over porous soils, backfilled with rocks or stones, and lined with filter fabric on the sides and bottom. Stormwater runoff is diverted into the infiltration trench. Since the trench has no outlet, runoff is stored in the void spaces between the stones or gravel. Stormwater infiltrates into the soil where pollutants are removed through a combination of filtration, adsorption, and biological processes.

Infiltration trenches are effective in reducing the pollutants of concern listed above. Pretreatment BMPs such as vegetative swales, buffer strips, or detention basins are typically required to remove coarser sediments that can clog and render the trench ineffective. An evaluation of the soils at the site is required to determine if an infiltration trench is an appropriate BMP to implement.

Infiltration trenches differ from infiltration basins in that the former is used for small drainage areas and stores runoff out of sight within the void spaces of rocks or stones underground. Infiltration basins are for larger drainage areas and runoff is stored within a visible surface pond.

ADVANTAGES	LIMITATIONS
• Avoids discharge to surface waters • Good pollutant removal capabilities • Controls runoff volume • Provides erosion and flood control • Provides groundwater recharge • Little aesthetic impact • Fits in narrow areas and unused areas of a development site • It replicates pre-development hydrology	• Dependent upon soil and subsurface conditions • High failure rates due to clogging and high maintenance burden • Not recommended to treat industrial sites or sites where hazardous spills may occur • Maximum drainage area should be less than 5 acres • Minimum soil infiltration rate of 0.5 inch/hour • Soil infiltration rates greater than 2.4 inches/hour require full treatment of water prior to infiltration due to risk of groundwater contamination • Not appropriate for sites with Hydrologic Soil Types C and D • In coarse soil types there is risk of groundwater contamination • Requires complete stabilization of upstream drainage areas prior to construction • Not suitable for fill areas or steep slopes • Once trench becomes clogged it is difficult to restore function • Accumulation of metals and petroleum hydrocarbons may reach toxic level

GENERAL CONSTRAINTS AND SITE CONCERNS

The use of infiltration trenches may be limited by a number of factors including type of native soil, climate, and location of groundwater table. Site characteristics such as excessive slope of the drainage area, fine-grained soil types, and proximate location of the water table and bedrock may preclude the use of infiltration trenches. Generally, infiltration trenches are not suitable for areas with relatively impermeable soils containing clay and silt or in areas with fill. As with any infiltration BMP, the potential for groundwater contamination must be carefully considered, especially if the groundwater is used for human consumption or agricultural purposes. The infiltration trench is not suitable for sites that use or store chemicals or hazardous materials unless hazardous and toxic materials are prevented from entering the trench. In these areas, other BMPs that do not allow interaction with the groundwater should be considered.

It is important to note that before construction begins, the entire drainage area needs to be stabilized. This can be done by implementing a temporary diversion berm around the perimeter of the construction site to prevent drainage and sediment buildup to this area. After construction is completed, the entire contributing drainage area needs to be stabilized and clean of construction material before runoff can be allowed into the infiltration trench.

To determine if the use of infiltration trenches is appropriate, the following factor must be considered:

- Determination of the soil type (ASTM D 3385-88 – Consider NRCS Soil Types A and B only) and consult USDA Soil Survey tables to review other parameters such as the amount of silt and clay, presence of a restrictive layer or seasonal high water table, and estimated permeability. The soil should not have more than 30 percent clay or more than 40 percent of clay and silt combined. Eliminate sites that are clearly unsuitable for infiltration.

- Groundwater separation should be at least 10 feet from the basin invert to the measured groundwater elevation and 100 feet away from groundwater wells. There is concern at the State and regional levels of the impact on groundwater quality from infiltrated runoff, especially when the separation between groundwater and the surface is small.

- Placement should be away from buildings, slopes, and highway pavement (greater than 10 feet) and production wells and bridge structures (greater than 100 feet).

- Sites constructed of fill, having a base flow, or with a slope greater than 15 percent should not be considered.

- Ensure that adequate head is available to operate flow-splitter structures (to allow the basin to be offline) without ponding in the splitter structure or creating backwater upstream of the splitter.

Note: Please refer to the *County of Los Angeles Department of Public Works Stormwater Best Management Practice Design and Maintenance Manual* for the most up-to-date information on this BMP.

LANDSCAPE IRRIGATION

DESCRIPTION

The majority of residential water usage is dedicated to landscape irrigation. Irrigation systems are often poorly designed and maintained, resulting in inefficient water usage and urban runoff. Urban runoff from irrigation often carries fertilizers, pesticides, herbicides, and other pollutants used on landscapes. Efficient irrigation design can minimize the amount of water used to irrigate a landscape and eliminate urban runoff from the site. Methods to increase irrigation efficiency include low-flow sprinkler heads, smart controllers that take into account local evapotranspiration rates, sensors that detect unfavorable weather conditions, and low-flow sprinkler heads.

DESIGN SPECIFICATIONS

SMART IRRIGATION CONTROLLERS

A smart irrigation controller is a device that automatically adjusts watering times in response to weather changes. Smart irrigation controllers use sensors and weather information to manage watering times and frequency. In order to comply with the landscape irrigation option for small scale residential projects, the applicant shall install a smart irrigation controller for any area of the lot that is either landscaped or designated for future landscaping.

PLANTER BOXES

POLLUTANT REMOVAL

Sediment	High
Nutrients	High
Trash	High
Metals	High
Bacteria	High
Oil and Grease	High
Organics	High

DESCRIPTION

There are two types of planter boxes: contained planters and infiltration planters. Contained planters are used for planting trees, shrubs, and ground cover to be placed over impervious surface. The planter may be a prefabricated pot of various dimensions or may be constructed in place and have an infinite variety of shapes and sizes. Contained planters are placed on impervious surfaces such as sidewalks, plazas, and rooftops. Drainage is allowed through the bottom of the planter.

Infiltration planters are structural landscaped reservoirs used to collect, filter, and infiltrate stormwater runoff allowing pollutants to settle and filter out as the water percolates through the planter soil and infiltrates into the ground. In addition to providing pollution reduction, flow rates and volumes can also be managed with infiltration planters. Planters can be used to reduce the total impervious area and should be integrated into the overall site design. Numerous design variations of shape, wall treatment, and planting scheme can be used to fit the character of a site. An overflow to an approved conveyance and disposal method will be required.

ADVANTAGES	LIMITATIONS
• Requires very little space • Aesthetically pleasing • Can provide water treatment or infiltration • Wide applicability • Useful for disconnecting downspouts	• Infiltration rate limited to infiltration capacity of underlying soil • A relatively limited volume of stormwater can be mitigated using planter boxes

GENERAL CONSTRAINTS AND SITE CONCERNS

Contained planter boxes are suitable for any location as they are placed over impervious surfaces. Planter boxes are ideal for urban infill environments where space is limited. For infiltration planters, the infiltration rate of the native soil is a key element in determining size.

DESIGN SPECIFICATIONS

DESIGN CONSIDERATIONS

Plants shall be relatively self-sustaining with little need for fertilizers or pesticides. Irrigation is optional, although plant viability must be maintained. Trees are encouraged for stormwater interception. Planter storage depth must be at least 12 inches unless a larger than --required planter square footage is used. Minimum planter width is 30 inches. Planters shall be constructed without slope.

SOIL SUITABILITY

Contained planters are appropriate for all soil types as they are placed over impervious surface. Topsoil shall be used within the top 12 to 18 inches of the facility. Infiltration planters are appropriate for soils with a minimum infiltration rate of 0.5 inch per hour. There shall be no less than 3 feet of undisturbed infiltration medium between the bottom of the facility and any impervious layer (i.e., hardpan, solid rock, high groundwater levels, etc.). Topsoil shall be used within the top 18 inches of the facility.

PLANTER WALLS

Planter walls shall be made of stone, concrete, brick, clay, plastic, wood, or other stable material. Chemically treated wood that can leach out toxic chemicals and contaminate stormwater shall not be used.

SIZING

Individual infiltration planters sized with the simplified approach shall be designed to receive less than 15,000 square feet of impervious area runoff. Planters shall be designed to pond water for less than 36 hours after each storm event.

LANDSCAPING

Contained planters shall be planted to cover at least 50 percent of the planter surface. Tree planting is not required in planters, but is encouraged where practical. Tree planting is also encouraged near planters.

CONSTRUCTION CONSIDERATIONS

Infiltration planter areas should be clearly marked before site work begins to avoid soil disturbance during construction. No vehicular traffic, except that specifically used to construct the facility, should be allowed within 10 feet of planter areas.

OPERATIONS AND MAINTENANCE

INSPECTION AND MAINTENANCE ACTIVITIES SUMMARY	
ROUTINE MAINTENANCE	• Downspout from rooftop or sheet flow from paving allows unimpeded stormwater flow to the planter. Debris shall be removed routinely (e.g., no less than every 6 months) and upon discovery. Damaged pipe shall be repaired upon discovery. • Planter reservoir receives and detains stormwater prior to infiltration. Water should drain from reservoir within 3 to 4 hours of storm event. Sources of clogging shall be identified and corrected. Topsoil may need to be amended with sand or replaced all together. • Overflow pipe safely conveys flow exceeding reservoir capacity to an approved stormwater receiving system. Overflow pipe shall be cleared of sediment and debris when 50 percent of the conveyance capacity is plugged. Damaged pipe shall be repaired or replaced upon discovery. • Spill prevention measures shall be exercised when handling substances that contaminate stormwater. Releases of pollutants shall be corrected as soon as identified. • Training and/or written guidance information for operating and maintaining stormwater planters shall be provided to all property owners and tenants. A copy of the Operations and Maintenance Plan shall be provided to all property owners and tenants.

ROUTINE MAINTENANCE	• Vegetation shall be healthy and dense enough to provide filtering while protecting underlying soils from erosion. Mulch shall be replenished at least annually. Vegetation, large shrubs, or trees that limit access or interfere with planter operation shall be pruned or removed. Fallen leaves and debris from deciduous plant foliage shall be raked and removed. Nuisance or prohibited vegetation shall be removed when discovered. Invasive vegetation contributing up to 25 percent of vegetation of all species shall be removed and replaced. Dead vegetation shall be removed to maintain less than 10 percent of area coverage or when planter function is impaired. Vegetation shall be replaced within a specific timeframe (e.g., 3 months) or immediately, if required, to maintain cover density and control erosion where soils are exposed. • Access to the stormwater planter shall be safe and efficient. Egress and ingress routes shall be maintained to design standards. Roadways shall be maintained to accommodate size and weight of vehicles if applicable. Obstacles preventing maintenance personnel and/or equipment access to the stormwater planter shall be removed. Gravel or ground cover shall be added if erosion occurs (e.g., due to vehicular or pedestrian traffic). • Insects and rodents shall not be harbored in the stormwater planter. Pest control measures shall be taken when insects/rodents are found to be present. If sprays are considered, then a mosquito larvicide such as Bacillus thurendensis or Altoside formulations can be applied only if absolutely necessary, and only by a licensed individual or contractor. Holes in the ground located in and around the stormwater planter shall be filled and compacted.
MAJOR MAINTENANCE	• Splash blocks prevent splashing against adjacent structures and convey water without disrupting media. Any deficiencies in structure such as cracking, rotting, and failure shall be repaired. • Planter shall contain filter media and vegetation. Structural deficiencies in the planter including rot, cracks, and failure shall be repaired. • Filter media consisting of sand, gravel, and topsoil shall allow stormwater to percolate uniformly through the planter. The planter shall be excavated and cleaned; and gravel or soil shall be replaced to correct low infiltration rates. Holes that are not consistent with the design and allow water to flow directly through the planter to the ground shall be plugged. Sediment accumulation shall be hand removed with minimum damage to vegetation using proper erosion control measures. Sediment shall be removed if it is more than 4 inches thick or so thick as to damage or kill vegetation. Litter and debris shall be removed routinely (e.g., no less than quarterly) and upon discovery.

POROUS PAVEMENT

POLLUTANT REMOVAL	
Sediment	**Low**
Nutrients	**High**
Trash	**High**
Metals	**High**
Bacteria	**Low**
Oil and Grease	**High**
Organics	**Low**

DESCRIPTION

There are many types of pervious pavement on the market today. Numerous products and design approaches are available including special asphalt paving; manufactured products of concrete, plastic, and gravel; paving stones; and brick. It may be used for walkways, patios, plazas, driveways, parking lots, and some portions of streets subject to compliance with building codes. The material must be installed and maintained to manufacturers' specifications. These materials may not be allowed in certain areas. A professional engineer must design pervious pavement systems that will be supporting vehicular traffic.

ADVANTAGES

- Provide significant reductions in surface runoff and pollutant loading
- Can be designed with an underdrain in situations where infiltration is not feasible
- Reduces pavement ponding

LIMITATIONS

- Only applicable for low traffic volume areas
- To maintain effectiveness, porous pavements require frequent maintenance
- Easily clogged by sediments if not situated properly
- Extended rain can reduce the pavement's load bearing capacity

GENERAL CONSTRAINTS AND SITE CONCERNS

When designing pervious pavement systems, the infiltration rate of the native soil is a key element in determining the depth of base rock for the storage of stormwater or for determining whether an underdrain system is appropriate. Traffic loading and design speed are important considerations in determining which type of pervious pavement is applicable. Pedestrian, Americans with Disabilities Act accessibility, aesthetics, and maintainability are also important considerations depending on pavement use.

Pervious pavements shall not be used on sites with a likelihood of high oil and grease concentrations. These site uses include vehicle wrecking or impound yards, fast food establishments, automotive repair and sales, and parking lots that receive a high number of average daily trips (> 1,000). Runoff from unpaved areas should not be directed toward pervious pavement due to the potential for sediment loads to clog the pavement.

MULTIUSE OPPORTUNITIES

Pervious pavement is highly versatile and can be used in replacement of impermeable asphalt in many situations.

DESIGN SPECIFICATIONS

CONSTRUCTION CONSIDERATIONS

Installation procedures are vital to the success of pervious pavement projects, particularly pervious asphalt and concrete pavement mixes. The subgrade cannot be overly compacted with the inclusion of fine particulates or the void ratio critical to providing storage for large storm events will be lost. Weather conditions at the time of installation can affect the final product. Extremely high or low temperatures should be avoided during construction of pervious asphalt and concrete pavements.

SOIL SUITABILITY

Pervious pavement systems are appropriate for all soil types, but will require underdrain systems for soils that do not infiltrate well (less than 0.5 inch per hour). There shall be no less than 3 feet of undisturbed infiltration medium between the bottom of the base rock and any impervious layer (i.e., hardpan, solid rock, high groundwater levels, etc.), unless an underdrain system is used.

DIMENSIONS AND SLOPES

Minimum/maximum dimensions and other specifications are product specific and shall comply with manufacturers' recommendations. Slopes shall be less than 10 percent in all cases.

SIZING

Porous pavement should be designed to capture at least the water quality design storm event for its tributary area. The remaining storm volume bypasses the BMP and can be routed to another treatment or infiltration BMP or to the conventional stormwater conveyance system.

1. The prediction of the rate of infiltration of water through natural soils is related to soil type, porosity, degree of compaction, moisture content, and field capacity. This complexity governs soil drain times and has made the development of a single comprehensive model to predict drain times in actual porous pavement applications difficult. However, determining drain time is the key element in designing the size of porous pavement systems. The depth of the subbase can be determined by:

   $$H_d = E \times t_d / r$$

   Where:

   H_d = Depth of reservoir layer (in).

   t_d = Detention time (hr).

   E = Soil infiltration rate (in/hr).

   r = Void ratio.

   The required porous pavement surface area can then be computed by:

   $$A_s = V / (r \times H_d)$$

   Where:

   A_s = Porous pavement surface area (ft^2).

   V = Water quality volume (ft^3).

2. Specifications. The cross-section typically consists of four layers. A description of each layer is presented below.

3. Asphalt Layer. The surface asphalt layer consists of an open-graded asphalt mixture ranging from depths of 2 to 4 inches depending on required bearing strength and pavement design requirements. Porous pavements contain approximately 16 percent voids, compared to 3 to 5 percent for conventional pavements allowing runoff to quickly infiltrate.

4. Top Filter Layer. This layer consists of a 0.5-inch-diameter crushed stone to a depth of 1 to 2 inches. This layer serves to stabilize the porous asphalt layer.

5. Reservoir Layer. The reservoir subbase consists of 1.5 to 3-inches crushed stone. The depth of this layer depends on the desired storage volume, which is a function of the soil infiltration rate, void spaces, and in colder climates the depth of the frost line, but typically ranges from 2 to 4 feet. The reservoir layer should be designed to drain completely in 48 to 72 hours.

6. Bottom Filter Layer. This layer serves to stabilize the reservoir layer and is the interface between the reservoir layer and the filter fabric covering the underlying soil. It consists of a 2-inch-thick layer of 0.5-inch crushed stone.

7. Filter Fabric. It is very important to line the entire trench area, including the sides, with filter fabric prior to placement of the aggregate. The filter fabric serves a very important function by inhibiting soil from migrating into the reservoir layer and reducing storage capacity.

8. Underlying Soil. The underlying soil should have an infiltration capacity of at least 0.1 inch/hour, but preferably greater than 0.50 inch/hour. Soils at the lower end of this range may not be suited for a full infiltration system.

9. Construction Practices (adapted from Schueler, 1992).

   a. All adjacent areas should be stabilized to prevent any sediment from washing onto the pavement surface, leading to premature clogging.

   b. The subgrade shall be prepared as required while limiting undue compaction; permeability must be maintained. Equipment with tracks or over-sized rubber tires shall be used; DO NOT use vehicles with standard rubber tires.

   c. The reservoir base course shall be laid in lifts over the base filter course and lightly compacted. The base courses should be kept free of all dirt and debris during construction.

   d. The asphalt layer shall be laid directly over the top filter course in one lift. The laying temperature should be between 240 and 260 degrees. The ambient temperature should be above 50 degrees.

   e. Compaction should take place when the surface is cool enough to resist a 9-Mg roller (class equivalent of a 10-ton roller). One or 2 passes is all that is required for proper compaction. Any more may reduce porosity.

   f. Transporting of the mix to the site shall be in clean vehicles with smooth dump beds that have been sprayed with a nonpetroleum release agent. The mix should be covered during transport to limit cooling.

   g. After final rolling, no vehicular traffic of any kind should be permitted on the pavement until cooling and hardening has taken place; no sooner than 6 hours, but preferably a day or two.

INSPECTION AND MAINTENANCE ACTIVITIES SUMMARY	
ROUTINE MAINTENANCE	• Regular sweeping shall be implemented for porous asphalt or concrete systems. The surface shall be kept clean and free of leaves, debris, and sediment. The surface shall not be overlaid with an impermeable paving surface • Overflow devices shall be inspected for obstructions or debris, which shall be removed upon discovery. Overflow or emergency spillways shall be capable of transporting high flows of stormwater to an approved stormwater receiving system. • Vegetation and large shrubs/trees that limit access or interfere with porous pavement operation shall be pruned. • Fallen leaves and debris from deciduous plant foliage shall be raked and removed. • Poisonous, nuisance, dead, or odor producing vegetation shall be removed immediately. • Grass shall be mowed to less than 4 inches and grass clippings shall be bagged and removed. • Irrigation shall be provided as needed. • Spill prevention measures shall be exercised when handling substances that can contaminate stormwater. A spill prevention plan shall be implemented at all nonresidential sites and in areas where there is likelihood of spills from hazardous materials. • Access to the pervious pavement shall be safe and efficient. Egress and ingress routes shall be maintained to design standards. Roadways shall be maintained to accommodate size and weight of vehicles if applicable. • Obstacles preventing maintenance personnel and/or equipment access to the porous pavement shall be removed. • Standing water creating an environment for development of insect larvae shall be eliminated. • Holes in the ground located in and around the pervious pavement shall be filled and compacted.
MAJOR MAINTENANCE	• Sources of erosion damage shall be identified and controlled when native soil is exposed near the overflow structure. • Gravel or ground cover shall be added if erosion occurs, e.g., due to vehicular or pedestrian traffic. • Source control measures prevent pollutants from mixing with stormwater. Typical nonstructural control measures include raking and removing leaves, street sweeping, vacuum sweeping, limited and controlled application of pesticides and fertilizers, and other good housekeeping practices.

SAND FILTERS

POLLUTANT REMOVAL

Sediment	**High**
Nutrients	**Low**
Trash	**High**
Metals	**High**
Bacteria	**Medium**
Oil and Grease	**High**
Organics	**High**

DESCRIPTION

Sand filters consist of a layer of sand in a structural box used to trap pollutants. The water filters through the sand and then flows into the surrounding soils or an underdrain system that conveys the filtered stormwater to a discharge point. Water that has percolated through the sand is collected via a perforated underdrain system before being conveyed to the downstream storm drainage system. As stormwater passes through the sand, pollutants are trapped in the small pore spaces between sand grains or are adsorbed to the sand surface. Over time bacteria can grow in the sand bed and provide some biological treatment. However, continuous dry-weather flows would be necessary to maintain the moisture required by the bacteria. Stormwater sand filters may also be two-chambered, including a pretreatment settling basin and a filter bed filled with sand. As stormwater flows into the first chamber, large particles settle out, and then finer particles and other pollutants are removed as stormwater flows through the filtering media (sand) in the second chamber.

ADVANTAGES	LIMITATIONS
• Relatively high pollutant removal • Sufficient capture volume provides significant control of channel erosion and enlargement	• More expensive to construct than many other BMPs • May require more maintenance than some other BMPs depending on the size of the filter bed • High-solid loads will cause filter to clog • Does not work well in large watersheds • Certain designs maintain permanent sources of standing water where mosquito and midge breeding is likely to occur

GENERAL CONSTRAINTS AND SITE CONCERNS

In general, sand filters are preferred over infiltration practices, such as infiltration trenches, when contamination of groundwater with conventional pollutants is of concern. This usually occurs in areas where underlying soils alone cannot treat runoff adequately or groundwater tables are high. In addition, sand filters are the preferred treatment option in regions where evaporation exceeds rainfall since a wet pond would be unlikely to maintain the required permanent pool. Additionally, implementation of sand filters for stormwater management is ideal for relatively small impervious watersheds.

- High loading rates may clog quickly if flows are not adequately pretreated.
- Vertical relief and proximity to storm drain site must have adequate relief between land surface and storm drain to permit vertical percolation through the sand filter and collection and conveyance in underdrain to storm drain system.

Note: Please refer to the *County of Los Angeles Department of Public Works Stormwater Best Management Practice Design and Maintenance Manual* for the most up-to-date information on this BMP.

VEGETATED BUFFERS

POLLUTANT REMOVAL

Sediment	**High**
Nutrients	**Low**
Trash	**Medium**
Metals	**Medium**
Bacteria	**Low**
Oil and Grease	**High**
Organics	**Medium**

DESCRIPTION

Vegetated buffers are vegetated areas designated to treat sheet flow runoff from adjacent impervious surfaces or intensive landscaped areas such as golf courses. Vegetated buffers use biological and chemical processes to filter stormwater runoff by slowing runoff velocities, filtering out sediment and other pollutants, and providing some infiltration into underlying soils. While some assimilation of dissolved constituents may occur, vegetated buffers are generally more effective in trapping sediments and particulate-bound metals, nutrients, and pesticides. Although vegetated buffers are not designed to attenuate peak stormwater flows, their use can be an effective water quality measure, and like many other LID techniques, vegetated buffers can add development aesthetic value and cost significantly less than hardscaped stormwater infrastructure.

A vegetated buffer is commonly operated as a pretreatment BMP located upstream of other BMPs capable of greater pollutant removal rates. If designed properly, vegetated buffers are able to provide relatively high pollutant removal. As a stand-alone BMP, vegetated buffers can only treat low-intensity rainfall events. While providing water quality treatment for small frequent storms, vegetated buffers operating as online facilities must still retain the ability to convey high runoff rates from the roadway when high-intensity storms occur. Vegetated buffers cannot treat high-velocity flows and do not provide enough storage or infiltration to effectively reduce peak discharges to predevelopment levels.

ADVANTAGES	LIMITATIONS
• Simple to install (only planting and some earthwork) • Require minimal maintenance • Can provide reliable water quality by trapping, filtering, and infiltrating contaminants typically present in runoff • Can provide open space and recreation opportunities in residential areas • Can help to accent the natural landscape providing green space adjacent to parking lots and roadways	• Not recommended for arid areas where sustaining growth is difficult • Not appropriate for hilly or intensively paved areas due to high-velocity runoff • Not appropriate for industrial sites or locations where spills may occur • Thick vegetative cover must be maintained to work effectively • If improperly graded and designed this BMP can render an ineffective practice mainly due to erosion • Channelization and premature failure may result from poor design, imprecise construction, and lack of maintenance

GENERAL CONSTRAINTS AND SITE CONCERNS

The most important criteria for the selection of this BMP is soil, space, and slope.

- The effectiveness of a vegetated buffer depends heavily on having an evenly distributed sheet flow, the size of the contributing area, and the associated volume runoff to be treated. To prevent the formation of concentrated flows, it is advised to have each vegetated buffer serve a contributing area of 5 acres or less.

- Slopes should be less than 5 percent grade to avoid the formation of gullies and rills that can disrupt sheet flow. Vegetated buffers may have reduced effectiveness on slopes 6 to 15 percent and will not function at all on slopes 15 percent or greater. Limited site slope may cause ponding.

- The maximum length (in the direction of flow toward the buffer) of the tributary area should be 60 feet. The minimum length in direction of flow is 15 feet.

- A water table depth within 3 feet of the surface provides greater removal rate of soluble pollutants (i.e., within root zone).

- The effectiveness of vegetated buffers increases where the climate permits year-round dense vegetation and decreases in arid regions where vegetation in upland areas is scarce.

- Steep terrain and/or large tributary areas may cause concentrated erosive flow. A shallow, evenly distributed flow across entire width of strip is required. The maximum flow path from a contributory impervious surface should not exceed 150 feet. Sheet flow depth should be less than 0.5 inch for the design storm. Depending on the pollutant removal required, residence time should be at least 5 minutes preferably 9 minutes or more.

- A level spreader may be necessary to induce sheet flow over the vegetated buffer and avoid short-circuit caused by channelization of concentrated flows and sheet flow elimination. Level spreader options include porous pavement strip, stabilized turf strips, slotted spreader curbing, rock filled trench, concrete sills, or plastic-lined trench acting as a small detention pond.

- Vegetated buffers should be placed 3 to 4 feet from edge of pavement to accommodate a vegetation free zone.

Note: Please refer to the *County of Los Angeles Department of Public Works Stormwater Best Management Practice Design and Maintenance Manual* for the most up-to-date information on this BMP.

VEGETATED SWALES

POLLUTANT REMOVAL

Sediment	**Medium**
Nutrients	**Low**
Trash	**Low**
Metals	**Medium**
Bacteria	**Low**
Oil and Grease	**Medium**
Organics	**Medium**

DESCRIPTION

Vegetated swales are open, shallow channels with low-lying vegetation covering the side slopes and bottom that collect and slowly convey runoff flow to downstream discharge points. Vegetated swales provide pollutant removal through settling and filtration in the vegetation (usually grasses) lining the channels, provide the opportunity for volume reduction through infiltration and evapotranspiration, and reduce the flow velocity in addition to conveying stormwater runoff. An effective vegetated swale achieves uniform sheet flow over and through a densely vegetated area for a period of several minutes. The vegetation in the swale can vary depending on its location within a development project and is the choice of the designer depending on the functional criteria outlined below. Swales that are integrated within a project may use turf or other more intensive landscaping while swales that are located on the project perimeter, within a park, or close to an open space area may be planted with a more naturalistic plant palette.

ADVANTAGES	LIMITATIONS
• Potentially inexpensive • Significant collateral water quality benefits • Roadside ditches are easily converted to swales	• Can be difficult to avoid channelization • Cannot treat a large drainage area. Large areas may need to be divided and treated with several swales • Impractical in areas with steep topography • Not effective and may even erode when flow velocities are high if the grass cover is not properly maintained • In some places their use is restricted by law; many local municipalities require curb and gutter systems in residential areas • Swales are more susceptible to failure, if not properly maintained, than other treatment BMPs

GENERAL CONSTRAINTS AND SITE CONCERNS

- Steep terrain and/or large tributary areas may cause erosive flows.
- Limited site slope may cause ponding.
- Swales must not interfere with flood control functions of existing conveyance and detention structures.

MULTIUSE OPPORTUNITIES

Swales can easily be converted into roadside vegetated buffers or parking lot landscaping.

Note: Please refer to the *County of Los Angeles Department of Public Works Stormwater Best Management Practice Design and Maintenance Manual* for the most up-to-date information on this BMP.

WET PONDS

POLLUTANT REMOVAL	
Sediment	High
Nutrients	Medium
Trash	High
Metals	High
Bacteria	High
Oil and Grease	High
Organics	High

DESCRIPTION

Wet ponds are constructed, naturalistic ponds with a permanent or seasonal pool of water (also called a wet pool or dead storage). Aquascape facilities, such as artificial lakes, are a special form of wet pool facility that can incorporate innovative design elements to allow them to function as a stormwater treatment facility in addition to an aesthetic water feature. However, stormwater lakes are generally more appropriate for maintenance by a homeowners' association or an agency other than the Los Angeles County of Los Angeles Department of Public Works. In certain circumstances, a stormwater lake may be a candidate for the County of Los Angeles Department of Public Works maintenance. In such circumstances, special approval is required by the County.

ADVANTAGES

- If properly designed, constructed, and maintained, wet basins can provide substantial aesthetic/recreational value and wildlife and wetlands habitat
- Ponds are often viewed as a public amenity when integrated into a park setting
- Due to the presence of the permanent wet pool, properly designed and maintained wet basins can provide significant water quality improvement across a relatively broad spectrum of constituents including dissolved nutrients
- Widespread application with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to flow frequency relationships resulting from the increase of impervious cover in a watershed

LIMITATIONS

- Some concern about safety when constructed where there is public access
- Mosquito and midge breeding is likely to occur in ponds
- Cannot be placed on steep unstable slopes
- Need for base flow or supplemental water if water level is to be maintained
- Require a relatively large footprint
- Depending on volume and depth, pond designs may require approval from the State Division of Safety of Dams

GENERAL CONSTRAINTS AND SITE CONCERNS

- Availability of base flows - wet ponds require a regular source of water if water level is to be maintained.
- Slope stability – wet ponds are not permitted near steep slope hazard areas.
- Surface space availability - large footprint required.
- Compatibility with flood control - basins must not interfere with flood control functions of existing conveyance and detention structures.

MULTIUSE OPPORTUNITIES

Provided adequate surcharge storage, a wet pond may be combined with a flood control basin to provide both water quality control and peak-flow control. Wet ponds can also be designed with wildlife viewing areas and walking trails around the perimeter to provide passive recreation. Any planned multiuse facility must obtain special approval by the County of Los Angeles Department of Public Works.

Note: Please refer to the *County of Los Angeles Department of Public Works Stormwater Best Management Practice Design and Maintenance Manual* for the most up-to-date information on this BMP.

CHAPTER 6: EXAMPLE DESIGNS

LID EXAMPLE DESIGN NO. 1

DETERMINE REQUIREMENTS

For a single-family residential tract with more than 5 units, the following applies:

- Infiltrate or retain the increase in the volume of the runoff from the water quality storm on the parcel level.
- Treat the entire volume of the runoff from the water quality storm.

DETERMINE HYDROLOGIC PARAMETERS

The total area of the site is 25 acres. Of that, 10 acres is dedicated open space. The total area that must be mitigated for is 15 acres.

A = 15 acres

Soil 97

Assume 42% impervious

Flow path = 1080'

Average Slope = (1600-1580) / 1080 = 1.85%

IDENTIFY DESIGN STORM

Select a water quality storm from the menu of storm events. For this example, assume a 3/4-inch storm over 24 hours.

CALCULATE UNDEVELOPED RUNOFF VOLUME

The rate and volume of runoff can be calculated using the Tc Calculator utility (available at http://ladpw.org/wrd/publication/).

$Q_u = 0.29\ cfs$
$V_u = 4000\ ft^3$

CALCULATE DEVELOPED RUNOFF VOLUME

Using the same design storm and methodology, calculate the runoff rates and volumes that would occur after development.

$Q_d = 1.25$ *cfs*
$V_d = 17700$ ft^3

The developed volume V_d is the total volume that must be treated.

CALCULATE ∆V

$\Delta V = Q_d – Q_u = 17700 – 4000 = 13700$ ft^3

The increase in runoff volume ∆V is the amount that must be infiltrated on a parcel level.

CHOOSE BMPS

For this example, porous pavement driveways with underlying infiltration trenches have been selected as one method of infiltrating the ∆V.

There are 42 lots and it is assumed that each lot has a 15- x 15-foot driveway.

The depth of the infiltration trench under each driveway can then be calculated.

Assume a 0.4 void ratio for the underlying gravel.

D = 13700 ft^3 / (42 lots * 15’ x 15’ * .4) = 3.63 ft

LID EXAMPLE DESIGN NO. 2

DETERMINE REQUIREMENTS

For a commercial redevelopment project, the following applies:

- Infiltrate or retain the increase in the volume of the runoff from the water quality storm on the parcel level.

- Treat the entire volume of the runoff from the water quality storm.

DETERMINE HYDROLOGIC PARAMETERS

The total area of the site is 5 acres.

A = 5 acres

Soil 20

Assume 95 percent impervious.

Flow path = 680’

Average Slope = (1200-1170) / 680 = 4.4 percent.

Identify Design Storm

Select a water quality storm from the menu of storm events. For this example, assume a 3/4-inch storm over 24 hours.

CALCULATE UNDEVELOPED RUNOFF VOLUME

The rate and volume of runoff can be calculated using the Tc Calculator utility (available at http://ladpw.org/wrd/publication/).

$Q_u = 0.1\ cfs$
$V_u = 1343\ ft^3$

CALCULATE DEVELOPED RUNOFF VOLUME

Using the same design storm and methodology, calculate the runoff rates and volumes that would occur after development.

$Q_d = 0.86\ cfs$
$V_d = 11550\ ft^3$

The developed volume V_d is the total volume that must be treated.

CALCULATE ΔV

$$\Delta V = Q_d - Q_u = 11550 - 1343 = 10200\ ft^3$$

The increase in runoff volume ΔV is the amount that must be infiltrated on a parcel level.

CHOOSE BMPS

For this example, bioretention planters and porous pavement have been selected as the methods of infiltrating the ΔV.

Assuming a 3-foot depth and a 0.4 void ratio for gravel, 8500 ft^2 are necessary to infiltrate the total volume, or roughly 4 percent of the total area of the site.

The wasted space at the ends of parking spaces can be used for bioretention facilities.

$$175\ ft^2 \times 7 + 300\ ft^2 \times 5 = 2725\ ft^2$$

The remaining volume can be infiltrated using porous pavement.

$$8500 - 2725 = 5775\ ft^2$$