

## **Disclaimer**

**The use of this Guidebook is intended as a reference only.**

The administrative processes outlined within the Placer County Low Impact Development (LID) Guidebook does not reflect the Town of Truckee processes and should not be used as a guide for permit application and design submission. Development and Redevelopment Projects within the Town of Truckee should follow the application procedures found within the [Permit Application Handbook](#), [The Municipal Development Code](#), and [The Town of Truckee Public Improvement and Engineering Standards](#).

The introduction of LID Best Management Practices (BMPs) into all development and redevelopment projects is recommended and should be considered in the overall site design at the earliest stages. Thus, this Guidebook is intended to be a reference document to aid in the site planning and design process. However, following the guidance within the guidebook does not necessarily guarantee permit approval or compliance.

### **Important Exclusions**

Some select guidance and LID BMPs found within the LID guidebook are not recommended by the Town of Truckee, these include: the use of drip-line trenches and other infiltration methods within a close proximity to (adjacent to) foundations; the use of permeable pavements in high traffic areas where snow removal and/or routine winter application of road abrasives are typical (road sanding and deicing); the use of bioretention facilities, without a pre-filter, where heavy use of road abrasives are typical; and, the use of rain barrels and cisterns that are not winterized or able to maintain structural and functional integrity through freeze/thaw cycles (disconnection throughout the winter months may be acceptable).

### **Stormwater Management Techniques Have Been Evolving Very Quickly**

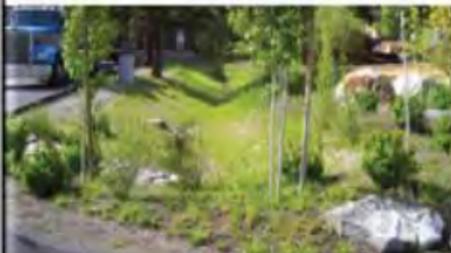
The BMPs presented in the Placer County LID Guidebook offer a small snapshot of potential LID techniques. The evolving field of stormwater management, in particular the techniques and principals of low impact design, dictate that flexibility in design be considered and that changes to BMP recommendations will likely take place. Because of this the Placer County Low Impact Development Guidebook should be used as a site design reference only and should not be construed as a manual for permit compliance.

If you have any questions regarding the contents of the manual please contact the Town of Truckee Engineering office at: 530-582-7700; or email: [truckee@townoftruckee.com](mailto:truckee@townoftruckee.com), subject: LID Guidance Question



PLACER COUNTY

LOW IMPACT DEVELOPMENT (LID)  
GUIDEBOOK



March 2012

**PLACER COUNTY**

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# Placer County

## LOW IMPACT DEVELOPMENT (LID) GUIDEBOOK

March 2012

*This document is best viewed on-line or printed in full color.*

### **THIS DOCUMENT IS AVAILABLE IN ALTERNATE FORMATS**

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[planning@placer.ca.gov](mailto:planning@placer.ca.gov). The webmaster will refer your request to the appropriate Department or program for assistance.

# ACKNOWLEDGEMENTS

## PROJECT SPONSORS AND FUNDING

*This project was made possible by a grant from the Sierra Nevada Conservancy. Additional funding and in-kind services were provided by Placer County, and in-kind services were provided by the Technical Advisory Committee members, Sierra Business Council, cbec eco engineering, inc., and CKB Environmental Consulting, Inc.*

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<http://www.placer.ca.gov/Departments/CommunityDevelopment/Planning.aspx>

<http://www.sbcouncil.org/Projects/Placer-Low-Impact-Development>

## DEVELOPMENT OF THE GUIDEBOOK

In 2004, Placer County identified Low Impact Development (LID) as a mitigation strategy for the County Aquatic Resource Program - a comprehensive strategy for state and federal environmental regulatory compliance on projects covered by the Placer County Conservation Plan. The County sought and secured grant funding from the Sierra Nevada Conservancy to develop this guidebook to describe application and adaptation of LID techniques to the county's unique environmental conditions, and to promote more widespread use of LID throughout the County.



**TAC Members at Homewood Pilot Study Design Workshop, June 2010**

The County retained the Sierra Business Council (SBC) and a team of technical consultants to prepare the document, with advice and assistance by County planning and engineering staff. SBC established a Technical Advisory Committee (TAC) of local stakeholders and technical professionals to provide oversight and direction to the effort. TAC workshops were conducted at various locations in the study area during development of the Guidebook to build awareness, share knowledge, create the tools included in the guidebook, and review and comment on draft versions of the document.

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# Chapter 1

## INTRODUCTION TO THE GUIDEBOOK

### 1.1 PURPOSE OF THE GUIDEBOOK

The Placer County Low Impact Development (LID) Guidebook provides planning and design guidance to promote and encourage the application of appropriate and cost effective LID principles and strategies for new and redevelopment projects in the Sierra Nevada.

### 1.2 INTRODUCTION TO LID

There are numerous definitions of LID and some people refer to LID as a particular type of best management practice (BMP) designed to solely infiltrate and reduce stormwater runoff. For the purposes of this Guidebook, LID is considered more holistically. It is a total site design philosophy and approach that conserves and uses existing natural site features and systems integrated with distributed, small-scale stormwater management controls (BMPs) to mimic or recreate the natural water balance for a site. A single BMP or system of BMPs can serve one function or several: control sources of pollution, reduce runoff, and/or treat runoff before it leaves the site.

#### *Guidebook Vision:*

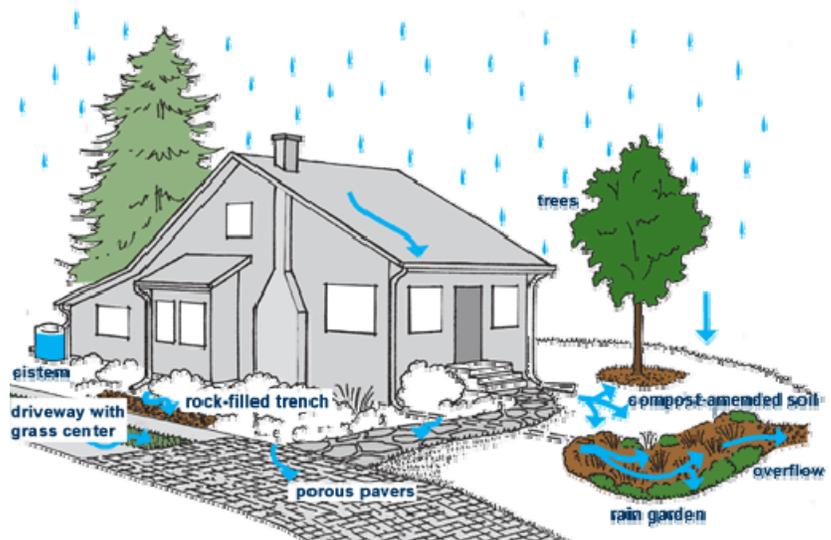
*To protect and enhance the natural environment of Placer County in the Yuba, Truckee and American River watersheds through the promotion of innovative stormwater and water quality management and other techniques applicable to the Sierra Nevada.*

*Placer County LID Guidebook Technical Advisory Committee, 2010*

#### What is LID?

Low Impact Development is a total site design approach that conserves and uses existing natural site features and systems integrated with distributed, small-scale stormwater controls to mimic or recreate the natural water balance for a site.

*Placer County LID Guidebook  
Technical Advisory Committee,  
2010*



Source: Seattle Public Utilities Residential Rainwise Program, 2011

LID opportunities may occur throughout the planning, design, and construction phases. When implemented early in the planning and design process, LID strategies allow owners, developers, builders and designers to address multiple objectives with qualitative environmental benefits in a single site design, including:

- runoff reduction
- pollution reduction
- groundwater recharge
- natural watershed function
- water quality/habitat protection

### How Does LID Work?

LID controls are small-scale, distributed stormwater management devices that have the capability to meet multiple stormwater management objectives, including peak flow attenuation, volume reduction, and water quality improvement. LID controls use unit processes of the natural hydrologic cycle to meet these objectives. By making use of hydrologic cycle processes, LID attempts to mimic the natural function of the developed landscape. These unit processes are essential to natural stormwater management and LID controls:

- *Infiltration* – the downward movement of water into the soil via percolation through pore spaces.
- *Evapotranspiration* – the combined effects of evaporation and transpiration in reducing the volume of water in a vegetated area during a specific period of time.
- *Interception* – a form of detention and retention storage that occurs when leaves, stems, branches, and leaf litter catch rainfall.
- *Conveyance* – the transport of surface runoff, from where a raindrop falls to where it enters the receiving body of water.
- *Detention* – the temporary storage of stormwater, so that the maximum outflow is less than maximum inflow; water is released soon after the maximum inflow has occurred.
- *Retention* – the capture of a volume of stormwater for a significantly longer period than detention facilities; water may be released after a storm has ended or retained for a longer period for other uses such as recreation, surface water supply or groundwater recharge.
- *Reuse* – capture of rainwater for later use by other processes such as non-potable water applications.
- *Recharge* – entry of water (through detention and/or infiltration through subsurface layers) into a groundwater aquifer.

See Chapter 2 for more details about the impacts of urbanization on the natural hydrologic cycle and how LID can help recreate the natural water balance on a development site.

*-Adapted from “LID Strategies and Tools for Phase II NPDES Communities”, Low Impact Development Center, [www.lowimpactdevelopment.org](http://www.lowimpactdevelopment.org). Definitions for detention and retention are consistent with the Placer County Stormwater Management Manual.*

In addition to environmental benefits, an integrated design approach can result in cost savings for the developer, long-term economic benefits to property owners such as reduced maintenance costs and enhanced market value, and community benefits such as improved aesthetics and recreational amenities. These and other benefits are listed in Table 1-1 and explained in more detail in Chapter 2.

**Table 1-1. Benefits of Low Impact Development\***

Item	Benefit
<b>Environmental Protection and Compliance with Environmental Regulations</b>	<ul style="list-style-type: none"> <li>• Improved water quality and protection of beneficial uses of receiving waters</li> <li>• Compliance with stormwater regulations and permits</li> <li>• Reduced potential for downstream erosion and habitat degradation</li> <li>• Control of hydromodification impacts</li> <li>• Protection of sensitive ecological resources on site, such as streams and riparian habitats, as well as trees and vegetation</li> <li>• Improved ecological health of terrestrial and aquatic habitat in receiving waters</li> <li>• Improved air quality</li> </ul>
<b>Stormwater Management and Flood Control</b>	<ul style="list-style-type: none"> <li>• Potential for flood mitigation</li> <li>• Reduced stormwater infrastructure (and associated capital and maintenance costs)</li> </ul>
<b>Economic Benefits</b>	<ul style="list-style-type: none"> <li>• Lower construction and maintenance costs (largely due to reduced need for stormwater infrastructure)</li> <li>• Potential for more buildable space to increase lot yields and community marketability</li> <li>• Potential for reduced utility costs</li> <li>• Potential for increased property value and tax revenue</li> </ul>
<b>Sustainability Benefits (Adaptation to Climate Change)</b>	<ul style="list-style-type: none"> <li>• Reduced energy demand</li> <li>• Water conservation</li> <li>• Greenhouse gas reduction (carbon sequestration)</li> <li>• Groundwater recharge through infiltration (geologic conditions permitting)</li> </ul>
<b>Community Benefits</b>	<ul style="list-style-type: none"> <li>• Improved quality of life</li> <li>• Enhanced aesthetics</li> <li>• Expanded recreational opportunities and protection of recreational beneficial uses of waterways (e.g., fishing, swimming, boating)</li> <li>• Heat island mitigation</li> <li>• Improved public health</li> <li>• Improved community livability with Green Infrastructure</li> </ul>

\*This is a brief summary; see Chapter 2 for a detailed discussion of the benefits.

### 1.3 SCOPE AND APPLICATION OF THE GUIDEBOOK

The Guidebook is a compilation of planning and design guidance for development and redevelopment projects in the High Sierra region of Placer County above 5,000 feet elevation (see Figure 1-1). While it is not specifically intended for use in other parts of the county - including the Placer County portion of the Lake Tahoe Basin or the west slope areas of the County below 5,000 feet— it will serve as a useful general reference for those areas. (In cases of conflict with other local requirements, the other requirements shall prevail). Also, during the development of the Guidebook, a pilot redevelopment project in the Tahoe Basin (Homewood) was selected and used by the Technical Advisory Team to apply, study and refine the various planning and design tools included in the Guidebook (Appendix B presents the results of the pilot study). This Guidebook is not intended to be an exhaustive resource on LID; other sources of information are listed in the References section and Appendix E.

### 1.4 USING THE GUIDEBOOK

Placer County developed the LID Guidebook to promote and encourage the application of appropriate and cost effective LID principles and strategies to new and redevelopment projects in the Sierra Nevada. LID strategies are recommended (and in some areas, required) by federal and state regulatory agencies as an effective way to protect natural resources as communities develop. This holistic design approach is becoming more widespread throughout the country as communities strive to become more sustainable and satisfy environmental permit requirements.

The Guidebook provides planning and design guidance applicable to all scales and types of development and redevelopment in Placer County.

Though it can function as general guidance for any location, the Guidebook includes specific information applicable to the High Sierra elevations above 5,000 feet with snow and freeze/thaw conditions that can sometimes make use of LID challenging. Concepts and techniques are presented in a format that will facilitate dialogue among developers, engineers, designers, and regulatory agencies. The intent is to encourage integration of these strategies into site design at the earliest possible stage.



**This Guidebook includes specific LID information for High Sierra elevations above 5,000 feet subject to snow and freeze/thaw conditions  
(Credit: University of Washington)**

# Placer County LID Guidebook Study Area

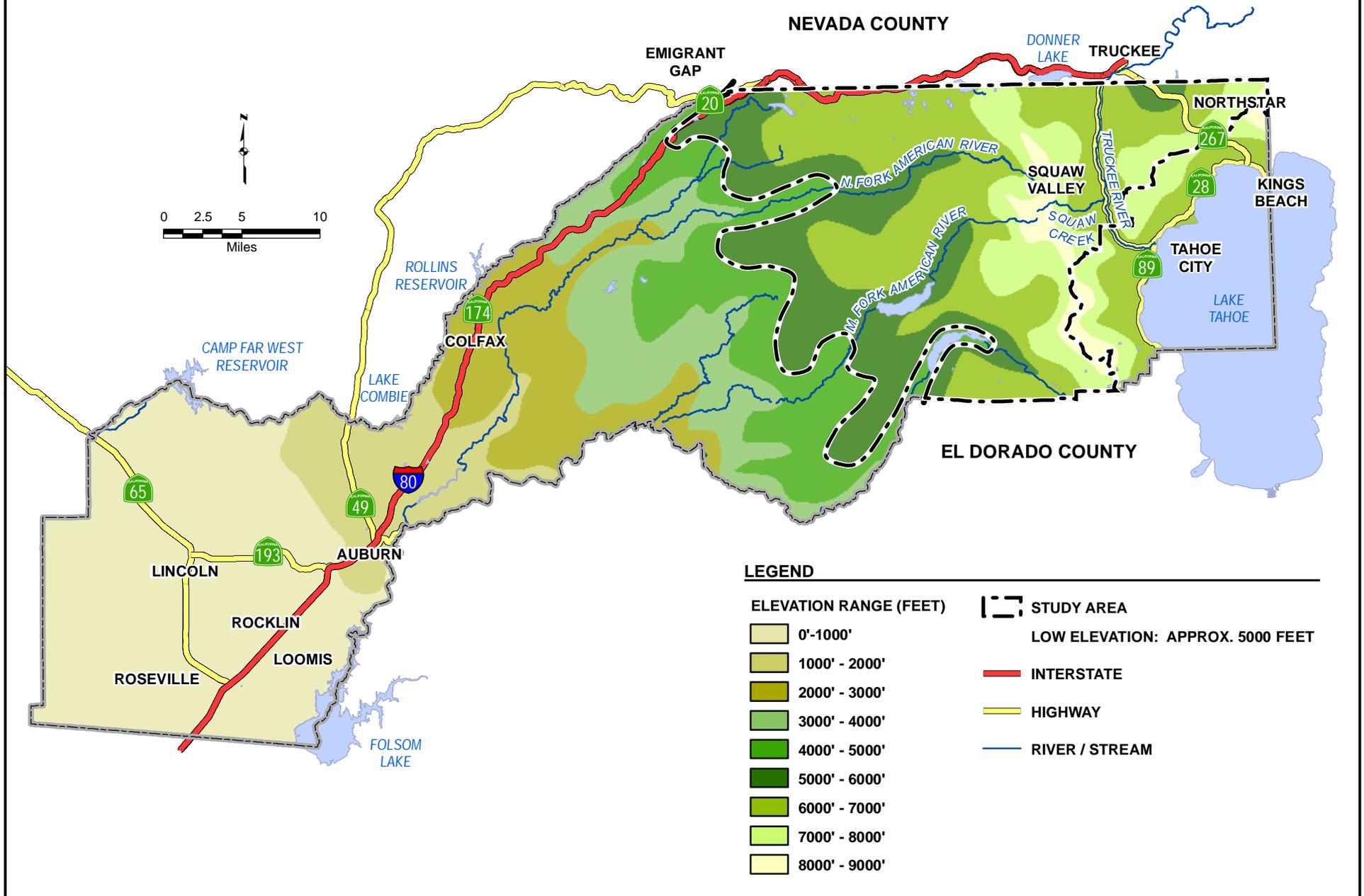


Figure 1-1

Regulatory agencies and local government agencies in California are encouraging LID design features as a means of reducing pollutants in urban runoff and reducing site runoff to maintain healthy receiving streams with optimal sediment balances. In some communities, State stormwater permits mandate that LID be required as a condition of development project approval; this will likely be the case in Placer County in the future. In fact, some of these techniques are already in use in the Lake Tahoe basin due to more stringent regulatory mandates related to reducing/infiltrating site runoff and preserving lake clarity. For projects in those areas, the Guidebook should be considered supplemental guidance and is not intended to supersede other adopted plans and requirements. In all cases, the project applicant should consult with the local permitting agency early in the design process.

## 1.5 NEXT STEPS FOR IMPLEMENTING LID IN PLACER COUNTY

Creation of this Guidebook is considered the first of several steps necessary to support more widespread use of LID in Placer County in the future. It is anticipated that future NPDES stormwater permits and other environmental regulations will require LID implementation in the county, at least on new and redevelopment projects, as is the case in other California communities. When this happens, Placer County and other local municipalities will need to adopt policies, codes, ordinances, and development standards to address LID. The Guidebook was created in a modular format with stand-alone fact sheets and flow charts to provide flexibility in how the document can be used and to facilitate updating the document in the future in response to changes in State regulations. Placer County will be responsible for future updates.

*As communities begin to plan more with watershed health in mind, many of our planning tools may need to be changed, refined or augmented to achieve the water protection that is vital to the future of our environment, our economy and our lives.*

*In many cases, these changes simply require looking back 100 years to the way our communities were originally constructed. Some of the fundamental characteristics that make small towns throughout the Sierra vital and coveted places to live and visit are the same characteristics that reduce the impact of development on water resources. Narrows streets, compact city centers and a mix of residential and commercial neighborhoods are examples of such qualities.*

*-Planning for Water-Wise Development in the Sierra, Local Government Commission and Sierra Nevada Alliance, 2008.*

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## Chapter 2

# APPLICATIONS AND BENEFITS OF LOW IMPACT DEVELOPMENT

This chapter of the Guidebook begins with a brief introduction to the impacts of urbanization on natural ecological systems and how Low Impact Development (LID) is considered one of the solutions for minimizing those impacts. The chapter then goes on to discuss the application of LID to various scales of development, redevelopment infill projects, and high elevation areas. Finally, the chapter presents information on the many benefits of LID, including environmental, economic and social/community benefits.

### 2.1 IMPACTS OF URBANIZATION ON WATER RESOURCES AND HOW LID CAN HELP

The hydrologic cycle describes the movement of water from the atmosphere to the earth's surface and subsurface layers, and back to the atmosphere again (Figure 2-1). Typically with each precipitation event, some water soaks into (infiltrates) the ground as shallow subsurface flow or deep percolation, depending on how porous the soil is, and the rest runs off the land surface into receiving waters (e.g., creeks, lakes, rivers) and on to the ocean. Water returns to the atmosphere when it evaporates from vegetation, soil, water bodies, and is transpired by vegetation (a process called evapotranspiration).



**Figure 2-1. The Hydrologic Cycle**  
(FISRWG, 1998; adapted by E. Berntsen, 2009)

In undeveloped areas, most of the precipitation infiltrates or is evapotranspired; there is typically very little or no surface runoff. The exception is in undeveloped areas with compacted or clay soils that do not infiltrate well (e.g., grazing lands and areas with vernal pools). In contrast, when land is developed using conventional practices, the hydrologic cycle is disrupted by removing vegetation, compacting soil and covering the ground with impervious surfaces (e.g., buildings and pavement). As shown in Figures 2-2 and 2-3, this leads to less natural infiltration and evapotranspiration and more surface runoff delivered to streams and rivers. Conventional development and stormwater management methods—especially the typical curb and gutter, pipe and pond system—alter the hydrology and, consequently, may affect the physical, chemical, and biological condition of streams and other receiving waters (Perrin, et al, 2009). Additionally, as shown in the inset soil profiles on Figures 2-2 and 2-3, compaction and impervious cover affects the composition and richness of the underlying native soil. Void spaces are reduced, organic matter/nutrients are depleted, and the soil’s ability to support healthy, diverse vegetation is compromised.

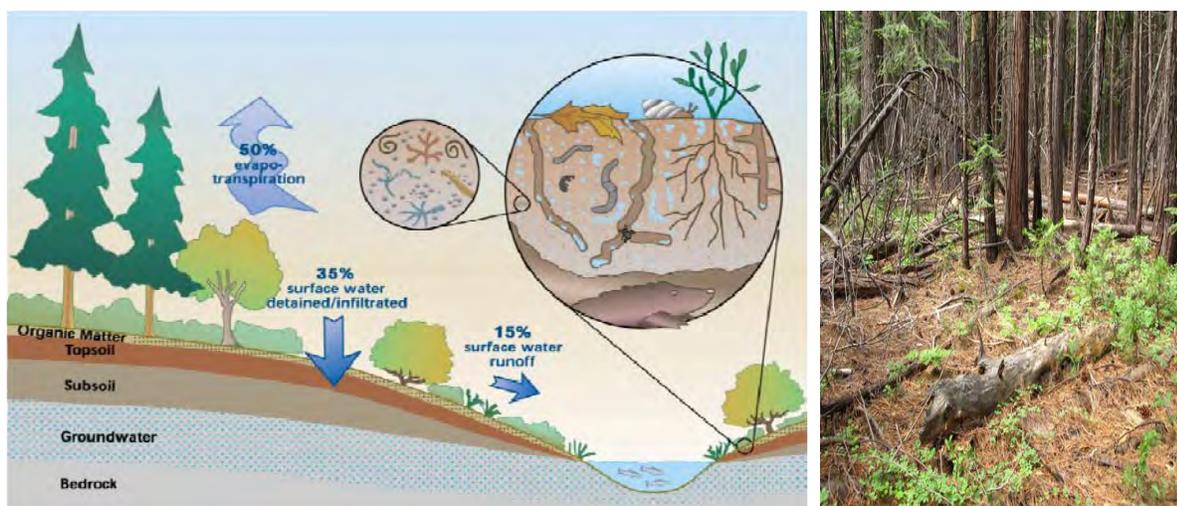


Figure 2-2. Pre-Urbanization Water Cycle and Soil Conditions (FISRWG, 1998; adapted by E. Berntsen, 2009)

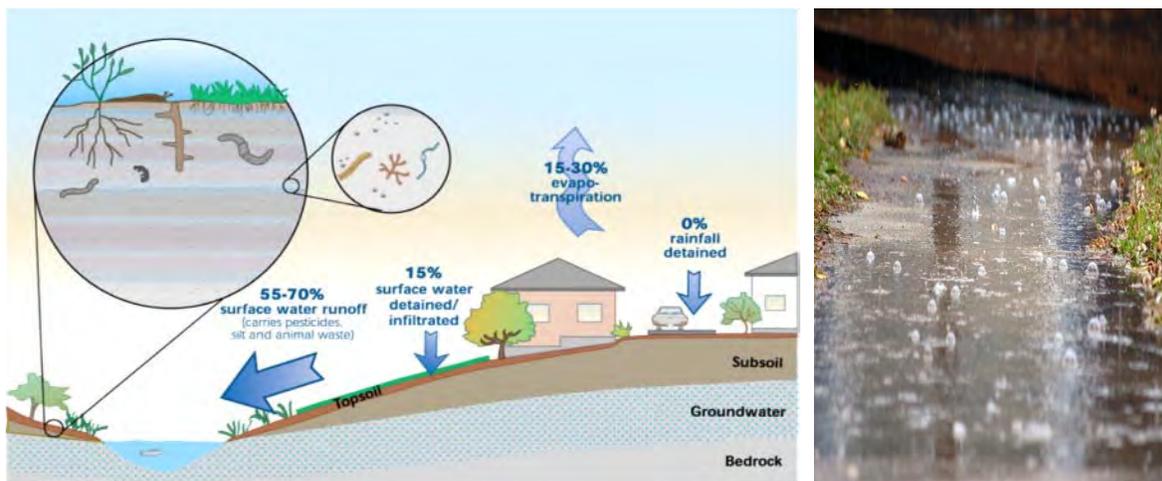
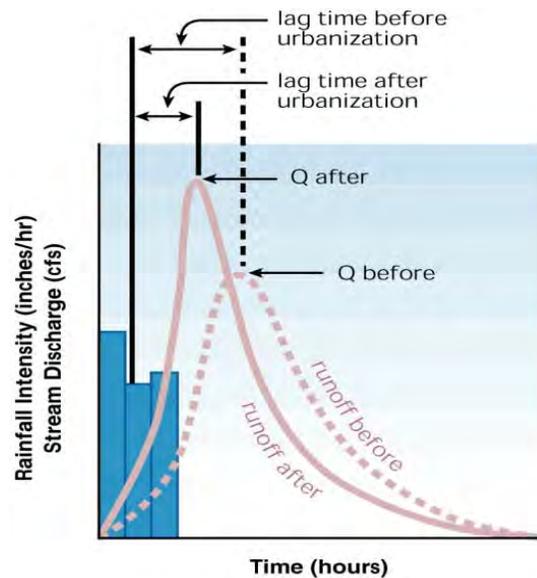


Figure 2-3. Post-Urbanization Water Cycle and Soil Conditions (FISRWG, 1998; adapted by E. Berntsen, 2009)

Scientists and engineers use hydrographs as another way of comparing the difference in runoff conditions of pre- versus post-development situations (see Figure 2-4). A hydrograph depicts the flow of water in a stream over a given period of time. Prior to development, rainfall and melting snow infiltrate the natural ground, replenishing groundwater and recharging local streams, and surface runoff to the local streams begins after the soil becomes saturated. In contrast, after pavement and buildings are added to the landscape, rainfall and snow lands on impervious surfaces and runoff and snowmelt is delivered more rapidly to the local storm drain system and streams; there is a reduced lag time between the start of the storm and the peak runoff as shown on Figure 2-4. Small tributaries and even larger streams cannot accommodate the increased water volume and flow that occur immediately following rainfall and snowmelt events, leading to eroded stream banks, incised channels, streams choked with sediment, impaired aquatic life and aquatic habitat, and increased flooding and property damage. In addition, urban runoff carries a broad mix of toxic chemicals, bacteria, sediments, fertilizers, oil and grease to nearby streams (EPA, 2007).



**Figure 2-4. Comparison of Runoff Before and After Urban Development**

**(FISRWG. 1998: adapted by E. Berntsen. 2009)**

In the past, stormwater management techniques focused on moving the water off developed sites as quickly as possible using pipes and channels and modifying the receiving streams as needed (e.g., widening, straightening and lining stream channels with concrete or riprap) to handle the increased flows. Flood control facilities were built to store and slowly release stormwater from large storm events, but neglected to address runoff from small events. In the last two decades, concerns about the quality of the runoff during small events prompted federal and state regulators to require measures to control pollutants at their source and to remove pollutants from runoff using techniques like detention basins (gravitational settling) and bioswales (vegetative filtration).

In recent years, the regulators' attention has turned to the need to control the quantity of runoff from the small events, which can chronically affect downstream erosion, sedimentation and habitat conditions. LID is one of the key ways to mitigate these effects. In this publication, LID is defined as a total site design approach that conserves and uses existing natural site features and systems integrated with distributed, small-scale stormwater controls to mimic or recreate the natural water balance for a site.

Unlike conventional approaches, which address only the precipitation, runoff conveyance and storage components of the hydrologic cycle (shown in Figure 2-1), LID recognizes the significance of the other components - infiltration, groundwater recharge and evapotranspiration - as well. There are many LID site design techniques that allow the site designer/engineer to create a stormwater management system for the site that more closely mimics the natural water balance. Rather than employing the traditional stormwater management approach that can use miles of costly pipes and acres of stormwater ponds to deal with runoff, LID uses natural vegetation and small-scale treatment systems to treat and infiltrate stormwater runoff close to where it originates. Reducing the amount of stormwater runoff generated reduces impacts on streams carrying stormwater.

*The goal of LID is to use a wide array of site-level planning, design, and control techniques to restore and optimize the land's ability to soak up water and capture and process pollutants naturally in the landscape.*

### Understanding Climatic, Hydrologic Cycle and Soil Conditions in the Placer County High Sierra Region

It is necessary to understand and evaluate the local site conditions for the site and its surrounding watershed, to create a design that maintains or mimics the natural hydrologic function of a site. The following information (based on published data) provides general information that may be useful for initial planning purposes for projects in the High Sierra region of Placer County. However, due to the wide environmental variability in the region, there is no substitute for site visits and site-specific investigations, particularly for confirming soil permeability. See Chapter 3, Section 3.4, for more details about addressing these factors in site design.

**Climate:** The High Sierra region of Placer County above 5,000 feet elevation (around Emigrant Gap) includes the Donner Summit area, the southern half of the Truckee Basin and the northwestern portion of the Lake Tahoe Basin (see Figure 3-2 in Chapter 3). Although these areas share many similarities in terms of climatic conditions, there are also some important differences. The Donner Summit area often receives the largest amounts of annual snowfall nationally, while portions of the eastern Truckee watershed, just a small distance to the east, are impacted by a rain shadow that creates almost a high desert type environment. In the Town of Truckee (located just north of the county border in Nevada County), for the period between 1971- 2000, the mean annual precipitation was almost 31 inches. Typically, about 75 percent of the precipitation occurs during the winter and spring (December to May) with an average annual snowfall of almost 204 inches. Large spatial temperature differences provide another good example of the climatic variation within the region. Each year, Truckee often registers the lowest daily temperature in the nation (the National Weather Service reports nearly 230 days a year with lows of 32 degrees F or lower). In contrast, the surrounding areas, which are higher in elevation or closer to Lake Tahoe, experience much milder temperatures due to temperature inversions and the moderating effect of the Lake's large water volume.

**Hydrologic Cycle:** The cold winter climate above 5,000 feet brings significant snowfall and snow retention during the winter months, therefore the timing for the hydrologic cycle is different than lower elevations of the county and LID features perform differently than elsewhere. For example, vegetated bioswales and filter strips in parking lots and along roads can be filled with accumulated snow for 3-4 months of the year. Although there is no vegetative uptake, absorption or transpiration occurring during this period, there is natural runoff reduction at work. As the weather warms and the snow melts, the LID features will infiltrate and absorb a good deal of the snowmelt.

**Geology and Soils:** The Truckee Basin lies within the eastern most complex of the Sierra Nevada range, between the 9,000-foot-high Sierra Nevada on the west and the 10,000-foot-high Carson Range on the east. The bedrock of the Truckee Basin is primarily defined by metamorphic rock with granite intrusions. These rocks are consolidated, very dense and hard, with small grain structure and little capacity for water storage. On top of the bedrock are volcanic flows, glacial deposits, and stream and lake deposits of mostly unconsolidated volcanic material and sedimentary material which is generally very porous and stores large amounts of groundwater. Much of the soil underlying the basin consists of silty/sandy gravels or gravelly/silty sands that contain large quantities of sediments that were transported to the Truckee Basin from the crest of the Sierra Nevada by glacial activity. Past glacial activity has also resulted in the deposition cobbles and boulders in the Basin. Soil depths typically range from 20 to 60 inches.

## 2.2 LID APPLICATIONS

### Applying LID at the Community, Neighborhood and Site Scales

LID stormwater management strategies can be applied at various scales ranging from the larger community (or watershed) scale, down to the neighborhood (or sub watershed) scale, and finally to the site scale. When possible, the most effective approach is to introduce LID at the watershed scale (e.g., community and specific plans) and subsequently refine at progressively more detailed scales in the neighborhood/village and site planning and design processes. Stormwater management opportunities identified at the larger scales can provide the basis for an overall stormwater management strategy that functions as a system of integrated facilities applied at the subdivision or site scales.

While this Guidebook focuses on planning and design at the site scale, it is important to understand the context and recognize the fact that community and neighborhood planning has a tremendous influence on what is achievable at the site level.

*While this Guidebook focuses on planning and design at the individual project or site scale, it is important to understand the broader context and recognize that community and neighborhood planning has a tremendous influence on what is achievable at the site level.*



When possible, the most effective approach is to introduce LID at the watershed scale (e.g., community and specific plans) and subsequently refine at progressively more detailed scales in the neighborhood/village and site planning and design processes.



### **Community (Watershed) Scale**

At the community scale, a thorough understanding of the physical and ecological characteristics of the landscape is essential in order to explore potential stormwater management solutions. In addition to inventories of natural features (e.g., native soils, groundwater depth, topography, and aquatic community objectives/targets) that would typically be addressed during Environmental Review, Community Master Plan or Watershed Plan, a LID-based approach to stormwater management planning requires understanding two additional parameters:

- Small headwater drainage features and their contributing catchment areas, and
- Groundwater recharge rates, flow patterns and discharge areas.

As an initial step in the planning process, it is important to identify opportunities to conserve natural features and incorporate features that contribute to the ecological integrity of the landscape into the overall development scheme. It is also important to preserve natural features whenever possible, not only for their ecological value and habitat function, but also to take advantage of their ability to evapotranspire and infiltrate stormwater. Maintaining and enhancing the urban tree canopy and forest cover in urban/urbanizing subwatersheds is one example of using natural vegetation to manage stormwater (Toronto and Region Conservation Authority [TRCA], 2010).

Development projects and communities are designed in consideration of a full range of environmental, transportation, social, practical, and functional objectives to optimize their function, marketability and long term sustainability. In the process of planning each of these components, it is important to also consider stormwater management objectives. For example, a designer can align major roads to follow the divides between sub-watershed areas and local roads to follow overland flow directions; this will help to maintain predevelopment drainage area divides and discharge points as closely as possible. Similarly, open space components can be situated within a community plan near the downstream limit of the sub-watershed area in order to accommodate and integrate stormwater management facilities within the open space system (TRCA, 2010).



### **Neighborhood (Subwatershed or Subdivision) Scale**

Typically, the location of lots, roads, parks and open space blocks, natural features and buffers and regional stormwater management facilities (e.g., detention basins) are defined at the neighborhood scale. At this stage in the planning process, a planner must consider how stormwater management objectives can be achieved and how these objectives might influence the location and configuration of each of the design elements. For example, look for opportunities to integrate stormwater management features in and alongside roadways, parking areas and parks and open spaces.

## Community and Neighborhood Design Opportunities: Roadways and Parks

The road network comprises a significant component of a specific plan or subdivision plan with its configuration typically designed to address transportation, transit and servicing objectives alone. However, the road network also represents opportunities for LID practices, such as:

- Minimize impervious surfaces by designing low traffic roads more narrowly with only one lane of parking, sidewalks on only one side, and/or infiltration island cul-de-sacs or roundabouts.
- Incorporate bioretention areas, bioswales, infiltration trenches and/or permeable pavement into boulevards, parking lanes, cul-de-sac islands and roundabouts, and perforated pipe conveyance systems below the road bed.

*(for both of the above examples, the features need to be designed properly to keep water out of the road base to protect the structural integrity and safety of the road)*

Parks, recreation areas (e.g., sports fields) and open spaces present the potential to integrate LID facilities as amenities within the landscape. However, it is important that the integration of such features within the public amenity space does not compromise its utility or function.

*Note that these techniques may pose conflicts with other codes and regulations; always consult with the permitting agency before proceeding with the design.*



Photo: High Point, WA



Source: City of Sacramento



### Site (Lot) Scale

At the project site scale (typically consisting of multiple lots or parcels), there are a range of opportunities to integrate stormwater management practices into all components of the development. Implementation of controls at the site level can effectively reduce reliance on end-of-pipe facilities and result in a stormwater management strategy that is more beneficial to the environment than conventional end-of-pipe based solutions. Other incentives for implementing site level controls include reduced costs for the construction of end-of-pipe facilities and potential reductions in the amount of land needed for stormwater detention.

Techniques should be consistent with the overall stormwater management strategy developed at the community and neighborhood scales.

The following are examples of site scale LID strategies:

- Harvesting of rainwater from rooftops for non-potable uses (e.g., irrigation, toilet flushing) using rain barrels or cisterns;
- Installation of vegetative green roofs to filter, evapotranspire and reduce runoff;
- Directing runoff from rooftops to pervious or vegetated areas;
- Placement of infiltration trenches or chambers below landscaped areas, parking areas, parks, sports fields, etc.;
- Integration of bioretention areas, rain gardens, biofilters or constructed wetlands into the landscaping;
- Use of permeable pavement in low and medium traffic areas where allowed;
- Directing parking lot and road runoff into bioretention areas, vegetated filter strips, and swales to filter out automobile-related pollutants; and
- Integration of detention ponds and wetlands as aesthetic and recreational features within the landscape.



An infiltration trench follows the topography to carry roof runoff safely away from the building on a multifamily residential site. (Credit: TRCA, 2010)

*For certain types of development (e.g., commercial property), legal agreements may be required to ensure proper operation and maintenance and long-term performance. For LID measures installed in residential areas, incentives and/or property owner educational materials about LID and the need for proper maintenance would be helpful.*

## Applying LID to Infill and Redevelopment Projects

Infill and redevelopment present the most complex challenges with respect to integrating landscape-based solutions for stormwater management. This is because:

- Sites are typically constrained with respect to the extent of potential open space available
- There is typically limited flexibility to manipulate topography since grades around the perimeter of the site are fixed
- Service infrastructure around the site, including stormwater conveyance systems are typically fixed in terms of location, depth and capacity
- The presence of other service infrastructure beneath and around the site may limit potential excavation depths and opportunities for infiltration

As a result, the exploration of stormwater management solutions for infill and redevelopment sites requires a high level of imagination, ingenuity and creativity, and close coordination with the local permitting agency at the earliest possible stage. Cities such as Emeryville in the San Francisco Bay Area (see inset) are proving it is achievable. However, the constraints involved are expected to make LID implementation on these types of projects more costly than in new development (So Cal LID Manual, 2010).

### The City of Emeryville's "güd" Program (Green Urban Design) – A Model of Success for Applying LID to Redevelopment and Infill Projects

Emeryville is a dense urban city adjacent to the San Francisco Bay with about 1 acre of open developable land that has succeeded in implementing LID in redevelopment and infill projects with space constraints, a high groundwater table, and pollution left over from previous industrial uses. Ten projects constructed over the last decade are referenced by urban planners, designers and contractors as models for applying LID in other urbanized areas in the state. The US EPA featured the City in its August 2010 publication Green Infrastructure Case Studies (EPA, 2010b). Emeryville's güd program comprehensively addresses stormwater, recycling, green building, bike and pedestrian needs, and trees. A presentation of case studies and lessons learned from Emeryville is available on the Local Government Commission's web site:

[http://water.lgc.org/water-workshops/san-francisco-bay-area/Emeryville\\_GUD\\_Schultze-Allen.pdf/view](http://water.lgc.org/water-workshops/san-francisco-bay-area/Emeryville_GUD_Schultze-Allen.pdf/view)



## Applying LID in High Elevations

### *Performance of LID Features in High Elevations*

The cold winter climate above 5000 feet brings significant snowfall and snow retention during the winter months, therefore the timing for the hydrologic cycle/process is different than at lower elevations and LID features perform differently. For example, vegetated bioswales and medians in parking lots and along roads can be filled with accumulated snow for 3-4 months of the year. Although there is no vegetative uptake, absorption or transpiration occurring during this period, there is natural runoff reduction at work. As the weather warms and the snow melts, the LID features will infiltrate and absorb a good deal of the snowmelt.

### *Advantages and Challenges of Applying LID in High Elevations*

The High Sierra region of Placer County offer opportunities to use LID as a way to maintain good quality water that is often present in higher headwater areas of the watershed. Use of LID in upstream areas can reduce turbidity and sediment loads to downstream water bodies by controlling and slowing the runoff and settling or filtering suspended and particulate matter in the runoff.

The steep terrain in the mountainous areas of Placer County may make it difficult to find enough space with suitable slopes for LID. LID features such as bioretention, vegetated filter strips and swales require a relatively gradual slope to provide the optimal contact time between the water and the plant or soil media for pollutants to settle out. The fact sheets in Chapter 4 of this Guidebook describe some design modifications that can help work around these types of challenges. For example, check dams can be used in the flow line of a vegetated swale or channel in steeper areas to slow down the water and encourage sediment and pollutants to settle out.

Freezing conditions in high elevations may also make it challenging to use certain LID measures in some areas and land uses. For example, pervious concrete and other types of permeable pavement depend on open void spaces in the pavement to receive and infiltrate runoff. Care must be taken during installation and long-term operation and maintenance to keep sediment from clogging the pavement and to clean/vacuum the pavement periodically to maintain infiltration capacity. Therefore, it would not be advisable to install this type of pavement surface near highways and other roads that may be sanded in the winter, unless maintenance and operational demands have been fully considered. Other concerns for pervious concrete in the high Sierra winter conditions include the potential for damage from snow removal equipment as well as a condition known as concrete spalling, where rain and melting snow seep through the top layer of the concrete, pooling underneath. When the water freezes, it expands and pushes upwards, causing the surface layer to pit, chip, flake or break off in chunks.



Signs help raise awareness about the need to keep sand off pervious pavement to prevent clogging  
(Credit: PR Design & Engineering)

### *How Do Freeze/Thaw Cycles in Cold Climates Affect Vegetation?*

As air temperatures drop in the fall and winter, the ground temperature drops and the ground eventually freezes. When that happens, plants that are in the ground are slightly lifted, usually breaking off some of the root system. This does not harm the plant as long as the ground stays frozen. This is typically the case in the high Sierra elevation areas of Placer County above 5000 feet, which have a good snow cover during most of the winter that protects the soils and root zones from deep/extreme freeze-thaw cycles and maintains an even temperature no less than 32 degrees F where the snow and soil meet (warmer as you go deeper into the soil).

However, out in the eastern, open, “high desert” areas of Placer County (e.g., Martis Valley and Glenshire), the temperatures fluctuate and snow tends to melt off for periods during the winter. As this happens, the soil thaws and the plants ever so slightly settle back into the soil. When this cycle is repeated over the course of the winter, additional damage can occur in the root zone. The damage will become evident in the spring as temperatures rise. As the plants warm up, they will begin to grow, but the damaged roots will inhibit the ability of the plant to take up water to hydrate their tissue and they will show signs of distress or die. In these eastern areas of the county, the predominant natural vegetation consists of plants that are adapted to dry conditions (e.g., sage, bitterbrush, Jeffrey pines, grasses, perennial wildflowers; all but the pines are less than 4-5 feet tall). This may be a natural adaptation to the freeze-thaw cycling. For new landscapes in these areas, the best choice is to select plants that mimic the natural landscape of adapted species. If other plants are selected, the best way to prevent the damage from the repeated freeze/thaw cycle is to cover the ground around the plants with a deep layer of mulch in the fall. The mulch acts as insulation to temper the fluctuations in soil temperature. In fact, mulch is strongly recommended for vegetation in all areas of the county and can provide year-round benefits. For example, during the spring and summer months when the county experiences cooler nights and warm days, the mulch will help keep soils warmer and help encourage more vigorous growth, in addition to helping retain soil moisture, deter weeds, and improve soil structure as it breaks down.

Another challenge for LID used in or near the roadway right of way is conflicts with snow plowing operations. For example, LID strategies to reduce street width in order to minimize impervious cover may be hard to achieve because winter snow conditions dictate street dimensions, maintenance and parking. A common LID technique to reduce street widths is to provide parking pull-outs and/or allow parking on one side of the street only; but in most high elevation areas of Placer County, on-street parking is prohibited in the winter to enable snow plow access and it would be difficult and time-consuming for conventional plows to remove snow from the pull-outs. More work is needed to identify innovative ways to include LID in street design in winter snow conditions; the solutions have to be practical from a maintenance viewpoint.

## 2.3 BENEFITS OF LID

Municipalities must balance growth needs with environmental protection, and LID techniques can help achieve this balance. In addition, LID provides advantages beyond the expected environmental protection, as discussed in this section. Use of LID approaches can save money, manage and treat stormwater/urban runoff, address sustainability goals, and enhance the community. Table 2-1 presents a summary of how LID can assist a variety of stakeholders to meet their goals.

**Table 2-1. LID Benefits for a Variety of Stakeholders**

<b>Developers/Builders</b>
<ul style="list-style-type: none"> <li>Reduces land clearing and grading costs</li> <li>Reduces infrastructure costs (streets, curbs, gutters, sidewalk)</li> <li>Reduces stormwater management costs</li> <li>Increases lot yields</li> <li>Increases lot and community marketability</li> </ul>
<b>Municipalities</b>
<ul style="list-style-type: none"> <li>Protects regional flora and fauna</li> <li>Balances growth needs with environmental protection</li> <li>Reduces municipal infrastructure and utility maintenance costs (streets, curbs, gutters, sidewalks, storm sewers)</li> <li>Helps satisfy environmental regulations related to water quality and climate change</li> <li>Potentially reduces localized flooding</li> <li>Fosters public/private partnerships</li> </ul>
<b>Property Owners</b>
<ul style="list-style-type: none"> <li>Preserves and protects amenities that can translate into higher value, more marketable homes and livable communities</li> <li>Reduces energy demand and costs due to temperature regulating trees and vegetation</li> <li>Potentially reduces localized flooding</li> <li>Protects water quality – public health benefit</li> <li>Reduces infrastructure costs which can be passed onto property owners</li> <li>Compliance with stormwater regulations</li> <li>Improved public relations associated with implementing green building strategies</li> </ul>
<b>Environment</b>
<ul style="list-style-type: none"> <li>Preserves integrity of ecological and biological systems</li> <li>Protects site and regional water quality by reducing sediment, nutrient, and toxic loads to water bodies</li> <li>Reduces impacts to local terrestrial and aquatic plants and animals</li> <li>Preserves trees and natural vegetation</li> <li>Reduces demands on water supply and encourages natural groundwater recharge</li> </ul>

*Source: Adapted from NAHB Research Center, 2003.*

### Environmental Protection and Compliance with Environmental Regulations

The practice of LID within the Placer County High Sierra region can result in many environmental benefits and will help the County, other local governments, developers, builders and property owners comply with water quality regulations, as described below.

## **Improved Water Quality and Compliance with TMDL and Stormwater Regulations**

Most LID techniques will facilitate and remove stormwater pollutants in addition to reducing runoff. The natural processes employed by LID practices allow pollutants to be filtered or biologically or chemically degraded before runoff reaches receiving streams.

This is critical for the portions of the county in the Truckee River Watershed and Tahoe Basin, where the State has established sediment TMDLs<sup>1</sup>, based in part on the finding that population growth and urbanization have negatively impacted the in-stream aquatic beneficial uses of the receiving waters. LID is a strategy which can help a project applicant and local permitting agency achieve the local TMDL goals. In addition, LID can help satisfy requirements for reducing pollutants in stormwater discharges contained in the Placer County and Town of Truckee's National Pollutant Discharge Elimination System (NPDES) municipal stormwater permits, issued and enforced by the Regional Water Quality Control Boards (Regional Water Boards). These water quality regulations are explained in more detail in Chapter 3 (Section 3.4).

### **Regulatory Requirements Addressed By the LID Approach**

#### **Water Quality**

- Total Maximum Daily Load (TMDL)
- National Pollutant Discharge Elimination System (NPDES) Stormwater Permits

#### **Water Quantity**

- Hydromodification management and instream erosion control (NPDES stormwater permits)

#### **Climate Change**

- AB 32 - Global Warming Solutions Act (reducing greenhouse gases/carbon dioxide equivalent)

## **Reduced Potential for Downstream Erosion and Habitat Degradation**

The use of LID techniques will reduce the potential for downstream erosion and habitat degradation that is often associated with urbanization. Typically, urbanization decreases the amount of pervious area (e.g. open space, forests) in a watershed, while significantly increasing impervious area (e.g. building, roads). Pervious areas act like a sponge and allow natural hydrologic processes (e.g. infiltration, storage, evaporation) to take place. In contrast, impervious areas prevent these processes from occurring, or substantially reduce the effects, typically due to some alteration of the natural form. The conversion of pervious area to impervious changes the natural flow on individual development sites and in the watershed as a whole. The natural flow is modified by increasing the volume of runoff delivered to receiving streams over a shorter time period; this process is called hydrologic modification, or hydromodification.

Hydromodification has been identified as a leading source of water quality impairment in the United States (*National Water Quality Inventory: 2004 Report to Congress* <http://www.epa.gov/305b/>) and for this reason, the next Phase II NPDES stormwater permit issued to Placer County is expected to require projects to address hydromodification. The State Office of Environmental Health Hazard Assessment has

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<sup>1</sup> Section 303(d) of the Clean Water Act requires each State to set a Total Maximum Daily Load (TMDL) for all impaired water bodies. A TMDL is the maximum amount of pollution that a water body can receive without violating state water quality standards.

published several fact sheets on the topics of urbanization's effect on the water cycle, LID and hydromodification; the agency's fact sheet index can be accessed at: <http://oehha.ca.gov/>.

Streams and rivers are dynamic systems striving for equilibrium in terms of water flow and sediment load. It is natural for streams to transport sediment downstream, and some amount of bank and channel erosion will continue to occur over time until an optimal balance of flow and sediment is achieved. Stormwater hitting and flowing over the ground surface in predeveloped conditions naturally erodes and delivers some sediment from the watershed into natural waterways. It is normal for some of that sediment to remain suspended in moving water, and the amount varies depending on the size of the sediment particles and the velocity of the water in the stream. In comparison, stormwater runoff from urbanized areas will often be delivered to the receiving streams in substantially higher flow rates than natural flow. While it would be expected that runoff in this situation is capable of carrying more sediment, urban runoff typically contains less sediment than natural flow, because the original source of sediment has been paved over. The result of urbanization is therefore "hungry" water, or water that is seeking additional sediment to carry down the stream or river. The "hungry" water flows through channel beds and banks, causing erosion and bed scour, and ultimately an increase in stream slope. Channel erosion and bed scour can result in habitat changes which can be detrimental to aquatic organisms and plants, frequently decreasing biodiversity

Implementing LID is one of the solutions for reducing hydromodification and minimizing the impacts of urbanization. The use of LID features will effectively maintain or increase the pervious area within the urban area by maintaining and/or increasing the use of hydrologic processes (e.g., infiltration, storage, evaporation, evapotranspiration) in the previously or newly developed area. The use of LID will also increase the flow path length for stormwater runoff, which will partially reduce the peak amount of water flowing down the stream post-urbanization, and subsequently reduce the ultimate amount of "hungry" water and potential erosive downstream effects.

### ***Protection of Sensitive Ecological Resources***

Benefits also include the protection of sensitive ecological resources through site design and conservation of natural features such as streams and riparian habitats, as well as trees and vegetation. The water quality benefits described previously will also help to improve the ecological health of the terrestrial and aquatic habitat within the region's watersheds.

The preservation and incorporation of vegetation through LID site design help to reduce impervious surfaces, thereby contributing to an overall "micro-climate" that cools and humidifies air and absorbs dust and smog as well as nitrates and other aerosol contaminants from air and rainfall.

*"It is important to note that while LID strategies .... provide important water quality and hydrologic benefits, [they] do not replace the ecological value of conserved lands."*

*Gunderson, et al, 2011*

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## What Do We Know About the Water Quality Benefits of LID?

The availability of water quality data for LID practices varies widely. Certain practices may have 20 years worth of monitoring data, while other relatively newly implemented practices may have little such data available. These data are often important to aid municipal managers in the selection of BMPs needed to implement effective stormwater management plans. The Low Impact Development Center has compiled some of these water quality data on its web site, primarily gathered from academic research or pilot project monitoring. For many pollutants and parameters a wide range of percent removals are reported in the literature. The variability in the data is often the result of environmental factors such as geographic weather patterns, season, antecedent soil moisture conditions and rainfall intensity and duration. There is also variability because many LID controls make use of vegetated, natural systems with designs that can vary on a site by site basis.

The findings of the research and monitoring programs indicate that properly designed and maintained LID systems will significantly reduce total suspended solids and metals concentrations from stormwater runoff. LID systems also provide the benefit of nutrient removal through vegetative uptake and infiltration. However, the effectiveness for total phosphorus and total nitrogen removals shows a high degree of variability. Research has indicated that total phosphorus removals will be influenced primarily by sediment transport to and export from LID BMPs, while total nitrogen removals will be influenced primarily by soil conditions. (Airborne nitrogen and phosphorus is a big concern in the Truckee-Tahoe area.)

The data presented and cited on the Low Impact Development Center's web site provide pollutant removals as a measure of concentration. A primary benefit that LID controls offer is the ability to reduce stormwater peak flow rates and discharge volumes. The ability to retain stormwater through infiltration and evapotranspiration enhances the effect of LID pollutant removal efficiencies. The combination of stormwater volume reductions and pollutant concentration reductions minimizes the total mass of pollutants discharged to receiving streams and waterways.

"LID Strategies and Tools for Phase II NPDES Communities", LID Center, [www.lowimpactdevelopment.org](http://www.lowimpactdevelopment.org)

## Improved Air Quality

Many of the LID approaches discussed in this Guidebook involve the use of vegetation. Trees and plants absorb and remove certain pollutants from the air through leaf contact and uptake, including carbon dioxide, sulfur dioxide, nitrogen oxides and particulates; most of which are generated during refining and combustion of fossil fuels (e.g., automobile exhaust). During photosynthesis, the vegetation takes in carbon dioxide and releases beneficial oxygen as a byproduct, helping to clean the air and reduce the earth's "greenhouse effect" (when heat is trapped in the atmosphere due to high levels of carbon dioxide and other heat-trapping gases). Also, if widely planted throughout a community, trees and plants can help to cool the air and slow the temperature-dependent reaction that forms ground-level ozone pollution (smog).

### *How Do Trees Help Improve Air Quality?*

*Trees and all green plants absorb carbon dioxide from the air and water from the soil, convert the water and carbon dioxide into sugars and release oxygen as a byproduct through photosynthesis. On average, an acre of new forest will sequester about 2.5 tons of carbon annually. Young trees absorb carbon dioxide at a rate of 13 pounds per tree each year. Trees reach their most productive stage of carbon storage at about 10 years, at which point they are estimated to absorb 48 pounds of carbon dioxide per year. An acre of trees can give off enough oxygen for 14 people daily.*

*(USFS. 2005)*

## How Does LID Relate to Drainage and Flood Control Design for a Development Project?

When designing a stormwater drainage system, engineers typically estimate the amount of runoff expected from the site using three factors: estimated precipitation (rainfall), drainage area, and runoff coefficient (based on the type of land use and percentage of impervious area). Various design approaches can be used to provide precipitation data for the analysis, including design storm, historic storm, and continuous simulation. The design storm approach is used most often. Design storms are developed from a statistical analysis of local precipitation records. The design storm concept assumes a precipitation event of a particular frequency will produce a runoff event of the same frequency. Design storms are widely accepted and used because they: a) require minimal resources in terms of time and money, b) can give conservative results, and c) provide a consistent methodology. However, this approach limits facility design to a narrow range of the possible precipitation patterns and durations.

For the planning and design of facilities (e.g., detention basins) which are highly dependent on spatial (geographical) and temporal distribution, as well as volume of precipitation, the use of historic storm data may be more appropriate. Historic storm data can be obtained from rainfall gauges or radar imagery. Continuous (hydrologic) simulation modeling (CSM) is another analysis approach, which involves the use of computer models and requires access to historical, long-term (typically 20+ years) precipitation records. CSM can provide a better approximation of rainfall-runoff volumes and durations, which can provide more reliable drainage facility sizing estimates.

These rainfall-runoff analysis methods have typically been used by engineers to conservatively size a watershed drainage system to handle the extreme runoff events, or floods, from the large, infrequent storm events (10 to 100-year events). Such events can overwhelm the drainage system of individual sites and the surrounding watershed, backing up the water and creating flooding problems and unsafe conditions.

When applying the LID approach to design, engineers cannot neglect their obligation to protect public safety. They must ensure that a site's drainage system will properly drain water in a reasonable time period, and that stormwater will be stored and released from the site in a way that prevents undue flooding of the surrounding watershed (typically short-term flooding of parking lots and some streets [e.g., local streets and portions of collector streets] may be allowed). Therefore, most flood control engineers today treat LID as a redundant feature. They do not account for the runoff reduction benefits of LID due to uncertainties in long term performance of the LID features. For example, an engineer does not have any assurances that a future property owner will continue maintaining the facilities or will not remove the facilities altogether (e.g., fill in a swale or replace pervious concrete with regular pavement). In the future, as more is learned about LID performance, this situation may change.

Also, small-scale LID facilities usually do not have sufficient capacity (volume) to store and detain the large infrequent flood events. However, multiple LID facilities distributed throughout the site can be useful in mitigating for "hydromodification" impacts. That is, controlling the smaller, more frequent (up to 10-year) storm events. Research has shown that cumulatively over time, the smaller events can do far more damage to receiving streams than the infrequent extreme storm events. For this reason, the future NPDES stormwater permits issued to Placer County will require projects to address hydromodification and include LID. For further information on hydromodification, see: <http://oehha.ca.gov/>.

## Stormwater Management and Flood Control

### Flood Control

In recent years, engineers have begun researching the potential flood reduction benefits of managing stormwater on site with LID and other stormwater treatment techniques. Such benefits may include reduced frequency, area, and duration of flooding. While individual lot-by-lot LID implementation may provide minimal flood reduction benefits for the individual lots, the cumulative benefits on the scale of a whole master-planned development or on a watershed-wide basis may be significant. However, there is understandably reluctance on the part of flood control authorities to decrease requirements for flood control in cases where LID is utilized, particularly in situations where LID features are owned and operated by residents and other private parties and long-term performance is therefore not guaranteed.

### Reduced Need for Stormwater Infrastructure

Another potential associated benefit of reduced flows in a development or watershed is reduced expenditures on drainage infrastructure. The ECONorthwest literature search found several studies by the Low Impact Development Center and others reporting that LID techniques such as bioswales, rain gardens, and permeable surfaces can help reduce the demand for conventional stormwater controls such as curb-and-gutter, pipes and ponds. A 2004 report by Braden and Johnston claimed that retaining stormwater runoff on site reduces the size requirements for downstream pipes and culverts, and reduces the need to protect stream channels against erosion (MacMullen, 2007).



### Village Homes Uses Natural Drainage System

Village Homes, a development built in the 1970s in Davis, CA, is a model for incorporating green infrastructure into a site design to manage stormwater runoff. The 240-unit mixed use residential development does not have a conventional curb and-gutter storm sewer system to manage runoff from the development. Instead, a network of vegetated swales wind through the community, providing common open space while functioning as a “green” stormwater drainage system.

When it rains, the system captures runoff from the development. The swales slow runoff, allowing some of it to infiltrate into the ground while the rest is conveyed from the site at a more natural rate. Vegetation, soils and catchments within the swale also serve to filter pollutants, cleansing runoff as it moves through the system. The system was designed to carry remaining water slowly to the City’s municipal facility; however, it works so well that the water rarely actually makes it there. Village Homes also features narrow streets, large areas of common open space, locally appropriate trees and other native vegetation.

*For more information: [www.lgc.org](http://www.lgc.org).*

## Economic Benefits

After compliance with environmental regulations and permits, economics is usually the most important consideration in LID selection and implementation. Typically new development projects provide the most cost effective path towards LID implementation. In new development, LID can be integrated into a project from its initiation when there are usually fewer project constraints and where LID features may be used in lieu of conventional stormwater management features, potentially at savings to the project. To be effective, that approach requires engagement of the entire design team (e.g., owner, engineer, architect and landscape architect) and early consultation with the local permitting agency.

Redevelopment and retrofit projects also provide an opportunity for LID. These types of projects have historically presented more constraints to LID implementation (e.g., limited space or legacy soil/groundwater contamination), potentially making LID implementation more challenging or costly. However, as communities are striving to be more sustainable and turn their attention to promoting infill and redevelopment within the urbanized area, there are more and more successful examples of using LID in the urban setting (*see City of Emeryville case study presented earlier in this chapter*).

In November 2007, ECONorthwest published the results of an extensive literature search of nationwide LID cost-benefit studies; it is the most comprehensive compilation available to date. The report includes tables summarizing cost savings for almost 30 projects, where savings ranged from \$500 to \$7,000 per lot for residential projects and \$2,000 to \$13,000 per acre for commercial projects. Although the reported costs were taken from studies conducted through 2006, the assessment remains a useful tool today for illustrating the relative cost savings of using LID instead of conventional stormwater management techniques. Appendix C-1 presents an excerpt of the report's findings, and readers of this Guidebook are encouraged to refer to the original document for the background, sources, and additional details (MacMullen, 2007).

### Economic and Social Benefits of Protected Habitat

Sustaining or improving natural habitat has numerous economic and social benefits. The cost of recovering or improving natural capital can be even more substantial. Any action that degrades, damages, or destroys ecosystems will reduce natural capital and thus the output of natural goods and services. LID can improve land value by addressing Endangered Species Act (ESA) requirements that may otherwise have to be mitigated if conventional stormwater treatment is used. For example, maintaining pre-project runoff conditions and habitat requires less mitigation than clearing the area, constructing a stormwater retention pond, and then providing separate mitigation (on-site or elsewhere) for the critical habitat impacted.

-LMI 2005

Economic evaluations of LID often focus on cost comparisons using initial construction costs, as this is the simplest evaluation to perform, and neglects operation and maintenance costs. In doing so, the assessments do not consider the potential increased values of environmental goods and services such as healthy fish populations and cleaner drinking water, or the avoided costs of pollution cleanup. Discussions on the economics of LID should take into account the *full range* of benefits and costs, including those benefits that are not easily monetized, but are important to quality of life. A fact sheet published by the North Carolina Cooperative Extension in 2009, *Low Impact Development—An Economic Fact Sheet*, provides a framework for discussing economics and includes examples of several economic studies (WECO, 2009).

*Economic evaluations of LID often focus on cost comparisons using initial construction costs, as this is the simplest evaluation to perform. However, this incomplete assessment neglects operation and maintenance costs, and it does not consider the increased values of environmental goods and services such as healthy fish populations and cleaner drinking water.*

*-North Carolina LID Guidebook, 2009*

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Another limitation of cost comparisons is that they do not examine differences in effectiveness between LID and conventional controls. Several researchers have reported that LID approaches can manage stormwater quantity and quality more effectively than the conventional approaches, either by controlling more flow, or filtering more pollutants, or both. In these cases, a simple comparison of construction costs may reveal that the LID option costs more than the conventional control, without accounting for the fact that the LID option can manage a larger volume of stormwater (MacMullen, 2007).

### **Lower Construction and Maintenance Costs**

Compared to conventional site development, the LID approach can reduce land clearing and grading costs when natural vegetation and site topography are preserved. By minimizing impervious surfaces and making use of a site's existing drainage features, the amount of infrastructure required may be reduced, such as streets, curbs, gutters, sidewalks, stormwater pipes, manholes, stormwater vault systems, large retention facilities, and drain inlets. Use of LID can therefore result in more buildable space to increase lot yields and community marketability. The effect is most evident when large stormwater treatment features such as detention basins can be avoided and excavation or fill costs can be eliminated. In one residential project in North Carolina, the developer saved \$2M in construction costs and was able to increase the number of lots in the subdivision from 56 to 60 (*see case study on next page*).

The Village Homes project in Davis, California has demonstrated that use of LID can reduce the potential for flooding (and therefore associated costs to the property owners and city). In that case, use of natural drainages instead of convention piped stormwater systems has resulted in no flooding in the development's 40-year history.

Depending on the community, reduced infrastructure and associated maintenance needs could also have a positive impact on building fees for developers and future stormwater fees for residents.

### **Cost Savings and Other Benefits for the Ridgefield Project in North Carolina (2010)**

In December 2010, the U.S. EPA's Watershed Academy profiled the Ridgefield residential subdivision project in Hanover County, North Carolina in a national webcast. This project was originally designed and permitted in 2008 using conventional stormwater management approaches and redesigned and approved by the County in 2010 using LID. Overall, the developer realized a savings of \$2M. This did not include the projected savings in maintenance costs following construction. The following highlights a few of the key benefits achieved:

- Gained 4 additional building lots (went from 56 lots in conventional plan to 60 lots in the redesign)
- Reduced stormwater pipe by almost 90% and eliminated 3 stormwater pumps
- Eliminated 9,000 ft of curb and gutter
- Decreased road widths (and associated materials) by almost 10%
- Eliminated 5 infiltration basins (includes construction and maintenance costs) yet increased on-site stormwater infiltration
- Saved \$1M in imported fill
- Increased functional and recreation open space

-EPA. 2010

In conventional site planning and design, projects are sometimes selected solely because they have lower upfront costs. Thus, for example, when two stormwater runoff alternatives are being considered, the option with the lowest initial costs may be selected regardless of long-term operation and maintenance or other costs. This example has practical significance for LID. Designing and constructing bioretention cells may be more expensive upfront than installing a typical storm drain system, but they generally require less long-term operation and maintenance costs and have virtually no rehabilitation or disposal costs. Over time, the storm drain system requires ongoing repair and cleaning and eventually expansion and replacement. When all of these costs are considered, the bioretention cells may yield a far higher return on investment than the conventional design and hence may be the more economical choice. Making these determinations requires a life-cycle cost analysis because the technique incorporates the costs of the project over its lifetime. Life-cycle cost analysis is discussed in greater detail later in this chapter.

Not all projects using LID will result in construction and maintenance cost savings. Examples of LID features that require specialized design and installation and therefore likely require greater upfront construction costs, are green roofs and pervious concrete. Additionally, maintenance personnel and contractor training will be needed for long-term maintenance to be successful for these techniques thus incurring additional ongoing costs. However, as these technologies mature, their use becomes more commonplace and practitioners become more educated, such costs are expected to go down.

### **Reduced Energy Costs**

LID techniques such as green roofs and those that incorporate shade trees can provide natural temperature regulation for buildings, which helps reduce energy demand and costs for the property owner. The U.S.EPA and Low Impact Development Center (2000) report that the insulation properties of vegetated roof covers can help reduce a building's energy demand, and notes that green roofs in Europe have successfully reduced energy use in buildings (MacMullen, 2007). Specifically, the US EPA reports that green roofs reduce a building's energy costs by 10 to 15 percent, and an additional 10 percent of urban tree canopy can provide 5 to 10 percent energy savings from shading and wind blocking (EPA GI web site, 2011).

Application of LID techniques that promote use of native vegetation and recycling of grass and leaves on-site as compost will result in less potable water used for irrigation. This type of water conservation not only conserves precious water supplies, it means less energy is required to pump, treat and deliver the potable water. In a time where Northern California communities are now required to convert to metered water systems, this translates to cost savings for property owners.

### **Increased Property Value and Tax Revenue**

Natural open space and trails are typically attractive to potential home buyers. Various LID projects and smart growth studies have found that clustered housing with open space appreciated in value at a higher rate than conventionally designed subdivisions. For example, in Amherst and Concord, MA, clustered housing sold at an average of \$17,100 more than houses in conventional subdivisions. The clustered homes appreciated at an average annual rate of 22 percent compared with 19.5 percent in conventional subdivisions. These increases in property values translate directly into increased tax revenue (National Park Service, Rivers, Trails and Conservation Assistance, Fourth Edition, Revised, 1995).

*Developers who have used LID practices and technologies have indicated that one of the keys to a successful project is to invest additional time and money in the initial planning stages of development. While this idea may be unpopular because of increased up-front costs, the expenditures are often recouped in the form of rapid home sales, enhanced community marketability, and higher lot yields.*

*-National Association of Home Builders Research Center (2003)*

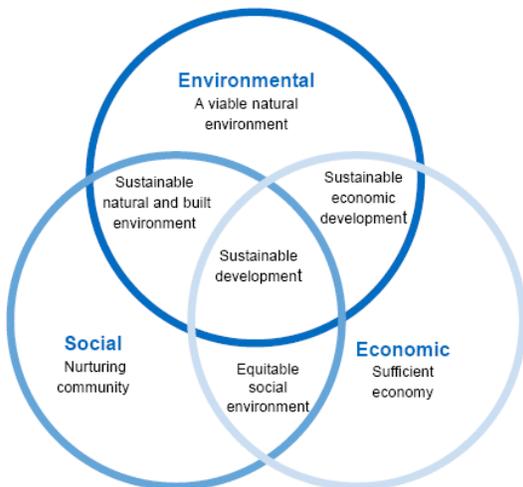
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## Nationwide Case Studies Showcase LID Cost Savings and Other Benefits

In its 2007 report *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*, the US EPA evaluated 17 case studies to demonstrate that LID practices can be both fiscally and environmentally beneficial to communities. Site-specific factors influenced project outcomes, but in general, for projects where open space was preserved and cluster development designs were employed, infrastructure costs were lower. In most cases, significant savings were realized due to reduced costs for site grading and preparation, stormwater infrastructure, site paving, and landscaping. Total capital cost savings ranged from 15 to 80 percent when LID methods were used, with a few exceptions where LID project costs were higher than conventional stormwater management costs.

In all cases, LID provided other benefits that were not monetized and factored into the project bottom line. These benefits include improved aesthetics, expanded recreational opportunities, increased property values due to the desirability of the lots and their proximity to open space, increased total number of units developed, increased marketing potential, and faster sales. The case studies also demonstrated other environmental benefits such as reduced runoff volumes and pollutant loadings to downstream waters.

<http://www.epa.gov/owow/NPS/lid/costs07/factsheet.html>



## Sustainability Benefits

The State of California and local government agencies in the state are striving to become more sustainable; that is, to achieve a better balance between economic viability, social equity and environmental protection (often referred to as the three “E”s). Given an uncertain climatic future, various state agencies have mandated reduction of greenhouse gas emissions and conservation of water supplies. However, economic conditions in recent years may make it challenging for local governments to achieve sustainability.

LID is one cost-effective tool that can help create more sustainable urban development projects and thus help local governments in their progress towards becoming more sustainable. LID promotes a balanced, sustainable approach to site design which regards rainfall and stormwater/irrigation runoff as a resource to be intercepted, captured and recharged and/or re-used on site, rather than than wasting the water. A few examples of LID techniques that promote sustainability are presented below.

## **Reduced Energy Demand**

The quality of life in our communities today is dependent upon access to a bountiful supply of cheap energy. For a sustainable future, the energy should be derived from non-fossil sources; ideally, it should also be reliable and safe, flexible in use, affordable, and limitless. Certain LID measures can help reduce the demand for fossil-fuel sources of electricity. For example, use of drought-tolerant landscaping materials or use of rainwater harvesting are techniques that reduce the need for water (and the energy used to clean and deliver the water). Also, trees provide shade to cool buildings and green roofs help to insulate; both of which can help cut down on energy needed for cooling and heating.

## **Water Conservation and Greenhouse Gas Reduction through Eco-Friendly Landscaping**

"Eco Friendly" Landscaping is an LID technique that exemplifies sustainability in many aspects. Use of this technique in landscape design and maintenance can conserve water by using low water use plantings and high efficiency irrigation systems; reduce air emissions by cutting down on use of gas powered equipment and delivering less green waste to the landfill; protect water quality by eliminating or reducing pesticide and fertilizers; and increase natural infiltration and groundwater recharge in some cases. In addition, Sacramento County is promoting sustainable landscaping as a strategy for reducing greenhouse gases and helping to meet State mandates for climate change. The County developed several guidance documents for landscape professionals and homeowners and a useful on-line River Friendly Landscaping calculator to evaluate how using the principles and practices can save money, time, water and reduce greenhouse gases ([www.riverfriendly.org](http://www.riverfriendly.org)). The Truckee River Watershed Council has launched a local River Friendly Landscaping program for the watershed that is modeled after the successful programs in Sacramento and the San Francisco Bay Area: (<http://www.truckeeriverwc.org/river-friendly-landscaping/rfl-overview>).



## **Groundwater Recharge**

A variety of LID techniques are designed to increase a site's pervious surface area and promote infiltration, so in areas with suitable soils and a shallow groundwater table, the amount of groundwater recharge can be increased. This in turn can increase the volume of water available for withdrawal and consumption. The improved access to subsurface water also can reduce pumping costs and increase well pressure, resulting in greater energy efficiency (LMI, 2005).

## Community Benefits

### ***Improved Quality of Life Due to Enhanced Aesthetics and Expanded Recreational Opportunities***

Developments which integrate vegetative stormwater management and LID facilities as aesthetic, open space and recreational features can enhance the quality of life in a community. An American Lives, Inc. Real Estate Study found nearly 80 percent of potential homeowners rated natural open space as “essential” or “very important” in planned communities. Community designs that offer quiet environments and low traffic levels were top ranked (LMI, 2005 [Note 3]).

### ***Improved Public Health***

As reported by the U.S. EPA on its web site, an increasing number of studies suggest that vegetation and green space - two key components of green infrastructure - can have a positive impact on human health. Preserving, restoring and adding vegetation, trees and green space to denser, impervious areas in the community can reduce the “heat island” effect, a condition that can affect public health and mortality rates, especially in elderly people. Heat islands form as communities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat. The displacement of trees and vegetation minimizes their natural cooling effects (EPA, 2011).

### ***Improved Community Livability with Green Infrastructure***

EPA uses the term “Green Infrastructure” to describe an array of products, technologies, and practices that use natural systems – or engineered systems that mimic natural processes – to enhance overall environmental quality and provide utility services.

EPA’s *Strategic Agenda to Protect Waters and Build More Livable Communities through Green Infrastructure* released in April 2011, commits EPA to developing tools and examples that demonstrate how communities can address existing institutional impediments to incorporating green infrastructure into stormwater management strategies, including code revisions and incentives. The concept is being referenced by regulators in NPDES stormwater permits across the country, including the State Water Board’s proposed draft Phase II NPDES permit, which will impact Placer County and cities within the county covered by the permit.

***“Green infrastructure changes improve the health of our waters while creating local jobs, saving communities money and making them healthier and more prosperous places to raise a family and start a business.”***

***US EPA Deputy Administrator Bob Perciasepe, April 29, 2011***

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Researchers with the Low Impact Development Center in Maryland have recently explored the integration of LID with traditional green infrastructure approaches. They report:

*“The combination of these two philosophies into a governing principle of green design and development offers an opportunity to better integrate developed and developing areas with the natural environment. Comprehensive programs that use LID to extend green space through urban and developed areas can provide water quality protection, air quality improvements, carbon sequestration and heat island benefits. Integrating LID with green infrastructure provides an alternative to traditional gray infrastructure and is a viable option for many communities struggling with the maintenance of aging systems. In addition, by providing multiple benefits, this approach offers the potential for municipalities to more cost effectively manage a number of environmental regulatory requirements” (LID Center, 2011).*

### **Estimating and Quantifying the Benefits Using Life Cycle Analysis**

The most challenging aspect of LID implementation is the need to quantifiably demonstrate the expected project benefits over the life of the project for the developer/property owner at the onset of the project. Various studies have been conducted over the years to compare the costs of conventional vs. LID approach, but little data exists to quantify other benefits. In particular, data is needed for the Placer County High Sierra area.

The economics of LID implementation warrants evaluation on both a capital and lifecycle basis. The capital cost analysis should include not only the cost to implement LID features, but also the potential savings in other features resulting from LID implementation. For example, a pervious parking lot may cost more to construct than a conventional asphalt-concrete parking lot, but these costs may be offset by a reduction in storm drain costs or treatment control BMP costs made possible by the runoff reduction provided by the LID BMP. The lifecycle cost analysis should include not only the operation and maintenance costs, but also the potential savings in energy use and replacement costs. In the previous example, a pervious parking lot may have a life two to three times the life of an asphalt concrete parking lot, resulting in replacement savings (LID Center, 2010).

A 2005 report by LMI Government Consulting recommended an approach for building an economic case to support LID. The approach entails use of a comprehensive cost estimation worksheet to calculate life cycle costs, determine effectiveness factors and estimate the value of secondary benefits. Although this type of analysis does not quantify environmental impacts in terms of pollutants removed or runoff reductions, it still enables the quantification of project effectiveness and secondary benefits that may be quite useful in evaluating and ranking project alternatives (LMI, 2005).

## 2.4 CHALLENGES TO LID IMPLEMENTATION

### Misconceptions

A common barrier to gaining support for LID is the perception that it is new, not well understood, and more expensive and challenging to design, construct and/or maintain. These criticisms can be overcome with a better understanding of LID, coupled with a grasp of its long term advantages. Placer County prepared this Guidebook to help promote a more common and comprehensive understanding of LID and its application in the county.

### Lack of Cost and Performance Data

LID cost data from national studies conducted between the mid 1990s and 2006 and compiled by ECONorthwest was referenced previously in this chapter, and is extremely helpful in appreciating the range of cost savings that can be achieved and the factors that contributed to the savings. But additional data is needed on the cost-effectiveness and performance of LID practices, in particular for California and for the High Sierra areas of Placer County. The California Stormwater Quality Association (CASQA) has recognized the need for more state-specific data and recently established an LID web portal to share information amongst practitioners in the state (<http://www.casqa.org>).

In its 2007 report on LID costs, EPA identified several areas that require further study; these were consistent with some of the further research needs identified by ECONorthwest in 2007. First, in all cases, there are benefits of LID (e.g., improved aesthetics or property values) that have not been monetized and factored into a project's bottom line. Second, more research is also needed to quantify the environmental benefits that can be achieved through the use of LID techniques and the costs that can be avoided. Examples of environmental benefits include reduced runoff volumes and pollutant loadings to downstream waters. Finally, more research is needed to monetize the cost reductions that can be achieved through improved environmental performance, reductions in long-term operation and maintenance costs, and/or reductions in the life cycle costs of replacing or rehabilitating infrastructure. (EPA, 2007)

Further, ECONorthwest identified these additional research topics of interest to Placer County (MacMullen, 2007):

- More detailed information on the factors that contribute to cost savings or cost increases of LID relative to conventional controls.
- Economic comparisons of LID and conventional methods that control for the effectiveness of the techniques regarding managing stormwater volumes and improving water quality (“apples-to-apples” comparisons).

*A common challenge to gaining support for LID is the perception that it is new, not well understood, and more difficult and expensive to design and construct. These criticisms can be overcome with a better understanding of LID, coupled with a grasp of its longer-term advantages. Managers should approach the option of LID as a business matter and work to show that, in many cases, it is the most cost-effective option.*

*-LMI, 2005*

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- More research and data on the economic outcomes of including LID methods in urban *redevelopment* projects.
- More retrospective studies of installed controls, rather than modeling comparisons of theoretical LID versus conventional controls.

### Reluctance to Use the Collaborative Team Approach

To be most effective, the LID approach requires engagement of the entire design team (e.g., owner, engineer, architect and landscape architect) at the very start of the project, ideally prior to site layout. In addition, the team should consult early with the local permitting agency and continue this engagement throughout the project. However, there is often reluctance to spend the necessary money up front to engage the entire team. All too often, the architect's design dictates the ultimate site footprint with little or no regard for preservation or utilization of natural topography, drainage and vegetative features for stormwater management.

*"Builders and developers support the goals of low impact development and believe that federal, state and local land development policies should be flexible and responsive to consumer preferences. Far more important than any regulation, [however], is the effort to improve cooperation between local governments, builders and developers, and other stakeholders. This collaborative approach can serve the industry – and the environment – as we all continue to work toward sustainable development."*

*-Bruce Boncke, testifying before Congress, on behalf of the National Association of Home Builders (NAHB), September 30, 2010.*

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When stormwater management is considered later in the process, it is often too late to effectively integrate LID into the project and redesigns can be costly and time consuming. Ironically, spending a little more money in the beginning of the project to use the LID approach can save money for the developer in the long run, due to a reduction in infrastructure (e.g., less pipes, curb and gutter; no need for underground stormwater vaults; and potentially reduced street widths), dual use of landscaped areas for stormwater treatment and runoff reduction, and less need for new plantings when natural areas are preserved.

### Institutional Constraints

Institutional constraints to effective LID implementation can come in several forms; for example: outdated codes and regulations, lack of trained agency staff (and the resources to train them), and resistance from fire and transportation authorities.

#### *Outdated or Restrictive Codes and Regulations*

Many municipalities in the state – including Placer County - have zoning and building codes and standards in place that were adopted many years ago, long before LID was an option. These local regulations may not be supportive of LID and may pose conflicts. For example, building codes and adopted development standards may not allow for disconnection of roof downspouts so that water can be directed to vegetative areas on the site for infiltration, or vegetated swales around the perimeter of a parking lot might be discouraged due to local requirements for bermed landscaping to provide visual and noise barriers. Outdated codes and regulations may require that project applicants request variances if

they want to use LID controls, or otherwise get special approvals from the permitting agency. Design and permit approval delays in turn delay construction and can increase a developer's financing costs.

Placer County recognizes that challenges to LID implementation still exist due to outdated policies, codes and regulations, and that updating the regulations to accommodate LID will help reduce the risk and expense that developers face. An updated regulatory framework along with education and training could also lessen the time needed for local agency planners, engineers and Planning Commissioners to process and make decisions on project applications. The County has taken the first step to promoting and encouraging LID with the preparation of this Guidebook. Like other municipalities in the region and the State faced with the same dilemma, the County's next step will be to seek the financial resources to update local policies, codes and regulations in order to identify, evaluate and resolve any conflicts. The County plans to consider the ideas and recommendations presented in Appendix D for making the transition within its planning and regulatory framework.

### ***Lack of Local Government Training Resources***

It will take time for permitting agency staff to become familiar with new techniques and adjust policies and procedures to allow for LID. In many cases, approval of a project which includes LID will require sign-off by several agencies (e.g., County development agency, regional fire district) and the agencies may not see eye-to-eye. Training and education is needed to ensure consistent application of new policies to projects, and the reality of limited local government resources may hinder that process. All of this may pose a barrier to getting a project with LID approved, or approved in a timely manner. As mentioned previously, Placer County has taken the first step in the educational process by donating staff time to the process to work with the Technical Advisory Committee in the development of this Guidebook, and publishing the Guidebook as a resource to encourage LID. It is anticipated that LID requirements will become mandatory in the future for certain kinds of development projects, in accordance with new mandates in the County's NPDES municipal stormwater permits.

### ***Resistance by Fire and Transportation Interests***

In Sacramento County, project applicants wishing to install pervious pavement or reduce street widths have encountered resistance from the regional fire district. Understandably, the district's first priority is protecting life and property and response time, and the agency is concerned about the structural stability of alternative pavements and requires sufficient roadway space for maneuvering large hook and ladder fire trucks. Disseminating case study information and photos from other areas in the state that have used the LID techniques successfully and conducting on-site demonstrations using the fire trucks are some of the ways the County is hoping to promote better understanding of LID. In 2009, some researchers at UC Davis funded by a Sea Grant published a LID fact sheet addressing the topics of fire access, reduced street widths and pervious pavement; see <http://www-csgc.ucsd.edu> (search "LID factsheet").

The City of Folsom's stormwater program staff found similar resistance from other engineers in the city when they proceeded to include infiltration stormwater planters in the design of a new parking garage in their historic district in 2009. In this case, the drainage and transportation engineers did not want water near the building foundation or under the roadway where it could undermine structural stability and pose a safety hazard. However, the only place to include the planters was in an area between the building and the street, less than the required ten feet clearance from the building foundation. This situation is very common in compact, dense infill and redevelopment projects (e.g., transit-oriented development) in other areas of the state, including Placer County. To solve the problem, the civil engineer placed the stormwater planters between the sidewalk and the street to provide the maximum possible clearance from the foundation, and adjusted the design specifications to add a concrete moisture barrier under the planter to direct water away from the building. This compromise satisfied the City and allowed the LID approach to move forward on the project.



**The stormwater planters in the City of Folsom's historic district were specially engineered to prevent water from damaging the foundation of the nearby parking structure. (Photo: City of Folsom)**

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## Chapter 3

# LOW IMPACT DEVELOPMENT PLANNING AND DESIGN PROCESS

This chapter of the Guidebook describes the recommended step-by-step planning and design process for integrating Low Impact Development (LID) in development and redevelopment projects in the High Sierra areas of Placer County. It provides tips for streamlining the planning and design process. This chapter also introduces and describes recommended tools to assist both the project team tasked with creating the site design and submitting the application, and on the other side of the counter, the County planning and engineering staff responsible for reviewing and conditioning the project for the decision makers/hearing body to consider.

### 3.1 PROCESS OVERVIEW

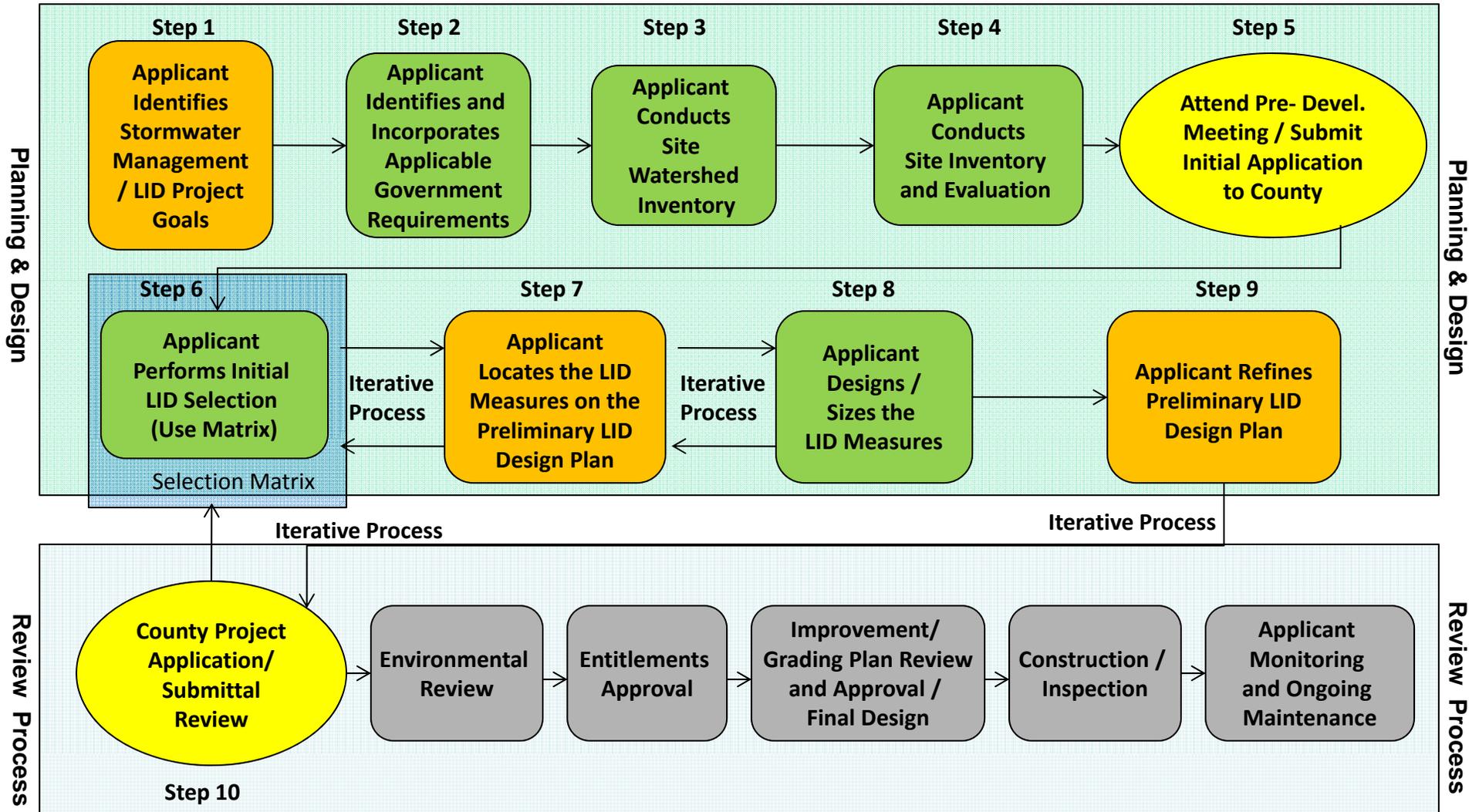
Figure 3-1 is a flowchart illustrating the recommended or ideal planning and design process for use in conjunction with this Guidebook. The process begins with development of stormwater management goals for the project, followed by research and investigations to understand the regulatory framework and unique site and surrounding area features, all of which will influence the design of the project. Next, the project applicant is encouraged to meet with permitting agency staff ( e.g., in a pre-development meeting) to confirm a mutual understanding of goals and local requirements. Following this, a set of LID practices and techniques can be selected to complement the natural site features and minimize impacts of the constructed project. This is an iterative process, with project goals, layout and LID features adjusted until the final plan is ready for submittal to the permitting agency.

The design process outlined in the LID Guidebook is intended to be adaptable to a wide range of sites, economic constraints, and regulatory requirements, including those associated with new development, redevelopment, and retrofits, which may be subject to a variety of water quality, water quantity, and other requirements.

The process is tailored for the typical local development planning and review process in the High Sierra areas of Placer County. Note that the LID process is nested within the County's overall development review process, which includes other steps (such as environmental impact/CEQA analysis and flood control/drainage design) not addressed by this Guidebook. Furthermore, the order in which the steps appear on Figure 3-1 may not be the same for every project.

# Figure 3-1. Low Impact Development (LID) Planning and Design Process Overview

(Use this Flowchart in conjunction with LID Planning and Design Checklist)



Note: This is "ideal case", not typical of all projects. Actual LID process is more iterative than shown, but the LID process has been displayed in a linear fashion to more easily identify steps of the LID design process.

## 3.2 TIPS FOR STREAMLINING THE PROCESS

### Incorporate LID Early in the Planning Process

LID is not intended to be implemented as an afterthought, with a few best management practices placed on an otherwise conventionally designed site. Consideration of natural resources such as topography, soils, groundwater, vegetation, and drainage flow paths not only influence the placement of buildings and paved surfaces, but also the selection and location of LID features. The various site elements should be designed in an integrated fashion, with LID/stormwater management goals considered at the earliest planning stages of a project, as shown in the recommended process flowchart (Figure 3-1).

A common mistake is to wait until the site's footprint and drainage plan have been completed, to attempt to incorporate LID. In the experiences of large urban communities that received stormwater permits two decades ago and have therefore been requiring stormwater treatment for many years, this type of delay results in lack of choices for the designer and property owner. Often, if LID planning is not incorporated early in the planning process, project applicants are forced to use below-ground devices which can be expensive to install and maintain, give up planned building space, or conduct a costly re-design of the site's drainage plan or overall layout. When LID is considered from the beginning, many designs can adequately meet the requirements for a project without significant loss of building space or additional costs.

### Balance LID with Other Requirements

The LID site design process entails the balancing and rebalancing of a myriad of requirements placed on today's development projects in addition to those for water quality protection and water quantity management. Table 3-1 presents a few examples of acceptable LID approaches which may complement other regulatory requirements (consult local permitting authorities to verify acceptance before proceeding with design).

**Table 3-1. Relationship of LID and Other Regulatory Requirements**

Requirement	Conventional Approach	Alternative LID Approach
American with Disabilities Act (ADA)	Specify smooth conventional pavement material (e.g., concrete)	Use selected types of pervious pavement with smooth/relatively smooth surfaces (e.g., permeable concrete and asphalt)
Water Conservation Regulations	Landscaping and swales planted with non-native grasses (sod)	Swales and bioretention planted with drought-tolerant vegetation  Eco-friendly landscaping
Fire Agency Requirements	Specify wide streets and large cul-de-sacs to accommodate large trucks  Prefer conventional pavements with presumed strength characteristics to support trucks	Prohibit parking on one or both sides of street  Install parallel parking cut-outs/pull-outs with main unobstructed traffic lanes  Use selected types of pervious pavement (e.g., permeable concrete and asphalt) for low traffic and emergency fire access lanes capable of supporting the local fire agency's heaviest fire apparatus (e.g., 40,000 lb truck)
Snow Plowing/Storage Requirements	Specify wide streets within minimal obstructions to accommodate plows	Narrow streets with no parking on either side may work in some instances  More work is needed in the future to identify additional acceptable LID approaches (in most cases, parallel parking cut-outs may pose an obstacle to plowing and snow storage operations)

### Use An Integrated Design Team Approach

For successful LID design, the project engineers, architect and landscape designer should work together as a team throughout the process to achieve a balance that meets all requirements within the project budget. The team should consult early with the planners and engineers at the local permitting agency in order to streamline the process. In addition, it is important to inform and involve the project owner along the way to avoid last minute decisions that could negate or significantly impact the entire design process and add to the cost of design and/or affect the project schedule.



**All members of the design team (architect, landscape architect and civil engineer) should meet and discuss LID opportunities as early as possible in the project design phase.**

## Success with the Integrated Design Team Approach: Mercy Housing, Sacramento, CA

In 2008, Mercy Housing completed its Colonia San Martin project in Sacramento County, California, a 60-unit transit-oriented infill development with a density of 20 units per acre. The project is widely recognized as the first affordable housing project in Sacramento with solar power and a wide array of other sustainable features, including disconnected downspouts and vegetated stormwater quality bioswales, extensive use of drought-tolerant water efficient landscaping, community gathering areas, and a community garden and edible fruit trees to provide food for the residents. The project decreased directly connected impervious area from 95% to 3% and reduced stormwater runoff to more than 60% *below* the predevelopment condition. Embracing the “Start at the Source” concept and recommendations in the Sacramento Stormwater Quality Design Manual, the architect facilitated early and continued meetings and correspondence with the entire design team. The question of how to manage stormwater at the site was covered in the first meeting, where the designers decided they did not want to use a vault under the ground to treat runoff.

The result of the team’s collaboration is a project where vegetated stormwater features are integrated naturally and beautifully into the fabric of the site, at a reduced cost to the property owner. The residents love living here, the owner is very proud of this project, and the design team is sharing the positive experience with colleagues and applying the techniques to other projects. Local community leaders and the State and Regional Water Boards are touting Colonia San Martin as a model of success for other infill development in the region. The project was the recipient of the California Stormwater Quality Association’s 2009 Sustainable Stormwater Project Award.



Colonia San Martin Mercy Housing Project. (Credit: Quadriga)

### 3.3 RECOMMENDED TOOLS FOR PLANNING, SELECTING AND DESIGNING LID STRATEGIES

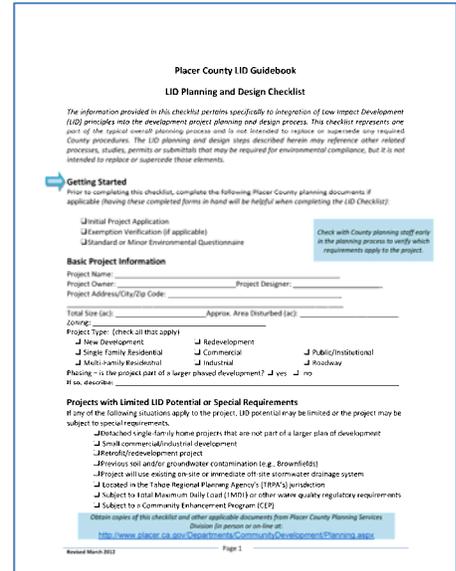
Various tools have been developed for use with this Guidebook, including the planning and design checklist, selection matrix, and site design and runoff management fact sheets.

#### LID Planning and Design Checklist

See end of Chapter 3 and Appendix F

For the ten steps shown on the process flowchart (Figure 3-1 shown previously in this chapter), the LID Planning and Design Checklist outlines questions for the planner/designer in an easy-to-use “fill in the blank” format. The checklist (located at the end of this chapter and in Appendix F) walks the project applicant through the planning and design process and helps ensure that LID is considered and integrated every step of the way. It can also serve as an educational tool for members of the design team new to LID. Additional information and instructions for completing the checklist can be found in the next section of this chapter.

Ideally, the completed checklist should be submitted to the permitting agency along with the design plans, calculations and other background documentation, to help educate and inform the planners and streamline the review process.



The LID Planning and Design Checklist is included at the end of Chapter 3 and In Appendix F.

#### LID Selection Matrix

See Figure 4-1 in Chapter 4 and Appendix F

The LID Selection Matrix (located in Chapter 4 and Appendix F) provides guidance for selecting the appropriate mix of LID site design practices and techniques for the project considering site condition factors, LID measure performance goals (runoff management and pollutant control), implementation concerns (e.g., costs and maintenance needs), and ancillary benefits (e.g., provides habitat, improves air quality). For each of the 12 features, design criteria are provided and relative ratings are given for performance, costs, and ancillary benefits.

The image shows a thumbnail of the 'Low Impact Development Selection Matrix for Placer County Guidebook'. The matrix is a grid with 12 rows representing LID measures (SD 1-3, BM 1-8) and 12 columns representing site condition factors (SC 1-12). Each cell in the matrix contains a rating from 1 to 5, indicating the suitability of a measure for a specific site condition. The matrix also includes a legend for LID measure effectiveness (Very Effective, Moderately Effective, Marginally Effective, Inapplicable, Not Applicable) and a legend for site condition factor ratings (1-5). The matrix is dated March 2012.

The LID Selection Matrix is included in Chapter 4 and In Appendix F

## LID Measure Fact Sheets

See end of Chapter 4 and Appendix F

Fact sheets for the 12 recommended LID measures are provided at the end of Chapter 4 and repeated again in Appendix F for easy access. Four Site Design (SD) measures relate to design and layout of the site and are mostly non-structural in nature, therefore tend to be the least expensive to implement. Eight Runoff Management (RM) measures are more structural in nature and entail installation of physical components on the site. Projects utilizing as many Site Design measures as possible are more likely to require less of the Runoff Management measures.

These tools provide guidance for incorporating LID into development projects in the High Sierra areas of Placer County, but can be used as guidance for planning and designing projects in other areas of the county as well. They have been designed for stand-alone and “at a glance” use by practitioners familiar with LID, based on an understanding of the background concepts and information discussed in this Guidebook.

**Protect Natural Conditions**  
Fact Sheet SD-1

Protect Natural Conditions is a site design measure that can be applied to most projects, and includes preserving natural areas such as riparian corridors and tree clusters, protecting environmentally sensitive areas and designated open-space, protecting natural drainage features, and minimizing soil compaction during site layout and grading.

**Planning and Design Strategies**  
Site design preserve natural conditions is guided by these general strategies:  
 • Protect as much of the existing natural/undisturbed areas of the site as possible.  
 • Protect environmentally sensitive areas and designated open space.  
 • Preserve and use additional natural drainage features and flow paths whenever possible. First, preserve these features to the project conditions.  
 • Minimize soil compaction during and after construction.

**Protect Natural Conditions**  
**Riparian Buffer:** Riparian buffers are important elements of local communities, green infrastructure and LID best practices. These areas are critical to the biological, chemical, and physical integrity of a watershed. Riparian buffers protect water quality by filtering sediment, filtering debris, mitigating flow, and providing for sediment and debris capture by filtering areas and meanders before it enters the water. The Environmental Protection Agency defines riparian areas as: "Areas of planted or growing vegetation between developed land and surface waters, sufficient for effective sediment and nutrient loads."  
**Trees and Tree Clusters:** Tree conservation at development sites can help to maintain a natural hydrologic regime. Tree conservation is not an option when new trees in riparian areas of development sites. Tree clusters located on hill slopes or along ground can reduce stormwater runoff volume and peak flow, improve water quality, generate organic acids, absorb greenhouse gases, create wildlife habitat, and provide shading to moderate temperature increases at development sites.  
**Protect Environmentally Sensitive Areas and Designated Open Space**  
**Open Space:** Open space areas are generally defined through zoning where urban development is not permitted. These areas may be used for parks, golf courses, etc.  
**Environmentally Sensitive Areas:** Environmentally sensitive features include wetlands of the state such as wetlands, vernal pools, seasonal and permanent swales, as well as habitat for endangered or threatened species.  
**Preserve Natural Drainage Features**  
 A main goal of LID is to maintain or restore a site's pre-developed hydrologic regime. Preserving natural drainage features, such as swales, depressions, and wetlands, and restoring the site's natural topographic relief, minimize site disturbances. The natural topography in these features will slow flow and infiltrate stormwater runoff to provide water quality. Designing natural drainage features to reduce or eliminate the need for structural underground drainage systems, in areas where natural drainage features may be needed is critical to accommodate the development, approval must be obtained from the appropriate permitting and resource agencies.  
**Minimize Soil Compaction**  
 Minimizing soil compaction is the practice of protecting and minimizing damage to existing soil quality and permeability caused by land development activities. Minimizing soil compaction will reduce and preserve infiltration rates for vertical LID features. Soils provide an essential soil compaction with an amendment and mechanical restoration after the final construction site has been completed.  
**Right Signs Help to raise public awareness and understanding about the need for and benefits of protecting natural resources.** Photo Credit: South Sierra CDM

**OPPORTUNITIES AND BENEFITS**  
 • Preserving riparian areas and trees can help to provide a natural hydrologic regime, which can help to reduce water runoff and provide water quality benefits.  
 • Preserving and using additional natural drainage features and flow paths can help to reduce stormwater runoff volume and peak flow, improve water quality, generate organic acids, absorb greenhouse gases, create wildlife habitat, and provide shading to moderate temperature increases at development sites.  
 • Tree conservation at development sites can help to maintain a natural hydrologic regime. Tree conservation is not an option when new trees in riparian areas of development sites.  
 • Tree clusters located on hill slopes or along ground can reduce stormwater runoff volume and peak flow, improve water quality, generate organic acids, absorb greenhouse gases, create wildlife habitat, and provide shading to moderate temperature increases at development sites.  
 • Preserving and using additional natural drainage features and flow paths can help to reduce stormwater runoff volume and peak flow, improve water quality, generate organic acids, absorb greenhouse gases, create wildlife habitat, and provide shading to moderate temperature increases at development sites.  
 • Minimizing soil compaction is the practice of protecting and minimizing damage to existing soil quality and permeability caused by land development activities. Minimizing soil compaction will reduce and preserve infiltration rates for vertical LID features. Soils provide an essential soil compaction with an amendment and mechanical restoration after the final construction site has been completed.

Example of Site Design (SD) Fact Sheet (included in Chapter 4 and Appendix F)

**GENERAL DESCRIPTION**  
 Stormwater disconnection is a technique that reduces the volume of stormwater delivered to street drains by diverting the runoff from roofs, driveways, patios, on the site and minor roads and redirecting the runoff to permeable areas (e.g., vegetation) that promote runoff filtration and infiltration. Design variations include:  
 • Rooftop downspout and downspout disconnection  
 • On-site driveway, walkway, small parking area, and patio disconnection  
 • Minor road runoff disconnection via curb cuts and curb removal

**PLANNING AND DESIGN STRATEGIES**

**GENERAL GUIDELINES**

COMPONENT	GUIDELINE
<b>Rooftop Downspout and On-Site Disconnection</b>	
Site Layout	Building setback - 20' Drainage Area - Average is 500 sq ft; maximum is 1,000 sq ft Topography - 10% maximum
Design Criteria	Infiltration: Porosity Ratio - 2:1 minimum Slope - Must discharge to a gradual slope away from the building at 1% to 5% Soil - Amended soils with infiltration rates less than 1 inch/hr or use an underdrain Water Table - 2' minimum separation, 10' minimum separation for infiltration devices
Conveyance and Overflow	Level Spreading Device - Place a level spreading device (e.g., pea gravel discharge) or energy dissipating device (e.g., splash pad) at the downspout discharge location to distribute runoff evenly over the pervious area
<b>Minor Road Disconnection</b>	
Site Layout	Available Space - Minimum disconnection flow length: 40' Drainage Area - 1 sq. maximum per unit Topography - 10% maximum
Design Criteria	Soil - Amended soils with infiltration rates less than 1 inch/hr Water Table - 2' minimum separation
Materials	Vegetation - Intervals of vegetated areas are dictated by the design team, soil type, climate, location and other factors. An initial target distance of 20 feet can be used for both road length and vegetative flow path length

**DESIGN STRATEGIES**

- Reduce amount and peak of stormwater flow. Where possible, use shallow infiltration and flow in lieu of paved discharge to increase the time of concentration of flow.
- Direct flow into stabilized vegetated areas for infiltration and detention. Flow can be diverted from riparian areas or above flow to these vegetated areas.
- Use curb cuts and curbs removed for minor road runoff disconnection. Peak flow can be attenuated using one of the techniques below. Downspout runoff is directed by removing part of a curb and allow for infiltration into a depression or planted bed, install curb cuts at intervals and route flow through street and vegetated areas in an alternating fashion.

**BENEFITS**

- Applicable with limited space constraints and under all soil conditions
- Water Quality: Reduces runoff volume and peak flow, provides infiltration and downflow path
- Water Quality: Provides treatment of sediment, nutrients, metals, and hydrocarbons
- Applicable on high-traffic areas
- Relatively low construction and O&M cost and ease of maintenance
- Conserves water and promotes groundwater recharge, and aesthetically pleasing
- Reduces volume of stormwater discharge areas, no additional space required
- Can reduce size of downstream stormwater quality treatment measures by reducing the volume required to treat
- Allows for more permeation in areas requiring pavement
- Vegetated areas provide green space

**LIMITATIONS**

- Potential for vector concerns due to standing water in vegetated features
- Water barrier will be required where porous material (such as regular asphalt) completely pavement and there is concern about water withering the regular pavement surface
- Subsurface infiltration device may eventually clog with sediment, requiring costly maintenance
- Soil permeability may limit applicability of subsurface infiltration structure
- Do not use on sites with a threshold of CMO or other hazardous spills

**COLD CLIMATE CONSIDERATIONS**

- Depth of Freeze: Insert underground components below the frost line to prevent frost heave and preventing water from freezing in space. Schedule soil infiltration with frost-free periods
- Extreme and Sustained Cold Temperature: Extreme or sustained cold temperatures can lead to pipe freezing and pavement cracking
- Length of Growing Season: Select some permeable plants in vegetated areas
- Rain on Snow Events: Higher rainfall volume may occur during these events
- Soil Depth: Soil management may affect vegetated area available area to prevent soil accumulation and drainage away from site. Use permeable system in a vegetative-covered environment, bury below the frost line permeable depth of infiltration to help with frost heave. Incorporate some surface infiltration when strong freezing seasons

**CONSTRUCTION CONSIDERATIONS**

- Soil Disturbance and Compaction: Allow only vehicular traffic necessary for construction on the pervious area until the final development is complete. If vehicle traffic is unavoidable, then the pervious area should be tilled to a depth of 1' to loosen the compacted soil.
- Excavation and Treatment Control: If possible, locate construction runoff away from the proposed discharge location. After the contributing drainage area and the discharge location are stabilized and vegetated, remove erosion and sediment control devices.
- Compaction: Compaction of amended soils will significantly decrease the efficiency of infiltration in permeable areas. Ban vehicle traffic and high foot traffic from the area. Planting trees around the perimeter of the amended area is one technique for preventing vehicle traffic, other permeable paving.
- Standing Water and Ponding: Two areas to be segregated to avoid ponding water, infiltration or evaporation within 48 hours following a runoff event. When longer ponding periods are developed, improve soil infiltration by reworking, aerating, tilling, regrading and/or adding compost.

**OPERATIONS AND MAINTENANCE CONSIDERATIONS**

- Inspect and maintain vegetated areas to maintain infiltration and filtering capacity.
- Periodically check for clogging of any subsurface pipes or infiltration systems and repair as needed.
- Develop a maintenance agreement with property owners or manager to ensure that downspout system disconnected and the pervious area remains pervious.
- If ponding of water for longer than 48 hours occurs, the pervious area should be de-vegetated and parked.
- If ponding persists, regrading or tilling to remove compaction and/or addition of compost to restore soil moisture retention may be required.

**REFERENCES**

- See Section six in the text for more information
- Low Impact Development Approaches Handbook, 2009, CWS, Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007
- Stormwater BMP Design Supplement for Cold Climates, 1997
- Low Impact Development Stormwater Management Planning and Design Guide, 2010, TRCA
- Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers, 2006, SEMCOG

**PLACER COUNTY LOW IMPACT DEVELOPMENT GUIDEBOOK**  
**SW Flowpath Disconnection**  
 Fact Sheet RM-1

**Example of a Runoff Management (RM) Fact Sheet (included in Chapter 4 and Appendix F)**

### 3.4 ADDITIONAL INFORMATION AND INSTRUCTIONS FOR COMPLETING THE LID PLANNING AND DESIGN CHECKLIST TOOL

This section is a supplement to the basic information and questions contained in the LID Planning and Design Checklist at the end of this chapter. It is intended to provide additional background information and examples and should be used side-by-side with the checklist, particularly by first-time users of this Guidebook and those new to LID planning and design.

#### Step 1 – Identify Stormwater Management/LID Project Goals

Often, property owners and/or design team members have an idea of the desired goals for stormwater management for the project from the outset. Nearly all projects are required to reduce pollutants to the maximum extent practicable, in compliance with the local stormwater quality requirements mentioned in Step 2 below. But additional goals such as flood control and runoff reduction/elimination will be determined by the site's existing or proposed drainage conditions or the size and condition of the receiving system/waterway. Also, based on the June 2011 draft NPDES Phase II permit published by the State Water Board, runoff controls (e.g., matching pre and post-project runoff for specified storm intervals) will likely become mandatory for many projects in the future.

This section of the checklist also asks the applicant to note any desired LID strategies (e.g., infiltration, detention) based on the stated goals. In some cases, site-specific information may be known before the Steps 3 and 4 inventories are performed. For example, knowing that the site has well-drained soils, the project applicant could indicate that infiltration is a desired LID strategy. For guidance in formulating project goals, the project applicant should consider the objectives included in the Placer County Phase II NPDES Permit for the Tahoe Basin:

*Conserve Natural Areas: If applicable, the following items are required and must be implemented in the site layout during the subdivision design and approval process, consistent with applicable General Plan and Local Area Plan policies:*

- *Concentrate or cluster development on portions of a site while leaving the remaining land in a natural undisturbed condition.*
- *Limit clearing and grading of native vegetation at a site to the minimum amount needed to build lots, allow access, and provide fire protection.*
- *Maximize trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native and/or drought tolerant plants.*
- *Promote natural vegetation by using parking lot islands and other landscaped areas.*
- *Preserve riparian areas and wetlands.*

#### Step 2 – Identify and Incorporate Applicable Government Requirements

Every project will be subject to local government requirements, and some projects will also be subject to regional, state and/or federal regulations. During this step in the process, the project applicant should make a note of all known applicable requirements, policies, plans and guidelines and become familiar with the documents. Some of the requirements overlap. For example, projects moving 250 cubic yards or more of dirt will need to comply with the County's Grading, Erosion and Sediment Control Ordinance

(Placer County Code 15.48), and additionally, projects disturbing one acre or more will be required to obtain coverage under the State Water Board's Construction General Permit. The following sections provide background for some of the regulations; however, it is not a comprehensive discussion and project applicants should check with the County to confirm which requirements apply.

### ***Water Quality Regulations Applicable to the LID Guidebook Study Area***

The County has been issued various National Pollutant Discharge Elimination System (NPDES) municipal stormwater permits by the state and regional water boards that require programs and activities to reduce, to the maximum extent practicable, discharge of pollutants in stormwater and urban runoff from the County's stormwater drainage systems to receiving water bodies. The County is also subject to total maximum daily load (TMDL) requirements for sediment, nitrogen and phosphorus that are designed to limit the amount of those pollutants that can be discharged daily to a particular water body. The stormwater permits and TMDLs apply to different areas of the county, as follows (also see the map in Figure 3-2):

#### **The Middle Truckee River Watershed**

Placer County and the Town of Truckee (located in Nevada County) are covered by the State's Phase II NPDES general permit (for small municipal separate storm sewer systems [MS4]) in this watershed. The watershed includes the sub-sheds for Martis Creek, Squaw Creek, and Bear Creek (and others) (See Figure 3-3). The two agencies have developed stormwater management plans to describe programs and best management practices (BMPs) that they are implementing to comply with the permits. This includes establishing and enforcing requirements for new and redevelopment projects to control sources of pollution and treat stormwater runoff. LID is encouraged, but not currently required, for development projects in the Truckee River Watershed, but LID may be mandated in the future due to anticipated new requirements in the new Phase II permit to be adopted by the State in 2012. For more information on the County's Stormwater Quality Program and stormwater management requirements for development projects, see: <http://www.placer.ca.gov/Departments/Works/StrmWtr/StrmWtrAbout.aspx> and [http://www.waterboards.ca.gov/water\\_issues/programs/stormwater/docs/final\\_sm\\_ms4\\_fact\\_order.pdf](http://www.waterboards.ca.gov/water_issues/programs/stormwater/docs/final_sm_ms4_fact_order.pdf).

In addition, sediment TMDLs were adopted by the Lahontan Regional Water Quality Control Board for Squaw Creek and the Truckee River in 2006 and 2008, respectively. The State established the TMDLs on the basis that flow events resulting from thunderstorms, snow melt and dam releases, as well as population growth and urbanization, produce turbidity spikes that exceed the State's water quality objective for Squaw Creek and Truckee River that have impacted the in-stream aquatic beneficial uses of the receiving waters. The TMDLs establish annual/daily sediment loading capacities and reduction targets to be attained over a period of 20 years. Compliance with the TMDLs requires implementation of management practices to control erosion and limit sedimentation (e.g., reducing sediment loadings from winter road sanding operations), and application of LID principles and practices in the Truckee River Watershed will also play an important role in helping to achieve compliance. For more information on the TMDL programs, see: [http://www.waterboards.ca.gov/lahontan/water\\_issues/programs/tmdl/](http://www.waterboards.ca.gov/lahontan/water_issues/programs/tmdl/)

# NPDES Storm Water Permit Areas in Placer County

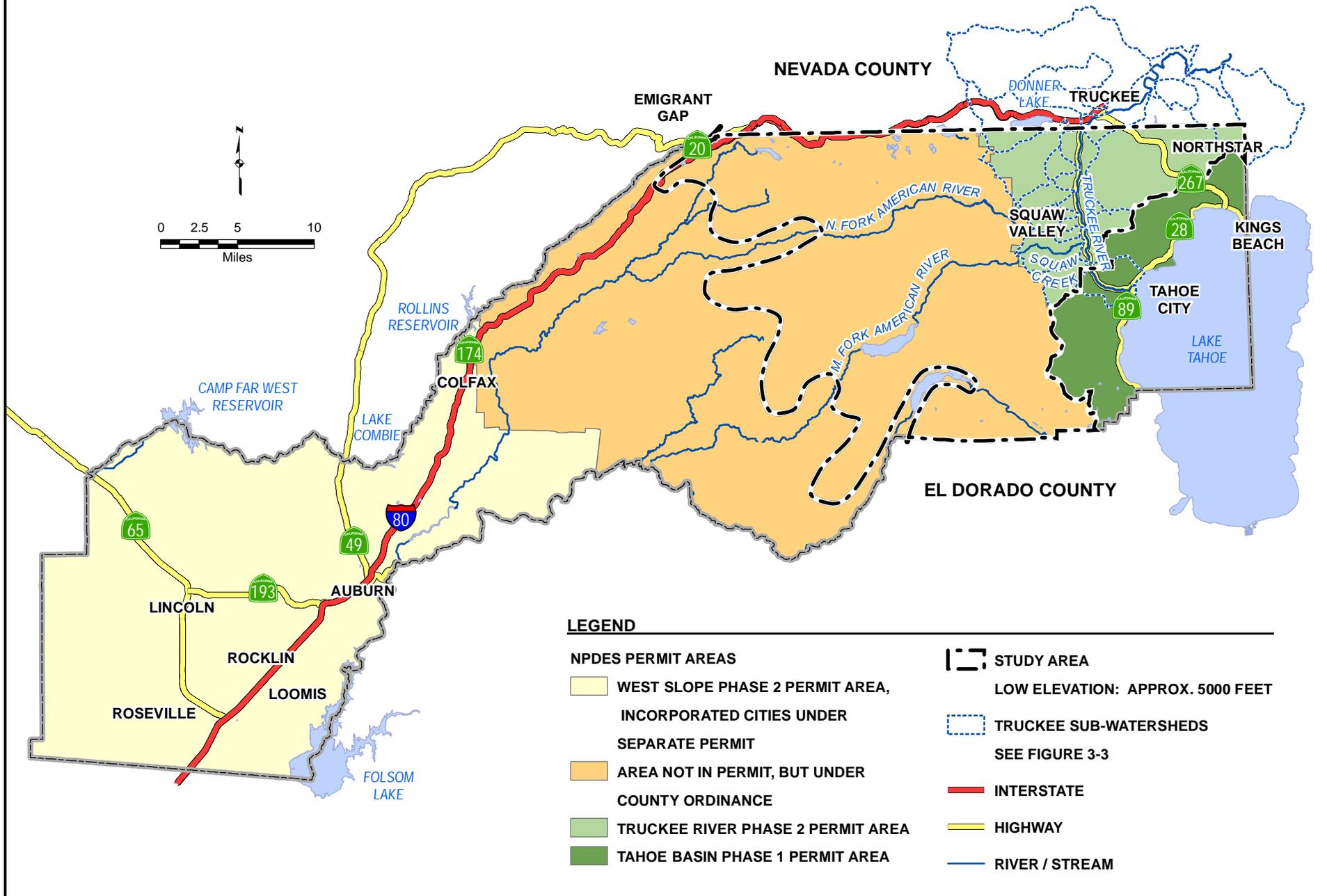


Figure 3-2

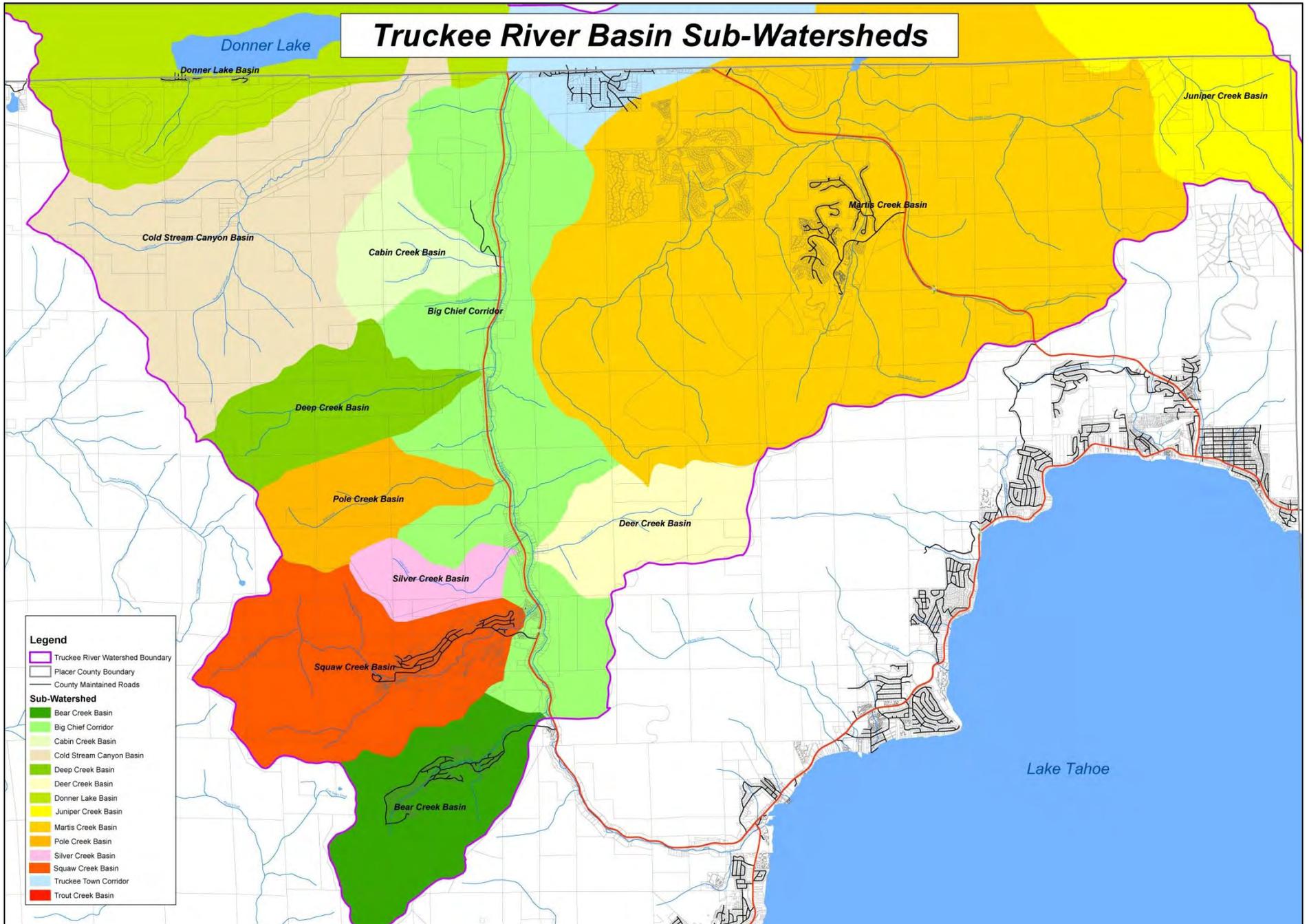


Figure 3-3

## **Unincorporated County Area Between 5,000 ft Elevation and Donner Summit**

The portion of the Guidebook project area above the 5,000 ft elevation level (near Blue Canyon-Nyack Airport) and below Donner Summit and outside the Truckee River Watershed (see Figure 3-2) is not covered by an NPDES permit due to low population and minimal growth potential, and the County does not anticipate any near-term mandate for LID implementation. But since the County uniformly enforces stormwater requirements for development projects throughout the county, development projects in this area are required to implement stormwater source and treatment controls to reduce pollutants in site runoff, and LID is encouraged. Should the updated NPDES Phase II permit mandate LID implementation within permitted areas, the County may modify its stormwater regulations to incorporate such requirements on a county-wide basis. See the County's web site for the stormwater requirements: (<http://www.placer.ca.gov/Departments/Works/StrmWtr/StrmWtrAbout.aspx>)

## ***Water Quality Regulations Applicable Outside the Guidebook Study Area***

The remaining areas of the county not described above include a portion of the Tahoe Basin and the areas below 5,000 ft elevation (see Figure 3-2). Although this Guidebook does not specifically address those areas, the County encourages the application of the LID principles and practices in the Guidebook throughout the County as long as they do not conflict with other requirements. The following is a brief synopsis of the water quality regulations that apply in those other areas.

### **The Tahoe Basin**

Placer County is an NPDES Phase I co-permittee with South Lake Tahoe and El Dorado County in the Tahoe Basin (see Figure 3-2). The permit was renewed in 2011 to incorporate TMDLs for fine sediment, nitrogen, and phosphorous adopted by the Lahontan Regional Water Board in 2010. The co-permittees are required to implement stormwater management plans and pollution load reduction plans to achieve compliance with both the stormwater permit and the TMDL and protect the beneficial uses of Lake Tahoe. Due to declining clarity of the lake and its status as a protected national resource, the stormwater requirements for development projects in the Lake Tahoe Basin are more stringent than elsewhere in the County. The Tahoe Regional Planning Agency (TRPA) regulates new and redevelopment in the basin, and they work closely with the Lahontan Regional Water Quality Control Board to insure that development-related water quality impacts are avoided. A basic requirement is the on-site retention of the 20 year/1 hour design storm total runoff volume from impervious areas. TRPA also regulates allowable impervious coverage. Both of these concepts are consistent with the LID principles discussed in this Guidebook. In addition to fine sediment, pollutants of concern in the Tahoe Basin include total nitrogen, total phosphate, total iron, turbidity, and oil and grease and suspended sediment. Additional information can be found on the TRPA web site: <http://www.trpa.org/> and at the Lahontan Regional Water Board web site: <http://www.waterboards.ca.gov/lahontan/>.

## West Placer County (from 5,000 ft Elevation to Sutter County)

The County is covered by the Phase II NPDES municipal stormwater general permit in the western, lower elevation portions of the county (generally from Colfax and Foresthill, southerly and westerly) in which the majority of the County's population resides (see Figure 3-2). The County has developed a stormwater management plan to describe programs and best management practices (BMPs) implemented to comply with the permit. This includes establishing and enforcing requirements for new and redevelopment projects to control sources of pollution and treat stormwater runoff. LID is encouraged, but not currently required, for development projects in this area, but LID may be mandated in the future due to anticipated new requirements in the new Phase II permit to be adopted by the State in 2012. See the County's web site for the stormwater requirements:

(<http://www.placer.ca.gov/Departments/Works/StrmWtr/StrmWtrAbout.aspx>)

### Step 3 – Conduct Site Watershed Inventory

Eleven questions are included on the checklist to guide the project applicant through a relatively quick inventory of the watershed in which the site is located. This step is not intended to be a comprehensive watershed characterization or assessment and no field data will be collected, although a field visit is recommended to confirm findings from review of aerial photographs, maps and written documentation. The goal of the inventory is to gather information about the surrounding watershed, neighboring properties upstream and downstream, and downstream receiving waters for the property. It is critical to plan for and design the drainage system to handle any run-on to the property, and to be familiar with any water quality, drainage or other environmental requirements or limitations posed by the downstream land areas or receiving system to which the project will deliver runoff. Such conditions could affect design of the LID features for the project.

### Step 4 – Conduct Site Inventory and Evaluation

Conducting the site investigation prior to creating the LID design is the most significant step in the planning process and three pages of the checklist are dedicated to this task. This section of the checklist is intended to be completed in conjunction with a site visit and it guides the project applicant through questions about physical site conditions, potential barriers to using LID and an opportunities analysis, all of which will help create the site design plans and identify the most appropriate LID features for the project.

*Planning for LID communities relies on the performance of a thorough site analysis. Site planners can use the information gathered during the site analysis to create the best balance between development and the conservation of natural resources. By identifying buildable and nonbuildable areas of a site, planners can direct development into areas that will experience the least impacts on air, soil, and water.*

*-National Association of Home Builders Research Center, 2003*

## ***Physical Site Constraints and Opportunities***

This section describes various physical site constraints and opportunities that should be identified before the work of laying out the site design begins; this information may already be available in existing environmental and engineering studies for the surrounding area, other projects in the vicinity of the site, or the site itself:

- Existing lot lines, lease areas and easements
- Proposed lot lines, lease areas, and easements
- Soils, including infiltration capacity and soil quality (contamination)
- Topography/slopes
- Hydrologic (surface water) features, including seeps, springs, closed depression areas, drainage swales, and contours
- Climate/precipitation patterns
- Groundwater depth and quality
- Vegetation, including riparian zones, habitat and overhead foliage/trees
- Utilities: stormwater/drainage and other underground utilities; overhead utilities
- Space Constraints/Configuration
- Cultural features (could affect site footprint and placement of LID facilities)

Site constraints can be identified by looking at the site topography, soils, groundwater mapping, flood mapping, sensitive features, unique features, etc. The goal of this evaluation is to determine, for example, if any of the following are present: soils with high or low infiltration rates, slopes greater than 25%, or shallow depth to groundwater. Site opportunities can also be identified by looking at the site features. The goal of this evaluation is to determine, for example, if any of the following are present: riparian areas, natural swale areas, soils with good infiltration rates, or existing impervious surfaces that can be converted to pervious. A more complete list of opportunities and constraints is provided in the checklist. Identifying and evaluating these site features will enable the designer to creatively explore which LID techniques can be incorporated into the design.

Realizing LID's full benefits requires the use of innovative site-specific approaches to minimize impervious surfaces, reduce stormwater volume, and maintain or improve natural ecosystem functions. Not all locations can effectively utilize LID techniques. Soil permeability, slope, and water table characteristics can limit the potential for local infiltration. LID requires precise engineering for soil characteristics, filtration rates, water tables, native vegetation, and other site features. The most reliable source of information with regard to any particular site is an experienced stormwater/LID management engineer. Such engineers have gained knowledge from experience to identify the hidden benefits, those difficult to quantify, and what works best for site-specific situations.

-LMI, 2005



### Soils

Soil types will determine which LID techniques are feasible and appropriate for the project site. Soils that typically have adequate drainage and permeability (Soil Types A, B) are typically appropriate for infiltration-type LID techniques, while soils with poor drainage and permeability (Soil Types C, D) are either not appropriate for infiltration, or will require additional design modifications to adapt to local soil conditions (such modifications are discussed in the LID fact sheets in Chapter 4). The National Resource Conservation Service (NRCS) (<http://www.nrcs.usda.gov/>) provides soils maps for most project areas, and some of these maps are available online (e.g., Soil Survey of the Tahoe Basin Area, California and Nevada). Additional soil investigations are typically necessary to inform the design process. Hydrologic soil group information should be used for preliminary siting studies only. Site specific soil testing, by a qualified civil or geotechnical engineer, is recommended before preliminary and final design and implementation of LID projects to confirm soil properties including infiltration capacity and should be done as early in the design process as possible.



### Topography

The topography of the site defines both the location and capacity requirements for potential LID implementations (LID Center, 2010). Typically, LID practices are easier to implement where adequate grade exists at the site. However, the steeper the slope, the more likely soil erosion or slides could occur. Generally, slopes greater than 25% should be avoided for clearing, grading and building. Steep slopes and slide prone areas are not advisable for infiltration LID techniques.

The topography of upstream and downstream sites should also be considered with respect to any potential contribution to the total runoff generated during a storm event. Designing effective LID into new or existing sites requires a careful analysis of the topography and how and where stormwater runoff will concentrate and flow. Site assessment of the pre-developed site during a storm event is highly recommended to observe and map areas of natural infiltration, concentration, flow and site discharge points. For redevelopment projects, the record drawings from the previous construction will be important. In the event that topographic data does not already exist for the site or the accuracy of pre-existing data is questioned, a topographic survey should be ordered prior to proceeding with the design phase of the project. The survey should produce a detailed site topographic map showing the smallest contour interval possible (1-foot contour intervals are preferred, but if not available, additional intervals can be interpolated from maps with larger intervals.)

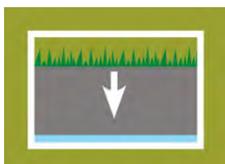


## Hydrologic Features

The following hydrologic features should be assessed during the site inventory:

- **Precipitation:** Precipitation patterns will often provide information that will inform the LID design. Rainfall events, snowfall events, or rain on snow events will often yield different runoff conditions varying on precipitation intensity, duration, and type. These patterns should be studied at the project area, but will likely reflect local conditions of the general area.
- **Onsite streams and other water bodies:** Water bodies should be delineated for the project site, to make use of existing drainage patterns to the extent practical. Working with the site's flow patterns may reduce grading and associated costs.
- **Floodplains and drainage hazards:** Floodplains on the site should be delineated to identify areas where significant flooding may occur. LID techniques generally target control of runoff during low stormwater flow events and are ineffective during high events, and therefore can sometimes be located within floodplain areas. Also, other areas of the site with potential drainage hazards should be identified.
- **Onsite drainage area:** Overall size of the drainage area within the project site should be identified to determine how many LID facilities maybe needed, and if the drainage area needs to be subdivided into smaller drainage areas for design purposes. *(Note, factors such as the location, quality and regulatory status of upstream and downstream drainage areas/receiving waters were considered in Step 3).*

Much of this information may be available from the County or other agencies. Existing flow paths and upslope drainage concerns can be assessed by examining topographic maps of the site, but one of the best ways to get a sense of how water moves on the site is to visit during a heavy rain, taking note of how and where water moves across the site. Where data is not available, on-site testing/mapping by a qualified professional is recommended.



## Groundwater Features

The depth to groundwater at a site will dictate whether or not certain LID measures (e.g., infiltration trench) will be feasible. The shallower the depth to groundwater, the less likely that an infiltration or bioretention technique will be able to handle runoff because the soils will already be saturated or the amount of water that can be infiltrated will be minimal. Information on depth to groundwater can be found in the Natural Resources Conservation Service (NRCS) Web Soil Survey.



### **Vegetation and Habitat**

The type and extent of existing vegetation in the area (including riparian zones adjacent to creeks and other water features) will provide a foundation for the project design. If the site has been previously undisturbed, substantial vegetation may be present on the site. Typically, sustainable design would recommend preserving natural vegetation to the extent practicable. What also must come into consideration is the quality of existing vegetation. If the existing site has native vegetation, then this vegetation should be preserved. However, if invasive species are dominant at the site, this vegetation should not be preserved. If a site has previously been disturbed, little or no native vegetation may be present at the site. The general rule-of-thumb for design purposes is to preserve and/or enhance the quality of the existing vegetation.

Assess the quality of the habitat on the site and identify any sensitive species. Species of concern may limit vegetation removal, and limit or increase the amount of open channel conveyance within a site.



### **Utilities**

Sites undergoing redevelopment will likely have existing utilities, including stormwater conveyance/ detention, sanitary sewer collection, and aboveground or overhead electrical, gas and/or communications lines. Making use of the existing connections to storm drainage systems when possible will reduce cost and design complexity and often save money, but the LID approach encourages use of aboveground vegetated features rather than convention piped systems. Locations of the utilities, whether below ground or overhead, should be noted on the site plan because they may pose conflicts for locating LID features. When the new site design involves adding trees to the site landscape, every effort should be made to select the most appropriate species and provide adequate clearance from buildings and overhead lines to promote a full, mature canopy that will provide air and water quality benefits and cool surfaces and runoff.



### **Space Constraints/Configuration**

For some sites, particularly those that were previously developed or destined for densities of 90-100% imperviousness (e.g., medium to high density residential, commercial, industrial or transportation-related land uses), it is critical to ensure early in the planning process the most appropriate type of LID for the application and that adequate space is available. Other communities have had success effectively integrating LID into dense urban redevelopment sites (see City of Emeryville case study described in Chapter 2).

## ***Understanding Climatic, Hydrologic Cycle and Soil Conditions in the Placer County High Sierra Region***

In LID site design, it is necessary to understand and evaluate the local climatic, hydrologic cycle and soil conditions in order to maintain or mimic the natural hydrologic function of a site. There is not one concise description of the conditions because the Guidebook study area is comprised of various areas (see Figure 3-2). Rather, the following information (based on published data for the Truckee area) provides general information that may be useful for initial planning purposes. However; due to the wide environmental variability in the region, this information is no substitute for the more detailed, site specific investigations that are necessary to support site design.

The High Sierra region of Placer County includes the Donner Summit area, the Town of Truckee and portions of the Lake Tahoe Basin. Although these areas do share many similarities in terms of climatic, hydrologic and soil conditions, there are also some important differences among these regions. For example, the Donner Summit area often receives the largest amounts of annual snowfall nationally, while portions of eastern Truckee, just a small distance to the east, are impacted by a rain shadow that creates almost a high desert type environment. Large spatial temperature differences provide another good example of the climatic variation within the region. Each year, the Town of Truckee often registers the lowest daily temperature in the nation, while the surrounding areas, higher in elevation, or closer to Lake Tahoe, experience much milder temperatures due to temperature inversions and the moderating effect of the Lake's large water volume.

### **Hydrologic Cycle in the High Sierra Region of Placer County**

The cold winter climate above 5,000 feet brings significant snowfall and snow retention during the winter months, therefore the timing for the hydrologic cycle/process is different than other parts of the state and LID features perform differently than elsewhere. For example, vegetated bioswales and medians in parking lots and along roads can be filled with accumulated snow for 3-4 months of the year. Although there is no vegetative uptake, absorption or transpiration occurring during this period, there is natural runoff reduction at work. As the weather warms and the snow melts, the LID features will infiltrate and absorb a good deal of the snowmelt.

### **Climate, Precipitation and Soils Data for the Truckee Area<sup>2</sup>**

#### *Temperature*

The Truckee area is located within a climate 'island' that encompasses the southern Cascade and Sierra mountain ranges and is characterized as humid-continental. The climate experiences relatively large changes in temperature and precipitation throughout the year (Lutgens et al, 1979). The National Weather Service reports that January is the coldest month with an average maximum temperature of 40.9 °F (4.9 °C) and an average minimum temperature of 16.3 °F (-8.7 °C). The record minimum temperature of -23 °F (-30.6 °C) was on February 27, 1962. Annually, there are an average of 228.4 days with lows of 32 °F (0 °C) or lower and 6.0 days with lows of 0 °F (-17.8 °C) or lower. Freezing temperatures have been observed in every month of the year.

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<sup>2</sup> Climatic information for the Truckee area in the Guidebook study area is presented as an example. This should be used as a planning guide only; project applicants should conduct site-specific assessments to verify conditions applicable to the site.

### *Rainfall*

In Truckee, for the period between 1971-2000, the mean annual precipitation was almost 31 inches, varying from about 16 inches (1976) to almost 55 inches (1996). Typically, about 75 percent of the precipitation occurs during the winter and spring (December to May) (WRCC, 2007). The average annual snowfall amounts to almost 204 inches; with a high occurring in 1952 of just over 401 inches of snow.<sup>3</sup>

### *Geology and Soils*

The Town of Truckee is located in the northern portion of the Sierra geologic province. The northern Sierra Nevada mountain range is subdivided into three main geologic complexes which are regions of distinct rock types, topography, and structure that were defined by the primary mountain building episodes of the Sierra Nevada Range. The Truckee Basin, in which the Town of Truckee is located, lies within the eastern most complex of the Sierra Nevada range. The basin is located between two north-trending mountain ranges, the 9,000-foot-high Sierra Nevada on the west and the 10,000-foot-high Carson Range on the east.

The bedrock of the Truckee Basin is primarily defined by metamorphic rock and includes granite intrusions associated with the Sierra Nevada range. These rocks are consolidated, very dense and hard, with small grain structure and little capacity for water storage. On top of the bedrock are volcanic flows, glacial deposits, and stream and lake deposits. The structure of the deposits is nearly horizontal beds of mostly unconsolidated volcanic material and sedimentary material. Sedimentary material is generally very porous and stores large amounts of ground water.

Much of the soil underlying the Town of Truckee consists of glacial till, moraines and outwash. These soils, which can be described as silty/sandy gravels or gravelly/silty sands contain large quantities of sediments that were transported to the Truckee Basin from the crest of the Sierra Nevada by glacial activity. Past glacial activity has also resulted in the deposition of cobbles and boulders in the Basin. Soil depths typically range from 20 to 60 inches.

### *Vegetation*

Plant communities in the Truckee River Watershed include mixed conifer forest, Great Basin sage scrub, and alpine meadows of grasses and wildflowers. Peaks are generally barren. Riparian vegetation of cottonwood, aspen, dogwood, willow, sedges and grasses grow along the river edges. (TRWC, 2012).

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<sup>3</sup> Snow water content varies based on crystal structure, wind speed, temperature, etc. Ten (10) inches of snow contains between 0.10 and 4.0 inches of water, but average U.S. snow fall varies between one inch of water for every 10-4 inches of snowfall.

## Step 5 – Attend Pre-Development Meeting/Submit Initial Application

The checklist provides guidance to the project applicant about what information to gather, compile and summarize to prepare for the pre-development meeting with the County, as well as additional agencies that must be contacted related to the LID design, such as the fire district. This is the point at which the applicant should re-evaluate the original stormwater management/LID goals documented in Step 1 and adjust them if needed.

## Step 6 – Perform Initial LID Selection (use LID Selection Matrix)

This step in the process involves use of the LID Selection Matrix (see Figure 4-1 in next chapter) along with the Site Design (SD) and Runoff Management (RM) fact sheets (also included in Chapter 4), to make the initial selection of LID measures appropriate for the project. As indicated on the LID selection matrix, there are various types of factors which will influence and/or determine the selection of LID measures for the project, described as follows:

**Low Impact Development Selection Matrix for Placer County Guidebook**

**Legend:**  
 ● Suitable  
 ◻ Not Suitable  
 ◻ Not Applicable

**Site Condition Factors:**  
 S1 Soil Infiltration  
 S2 Topography  
 S3 Setback Distance  
 S4 Slope  
 S5 Soil Type  
 S6 Soil Texture  
 S7 Soil Color  
 S8 Soil Structure  
 S9 Soil Moisture  
 S10 Soil Temperature  
 S11 Soil pH  
 S12 Soil Salinity  
 S13 Soil Nutrients  
 S14 Soil Microbes  
 S15 Soil Organic Matter  
 S16 Soil Bulk Density  
 S17 Soil Porosity  
 S18 Soil Permeability  
 S19 Soil Water Potential  
 S20 Soil Water Content

**Stormwater Runoff Control:**  
 R1 Detention  
 R2 Storage  
 R3 Infiltration  
 R4 Retention  
 R5 Treatment  
 R6 Filtration  
 R7 Sedimentation  
 R8 Nutrient Removal  
 R9 Pollutant Removal  
 R10 Odor Control  
 R11 Temperature Control  
 R12 Noise Control  
 R13 Aesthetics Control  
 R14 Safety Control  
 R15 Security Control  
 R16 Liability Control  
 R17 Insurance Control  
 R18 Regulatory Control  
 R19 Public Acceptance Control  
 R20 Political Control

**Pollutant Control:**  
 P1 Sediment  
 P2 Nutrients  
 P3 Pollutants  
 P4 Odor  
 P5 Temperature  
 P6 Noise  
 P7 Aesthetics  
 P8 Safety  
 P9 Security  
 P10 Liability  
 P11 Insurance  
 P12 Regulatory  
 P13 Public Acceptance  
 P14 Political  
 P15 Liability  
 P16 Insurance  
 P17 Regulatory  
 P18 Public Acceptance  
 P19 Political

**Implementation:**  
 I1 Cost  
 I2 Maintenance  
 I3 Longevity  
 I4 Reliability  
 I5 Safety  
 I6 Security  
 I7 Liability  
 I8 Insurance  
 I9 Regulatory  
 I10 Public Acceptance  
 I11 Political  
 I12 Liability  
 I13 Insurance  
 I14 Regulatory  
 I15 Public Acceptance  
 I16 Political

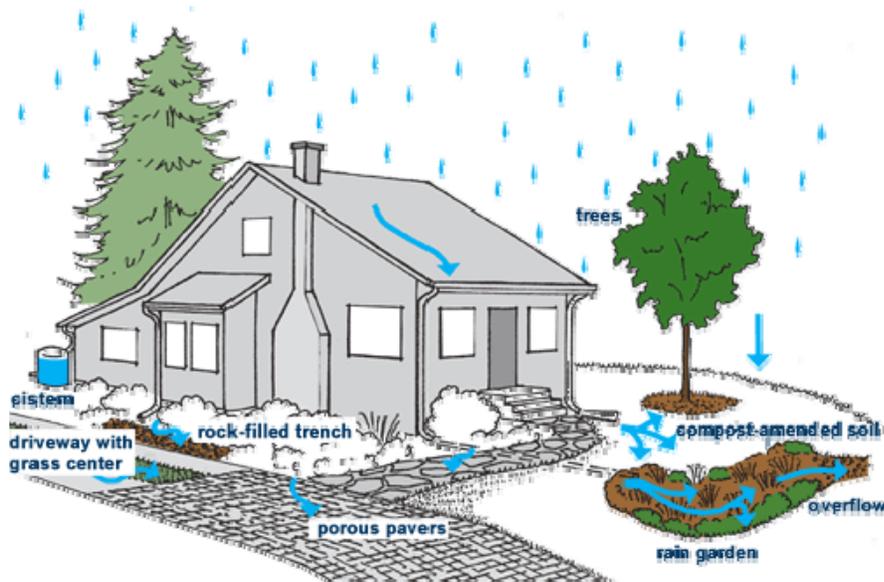
Placer County 2012

- **Site Condition Factors** – Factors such as the infiltration rate, setback distance, and topographic slope (data collected in Step 4) will dictate the type of LID appropriate for the project. See Chapter 4 for more details.
- **Stormwater Runoff Control** – SD and RM measures will provide varied amounts of detention storage, increased stormwater runoff travel time, and reduced overall volume of stormwater. See Chapter 4 for more details.
- **Pollutant Control** – SD and RM measures will provide different amounts of water quality treatment and/or pollution prevention. See Chapter 4 for more details.
- **Implementation** – As discussed in Chapter 2, it is critical to consider not only the initial costs of an LID technique, but also its projected long-term maintenance costs. Ideally, the design team should prepare a life-cycle analysis, which would include the monetized value of co-benefits (e.g., materials or energy saved) and replacement costs. The matrix provides relative comparisons of costs (low, medium and high) based on published national literature. Unfortunately, no state or local cost data is available. See Chapter 2 for more information and examples of economic benefits of LID. Designers should consider long-term maintenance needs of an LID measure before specifying it for the site and determine the likely party that will be responsible for conducting the maintenance. The property owner should be consulted during this step. In the case of a residential subdivision, consideration should be made about whether maintenance will fall to individual property owners or a homeowners’ association.
- **Ancillary Benefits** – Many of the LID measures will provide additional benefits such as habitat, groundwater recharge and reduction of greenhouse gases. See Chapter 4 for more details.

## Step 7 – Locate LID Measures on the Site and Create the Preliminary LID Design Plan

This step in the process entails locating the LID measures on the site plan, considering the site-specific inventory data compiled in Step 4 such as the site's unique topography, existing hydrologic features and soil infiltration rates. Also, the specifications noted in the LID measure fact sheets in Chapter 4 will help determine the size of the area needed for a particular measure and the maximum contributing drainage area for that measure. Several LID measures can be used in combination or the site can be broken up into smaller drainage sheds to satisfy the design criteria.

The site design should distribute the LID measures appropriately on the project site and connect them to on-site and/or off-site stormwater drainage systems or natural waterways, as shown in Figure 3-4. The goal should be to preserve as much valuable natural vegetation as possible, minimize disturbance and impervious surfaces on the site, and direct flow from any unavoidable impervious areas (e.g., roof downspouts) to vegetated areas for filtration and infiltration or to rainwater harvesting devices.



**Figure 3-4. Combination of LID measures distributed on a project site**

*(Source: Seattle Public Utilities Residential Rainwise Program)*

This is the stage in the process where the designer should look for multi-purpose opportunities, such as integrating the stormwater management functions into required landscaping areas (based on local codes), satisfying “art in public spaces” requirements with stormwater features, or installing stormwater detention (e.g., cisterns) under permeable pavement. Appendix B contains example site plans which incorporate LID into the proposed Homewood Project expansion in the Lake Tahoe Basin.

### Step 8 – Design/Size the LID Measures

Performing the engineering design to size the structural LID components will likely be an iterative process. The designer will calculate the size of the feature based on the expected volume/flow of runoff and the available space on the site. The LID measure fact sheets in Chapter 4 provide the general specifications. The County should be consulted for any additional design criteria, any variations to the data included in the fact sheets, and for any additional stormwater management requirements, so that a complimentary LID design can be developed.

*LID calculation methodology and design should be consistent with Placer County's recommended or accepted design criteria for stormwater management, including volume/peak rate control, water quality treatment, and any other factors specified by the agency.*

### Step 9 – Refine Preliminary LID Design

Developing a stormwater management program using LID principles and practices is a dynamic process. When the preliminary LID design plan is ready, the applicant should go back to Step 1 and verify that the new design satisfies the initial project stormwater management goals. If not, the design should be further refined or possibly the goals should be re-evaluated with the project owner to make sure they are realistic and achievable.

### Step 10 – Submit Project Application for Review

The final step in the process is the submittal of the application to the County for review. If the County requires revisions, the applicant will go back to Step 6 and repeat the LID selection and design process.



Example of LID Site Plan (Credit: New England Environmental Inc.)

# Placer County LID Guidebook

## LID Planning and Design Checklist

The information provided in this checklist pertains specifically to integration of Low Impact Development (LID) principles into the development project planning and design process. This checklist represents one part of the typical overall planning process and **is not intended to replace or supersede any required County procedures**. The LID planning and design steps described herein may reference other related processes, studies, permits or submittals that may be required for environmental compliance, but it is not intended to replace or supersede those elements.



### Getting Started

Prior to completing this checklist, complete the following Placer County planning documents if applicable (*having these completed forms in hand will be helpful when completing the LID Checklist*):

- Initial Project Application
- Exemption Verification (if applicable)
- Standard or Minor Environmental Questionnaire

**Town**  
*Check with ~~County~~ planning staff early in the planning process to verify which requirements apply to the project.*

### Basic Project Information

Project Name: \_\_\_\_\_  
Project Owner: \_\_\_\_\_ Project Designer: \_\_\_\_\_  
Project Address/City/Zip Code: \_\_\_\_\_

Total Size (ac): \_\_\_\_\_ Approx. Area Disturbed (ac): \_\_\_\_\_

Zoning: \_\_\_\_\_

Project Type: (check all that apply)

- New Development
- Single Family Residential
- Multi-Family Residential
- Redevelopment
- Commercial
- Industrial
- Public/Institutional
- Roadway

Phasing – is the project part of a larger phased development?  yes  no

If so, describe: \_\_\_\_\_

### Projects with Limited LID Potential or Special Requirements

If any of the following situations apply to the project, LID potential may be limited or the project may be subject to special requirements.

- Detached single-family home projects that are not part of a larger plan of development
- Small commercial/industrial development
- Retrofit/redevelopment project
- Previous soil and/or groundwater contamination (e.g., Brownfields)
- Project will use existing on-site or immediate off-site stormwater drainage system
- Located in the Tahoe Regional Planning Agency's (TRPA's) jurisdiction
- Subject to Total Maximum Daily Load (TMDL) or other water quality regulatory requirements
- Subject to a Community Enhancement Program (CEP)

*Obtain copies of this checklist and other applicable documents from Placer County Planning Services Division (in person or on-line at:*  
<http://www.placer.ca.gov/Departments/CommunityDevelopment/Planning.aspx>

## STEP 1 - Identify Stormwater Management and LID Project Goals

What are the stormwater management goals for the proposed project?  
(check all that apply)

- Improve Water Quality/Reduce Pollution in Runoff
- Flood Control/Reduce Peak Flows
- Reduce Runoff from the Site
- Eliminate Runoff from the Site (Retain on site)



If known, what are the stormwater management/LID strategies for the proposed project?  
(check all that apply)

- Infiltration
- Groundwater Recharge
- Retention
- Detention
- Disconnection of Runoff from Roofs/Impervious Surfaces
- On-Site Capture and Re-Use of Rain Water
- On-Site Capture and Re-Use of Runoff
- No Stormwater Discharge From the Site
- Other: \_\_\_\_\_
- Other: \_\_\_\_\_

*The types of LID strategies selected for the project will be influenced by site conditions such as soil type and slope/topography (see Step 4)*

## STEP 2 - Identify and Incorporate Applicable Government Requirements

### Step 2

**Applicant  
Identifies and  
Incorporates  
Applicable  
Government  
Requirements**

All projects are subject to the following Placer County requirements:

- General Plan
- Zoning Ordinance
- Land Development Manual
- Stormwater Management Manual
- Placer County General Specifications
- Subdivision Ordinance (PCC 16.04)
- Street Improvement Ordinance (PCC 12.08)
- Grading, Erosion and Sediment Control Ordinance (PCC 15.48)
- Flood Damage Prevention Ordinance (PCC 15.52)

Identify the additional local land use policy documents, plans, ordinances, requirements and guidelines that are applicable to the project.

*(check all that apply and provide document names)*

*Check with  
County Planning  
Services Division  
staff to verify  
which  
requirements  
apply to the  
project*

- Community Plan(s): \_\_\_\_\_
- Specific Plan(s): \_\_\_\_\_
- Master Plan: \_\_\_\_\_
- Master Use Permit: \_\_\_\_\_
- Design/Landscape Guidelines: \_\_\_\_\_
- Water Conservation: \_\_\_\_\_
- Other: \_\_\_\_\_



*Note: It is critical to review applicable documents checked above before proceeding with LID design. In case of conflict between other requirements and this Guidebook, the other requirements shall prevail.*

Regional/State/Federal Policies, Plans, Requirements or Guidelines - List all that apply to the project:

Regional (e.g., regional land use plans, watershed plans, etc.)

- \_\_\_\_\_
- \_\_\_\_\_

State (e.g., NPDES permits, 401 certifications, fire code, integrated regional water management, Title 24 accessibility, etc.)

- \_\_\_\_\_
- \_\_\_\_\_

Federal (e.g., Section 404, Endangered Species Act, ADA)

- \_\_\_\_\_
- \_\_\_\_\_

*In the event of  
conflict between  
other regulatory  
requirements and  
this Guidebook,  
the other  
requirements  
shall prevail.*



*Note: It is critical to review and understand applicable requirements listed above before proceeding with LID design. In case of conflict between other requirements and this Guidebook, the other requirements shall prevail.*

### STEP 3 - Conduct Site Watershed Inventory

### Step 3

Check the correct answer for each question and add responses if known:



- | Yes                      | No                       |  |
|--------------------------|--------------------------|--|
| <input type="checkbox"/> | <input type="checkbox"/> | Are there natural water bodies/waterways present on the site?<br>If yes, describe/name: _____  |
| <input type="checkbox"/> | <input type="checkbox"/> | Will the project site drainage/runoff discharge to a municipal storm drain system?<br>If yes, provide municipality name: _____   |
| <input type="checkbox"/> | <input type="checkbox"/> | Will the project site discharge to off-site receiving waters (e.g., creek, stream, river, lake, wetland)?<br>If yes, describe/name: _____<br><input type="checkbox"/> direct discharge <input type="checkbox"/> indirect discharge |
| <input type="checkbox"/> | <input type="checkbox"/> | Is the site's receiving water a 303d listed/impaired waterway, or a tributary to such a waterway?<br>If yes, describe: _____   |
| <input type="checkbox"/> | <input type="checkbox"/> | Are there existing or planned Total Maximum Daily Loads (TMDLs) for the receiving waters?<br>If yes, describe: _____   |
| <input type="checkbox"/> | <input type="checkbox"/> | Are there any known immediate downstream flooding problems?<br>If yes, describe: _____   |
| <input type="checkbox"/> | <input type="checkbox"/> | Is there run-on from neighboring properties that must be managed on the project site?<br>If yes, describe: _____<br>If yes, are there any known problems with the run-on?<br>If yes, describe: _____                               |
| <input type="checkbox"/> | <input type="checkbox"/> | Is additional development anticipated for the surrounding/adjacent area that could impact future hydrologic conditions on the site?<br>If yes, describe: _____   |
| <input type="checkbox"/> | <input type="checkbox"/> | Is additional development anticipated for the surrounding/adjacent area that could lead to further opportunities (e.g., partnerships in multi-site or regional water quality or quantity controls)?<br>If yes, describe: _____     |
| <input type="checkbox"/> | <input type="checkbox"/> | Are there other issues that could affect design of stormwater management measure for the site?<br>If yes, describe: _____<br>_____<br>_____  |

*The municipal storm drain system is defined as a conveyance or system of conveyances, including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains owned or operated by a state, county, city, special district, etc.*

## STEP 4 - Conduct Site Inventory and Evaluation

### Step 4

Perform a site visit to observe physical site features and identify potential barriers and opportunities for using LID. Use this checklist to record observations and measurements and note the locations of the features on a topographic map of the project site, or the preliminary project site plan, if available.

**Applicant  
Conducts  
Site Inventory  
and Evaluation**



*Note: Most LID runoff management measures are intended to manage water for small contributing drainage areas. If the site is greater than 5 acres, you will likely need to divide the site into separate drainage areas to each be served by one or more LID runoff management measures.*

### Identify Physical Site Conditions

Identify and note key physical site conditions on the site map/plan; for example:

- Existing lot lines, lease areas and easements
- Proposed lot lines, lease areas, and easements
- Major and minor hydrologic features, including 100-year floodplain (FEMA and/or fully developed, unmitigated floodplain), seeps, springs, closed depression areas, drainage swales, and contours.

### Identify Physical Constraints/Potential Barriers to Using LID

Do any of these **physical constraints** apply to the project site? *(check all that apply and note location on the site map/plan)*

- Soils with low infiltration (e.g., clays)
- Soils with high infiltration (e.g., rocky soils, cobbles)
- Slope > 25%
- Shallow depth to groundwater (< 10 feet)
- Project within 100-year floodplain/flood hazard area
- Sensitive water features that need to be protected (e.g., wetlands)
- Existing stormwater conveyance and/or treatment facilities (on-site and off-site)
- Areas with known or suspected contaminated soils and/or groundwater
- Aquifer and wellhead protection areas on or adjacent to the site
- Power lines/major underground utilities (e.g., buried natural gas lines)
- Areas subject to high flow conditions
- Dense overhead foliage (shade considerations for vegetative growth)
- Project space constraints based on preliminary site plan (if known)
- Other: \_\_\_\_\_
- Other: \_\_\_\_\_
- Other: \_\_\_\_\_

## Identify Opportunities for LID

Do any of these **opportunities** apply to the project site? (*check all that apply and note location on the site map/plan*)

Feature (Existing or Proposed)	LID/Site Design Opportunities
<input type="checkbox"/> Natural vegetation and environmentally sensitive areas (areas that may support habitat)	<input type="checkbox"/> Preservation of natural pervious areas to infiltrate/filter stormwater <input type="checkbox"/> Protect sensitive areas - during and after construction <input type="checkbox"/> Preserve open space by clustering buildings in a smaller area <input type="checkbox"/> Locate trash facilities away from these areas
<input type="checkbox"/> Riparian areas, natural swales, drainages, depressions	<input type="checkbox"/> Configure site to take advantage of natural site topography and avoid unnecessary cut and fill that will change the hydrologic regime <input type="checkbox"/> Bioretention/filtration of stormwater to reduce runoff and remove pollutants <input type="checkbox"/> Infiltration/groundwater recharge <input type="checkbox"/> Evapotranspiration <input type="checkbox"/> Flowpath disconnection <input type="checkbox"/> Snow storage
<input type="checkbox"/> Soils with good/moderate infiltration capacity (e.g., NRCS Types A and B)	<input type="checkbox"/> Configure site to locate LID measures such as infiltration, bioretention and pervious pavement in areas with well-drained soils (place buildings and other impervious features in other areas of the site if possible)
<input type="checkbox"/> Exposed, bare areas	<input type="checkbox"/> Revegetation, reforestation to restore infiltration/filtration functions
<input type="checkbox"/> Existing stormwater conveyance and/or treatment facilities	<input type="checkbox"/> Analyze existing stormwater treatment facilities for potential to treat additional runoff
<input type="checkbox"/> Existing impervious areas that can be converted to pervious areas	<input type="checkbox"/> Replace with pervious/ permeable pavement (e.g., porous concrete, asphalt or paving stones) <input type="checkbox"/> Use alternative driveways (e.g., with center strip of plants/DG, subject to fire approval)
<input type="checkbox"/> Buildings/ Lots	<input type="checkbox"/> Minimize individual lot size <input type="checkbox"/> Concentrate/cluster uses and lots <input type="checkbox"/> Configure lots/development to avoid sensitive natural areas and conform to natural topography <input type="checkbox"/> Integrate stormwater management/LID with lot/building layout to mitigate impacts from buildings and other impervious surfaces <input type="checkbox"/> Use rain barrels and/or cisterns to store rainwater for lot irrigation
<input type="checkbox"/> Rooftops	<input type="checkbox"/> Consider vegetation for rooftops, walls and adjacent areas to filter, evapotranspire rainwater, reduce runoff and shade/insulate buildings <input type="checkbox"/> Disconnect downspouts from piped storm drain system <input type="checkbox"/> Route roof runoff (rainfall/snowmelt) to vegetated areas for infiltration/filtration <input type="checkbox"/> Route roof runoff to dry wells or pervious areas for infiltration <input type="checkbox"/> Route roof runoff to rain barrels/cisterns for storage and re-use
<input type="checkbox"/> Parking lots, sidewalks, driveways	<input type="checkbox"/> Utilize permeable pavement (with or without underdrains, depending on soil type) for pedestrian and low traffic vehicular areas such as parking and alleyways ( <i>subject to fire approval</i> ) <input type="checkbox"/> Use vegetation in medians and islands within turnaround areas to

Feature (Existing or Proposed)	LID/Site Design Opportunities
<input type="checkbox"/> Parking lots, sidewalks, driveways (cont'd)	infiltrate/filter stormwater (rain and snowmelt, subject to fire approval) <input type="checkbox"/> Disconnect drives/walkways/small impervious areas to natural areas <input type="checkbox"/> Consider underground cisterns to detain water to reduce peak runoff flows or store water for re-use <input type="checkbox"/> Use minimum standards for road width ( <i>subject to fire approval</i> ) <input type="checkbox"/> Use cul-de-sacs and turnarounds at minimum standard width <input type="checkbox"/> Use minimum standards for driveway lengths and widths <input type="checkbox"/> Use minimum standards for parking ratios <input type="checkbox"/> Consider shared parking potential (e.g., shared driveways) <input type="checkbox"/> Tuck parking under buildings (tuck-under parking)
<input type="checkbox"/> Green Space/ Site Landscaping/ Road and Parking Lot Medians	<input type="checkbox"/> Connect open space/sensitive areas with larger community greenways plan <input type="checkbox"/> Connect upstream features with drainage features that infiltrate, treat, and convey stormwater <input type="checkbox"/> Determine which areas are viable for snow storage <input type="checkbox"/> Disconnect runoff flow paths with vegetation wherever possible

**STEP 5 - Attend Pre-Development Meeting / Submit Initial Application to County**

**Step 5**



Prior to scheduling the pre-development meeting or submitting the initial planning application to the Planning Services Division, the following tasks are recommended (check off when completed):

Review the following if available (if not available before the pre-development meeting, planning staff will ask for these types of reports to be prepared after the meeting):

- A **soils report** prepared by a licensed geotechnical engineer or licensed engineering geologist. The report shall identify infiltration capability, natural stormwater conveyance, depth to groundwater and geologic hazard areas.
- An **inventory of existing native vegetative** cover by a licensed landscape architect, arborist or qualified biologist, identifying any forest areas on the site, species and condition of ground cover and shrub layer, tree species and canopy cover.
- A **streams, wetland, and water body inventory and classification** report by a qualified biologist showing wetland and buffer boundaries, if present.
- Stormwater best management practices plan** prepared by a licensed civil engineer.

Based on the previous steps 2-4, summarize any issues associated with:

- Hydrologic Features \_\_\_\_\_
- Soils/Grading \_\_\_\_\_
- Vegetation \_\_\_\_\_
- Wetlands \_\_\_\_\_
- Flooding \_\_\_\_\_
- Groundwater \_\_\_\_\_
- Other \_\_\_\_\_

Re-evaluate the stormwater management/LID project goals originally developed in Step 1 and adjust page 2 of the checklist as needed to reflect the site opportunities and constraints.

Check with the Planning Services Division to determine which of these agencies/groups needs to be consulted during or after meeting (*check all that apply*):

- Planning Services
- Engineering and Surveying Department
- Environmental Engineering and Utilities (Special Districts)
- Environmental Health Services
- CalFire
- Building Services
- Facility Services-Parks
- Department of Public Works

## Step 6 –Perform Initial LID Selection (Use LID Selection Matrix)



*In this step in the process, use the results from the site evaluation (Step 4) to determine which LID design concepts are viable, and which concepts are not feasible for the project site. This evaluation may result in a need to revisit and revise any preliminary site design in an iterative fashion.*

Use the LID Selection Matrix (at the end of this checklist) and the 12 associated fact sheets in Chapter 4 of the LID Guidebook to consider and initially select Site Design (SD) measures and LID Runoff Management (RM) measures for the project.

### LID Site Design Measures:

- SD-1: Protect Natural Conditions and Sensitive Areas
- SD-2: Optimize Site Layout
- SD-3: Control Pollutants at Source
- SD-4: Integrate Eco-Friendly Landscaping

### LID Runoff Management Measures:

- LID 1: Stormwater Disconnection
- LID 2: Rainwater and Snowmelt Harvesting
- LID 3: Infiltration Trench / Dry Well
- LID 4: Bioretention
- LID 5: Vegetated Filter Strip
- LID 6: Vegetated Swale
- LID 7: Permeable Pavement
- LID 8: Green Roof

Plan ahead for short and long-term maintenance needs and identify likely responsible party to provide the maintenance, as well as funding mechanism to pay for such maintenance to ensure optimum performance (*consider consulting maintenance personnel before design is complete*)

## Step 6

**Applicant  
Performs Initial  
LID Selection  
(Use Matrix)**

### *Iterative Process*

**Step 6. SELECT LID Measure**  
**Step 7. LOCATE LID Measure**  
**Step 8. SIZE LID Measure; if feature does not work, then go back to Step 6 to select another LID measure.**

*Site design measures are typically non-structural and relate to the layout of the site, whereas the LID measures are structural in nature and have associated construction/installation and maintenance costs.*

## STEP 7 – Locate the LID Measures on the Preliminary LID Design Plan

Use the information from Steps 4, 5 and 6 to locate the LID features on the Preliminary LID Design Plan. Sketch a design concept that distributes the LID measures appropriately on the project site, including notes on how the LID measures connect to on-site and/or off-site stormwater drainage systems.

Keep these ideas in mind as you locate LID measures on the LID Design Plan:

- Preserve and utilize existing natural/vegetated areas as much as possible
- Minimize site disturbance, building footprints and impervious areas
- Locate new impervious features on previously disturbed areas or over areas of the site with clay/impervious soils, shallow groundwater table, known pollution, etc.
- Disconnect all impervious surfaces (roofs, roads, driveways, patios, etc.) and direct flow to vegetated areas
- Manage stormwater runoff (including rainfall and snowmelt) and pollutants as close to the source as possible to minimize costs of storm drain pipes and other conveyance features
- Consider LID runoff management measures that can capture/manage stormwater from adjacent impervious areas
- Consider multipurpose benefits of stormwater management/LID techniques/facilities. For example:
  - Preserved or new natural areas can provide habitat for wildlife and increase aesthetic value for the community
  - Recreation areas can be located in networks of open space or green corridors or dual-purpose detention facilities
  - Pervious parking areas can be combined with sub-surface detention facilities such as cisterns and/or infiltration chambers
  - Developments integrated with natural areas and/or community open space can have higher property values
  - Adding interpretive signage can provide educational value
- Estimate construction and maintenance costs

### Step 7

**Applicant  
Locates the LID  
Measures on the  
Preliminary LID  
Design Plan**

#### ***Iterative Process***

*Step 6. SELECT LID Measure  
Step 7. LOCATE LID Measure  
Step 8. SIZE LID Measure; if  
feature does not work, then  
go back to Step 6 to select  
another LID measure.*

## STEP 8 – Design/Size the LID Measures

Perform engineering design and calculations to develop the structural LID components. The calculation methodology and design should be consistent with the County’s recommended or accepted design criteria for stormwater management, including volume/peak rate control, water quality treatment, and any other factors specified by the agency. Additionally, the fact sheets in Chapter 4 of the Guidebook will be helpful.

### Step 8

**Applicant Designs / Sizes the LID Measures**

#### *Iterative Process*

*Step 6. SELECT LID Measure  
Step 7. LOCATE LID Measure  
Step 8. SIZE LID Measure; if feature does not work, then go back to Step 6 to select another LID Measure.*

## STEP 9 – Refine Preliminary LID Design Plan Based on Stormwater Management Objectives

Developing a stormwater management program using LID principles and practices is a dynamic process. Evaluate the design to see if it meets project stormwater management objectives.

### Step 9

**Applicant Refines Preliminary LID Design Plan**

## STEP 10 – County Project Application/ Submittal Review

Submit the application to the County for evaluation of the LID design to determine if it is acceptable. If the County requires revisions, go back to Step 6 and repeat the LID selection and design process.

### Step 10

**County Project Application/ Submittal Review**

**>>END OF LID CHECKLIST**

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# Chapter 4

## LID SITE DESIGN AND RUNOFF MANAGEMENT MEASURES

This chapter provides information – including fact sheets – for twelve recommended Low Impact Development (LID) measures for use in the High Sierra areas of Placer County. Four of the measures (site design measures) relate to design and layout of the site and are mostly non-structural in nature, therefore tend to be the least expensive to implement. Projects utilizing as many site design measures as possible are more likely to require less of the runoff reduction measures. The remaining eight measures (runoff management measures) are more structural in nature and entail installation of physical components on the site.

### Site design measures:

- SD-1 Protect Natural Conditions and Sensitive Areas
- SD-2 Optimize Site Layout
- SD-3 Control Pollutants at Source
- SD-4 Integrate Eco-Friendly Landscaping

### Runoff management measures:

- RM-1 Stormwater Disconnection
- RM-2 Rainwater and Snowmelt Harvesting
- RM-3 Infiltration Trench/Dry Well
- RM-4 Bioretention
- RM-5 Vegetated Filter Strip
- RM-6 Vegetated Swale
- RM-7 Permeable Pavement
- RM-8 Green Roof

*Projects utilizing as many site design measures as possible are more likely to require less physical controls to convey and manage site runoff and therefore may result in lower project costs. It is important to engage the entire design team (e.g., planner, engineers, architect, and landscape designer) early in the process to select the appropriate mix of LID measures to be integrated into the site design.*

Fact sheets for each LID measures are included in this chapter and repeated in Appendix F for easy reference.

## 4.1 GUIDANCE FOR SELECTING APPROPRIATE LID MEASURES

It is important to understand the local landscape and regional context of the development site to get inspiration for designing stormwater management and LID systems that are functionally effective, efficient and complementary to the environment and the community of which they are a part. There are several basic strategies to address stormwater management objectives at the broad scale. For example, an area with predominantly well-drained soils signals the potential to develop a stormwater strategy based primarily on infiltration practices. In contrast, sites located in areas with more impervious clay-based soils will require the designer to explore strategies that employ a combination of storage, filtration, harvesting, evapotranspiration and infiltration practices to achieve stormwater management objectives.

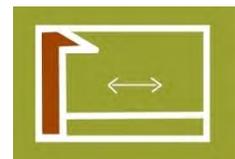
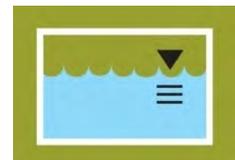
The LID Selection Matrix (Figure 4-1) is an informative tool to assist with comparing and selecting the appropriate mix of LID measures for the development project, considering site conditions, performance of the measure, implementation concerns (e.g., costs and maintenance), and co-benefits (e.g., provides habitat, improves air quality). For each of the 12 recommended LID measures, basic site criteria are provided and relative ratings are given for performance, costs, and co-benefits.

The LID Selection Matrix (Figure 4-1) should be used in conjunction with the fact sheets presented later in this chapter and in Appendix F.

### Site Condition Factors

Design criteria are outlined in the matrix relative to the following site conditions (some of these factors were introduced in Chapter 3):

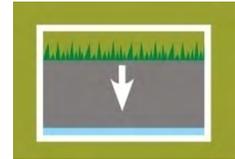
- **Minimum Soil Infiltration Rate Requirement** – There is a minimum vertical infiltration rate associated with the RM measure. Soil types A and B (sandy soils) will likely meet these requirements, but soil types C and D (clay) will not likely meet the infiltration rate required so that water infiltrates within 48 hours. Soils with less than 1 in/hr infiltration rates can be amended to increase infiltration, or an underdrain can be installed.
- **Minimum Required Head Requirement** (for LID measure under consideration) – A certain amount of fall or elevation difference (e.g. 3 ft) from the inlet to the outlet of the RM measure is required so that water flows through the measure.
- **Setback Distance** (from structures, foundations) – Certain infiltration measures need to be set back a sufficient distance (e.g., 20 feet) so that infiltrated water does not impact building foundations.



- **Slope > 25%** – Most RM features will not work above slopes of 25% without modification. In these instances, ground terracing can be used to reduce the slope so that measures such as bioretention can be used, as shown in the photo below.



- **Minimum Depth to Groundwater Limitation** (seasonally high groundwater table) – RM measures with infiltration need to have a minimum separation distance from groundwater (typically 5-10') so that there is infiltration and storage capacity underground for the stormwater.



- **Substantial Additional Footprint** – Several RM measures require a larger footprint. The application of these measures may be reduced if sufficient space is not available in a development.

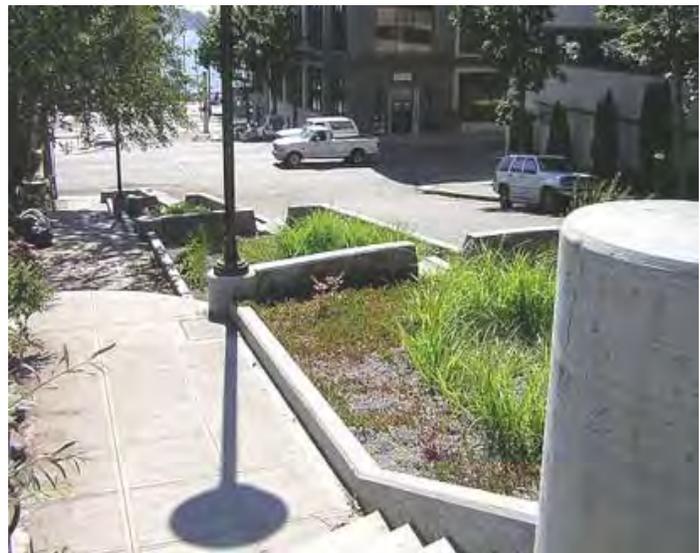


- **Vector Concerns** – Standing water attracts vectors, and is an important consideration. Any RM measure that detains stormwater may have vector concerns.



- **Long Life Expectancy** – Several RM measures will work longer than conventional stormwater methods. This is a benefit that shows through Life Cycle Analysis.

As indicated on the matrix, all of the Site Design (SD) measures are appropriate for any project regardless of site conditions, but the Runoff Management (RM) measures require certain physical conditions in order to function properly. For example, an infiltration trench or dry well requires well-drained soils, a 20-ft setback distance from buildings in order to protect foundations, 10 ft of separation from the seasonally high groundwater table so the device is not saturated all the time, and can accept runoff from an area no larger than five acres in size.



The Growing Vine Project in Seattle raises stormwater to the surface, integrating it in a visually appealing manner into a street with steep slopes. (Credit: SvR Design Company)

# Low Impact Development Selection Matrix for Placer County Guidebook

Low Impact Development (LID) Measure		Site Condition Factors <sup>(a)</sup>								Runoff Control			Pollutant Control				Implementation				Ancillary Benefits													
		Minimum Infiltration Rate Requirement	Minimum Head Requirement	Setback Distance Requirement	Slope > 25%	Minimum Depth to Groundwater Limitation	Substantial Additional Footprint	Vector Concerns	Long Life Expectancy, >= 20 years	Provides Detention / Impoundment Storage	Increases SW Runoff Travel Time	Reduces Volume of Overall SW Runoff	Metals Reduction	Nutrient Reduction	Oil and Grease/ Hydrocarbon Reduction	Sediment Reduction	Temperature Reduction	Construction Cost (\$ / cf) <sup>(b)</sup>	Construction Cost (\$ / feature) <sup>(c)</sup>	Annual O&M Cost (\$) <sup>(d)</sup>	Reduces Public Agency Maintenance Costs	High Elevation Winter Conditions <sup>(e)</sup>	Provides Evapotranspiration (ET)	Provides Habitat	Promotes GW Recharge	Provides Shade (Reduces Heat Island Effect)	Reduces Greenhouse Gases	Reduces Energy Use	Aesthetically Pleasing	Reduces Downstream Erosion and Flooding	Enhances Property Value			
ID	<b>LID Site Design (SD) Measures</b>	Site Condition Factors do not limit the application of Site Design Measures																																
SD-1	Protect Natural Conditions and Sensitive Areas									○	○	●	○	●	○	●	○	\$	\$	\$	○	●	●	●	●	●	○	○	●	●	●			
SD-2	Optimize Site Layout									●	●	●	●	●	●	●	●	\$	\$	\$	●	●	●	●	●	●	○	○	●	●	●			
SD-3	Control Pollutants at Source												●	○	●	●	●	\$	\$	\$\$	●	○					●	●						
SD-4	Integrate Eco-Friendly Landscaping	○	○	●	○	●	○	●	○	\$	\$	\$	○	●	●	●	●	●	○	○	●	●	●											
	<b>LID Runoff Management (RM) Measures</b>																																	
RM-1	Stormwater Disconnection	x				x	x	x		●	●	●	●	●	●	●	●	\$	\$	\$	○	●	●	○	●	○	●		●	●	●			
RM-2	Rainwater and Snowmelt Harvesting			x	x			x		●		●						\$\$\$	\$\$	\$\$	●	●			○					●	●	●		
RM-3	Infiltration Trench / Dry Well	x	x	x		x		x	x	●	○	●			○	●	\$\$\$	\$\$	\$\$\$	●	●			●					●	○				
RM-4	Bioretention		x	x				x		●	●	●	●	●	●	●	●	\$\$	\$\$\$	\$\$	○	○	●	●	●	○	●	●	●	●	●	●		
RM-5	Vegetated Filter Strip			x		x	x	x	x	○	●	●	○	○	○	●	○	\$	\$	\$	●	●	●	○	○	○	●		●	●	○			
RM-6	Vegetated Swale	x	x	x		x	x	x	x	●	●	●	●	●	●	●	●	\$	\$	\$\$	●	●	●	●	●	○	●	○	●	●	●			
RM-7	Permeable Pavement	x	x	x		x			x	●	●	●	●		●	●	●	\$\$	\$\$\$	\$\$\$	○	●			●					●	●			
RM-8	Green Roof							x	x	○	●	●						\$\$\$	\$\$\$	\$\$\$	●	●	●	○		●	●	●	●	●	●			

**Legend:**

- Very Effective
- ◐ Moderately Effective
- Mildly Effective
- x Applicable
- Not Applicable

Notes: Information presented in this matrix is based on published, national literature and is intended for planning purposes only. Check References section of the LID Guidebook for sources of data.

Other Best Management Practices (BMPs) such as detention basins and constructed wetlands are not considered "small scale controls" and therefore are not included in this Guidebook.

During large storm events (when groundwater and soil is saturated), these measures will provide little, if any, hydraulic management.

(a) Specific rates and distances for each site condition factor are provided in SD and RM fact sheets.

(b) Construction Cost (\$ / cf) (2006 dollars)                      \$ = < \$3                                      \$\$ = \$3 - \$15                                      \$\$\$ = > \$15

(c) Construction Cost (\$ / feature) (2006 dollars)                      \$ = \$0 - \$10,000                                      \$\$ = \$10,000 - \$50,000                                      \$\$\$ = > \$50,000

(d) Annual O&M Cost (\$ / feature) (2006 dollars)                      \$ = < \$1,000                                      \$\$ = \$1,000 - \$5,000                                      \$\$\$ = > \$5,000

(e) Relative effectiveness ratings are based on comparison of the various practices to each other for use in High Sierra, rather than comparing the practices used in High Sierra to those on the valley floor.

The design of some measures can be modified to function in less than ideal site conditions. For example, in poorly draining clay soils, bioretention stormwater planters can be fitted with under drains and/or overflow weirs to carry excess water to the street gutter and/or local storm drain system. In cases where there is a large contributing drainage area, designers can break up the site into several drainage sheds, each handled by a different LID measure, or use several of the measures in parallel or series to accommodate the expected site runoff (stormwater and irrigation) flows. Information is provided in this chapter for alternative design modifications/configurations as applicable.

### Runoff Control Factors

Three Runoff Control factors are included in the selection matrix:

- Provides Detention/Retention Storage
- Increases Stormwater Runoff Travel Time
- Reduces Volume of Overall Stormwater Runoff

Several of the RM measures provide detention, and all of the site design and runoff management measures reduce the volume of overall stormwater runoff, with the exception of SD-3 Control Pollutants at Source.

*Typically the primary goal with LID design is runoff reduction. It may or may not satisfy all of the permitting agency's stormwater quality requirements. However, using infiltration-based LID features can reduce the volume of runoff to be managed and treated, therefore reducing the amount of storm drain piping and the size of stormwater treatment facilities, which saves buildable land and costs.*

---

### Pollutant Control Factors

The following Pollutant Control factors are included in the selection matrix:

- Metals Reduction
- Nutrient Reduction
- Oil and Grease/ Hydrocarbon Reduction
- Sediment Reduction
- Temperature Reduction

Some of the RM measures provide treatment for some of these constituents, whereas three measures (stormwater flowpath disconnection, bioretention, and vegetated swale) provide treatment for all of these constituents. Additional information on stormwater quality is provided as follows.

The water quality concerns associated with stormwater and resulting regulatory requirements for protection of receiving water quality are of paramount importance in LID design. Table 4-1 shows pollutants commonly found in urban runoff. A particular constituent of concern for Placer County is sediment. Table 4-2 outlines typical pollutant source areas and runoff characteristics on a development site, along with potential opportunities for stormwater treatment and LID.

**Table 4-1. Pollutants Commonly Found in Urban Runoff**

Pollutant	Major Sources	Potential Effects
Nutrients <ul style="list-style-type: none"> <li>• Nitrogen</li> <li>• Phosphorus</li> </ul>	<ul style="list-style-type: none"> <li>• Fertilizers</li> <li>• Animal waste</li> <li>• Detergents</li> <li>• Atmospheric deposition</li> <li>• Leaking sanitary sewer pipes</li> </ul>	<ul style="list-style-type: none"> <li>• Lowers oxygen levels</li> <li>• Destroys habitat</li> <li>• Promotes algal blooms</li> <li>• Limits recreation</li> <li>• Interferes with navigation</li> </ul>
Pathogens <ul style="list-style-type: none"> <li>• Bacteria</li> <li>• Viruses</li> </ul>	<ul style="list-style-type: none"> <li>• Animal waste</li> <li>• Illicit connections between sewage lines and storm drains</li> <li>• Leaking sanitary sewer pipes</li> </ul>	<ul style="list-style-type: none"> <li>• Poses human health risks</li> <li>• Closes beaches</li> <li>• Closes shellfish harvesting areas</li> </ul>
Hydrocarbons <ul style="list-style-type: none"> <li>• Oil</li> <li>• Grease</li> <li>• Petroleum products</li> <li>• Polycyclic aromatic hydrocarbons (PAHs)</li> </ul>	<ul style="list-style-type: none"> <li>• Roads</li> <li>• Parking lots</li> <li>• Automobile emissions</li> <li>• Improper disposal of used motor oil</li> <li>• Illicit connections</li> </ul>	<ul style="list-style-type: none"> <li>• Lowers dissolved oxygen levels</li> <li>• Causes toxic impacts</li> <li>• Damages habitat</li> </ul>
Toxic Organics <ul style="list-style-type: none"> <li>• Pesticides</li> <li>• Polychlorinated biphenyls (PCBs)</li> </ul>	<ul style="list-style-type: none"> <li>• Lawn and garden care</li> <li>• Agricultural lands</li> <li>• Industrial uses</li> <li>• Illicit connections</li> </ul>	<ul style="list-style-type: none"> <li>• Toxic impacts</li> <li>• Leads to human and animal reproductive abnormalities</li> <li>• Increases animal mortality rates</li> </ul>
Sediment	<ul style="list-style-type: none"> <li>• Construction sites</li> <li>• Agricultural lands</li> <li>• Logged forest lands</li> <li>• Eroded streambanks</li> </ul>	<ul style="list-style-type: none"> <li>• Increases turbidity (cloudiness)</li> <li>• Alters water flows</li> <li>• Destroys benthic habitat</li> <li>• Blocks sunlight</li> <li>• Attracts particulate forms of metals and nutrients</li> </ul>

Source: City of Reno, 2007.

**Table 4-2. Types of stormwater source areas, typical runoff characteristics and opportunities for stormwater management (adapted from TRCA, 2010)**

SW Source Area	Runoff Characteristics	Opportunities	Principles
Foundation drains, slab under drains, road or parking lot under drains	Relatively clean, cool water.	Suitable for infiltration or direct discharge to receiving watercourses.	Should not be directed to stormwater management facility that receives road or parking lot runoff.
Roof drains, roof terrace area drains, overflow from green roofs	Moderately clean water, contaminants may include asphalt granules, low levels of hydrocarbons and metals from decomposition of roofing materials, animal droppings, natural organic matter and fallout from airborne pollutants, potentially warm water.	<ul style="list-style-type: none"> <li>- Infiltration;</li> <li>- Filtration;</li> <li>- Harvesting with rain barrels or cisterns and use for non-potable purposes (e.g., irrigation, toilet flushing) after pretreatment;</li> <li style="padding-left: 20px;">- Attenuation and treatment in wet pond or wetland detention facility.</li> </ul>	Runoff should be treated with a sedimentation and/or filtration practice prior to infiltration. Where possible, runoff should not be directed to end-of-pipe facilities to capitalize on potential for infiltration or harvesting. Flow moderation (quantity control) prior to discharge to receiving watercourse is required.
Low and medium traffic roads and parking lots, driveways, pedestrian plazas, walkways	Moderately clean water, contaminants may include low levels of sediment, de-icing salt constituents, hydrocarbons, metals and natural organic matter. Typically warm water.	<ul style="list-style-type: none"> <li>- Infiltration after pretreatment;</li> <li>- Filtration after pretreatment;</li> <li>- Harvesting with cisterns or permeable pavement reservoirs and use for outdoor non-potable purposes (e.g., vehicle washing, irrigation) after pretreatment;</li> <li style="padding-left: 20px;">- Attenuation and treatment in wet pond or wetland detention facility.</li> </ul>	Runoff should be treated with a sedimentation and/or filtration practice prior to infiltration. Flow moderation (quantity control) prior to discharge to receiving watercourse is required. Water quality should be tested prior to use for non-potable purposes.
High traffic roads and parking lots	Potential for high levels of contamination with sediment, de-icing salt constituents hydrocarbons and metals. Typically warm water.	<ul style="list-style-type: none"> <li>- Filtration after sedimentation pretreatment;</li> <li>- Attenuation and treatment in wet pond or wetland detention facility;</li> <li>- Infiltration after pretreatment only where groundwater uses are limited.</li> </ul>	Runoff should be treated with a sedimentation and/or filtration pretreatment practice prior to infiltration.
Pollution hot spots* such as vehicle fueling, servicing or demolition areas, outdoor storage and handling areas for hazardous materials, some heavy industry sites	Potential for high levels of contamination with sediment, de-icing salt constituents, hydrocarbons, metals, and other toxicants.	<ul style="list-style-type: none"> <li>- Attenuation and treatment in wet pond, wetland or hybrid detention facility;</li> <li>- Potential requirement for sedimentation pretreatment;</li> <li>- Infiltration and harvesting practices not recommended.</li> </ul>	Runoff from these sources should not be infiltrated or used for irrigation. Spill containment or mitigation devices recommended contingent on size of storage facilities.

\* *Pollution hot spots* are areas where certain land uses or activities have the potential to generate highly contaminated runoff (e.g., vehicle fuelling, service or demolition areas, outdoor storage and handling areas for hazardous materials and some heavy industry sites).

The following implementation factors are noted on the matrix:

- Construction Cost (per cubic foot and per feature)
- Annual Operations and Maintenance Cost
- Reduces Public Agency Maintenance Costs
- High Elevation Winter Conditions

The Site Design (SD) measures typically have low or moderate construction costs as compared to implementing the Runoff Management (RM) measures at high elevations. Moreover, the SD measures would have significantly less cost than conventional stormwater management systems, but would not provide adequate stormwater management without being combined with RM measures. Any physical site features conserved or put in place as result of using any of the measures (e.g., protected natural areas, covers on trash enclosures to control pollutant sources, or new eco-friendly landscaping) are fairly easy to maintain, and therefore have a lower annual Operations and Maintenance (O&M) cost than RM features.

Construction costs and annual O&M costs vary greatly in the eight recommended LID RM Measures. Construction costs and annual O&M costs for stormwater flowpath disconnection (RM-1), vegetated filter strips (RM-5), and vegetated swales (RM-6) are typically lower than the other RM measures when installed at high elevations. It should be noted, however, that there is a wide range in construction costs based on how simple or complex the RM design is; therefore, a simple bioretention system (rain garden) could actually cost less to construct than a complex tiered vegetated swale with inlet/outlet control. Typically, LID RM features will cost less than conventional stormwater methods, but again, the construction cost will typically follow how complex the design is and what construction materials are necessary for the measures. Permeable pavement (RM-7) and green roofs (RM-8) are likely to cost more to construct than other RM measures and conventional systems due to materials required and additional maintenance over their lifetimes. However, these types of systems provide many other benefits that can reduce life-cycle costs as compared to conventional techniques, as described below. Specific cost data for SD and RM measures are provided in the LID Selection Matrix.

The matrix also rates the recommended LID measures with respect to their performance in high elevation winter conditions, such as those experienced in the High Sierra areas of Placer County. The basis for the ratings comes from nationally published literature (see References section of this Guidebook for source of data for each LID measure).

Additional information in these areas is described as follows.

### **Construction and Life Cycle Costs**

As discussed in Chapter 2, in addition to initial construction costs, operation and maintenance (O&M) cost evaluations should be evaluated when estimating the costs of LID and comparing to conventional stormwater management approaches. The fact sheets in Chapter 4 present the cost ranges for construction and O&M costs, based on published national literature (this information has also been translated to the LID Selection Matrix [Figure 4-1] as relative “low, medium, high” rankings.)

The value of using LID techniques becomes evident over time for several reasons. The initial capital costs for LID may appear higher because such features may cost more to design (e.g., the integrated design team approach discussed previously) or may result in a loss of buildable space, as compared to the traditional pipe, curb and gutter and pond systems. However, literature comparisons of LID versus conventional approaches (see Chapter 2) show that there can be construction cost savings due to the reduced amount of construction materials required for the LID approach. The LID approach uses decentralized, somewhat modular techniques, located as close to the source of the runoff as possible and integrated into the site’s landscaping whenever possible, whereas the conventional approach requires piping, concrete curb and gutter, and ponds or below-ground structures for stormwater detention and treatment. Also, long-term maintenance costs for LID can be lower than conventional approaches. As residential density increases over time, conventional stormwater conveyance facilities may need to be enlarged to handle augmented flows from additional development, and aging infrastructure will need to be continuously maintained and eventually replaced. Since most LID features are installed above ground and use vegetation for the passive treatment component, long-term maintenance is projected to cost less.

When possible, a life-cycle analysis should be done to monetize the value of all benefits (e.g., energy and water savings, higher property values due to aesthetic and recreational amenities, multi-purpose benefits, and replacement costs) over the projected life of the LID techniques. When evaluating the entire life-cycle of the project, the LID approach will most likely compare more favorably to the conventional approach.

### **Maintenance Needs to Facilitate Continued Performance**

Ongoing maintenance is critical for LID techniques to ensure long-term optimum performance. Aesthetic appearance can also be improved by maintenance (especially in the case of vegetative features), but is typically not required for enhanced treatment performance. The following provides a standard set of maintenance goals for LID features (*Maintenance of Low Impact Development Facilities, 2007*):

Ensure the sufficient carrying capacity for emergency Flow Control and Drainage:

- Maintain pre-development infiltration capacity (reduce total volume of surface flows) and flow attenuation of facility.
- Maintain pre-development detention capability to reduce peak flows.
- Safely convey design storm flows.

Water Quality Treatment:

- Maintain pre-development infiltration and detention capability.
- Preserve soil and plant health and contact of storm flows with those plant soil systems.

Safety and Emergency Vehicle Access:

- Maintain adequate sight distances.
- Create signage for emergency vehicle access and facilities vehicles of any permeable load-bearing surfaces.

Cost Effectiveness:

- Maintain facilities for long-term, high quality performance at a cost that is equal to, or less than, conventional systems.
- Prevent expensive repair of large scale or catastrophic problems through continued routine procedures.

Aesthetics:

- Develop LID facilities as a landscape amenity as well as a stormwater management system.

Public Health:

- Minimize potential for disease transmission and mosquito breeding by maintaining designed infiltration capacity, storm flow conveyance, ponding depths, and dewatering rates.

Community Participation:

- Provide educational materials to homeowners and commercial property owners explaining the benefits, function, and importance of community participation for the long-term performance of LID facilities.

## **High Elevation Winter Conditions - Performance in Placer County High Sierra Areas**

The focus of this Guidebook is on the High Sierra areas of Placer County above 5,000 feet, which experience significant snowfall and snow retention from late fall to early spring. The high elevation climate poses concerns for performance of LID measures such as:

- Effect of freeze/thaw conditions on performance
- Concern with roadway sands clogging permeable pavements
- Inadequate growing season for green roofs and other vegetative features
- The negative impact of salt and deicers on vegetation and concrete
- Damage and debris loading from snow storage
- Rain on snow events
- Damage from snow removal equipment and operations
- Slope instability
- Hydrophobic soil
- Access issues due to snow storage
- Effect of consecutive winter seasons on long-term performance

### **Addressing Concerns About Potential Permeable Pavement Clogging at a Retail Project in New Hampshire**

*To address concerns about potential clogging of porous asphalt at the new Greenland Meadows retail shopping center in Greenland, New Hampshire, the design team equipped the porous pavement systems with relief valve designs. “This was a conservative ‘belt and suspenders’ approach to the porous asphalt design,” according to one of the project designers. “Although the porous pavement system is not anticipated to fail, this design and strategy provided the developers with a safety factor and insurance in the event of limited surface infiltration”.*

*To further alleviate the project owner’s concerns about potential clogging, a combination paving approach was used. Porous asphalt was limited to passenger vehicle areas and installed at the far end of the front main parking area as well as in the side parking area, while standard pavement was put in near the front and more visible sections of the retail center as well as the loop roads and delivery areas that were expected to receive truck traffic. “This way, in case there was clogging or a failure, it would be away from the front entrances and would not impair access or traffic into the stores,” according to one of the project’s designers.*

Gunderson et al. 2011

Many of these concerns can be overcome through design modifications such as those summarized in Table 4-3 and described in the fact sheets for recommended LID measures.

**Table 4-3. High Elevation Winter Conditions Performance Concerns and Associated Design Modification Solutions**

Potential Problem	LID Measure	Recommended Design Modification/Possible Solutions
Performance may decrease over time due to freeze/thaw cycling, which can negatively impact vegetation	RM-3 Infiltration RM-4 Bioretention RM-5 Filter Strip RM-6 Swale RM-8 Green Roof	<ul style="list-style-type: none"> <li>• Cover the ground around plants and trees with a layer of mulch in the fall to prevent damage from repeated freeze/thaw cycling (<i>mulch acts as insulation to keep the soil frozen and helps to prevent the cycling</i>).</li> </ul>
Road sands may clog the LID measures	RM-1 Flowpath Disconnection RM-5 Filter Strip RM-6 Swale RM-7 Permeable pavement	<ul style="list-style-type: none"> <li>• Increase frequency of routine sediment removal, and check for clogging during late winter/ spring.</li> <li>• Vacuum permeable pavements in the spring.</li> <li>• Do not use permeable pavements in areas where sand is used (e.g., highways and major roads).</li> <li>• Restrict/eliminate sand usage in areas with permeable pavement.</li> </ul>
Relatively short growing season for vegetation	RM-4 Bioretention RM-5 Filter Strip RM-6 Swale RM-8 Green Roof	<ul style="list-style-type: none"> <li>• Choose appropriate plant species for adequate growth in high elevations and cold climates (see Appendix A).</li> <li>• Install erosion control measures such as mats or blankets while the vegetative cover becomes established.</li> </ul>
Use of salt or other deicing compounds may damage vegetation and concrete	RM-5 Filter Strip RM-6 Swale RM-7 Permeable Pavement	<ul style="list-style-type: none"> <li>• Avoid using salt or other deicing compounds that react with concrete.</li> <li>• Choose salt-tolerant plant species. Grasses are more tolerant than trees and woody plants.</li> <li>• Incorporate mulch into the soil.</li> </ul>

Potential Problem	LID Measure	Recommended Design Modification/Possible Solutions
Snow storage impacts	RM-3 Infiltration RM-4 Bioretention RM-5 Filter Strip RM-6 Swale RM-8 Green Roof	<ul style="list-style-type: none"> <li>• Provide adequate snow storage areas, properly designed, and possibly with their own infiltration systems.</li> <li>• Provide signage prohibiting stockpiling of snow on top of sensitive LID features, unless specifically intended as a snow melt system (<i>note: this solution may be hard to enforce or impractical during extreme snow events</i>)</li> <li>• Schedule snow removal to limit period of time snow remains on top of LID features (care should be taken when removing snow so as not to displace vegetation; also, consider snowmelt harvesting benefits as melting snow infiltrates.</li> <li>• Periodically amend soils (<i>if possible, remove and set aside top vegetation and replace after soil amendments are made</i>).</li> <li>• Install a hydronic or electric snowmelt system.</li> </ul>
Stored snow and rain on snow events will produce higher runoff than normal	RM-3 Infiltration RM-4 Bioretention RM-6 Swale RM-7 Permeable pavement	<ul style="list-style-type: none"> <li>• Additional volume required for snow storage and increased runoff volume from rain on snow events should be taken into account when sizing storage volumes</li> </ul>
Damage from snow removal equipment	RM-5 Filter Strip RM-6 Swale RM-7 Permeable pavement	<ul style="list-style-type: none"> <li>• Raise blade level of snow removal equipment high enough to avoid damage to permeable pavement material or vegetation</li> </ul>

Potential Problem	LID Measure	Recommended Design Modification/Possible Solutions
Pipe Freezing, Frost Heave	RM-1 Flowpath Disconnection RM-2 Rainwater Harvesting RM-3 Infiltration RM-4 Bioretention RM-5 Filter Strip RM-6 Swale RM-7 Permeable pavement	<ul style="list-style-type: none"> <li>• Insert underground components below the frost line to prevent frost heave and to prevent water from freezing in pipes.</li> <li>• For pipes that cannot be installed below the frost line, such as conveyance pipes used with cisterns, insulate or equip with heat tracing (<i>electrical heating element run in physical contact along the length of a pipe, which is then covered with insulation</i>)</li> </ul>
Permanent pool ice covering may form on areas of stormwater detention impeding the function of the LID measure	RM-1 Flowpath Disconnection RM-2 Rainwater Harvesting RM-3 Infiltration RM-4 Bioretention RM-6 Swale RM-7 Permeable pavement	<ul style="list-style-type: none"> <li>• Provide a deeper sub base rock layer below permeable pavement to ensure good drainage of the runoff and emptying of the void spaces in the pavement before there is time for the water to freeze.</li> <li>• Rainwater harvesting tank placement is recommended on the south side of the structure when possible to discourage ice build-up</li> </ul>
Extreme or sustained cold temperatures can lead to reduced soil infiltration rates	RM-1 Flowpath Disconnection RM-3 Infiltration RM-4 Bioretention RM-6 Swale RM-7 Permeable pavement	<ul style="list-style-type: none"> <li>• Make allowance in site stormwater design for the fact that these LID measures will infiltrate site runoff effectively during part of the winter only (on days with above-freezing temperatures)</li> <li>• Install an underdrain system to drain the ground beneath an infiltration system. The underdrain is used to drain the soils before the winter season begins, and then is closed throughout the winter.</li> <li>• The bottoms of basins or trenches can be lined with one foot of gravel or sand to encourage infiltration.</li> </ul>
Extreme or sustained cold temperatures may lead to reduced biological activity and settling velocities	RM-4 Bioretention RM-5 Filter Strip RM-6 Swale	<ul style="list-style-type: none"> <li>• Size facilities for coldest temperature removal rates (assume decreased biological activity and settling during sustained cold temperatures)</li> </ul>

## Ancillary Benefit Factors

Most of the recommended measures potentially provide ancillary benefits in addition to stormwater management, such as:

- Increased evapotranspiration
- Provides habitat
- Promotes groundwater recharge
- Provides shade (reduces heat island effect)
- Reduced greenhouse gases
- Reduced energy use
- Aesthetically pleasing
- Reduced downstream erosion and flooding
- Enhanced property value

Most of the recommended LID measures provide some level of effectiveness relative to the ancillary benefits listed above. Note that where vegetation is used (e.g., vegetated swale, green roof), ancillary benefits are provided almost across the board, demonstrating the advantage of using vegetative systems as much as practicable in LID design.

## 4.2 LID MEASURE FACT SHEETS: OVERVIEW

This section of Chapter 4 contains fact sheets for the 12 recommended LID measures, which include site design and runoff management measures.

The following type of information is presented on a single double-sided fact sheet for each of the four Site Design (SD) measures:

- Brief Introduction
- Planning and Design Strategies
- Design Elements
- Opportunities and Benefits
- Limitations
- Construction, Installation and Maintenance Considerations (where applicable)
- Photos and Schematics (local conditions are shown whenever possible)
- References

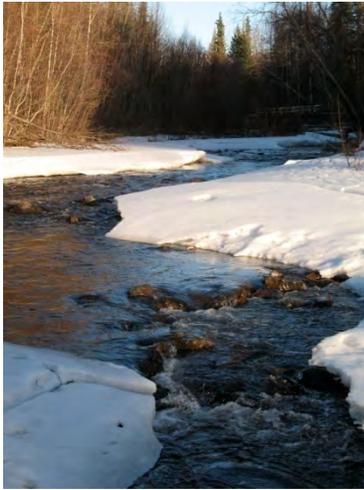
Each of the eight Runoff Management (RM) fact sheets are presented as a single 11x17 page for easy at-a-glance reference in the office or in the field. These sheets contain the following type of information:

- General Description
  - Planning and Design Strategies
  - General Guidelines
  - Design Strategies
  - Benefits
  - Limitations
- Cold Climate Considerations
- Construction Considerations
- Operations and Maintenance Considerations
- Water Quality Pollutant Percent Removals (where applicable)
- Photos and schematics (local conditions are shown whenever possible)
- References

## 4.3 LID MEASURE FACT SHEETS: SITE DESIGN MEASURES

LID Site Design (SD) fact sheets are presented on a single double-sided fact sheet for each of the four measures, which include the following that are briefly introduced below:

- SD-1 Protect Natural Conditions and Sensitive Areas
- SD-2 Optimize Site Layout
- SD-3 Control Pollutants at Source
- SD-4 Integrate Eco-Friendly Landscaping



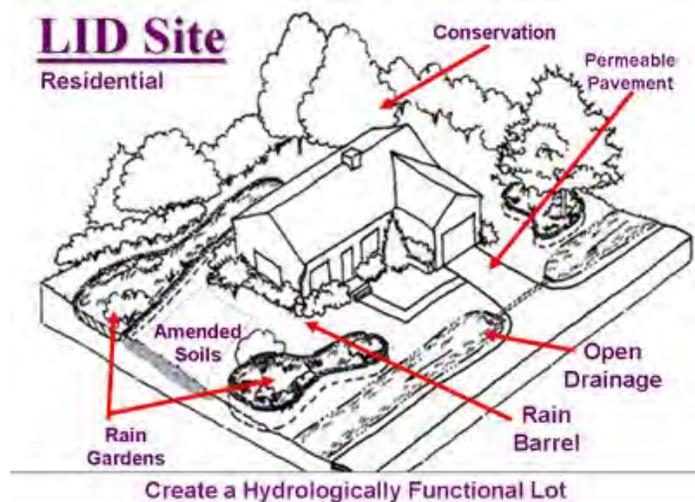
**Wide buffers around environmentally sensitive areas such as creeks will filter out pollutants and reduce runoff**

### SD-1 Protect Natural Conditions and Sensitive Areas

Site design to preserve natural conditions is guided by the strategy to protect as much of the existing natural/vegetated areas and drainage features of the site as possible (including environmentally sensitive areas) and to minimize soil compaction in these areas during construction. Protecting natural areas and riparian buffers (if present) will improve water quality and reduce runoff velocities and flows through filtration and infiltration, enhance site aesthetics, and provide habitat. Additional benefits include cleaner air and carbon sequestration by trees and lower construction costs due to the reduced need for clearing, excavation and disposal, and structural stormwater conveyance facilities. See the SD-1 fact sheet for detailed information about this measure.

### SD-2 Optimize Site Layout

Optimize Site Layout is a site design measure for minimizing the site footprint that can be applied to all projects. It is accomplished using strategies such as minimizing total disturbed area, reducing the amount of impervious surfaces, and integrating stormwater management features with buildings and vegetation. Key considerations include taking advantage of pre-project natural site conditions and looking for opportunities to install features that can serve multiple purposes. See the SD-2 fact sheet for detailed information about this measure.



Residential LID Site Layout (Source: Puget Sound LID Manual, 2005)



### SD-3 Control Pollutants at the Source

Control Pollutants at the Source is a site design measure for containing pollutants before they come into contact with water. Managing pollutants as close to the source as possible can minimize the cost of treatment and conveyance. Options include covering and containing storage areas (e.g., install roofs over trash enclosures), designing site features to keep pollutants out of storm drains (e.g., placing “no dumping” signs) and strategically locating areas with a likelihood of generating pollutants away from storm drains and water bodies. See the SD-3 fact sheet for detailed information about this measure.

”Start at the Source” (BAASMA, 1999) is an excellent reference for site design to minimize pollution and the cost of stormwater quality treatment.

### SD-4 Integrate Eco-Friendly Landscaping

Integrate Eco-Friendly Landscaping is a site design measure that can be applied to most projects, including small urban infill projects and sites with steep slopes or clay soils. It entails specifying locations on the site plan where native and climate appropriate vegetation should be installed. Such landscaping will require less maintenance, water, fertilizers and pesticides. The design specifications should call for soil amendments as needed and water efficient irrigation for landscaped areas. Overall using eco-friendly landscaping can reduce water and energy use, provide habitat, and increase soil infiltration capacity. See the SD-4 fact sheet for detailed information about this measure.



Slope revegetation in Placer County (Photo: Bob Costa, Placer County)

# Protect Natural Conditions

PLACER COUNTY LOW IMPACT DEVELOPMENT **GUIDEBOOK**



## Fact Sheet SD-1

Protect Natural Conditions is a site design measure that can be applied to most projects, and includes preserving natural areas such as riparian buffers and tree clusters; protecting environmentally sensitive areas and designated open space; protecting natural drainage features; and minimizing soil compaction during site clearing and grading.

### Planning and Design Strategies

Site design to preserve natural conditions is guided by these general strategies:

- Protect as much of the existing natural/vegetated areas of the site as possible
- Protect environmentally sensitive areas and designated open space
- Preserve and use existing natural drainage features and flow paths whenever possible. If not possible, restore these features to pre-project conditions
- Minimize soil compaction during and after construction

#### Protect Natural Conditions

**Riparian Buffer:** Riparian buffer areas are important elements of local communities' green infrastructure and/or LID tool box. These areas are critical to the biological, chemical, and physical integrity of our waterways. Riparian buffer areas protect water quality by cooling water, stabilizing banks, mitigating flow rates, and providing for pollution and sediment removal by filtering overland sheet runoff before it enters the water. The Environmental Protection Agency defines buffer areas as, "areas of planted or preserved vegetation between developed land and surface water, [which] are effective at reducing sediment and nutrient loads."

**Trees and Tree Clusters:** Tree conservation at development sites will help to maintain a natural hydrologic regime. If tree conservation is not an option, plant new trees in pervious areas of development sites. Tree clusters planted in turf grass or barren ground can reduce stormwater runoff volume and peak flow, improve water quality, generate organic soils, absorb greenhouse gases, create wildlife habitat, and provide shading to mitigate temperature increases at development sites.

#### Protect Environmentally Sensitive Areas and Designated Open Space

**Open Space:** Open space areas are generally defined through zoning where urban development is not permitted. These areas may be used for parks, parkways, etc.

**Environmentally Sensitive Areas:** Environmentally sensitive features include waters of the state such as wetlands, vernal pools, seasonal and perennial creeks; as well as habitat for endangered or threatened species.

#### Preserve Natural Drainage Features

A main goal of LID is to maintain or mimic a site's pre-project hydrologic regime. Preserving natural drainage features, such as swales, depressions, and watercourses, and utilizing the site's natural topography will minimize site disturbance. The natural vegetation in these features will filter, slow and infiltrate stormwater runoff to protect water quality. Designers can use natural drainage features to reduce or eliminate the need for structural underground drainage systems. In areas where natural drainage features need to be modified or piped to accommodate the development, approval must be obtained from the appropriate permitting and resource agencies.

#### Minimize Soil Compaction

Minimizing soil compaction is the practice of protecting and minimizing damage to existing soil quality and permeability caused by land development activities. Minimizing soil compaction will sustain and maintain infiltration rates for various LID features. It is also possible to enhance soil composition with soil amendments and mechanical restoration after it has been damaged (see fact sheet SD-4).

### OPPORTUNITIES AND BENEFITS

- Protecting of natural areas and riparian buffers (if present) will improve water quality and reduce runoff velocities and flows through filtration and infiltration, enhance site aesthetics, and provide habitat.
- Owning residences with natural and aesthetic value can lead to higher property values.
- Using riparian buffers can provide a canopy to reduce water temperature and deter growth of invasive aquatic vegetation, and prevent shoreline and bank erosion.
- Protecting trees and tree clusters offers many benefits. Trees absorb, filter and evapotranspire rainwater; sequester carbon and create oxygen which reduces greenhouse gases and provides cleaner air; and provides shade to reduce surface and runoff temperatures. Tree roots enhance infiltration capacity of the soil.
- Protecting natural drainage features and working with the existing site topography will maximize natural hydrological functions and reduce the need for cut and fill, structural stormwater conveyance facilities, and associated costs.
- Minimizing soil compaction maintains the site's natural infiltration capacity and maintains a healthy soil environment for vegetation.

**Right: Signs help to raise public awareness and understanding about the need for and benefits of protecting natural resources.** Photo Credit: Stefan Schuster, CDM



# PROTECT NATURAL CONDITIONS

## Design Elements

### Protect Natural Conditions

- **Identify and protect riparian buffers:** Identify and map riparian buffer areas on the site and specify setback distances and other methods for physical protection (e.g., orange protective fencing and signs) on the site plan. Consult with the local permitting agency about environmental overlay zones and any other special requirements that may apply.
- **Preserve and/or reintroduce trees and tree clusters:** Design the site plan to preserve existing trees where possible. On larger sites, install tree protection (e.g., orange protective fencing and signs) approximately 50 feet outside of the drip line (canopy) of the tree. If trees are not present at a site, design the site plan to incorporate additional trees and/or tree clusters as appropriate. A tree cluster consists of 3 or more trees and is installed using 3 feet of backfill that is compatible with site soils. Plant native trees that are salt tolerant species in areas that will receive snow melt from roadways, parking lots, or snow storage piles. Plant native trees that can withstand frequent inundation (flooding) if shallow depth to groundwater is present.

### Protect Environmentally Sensitive Areas and Designated Open Space

- **Designated Open Space:** Identify and map designated open space areas on the site. Preserve and/or create as much open space as possible. Examples of increasing the amount of open space are clustering buildings and incorporating open space as overflow parking. Open space area runoff is typically not as polluted as runoff from impervious surfaces. Isolate runoff from open space areas and use them as self-treatment areas, which are areas that use natural processes to remove pollutants from stormwater. Refrain from using pesticides or quick-release synthetic fertilizers to minimize contaminants in runoff from self-treating areas directly to the storm drain system or other receiving water.
- **Environmentally Sensitive Areas:** Identify and map environmentally sensitive areas on the site. Avoid these areas during construction, and install protection (e.g., orange protective fencing and signs) surrounding them.

### Protect Natural Drainage Features

- Identify and map drainage features (e.g., swales, channels, ephemeral streams, depressions, etc.) and specify setback distances and other methods for physical protection of these features (e.g., orange protective fencing and signs). Use existing natural drainage features, if present, to convey stormwater where appropriate. Distribute non-erosive surface flow to natural drainage features, and keep non-erosive channel flow within drainage pathways. If existing drainage modifications are required, then restore modified drainages to pre-development conditions to the extent practicable. If no natural drainage features are present, use topographic features to design stormwater conveyance to minimize cut and fill requirements.

### Minimize Soil Compaction

- Minimize soil compaction throughout project construction. Limit areas of heavy equipment, and keep heavy equipment in these areas. Following construction, aerate and plow these areas if possible to increase infiltration back to pre-development standards. Enhance soil composition with soil amendments to restore it after it has been damaged.

## Limitations

- The use of trees and tree clusters may be limited by available space, underground utilities, overhead powerlines, and shallow depth to water table (found within 3 feet of the surface).
- Soil compaction minimization may be difficult to implement on smaller sites.

## References

C.3 Stormwater Technical Guidance. San Mateo PPP, 2010.  
 Massachusetts LID Toolkit, 2007.  
 SEMCOG, LID Manual for Michigan, 2008.



Protect the root zones of trees from compaction and damage by keeping the natural area under the canopy (inside the drip line) clear.  
 Photo Credit: Carmel Brown



Diagram of site stormwater treatment and discharge. Source ACCWP, 2010

Below: Preservation of native trees or reforestation, particularly use of tree clusters, provides a wide range of water and air quality benefits while adding aesthetic value  
 Photo Credit: Carmel Brown



# Optimize Site Layout



Optimize Site Layout is a site design measure for minimizing the site footprint that can be applied to all projects, and is accomplished using strategies such as minimizing total disturbed area, reducing the amount of impervious surfaces and integrating stormwater management features with buildings and vegetation. Key considerations include taking advantage of pre-project natural site conditions and looking for opportunities to install features that can serve multiple purposes.

## Planning and Design Strategies

Once natural conditions and features on a site have been protected (see Fact Sheet SD-1), consider these strategies to optimize site layout and reduce environmental impacts of the development:

**Minimize Total Disturbed Area.** Lay out the site and building footprint(s) to minimize the amount of site clearing and grading (cut and fill) needed. This process will, in turn, reduce the erosion potential and amount and cost of erosion and sediment controls needed during construction. One way to minimize disturbed area is to concentrate development on smaller lots on a portion of the site, while leaving other areas as open or community space. "Cluster development" like this can help to avoid sensitive and constrained areas, such as steep slopes, water bodies and floodplains, without sacrificing building units.

**Reduce Impervious Surfaces.** Look for opportunities to reduce impervious surfaces so that the site features act more like a natural sponge to absorb and reduce runoff. This approach means reducing the building footprint (e.g., multi-story instead of single story), decreasing width of private roads, creating smaller parking lots and utilizing alternative driveway designs, all subject to approval of the permitting agencies. The strategy also includes using pervious pavement instead of using conventional impervious pavement.

**Integrate Stormwater Management Features with Buildings, Landscaping and Recreation Uses.** Coordinate placement of stormwater management features with buildings and vegetation and find opportunities for multi-purpose uses, such as detention basins that can function as recreational fields in drier summer months.



**Village Homes in Davis, California (built in 1975) is a good example of a LID cluster development that provides community open space/ gardens and natural treatment of stormwater in drainage swales without flooding. About 800 residents enjoy the close community connections and home resale value here have consistently been higher than similar developments in the area.**

Photo Credit: Michael Corbett

## OPPORTUNITIES AND BENEFITS

- Minimizing site disturbance, building footprints and other impervious areas maintains more natural areas that promote filtration, infiltration and evapotranspiration of stormwater and reduce runoff volumes and peak rates
- Reduced disturbance of the site and use of clustered development and multi-use features can result in less grading and structural storm drain infrastructure and associated costs
- Less clearing and grading lowers the potential for sediments to be carried off the site in runoff to local streams where it can impair habitat
- Clustered development allows space for community gardens, parks, recreational trails and/or open spaces
- New impervious features can be located over problematic areas of the site such as those with clay/impervious soils, shallow groundwater table, and known contamination
- Recreation areas can be located in networks of open space or green corridors or combined with stormwater management features (e.g., dual-purpose detention basins)
- Pervious parking areas can be combined with sub-surface detention facilities such as cisterns

## Limitations

- Check with the local fire control agency and engineering department for restrictions about use of permeable paving materials for roadways, driveways and fire access lanes (also see Fact Sheet LID-7)
- Clustering may be difficult to achieve on small, constrained development sites

**A narrow road along Fallen Leaf Lake, Lake Tahoe, CA**

Photo Credit: Bill C.



# OPTIMIZE SITE LAYOUT

## Design Elements

### Minimize Disturbed Areas

- Configure lots/development to avoid sensitive natural areas and conform to natural topography
- Preserve open space and natural conditions by clustering lots, buildings and uses in a smaller area of the site
- Locate features (e.g., site access points, driveways) to minimize impacts to sensitive environmental features
- Indicate on the site plan where exposed, bare areas that can be revegetated to enhance infiltration and slow runoff
- For redevelopment projects, plan to convert existing impervious areas to pervious areas whenever possible

### Reduce Impervious Surfaces

#### Building Lots

- Use minimum standards for driveway lengths and widths, subject to permitting agencies' approval
- Reduce front yard setbacks to allow for shorter driveways, but allow a minimum of 20 feet length for driveway parking
- Consider alternative driveway styles, such as Hollywood driveways (vegetated center strip), permeable paving (see fact sheet LID-7) and shared driveways
- Use alternative materials for sidewalks, walkways and patios such as pavers or decomposed granite

#### Parking Lots

- Design parking lots for average annual demand instead of seasonal/infrequent peak demand
- Install overflow parking areas constructed of pervious paving materials for seasonal peak demand
- Use minimum standards for allowable parking ratios
- Analyze parking lot layout to reduce impacts, including use of narrowed one-way circulation traffic lanes, varied parking stall orientations and permeable paving materials in low-traffic areas
- Arrange for shared parking where possible, particularly when adjoining land uses have different hours of operation (e.g., commercial building and church)
- Construct parking areas/ garages under buildings

#### Streets

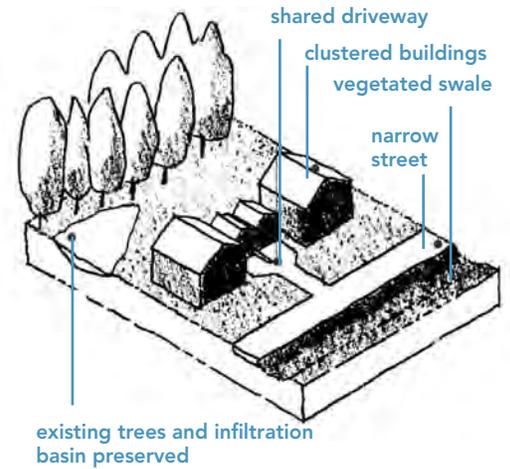
- Use minimum standards for road width, subject to permitting agencies' approval
- Avoid use of cul-de-sacs or design cul-de-sacs at the minimum standards for width and turning radius, subject to fire approval
- Integrate stormwater management with complete street design to create low impact "green streets"

### Integrate Stormwater Management Features with Buildings, Landscaping and Recreational Uses

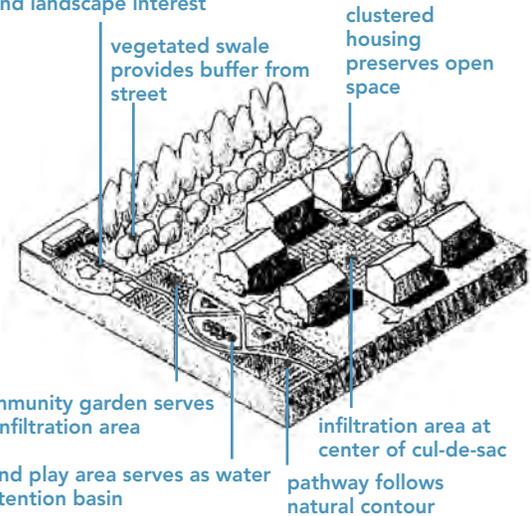
- Integrate stormwater management techniques (see LID fact sheet series) with lot/building layout to treat runoff from buildings and other impervious surfaces
- Locate LID features such as infiltration, bioretention and pervious pavement in areas with well-drained soils (configure the site plan to place buildings and other impervious features in other areas of the site if possible)
- Consider vegetation for rooftops (see Fact Sheet LID-8), walls and adjacent areas to filter, evapotranspire rainwater and snowmelt, reduce runoff and shade/insulate buildings
- Use vegetation in medians and circulation areas to infiltrate/filter stormwater (rain and snowmelt)

### References

BASMAA, *Start at the Source*, 1999.  
SEMCOG, *LID Manual for Michigan*, 2008.



footbridge provides connectivity and landscape interest



Examples of optimizing site layout for residential areas. Adapted from Start at the Source (BASMAA, 1999)

## CONSTRUCTION CONSIDERATIONS

Provide instructions to the owner or contractor with the site plans to minimize impacts during construction. For example:

- Obtain coverage under the State's Construction General Permit if the project will disturb one or more acres (including parking and staging areas)
- Minimize construction traffic/soil disturbance areas and stabilize as needed to prevent sediment tracking off the site
- Minimize and control construction stockpiling and storage areas and use erosion and sediment controls to keep sediments from traveling off the site in runoff
- Cover/protect newly installed pervious pavements until construction is complete to keep fine construction and landscaping sediments from clogging void spaces

# Control Pollutants at the Source

PLACER COUNTY LOW IMPACT DEVELOPMENT **GUIDEBOOK**



Fact Sheet SD-3

Control Pollutants at the Source is a site design measure that can be applied to all projects, and includes designing materials storage and housekeeping site features to keep water from contacting pollutants (for example, putting roofs over storage areas) and to keep pollutants from contacting water (for example, locating areas with a likelihood of generating pollutants away from storm drains and water bodies).

## Planning and Design Strategies

The following are general strategies/design considerations related to activities that are common to storage and work areas at commercial and industrial sites, such as garbage and recycling, maintenance, and loading. These activities can have a significant negative impact on stormwater quality, and special attention should be paid to the siting and design of the activity area. Evaluate local ordinances affecting the use of the site and specific areas of the site, as many local jurisdictions have specific requirements. In the case of conflict, the local requirements shall prevail.



**Pollutant source areas such as trash enclosures should be set on concrete and covered with roofs to prevent pollutants from being carried to storm drains and streams.**

- **Prevent water from contacting work and storage areas.** Design the site to prevent water (including rainfall, stormwater runoff and runoff, and other water generated during site activities [e.g., washwater]) from entering/passing through loading areas, maintenance yards/buildings, storage areas, fueling areas and other work places before it reaches storm drains. Example strategies include: using roofs and locating pollutant source areas away from storm drain inlets. The objective is to prevent the discharge of water laden with pollutants to surface waters or sensitive resource areas.
- **Prevent pollutants from contacting surfaces that come into contact with water.** Design the site to keep pollutants from contacting surfaces that will come into contact with water (including rainfall, stormwater runoff and runoff, and other water generated during site activities [e.g., washwater]). Although pollution control is largely an operational element, there are a number of features that can be designed into a project that function as source controls once the project is completed. Example strategies include: marking new drain inlets with “no dumping” messages, posting informational signs, placing outdoor material and trash storage areas away from storm drain inlets, plumbing wash areas to the sanitary sewer, and permanently protecting slopes and channels from erosion.

## OPPORTUNITIES AND BENEFITS

- Managing stormwater runoff (including rainfall and snowmelt) and pollutants as close to the source as possible can minimize costs of storm drain pipes and other conveyance features.
- Controlling pollution at the point of generation is less costly than treating the runoff to remove the pollutants and may reduce or eliminate the need for treatment.
- Source controls will reduce potential for illegal pollutant discharges to the storm drain or local waterway.



**Erosion Control & Veg Fence; Northstar CSD Administration Building.** Photo Credit: PR Design & Engineering



## Limitations

- Effectiveness of source control measures will depend not only on good site design but on behaviors by those using the site after construction is complete. Prior to final acceptance of the project, provide instructions for operation and maintenance for the new property owners. In the case of commercial sites, also provide guidelines for site personnel training.
- Sometimes the solution for stormwater pollution prevention is to direct water to the sanitary sewer. However, check with the local sanitary sewage system operator for restrictions on quality and quantity of allowed discharges. Additional fees may apply.
- Check with the local fire control agency for restrictions about use of dead end sumps for containing spills (will depend on nature of potential pollutants).
- Check with local solid waste hauler for height restrictions on roofs and overhangs for loading docks and trash enclosures.

## CONTROL POLLUTANTS AT THE SOURCE

### Design Elements

Site design to control pollutant sources is guided by the following general principles:

- Locate the storage and work areas away from hose bibs, storm drains, water bodies and sensitive natural areas of the site. If the work area is adjacent to or directly upstream from a storm drain or landscaped drainage feature (e.g. bioswale), debris or liquids from the work area can migrate into the stormwater system.
- Create an impermeable surface, such as concrete or asphalt where potential pollutants are stored. A concrete surface is more expensive, but is generally less permeable and will typically last longer than asphalt, as vehicle fluids can either dissolve asphalt or can be absorbed by the asphalt and released later. Porous pavement, discussed elsewhere in the LID Guidebook, should not be used in high traffic areas and areas that have the potential to generate pollutants.
- Cover the storage or work area with a roof. This prevents rain from falling on the work area and becoming polluted runoff.
- Berm or mounding around the perimeter of the area to prevent water from adjacent areas to flow on to the surface of the work area (runon) and to prevent spills from migrating away from the area. In this way, the amount of polluted runoff is minimized.
- Directly connect runoff. Unlike other areas of the site where runoff disconnection would be recommended to reduce site runoff, the runoff from outdoor work, storage and vehicle/equipment wash areas may need to be directly connected to the sanitary sewer, dead end sumps or other specialized containment systems. This would allow the more highly concentrated pollutants from these areas to receive special treatment that removes pollutants. Obtain approval for such features from the appropriate sanitary sewage or other agency (see Limitations).
- Locate and design garbage and recycling areas properly. In addition to the above strategies, other factors must be considered for these areas. They must be sited so that receptacles are accessible for collection by standard collection trucks, yet out of the way so as not to disturb the aesthetics of the site. Consult with the local waste hauler and plan an adequate space for the sizes of trash and recycling receptacles. For food and restaurant establishments, design segregated areas for tallow bin storage, away from trash and recycling. Do not place storm drains or hose bibs inside trash, recycling and/or tallow bin storage areas. In cases where water cannot be diverted from the enclosure (such as areas located within a low spot), a self contained drainage system should be included, subject to approval of the local permitting agency. Provide signage and operation and maintenance instructions for sweeping, litter control, and spill cleanup to the new property owner/operator.

The "Start at the Source Design Guidance Manual for Stormwater Quality Protection", first published in 1999, continues to be the best guide available today for designing a site to control sources of pollution.  
[http://www.flowstobay.org/bs\\_new\\_development.php](http://www.flowstobay.org/bs_new_development.php)



Hose bibs and pollutant source areas such as vehicle/equipment washing areas should be located away from storm drain inlets to reduce the threat of pollution.



Marking storm drain inlets with permanent "no dumping" messages is a simple way to educate the public about stormwater pollution



### TYPICAL STORMWATER POLLUTANTS AND SOURCES:

**Sediment.** Roads, parking lots, and roofs are common sources of sediment due to wear. Unstabilized landscaped areas and streambanks, unprotected slopes and bare dirt areas also contribute. Sediment is a main component of total suspended solids (TSS), and is detrimental to aquatic life because it can clog fish gills, cover spawning gravels and create turbid conditions which affect photosynthesis. Sediment also transports other pollutants that attach to soil particles, so sediment control practices will help reduce most other pollutants in this list as well.

**Organic Compounds.** These compounds are derived from automotive fluids, pesticides, and fertilizers. Organic compounds often attach to soil particles.

**Nutrients.** Nutrients include nitrogen, phosphorus, and other organic compounds which can be found in organic litter, green waste, fertilizers, food waste, sewage and sediment. Excess nutrients impact creek health and impair use of water in lakes and other water supply sources by promoting excessive growth of algae or vegetation (i.e. eutrophication). As the vegetation dies off, it robs the waterway of dissolved oxygen, essential for fish and other aquatic life.

**Metals.** Sources of trace metals (copper, lead, cadmium, chromium, nickel, and zinc) can include motor vehicles, roofing and construction materials, chemicals and sediments. Trace metals can be toxic to aquatic organisms and, in accumulated quantities, can contaminate drinking water supplies.

**Bacteria and viruses.** Sources include animal excrement (found in areas where pets are often walked), sanitary sewer overflow, and trash handling areas (dumpsters). Bacteria and viruses may pose public health and safety concerns to drinking water and recreational water bodies.

**Oil and Grease.** Some sources of oil and grease include motor vehicles, food service establishments, and fueling stations. Oil and grease act as carriers for heavy metals and contain hydrocarbon compounds, which even at low concentrations may be toxic to aquatic organisms.

### References

CASQA California Stormwater BMP New Development and Redevelopment, 2003.  
 KJ, The Truckee Meadows Structural Controls Design Manual, 2007.

# Integrate Eco-Friendly Landscaping



Integrate Eco-Friendly Landscaping is a site design measure that can be applied to most projects, including small urban infill projects and sites with steep slopes or clay soils. It entails locating and specifying various features on the site plan and construction specifications, such as: locations and types of native and climate appropriate vegetation that will require less maintenance, water, fertilizers and pesticides; soil amendments where needed to create functional soil conditions that will sustain vegetation; and water efficient irrigation for landscaped areas.

## Planning and Design Strategies

Several strategies can be used to integrate eco-friendly landscaping on the project site to reduce environmental impacts of the development. Due to the non-structural nature of these solutions, they can be very cost-effective:

### Specify and Properly Locate Native and Climate Appropriate Grasses, Plants and Trees:

Native plants are eco-friendly because they were originally a natural part of the landscape. Native plants typically require less water, are slower growing and require less maintenance. Additionally, local native species are tolerant to dry summers and diurnal temperature fluctuations. Reforesting with trees and tree clusters will provide many benefits including improved air and water quality and reduced greenhouse gases.

**Plan for Functional Soil Conditions:** Soil amendments can help restore soil properties to pre-project conditions by reversing the loss of organic matter and compaction. Amendments can make clay soils suitable to receive and filter/infiltrate site runoff. Soil amendments consist of fibrous materials such as peat, wood chips, and hardwood bark; humus such as compost and aged manure; and inorganic materials such as vermiculite and perlite. The practice can increase infiltration rates, plant survival rates and health, enhance root growth, provide erosion stabilization, and decrease need for irrigation and fertilization.

**Design a Water-Efficient Site:** The first step in creating a water-efficient site is to eliminate or limit the amount of vegetation that requires frequent watering (e.g., turf, non-native grasses and shrubs). After that, specify water efficient landscape irrigation systems (e.g., evapotranspiration (ET) controllers, timers and drip irrigation) to reduce future water use by the property owners/tenants.



**Eco-friendly landscaping**

Photo Credit: David Roberts Landscape

## OPPORTUNITIES AND BENEFITS

- Eco-friendly landscaping provides a wide range of benefits, including improved water and air quality, reduced greenhouse gases, water and energy conservation, and reduction of waste to the landfill.
- Native grasses and plants typically require less water and are slower growing and require less maintenance. They can provide pollutant removal and reduce stormwater flows.
- Protecting trees and tree clusters offers many benefits. Trees absorb, filter and evapotranspire rainwater; sequester carbon and create oxygen which reduces greenhouse gases and provides cleaner air; and provides shade to reduce surface and runoff temperatures. Tree roots enhance infiltration capacity of the soil.
- Revegetation and reforestation can restore filtration, infiltration and groundwater recharge functions.
- Vegetated areas can provide habitat for wildlife and increase aesthetic value for the community.
- Amended soils can yield moderate increases in infiltration rates from 2 to 10 times over unamended soil rates and reduce the need to irrigate and fertilize the landscaping.

## Limitations

- Native plants and trees can be slower growing and can take longer to establish than other plants.
- Maximum slope for using soil amendments is typically 10%, unless geotextile matting is provided.
- Do not plant trees in areas with shallow groundwater (less than 3 feet).
- Tree selection and use may be limited on constrained sites with overhead power lines and/or underground utilities and on dense infill sites with high building lot coverage and minimum setbacks.



**Vegetation and Mulch Treatments**

Photo Credit: Dana Olson, Tahoe RCD

# INTEGRATE ECO-FRIENDLY LANDSCAPING

## Design Elements

### Specify and Properly Locate Native and Climate Appropriate Grasses, Plants, and Trees

Select grasses, plants and trees that are appropriate for the site and its intended use, considering sun exposure and shade conditions, climate, soils, drainage, and irrigation/maintenance needs. Refer to a recommended plant/tree list in Appendix A.

#### Grasses and Plants

- Select hydrophilic plants/grasses for areas that will be more frequently inundated (e.g., in stormwater planters and swales, see Fact Sheets LID-4 and 6).
- Consider the expected life and future size and root zone of the mature species when locating plants in landscaped areas, and space the plants appropriately. If additional information is needed, visit a native plant demonstration garden or view photos of full-grown plants on the internet.

#### Trees

- Involve an arborist in the design process.
- Consider the future size/canopy and root zone of the fully-grown mature species when locating trees on the site, providing proper clearance from building foundations, pavement and overhead/underground utilities. Ideally, provide a setback of 10 to 15 feet from the expected 10-year canopy to overhead lines.
- The total soil area to be excavated for tree root balls is typically two cubic feet per square foot of future canopy cover at maturity.
- Use root guards and structural soil in areas near underground utilities and pavement, and streets.

### Plan for Functional Soil Conditions

- Test the soil and infiltration rates prior to preparing the landscape plan.
- For sites with permeable soils (typically infiltration rates greater than 1 in/hr), specify protection of native topsoil in place or stock it in a protected area of the site until building construction is complete and landscaped areas are ready.
- Specify soil amendments before planting when infiltration rates are less than 1 in/hr, or even in cases where native soils are good quality. Soil amendments are particularly important for trees in soils with low infiltration capacity.
- Prepare construction specifications for preparing soils on the site. For example:
  - Scarify or till existing soils to a depth of 15 inches and add 4 to 6 inches of well-aged compost to achieve organic matter content in the range of 8 to 13%.
  - Stabilize amended soil areas with groundcovers, perennial grass species, trees or other herbaceous plants. Use geotextile matting in sloped areas.
  - Use orange fencing to designate and protect amended soil areas from compaction during construction and plant perimeter shrubs or trees for long term protection from vehicle and heavy foot traffic.

### Design a Water-Efficient Site

- Divide landscape areas into hydrozones that have varying irrigation requirements.
- Select irrigation systems that can be configured to water less frequently, but for longer periods of time to provide dry periods between watering and enhance rooting depth.
- Specify use of drip irrigation to convey water via a mild pressure distribution system, enhance infiltration and plant uptake, and prevent overspray/overwatering and runoff.
- Develop a water balance to determine seasonal irrigation needs, based on local ET rates and efficiency factors.

### References

SSQP, *River Friendly Landscape Guidelines*, 2007.  
SEMCOG, *LID Manual for Michigan*, 2008.

## INSTALLATION AND MAINTENANCE CONSIDERATIONS

- Specify ideal season for spreading native grass seed (typically in the early fall or early spring) and planting woody vegetation and trees (typically in early spring).
- Plan for temporary irrigation if needed.
- Provide maintenance instructions for the plant establishment period (up to 2 years) and thereafter.



**Before: Bare Areas in Tahoe area**

Photo Credit: Dana Olson, Tahoe RCD



**After: Revegetation and Mulching**

Photo Credit: Dana Olson, Tahoe RCD

## 4.4 LID MEASURE FACT SHEETS: RUNOFF MANAGEMENT MEASURES

LID Runoff Management (RM) fact sheets are presented as a single 11x17 page for easy at-a-glance reference in the office or in the field. These measures include the following that are briefly introduced below:

- RM-1 Stormwater (SW) Flowpath Disconnection
- RM-2 Rainwater and Snowmelt Harvesting
- RM-3 Infiltration Trench/Dry Well
- RM-4 Bioretention
- RM-5 Vegetated Filter Strip
- RM-6 Vegetated Swale
- RM-7 Permeable Pavement
- RM-8 Green Roof

### RM-1 Stormwater (SW) Flowpath Disconnection

Stormwater (SW) flowpath disconnection is a technique that reduces the volume of stormwater delivered to storm drains by disconnecting the runoff from roofs, impervious areas on the site and minor roads, and redirecting the runoff to permeable areas (e.g., vegetation) that promote runoff filtration and infiltration. This can be accomplished by disconnected roof gutter downspouts and grading impervious areas (e.g., driveway, walkway, small parking areas, and patio) to drain into vegetated areas of the site (preferably bioretention areas with capacity to infiltrate). For disconnecting private roadway runoff, curb cuts can be used to direct flows into roadside swales or bioretention planters; the local permitting agency should be consulted for applicability to public roadways. This technique works well on sites with space constraints and under all soil conditions including redeveloped sites and can be done at a relatively low cost, as compared to other LID measures. Care must be taken to provide adequate clearances between vegetated infiltration areas and building foundations and road subbase. However, on extremely tight sites, the local permitting agency may allow a reduced clearance if moisture barriers are used between the vegetated planter and building foundation or roadway. See the RM-1 fact sheet for detailed information about this runoff management measure.



Photo of Flow path of disconnected roof downspout.  
(Credit: CWS, 2010)

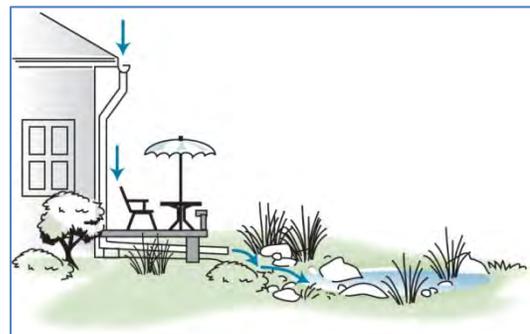


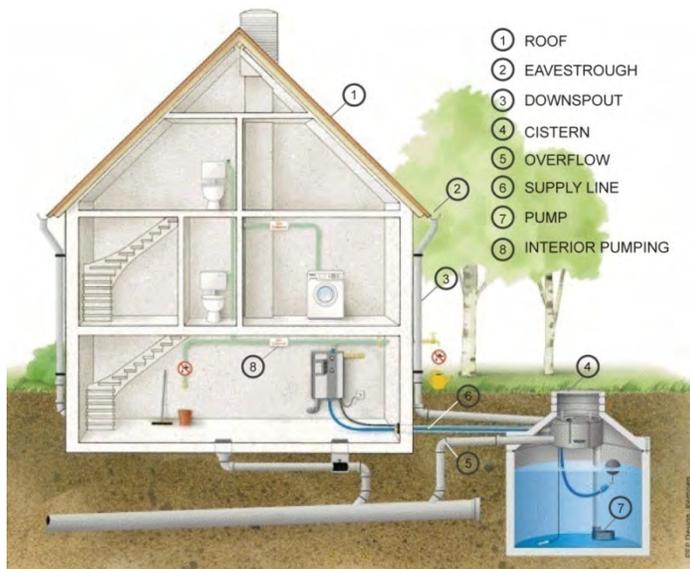
Diagram of Flow path of disconnected roof downspout.  
(Credit: TRCA 2010)

## RM-2 Rainwater and Snowmelt Harvesting

Rainwater and snowmelt harvesting consists of collecting, conveying and storing rainfall and snowfall for future outdoor (and possibly indoor) uses. The goal is to collect high quality water to offset potable water demands. The rain or snow that falls upon an impervious surface (e.g. roof, driveway, or walkway) is collected and conveyed into a storage tank (e.g. rain barrel or cistern). With minimal pretreatment (e.g., gravity filtration or first-flush diversion), the captured rainwater or snowmelt can be used for outdoor non-potable water uses such as irrigation and pressure washing, or in the building to flush toilets or urinals. Removing rainwater and snowmelt from the stormwater runoff before it becomes contaminated with pollutants or sediment can reduce the load on treatment/conveyance systems significantly. The operations and maintenance cost to implement this LID measure is low in comparison to most other RM measures. Note that local governments and health authorities may not yet have supportive policies or allowances for this measure. See the RM-2 fact sheet for detailed information about this runoff management measure.



Rainwater Harvesting Barrel (Credit: TRCA, 2010)



Components of a Rainwater Reuse System (Credit: TRCA, 2010)

## RM-3 Infiltration Trench/Dry Well

Dry wells and infiltration trenches store water in the void (pore) space between crushed stone or gravel where the water slowly percolates downward into the subsoil. The infiltration trench is a long trench filled with gravel and a perforated pipe at the bottom that directs flow both horizontally and vertically, whereas, the dry well is a pit filled with gravel that directs flow vertically down into deeper subsurface layers. The infiltration trench/drywell is useful for infiltrating fairly clean or pretreated runoff into the soil. A filter



Infiltration Trench (Credit: Bob Costa, Placer County)

fabric/geomembrane is typically used to line the trench or well to keep fine sediments from clogging the device. However, the device should be protected from receiving heavy sediment loads during its life, and it is not recommended in locations where spills can occur (e.g., gas stations, industrial land uses). When used effectively dry wells and infiltration trenches can significantly reduce the total volume of runoff from a site. An overflow outlet is needed for runoff from large storms that cannot be fully infiltrated by the trench or dry well. The overflow can be directed to the storm drain or to another LID RM measure. See the RM-3 fact sheet for detailed information about this runoff management measure.



**Bioretention Planter in the City of Auburn Streetscape filters roadway runoff before it enters the storm drain. (Credit: Foothill Associates)**

#### **RM-4 Bioretention**

Bioretention areas, also known as rain gardens, tree wells/pits, and stormwater planters, are planted depressions that store and filter rainwater to enhance water quality. Stormwater runoff that flows into the cell is slowly filtered through vegetation and soil media, and where geologic conditions permit, into the groundwater. Some of the water is also taken up by the plants and released through evapotranspiration. The filtration through the plant and soil medium in this RM measure is very effective at pollutant reduction. Pollutants of concern include sediment, metals, nutrients, and hydrocarbons. The vegetation in the bioretention area may also act as landscaping and can provide multiple benefits in

addition to runoff management benefits. Bioretention areas are usually designed to allow shallow ponding, with an overflow outlet to prevent flooding during heavy storms. The overflow can be directed to the storm drain or to another LID RM measure. See the RM-4 fact sheet for detailed information about this runoff management measure.

#### **RM-5 Vegetated Filter Strip**

Vegetated filter strips (buffer strips and grass filter strips) are gently sloping, densely vegetated areas that treat runoff in the form of sheet flow from adjacent impervious areas. They should be used with some form of flow spreader and they function to slow runoff velocity, filter out suspended sediment, and provide some infiltration into underlying soils. They can be an effective form of pretreatment for another LID measure, such as an infiltration trench or porous pavement, both of which will clog if too much sediment is introduced. Vegetation may be comprised of a variety of trees, shrubs and groundcover to add aesthetic value as well as water quality benefits; however, care should be taken to ensure uniform distribution of the flow across the surface to the extent possible. Filter strips can provide a convenient area for snow storage and treatment, and are particularly valuable due to their capacity for snowmelt infiltration. See the RM-5 fact sheet for detailed information about this runoff management measure.



**Zoned/ Phased Vegetated Filter Strip. (Credit: TRCA 2010)**

### RM-6 Vegetated Swale

Vegetated swales are essentially bioretention cells that are configured as linear channels. They are stormwater conveyance and soil filter systems that temporarily store and then filter the desired water quality design flow. Stormwater runoff is typically directed to a swale via curb cuts and is conveyed slowly through the swale due to the roughness associated with the plants. Pollutants are removed from the runoff by filtering through plants and soil and runoff is reduced by infiltration. A gradual bottom slope is preferred, but in steeper areas, shallow check dams can be used to slow the water and allow pooling. In clay soils, an underdrain should be installed to convey treated runoff to the conveyance system further downstream. Similar to filter strips previously discussed, vegetated swales can be useful as a pretreatment method to remove sediment from runoff before the water enters another type of LID facility such as an infiltration trench or pervious pavement. The large surface area provided by the swale can also be used for temporary snow storage with the appropriate choice of vegetation. See the RM-6 fact sheet for detailed information about this runoff management measure.



**Vegetated Swale in Placer County (Credit: Allen Breuch, Placer County)**



**Vegetated Swale in Tahoe Basin (Credit: PR Design & Engineering)**

## RM-7 Permeable Pavement



Permeable Pavement (Credit: PR Design & Engineering)

Permeable paving allows rainwater to percolate through the paving and into the ground. This approach reduces stormwater runoff volumes and minimizes the pollutants introduced into stormwater runoff from roads and parking areas. All permeable paving systems consist of a durable, load bearing, pervious surface overlying a crushed stone base that stores rainwater before it infiltrates into the underlying soil. Permeable paving variations include porous asphalt, pervious concrete, paving stones, and manufactured “grass pavers” made of concrete or plastic. Permeable paving may be used for walkways, patios, plazas,

driveways, parking stalls, and overflow parking areas, but should not be installed in high traffic zones and roadways that will serve heavy trucks. See the RM-7 fact sheet for detailed information about this runoff management measure.

## RM-8 Green Roof

Green roofs, also known as “living roofs” or “eco-roofs,” consist of a layer of vegetation and soil installed on top of a conventional flat or sloped roof. Green roofs can improve energy efficiency of a building, reduce the “heat island” effect, and create urban green space for passive recreation or aesthetics. Hydrologically speaking, the green roof assembly acts like a lawn or meadow by storing rainwater in the soil. Excess rainfall flows to underdrains and overflow points and is conveyed in a typical building drainage system (e.g., gutters and downspouts). After a storm, any water remaining in the soil on the roof either evaporates or is evapotranspired by the plants.

For green roofs used in the High Sierra region, the structure supporting the green roof must be engineered to support its dead load and various live loads (e.g., snow, wind, and seismic) cumulatively. Typically, heavy steel I-beams, moment frames, and spaced gluelam beams are used in the construction. The roof should also be designed so that it does not require shoveling. Included below is a photo of a hotel in Truckee which was designed in this fashion and is working extremely well, according to the owner. See the RM-8 fact sheet for detailed information about this runoff management measure.



Cedar House Sport Hotel Green Roof, Truckee (Credit: <http://www.cedarhousesporthotel.com>)

## GENERAL DESCRIPTION

Stormwater disconnection is a technique that reduces the volume of stormwater delivered to storm drains by disconnecting the runoff from roofs, impervious areas on the site and minor roads and redirecting the runoff to permeable areas (e.g., vegetation) that promote runoff filtration and infiltration. Design variations include:

- Rooftop direct runoff and downspout disconnection
- On-site (driveway, walkway, small parking areas, and patio) disconnection
- Minor road runoff disconnection via curb cuts and curb removal

## PLANNING AND DESIGN STRATEGIES

### GENERAL GUIDELINES

COMPONENT	GUIDELINE
<b>Rooftop Direct Runoff and On-Site Disconnection</b>	
<b>Site Layout</b>	Building Setback – 20' Drainage Area – Average is 500 sf; maximum is 1,000 sf Topography – 10% maximum
<b>Design Criteria</b>	Impervious/Porous Ratio – 2:1 maximum Slope – Must discharge to a gradual slope away from the building at 1% to 5% Soil – Amend soils with infiltration rates less than 1 in/hr or use an underdrain Water Table – 2' minimum separation, 10' minimum separation for infiltration devices Design water surface elevation below the road subbase
<b>Conveyance and Overflow</b>	Level Spreading Device – Place a level spreading device (e.g., pea gravel diaphragm) or energy dissipating device (e.g., splash pad) at the downspout discharge location to distribute runoff evenly over the pervious area
<b>Minor Road Disconnection</b>	
<b>Site Layout</b>	Available Space – Minimum disconnection flow length: 60' Drainage Area – 1 ac maximum per unit Topography – 10% maximum
<b>Design Criteria</b>	Soil – Amend soils with infiltration rates less than 1 in/hr Water Table – 2' minimum separation
<b>Materials</b>	Vegetation – Intervals of vegetated areas are dictated by the design storm, road slope, sinuosity, location and other factors. An initial target distance of 20' can be used for both road length and vegetative flow path length.

Curb Cut, Sierra Tract 1b, South Lake Tahoe, CA. Credit: Eric Friedlander, CSLT



## DESIGN STRATEGIES

- **Reduce amount and peak of stormwater flow.** Where possible, use shallow unchannelized flow in lieu of piped discharge to increase the time of concentration of flow.
- **Direct flow into stabilized vegetated areas for infiltration and detention.** Flow can also be diverted from impervious surfaces via sheet flow to these vegetated areas.
- **Use curb cuts and curb removal for minor road runoff disconnection.** Peak flow can be attenuated using one of the strategies below: Disconnect runoff in streets by removing part of a curb and allow for infiltration into a depression or planter box; Install curb cuts at intervals and route flows through street and vegetated areas in an alternating fashion.

## BENEFITS

- Applicable with limited space constraints and under all soil conditions
- Reduces runoff volume and peak flow, provides infiltration and disconnects flow path
- Provides treatment of sediment, nutrients, metals, O&G and temperature
- Water Quantity: Reduces runoff volume and peak flow, provides infiltration and disconnects flow path
- Water Quality: Provides treatment of sediment, nutrients, metals, and temperature
- Relatively low construction and O&M cost and ease of maintenance
- Promotes groundwater recharge, and is aesthetically pleasing
- Conserves water and promotes groundwater recharge, and is aesthetically pleasing
- Takes advantage of already-required landscape areas; no additional space required
- Can reduce size of downstream stormwater quality treatment measures by reducing the volume required to treat
- Allows for tree preservation in areas requiring pavement
- Vegetated areas provide green space

## LIMITATIONS

- Potential for vector concerns due to standing water in vegetated features
- Water barrier will be required where porous material abuts regular asphalt/concrete pavement and there is concern about water infiltrating the regular pavement subbase
- Subsurface infiltration devices may eventually clog with sediment, requiring costly reconstruction
- Soil permeability may limit applicability of subsurface infiltration structures
- Do not use on sites with a likelihood of O&G or other hazardous spills
- Some very rocky/granite soils may allow for only limited infiltration

## COLD CLIMATE CONSIDERATIONS

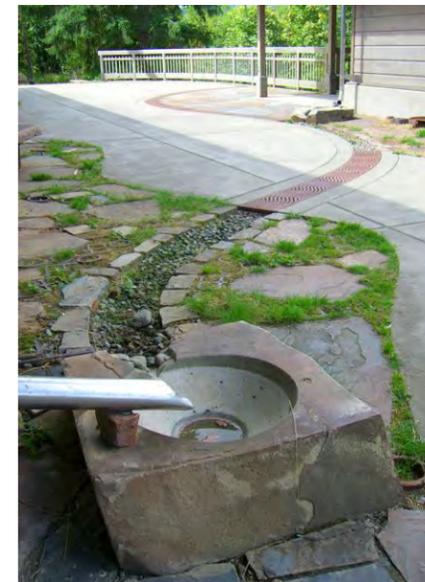
- **Depth of Freeze:** Insert underground components below the frost line to prevent frost heave and prevent water from freezing in pipes. Reduced soil infiltration will likely occur during winter months.
- **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months. Little or no roof runoff may occur during winter months.
- **Length of Growing Season:** Select cold climate appropriate plants for vegetated areas.
- **Rain on Snow Events:** Higher runoff volumes may occur during these events.
- **Snow Depth:** Select vegetation to withstand expected snow depths. Incorporate snow volume estimates when sizing storage volumes. Road deicers may cause additional sediment and/or pollutant loads during winter months.

## CONSTRUCTION CONSIDERATIONS

- **Soil Disturbance and Compaction:** Allow only vehicular traffic necessary for construction on the pervious areas where flow will be discharged. If vehicle traffic is unavoidable, then the pervious area should be tilled to a depth of 1' to loosen the compacted soil.
- **Erosion and Sediment Control:** If possible, direct construction runoff away from the proposed discharge location. After the contributing drainage area and the discharge location are stabilized and vegetated, remove erosion and sediment control structures.
- **Standing Water and Ponding:** Test areas to be vegetated to verify that standing water infiltrates or evaporates within 48 hours following a runoff event. When longer ponding periods are observed, improve soil infiltration by dethatching, aerating, tilling, regrading and/or adding compost.

## OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Irrigate and maintain vegetated areas to maintain infiltration and filtering capacity.
- Periodically check for clogging of any subsurface pipes or infiltration systems and repair as needed.
- Develop a maintenance agreement with property owners or managers to ensure that downspouts remain disconnected and the pervious area remains pervious.
- If ponding of water for longer than 48 hours occurs, the pervious area should be dethatched and aerated.
- If ponding persists, regrading or tilling to reverse compaction and/or addition of compost to improve soil moisture retention may be required.



Left: Downspout routed through sinuous gravel-lined decorative stormwater feature. Photo credit: Carrie Pak, CWS.

Below: Roof runoff flows to energy dissipator under gutter downspout. South Lake Tahoe, CA. Photo credit: Dana Olson, TRCD



## REFERENCES

- See Section 4.4 in the text for more information.
- *Low Impact Development Approaches Handbook*, 2009. CWS, *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- TRCA, *Low Impact Development Stormwater Management Planning and Design Guide*, 2010.
- SEMCOG, *Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers*. 2008.

## GENERAL DESCRIPTION

Rainwater and snowmelt harvesting consists of collecting, conveying and storing rainfall and snowfall for future indoor and outdoor uses. The purpose of this harvesting is to collect high quality water to offset potable water demands. The rain or snow that falls upon an impervious surface (e.g. roof, driveway, or walkway) is collected and conveyed into a storage tank (e.g. rain barrel or cistern). With minimal pretreatment (e.g., gravity filtration or first-flush diversion), the captured rainwater or snowmelt can be used for outdoor non-potable water uses such as irrigation and pressure washing, or in the building to flush toilets or urinals.

## PLANNING AND DESIGN STRATEGIES

### GENERAL GUIDELINES

COMPONENT	GUIDELINE
<b>Site Layout</b>	<p>Available Space – Place storage tanks underground, indoors, on roofs, or adjacent to buildings, outside of County ROW</p> <p>Building Setback – Make tanks water tight to avoid ponding or saturation of soils within 10' of building foundations</p> <p>Drainage Area – Dependent upon conveyance and storage tank sizing</p> <p>Topography – Influences the placement of the storage tank and design of the distribution and overflow systems</p>
<b>Design Criteria</b>	<p>Head – Locate rain barrels or above ground cisterns with gravity distribution systems up-gradient from irrigated areas</p> <p>Soil – Locate underground cisterns in native, rather than fill soil for stability</p> <p>Utility/Tree Clearance – Utilities may constrain the location of underground storage tanks</p> <p>Water Table – Can be used under various depth to water ranges</p>
<b>Pretreatment</b>	<p>Pretreat runoff to remove debris, dust, leaves, and other debris</p> <p>Use Leaf and mosquito screens (1 mm mesh size), first-flush diverter, or in-tank filter</p> <p>Use settling compartment for tanks over 2,500 gallons</p>
<b>Conveyance and Overflow</b>	<p>Rain barrels use head and gravity to feed hoses via a tap and spigot</p> <p>Use a water pump for underground cisterns. Indoor systems usually require a pump, pressure tank, back-up water supply line and backflow preventer</p> <p>Include an overflow system in the design (outflow pipe = inflow pipe size)</p>
<b>Storage</b>	<p>Tank size varies based on rainfall and snowfall frequencies and totals, end-use of water, the catchment surface area, aesthetics, and budget</p> <p>Storage tanks range in size from rain barrels for residential land uses (typically 50 to 100 gallons), to large cisterns (200-400 gallons) for industrial, commercial and institutional land uses</p> <p>Use opaque, potable or food-grade structurally sound materials to construct storage tanks</p> <p>Install tanks in locations where native soils or building structures can support the load from the stored water</p> <p>Childproof rain barrels and cisterns and seal against mosquitoes</p>
<b>Materials</b>	<p>Roof – Metal roofs are recommended</p> <p>Downspouts and Eavestroughs – Materials include PVC pipe, vinyl, aluminum and galvanized steel</p> <p>Do not use lead as solder</p>

## DESIGN STRATEGIES

- **Reduce volume of stormwater runoff** by directing downspout to a rain barrel with gravity distribution, routing multiple downspouts to a cistern and pump to reuse water, or collecting flows from impervious areas. Roof can also be used for snow storage, prior to snowmelt collection.
- **Reduce potable water demands** by using diverted and stored stormwater in lieu of potable water. Stored rain water and snowmelt can be used for non-potable uses, such as, landscaping, flushing toilets, and powerwashing.
- **Reuse stormwater prior to pollutant contamination**, as rainwater or snowmelt at the source is much cleaner than downstream runoff. Water from the roof or from low traffic areas is of higher quality and can be reused readily.

## BENEFITS

- Applicable with limited space constraints and under all soil conditions
- Reduces runoff volume and peak flow and disconnects flow path
- Does not add additional pollutants to runoff
- Relatively low construction and O&M cost and ease of maintenance
- Conserves water and promotes groundwater recharge
- Managing stormwater runoff (including rainfall and snowmelt) and pollutants close to the source can minimize costs of conveyance features
- Cisterns can be combined with pervious parking areas
- Rainwater harvesting systems can help reduce demand on municipal treated water supplies
- Reduced loads delay expansion of treatment and distribution systems, conserve energy used for pumping and treating water and lower consumer water bills
- It is estimated that these applications alone can reduce household municipal water consumption by up to half
- Where site designs permit, cisterns may be quite large, and shared by multiple households, achieving economies of scale
- Can be retrofitted into existing property

## LIMITATIONS

- Potential vector concerns should be addressed by using filter screens and keeping storage tanks covered.
- The stormwater volume/peak discharge rate benefits of cisterns and rain barrels depend on the amount of storage available at the beginning of each storm. One rain barrel may provide a useful amount of water for garden irrigation, but it will have little effect on overall runoff volumes, especially if the entire tank is not drained in between storms.
- Greater effectiveness can be achieved by having more storage volume and by designing the system with a continuous discharge to an infiltration mechanism, so that there is always available volume for retention.
- Rain barrels and cisterns offer no primary pollutant removal benefits. However, this water is often cleaner than downstream runoff.
- The water collected is for nonpotable uses only.
- Immediate use of harvested water is preferred to storage.

## COLD CLIMATE CONSIDERATIONS

- **Depth of Freeze:** Pipes are at risk for frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
- **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Little or no roof runoff may occur during winter months.

To prevent ice accumulation and damage during winter, place first-flush diverters or in-ground filters in a temperature controlled environment, bury below the local frost penetration depth or insulate or equip with heat tracing. Do the same with dual use cisterns and conveyance pipes leading to cisterns. Tank placement is recommended on the south side of the building. Insulate the tank outlet hose to the pump or services with mineral wool mat or molded insulation foam.

## CONSTRUCTION CONSIDERATIONS

- **Soil Disturbance and Compaction:** Allow only vehicular traffic necessary for construction on the pervious areas where flow will be discharged. If vehicle traffic is unavoidable, then the pervious area should be tilled to a depth of 1' to loosen the compacted soil.
- **Erosion and Sediment Control:** If possible, direct construction runoff away from the proposed discharge location. After the contributing drainage area and the discharge location are stabilized and vegetated, remove erosion and sediment control structures.
- **Standing Water and Ponding:** Test areas to be vegetated to verify that standing water infiltrates or evaporates within 48 hours following a runoff event. When longer ponding periods are observed, improve soil infiltration by dethatching, aerating, tilling, regrading and/or adding compost.

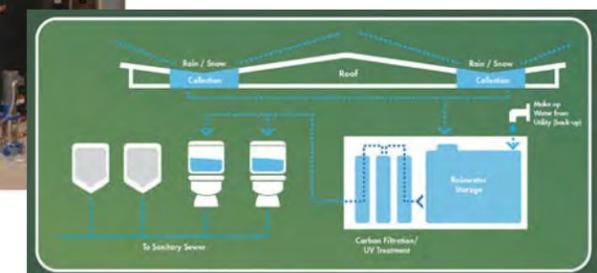
## OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Maintenance requirements for rainwater harvesting systems vary according to use
- Systems that are used to provide supplemental irrigation water have relatively low maintenance requirements, while systems designed for indoor uses have much higher maintenance requirements.
- Perform regular inspections every six months during the spring and fall seasons to keep leaf screens, eavestroughs and downspouts free of leaves and other debris; check screens and patch holes or gaps; clean and maintain first flush diverters and filters, especially those on drip irrigation systems; inspect and clean storage tank lids, paying special attention to vents and screens on inflow and outflow spigots; and replace damaged system components as needed.
- If screening is not sufficient to deter mosquitoes, use vegetable oil to smother larvae, or use mosquito dunks or pellets containing larvicide.



Left: TCES Rainwater Harvesting System with UV, Photo Credit: Heather Segale, TERC

Below: Water Capture System, Credit: Heather Segale, TERC



## REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- MAPC, *Mass LID Toolkit*, 2007.
- CASQA, *California Stormwater Best Management Practice Handbook, New Development and Redevelopment*, 2003.
- UDFCD, *Best Management Practices*, 1999.

## GENERAL DESCRIPTION

Dry wells and infiltration trenches store water in the void (pore) space between crushed stone or gravel where the water slowly percolates downward into the subsoil. An overflow outlet is needed for runoff from large storms that cannot be fully infiltrated by the trench or dry well.



Driveway runoff conveyed by slotted channel drain to infiltration system  
Photo Credits: Dana Olson, TRCD



Sloped driveway conveys runoff to infiltration trench

## CONSTRUCTION CONSIDERATIONS

- **Soil Disturbance and Compaction:** Before site work begins, clearly mark areas for dry well pits. Only allow vehicular traffic used for construction close to the strip.
- **Erosion and Sediment Control:** Do not use infiltration practices as a sediment control device during construction. Direct construction runoff away from the proposed filter strip site. After the site is vegetated, remove erosion and sediment control structures.

## PLANNING AND DESIGN STRATEGIES

### GENERAL GUIDELINES

COMPONENT	GUIDELINE
<b>Site Layout</b>	Building Setback – 20' minimum distance Drainage Area – <5ac maximum per unit Topography – 5% maximum contributing slope Install outside of County ROW
<b>Design Criteria</b>	Soil – Infiltration rates of existing site soils must be a minimum of 0.5 in/hr and a maximum of 2.4 in/hr, or use an underdrain Slope – do not apply on slopes greater than 20 percent Utility/Tree Clearance – do not locate under tree drip lines; Consider removing all trees within 10' Water Table – 10' minimum separation Wellhead Protection – 100' setback from potable water wells Maximum trench depth recommended is 10" The maximum depth of the stone in the dry well pit is 5'
<b>Infiltration Rate</b>	Drill borings to determine infiltration rate (one boring at each dry well, two borings at each infiltration trench), with additional borings at 50 feet intervals Determine the infiltrative capacity using a double-ring infiltrometer Base trench/drywell sizing on the slowest rate Do not use trenches or dry wells where soils are >30% clay or >40% silt clay
<b>Pretreatment</b>	Remove sediment prior to treatment to prevent reduction of infiltration capacity Vegetated filter strip, Vegetated swale, and Bioretention are all suitable pretreatment measures
<b>Conveyance and Overflow</b>	Inlet pipes are typically perforated pipe connected to a standard non-perforated pipe or eavestrough The overflow outlet can be the perforated pipe inlet that backs up and discharges to a splash pad and pervious area at grade or can be a pipe that is at the top of the gravel layer and is connected to a storm sewer Outlet pipes must have capacity equal to or greater than the inlet. Use distribution pipes with perforations of 0.5" that are capped at least 1 foot short of the wall of the trench or well
<b>Materials</b>	The dry well should be filled with uniformly-graded, washed 2" diameter stone with a 40% void capacity Trench should be filled with washed 3/4" to 1 1/2" drain rock Add optional horizontal layer of geotextile fabric layer 2"-6" below the trench surface to reduce sediment Non-woven filter cloth should be used to line the trench to prevent the pore space between the stones from being blocked by surrounding native material Trim tree roots flush with the trench sides in order to prevent puncturing or tearing the filter fabric Use an HDPE underdrain pipe that has a perforated, smooth interior, and minimum inside diameter of 4". Perforated pipe should run lengthwise through the dry well Install containment borders using pressure treated lumber, recycled composites, brick, stone, cobble, or other landscape edging material

### DESIGN STRATEGIES

- **Reduce peak discharge rate and total runoff volume** by infiltrating a portion of stormwater generated on-site, which will result in modest groundwater recharge.

### BENEFITS

- Reduce stormwater runoff volume, including most of the runoff from small frequent storms
- Reduce peak discharge rates by retaining the first flush of stormwater runoff and creating longer flow paths for runoff
- Reduce the size of more expensive downstream stormwater management structures

### LIMITATIONS

- Potential vector concerns due to standing water during infiltration
- Cannot receive untreated stormwater runoff, except roof- top runoff. Pretreatment is necessary to prevent premature failure that results from fine sediment, and to prevent potential groundwater contamination due to nutrient, salts, and hydrocarbons
- Can not be used to treat runoff from portions of the site that are not stabilized, and might result in erosion
- Rehabilitation of failed infiltration trenches requires complete reconstruction
- Difficult to use in slowly permeable soils or in fill areas

## COLD CLIMATE CONSIDERATIONS

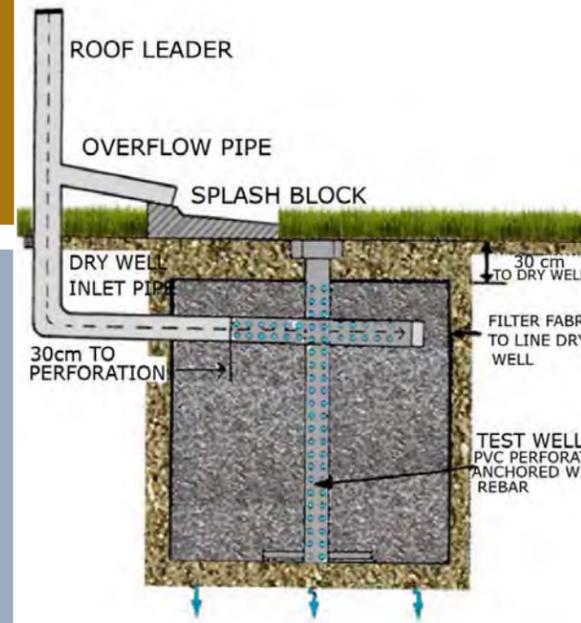
- **Depth of Freeze:** Pipes are at risk for freezing and/or frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
- **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months.
- **Rain on Snow Events:** Higher runoff volumes may occur during these events. To prevent ice accumulation and damage during winter, place conveyance pipes below the local frost penetration depth and/or insulate pipes. Increase depth of feature to keep stored runoff below frost line. Incorporate snow volume estimates when sizing storage volumes. Due to increased sediment and pollutant loads do not treat snow that has been exposed to deicers without pretreatment.



Infiltration Trench contoured along house  
Photo Credit: TRCA, 2010

## OPERATIONS AND MAINTENANCE CONSIDERATIONS

- After construction, inspect after every major storm for the first few months to ensure stabilization and proper function.
- On a monthly basis, remove sediment and oil/grease from pretreatment devices, overflow structures, and the surface of infiltration trenches.
- Semi-annually, check observation wells 3 days after a major storm. Failure to percolate within this time period indicates clogging.
- Semi-annually, inspect pretreatment devices and diversion structures for structural damage.
- If ponding occurs on the surface of an infiltration trench, remove and replace the topsoil or first layer of stone and top layer of filter fabric.
- Upon failure, perform total rehabilitation of the trench to maintain a storage capacity within 2/3 of the design treatment volume and 72-hour exfiltration rate.



Credit: TRCA, 2010



Dry Rock Dry Well  
Photo Credit: Dana Olson, TRCD

## REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- Massachusetts *LID Toolkit*, 2007.
- TRCD and NTCD, *Drip Line Infiltration Trench*, 2006.

## GENERAL DESCRIPTION

Bioretention areas (raingardens, tree pits, planters, and curb extensions) are planted depressions that store and filter rainwater to enhance water quality. Stormwater runoff flows into the cell and slowly percolates through the soil (which acts as a filter) and into the groundwater; some of the water is also taken up by the plants. Bioretention areas are usually designed to allow shallow ponding, with an overflow outlet to prevent flooding during heavy storms.

## PLANNING AND DESIGN STRATEGIES

### GENERAL GUIDELINES

COMPONENT	GUIDELINE
<b>Site Layout</b>	Available Space – Minimum dimensions 15' wide by 40' long Building Setback – If no impermeable liner, minimum 10' setback Drainage Area – Typically 1,000 sf to 1 ac Topography – Contributing slopes between 1 to 5%
<b>Design Criteria</b>	Freeboard – Allow 3" of freeboard above ponding depth to prevent flooding to adjacent parking areas Head – 3' minimum vertical distance from invert to inflow point Inlets and outlets should be located as far apart as possible Soil – Infiltration rates of existing site soils must be a minimum of 0.5 in/hr and a maximum of 2.4 in/hr, or use an underdrain Slope – Do not apply on slopes greater than 20 percent Water Table – Minimum 5' separation Wellhead Protection – Minimum separation of 100' from potable water supply wells
<b>Pretreatment</b>	Pre-treatment measures include, grass filter strip, and vegetated swale May also be used to infiltrate overflow from infiltration trench/drywell or rainwater harvesting
<b>Conveyance and Overflow</b>	The inflow conveyance may consist of, downspout, sheet flow, curb cuts, covered drain, or pop-up emitters. Overflow can either be diverted by: <ul style="list-style-type: none"> <li>• Sizing curb openings to capture only the water quality volume while higher flows remain in the gutter</li> <li>• Utility landscaping type inlets or standpipes with trash guards as overflow devices</li> <li>• Using a pre-treatment chamber with a weir design that limits flow to the filter bed area</li> </ul>
<b>Storage</b>	Snow can be stored in shallow depressions Water can be stored in pool areas
<b>Materials</b>	Vegetation – Planting plan generally includes one tree or shrub per 50 s.f. of bioretention area, and at least 3 species each of native herbaceous perennials, shrubs, and trees. Select plants that tolerate intermittent flooding, occasionally saline conditions, and extended dry periods. Filter medium – 85% sand, 10% fines, 5% organic matter Mulch layer – Shredded hardwood or bark Geotextile: Should be woven monofilament or non-woven needle punched fabrics. Woven slit film and non-woven heat bonded fabrics should not be used as they are prone to clogging. Gravel: Washed 2" diameter stone should be used to surround the underdrain and for the gravel drainage layer

## DESIGN STRATEGIES

- **Provide water quality treatment through filtration:** Bioretention areas treat stormwater runoff by passing it through a mixture of sand, soil, and organic material.
- **Increase groundwater recharge through infiltration:** Bioretention areas allow infiltration to occur over an extended time period to enhance overall infiltration.
- **Reduce peak discharge rates and total runoff volume:** Bioretention areas may be used to store excess stormwater when the downstream infiltration system has been surcharged.
- **Improve site landscaping:** Bioretention areas are typically installed in commercial, institutional, and residential sites in spaces that are traditionally pervious and landscaped.

## BENEFITS

- Properly designed cells remove suspended solids, metals, and nutrients, and can infiltrate an inch or more of rainfall.
- Can provide excellent pollutant removal and recharge for the "first flush" of stormwater runoff
- Increase groundwater recharge as compared to a conventional "pipe and pond" approach
- Low-tech, decentralized bioretention areas are also less costly to design, install, and maintain than conventional stormwater technologies that treat runoff at the end of the pipe.
- Bioretention areas enhance the landscape in a variety of ways: they improve the appearance of developed sites, provide wind breaks, absorb noise, provide wildlife habitat, and reduce the urban heat island effect.

## LIMITATIONS

- Potential vector concerns due to standing water in vegetated features
- Not suitable for locations where the seasonally high groundwater table is near the surface
- Clogging may be a problem in areas with high sediment loads in runoff
- Vegetation may require irrigation

## COLD CLIMATE CONSIDERATIONS

- **Depth of Freeze:** Pipes are at risk for freezing and/or frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
  - **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months.
  - **Length of Growing Season:** Select cold climate appropriate plants for vegetated areas.
  - **Rain on Snow Events:** Higher runoff volumes may occur during these events.
  - **Snow Depth:** Select vegetation to withstand expected snow depths.
- To prevent ice accumulation and damage during winter, place conveyance pipes below the local frost penetration depth and/or insulate pipes. Size facilities for coldest temperature removal rates (decreased biological activity, settling etc.), expect enhanced removal during non-winter months.
- Incorporate snow volume estimates when sizing storage volumes. Road deicers may cause additional sediment and/or pollutant loads during winter months.



**Left: Flow-through-Planter**

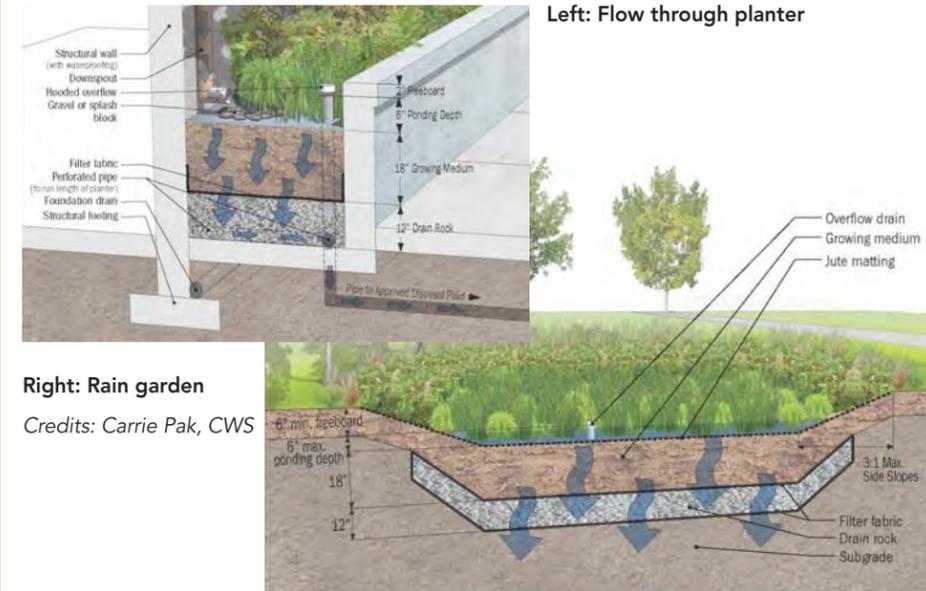
Photo Credit: Ed Armstrong, Foothill

**Right: Rain Garden**  
Photo Credit: Dana Olson, TRCD



## CONSTRUCTION CONSIDERATIONS

- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded, seeded, and/or planted areas with suitable erosion control materials.
- For planters flush with the surrounding landscape, install sediment controls (staked straw wattles) around the planter to prevent high sediment loads from entering during construction activities.
- Focus on erosion and sediment control, materials elevation, and landscape stabilization during Construction Inspection.



**Left: Flow through planter**

**Right: Rain garden**

Credits: Carrie Pak, CWS

## OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Inspect pretreatment devices and bioretention cells regularly for sediment build-up, structural damage, and standing water.
- Inspect soil and repair eroded areas monthly. Re-mulch void areas as needed. Remove litter and debris monthly.
- Treat diseased vegetation as needed. Remove and replace dead vegetation twice per year.
- Remove invasive species as needed to prevent these species from spreading into the bioretention area.
- Replace mulch every two years, in the early spring.
- Upon failure, excavate bioretention area, scarify bottom and sides, replace filter fabric and soil, replant, and mulch.

## REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- CASQA, *California Stormwater Best Management Practice Handbook, New Development and Redevelopment*, 2003.
- UDFCD, *Best Management Practices*, 1999.

POLLUTANT	% REMOVAL
TSS	75-90
TP	70-80
TN	65-80
ZINC	75-80
LEAD	75-80
ORGANICS	75-90
BACTERIA	75-90

## GENERAL DESCRIPTION

Vegetated filter strips (buffer strips and grass filter strips) are gently sloping, densely vegetated areas that treat runoff as sheet flow from adjacent impervious areas. They slow runoff velocity, filter out suspended sediment, provide some infiltration into underlying soils and are effective as a pretreatment practice. Vegetation may be comprised of a variety of trees, shrubs and groundcovers to add aesthetic value as well as water quality benefits. Vegetated Filter Strips provide a convenient area for snow storage and treatment, and are particularly valuable due to their capacity for snowmelt infiltration.



**Vegetated filter strip**  
Photo Credit: Carrie Pak, CWS

## CONSTRUCTION CONSIDERATIONS

- **Soil Disturbance and Compaction:** Clearly show the limits of disturbance on all construction drawings. Before site work begins, clearly mark areas for filter strips and protect them by using acceptable signage and silt fencing. Isolate construction vehicular traffic so that other traffic does not come near the filter strip.
- **Erosion and Sediment Control:** Direct construction runoff away from the proposed filter strip site. If used for sediment control during construction, regrade and revegetate after construction is finished.



## PLANNING AND DESIGN STRATEGIES

### GENERAL GUIDELINES

COMPONENT	GUIDELINE
<b>Site Layout</b>	Available Space – Ratio of drainage area and footprint = 6:1. Minimum 20' in direction of flow, 60' maximum for impervious surfaces, and 100' maximum for pervious surfaces Building Setback – 10' minimum separation
<b>Design Criteria</b>	Soil – All soil types Slope – Specify slopes should be between 1% and 15%, though slopes less than 5% are preferred. Design the top and toe of the slope to be as flat as possible. Water Table – Minimum 3' separation Sheet flow must be maintained across strips Vegetation – Requires dense vegetation minimum of 2" to 4" tall Normal velocity should be <1.0 ft/s for design flow, with maximum permissible velocity of 3.0 ft/s for peak discharge during 10-yr storm
<b>Pretreatment</b>	Functions well as a pretreatment device
<b>Conveyance and Overflow</b>	Use a cement level spreader or pea gravel diaphragm at the top of the slope. Filter strips can be designed with a pervious berm of sand and gravel at the toe of the slope. This feature provides an area for shallow ponding at the bottom of the filter strip. Runoff ponds behind the berm and gradually flows through outlet pipes in the berm. The volume ponded behind the berm should be equal to the water quality volume.
<b>Storage</b>	Snow can be stored on feature
<b>Materials</b>	Soil – If soils on the filter strip site are highly compacted, or of such low fertility that vegetation cannot become established, they should be tilled to a depth of 1' and amended with compost to achieve an organic content of 8 to 15% by weight or 30 to 40% by volume. Vegetation – Select vegetation that can withstand calculated flow velocities, and both wet and dry periods. Also consider depth to groundwater and choose facultative wetland species if appropriate.

### DESIGN STRATEGIES

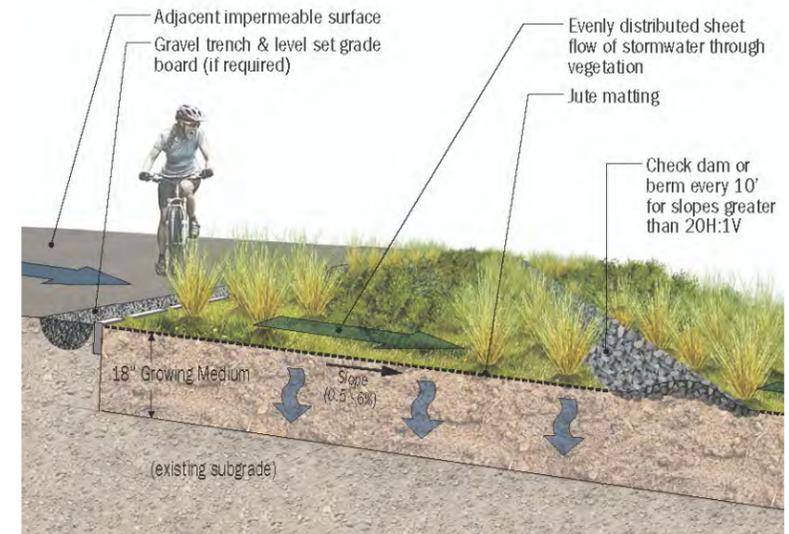
- **Reduce peak discharge rate and total runoff volume:** Vegetated filter strips redirect stormwater from pervious areas and slow the flow due to increased roughness in the vegetation.
- **Provide snow storage areas:** Grass filter strips provide areas where snow can be stored.

### BENEFITS

- **Provide runoff pretreatment by trapping, filtering and infiltrating particulates and associated pollutants.** Effectiveness depends largely on the quantity of water treated, the slope and length of the filter strip, the type of vegetation, and the soil infiltration rate
- **Reduce runoff velocities and increase the time of concentration as compared to channelized flow,** resulting in a reduction of erosion and peak discharge rates

### LIMITATIONS

- Because filter strips infiltrate runoff to groundwater, they could be inappropriate at stormwater "hotspots" (such as gas stations) with higher potential pollutant loads. Combine them with other LID features to ensure adequate treatment of polluted runoff prior to discharge.
- Channelization and premature failure may result from poor design, imprecise construction, or lack of maintenance. Proper design requires a great deal of finesse, and slight problems in the construction, such as improper grading, can render the practice less effective in terms of pollutant removal.
- Filter strips have low removal rates for nutrients, so use them in conjunction with other LID features.
- Filter strips often require lots of space, making them often infeasible in urban environments where land prices are high.
- Vegetation may require irrigation.



**Vegetated filter strip profile** Credit: Carrie Pak, CWS

## OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Inspect level spreader monthly and remove built-up sediment.
- Inspect vegetation monthly for rills and gullies and correct. Fill any depressions or channels. Seed or sod bare areas.
- In the year following construction, inspect the filter strip regularly to ensure that grass has established. If not, replace with an alternative species. Allow natural succession by native grasses and shrubs if it occurs.
- Mow grass, as rarely as 2-3 times per year, to maintain 4" to 6" of dense grass cover. Grass clippings should be collected and composted elsewhere. Provide a minimum of fertilizer only when necessary. Mow when the soil is dry and firm to prevent rutting.
- Semi-annually, remove sediment that has accumulated to prevent berms or channels.

## REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
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- UDFCD, *Best Management Practices*, 1999.

## COLD CLIMATE CONSIDERATIONS

- **Depth of Freeze:** Pipes are at risk for freezing and/or frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
  - **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months.
  - **Length of Growing Season:** Select cold climate appropriate plants for vegetated areas.
  - **Rain on Snow Events:** Higher runoff volumes may occur during these events
  - **Snow Depth:** Select vegetation to withstand expected snow depths.
- Install pipes components below the frost line to prevent frost heave and preventing water from freezing in pipes. Size facilities for coldest temperature removal rates (decreased biological activity, settling etc.), expect enhanced removal during non-winter months. Road deicers may cause additional sediment and/or pollutant loads during winter months.



**Vegetated filter strip traffic island**  
Photo Credit: Carrie Pak, CWS

## GENERAL DESCRIPTION

Vegetated swales are essentially bioretention cells that are configured as linear channels.

They are stormwater conveyance and soil filter systems that temporarily store and then filter the desired water quality volume. Stormwater is conveyed slowly through a vegetated swale due to roughness associated with plants, where it can pool behind shallow check dams. Stormwater is treated by filtering through the soil bed which can then flow to an underdrain, which conveys treated runoff back to the conveyance system further downstream.

## PLANNING AND DESIGN STRATEGIES

### GENERAL GUIDELINES

COMPONENT	GUIDELINE
<b>Site Layout</b>	Available Space – Footprint 5% to 15% of drainage area. Swale length > culvert length, Minimum swale length 100' Building Setback – Minimum 10' setback Drainage Area – Maximum drainage area 5 ac Topography – Do not apply in areas with adjacent slopes of 5% or greater or in areas with highly erodible soils
<b>Design Criteria</b>	Head – Elevation drop needed between inflow and outflow Soil – Minimum infiltration rate of 0.5 in/hr and a maximum of 2.4 in/hr, or use an underdrain Water Table – Minimum 2' separation Wellhead Protection – Minimum separation of 100' from potable water supply wells Shape – a trapezoidal or parabolic shape is preferable for aesthetic, maintenance and hydraulic reasons Bottom Width – 2' to 8' Side Slopes – Max 3:1 Swale Longitudinal Slope: Moderately flat with a slope between 1% and 2% is recommended. Slopes of up to 4% can be utilized, if check dams are used. It should be wide enough for maintenance access.
<b>Pretreatment</b>	Pre-treatment measures include, grass filter strip, and bioretention May also be used to infiltrate flow from roadway disconnection, infiltration trench/drywell or rainwater harvesting
<b>Conveyance and Overflow</b>	Inflow controls include: <ul style="list-style-type: none"> <li>Gravel diaphragm (sheet flow) at the end of pavement, perpendicular to the flow path. Select gravel that is clean and washed.</li> <li>Rip rap and/or dense vegetation (channel flow) can be used on smaller swales</li> </ul> Dry swales should be designed for a max velocity of 1 ft/s for the water quality design storm. The swale should also convey the locally required design storm (usually the 10 yr storm) at non-erosive velocities. Check dams at 50' intervals (<2' drop) help to maximize retention time, increase infiltration, promote particulate settling, and decrease flow velocities. Check dams are not necessary with very low longitudinal slopes. Provide scour protection below check dam.
<b>Storage</b>	Snow can be stored in shallow depressions Water can be stored behind check dams
<b>Materials</b>	Filter Media – soil mixture should be 85% sand, 10% soil fines, and 5% organic matter. Underdrain – Use a soil bed depth of 2' to 3' with a gravel/pipe underdrain system. The minimum interface between the underdrain gravel and the underlying soil should be 0.5'. Vegetation – Select salt-tolerant, native grasses, herbaceous plants, or trees that can withstand both wet and dry periods. Use taller and denser grasses, though the species is less important than good stabilization.

## DESIGN STRATEGIES

- Provide water quality treatment through filtration:** Vegetated swales treat stormwater runoff by conveying it through a rough vegetated pathway, where flow can infiltrate through a soil medium.
- Increase groundwater recharge through infiltration:** Vegetated swales allow infiltration to occur over an extended duration of time. Small check dams can be added perpendicular to the flow to add infiltration or step pools.
- Reduce peak discharge rates and total runoff volume:** Vegetated swales may be used to store excess stormwater when the downstream system has been surcharged.
- Provide a location for snow storage:** Vegetated swales provide an area for snow storage, where snow can be infiltrated as it melts.

## BENEFITS

- Swales help to control peak discharges by reducing runoff velocity, lengthening flow paths, and increasing time of concentration.
- Infiltration through the natural substrate helps to reduce total stormwater runoff volume.
- Swales provide effective pretreatment for downstream BMPs by trapping, filtering and infiltrating particulates and associated pollutants.
- Swales accent the landscape and may help to satisfy landscaping and greenspace requirements.
- Swales can provide a location for snow storage during winter months.
- Roadside swales effectively keep stormwater flows away from street surfaces.
- Construction may cost less than conventional curb and gutter systems.

## LIMITATIONS

- Potential vector concerns due to standing water in vegetated features
- Effectiveness decreased by compacted soils, frozen ground conditions, short grass heights, steep slopes, large storm events, high discharge rates, high velocities and short runoff contact time
- Effectiveness may be limited in areas where gophers or other burrowing animals are abundant
- Use swales carefully on industrial sites or areas of higher pollutant concentrations. If used, use them as part of a "treatment train" that includes other treatment features.
- Swales not effective at reducing soluble nutrients such as phosphorous
- In some places, the use of swales is restricted by law; many local municipalities may require curb and gutter systems in residential areas.
- Vegetation may require irrigation
- Swales take up more site area than conventional curb and gutter systems

## COLD CLIMATE CONSIDERATIONS

- Depth of Freeze:** Pipes are at risk for freezing and/or frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
- Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months.
- Length of Growing Season:** Select cold climate appropriate plants for vegetated areas.
- Rain on Snow Events:** Higher runoff volumes may occur during these events.
- Snow Depth:** Select vegetation to withstand expected snow depths.

To prevent ice accumulation and damage during winter, place conveyance pipes below the local frost penetration depth and/or insulate pipes. Size facilities for coldest temperature removal rates (decreased biological activity, settling etc.), expect enhanced removal during non-winter months. Incorporate snow volume estimates when sizing storage volumes. Road deicers may cause additional sediment and/or pollutant loads during winter months.

## CONSTRUCTION CONSIDERATIONS

- Prevent soil compaction by locating vegetated swales outside the limit of disturbance until construction of the swale begins.
- Do not locate vegetated swales in areas where sediment basins were located during construction, as the concentration of fines will prevent post-construction infiltration.
- To prevent sediment from clogging the surface of a vegetated swale, divert stormwater away from the swale until the drainage area is fully stabilized.
- Used clean and washed gravel for the underdrain, if present, so that no fines are present in the material.
- Rapidly stabilize the swale channel and side slopes with biodegradable geotextile blankets and seeding before bringing the swale "on-line".

## OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Develop permits for vegetated swales that specify schedules and responsibility for inspection and maintenance.
- Inspect on a semi-annual basis: Assess slope integrity, soil moisture, vegetative health, soil stability, compaction, erosion, ponding, and sedimentation.
- Mow at least once per year, but do not cut grass shorter than the design flow depth because the effectiveness of the vegetation in reducing flow velocity and pollutant removal may be reduced. Grass cuttings should be removed from the swale and composted.
- Remove accumulated sediment when it is 3" deep or higher than the turf, to minimize potential concentrated flows and sediment resuspension.
- Irrigate only as necessary to prevent vegetation from dying.
- Apply fertilizers and pesticides minimally.
- Reseed periodically to maintain dense turf.
- Remove trash or obstructions that cause standing water.
- Prevent off-street parking or other activities that can cause rutting or soil compaction.



**Vegetated Swales in Tahoe**

Left: Photo Credit: Dana Olson, TRCD

Right: Photo Credit: Allen Breuch, Placer County



## REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- MAPC, *Mass LID Toolkit*, 2007.
- CASQA, *California Stormwater Best Management Practice Handbook, New Development and Redevelopment*, 2003.
- UDFCD, *Best Management Practices*, 1999.

POLLUTANT	% REMOVAL
TSS	60-95
TP	5-45
TN	16-65
NITRATE	25-65
METALS	20-90
ORGANICS	75-90
BACTERIA	75-90

## GENERAL DESCRIPTION

Permeable paving allows rainwater to percolate through the paving and into the ground before it runs off. This approach reduces stormwater runoff volumes and minimizes the pollutants introduced into stormwater runoff from parking areas. All permeable paving systems consist of a durable, load bearing, pervious surface overlying a crushed stone base that stores rainwater before it infiltrates into the underlying soil. Permeable paving techniques include porous asphalt, pervious concrete, paving stones, and manufactured "grass pavers" made of concrete or plastic. Permeable paving may be used for walkways, patios, plazas, driveways, parking stalls, and overflow parking areas.

## PLANNING AND DESIGN STRATEGIES

### GENERAL GUIDELINES

COMPONENT	GUIDELINE
<b>Site Layout</b>	Available Space – Impervious areas should not exceed 2x the permeable pavement area Building Setback – Minimum 10' setback Drainage Area – Impervious areas should not exceed 2x the permeable pavement area Topography – Typical 1% to 5% slope. Maximum slope of contributing area: 20%
<b>Design Criteria</b>	Head – Minimum vertical distance between inflow and outlet is 1.5' to 3' Soil – Soils with infiltration less than 1 in/hr will need underdrain Utility/Tree Clearance – Consult local utilities for design guidance Water Table – Minimum separation of 3' Wellhead Protection – Minimum separation of 100' from potable water supply wells
<b>Conveyance and Overflow</b>	Underdrain – Construct with 4" perforated pipes Terminate outflow pipe 1' short of side of opening for base
<b>Storage</b>	Can be used for snow storage if snow is free of pollutants (e.g. sediment, oil) that may clog pavement Water can be stored in base course below permeable pavement prior to infiltration/runoff
<b>Materials</b>	Base Course – Reservoir layer of 1" to 2" crushed stone; depth to be determined by storage required and frost penetration depth Choice of base material is a compromise between stiffness, permeability, and storage capacity Use angular crushed rock material with a high surface friction to prevent traffic compaction and rutting Filter Course – 2" thick layer of 0.5" crushed stone is applied over the base course Geotextile fabric may be laid at the top of the filter layer to trap sediment and pollutants. Vegetation – select durable grass varieties and install by plug, seed, or sod
<b>Pervious Concrete Specs</b>	NO4-RG-S7 Proven to have the best freeze-thaw durability after 300 freeze- thaw cycles 28 day compressive strength = 5.5MPa to 20MPa Void Ratio = 14% to 31% Permeability= 35in/hr to 800in/hr
<b>Permeable Paver Specs</b>	Pavers to meet minimum material and physical properties set forth in the ASTM C 936 Pigment on concrete pavers must conform to ASTM C979 Max allowable breakage – 5% Min paver thickness 3" (vehicular) and 2.5" (pedestrian) Joint width max 0.6" (pedestrian)

## DESIGN STRATEGIES

- **Provide water quality treatment through filtration:** Permeable pavement acts as a filter to remove particulate matter from stormwater.
- **Increase groundwater recharge through infiltration:** Permeable pavement allows infiltration to occur.
- **Reduce peak discharge rates and total runoff volume:** The portion of flow that is filtered through the permeable pavement will reduce the overall amount of stormwater flowing downstream.
- **Infiltrate into storage areas:** Permeable pavement can be used to infiltrate stormwater into underground cisterns or storage areas (infiltration galleries)

## BENEFITS

- Permeable paving can infiltrate as much as 70% to 80% of annual rainfall.
- Porous pavement can reduce peak discharge rates significantly by diverting stormwater into the ground and away from the pipe-and-pond stormwater management system.
- Grass pavers can improve site appearance by providing vegetation.
- Porous paving increases effective developable area on a site because portions of the stormwater management system are located underneath the paved areas, and the infiltration provided by permeable paving can significantly reduce the need for large stormwater management structures on a site.

## LIMITATIONS

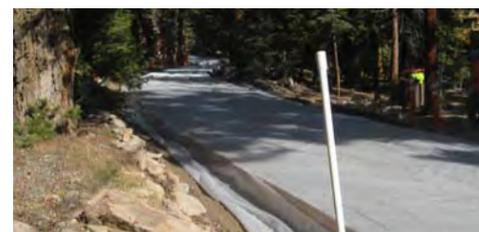
- Typically not to be applied on streets with speeds greater than 30 mph or streets with high traffic loads
- Permeable paving can be prone to clogging from sand and fine sediments that fill void spaces and the joints between pavers.
- In cold climates, the potential for frost heave may be a concern for the use of permeable paving. Some design manuals recommend excavating the base course to below the frost line, but this may not be necessary in rapidly permeable soils. In addition, the dead air and void spaces in the base course provide insulation so that the frost line is closer to the surface.
- Snow plows can catch the edge of grass pavers and some paving stones. Rollers should be attached to the bottom edge of a snowplow to prevent this problem.
- Permeable paving should not receive stormwater from other drainage areas, especially any areas that are not fully stabilized.

## COLD CLIMATE CONSIDERATIONS

- **Depth of Freeze:** Pipes are at risk for freezing and/or frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
- **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months.
- **Rain on Snow Events:** Higher runoff volumes may occur during these events. To prevent frost heave, increase depth of aggregate base to keep stored runoff below frost line. Incorporate snow volume estimates when sizing storage volumes. Do not use road deicers on permeable paving or allow contact with runoff that has been exposed to road deicers, to prevent clogging from added sediment load. Raise blades or add rollers on snow removal equipment in order to prevent damage to permeable pavement.



Base layer during construction



After pouring Photo Credits: Stefan Schuster, CDM

## CONSTRUCTION CONSIDERATIONS

- Fully protect treatment area throughout construction
- Compact aggregate with a minimum 10 ton steel drum
- Avoid extremely high and low temperatures during construction
- Test materials onsite
- Consult industry reps should be consulted for specifications on batching and placement
- Construct as one of the last items to be built on a development site, after most heavy construction vehicles are finished and after the majority of the landscaping work is completed.

## OPERATIONS AND MAINTENANCE CONSIDERATIONS

- The blade of the snow plow should be set 1 inch higher than normal when plowing on these surfaces. When contamination is an issue, do not direct snow piles and melt toward these systems.
- Post signs identifying porous pavement areas
- Minimize use of salt or sand during winter months
- Keep landscaped areas well-maintained and prevent soil from being transported onto the pavement
- Clean the surface using vacuum sweeping machines
- For paving stones, periodically add joint material (sand) to replace material that has been transported
- Monitor regularly to ensure that the paving surface drains properly after storms
- Do not reseal or repave with impermeable materials
- Inspect the surface annually for deterioration
- Grass pavers may require periodic reseedling to fill in bare spots
- Clean out drainage pipes and structures within or draining to the subsurface bedding beneath porous pavement at regular intervals



Leveling



Finished Project  
Photo Credits: PR Design & Engineering

## REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- MAPC, *Mass LID Toolkit*, 2007.
- UDFCD, *Best Management Practices*, 1999.

POLLUTANT	% REMOVAL
TSS	70-90
TP	40-55
TN	10-20
ZINC	40-80
LEAD	60-70
ORGANICS	75-90
BACTERIA	75-90

## GENERAL DESCRIPTION

Green roofs, also known as “living roofs” or “eco-roofs,” consist of a layer of vegetation and soil installed on top of a conventional flat or sloped roof. Green roofs are touted for their benefits to cities, as they can improve energy efficiency, reduce heat island effects, and create urban green space for passive recreation or aesthetics. Hydrologically speaking, the green roof assembly acts like a lawn or meadow by storing rainwater in the soil and pond areas. Excess rainfall flows to underdrains and overflow points and is conveyed in a typical building drainage system. After a storm, stored water either evaporates or is evapotranspired by the plants.



**Cedar Hotel Vegetated Roof**  
Photo Credit: Cedar House Sport Hotel

## PLANNING AND DESIGN STRATEGIES

### GENERAL GUIDELINES

COMPONENT	GUIDELINE
<b>Site Layout</b>	Available Space – Limited to rooftop Drainage Area – Green rooftops are designed to capture rainfall directly onto the surface Topography – Green rooftops may be installed on roofs with slopes up to 10%
<b>Design Criteria</b>	Soil – Soils with adequate infiltration rates (1 in/hr) Load – Roof structure must be able to support soil and plants of the green roof assembly, and maintenance staff accessing the roof. Slope – Can be used on roof slopes up to 10%. ASTM International released the following Green Roof standards in 2005: <ul style="list-style-type: none"> <li>• E2396-05 Standard Test Method for Saturated Water Permeability of Granular Drainage Media;</li> <li>• E2397-05 Standard Determination of Dead Loads and Live Loads associated with Green Roof Systems;</li> <li>• E2398-05 Standard test method for water capture and media retention of geocomposite drain layers for green roof systems;</li> <li>• E2399-05 Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems; and</li> <li>• E2400-06 Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems.</li> </ul>
<b>Conveyance and Overflow</b>	The drainage system includes a porous drainage layer and a geosynthetic filter mat to prevent fine soil particles from clogging the porous media. The drainage layer can be made up of gravels or recycled-polyethylene materials that are capable of water retention and efficient drainage. The depth of the drainage layer depends on the load bearing capacity of the roof structure and the stormwater retention requirements. The porosity of the drainage layer should be greater than or equal to 25%.
<b>Materials</b>	Waterproof Membrane – Modified asphalts (bitumens), synthetic rubber (EPDM), hypolan (CPSE), and reinforced PVC Modified asphalts usually require a root barrier, while EPDM and reinforced PVC generally do not Common european membrane design is a 60-80 mil PVC singleply roof system Growing Medium – Typically a mixture of sand, gravel, crushed brick, compost or organic matter combined with soil, 3” to 6” in depth, increasing the roof load by 16 lb/sqft to 35 lb/sqft when fully saturated Do not use growing media that contain phosphorus rich fertilizers or excessive nutrient levels Vegetation – Use low-growing, spreading perennial or self-sowing annuals that are drought tolerant including: sedum, delospermum, sempervivium, creeping thyme, allium, phloxes, anttenaria, ameria, and abretia Vegetation may be planted as vegetation mats, plugs or potted plants, sprigs (cuttings), or seeds

### DESIGN STRATEGIES

- **Reduce peak discharge rates and total runoff volume:** The portion of flow that is collected by a green roof will reduce the overall amount of stormwater flowing downstream.
- **Reduce heating and cooling costs through roof insulation:** Green roofs provide cooling effects through soil, plant, and water mixture on the roof which provides insulation.

### BENEFITS

- Green roofs reduce peak discharge rates by retaining runoff and creating longer flow paths. Research indicates that peak flow rates are reduced by 50% to 90% compared to conventional roofs, and peak discharge is delayed by an hour or more.
- Green roofs lower heating and cooling costs because the trapped air in the underdrain layer and in the root layer help to insulate the roof of the building. During the summer, sunlight drives evaporation and plant growth, instead of heating the roof surface. During the winter, a green roof can reduce heat loss by 25% or more.
- Because green roofs shield roof membranes from intense heat and direct sunlight, the entire roofing system has a longer lifespan than conventional roofs.
- The presence of a green roof helps to reduce air temperatures around the building, reducing the “heat island” effect and reducing the production of smog and ozone, which forms in the intense heat (175 degrees F) over large conventional roofs. The vegetation on green roofs also consumes carbon dioxide and increases the local levels of oxygen and humidity.
- Green roofs have demonstrated aesthetic benefits that can increase community acceptance of a high-visibility project; they may also add value to the property if marketed effectively.

### LIMITATIONS

- Load restrictions are usually the main limitation for green roofs in retrofit applications. A professional structural engineer must assess the necessary load reserves and design a roof structure that meets state and local codes.
- Slopes greater than 15% require a wooden lath grid or other retention system to hold substrate in place until plants form a thick vegetation mat.
- Green roofs should not be used where groundwater recharge is a priority, such as in aquifer recharge areas or watersheds experiencing low-flow stresses.
- The initial construction cost is higher than conventional roofs.
- Vegetation may require irrigation

### COLD CLIMATE CONSIDERATIONS

- **Extreme and Sustained Cold Temperature:** Permanent pool ice covering, reduced biological activity
- **Length of Growing Season:** Select cold climate appropriate plants for vegetated areas.

Size facilities for coldest temperature removal rates (decreased biological activity, settling etc.), but will see enhanced removal during non-winter months. Select climate appropriate vegetation.

### CONSTRUCTION CONSIDERATIONS

- Use an experienced professional green roof installer to install the green roof designed by an architect (or landscape architect) who must work with contractor to ensure that the waterproofing membrane installed is appropriate for use under a green roof assembly.
- Construct conventional green roof assemblies in sections for easier inspection and maintenance access to the membrane and roof drains.
- Green roofs can be purchased as a complete system from specialized suppliers who distribute all the assembly components, including the waterproofing membrane. Alternatively a professional landscape architect can design a customized green roof and specify different suppliers for each component of the system.

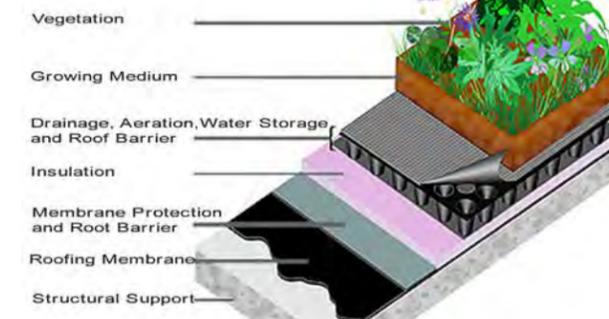
### OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Green roofs require some support during establishment and then yearly maintenance thereafter. Irrigate plants or sprigs until established, and additional plants or sprigs added to ensure good plant coverage if necessary. With drought-resistant vegetation, irrigation of an extensive green roof is rarely necessary after the two-year establishment period.
- Weed and mulch during the establishment period and periodically thereafter over the life of the roof. Remove any woody plants which become established on the roof.
- If necessary (many roofs can survive on deposition of airborne nitrogen and biomass breakdown), apply a slow-release fertilizer once a year will ensure continued vigorous growth of the vegetation. Do not use soluble nitrogen fertilizers and compost due to the potential for nutrient and bacteria export.



**Above: California Academy of Sciences Green Roof**  
Photo Credit: California Academy of Sciences

**Green Roof Layers**  
Credit: TRCA



### REFERENCES

- See Section 4.4 in the text for more information.
- CWS, *LID Approaches Handbook*, 2009.
- *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- MAPC, *Mass LID Toolkit*, 2007.

## GLOSSARY<sup>4</sup>

**Aggregate:** A broad category of particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates, and available in various particulate size gradations.

**Anthropogenic:** Of, relating to, or resulting from human activity.

**Aquifer:** A porous water-bearing formation of permeable rock, sand, or gravel capable of yielding a significant quantity of groundwater.

**Assimilative Capacity:** Capacity of a water body or watershed to receive and absorb pollutants while maintaining designated uses and water quality standards.

**Beneficial Use:** Uses of a water resource, such as recreation, aquatic life, and human consumption, which is protected by state water quality standards.

**Best Management Practice (BMP):** A practice or combination of practices that are the most effective and practicable (including technological, economic, and institutional considerations) means of controlling point or nonpoint source pollutants at levels compatible with environmental quality goals.

**Bioretention:** Also known as Rain Garden, Bio-Filter and an LID BMP. On-lot retention of stormwater through the use of vegetated depressions engineered to collect, store, and infiltrate runoff.

**Bioswale:** Shallow channels lined with grass and used to convey and store runoff.

**Buffer:** A vegetated area, forested or otherwise vegetated, located between water bodies such as streams, wetlands, and lakes, that provides a permanent barrier against runoff from development, agriculture, construction, and other land uses. Buffers are designed to filter pollutants in runoff before the pollutants reach surface waters.

**Carbon Sequestration:** The removal and storage of carbon from the atmosphere in carbon sinks (such as oceans, forests or soils) through physical or biological processes, such as photosynthesis.

**Catchment:** A drainage area, stormwater feature or structure that collects rainwater—drain inlet, basin, etc.

**Check Dam:** Structures constructed of a non-erosive material, such as suitably sized aggregate, wood, gabions, riprap, or concrete, used to slow runoff water to allow sedimentation, filtration, evapotranspiration, and infiltration into the underlying native soil. Check dams can be employed in practices such as dry and enhanced grass swales.

**Clean Water Act (CWA):** (33 U.S.C. 1251 et seq.) Requirement of the National Pollutant Discharge Elimination System (NPDES) program are defined under Sections 307, 402, 318 and 405 of the CWA.

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<sup>4</sup> Sources for the glossary are most recent and available LID design and guidance handbooks, as well as other pertinent sources.

**Cluster Development:** Designs that incorporate open space into a development site. In cluster patterns, buildings and roads are arranged on a compact portion of the site to reserve areas of common open space or greenways; these areas can be used for recreation or preserved as naturally vegetated land.

**Complete Street:** Roadways designed and operated to enable safe, attractive, and comfortable access and travel for all users, including pedestrians, bicyclists, motorists and public transport users of all ages and abilities.

**Connectivity:** A measurement of the continuity of a corridor such as a riparian corridor. Connectivity promotes valuable natural functions, such as movement of animals through their habitat and transport of materials and energy, which help maintain the integrity of natural communities.

**Conveyance System:** Any channel or pipe for collecting and directing stormwater.

**Depression Storage:** A technique for incorporating shallow depressed areas into urban landscaped areas for storing and infiltrating runoff. Typically, depression storage areas are small and have limited capacity and limited duration of retention in order to address property owner concerns relating to insects, damage to structures and inconvenience of ponded water on their property.

**Detention Basin:** The temporary storage of stormwater to control discharge rates, allow for infiltration, and improve water quality.

**Development:** Any construction, rehabilitation, redevelopment or reconstruction of any public or private residential project (whether single-family, multi-unit or planned unit development); industrial, commercial, retail and any other nonresidential projects, including public agency projects; or mass grading for future construction.

**Drainage Area:** An area that contributes all precipitation falling within its boundaries to a single common or outflow point.

**Dry Well:** Small excavated trenches filled with stone to control and infiltrate rooftop runoff.

**Dry Swale:** Linear bioretention cells designed to convey, treat and attenuate stormwater runoff. The engineered filter media soil mixture and vegetation slows the runoff water to allow sedimentation, filtration through the root zone, evapotranspiration, and infiltration into the underlying native soil.

**Eco-Friendly Landscaping:** Landscaping intended to conserve, protect, and enhance a site's natural resource systems through careful planning and design of site elements.

**Ecological Integrity:** Supporting and maintaining all components, biological, physical, and chemical components, of an ecosystem to a level comparable to that of natural habitats of the surrounding region.

**Ecosystem:** The network of a biological community and its surrounding interconnected physical and chemical environment.

**Edge Effect:** A condition in which otherwise suitable habitat becomes less suitable for a species because it is adjacent to land that is unsuitable habitat. The degradation of habitat may be due to predator species that live outside the patch, or increased competition with species that live outside the habitat patch.

**EPA:** Environmental Protection Agency.

**Erosion:** The process of soil detachment and movement by the forces of wind, water, gravity, and/or human activities.

**Evaporation:** Phase change of liquid water to water vapor.

**Evapotranspiration (ET):** The flux of water from land and water surfaces to the atmosphere by the combined processes of evaporation and transpiration. Evaporation can occur from hard surfaces such as rooftops and parking lots, from water surface features such as ponds, lakes, streams, marshes, and oceans, from soil surfaces, especially ponded and wet areas, and from vegetative surfaces such as forest canopies. Transpiration is the general uptake and release of water by vegetation to the atmosphere.

**Filtration:** The passage of a fluid through a porous medium (or media) in order to remove matter held in suspension.

**Filter Strip:** Bands of closely-growing vegetation, usually grass, planted between pollution sources and downstream receiving waterbodies.

**Filtration Rate:** The rate at which fluid passes through a porous medium (or media).

**First Flush:** Stormwater that initially runs off an area, which is typically more polluted (concentrated) than the stormwater that runs off later.

**Flood (Base Flood or 100-Year Flood):** The flood having a one percent chance of being equaled or exceeded in any given year.

**Floodplain:** Any land area susceptible to being inundated by water from any source (PCC 15.52, Flood Damage Prevention Ordinance).

**Floodway (aka Regulatory Floodway):** The channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than one foot.

**Flow-Through Planters:** Structural landscaped reservoirs placed on impervious surfaces used to collect, filter, and temporarily store stormwater runoff, allowing pollutants to settle and filter out as the water percolates through the planter soil until flowing through to an approved conveyance.

**French Drain:** A drain consisting of an excavated trench filled with pervious material, such as coarse sand, gravel, or crushed stone; water percolates through the material and flows to an outlet.

**Green Roof:** Conventional rooftops that include a thin covering of vegetation allowing the roof to function more like a vegetated surface. The layer thickness varies between 2-6 inches and consists of vegetation, waterproofing, insulation, fabrics, growth media, and other synthetic components.

**Green Street:** A Green Street uses a natural systems approach to reduce stormwater flow, improve water quality, reduce urban heating, enhance pedestrian safety, reduce carbon footprints, and beautify neighborhoods. Green Street features include vegetated curb extensions, sidewalk planters, landscaped medians, vegetated swales, permeable paving, and street trees. (EPA, 2009)

**Groundwater:** Water that is underground in cracks and spaces in soil, sand, and rocks. The layers of soil, sand, and rocks are also known as aquifers. Groundwater is used for drinking water by more than 50 percent of the U.S. population, including residents of rural areas.

**Groundwater Recharge:** The replenishment of existing natural water bearing subsurface layers of porous stone, sand, gravel, silt or clay via infiltration.

**Habitat Integrity:** Supporting and maintaining the physical and environmental conditions of an aquatic ecosystem to a level comparable to that of natural habitats of the surrounding region.

**Headwater:** The source of a river or stream. Typically a very small, permanently flowing or intermittent, waterway from which the water in a river or stream originates.

**Hydrologic Cycle:** The movement of rainfall from the atmosphere to the land surface, to receiving waters and then back to the atmosphere through evaporation.

**Hydrologically Functional Landscape:** A design approach for the built environment that attempts to more closely mimic the overland and subsurface flow, infiltration, storage, evapotranspiration, and time of concentration characteristic of the native landscape of the area.

**Hydrologic Soil Groups:** A soil classification system created by the National Resource Conservation Service (formerly Soil Conservation Service) based on the ability to convey and store water; divided into four groups:

- A – well drained sands and gravel, high infiltration capacity, high leaching potential and low runoff potential;
- B – Moderately drained fine to coarse grained soils, moderate infiltration capacity, moderate leaching potential and moderate runoff potential;
- C – Fine grained, low infiltration capacity, low leaching potential and high runoff potential;
- D – Clay soils, very low infiltration capacity, very low leaching potential and very high runoff potential.

**Hydrology:** The science dealing with the waters of the earth, their distribution on the surface and underground, and the cycle involving evaporation, precipitation, flow to the seas, etc.

**Hydromodification:** Alteration of the hydrologic characteristics of coastal and non-coastal waters, which in turn could cause degradation of water resources.

**Impervious Area:** A hard surface area (e.g., parking lot or rooftop) that prevents or retards the entry of water into the soil, thus causing water to run off the surface in greater quantities and at an increased rate of flow.

**Incised Channel:** A stream, river or channel where the bottom is lowered by erosion to the point where flood flows no longer reach the floodplain. Incised channels typically form in areas where changes in watershed land use increase the frequency, duration and volume of peak flow rates.

**Infill:** The development of undeveloped or underdeveloped land within a developed urban area with infrastructure (link services) available.

**Infiltration:** Best management practices (bed, trench, basin, well, etc.) that allow for rainfall to soak vertically into the soil mantle.

**Invasive Species:** A non-native plant species whose introduction has the potential to cause economic or environmental harm, or harm to human health.

**Leadership in Energy and Environmental Design (LEED):** A measuring system created by the U.S. Green Building Council that rates buildings based on their eco-friendliness in the areas of energy efficiency, water consumption, materials usage, indoor air quality and other contributions that promote sustainability in buildings.

**Life Cycle Analysis (LCA):** A technique to assess the environmental aspects and potential impacts associated with a product, process, or service, by:

- Compiling an inventory of relevant energy and material inputs and environmental releases;
- Evaluating the potential environmental impacts associated with identified inputs and releases;
- Interpreting the results to help the consumer make an informed decision.

**Lot-Level:** The treatment of urban runoff as close to the source area as possible through application of small scale stormwater management practices on individual properties that are linked to downstream conveyance and end-of-pipe practices.

**Low Impact Development (LID):** A total site design approach that conserves and uses existing natural site features and systems integrated with distributed, small-scale stormwater management controls (BMPs) to mimic or recreate the natural water balance for a site (definition used for purposes of this Guidebook).

**Monitoring:** Repeated observation, measurement, or sampling at a site, on a scheduled or event basis, for a particular purpose.

**Municipal Separate Storm Sewer System (MS4) Permit:** A NPDES permit issued by the Regional Water Quality Control Board for the discharge of stormwater from Municipal Separate Storm Sewer Systems.

**National Pollutant Discharge Elimination System (NPDES):** A regulatory program in the Federal Clean Water Act that prohibits the discharge of pollutants into surface waters of the United States without a permit.

**Native Vegetation:** Plants that historically co-evolved with the local ecology, geology and climate. EPA has categorized native (presettlement by Europeans) plant groups by Ecoregions.

**Open Space:** Land set aside for public or private use within a development that is not built upon.

**Operations and Maintenance (O&M):** The continuing activities required to keep storm water management facilities and their components functioning in accordance with design objectives.

**Ordinance:** A law, a statute, or a decree enacted by a municipal body, such as a city council or county board of supervisors. Ordinances often govern matters not already covered by state or federal laws (such as local zoning, safety and building regulations), but may also be used to require stricter standards in local communities than those imposed by state or federal law.

**Outfall:** The point where water discharges from a conduit, pipe, or drain to a stream, river, lake or other water body.

**Outlet:** The point at which water discharges from a structure such as a basin, a trench or a concrete structure to another structure or a pipe or channel.

**Peak Discharge Rate:** The maximum instantaneous rate of flow (volume of water passing a given point over a specific duration, such as cubic feet per second) during a storm, usually in reference to a specific design storm event.

**Permeable:** Soil or other material that allows the infiltration or passage of water or other liquids.

**Permeable or Pervious Pavement:** Asphalt or concrete rendered porous by the aggregate structure surfaces that allow water to pass through voids in the paving material and/or between paving units while providing a stable, load-bearing surface. An important component to permeable pavement is the reservoir base course, which provides stability for load-bearing surfaces and underground storage for runoff.

**Pollutant:** An elemental or physical material that can be mobilized or dissolved by water or air and creates a negative impact to human health and/ or the environment. Pollutants include suspended solids (sediment), heavy metals (such as lead, copper, zinc, and cadmium), nutrients (such as nitrogen and phosphorus), bacteria and viruses, organics (such as oil, grease, hydrocarbons, pesticides, and fertilizers), floatable debris, and increased temperature.

**Porosity:** Ratio of pore volume to total solids volume.

**Potable Water:** Water that is of suitable quality for drinking purposes. Drinking water.

**Precipitation:** Any form of rain or snow.

**Rain garden:** A lot-level bioretention cell designed to receive and detain, infiltrate and filter runoff, typically used for discharge from roof leaders.

**Rainwater Harvesting:** The practice of intercepting, conveying and storing rainwater for future use. The captured rainwater is typically used for outdoor non-potable water uses such as irrigation and pressure washing, or in the building to flush toilets or urinals or other uses that do not require potable water.

**Receiving Waters:** Surface waters, whether natural or man-made, into which materials are discharged.

**Recharge:** The infiltration and movement of surface water into the soil, past the vegetation root zone, to the zone of saturation or water table.

**Redevelopment:** Land-disturbing activity that results in the addition or replacement of impervious surface area on an already developed site. This may include the expansion of a building footprint, changes that are not part of routine maintenance, change to or an addition of a structure, and any related land disturbing activities.

**Retrofit (Stormwater application):** The installation of a new stormwater practice or the improvement of an existing one in a previously developed area.

**Riparian:** Of, or pertaining to, stream systems or stream corridors. Riparian areas usually include a stream channel, its banks, the floodplain, and associated vegetated buffers.

**Riparian Habitat:** The area adjacent to a stream or river (sometimes also used for lakes) that preserves water quality by filtering sediments and pollutants from stormwater before it enters the waterbody, protects banks from erosion, provides storage area for flood waters, preserves open space, and provides food and habitat for wildlife.

**Runoff:** Water flowing across the land that does not infiltrate the soil, but drains into surface or groundwater, or when rainfall exceeds the infiltration capacity of the land.

**Runon:** Stormwater surface flow or other surface flow that enters property that did not originate onsite.

**Sand Filter:** A packed-bed filter of sand or other granular material used to provide advanced secondary treatment of settled wastewater or septic tank effluent. Sand/media filters consist of a lined (e.g., impervious PVC liner on sand bedding) excavation or structure filled with uniform washed sand that is placed over an underdrain system. The wastewater is dosed onto the surface of the sand through a distribution network and allowed to percolate through the sand to the underdrain system, which collects the filter effluent for further processing or discharge.

**Sedimentation:** Particles of soil, sand, silt, clay, or organic matter that are deposited onto the bottom of any surface water or are left behind when water leaves.

**Setback:** The minimum distance that design elements must be placed from other elements. For example, houses usually have front, side, and rear yard setbacks from streets and other buildings.

**Soil Amendment:** Minerals and organic material added to soil to increase its capacity for absorbing moisture and sustaining vegetation.

**Stormwater Management:** The process of collecting, conveying, storing, treating, and disposing of storm water to ensure control of the magnitude and frequency of runoff to minimize the hazards associated with flooding and the impact on water quality caused by manmade changes to the land.

**Storm Water Pollution Prevention Plan (SWPPP):** A written document that describes the activities required to control the discharge of pollutants in storm water and non-storm water runoff. It is intended to facilitate a process whereby the operator evaluates potential pollutant sources at the site and selects and implements appropriate BMPs.

**Stream Corridor:** The ecosystem surrounding a stream, linear in shape, that includes the stream channel, riparian vegetation, floodplains, streambank, tributary streams, and trails, roads, and other development.

**Suspended Solids:** Organic and inorganic particles suspended in the water column and carried by the water. The presence of suspended solids in water may reduce the amount of light reaching the water column, clog the gills of fish and other animals, and are often associated with toxic contaminants that bind to particles.

**Sustainability:** Sustainability means using, developing and protecting resources at a rate and in a manner that enables people to meet their current needs and also provides that future generations can meet their own needs.

**Swale:** A shallow stormwater channel that can be vegetated with some combination of grasses, shrubs, and/or trees designed to slow, filter, and often infiltrate stormwater runoff.

**Topography:** The detailed mapping or charting of the elevation and features of a relatively small area, district, or locality.

**Total Maximum Daily Load (TMDL):** Calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards and allocation of that amount to the pollutant's sources.

**Total Suspended Solids (TSS):** The weight of all suspended solids in water.

**Tributary:** A stream or river that feeds into a larger stream, lake, or river.

**Turbidity:** Measures the clarity of water. High turbidity results when there are a lot of particulates floating around and the water is cloudy. Low turbidity results when there are few floating particulates and the water is clear.

**Variance:** A request to a zoning authority to deviate from the approved development standards of a particular area. For instance, a variance might be requested to reduce a 40-ft front yard setback to 20 ft so that houses might be sited closer to the street.

**Vegetated Filter Strip:** Gently sloping, densely vegetated areas that treat runoff as sheet flow from adjacent impervious areas. They function by slowing runoff velocity and filtering out suspended sediment and associated pollutants, and by providing some infiltration into underlying soils. Also known as buffer strips and grassed filter strips.

**Vegetated Swale:** A long and narrow, trapezoidal or semicircular channel, planted with a variety of trees, shrubs, and grasses or with a dense mix of grasses. Stormwater runoff from impervious surfaces is directed through the swale, where it is slowed and in some cases infiltrated, allowing pollutants to settle out. Check dams are often used to create small ponded areas to facilitate infiltration.

**Underdrain:** A perforated pipe used to assist the draining of soils in some LID applications that have impaired infiltration.

**Urban Heat Island:** An urban heat island (UHI) is a metropolitan area which is significantly warmer than its surrounding rural areas.

**Water Balance:** The accounting of inflow and outflow of water in a system according to the components of the hydrologic cycle.

**Water Sensitive Urban Design:** A philosophical approach to urban planning and design that aims to minimize hydrologic and water quality impacts of urban development.

**Water Table:** Subsurface water level defined by the level below which all the spaces in the soil are filled with water; the entire region below the water table is called the saturated zone.

**Watershed:** Ecosystem consisting of three major components—stream channel, floodplain, and upland areas—that function together and drain to water bodies, including lakes, rivers, estuaries, wetlands, streams, and the surrounding landscape.

**Zoning:** Regulations governing the use, placement, spacing, and size of land and structures within a specific area.

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		Site Condition Factors							Runoff Man.			Pollutant Control				Implementation			Ancillary Benefits																
Legend: ● Very Effective ○ Moderately Effective ○ Mildly Effective X Applicable □ Not Applicable		Minimum Infiltration Rate Requirement	Minimum Head Requirement	Setback Distance Requirement	Slope > 25%	Minimum Depth to Groundwater Limitation	Substantial Additional Footprint	Vector Concerns	Long Life Expectancy, >= 20 years	Provides Detention / Impoundment Storage	Increases SW Runoff Travel Time	Reduces Volume of Overall SW Runoff	Metals Reduction	Nutrient Reduction	Oil and Grease/ Hydrocarbon Reduction	Sediment Reduction	Temperature Reduction	Construction Cost (\$ / cf)	Construction Cost (\$ / feature)	Annual O&M Cost (\$)	Reduces Public Agency Maintenance Costs	High Elevation Winter Conditions	Provides Evapotranspiration (ET)	Provides Habitat	Promotes GW Recharge	Provides Shade (Reduces Heat Island Effect)	Reduces Greenhouse Gases	Reduces Energy Use	Aesthetically Pleasing	Reduces Downstream Erosion and Flooding	Enhances Property Value				
ID	<b>LID Site Design (SD) Measures</b>																																		
SD-1	Protect Natural Conditions and Sensitive Areas										6,9,10, BPEJ		6,9,10, BPEJ																						
SD-2	Optimize Site Layout										10,13, BPEJ		10, 13, BPEJ																						
SD-3	Control Pollutants at Source										1,7, BPEJ		1, 7, BPEJ																						
SD-4	Integrate Eco-Friendly Landscaping										10,14, BPEJ		10, 14, BPEJ																						
	<b>LID Runoff Management (RM) Measures</b>																																		
RM-1	Stormwater Disconnection	2,4									2,3, BPEJ		2,3, BPEJ																						
RM-2	Rainwater and Snowmelt Harvesting	1,2, 3, 4																																	
RM-3	Infiltration Trench / Dry Well	1,2, 4																																	
RM-4	Bioretention																																		
RM-5	Vegetated Filter Strip	1,2, 3, 4								3	1,7,8, BPEJ		1,7,8, BPEJ																						
RM-6	Vegetated Swale																																		
RM-7	Permeable Pavement																																		
RM-8	Green Roof	2,3									2,3		2,3																						

TAC Technical Advisory Committee (TAC)

BPEJ Best Professional Engineering Judgment

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### **RM-1 Stormwater Disconnection**

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### **RM-3 Infiltration Trench/ Dry Well**

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*Stormwater BMP Design Supplement for Cold Climates*. 1997 (December). Prepared for US EPA Office of Wetlands, Oceans and Watersheds and US EPA Region 5. Prepared by Deb Caraco and Richard Claytor Center for Watershed Protection.

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## APPENDIX A RECOMMENDED PLANTS AND TREES

The matrix included in this appendix was developed by Robie Wilson Litchfield, a vegetation expert from the Tahoe Region, and one of the Placer LID Guidebook Technical Advisory Committee members.

The information is intended as a general guide for identifying plants and trees likely to be suitable for use in LID site design in the High Sierra areas of Placer County, the focus area for this Guidebook. The information is not exhaustive, and is not a substitute for the planting recommendations of a qualified landscape professional who is familiar with LID and has conducted a site and design-specific evaluation of project conditions.

# Plant Selection Guidance for Low Impact Development Features in the Placer County Sierra Nevada

PLANTS <sup>1</sup>			Drought & Inundation Tolerance <sup>2</sup>			Defensible Space Considerations <sup>3</sup>		Origin		Suitability for Use with LID Features (see Guidebook Chapter 3)							
Scientific Name	Common Name	Optimal Site Conditions <small>Habitat/water requirements, sun, shade, part shade, special notes</small>	Tolerant of both Wet and Dry Periods	Better with Supplemental Irrigation	Requires Supplemental Irrigation	Fire Hazard	Native	Adapted Non-Native	RM-1 Disconnected Flow Paths	RM-2 Suitable for Snow Storage	RM-4 Bioretention	RM-5 Vegetated Filter Strips	RM-6 Grass Swale or Vegetated Swale	RM-7 Permeable Pavement	RM-8 Green Roof		
<b>Shrubs</b>																	
<i>Acer circinatum</i>	Vine Maple	wet to moderately wet, shade to part sun, accent, California native	●	●	●	●		●									
<i>Acer ginnala</i>	Amur Maple	moderately wet, sun to part shade	●	●	●	Unknown		●									
<i>Acer glabrum</i>	Rocky Mountain Maple	wet to moderately wet, part shade	●	●	○	Unknown	●		●		●						
<i>Alnus tenuifolia</i>	Mountain Alder	wet, sun to part shade	●	●	○	●	●		●		●						
<i>Amelanchier alnifolia</i>	Western Serviceberry	moderately wet to dry, sun to part shade	●	●	○	Unknown	●		●		●	●					
<i>Arctostaphylos patula</i>	Greenleaf Manzanita	dry, sun, rarely available	●	○	○	●	●			●							
<i>Artemisia tridentata</i>	Sagebrush	dry, sun	○	○	○	●	●			●							
<i>Betula occidentalis</i>	Western River Birch	wet to moderately wet, sun to part shade	●	●	●	●	●		●	●	●						
<i>Ceanothus cordulatus</i>	Mountain Whitethorn	moderately wet to dry, pale yellow sun to part shade	○	○	○	●	●			●							
<i>Chrysolepis sempervirens</i>	Chinquapin	moderately wet to dry, sun	○	○	○	●	●			●							
<i>Chrysothamnus nauseosus</i>	Rabbitbrush	dry, sun	○	○	○	●	●			●		●					
<i>Cornus sericea</i>	Redstem Dogwood	wet to moderately wet, sun to part shade	●	●	●	○	●		●	●	●						
<i>Holodiscus discolor</i>	Creambush	moderately wet to dry, white sun to part shade	●	●	○	Unknown	●				●						
<i>Lonicera involucrata</i>	Twinberry	wet to moderately wet, part shade	●	●	○	Unknown	●		●	●	●						
<i>Lonicera tatarica</i>	Tatarian Honeysuckle	wet to moderately wet, full sun to part shade, poisonous berries	●	●	●	Unknown		●			●						
<i>Physocarpus capitatus</i>	Ninebark	wet to moderately wet, sun to part shade	●	●	●	Unknown		●									
<i>Pinus mugo mugo</i>	Dwarf Mugo Pine	moderately wet to dry, sun to part shade	●	●	●	●		●		●							
<i>Potentilla fruticosa</i>	Shrubby Cinquefoil	wet to moderately wet, sun to part shade, many cultivars	●	●	●	Unknown	●		●	●							
<i>Prunus cistena</i>	Western Sandcherry	moderately wet, sun to part shade, unsuitable for upper elevation snow loads	●	●	●	●		●									

PLANTS <sup>1</sup>			Drought & Inundation Tolerance <sup>2</sup>			Defensible Space Considerations <sup>3</sup>	Origin		Suitability for Use with LID Features (see Guidebook Chapter 3)							
Scientific Name	Common Name	Optimal Site Conditions <small>Habitat/water requirements, sun, shade, part shade, special notes</small>	Tolerant of both Wet and Dry Periods	Better with Supplemental Irrigation	Requires Supplemental Irrigation	Fire Hazard	Native	Adapted Non-Native	RM-1 Disconnected Flow Paths	RM-2 Suitable for Snow Storage	RM-4 Bioretention	RM-5 Vegetated Filter Strips	RM-6 Grass Swale or Vegetated Swale	RM-7 Permeable Pavement	RM-8 Green Roof	
<b>Shrubs</b>																
<i>Prunus emarginata</i>	Bittercherry	moderately wet, sun to part shade	●	○	○	Unknown	●			●	●					
<i>Prunus virginiana var. demissa</i>	Western Chokecherry	moderately wet, sun to part shade	●	●	○	Unknown	●		●	●						
<i>Purshia tridentata</i>	Bitterbrush	dry, sun	○	○	○	●	●			●						
<i>Quercus vaccinifolia</i>	Huckleberry Oak	moderately wet to dry, sun	○	○	○	●	●									
<i>Rhamnus rubra</i>	Sierra Coffeeberry	moderately wet to dry, sun	○	○	○	Unknown	●									
<i>Rhus trilobata</i>	Skunkbrush Sumac	moderately wet to dry, sun to part shade	○	○	○	Unknown		●		●						
<i>Ribes alpinum</i>	Alpine Currant	wet to moderately wet, sun to part shade	●	●	●	○	●			●						
<i>Ribes aureum</i>	Golden Currant	moderately wet to dry, sun to part shade	○	●	●	Unknown		●		●						
<i>Ribes cereum</i>	Wax Currant	moderately wet to dry, sun	○	○	○	Unknown		●		●						
<i>Ribes nevadense</i>	Sierra Currant (Mountain Pink Currant)	wet to moderately wet, sun part shade	●	●	○	Unknown	●		●	●	●	●				
<i>Ribes roezlii</i>	Sierra Gooseberry	moderately wet to dry, sun to part shade	○	○	○	Unknown	●			●		●			●	
<i>Ribes viscosissimum</i>	Sticky Currant	moderately wet to dry, sun	○	○	○	Unknown	●									
<i>Rosa rubrifolia</i>	Redleaf Rose	moderately wet, sun to part shade	○	●	○	Unknown		●		●						
<i>Rosa rugosa</i>	Tomatoe Rose	moderately wet, sun to part shade, accent	○	●	○	○		●		●	●	●				
<i>Rosa woodsii</i>	Wood's Rose	moderately wet, pink sun to part shade	●	○	○	Unknown	●		●	●	●	●				
<i>Salix exigua</i>	Narrow-leaved Willow	wet, sun to part shade, SEZ, invasive	●	●	○	○	●		●							
<i>Salix geeyeriana</i>	Geyer's Willow	wet, sun to part shade, SEZ	●	●	○	○	●		●							
<i>Salix lemmonii</i>	Lemmon's Willow	wet, sun to part shade, SEZ	●	●	○	○	●		●	●						
<i>Salix purpurea 'nana'</i>	Dwarf Arctic Willow	wet to moderately wet, sun to part shade	○	●	●	○		●	●							
<i>Salix scouleriana</i>	Scouler's Willow	wet to moderately wet, sun to part shade	●	●	○	○	●		●	●						
<i>Sambucus cerulea mexicana</i>	Blue Elderberry	wet to dry, sun to part shade	○	○	○	Unknown	●			●		●				
<i>Sambucus racemosa</i>	Red Elderberry	wet to moderately wet, sun to part shade	○	○	○	Unknown	●			●						
<i>Sorbus californica</i>	Mountain Ash	wet to moderately wet, part shade, rarely available	●	●	●	Unknown	●		●		●					

PLANTS <sup>1</sup>			Drought & Inundation Tolerance <sup>2</sup>			Defensible Space Considerations <sup>3</sup>	Origin		Suitability for Use with LID Features (see Guidebook Chapter 3)							
Scientific Name	Common Name	Optimal Site Conditions <small>Habitat/water requirements, sun, shade, part shade, special notes</small>	Tolerant of both Wet and Dry Periods	Better with Supplemental Irrigation	Requires Supplemental Irrigation	Fire Hazard	Native	Adapted Non-Native	RM-1 Disconnected Flow Paths	RM-2 Suitable for Snow Storage	RM-4 Bioretention	RM-5 Vegetated Filter Strips	RM-6 Grass Swale or Vegetated Swale	RM-7 Permeable Pavement	RM-8 Green Roof	
<b>Shrubs</b>																
<i>Spiraea densiflora</i>	Mountain Spirea	wet to moderately wet, sun to part shade	●	●	○	Unknown	●		●	●	●				●	
<i>Spiraea spp.</i>	Spirea species - Snowmound, Goldflame, etc	wet to moderately wet, sun to part shade, many varieties	○	●	●	Unknown		●		●						
<i>Symphoricarpos albus var. laevigata</i>	Snowberry	wet to moderately wet, sun to part shade	○	●	○	Unknown		●	●	●	●					
<i>Syringa spp.</i>	Lilac Hybrids	moderately wet, sun to part shade, accent, many cultivars	○	●	●	○										
<i>Syringa vulgaris</i>	Common Lilac	moderately wet, sun to part shade, accent	○	●	●	○		●								
<b>Perennials and Annuals</b>																
<i>Viburnum spp.</i>	Viburnum species	moderately wet, sun to part shade, many species and cultivars	○	●	●	Unknown		●								
<i>Aconitum napellus</i>	Monkshood	wet to moderately wet, part shade	●	●	○	○		●	●	●	●					
<i>Aconitum columbianum</i>	Columbian Monkshood	wet to moderately wet, part shade	●	●	●	○	●		●	●						
<i>Aquilegia formosa</i>	Crimson/Western Columbine	wet to moderately wet, sun to part shade	●	●	○	○	●		●	●	●					
<i>Aquilegia spp.</i>	Columbine	moderately wet, sun to part shade, many cultivars	●	●	●	○			●	●	●					
<i>Arnica chamissonis ssp. foliosa</i>	Arnica	moderately wet, sun	●	●	○	○	●			●	●					
<i>Aster occidentalis</i>	Western Mountain Aster	wet to moderately wet, sun to part shade	●	●	○	○			●	●	●	●	●			
<i>Aster species</i>	Aster	wet to moderately wet, sun to part shade, many cultivars	○	●	●	○	●	●	●	●	●					
<i>Astilbe chinensis</i>	Meadowsweet	moderately wet, shade to part shade, accent	○	●	●	○		●	●	●	●					
<i>Balsamorhiza sagittata</i>	Arrowleaf Balsam Root	moderately wet to dry, sun to part shade	●	●	○	○	●			●	●	●	●			
<i>Delphinium glaucum</i>	Mountain Larkspur	wet to moderately wet, sun to part shade	●	●	○	○	●		●	●	●					
<i>Delphinium spp.</i>	Larkspur/Delphinium	wet to moderately wet, sun to part shade, many cultivars, accent	○	●	●	○		●	●	●	●					
<i>Dianthus spp.</i>	Sweet William, Pinks	moderately wet sun to part shade	○	●	●	○		●	●	●	●					
<i>Dicentra spp.</i>	Bleeding Heart	moderately wet, shade, accent	○	●	●	○	●		●	●	●					

PLANTS <sup>1</sup>			Drought & Inundation Tolerance <sup>2</sup>			Defensible Space Considerations <sup>3</sup>	Origin		Suitability for Use with LID Features (see Guidebook Chapter 3)							
Scientific Name	Common Name	Optimal Site Conditions <small>Habitat/water requirements, sun, shade, part shade, special notes</small>	Tolerant of both Wet and Dry Periods	Better with Supplemental Irrigation	Requires Supplemental Irrigation	Fire Hazard	Native	Adapted Non-Native	RM-1 Disconnected Flow Paths	RM-2 Suitable for Snow Storage	RM-4 Bioretention	RM-5 Vegetated Filter Strips	RM-6 Grass Swale or Vegetated Swale	RM-7 Permeable Pavement	RM-8 Green Roof	
<b>Perennials and Annuals</b>																
<i>Digitalis spp.</i>	Foxglove	moderately wet, sun to part shade, accent	●	●	○	○		●	●	●	●					
<i>Echinacea purpurea</i>	Purple Coneflower	moderately wet to dry, sun, accent	●	●	○	○ / ●		●		●	●	●				
<i>Epilobium angustifolium</i>	Fireweed	wet to moderately wet, sun to part shade	●	●	○	○	●		●	●	●	●	●			
<i>Epilobium canum spp latifolium</i>	California Fuchsia	moderately wet to dry, sun	○	○	○	○	●		●						●	
<i>Eriogonum umbellatum</i>	Sulphur-Flower Buckwheat	sun, dry	○	○	○	○	●	●		●					●	
<i>Eschscholzia californica</i>	California Poppy	moderately wet to dry, sun to part shade, annual	○	●	○	○	●			●	●	●			●	
<i>Gaillardia spp.</i>	Blanket Flower	moderately wet to dry, sun to part shade	○	●	○	○		●		●					●	
<i>Geranium richardsonii</i>	Richardson's Cranesbill	wet to moderately wet, part shade	●	●	●	○	●			●	●					
<i>Geranium spp.</i>	Hardy/Cranesbill Geranium	wet to dry, sun to part shade	●	●	○	○		●	●	●	●	●	●			
<i>Gilia agregata</i>	Scarlet Gilia	moderately wet to dry, sun to part shade	○	○	○	○		●		●						
<i>Hemerocallis spp.</i>	Daylily species	moderately wet, sun to part shade, many cultivars, accent	●	●	●	○		●	●	●	●					
<i>Hemerocallis 'Stella D'Oro'</i>	Stella D'Oro Daylily	yellow sun to part shade, 12-14'	●	●	●	○		●	●	●	●				●	
<i>Heracleum lanatum</i>	Cow Parsnip	wet to moderately wet, sun to part shade	●	●	○	○	●		●	●	●					
<i>Heuchera species</i>	Coral Bells, Alumroot	wet to moderately wet, shade to part shade	●	●	●	○		●		●	●					
<i>Iberis sempervirens</i>	Candytuft	moderately wet to dry, sun, accent	●	●	○	Unknown		●		●					●	
<i>Iris missouriensis</i>	Western Blue Flag Iris	wet to moderately wet, sun to part shade	●	●	○	○	●		●	●	●	●	●			
<i>Iris spp.</i>	Bearded Iris, Siberian Iris, accent	wet to dry, sun to part shade, many cultivars, accent	●	●	●	○		●		●						
<i>Lavandula angustifolia</i>	English Lavander	dry, sun	●	●	○	○		●		●					●	
<i>Leucanthemum x superbum</i>	Shasta Daisy	moderately wet to dry, sun to part shade	●	●	○	○		●		●						
<i>Ligularia stenocephala</i>	Ligularia 'The Rocket'	wet to moderately wet, shade, accent	○	●	●	○		●	●	●	●					
<i>Lilium pardalinum</i>	Leopard Lily	wet, sun to part shade	●	●	○	○	●		●	●	●					

PLANTS <sup>1</sup>			Drought & Inundation Tolerance <sup>2</sup>			Defensible Space Considerations <sup>3</sup>	Origin		Suitability for Use with LID Features (see Guidebook Chapter 3)							
Scientific Name	Common Name	Optimal Site Conditions <small>Habitat/water requirements, sun, shade, part shade, special notes</small>	Tolerant of both Wet and Dry Periods	Better with Supplemental Irrigation	Requires Supplemental Irrigation	Fire Hazard	Native	Adapted Non-Native	RM-1 Disconnected Flow Paths	RM-2 Suitable for Snow Storage	RM-4 Bioretention	RM-5 Vegetated Filter Strips	RM-6 Grass Swale or Vegetated Swale	RM-7 Permeable Pavement	RM-8 Green Roof	
<b>Perennials and Annuals</b>																
<i>Lilium parvum</i>	Alpine Lily	wet to moderately wet, sun to part shade	●	●	○	○	●		●	●						
<i>Lilium spp</i>	Asiatic, Ornamental Hybrid Lily	wet to moderately wet, sun to part shade, many cultivars, accent	○	●	●	○		●		●						
<i>Linum lewisii</i>	Mountain Blue Flax	moderately wet to dry, sun	●	○	○	○	●			●		●			●	
<i>Lupinus breweri</i>	Brewer's Lupine	dry, sun	○	○	○	○	●			●		●			●	
<i>Lupinus polyphyllus</i>	Large-leaved Lupine	wet to medium, sun to part shade	●	●	○	○	●		●	●	●		●			
<i>Lupinus spp.</i>	Lupine	moderately wet to dry, many species and cultivars, accent	○	●	●	○		●		●						
<i>Mimulus guttatus</i>	Yellow Monkeyflower	wet to moderately wet, shade to sun	●	●	○	○	●		●	●	●		●			
<i>Mimulus lewisii</i>	Lewis' Monkeyflower	wet to moderately wet, shade to part shade	○	●	○	○		●	●	●	●					
<i>Monarda didyma</i>	Bee Balm	moderately wet, part shade	○	●	●	○		●		●	●					
<i>Monardella odoratissima</i>	Mountain Pennyroyal	dry, sun	○	○	○	○	●			●					●	
<i>Paeonia spp.</i>	Peony	wet to moderately wet, sun to part shade, many cultivars, accent	○	●	●	○		●		●						
<i>Papaver oriental</i>	Oriental Poppy	moderately wet to dry, sun to part shade, accent	○	●	○	○		●		●						
<i>Penstemon azureus</i>	Azure Penstemon	moderately wet, sun	●	○	○	○	●			●					●	
<i>Penstemon heterodoxus</i>	Whorled Penstemon	moderately wet to dry, sun to part shade	●	●	○	○	●		●	●	●		●		●	
<i>Penstemon newberryi</i>	Mountain Pride Penstemon	moderately wet to dry, sun to part shade	○	○	○	○	●			●					●	
<b>Trees</b>																
<i>Penstemon rydbergii</i>	Meadow Penstemon	wet to moderately wet, sun to part shade	●	●	○	○	●		●	●	●		●			
<i>Penstemon strictus</i>	Rocky Mountain Penstemon	moderately wet to dry, sun to part shade	○	●	○	○		●		●	●					
<i>Phlox paniculata</i>	Garden Phlox	moderately wet to dry, sun to part shade	○	●	○	○		●		●	●					
<i>Polemonium occidentale</i>	Jacob's Ladder	wet to moderately wet, shade to part shade	●	●	○	○		●	●	●	●					
<i>Potentilla glandulosa</i>	Sticky Cinquefoil	wet to moderately wet, sun to part shade	○	●	○	○	●		●	●	●		●		●	

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Scientific Name	Common Name	Optimal Site Conditions <small>Habitat/water requirements, sun, shade, part shade, special notes</small>	Tolerant of both Wet and Dry Periods	Better with Supplemental Irrigation	Requires Supplemental Irrigation	Fire Hazard	Native	Adapted Non-Native	RM-1 Disconnected Flow Paths	RM-2 Suitable for Snow Storage	RM-4 Bioretention	RM-5 Vegetated Filter Strips	RM-6 Grass Swale or Vegetated Swale	RM-7 Permeable Pavement	RM-8 Green Roof	
<b>Trees</b>																
<i>Potentilla gracilis var. fastigiata</i>	Graceful Cinquefoil	wet to moderately wet, part shade	●	●	○	○	●		●	●	●				●	
<i>Rubus parviflorus</i>	Thimbleberry	wet to moderately wet, sun to part shade	●	●	○	○	●		●	●	●	●	●		●	
<i>Solidago canadensis</i>	Canada Goldenrod	moderately wet, sun	○	○	○	○		●	●							
<i>Stachys byzantia</i>	Lamb's Ear	moderately wet to dry, sun to part shade, groundcover type habit, accent	●	○	○	○		●	●							
<i>Abies concolor</i>	White Fir	moderately wet, sun to part shade, plant 5g or smaller	○	●	○	●	●									
<i>Abies magnifica</i>	Red Fir	moderately wet, shade to sun, slow growing	○	●	○	●	●									
<i>Acer ginnala</i>	Amur Maple	moderately wet, sun to part shade, shrub habit - prune to multi-stemmed tree	○	●	●	Unknown		●	●							
<i>Betula occidentalis fonanalis</i>	Western River Birch	wet to moderately wet, sun to part shade, shrub habit - prune to multi-stemmed tree, plant from high elevation seed source	●	●	○	○	●		●	●	●					
<i>Calocedrus decurrens</i>	California Incense Cedar	moderately wet to dry, sun to part shade	○	●	○	●	●									
<i>Crataegus spp.</i>	Hawthorn	moderately wet, sun to part shade, many cultivars, accent	○	●	●	Unknown		●								
<i>Juniperus occidentalis var. occidentalis</i>	Western Juniper	dry, sun, slow growing	○	●	○	●	●									
<i>Malus spp.</i>	Crabapple species	moderately wet, sun to part shade, many cultivars, accent	○	●	○	Unknown		●	●							
<i>Pinus contorta var. murrayana</i>	Lodgepole Pine	wet to dry, sun to part shade	●	●	●	●	●		●							
<i>Pinus jeffreyi</i>	Jeffrey Pine	moderately wet to dry, sun to part shade	●	●	○	●	●									
<i>Pinus lambertiana</i>	Sugar Pine	moderately wet, generally	○	●	○	●	●									
<i>Pinus ponderosa</i>	Ponderosa Pine	moderately wet to dry, sun to part shade	○	●	○	●	●									
<i>Populus tremuloides</i>	Quaking Aspen	wet to moderately wet, sun to part shade, SEZ, invasive roots	○	●	●	○	●		●	●						
<i>Populus trichocarpa</i>	Black Cottonwood	wet, sun to part shade SEZ, invasive roots	●	●	●	Unknown	●		●	●						

PLANTS <sup>1</sup>			Drought & Inundation Tolerance <sup>2</sup>			Defensible Space Considerations <sup>3</sup>	Origin		Suitability for Use with LID Features (see Guidebook Chapter 3)							
Scientific Name	Common Name	Optimal Site Conditions <small>Habitat/water requirements, sun, shade, part shade, special notes</small>	Tolerant of both Wet and Dry Periods	Better with Supplemental Irrigation	Requires Supplemental Irrigation	Fire Hazard	Native	Adapted Non-Native	RM-1 Disconnected Flow Paths	RM-2 Suitable for Snow Storage	RM-4 Bioretention	RM-5 Vegetated Filter Strips	RM-6 Grass Swale or Vegetated Swale	RM-7 Permeable Pavement	RM-8 Green Roof	
<b>Trees</b>																
<i>Salix scouleriana</i>	Scouler's Willow	wet to moderately wet, sun/part shade, prune to multi-stemmed tree	●	●	○	●	●		●	●						
<i>Sequoiadendron giganteum</i>	Giant Sequoia	moderately wet, sun to part shade, California Native	○	●	○	Unknown		●	●							
<b>Groundcovers</b>																
<i>Sorbus aucuparia</i>	European Mountain Ash	moderately wet, sun to part shade, accent , protect from Sap Suckers	●	●	●	●		●								
<i>Aegopodium podagraria 'variegatum'</i>	Bishop's Weed	wet to moderately wet, shade to part shade, aggressive	●	●	●	○	●		●							
<i>Arctostaphylos nevadensis</i>	Pinemat Manzanita	dry, sun, rarely available	○	○	○	●			●							
<i>Arctostaphylos uva-ursi</i>	Bearberry Manzanita, Kinnikinnick	moderately wet to dry, sun to part shade	●	●	○	●		●	●						●	
<i>Asperula odorata</i>	Sweet Woodruff	wet to moderately wet, shade to part shade, fast	○	●	●	○	●		●							
<i>Bergenia spp.</i>	Bergenia	moderately wet, shade to part shade	●	●	●	○	●		●	●						
<i>Ceanothus prostratus</i>	Mahala Mat (Squaw Carpet)	moderately wet to dry, sun to part shade	○	○	○	Unknown	●		●		●					
<i>Cotoneaster dammeri</i>	cultivars 'Eicholz', 'Coralberry', 'Bearberry'	moderately wet to dry, sun to part shade	○	●	●	Unknown	●		●						●	
<i>Dianthus spp.</i>	Creeping Pinks	moderately wet, sun to part shade	●	●	●	○		●	●	●					●	
<i>Erigeron coulteri</i>	Coulter's Daisy	wet to moderately wet, sun	●	●	○	○	●		●	●		●	●	●	●	
<i>Eriogonum umbellatum</i>	Sulphur-Flower Buckwheat	dry, sun	○	○	○	Unknown	●		●						●	
<i>Fragaria vesca</i>	Wood Strawberry	wet to moderately wet, part shade	●	●	○	○	●		●	●					●	
<i>Fragaria virginiana</i>	Mountain Strawberry	wet to moderately wet, sun to part shade	●	●	○	○		●	●	●	●				●	
<i>Lupinus breweri</i>	Brewer's Lupine	dry, sun	●	○	○	○	●		●		●		●		●	
<i>Penstemon newberryi</i>	Mountain Pride	moderately wet to dry, sun	○	○	○	○	●		●						●	

PLANTS <sup>1</sup>			Drought & Inundation Tolerance <sup>2</sup>			Defensible Space Considerations <sup>3</sup>	Origin		Suitability for Use with LID Features (see Guidebook Chapter 3)							
Scientific Name	Common Name	Optimal Site Conditions <small>Habitat/water requirements, sun, shade, part shade, special notes</small>	Tolerant of both Wet and Dry Periods	Better with Supplemental Irrigation	Requires Supplemental Irrigation	Fire Hazard	Native	Adapted Non-Native	RM-1 Disconnected Flow Paths	RM-2 Suitable for Snow Storage	RM-4 Bioretention	RM-5 Vegetated Filter Strips	RM-6 Grass Swale or Vegetated Swale	RM-7 Permeable Pavement	RM-8 Green Roof	
<b>Groundcovers</b>																
<i>Phlox subulata</i>	Creeping Phlox	moderately wet to dry, sun	○	●	○	Unknown		●		●					●	
<i>Potentilla verna</i>	Creeping Cinquefoil	wet to moderately wet, sun to part shade, moderate traffic tolerance	●	●	●	○		●	●	●	●		●	●	●	
<i>Rubus parviflorus</i>	Thimbleberry	wet to moderately wet, part shade	●	●	○	○	●		●	●	●	●	●		●	
<b>Grasses</b>																
<i>Sedum spp.</i>	Stonecrop	dry, sun	○	●	○	○		●		●	●				●	
<i>Symphoricarpos mollis</i>	Creeping Snowberry	moderately wet to dry, part sun	●	●	○	Unknown	●			●		●			●	
<i>Symphoricarpos sp.</i>	Hancock Coralberry	moderately wet to dry, part sun	●	●	○	Unknown	●			●		●			●	
<i>Thymus serpyllum</i>	Creeping Thyme	moderately wet to dry, sun to part shade	●	●	○	○		●		●				●	●	
<i>Veronica prostrata</i>	Creeping Speedwell	wet to medium, sun to part shade, moderate traffic tolerance	○	●	●	○		●	●	●		●	●	●	●	
<i>Agrostis scabra</i>	Ticklegrass	wet to dry, sun part shade	●	●	○	○	●		●	●		●	●		●	
<i>Agrostis stolonifera 'Penncross'</i>	Creeping Bentgrass	moderately wet to wet, sun, turf	○	●	●	○		●	●	●	●	●	●	●		
<i>Bromus carinatus</i>	Mountain/California Brome	moderately wet to dry, sun to part shade	●	○	○	○	●		●	●	●	●	●			
<i>Carex athrostachya</i>	Slender Beaked Sedge	wet to dry, sun part shade	●	●	○	○	●		●	●		●		●	●	
<i>Carex nebraskensis</i>	Nebraska Sedge	wet to dry, sun part shade	●	●	○	○	●		●	●		●	●	●		
<i>Deschampsia cespitosa</i>	Tufted Hair Grass	moderately wet to wet, sun part shade	●	●	○	○	●		●	●		●	●			
<i>Deschampsia danthonioides</i>	Annual Hair Grass	moderately wet to wet, sun part shade	●	●	○	○	●		●	●	●	●	●			
<i>Eleocharis palustris</i>	Spikerush	wet to dry, sun part shade	●	●	○	○	●			●		●	●		●	
<i>Elymus elymoides ssp. californicus</i>	Squirreltail Grass	dry, sun	●	●	○	○	●		●	●						
<i>Elymus glaucus</i>	Blue Wildrye	moderately wet to wet, sun part shade, SEZ	●	●	○	○		●		●		●	●			
<i>Elymus triticoides</i>	Creeping Wildrye	moderately wet, sun part shade, competitive	●	●	○	○		●		●		●	●	●	●	
<i>Elytrigia intermedia</i>	Intermediate/Pubescent	dry, sun, drought tolerant,	○	●	○	○		●		●		●	●			
<i>Elytrigia intermedia 'Luna'</i>	Luna Wheatgrass	dry, sun, drought tolerant, competitive	●	●	●	○	●		●	●			●	●	●	

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<b>Grasses</b>																
<i>Elytrigia intermedia</i> 'Tegmar'	Dwarf Intermediate/Pubescent Wheatgrass	dry, sun, drought tolerant, excellent erosion control	●	●	○	○		●	●	●			●			
<i>Festuca arundinacea</i>	Tall Fescue	moderately wet, sun part shade, turf types and dwarfs, not suitable for SEZ	●	●	?	○		●		●						
<i>Festuca glauca</i>	Blue Fescue	moderately wet, sun part shade, ornamental bunch grass	●	●	?	○		●	●	●	●	●				
<i>Festuca idahoensis</i>	Idaho Fescue	wet to dry, sun part shade	●	●	○	○		●	●	●			●	●		
<i>Festuca ovina</i> var. <i>duriuscula</i>	Hard Fescue	moderately wet to dry, sun part shade, cultivars 'Durar', 'Sierra', 'Scaldis'	●	●	○	●		●		●					●	
<i>Festuca rubra</i>	Red Fescue	moderately wet to wet, shade, turf	●	●	?	○		●	●	●		●	●			
<i>Festuca rubra</i> ssp. <i>comutata</i>	Chewings Fescue	moderately wet, sun part shade, turf	?	●	?	○		●	●	●		●	●			
<i>Festuca trachyphylla</i>	Sheep Fescue	dry, sun part shade	?	?	○	○	●			●	●	●	●	●		
<i>Hordeum barachyantherum</i>	Meadow Barley	wet to dry, sun part shade	●	●	○	○	●		●	●	●	●	●		●	
<i>Juncus articulatus</i>	Jointleaf Rush	wet to dry, sun part shade	●	●	○	○	●		●	●	●	●	●		●	
<i>Juncus balticus</i>	Baltic Rush	wet to dry, sun part shade	●	●	○	○	●		●	●	●	●	●		●	
<i>Koeleria macrantha</i>	Prarie Junegrass	wet to dry, sun part shade	●	●	○	○	●			●	●	●	●		●	
<i>Lolium perenne</i>	Perennial Ryegrass	moderately wet to dry, turf	●	●	○	○		●	●	●	●	●	●		●	
<i>Miscanthus sinensis</i>	Maiden Grass	wet to moderately wet, accent	○	●	●	○		●	●	●	●	●	●		●	
<i>Poa ampala</i> 'Canby's'	Bluegrass, big	moderately wet to dry, sun part shade	?	?	○	○	●		●	●	●	●	●		●	
<i>Poa ampala</i> 'Sherman's'	Bluegrass, big	moderately wet to dry, sun part shade	?	?	○	○	●		●	●	●	●	●		●	
<i>Poa pratensis</i>	Kentucky Bluegrass	wet to moderately wet, sun part shade, turf	●	●	●	○	●		●	●	●	●	●		●	
<i>Poa sandbergii</i>	Sandberg Bluegrass	wet to dry, sun part shade	●	●	○	○		●		●	●	●	●		●	
<i>Pseudoroegneria spicata</i>	Bluebunch Wheatgrass	dry, sun	?	?	○	○	●			●	●	●	●		●	

PLANTS <sup>1</sup>			Drought & Inundation Tolerance <sup>2</sup>			Defensible Space Considerations <sup>3</sup>			Origin		Suitability for Use with LID Features (see Guidebook Chapter 3)				
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<b>Acknowledgements</b>															
We would like to acknowledge the author Robie Wilson Litchfield, ASLA Principal, Certified Green Building Professional L+P DesignWorks, Landscape Architecture + Planning for her development of this document. Special thanks also to Sarah Trebilcock, Botanist and Plant Ecologist, The Villager Nursery, Truckee, California, who reviewed this document.															
<b>Disclaimer</b>															
This list is a compilation of information based upon the author's long term experience with Sierra botany and environs beginning in the early 1970's and as a Landscape Architect in the Tahoe-Truckee region since 1990. This information is supplemented and verified by the references listed below. The author acknowledges that opinions and other lists will vary as to the appropriateness of certain plant materials for the recommended uses. As experience with emerging practices in Stormwater Management and Wildfire Management evolves, recommended uses will likely change. The information contained in this list is complete and true to the best of the author's knowledge to date. No guarantee is made as to the recommendations written herein and the author and publisher shall not be held liable in connection with the use of this information.															
<b>Legend</b>															
●	Indicates good, or yes for drought and inundation tolerance; indicates high for fire hazard														
◐	Indicates fair for drought and inundation tolerance; indicates medium for fire hazard														
○	Indicates poor, or no for drought and inundation tolerance; indicates low for fire hazard														
<b>Footnotes</b>															
1	<i>Because hardiness zones vary significantly in the Sierra, it is highly recommended that your local landscape professional or nursery be consulted to verify that chosen species are appropriate for the project area. A consulting fee may be required.</i>														
2	<i>Refers to established plant material</i>														
3	<i>Opinions on Fire Hazard levels will vary from fire district to fire district, this list is meant as a general guide in planning LID facilities and not as a Defensible Space guide. Consult your local fire district to verify what will be allowed in your area.</i>														
<b>References</b>															
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Micki Kelly, Kelly Biological Consulting, Truckee, California															
Sarah Trebilcock, Botanist and Plant Ecologist, The Villager Nursery, Truckee, California															

## **Appendix B**

### **Placer County LID Guidebook Pilot Project: Incorporating LID Into the Homewood South Base Redevelopment Project**

This appendix documents the process used by the project team and TAC to learn about innovative ways to integrate LID into local commercial projects and to pilot test the preliminary LID Guidebook tools using the proposed Homewood expansion project design plans.

*Thank you to David Tirman of JMA Ventures, LLC for hosting the June 9, 2010 TAC meeting (held on location at Homewood South Base), for his presentation on the Homewood Master Plan, and for his help compiling the necessary materials for this summary of the pilot project workshop and its outcomes.*

## Appendix B

# Placer County LID Guidebook Pilot Project: *Incorporating LID Into the Homewood Mountain Resort Redevelopment Project*

### Introduction/Background

In early 2010, Placer County and Sierra Business Council reached out to the Technical Advisory Committee formed to oversee development of the LID Guidebook to solicit ideas on a suitable pilot project which could both demonstrate LID principles and features and inform development of the Guidebook. David Tirman, Executive Vice President of JMA Ventures, LLC (JMA) offered the use of the Homewood Mountain Resort proposed redevelopment master plans for this purpose. Mr. Tirman is a licensed architect and an accredited LEED professional and his company had already committed to include LID in the master plan, but he was very interested in any recommendations his fellow TAC members might present. He provided all the necessary background, engineering studies and plans for the June 9, 2010 TAC workshop, which he hosted at the Homewood South Base so that the TAC members could get a firsthand look at site conditions (e.g., terrain, vegetation, soils, and hydrologic features) before conducting small group analyses and discussions related to integrating LID into the project design.

This appendix presents the results and outcomes of the TAC workshop and how the TAC feedback informed the development of the planning and design tools included in the Guidebook.

### Pilot Project Description

The development of the Homewood Mountain Resort Master Plan began in 2006 and has undergone extensive regulatory and community review as a result of meetings with the regulators and the community, as well as the Draft Environmental Impact Statement (EIS) review process in 2009 (which generated over 1,800 comments), and the Draft EIR review process conducted in 2010-11. The project has been guided by the following three principles as a result of extensive input from the community:

The Homewood Master Plan will:

1. Remain consistent with the scale and character of Homewood.
2. Enhance the lifestyle and property values of West Shore residents.
3. **Elevate the environmental thresholds within the Lake Tahoe Basin.**

The master plan involves redevelopment of the North Base and South Base. For the purposes of this pilot project, only the South Base was studied (see maps in the appendix).



The proposed redevelopment project is or plans to use LID; for example, the following techniques are being employed or proposed:

- Watershed-based planning to place the redevelopment project in the context of the entire watershed (the project began in 2007 with the development of a watershed plan including identification of streams, drainage areas, uplands, forests, meadows, structures and the myriad of other elements that make up the watershed, to get an idea of how that watershed is functioning, how it can be protected, improved, etc. as resort redevelopment takes place)
- Clustered buildings to preserve natural vegetated areas.
- Narrow roadways to reduce impervious surfaces.
- Removal and revegetation of old impervious parking areas.
- Revegetation of disturbed areas with natives by restoration experts who have been conducting demonstration revegetation projects for the Homewood Resort for several years.
- Infiltration facilities to capture, store and slowly release stormwater and snowmelt into the ground to reduce runoff to the receiving stream and naturally recharge the groundwater table.
- Protection of the stream that flows through the property with a wide buffer to allow natural filtration of runoff, prevent streambank erosion and protect habitat.

The proposed development is being designed in a watershed context. Attachment 1 includes a Homewood newsletter article written by the Restoration Ecologist hired by the developer, Michael Hogan, which explains the goals and process.

## June 9, 2010 TAC Workshop, Homewood South Base, Tahoe

On June 9, 2010, Placer County and their consultant team facilitated a TAC workshop at the Homewood South Base lodge (see agenda and list of TAC members in Attachment 2). The main goal of the workshop was to allow the TAC members to experience what it was like to participate in a simulated “integrated design team” to plan and design a “real world” LID project, using the draft Guidebook tools. The desired outcomes of the workshop included:

- Feedback and recommendations to the pilot project developer (JMA, Homewood Mountain Resort) from other design colleagues/technical experts about innovative ways to integrate additional LID into the design
- Feedback to the Guidebook consultant team about the usefulness, content and format of key Guidebook planning and design tools (process flowchart, planning and design checklist, LID selection matrix and LID fact sheets)

JMA provided the materials for the workshop, including base maps, groundwater elevations, soils report and the engineer’s preliminary storm drain routing plan (copies provided in Attachment 2). Although they also provided preliminary LID plans/approaches, this information was withheld from the TAC until the end of the workshop, so as to allow the TAC to create their LID plans using only the basic information, their observations of the site, and their own technical experience.



Following an introductory presentation and site tour by David Tirman, as well as a water quality presentation by Bob Costa of Placer County (to provide regulatory context), the TAC was split into two teams and tasked with creating their ideal LID design plan for the site. Assignments were made so that each team was truly integrated, with a developer/builder, architect, landscape architect, engineer, planner and County staff person on each.





At the end of the workshop, the teams presented their plans to the group and additional discussion ensued about opportunities and constraints. JMA then presented the proposed LID plans for South Base and thanked the group for the additional feedback and recommendations, which would be considered during subsequent phases of the Homewood design process.

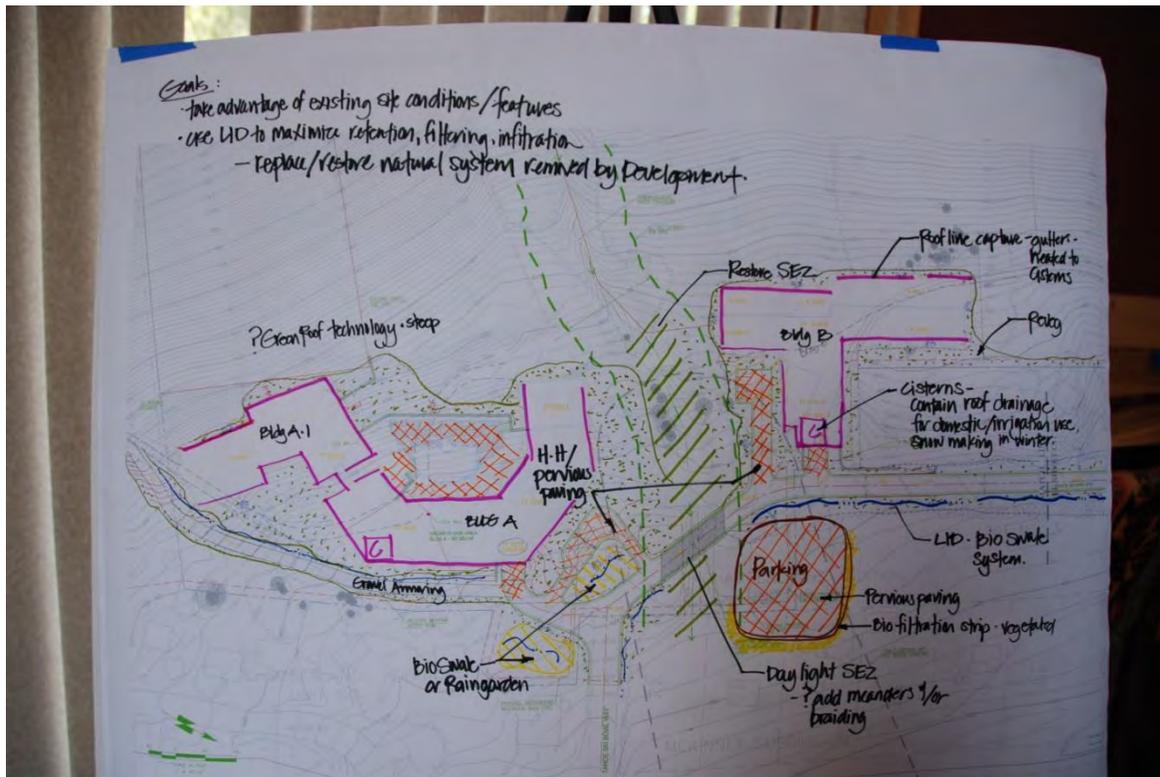




## OrangeTeam Recommendations

(see large scale LID site plan in Attachment 3)

- Take advantage of existing conditions/features (creek, vegetation, topography, hydrologic features)
- Use LID to restore any part of the natural system removed by the new development
- Use cisterns to capture rainwater from roofs and consider using the water to make new snow for ski operations
- Use pervious pavement (e.g., decorative pavers for architectural interest) for parking and low traffic areas
- Install vegetated swales to treat and infiltrate road and parking lot runoff
- Daylight the portion of the stream (including outfall) that is currently in a pipe/culvert under the building/road
- Consider use of hydroponic heating to create “snow free” zones
- Do not recommend green roof due to historic architectural roof design/pitch and expected snow loads



# **Attachment 1**

## **Background on the Ecological and Watershed Management Goals for the Homewood Mountain Resort Project**

*(Article by M. Hogan printed in 2007 Homewood Mountain Resort Master Plan Project Newsletter)*

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on the

# HOMEFRONT

FEBRUARY 2007

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Welcome to the second in a series of informational newsletters from *Homewood Mountain Resort*. The goal of these reports is to keep all interested parties updated on the exciting changes underway at Homewood as it moves forward under new ownership.



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## HOMewood MOUNTAIN RESORT: A NEW APPROACH

Ski areas are notorious polluters. Everybody knows that, right? If you cut a ski run, you ruin (or seriously threaten) the watershed. At least that's what many people believe. And I'd actually go a step further and say that many folks feel they "know" that as sure as they know the sun rises in the east. But I've spent the last several years of my career asking simple questions such as "How do we 'know'?" and, just as importantly, "What do we really know about ski area erosion?"

It turns out that the research data shows us that we don't know as much as we thought we did. And sometimes the data challenges the core of our beliefs. For instance, simulated rainfall (and seasons of direct field observations) showed us that plants don't always minimize or even slow erosion significantly. We've also recently seen that some ski run construction practices can have negligible impacts on erosion. We've also seen that some restoration and erosion control practices can reduce

erosion below native or background rates. How is that possible?

I think a couple of more important questions are: Why have we been using essentially the same practices for erosion control for so long without asking the hard questions, such as do they work? And that question leads to: How do we start to ask the tough questions in every erosion control project we do so that we can learn and understand how things are working? As humbling as it is, the so-called "experts"

don't have all the answers. Nor do the agencies tasked with regulating erosion, construction, etc. I don't see this as a problem. It's more like a great starting point.

Where does Homewood fit into this picture?

Homewood has long been the epitome of small, family-run ski resorts – old infrastructure, runs and roads built the “old way.” The downside to older resorts is that there is seldom an excess of capital

improvement – and still make money? It's a good question.

One of the issues of ski area operations is whether ski runs and environmental protection can go side by side. Even in the short period of time that JMA Ventures has owned Homewood, they have already engaged in putting environmental protection projects on the ground and putting in place a process to monitor and quantify the benefits of those projects. We (Integrated Environmental

ing in areas where plants are growing but soil is compacted and prone to rapid runoff. Homewood has over 1.5 million square feet of roads that may eventually be removed and our task is to determine the most cost and environmentally effective restoration methods that can be used on those roads. And since we don't know all of the possible treatment types, we're testing some new ones on the mountain. We are basing our approach on the fact that if water can infiltrate the



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to fix, repair or replace aging infrastructure, including the environmental infrastructure.

The new owners have a different vision of what Homewood should be. They are posing the question: Can we still be a small, local, family-oriented resort, run for the love of skiing, and still set a new, higher standard across the board for community involvement, community improvement, environmental protection AND environmental

Restoration Services) have been contracted to install three moderate-sized restoration demonstration projects in order to determine the types of materials and processes that will give us the greatest benefit going into the future.

These projects are designed to test and measure treatment outcome on three very different types of sites. Treatments range from complete road removal and recontouring to simple soil loosen-

soil, it can't run off (until soils become saturated). Thus, we are tilling soils, adding organic matter, seeding (using native grass and shrub seed) and using a variety of mulches to test concepts, determine effectiveness and assign a cost to various methods. We have seen, even after two small rainstorms, that this approach has resulted in zero runoff from treatment plots while areas all around the plots are showing signs of runoff. Thus, our way is

fairly clear and the results are visibly obvious.

But that's not enough. We have also begun research-level monitoring of treatment areas using simulated rainfall to directly measure the benefits of treatment as compared to background and to other types of treated and untreated areas. In this way, when we continue to restore additional roads and runs next summer, we'll know how much benefit we get from each type of treatment.

We expect that Homewood will help lead the way in implementing

state-of-the-art restoration and erosion control techniques and that the resort will do so in a manner that makes economic as well as environmental sense. Skiing is directly based on the environment. It seems strange that ski resorts are so often viewed as being at odds with the environment and that ski area operators see themselves at odds with the environmental community. Ski areas offer so many people the opportunity to engage with nature.

We now see ski resorts as being a prime opportunity to learn more about environmental restoration

practices as well. And through efforts by groups like the California Alpine Resort Environmental Cooperative (CAREC) and resorts like Homewood, we believe that the gap between environment and business may be narrowed considerably. As Robert Kennedy, Jr. recently said: "The economy is a wholly owned subsidiary of the environment." We hope to show (and measure) that at Homewood Mountain Resort that statement is the gateway to a new standard of operations.

## HOMWOOD: LEADING THE WAY INTO WATERSHEDS

The thing that makes skiing great is the same thing that creates a high potential for runoff and erosion: steep, mountainous slopes. When those slopes are undisturbed, they tend to stay put and the streams that run through them tend to run clear. But when development takes place, disturbance can drastically accelerate erosion. That erosion is the thing that can have such a devastating effect on water quality, fish and all the other water-related benefits that we usually take for granted.

However, development and erosion don't have to go hand in hand. Careful planning and consideration of watershed processes are two critical elements in reducing or eliminating erosion in ski resorts. The third critical element is applying the

right protections against erosion. In other words, once you've thought about where erosion might occur, you need to have the best tools available to do the job.

Homewood is engaged in a process to 1) look at the entire watershed and place the future of the ski resort and its related activities within that context, and 2) not only apply the best tools to protect water quality, but, where those tools don't exist, help develop them. With that in mind, Homewood is teaming with my company, Integrated Environmental, as well as with Jason Drew and Nichols Consulting Engineers to develop a whole watershed plan. This plan will serve as the foundation of all other management and development activities as the resort moves forward.

Many developments consider only the immediate surroundings. Homewood and IERS/Nichols are beginning down the road of looking at the whole watershed, including streams, drainage areas, uplands, forests, meadows, structures and the myriad of other elements that make up the watershed, and beginning to get an idea of how that watershed is functioning, how it can be protected, improved, etc. And as we go forward, we will fit our management into that context rather than try to make the watershed fit into our plan.

Watershed planning can be complex but can also provide us with extremely useful information. For instance, we want to know how much erosion is currently coming from the mountain, and as we move forward, we have a



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plan to remove many of the dirt roads on the mountain in order to restore hydrologic function. By doing this in a whole watershed context, we'll be better able to quantify the improvements in water quality and habitat quality. Homewood has been discussing a range of energy saving and energy production alternatives. Watershed planning will allow us to understand, for instance, how well small hydroelectric plants might work and whether they may have an impact on the overall watershed.

Another approach that Homewood and IERS is taking is to understand where our knowledge of watershed restoration is limited, and, in those cases, tackle that head-on by setting up test or experimental plots that can be measured. These plots can provide us and others with critical information that can be used at Homewood and elsewhere through the Tahoe Basin and beyond. The IERS team has been working on this issue for a number

of years, working with the local Water Quality Control Board, TRPA, UC Davis researchers, the Sierra Business Council and our own team of specialists to develop and apply restoration and water quality protection technologies that mimic nature and ultimately result in a higher level of water quality.

Ski runs, roads and other disturbed areas are ultimately field laboratories where we can continually learn how to develop and apply management practices that can result in high levels of environmental protection. This information, when put into the context of an overall watershed management plan, will give us all something that we can not only live with, but that will ultimately improve the Lake Tahoe environment and help improve Lake clarity. At the same time, it can provide us with a high level of recreational opportunities and be something that we, as residents and visitors to the Tahoe Basin,

can be proud of. We believe that this approach will lead the way into the future of watershed planning, environmental protection and restoration practices. The goal of "raising the bar on every level" starts here.

**Article Written by Michael Hogan.**

*Michael has been involved in erosion control and restoration in the Sierras since 1985, having worked for the Forest Service, Squaw Valley, UC Davis and others before founding Integrated Environmental Restoration Services (IERS) in 1995. IERS is dedicated to developing and implementing science-based restoration practices throughout the Sierra Region. He additionally is a member of the Pathway 2007 Soils and SEZ technical advisory committee as well as heads the Forested Upland Category Group for the Tahoe Basin TMDL.*

NEXT EDITION:  
TRANSPORTATION ISSUES



[skihomewood.com](http://skihomewood.com)

530.525.2992 P.O. Box 165, HOMEWOOD, CA 96141

## **Attachment 2**

### **June 2010 Technical Advisory Committee (TAC) Workshop Materials**

- Agenda
- List of TAC Members
- Fact sheet of supplemental pilot project site information (soils, groundwater, surface water) provided to TAC teams prior to June 2010 workshop group exercise (prepared by consultant team based on review of soils report and storm drainage plan information prepared by project consultants)
- South Base maps and engineering plans provided by project owner



## Placer County Low Impact Development Guidebook Technical Advisory Committee Meeting #2

At Homewood Mountain Resort, South Base  
Tahoe Ski Bowl Way

<http://www.skihomewood.com/visit-ski-homewood/directions>

June 9, 2010 • 9:30 am - 2:30 pm  
Optional Tour to Homewood North Base 2:30- 4:00 pm

### AGENDA

- 9:30 Welcome, Introductions
- 9:45 Homewood Pilot Project to Demonstrate LID Guidebook Tools
- Introduction to the Group Exercise
  - Introduction to the Site/Setting
- 10:15 Work on Pilot Project (2 groups)
- Review LID Process Toolkit
  - Visit Site
  - Formulate Design Concepts
- 12:15 Lunch
- 12:45 Present Pilot Project Conceptual LID Designs
- 1:15 LID Toolkit Comments/Recommendations
- 2:00 Homewood Feedback LID Concepts
- 2:15 Vision/ Purpose Discussion
- 2:30 Adjourn – Set Next Meeting Date
- 2:30-4:00 Optional Site Visit – Homewood North Base



**Placer County LID Guidebook: Technical Advisory Committee**

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Carmel Brown, P.E. CKB Environmental Consulting, Inc.	Chris Bowles, Ph.D. cbec eco engineering
	Melanie Carr, M.S., P.E. cbec eco engineering

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Jennifer Dzakowic Placer County Planning Department	Crystal Jacobsen Placer County Planning Department
Charlene Daniels Placer County Planning Department	

**Sierra Business Council**

Nancy Richards Project Manager	Martini Morris Sierra Nevada AmeriCorps Partnership
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Updated May 21, 2010

TAC documents web portal address: <http://cbecoeng.com/placerLIDTAC.php>

## Supplemental Information for Placer LID Guidebook TAC Meeting – June 9, 2010

### Homewood Pilot Project to Demonstration LID Guidebook Tools

*(team members can add their own notes if desired during the overviews by Chris, Michael, David & Bob)*

#### Soils

- Silty sand, gravelly sand, gravel, cobble and boulders
- Infiltration rate: 4 inches/hour (102 mm/hr)

#### Groundwater

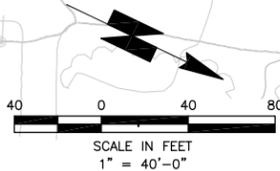
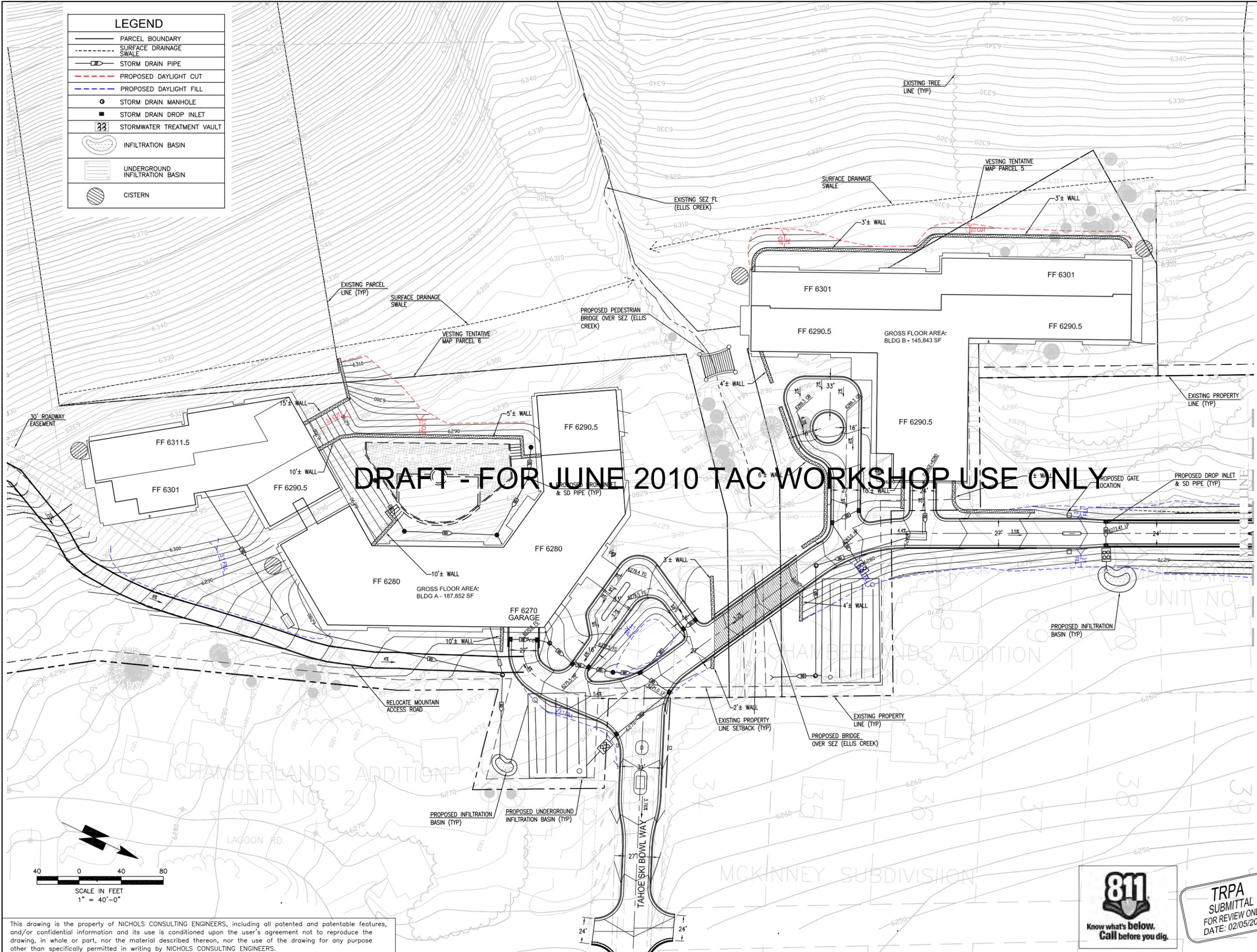
- Groundwater flow is to the east toward Lake Tahoe
- Depth to seasonal high groundwater is extremely variable on the site. For this exercise, assume:
  - beneath and in vicinity of north building (B): 2-3 ft (.6-.9 m)
  - beneath and in vicinity of south buildings (A1 and A2): 6-8 ft (1.8 – 2.4 m)
  - in the vicinity of Tahoe Ski Bowl Way: 4 ft (1.2 m)
- TRPA requires a minimum 1-foot separation between the bottom of an infiltration device to the seasonal high groundwater.
- Assume no existing groundwater contamination problems/concerns at this site.

#### Surface Water/Watershed

- Ellis Creek (aka Homewood Creek) traverses the property between the two main buildings – see flow line on plan; see SEZ setback shown on plan
- Any urban runoff discharges to the creek need to be treated. SEZ should only be used for final dissolved nutrient removal, after pretreatment to remove other pollutants.
- Assume no on-site wetlands
- Contributing drainage areas; assume:
  - North buildings (A1 and A2) and surrounding areas: 2 acres
  - South building (B) and surrounding areas: 1 acre
  - All site run-on is diverted around the development

#### Other Notes

LEGEND	
	PARCEL BOUNDARY
	SURFACE DRAINAGE SWALE
	STORM DRAIN PIPE
	PROPOSED DAYLIGHT CUT
	PROPOSED DAYLIGHT FILL
	STORM DRAIN MANHOLE
	STORM DRAIN DROP INLET
	STORMWATER TREATMENT VAULT
	INFILTRATION BASIN
	UNDERGROUND INFILTRATION BASIN
	CISTERN



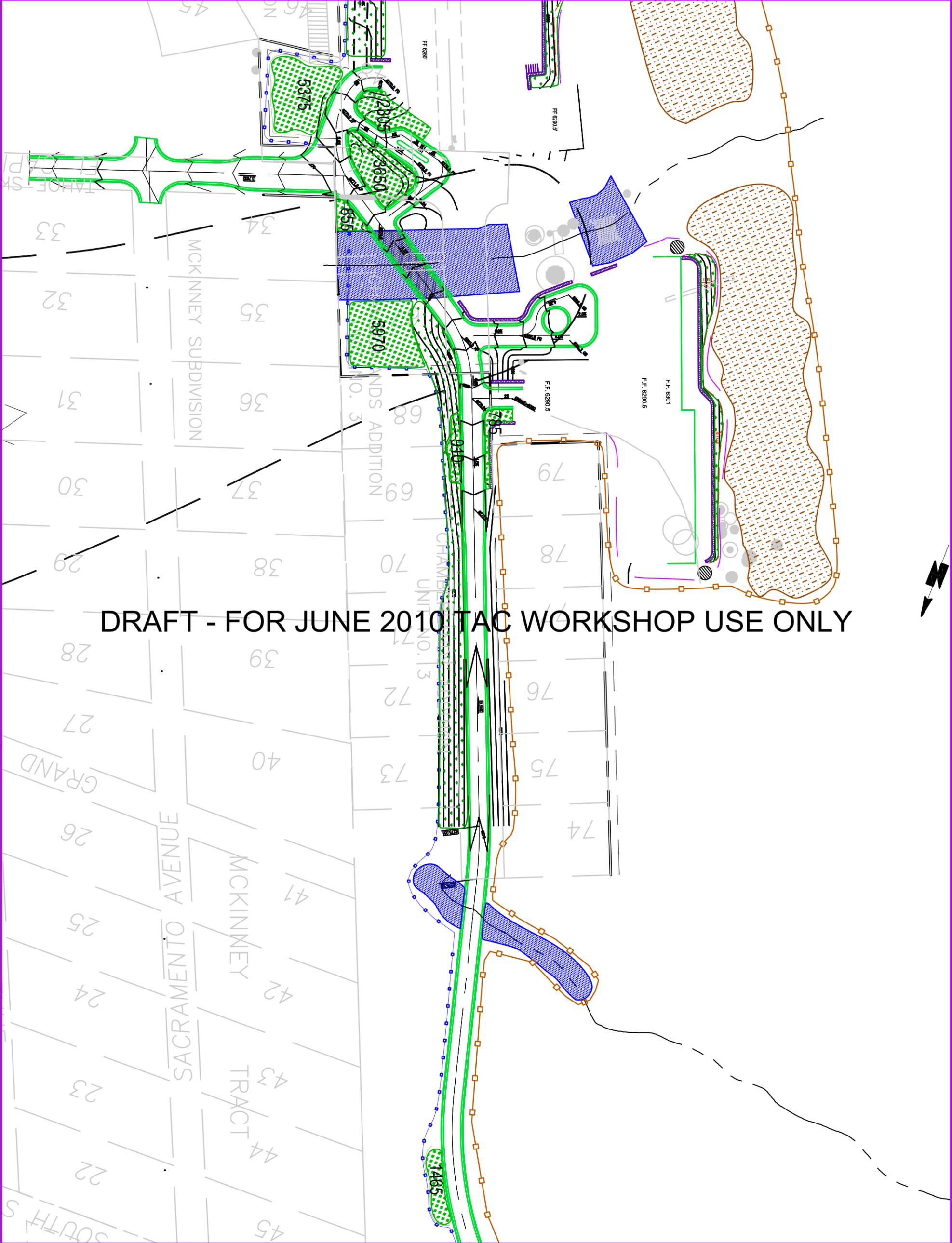
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SOUTH LODGE GRADING & DRAINAGE PLAN							SHEET <b>C12</b> OF 29		



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# **Attachment 3**

## **June 2010 TAC Workshop Results**

- Notes prepared by Sierra Business Council
- Orange Team LID Site Plan
- Green Team LID Site Plan

## **Placer County LID Guidebook TAC Meeting # 2 June 9, 2010, Homewood**

**Technical Advisory Committee (TAC)** in attendance: Kaitlin Backlund, Allen Breuch, Pat Davison, Darin Dinsmore, Keith Franke, Michael Hogan, Jeff Loux, Stefan Schuster, Ed Staniforth, Jessica Thompson, David Tirman, Robie Wilson Litchfield

**Core Team** in attendance: Carmel Brown, Chris Bowles, Melanie Carr, Edmund Sullivan, Jennifer Dzakowic, Bob Costa, Nancy Richards, Martini Morris (notetaker)

### **Introduction (Ed Sullivan, Nancy Richards)**

No comments

### **Homewood overview (David Tirman)**

See PowerPoint Presentation (Attachment 1)

Other Notes:

- Admin draft EIR-next week, public draft September
- 1100 acres, 3 watersheds
- Master plan goals:
- Elevate environmental thresholds
- Stewardship of growth
- Reestablish west shore community center
- Enhance lifestyle and property value
- Micro-hydro units In streams on site
- Solar power shingles
- Complete missing link of Tahoe bike trail
- Free use bicycles
- Pedestrian oriented neighborhood area at north base
- Day lodge up on the mountain

### **Site Setting and Regulatory Context (Bob Costa, Placer County)**

- TRPA/Lahontan RWQCB are key regulatory agencies
- Sediment TMDL for Lake Tahoe area (on the verge – releasing this month)

### **Notes from Breakout Sessions**

#### ***Flipchart Notes from Green Team (M Carr, Facilitator)***

- Natural flows
- Drainage
- Existing vegetation
- Identifying reveg. Areas

- Restoration
- LID features
- Clustered some of the tools together in systems
- 1-dry well (from roof)
- 2-rain garden (includes snow melt)
- 3-swale (tertiary treatment)
- Two different types-smaller systems, larger systems
- Two different scales (natural/built)
- Helps with maintenance/cost, site use efficiency
- Without knowing the owner's intent –they had to make some concept decisions
- Construction phasing – constrained site
- Try to put soil back on site rather than haul it offsite
- Snow removal is an important
- Created typologies, could be low flow swale, soil amendments, infiltrail (trail with infiltration on it)
- Need interaction with architect and owners
- Maintained native vegetation,
- Also unmaintained vegetation
- Harvesting of rainwater, stormwater, potential to capture some of the water, or potentially feeding a portion of the water to make snow (snow would be storage)
- Heat transfer from sewer system, and circulate that heat to sidewalks
- Micro-hydro – visibility – indicator of how much electricity is being generated
- Added a pedestrian bridge – public education facilities, taking advantage of the resource of the creek
- Make Public art out of treatment system

#### *Flipchart Notes from Green Team (C Brown, Facilitator)*

- Goals – take advantage of existing conditions/features
- Use LID to restore natural system removed by developed
- Used hydroponic heating for snow free zones
- Used pavers for low traffic areas
- Did not do green roofs
- Tried some rainwater cistern capture from roofs- captured to make snow
- Bioswales
- Daylight SEZ stream
- Small amounts of capture areas
- Bioswale along road going north
- Porous paving

## Comments on Guidebook Tools

### *Process Flowchart*

- Step 1 – Concept project program?
- Needs to work for both audiences: large developers and mom and pop projects (use visual and written, it's important)
- Step 3 – Pre-development meeting – agency expectations, info sharing
- Is it really a flowchart if no inputs, outputs, decision nodes?
- Perhaps there is need for flowcharts at some of the steps?
- Need to put this in context with other aspects of overall site design (sw quality, buildings, flood control, etc.)
- How to illustrate/build in the iterative approach
- Simple graphic to put LID into context with the overall process
- Are the steps really in the right order?
- Need to have a dialogue between landscape architects and designers
- Need to include NEXT STEPS in the document
- Watershed context/watershed context/regulatory context
- How do we address design styles: Community Based, Iterative Approach, Top Down approach
- How do we address these various levels of engagement?
- Three process flow chart
- Applicant driven
- Community based flowchart
- EIR/EIS driven flowchart (we're not going to have that anymore hopefully)
- Old way of doing things... new way of doing things... explain it
- Lisa Wallace (per Robie Wilson) wanted more about the process than LID BMPs
- Private versus public development
- Think about the issue of scale... they need to be geared to both large scale and single residence
- (small and distributed building blocks)
- Big and small
- Sophisticated and not sophisticated
- Be sure to link the flowchart and explanations to the overall design process
- Drainage paths – we need to have a piece of paper that shows where the hydrology is
- Create a reference to a few LID sizing calculators
- CONTEXT – put the written material in context with some initial sections:
  - Issues of scale (site vs. neighborhood, mom vs. pop, major developer)
  - Watershed context
  - Regulatory context
  - Team partnership / community context
- (biochar – soil amendment)-invest long-term in carbon storage in soils

### *LID Planning and Design Checklist*

- Reduce redundancy between steps and individual checklists
  - Combine 4a and 4b, maybe these with 2 as well?
  - And/or breakout regulatory versus site specific characteristics
- Some items on this checklist are related to overall site design and others are specific to LID... that's ok, but talk about it up front.
- Step 5b – should be up front in preamble (context) – this is a philosophy, not a step in the process
- How to build in/ allow for iterative process?
- Comingled sources – combining with onsite drainage and roadblocks from placer county

### *LID Selection Matrix*

- Appropriate and may be appropriate works for site factors, but not for project type
- Site factors – add regulatory constraints (SEZ) and existing vegetation
- Infiltration trench/dry well – more traditional BMPs leave them on list, but de-emphasize (not really green techniques due to excavation and import rock)
- We need to have a reference to 4 or whatever calculators or sizing
- Careful – this might become pick and choose menu; how does this matrix support a systems approach?

### *LID Fact Sheets*

*(used the Fact Sheets from TRPA in Toronto)*

- 4-fold concept works well for public counters/ displays
- Specificity to high alpine perennial streams/snowmelt, steep slopes and erosive soils?

## Presentations after the Team Breakout Sessions

### *Homewood Restoration Projects (Michael Hogan)*

- We started by looking at the whole entire watershed
- Needed to look at where the water is going... very important
- Putting a bunch of people in the room to develop the site plan
- The whole sense of connectivity for water
- Hydrology/ soil interface is critical to this evaluation
- Soil adaphic measures
- The more you connect all the dots between different disciplines, the better your project will be
- Big conceptual watershed scale that integrates the whole project
- Bottom up – we assume we're going to get a lot of benefit, but we need to quantify what we're getting from bioswales, etc.
- Water quality, flow attenuation, adaptive management
- What are your assumptions? What are you measuring?
- Take measurements, adapt, and revise your assumptions, then redesign
- Homewood design –infiltration galleries and cisterns
- Landscaped and non-landscaped areas will be LID
- If you think about routing, this stuff will become apparent

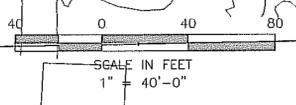
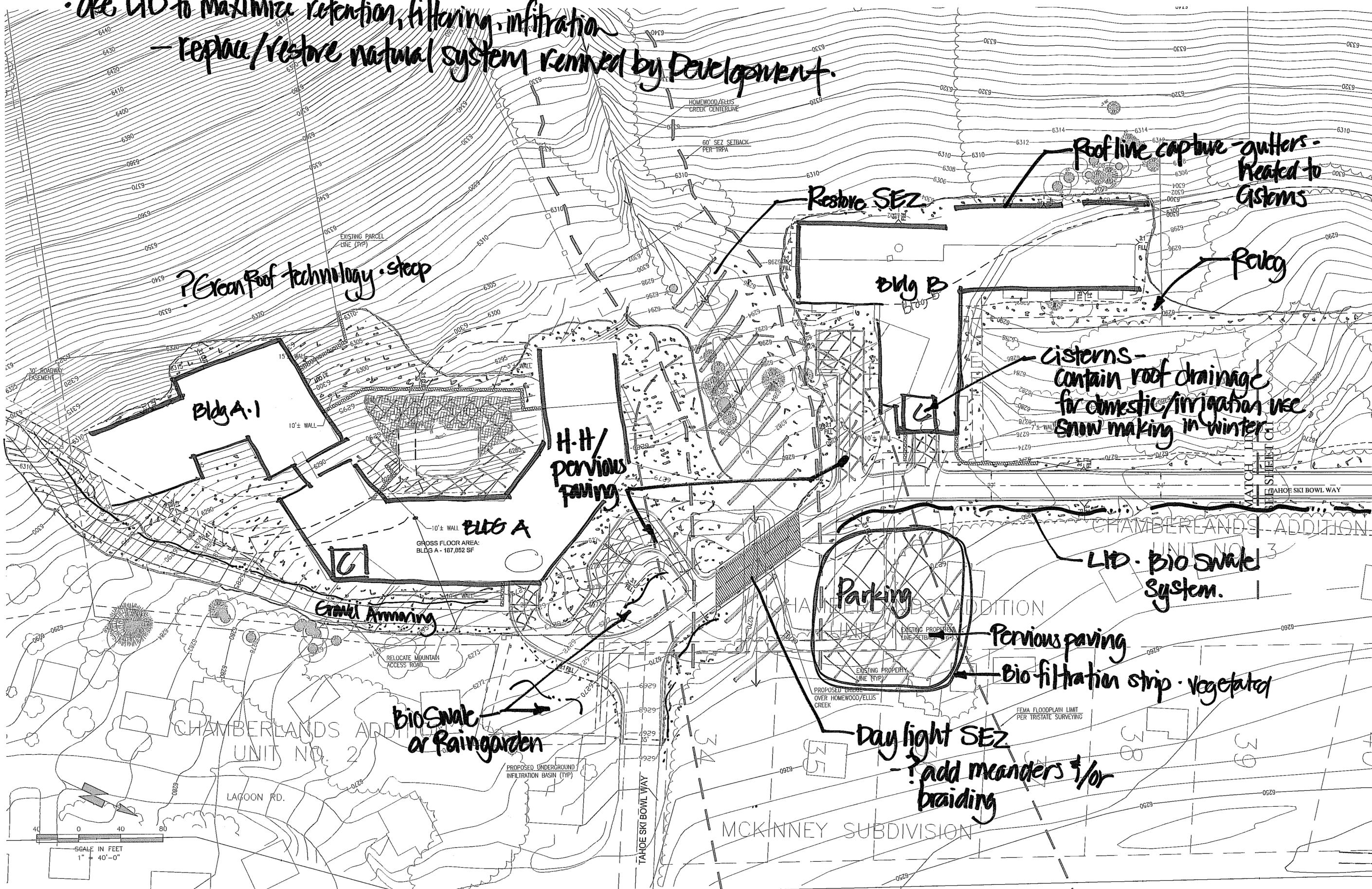
### *Closing (David Tirman, JMA)*

- A year ago, they had a traditional plan
- But they brought everyone in, and developed the LID features and the more organic process
- Subsurface infiltration galleries
- Restoration planned along stream
- Culvert removal and daylighting of creek
- Relocate pedestrian path
- Cisterns will capture 1/3 of the roof runoff -cisterns are above ground and made of wood (5,000 gallons)
- County health may require treatment of any stored rainwater/snow melt



Goals:

- take advantage of existing site conditions/features
- use LID to maximize retention, filtering, infiltration
- replace/restore natural system removed by development.



## **APPENDIX C LID CASE STUDIES**

### **C-1 Economic Analyses Case Studies**

### **C-2 LID Case Studies**

## C-1 Economic Analyses Case Studies

This appendix contains summary tables showing cost savings for almost 30 LID projects based on a literature search of nationwide LID cost-benefit studies conducted by ECONorthwest in 2007. Reported savings ranged from \$500 to \$7,000 per lot for residential projects and \$2,000 to \$13,000 per acre for commercial projects. The authors reported information only for those fraction of the total studies analyzed for which details of the source of the cost savings (e.g., reduced storm drain pipe or reduced fill) were available. Although the reported costs were taken from studies conducted in different years (late 1990s through 2006) and therefore perhaps not directly comparable, the assessment is nonetheless a useful tool for illustrating the potential cost savings of using LID instead of conventional stormwater management. (MacMullen, 2007).

**Table 5-1: Cost savings attributed to installing LID stormwater controls in residential developments.**

<b>Location</b>	<b>Description</b>	<b>LID Cost Savings<sup>a</sup></b>
<b>Meadow on the Hylebos</b> Residential Subdivision Pierce County, WA	9-acre development reduced street width, added swale drainage system, rain gardens, and a sloped bio-terrace to slowly release stormwater to a creek. Stormwater pond reduced by 2/3, compared to conventional plan. (Zickler 2004)	LID cost 9% less than conventional
<b>Somerset Community</b> Residential Subdivision Prince George's Co., MD	80-acre development included rain gardens on each lot and a swale drainage system. Eliminated a stormwater pond and gained six extra lots. (NAHB Research Center Inc. 2003)	\$916,382 \$4,604 per lot
<b>Pembroke Woods</b> Residential Subdivision Frederick County, MD	43-acre, 70-lot development reduced street width, eliminated sidewalks, curb and gutter, and 2 stormwater ponds, and added swale drainage system, natural buffers, and filter strips. (Clar 2004; Lehner et al. 2001)	\$420,000 \$6,000 per lot <sup>b</sup>
<b>Madera Community</b> Residential Subdivision Gainesville, FL	44-acre, 80-lot development used natural drainage depressions in forested areas for infiltration instead of new stormwater ponds. (PATH 2005)	\$40,000 \$500 per lot <sup>b</sup>
<b>Prairie Crossing</b> Residential Subdivision Grayslake, IL	667-acre, 362-lot development clustered houses reducing infrastructure needs, and eliminated the need for a conventional stormwater system by building a natural drainage system using swales, constructed wetlands, and a central lake. (Lehner et al. 2001; Conservation Research Institute 2005)	\$1,375,000- \$2,700,000 \$3,798-\$7,458 per lot <sup>b</sup>
<b>SEA Street Retrofit</b> Residential street retrofit Seattle, WA	1-block retrofit narrowed street width, installed swales and rain gardens. (Tilley 2003)	\$40,000
<b>Gap Creek</b> Residential Subdivision Sherwood, AK	130-acre, 72-lot development reduced street width, and preserved natural topography and drainage networks. (U.S. EPA 2005; Lehner et al. 2001; NAHB Research Center Inc. 2003)	\$200,021 \$4,819 per lot
<b>Poplar Street Apartments</b> Residential complex Aberdeen, NC	270-unit apartment complex eliminated curb and gutter stormwater system, replacing it with bioretention areas and swales. (U.S. EPA 2005)	\$175,000
<b>Kensington Estates*</b> Residential Subdivision Pierce County, WA	24-acre, 103-lot hypothetical development reduced street width, used porous pavement, vegetated depressions on each lot, reduced stormwater pond size. (CH2MHill 2001; U.S. EPA 2005)	\$86,800 \$843 per lot <sup>b</sup>
<b>Garden Valley*</b> Residential Subdivision Pierce County, WA	10-acre, 34-lot hypothetical development reduced street width, used porous paving techniques, added swales between lots, and a central infiltration depression. (CH2MHill 2001)	\$60,000 \$1,765 per lot <sup>b</sup>
<b>Circle C Ranch</b> Residential Subdivision Austin, TX	Development employed filter strips and bioretention strips to slow and filter runoff before it reached a natural stream. (EPA 2005)	\$185,000 \$1,250 per lot

Location	Description	LID Cost Savings <sup>a</sup>
<b>Woodland Reserve*</b> Residential Development Lexana, KS	Reduced land clearing, reduced impervious surfaces, and added native plantings. (Beezhold 2006)	\$118,420
<b>The Trails*</b> Multi-Family Residential Lexana, KS	Reduced land clearing, reduced impervious surfaces, and added native plantings. (Beezhold 2006)	\$89,043
<b>Medium Density Residential*</b> Stafford County, VA	45-acre, 108-lot clustered development, reduced curb and gutter, storm sewer, paving, and stormwater pond size. (Center for Watershed Protection 1998b)	\$300,547 \$2,783 per lot <sup>b</sup>
<b>Low Density Residential*</b> Wicomico County, MD	24-acre, 8-lot development eliminated curb and gutter, reduced paving, storm drain, and reforestation needs. Eliminated stormwater pond and replaced with bioretention and bioswales. (Center for Watershed Protection 1998b)	\$17,123 \$2,140 per lot <sup>b</sup>

Source: ECONorthwest, with data from listed sources.

Notes: \* indicates hypothetical or modeled project, not actually constructed.

<sup>a</sup> Dollar amounts as reported at the time of study.

<sup>b</sup> Per-lot cost savings calculated by ECONorthwest.

**Table 5-2: Cost savings attributed to installing LID stormwater controls in commercial developments.**

<b>Location</b>	<b>Description</b>	<b>LID Cost Savings<sup>a</sup></b>
<b>Parking Lot Retrofit</b> Largo, MD	One-half acre of impervious surface. Stormwater directed to central bioretention island. (U.S. EPA 2005)	\$10,500-\$15,000
<b>Old Farm Shopping Center*</b> Frederick, MD	9.3-acre site redesigned to reduce impervious surfaces, added bioretention islands, filter strips, and infiltration trenches. (Zielinski 2000)	\$36,230 \$3,986 per acre <sup>b</sup>
<b>270 Corporate Office Park*</b> Germantown, MD	12.8-acre site redesigned to eliminate pipe and pond stormwater system, reduce impervious surface, added bioretention islands, swales, and grid pavers. (Zielinski 2000)	\$27,900 \$2,180 per acre <sup>b</sup>
<b>OMSI Parking Lot</b> Portland, OR	6-acre parking lot incorporated bioswales into the design, and reduced piping and catch basin infrastructure. (Liptan and Brown 1996)	\$78,000 \$13,000 per acre <sup>b</sup>
<b>Light Industrial Parking Lot*</b> Portland, OR	2-acre site incorporated bioswales into the design, and reduced piping and catch basin infrastructure. (Liptan and Brown 1996)	\$11,247 \$5,623 per acre <sup>b</sup>
<b>Point West Shopping Center*</b> Lexana, KS	Reduced curb and gutter, reduced storm sewer and inlets, reduced grading, and reduced land cost used porous pavers, added bioretention cells, and native plantings. (Beezhold 2006)	\$168,898
<b>Office Warehouse*</b> Lexana, KS	Reduced impervious surfaces, reduced storm sewer and catch basins, reduced land cost, added bioswales and native plantings. (Beezhold 2006)	\$317,483
<b>Retail Shopping Center*</b>	9-acre shopping development reduced parking lot area, added porous pavers, clustered retail spaces, added infiltration trench, bioretention and a sand filter, reduced curb and gutter and stormwater system, and eliminated infiltration basin. (Center for Watershed Protection 1998b)	\$36,182 \$4,020 per acre <sup>b</sup>
<b>Commercial Office Park*</b>	13-acre development reduced impervious surfaces, reduced stormwater ponds and added bioretention and swales. (Center for Watershed Protection 1998b)	\$160,468 \$12,344 per acre <sup>b</sup>
<b>Tellabs Corporate Campus</b> Naperville, IL	55-acre site developed into office space minimized site grading and preserved natural topography, eliminated storm sewer pipe and added bioswales. (Conservation Research Institute 2005)	\$564,473 \$10,263 per acre <sup>b</sup>
<b>Vancouver Island Technology Park Redevelopment</b> Saanich, British Columbia	Constructed wetlands, grassy swales and open channels, rather than piping to control stormwater. Also used amended soils, native plantings, shallow stormwater ponds within forested areas, and permeable surfaces on parking lots. (Tilley 2003)	\$530,000

Source: ECONorthwest, with data from listed sources.

Notes: \* indicates hypothetical or modeled project, not actually constructed.

<sup>a</sup> Dollar amounts as reported at the time of study.

<sup>b</sup> Per-acre cost savings calculated by ECONorthwest.

## C-2 LID Case Studies

Descriptive information is included in this appendix for more than 30 projects, including three local Placer County case studies. Fact sheets are presented for the four California projects and more details for the remaining projects can be found on the Placer LID TAC web portal: <http://cbecoeng.com/placerLIDTAC>. The case studies were compiled by Charlene Daniels of Placer County.

## Low Impact Development Case Studies for Use in the Placer County Sierra Nevada

SD-1. Protect Natural Conditions	SD-2. Optimize Site Layout	SD-3. Control Pollutants at Source	SD-4. Integrate Eco-Friendly Landscaping	RM-1. SW Flowpath Disconnection	RM-2. Rainwater and Snowmelt Harvesting	RM-3. Infiltration and Dry Well	RM-4. Bioretention	RM-5. Vegetated Filter Strip	RM-6. Vegetated Swale	RM-7. Permeable Pavement	RM-8. Green Roof	Project Name	Location	Landuse Type	New Construction/ Retrofit	Weblink	PDF	Contact Name/ Number/ Info
Local Studies																		
										•		Minnow Avenue Public Parking Lot	Kings Beach, California	Parking Lot	New Construction		 Minnow Ave Parking Lot	Brian Stewart, (530) 581-6216
			•									Truckee Meadows Stormwater Plan	Reno, Sparks Nevada	Plan Area	New Construction/ Retrofit	<a href="http://www.werf.org/livablecommunities/studies/truckee_nv.htm">http://www.werf.org/livablecommunities/studies/truckee_nv.htm</a>	 Truckee Meadows	N/A
			•									Truckee River Friendly Landscaping Program	Truckee, California	Existing Residential Development	Retrofit		 Truckee River Program	Andy Otto (530) 550-8760, ext. 3, aotto@truckeeriverwc.org
			•			•					•	Cedar House Sport Hotel	Truckee, California	Existing Commercial Development	New Construction		<a href="#">Cedar House.pdf</a>	Jeff Baird, (530) 559-5254, patty@cedarhousesporthotel.com
						•		•				UC Davis Tahoe City Field Station	Tahoe City, California	Existing Commercial Development	Retrofit		<a href="#">UC Davis Tahoe City Field Station.pdf</a>	Dr. Alan Heyvaert, (775) 673-7322, Alan.Heyvaert@dri.edu
Protect Natural Conditions																		
•												Western Michigan University Business Park	Kalamazoo, Michigan	Office Park	New Construction	<a href="http://www.semco.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_chapter6.pdf">http://www.semco.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_chapter6.pdf</a>	 Western Michigan University Business	David Dakin (269) 387-8543
•												Pembroke Subdivision	Frederick County, Maryland	Subdivision	New Construction		 NRDC Stormwater Strategies Ch12	Michael Clar (410) 804-8000
Optimize Site Layout																		
	•											Marywood Health Center	Grand Rapids, Michigan	Health Center	New Construction	<a href="http://www.semco.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_chapter6.pdf">http://www.semco.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_chapter6.pdf</a>	 Protect Natural Flow Pathways	Maureen Geary (616) 647-0133
		•										Gap Creek Subdivision	Sherwood, Arkansas	Residential Subdivision	New Construction		 Sherwood Arkansas	Ron Tyne, roty@aol.com
			•									Nankin Mills Interpretive Center	Wayne County, Michigan	Interpretive Center	Restoration	<a href="http://www.semco.org/Data/lid.report.cfm?lid=168">http://www.semco.org/Data/lid.report.cfm?lid=168</a>	 Nankin Mills Interpretive Center	Noel Mullet (734) 326-4486
				•								Macomb County Riparian Corridor Preservation	Clinton Township, Michigan	Office Building	New Construction	<a href="http://www.semco.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_chapter6.pdf">http://www.semco.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_chapter6.pdf</a>	 Macomb County Riparian Corridor	Lynne Seymour (586) 307-8229
					•							Willard Beach Implementation Project	Battle Creek, Michigan	Park Road System	Retrofit	<a href="http://www.semco.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_chapter6.pdf">http://www.semco.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_chapter6.pdf</a>	 Willard Beach Impl Project	Christine Kosmowski (269) 966-0712
												Somerset	Prince George County, Maryland	Residential Subdivision	New Construction		 Somerset	N/A

## Low Impact Development Case Studies for Use in the Placer County Sierra Nevada

SD-1. Protect Natural Conditions	SD-2. Optimize Site Layout	SD-3. Control Pollutants at Source	SD-4. Integrate Eco-Friendly Landscaping	RM-1. SW Flowpath Disconnection	RM-2. Rainwater and Snowmelt Harvesting	RM-3. Infiltration and Dry Well	RM-4. Bioretention	RM-5. Vegetated Filter Strip	RM-6. Vegetated Swale	RM-7. Permeable Pavement	RM-8. Green Roof	Project Name	Location	Landuse Type	New Construction/ Retrofit	Weblink	PDF	Contact Name/ Number/ Info
Control Pollutants at Source																		
		•										Village at Springbrook Farms	Lebanon County Pennsylvania	Subdivision	New Construction	<a href="http://www.stormwaterpa.org/low-impact-development.html">http://www.stormwaterpa.org/low-impact-development.html</a>		N/A
		•										Grayling Stormwater Project	Grayling, Michigan	Stormwater Project	Retrofit			Jennifer Muladore (989) 344-0753
		•										Washington Naval Yard	Washington, DC	Primarily parking and storage areas	Retrofit			Camille Destafney (202) 433-6388
Integrate Eco-Friendly Landscaping																		
			•									Black River Heritage Trail and Waterfront Redev	Bangor, Michigan	Public Park	Retrofit	<a href="http://www.semco.org/Data/lid.report.cfm?lid=164">http://www.semco.org/Data/lid.report.cfm?lid=164</a>		Erin Fuller (269) 657-4030
			•									Nemadji River Watershed Restoration	Minnesota Wisconsin	Watershed Restoration	Restoration			Brad Matlack, bradmatlack@carltonswcd.org
Stormwater Flowpath Disconnection																		
				•								Saugatuck Center for the Arts	Saugatuck, Michigan	Art Center	Retrofit	<a href="http://www.semco.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_chapter6.pdf">http://www.semco.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/LID_Manual_chapter6.pdf</a>		Gordan Gallagher (269) 857-2603
				•								Clean River Plan	Portland, Oregon	Retrofits for existing buildings	Retrofit			Henry Stevens, henrys@bes.ci.portland.or.us
Rainwater and Snowmelt Harvesting																		
					•							People's Food Cooperative	Portland, Oregon	Commercial Building	Retrofit	<a href="http://www.portlandonline.com/bps/index.cfm?c=41950">http://www.portlandonline.com/bps/index.cfm?c=41950</a>		Miles Uchida (530) 232-9051
					•							Harvesting Rainwater	Eugene, Oregon	Residential Building	New Construction	<a href="http://www.uoregon.edu/~hof/S01havestingrain/index.html">http://www.uoregon.edu/~hof/S01havestingrain/index.html</a>		N/A
Infiltration and Dry Well																		
						•						Saugatuck Center for the Arts	Saugatuck, Michigan	Art Center	Retrofit	<a href="http://library.semco.org/InmagicGenie/DocumentFolder/LIDManualWeb.pdf">http://library.semco.org/InmagicGenie/DocumentFolder/LIDManualWeb.pdf</a>	<a href="#">see above</a>	Kirk Harrier (269) 857-2603
						•						Hills of Sullivan	London Grove Township, Pennsylvania	Residential Subdivision	New Construction			
						•						CVS Pharmacy	Elk Grove, California	Retail	New Construction			Marie Silveira, (916) 929-3323
Bioretention																		
							•					St. Francis Subdivision	Cross Plains, Wisconsin	Subdivision	New Construction	<a href="http://www.botany.wisc.edu/zedler/images/MorzaLunaJAWRA.pdf">http://www.botany.wisc.edu/zedler/images/MorzaLunaJAWRA.pdf</a>		N/A

## Low Impact Development Case Studies for Use in the Placer County Sierra Nevada

SD-1. Protect Natural Conditions	SD-2. Optimize Site Layout	SD-3. Control Pollutants at Source	SD-4. Integrate Eco-Friendly Landscaping	RM-1. SW Flowpath Disconnection	RM-2. Rainwater and Snowmelt Harvesting	RM-3. Infiltration and Dry Well	RM-4. Bioretention	RM-5. Vegetated Filter Strip	RM-6. Vegetated Swale	RM-7. Permeable Pavement	RM-8. Green Roof	Project Name	Location	Landuse Type	New Construction/ Retrofit	Weblink	PDF	Contact Name/ Number/ Info
							•					East Ridge Community Church	Duluth, Minnesota	Church	New Construction	<a href="http://www.lakesuperiorstreams.org/stormwater/toolkit/eastridge.html">http://www.lakesuperiorstreams.org/stormwater/toolkit/eastridge.html</a>	 East Ridge Comm Church	Barr Engineering (218) 529-8204
Vegetated Filter Strip																		
								•				Ford Road Outer Drive	Michigan	County Park	Retrofit	<a href="http://library.semco.org/InmagicGenie/DocumentFolder/LIDManualWeb.pdf">http://library.semco.org/InmagicGenie/DocumentFolder/LIDManualWeb.pdf</a>	 Ford Rd Outer Dr	Noel Mullet (734) 326-4486
								•				Proctor City Hall	Proctor, Minnesota	City Hall	New Construction		 Proctor	N/A
Vegetated Swale																		
									•			Nestucca Valley Prebyterian Church	Pacific City, Oregon	Church	New Construction	<a href="http://www.oeonline.org/our-work/rivers/rivers-files/stormwater-case-studies/LID_CaseStudy_NestuccaBioswale.pdf">http://www.oeonline.org/our-work/rivers/rivers-files/stormwater-case-studies/LID_CaseStudy_NestuccaBioswale.pdf</a>	 Nestucca Bioswale	Robert Emanuel (503) 842-5708 X210
									•			Pingree Grove Case Study	Pingree Grove, Illinois	Historic Downtown	Retrofit	<a href="http://www.mickeywilson.com/articles/ML/2008-October-The_Future_Of_Stormwater_Management.pdf">http://www.mickeywilson.com/articles/ML/2008-October-The_Future_Of_Stormwater_Management.pdf</a>	 The Future Of Stormwater Manag	N/A
Permeable Pavement																		
										•		Stratford Place	Sultan, Washington	Residential Subdivision	New Construction		 Stratford Place WA	Craig Morrison, www.cmihomes.com
										•		City of Kinston Public Service Complex	Eastern North Carolina	Parking Lot	New Construction	<a href="http://www.bae.ncsu.edu/info/permeable-pavement/CPI.2007Report.Final.EDITED.pdf">http://www.bae.ncsu.edu/info/permeable-pavement/CPI.2007Report.Final.EDITED.pdf</a>	 Eastern No Carolina	Scott Stevens and Steve Miller with the City of Kinston
Green Roof																		
											•	Seven Examples in Kings County	Seattle, Washington	Various public buildings	New Construction	<a href="http://www.cityofseattle.net/dpd/cms/groups/pan/@pan/@sustainableblding/documents/web_informational/dpdp_020117.pdf">http://www.cityofseattle.net/dpd/cms/groups/pan/@pan/@sustainableblding/documents/web_informational/dpdp_020117.pdf</a>	 King County	N/A
											•	Battle Creek Police Department	Battle Creek, Michigan	Public Building	Retrofit	<a href="http://www.semco.org/Data/lid.report.cfm?lid=173">http://www.semco.org/Data/lid.report.cfm?lid=173</a>	 Battle Creek Police Dept	Christine Kosmowski (269) 966-0712
											•	Chicago City Hall	Chicago, Illinois	Public Building	Retrofit	<a href="http://www.metrofieldguide.com/?p=82">http://www.metrofieldguide.com/?p=82</a>	 Chicago City Hall	N/A
Mountain Communities																		
											•	Holiday Development	Boulder, Colorado	Subdivision	New Construction	<a href="http://www.sustainablefutures.us/Best_Practices/Holiday_Neighborhood/Water_Quality_CU_Final_Rpt_StormWater.pdf">http://www.sustainablefutures.us/Best_Practices/Holiday_Neighborhood/Water_Quality_CU_Final_Rpt_StormWater.pdf</a>	 Holiday Development	N/A
				•								Environmental Center of the Rockies	Boulder, Colorado	Office Building	Retrofit	<a href="http://www.nrdc.org/water/pollution/storm/chap12.asp">http://www.nrdc.org/water/pollution/storm/chap12.asp</a>	 Boulder CO	James Heaney (303) 492-3276, Heaney@spot.colorado.edu

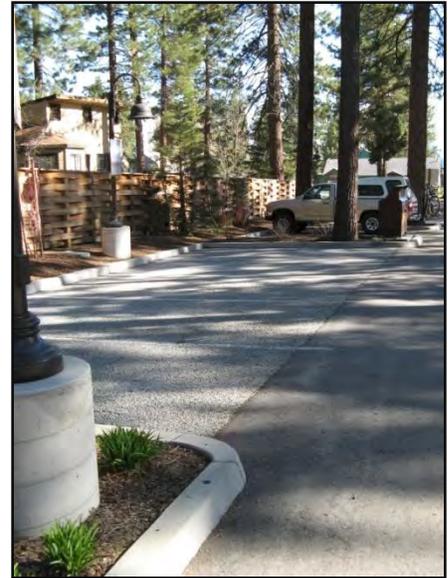
# Minnow Avenue Public Parking Lot Kings Beach, California

## Case Study (2010)

In 2007, Placer County needed to construct a 21-space public parking lot in Kings Beach to help address an existing parking deficit identified in the Kings Beach Community Plan as well as to accommodate planned future development in the area. In order to comply with the Tahoe Regional Planning Agency's requirement to treat stormwater run-off before it enters Lake Tahoe, a special design concept utilizing Low Impact Development concepts was developed.

The site is approximately 9,600 square feet in size, relatively flat, and contained numerous conifer trees. Soil composition consisted of silty red/brown sandy layers and no expansive soils were identified.

The stormwater drainage system was designed to contain runoff from a 20-year, one-hour storm event to satisfy the standards establish in the Placer County Stormwater Management Manual. The proposed drainage system consists of crowning the centerline of the parking lot to allow drainage towards the pervious pavement located in the parking stalls. The design eliminated the need for the project to provide traditional stormwater infrastructure (manhole, storm drain piping, etc)



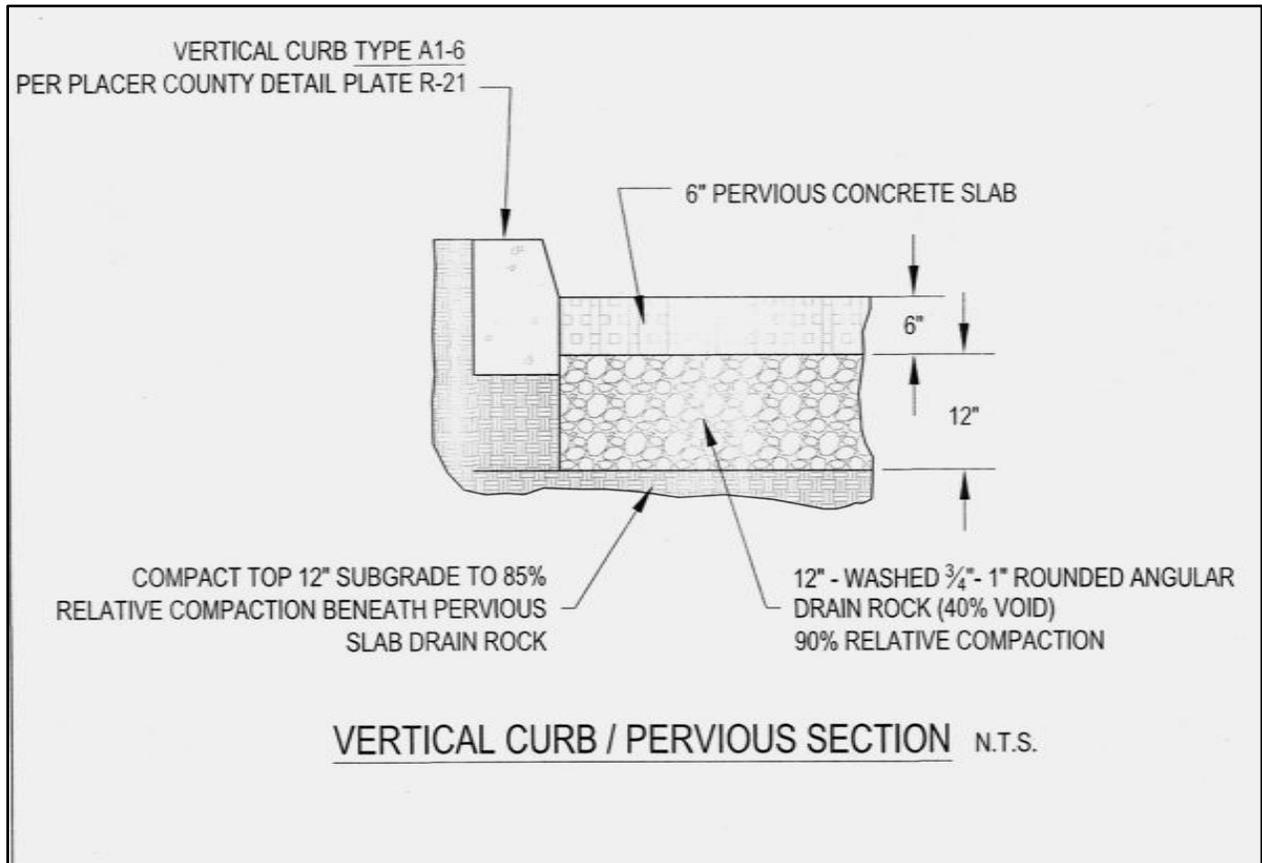
Several variances were granted to Placer County's parking lot standards, including reducing the 25-foot traffic aisle requirement to 22 feet. These variances decreased the total amount of impervious surfaces and also preserved some of the site's existing trees.

The use of pervious concrete provides several benefits to the project. Pervious concrete reduces the effect of heat islands (ground level ozone, etc) because it is a high albedo surface and the light colored pavement also reduces the need for more intensive night lighting. Automotive fluids discharged from vehicles are bioremediated by microbes living in the pervious concrete and soil to ensure that only treated stormwater enters Lake Tahoe. In addition, since there was no need to devote additional land area to accommodate traditional stormwater infrastructure, the maximum number of parking spaces could be achieved.

One of the main concerns with using pervious concrete in the harsh Lake Tahoe winters is the freeze/thaw cycles that can be damaging to all weather surfaces. Several years after the parking lot was constructed, the pervious pavement is providing the required rate of infiltration. However, there are some signs of wear and tear on the pervious pavement. In order to extend the life of pervious concrete in future projects, the Placer County Tahoe Design Division of Public Works has determined that by adding a plasticizer to the pervious concrete mixture, the strength and spalling components of

the pervious concrete can be enhanced. The Tahoe Design Division has also started requiring that a concrete strip, or flushing, be added between the asphalt and the pervious surfaces. This barrier helps avoid water intrusion from flowing under the asphalt paving section and creating a base failure.

Contact: Brian Stewart , Tahoe Design Division  
(530) 581-6216





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[Municipal Stormwater Manager](#)  
[Planner](#)  
[Builder/Developer](#)  
[Engineer/Designer](#)  
[Landscape Architect](#)  
[Homeowner/General Public](#)  
[Additional Perspectives](#)

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## Truckee Meadows Region, Nevada

### Regional Stormwater Quality Management Plan: A Comprehensive Approach

Nevada has experienced a tremendous growth in population over the past decade and is presently the fastest growing state in the country. Washoe County currently has a population of just under 400,000 people, an increase of roughly 20 percent since 2000 (Nevada State Demographer, 2006). The majority of this population resides in an area called Truckee Meadows, which includes the cities of Reno and Sparks and unincorporated areas of the County immediately adjacent. The climate is arid, with low humidity and an average annual rainfall of approximately seven inches. The Truckee River bisects Truckee Meadows into north and south sections and provides the major source of drinking water supply to the area, as well as recreational opportunities and habitat for fish and wildlife.

The Cities of Reno and Sparks, Washoe County, and the Nevada Department of Transportation (NDOT) operate and maintain the municipal storm drainage system, which includes conventional catch basin and storm drain pipes, open ditches, and wet pond structures and dry pond detention basins that are used primarily for flood control. Most of the stormwater that drains into the Truckee Meadows municipal storm drain system is conveyed untreated to the receiving waters of the Truckee River, and to three playas in unincorporated Washoe County.

Total Maximum Daily Load (TMDL) requirements have been established for the Truckee River, addressing three pollutants: nitrogen, phosphorus, and total dissolved solids. Nitrogen and phosphorus concentrations in the river have historically caused excessive plant and algal growth, which depletes oxygen when the plants die and decay. Oxygen depletion can result in the destruction of fish, wildlife, and habitats. The Nevada Division of Environmental Protection (NDEP), the cognizant regulatory authority, does not set specific requirements for TMDL implementation, but does expect that the cities and county will undertake programs that will improve water quality in the Truckee River and support the goals of the TMDL program.

### The "Early Years"—Formation of the Truckee Meadows Interlocal Stormwater Committee

The first Phase I National Pollutant Discharge Elimination System permit (NPDES) was issued jointly to the City of Reno, the City of Sparks, Washoe County, and NDOT in 1990.



Infiltration "tree boxes" being pilot-tested as part of a roadway and streetscape improvement project in the City of Reno. (Image courtesy of Sue Donaldson)

With the City of Reno as the lead agency, the permittees entered into an interlocal agreement and formed the Truckee Meadows Interlocal Stormwater Committee (TMISC), to better define responsibilities and address permit requirements in a coordinated effort. Responsibilities of the committee include the following:

- Complying with the NPDES permit conditions
- Coordinating and participating in committee meetings
- Funding and implementing NPDES permit compliance efforts
- Coordinating and implementing annual operating budgets for jointly shared tasks
- Submitting reports prepared by various parties to NDEP and the USEPA as required by the NPDES permit
- Maintaining knowledge of current and proposed state and federal policies, regulations and programs that impact "nonpoint" source pollution programs

The permit required preparation of a drainage basin map with outfalls to the Truckee River identified, an inventory of existing Best Management Practices (BMPs), an inventory of potential sources of commercial and industrial pollution, a work plan for a stormwater monitoring program, and submittal of monitoring program reports at 24, 36, and 48 months after the effective date of the permit. Stormwater monitoring took place between October 1990 and February 1992 with samples collected from all major storm drain outfalls located along the Truckee River within the Truckee Meadows and monitoring reports submitted at the specified intervals.

### [The Impetus for Change—Creation of the Regional Stormwater Management Quality Program](#)

This initial permit (and most of the compliance activities) lapsed in 1995. The permit was finally reissued by NDEP in 2000. It required the permittees to establish a Regional Stormwater Quality Management Program and to implement methods for controlling pollutants "to the maximum extent practicable." "Maximum extent practicable" is a regulatory standard, developed by the U.S. Environmental Protection Agency, that has been interpreted to give local governments some flexibility in developing stormwater management programs that respond to their unique circumstances and local conditions.

The Stormwater Quality Management Program was further required to include the following components:

1. Best Management Practices—BMPs for local government operations, including standard plans and specifications, storm drain maintenance, street sweeping, litter control, spill response and hazardous material disposal.
2. Stormwater Discharge Monitoring—Development and implementation of a monitoring program to assess the quality of stormwater discharges, the effectiveness of BMPs, and impacts on receiving waters.
3. Illegal Discharge Detection and Elimination—Development and implementation of a program to detect and eliminate illegal discharges.
4. Structural BMP Controls for Water Quality Improvements—Consideration of structural controls in site drainage plans, storm drain projects, and flood control projects.
5. Discharges to Storm Drains and Watercourses—A plan and schedule for developing and implementing a local program for the regulation of stormwater discharges from industrial facilities and construction sites.
6. Public Education and Participation—Outreach to the public to provide information on stormwater pollution and its management and to ensure public participation in program development and implementation.
7. Intergovernmental Coordination—Inclusion of appropriate government agencies in implementation of the program.

The first monitoring report was to include a plan and implementation schedule for regulating stormwater discharges from construction and industrial sites, which, given the rapid pace of development in the County, posed particular concerns.

To address coordination, the TMISC was reconstituted as the Stormwater Permit Coordinating Committee (SWPCC), consisting of two representatives each from the City of Reno, the City of Sparks, and Washoe County. The City of Reno contributes legal counsel services, clerical support, and a Stormwater Coordinator. The Committee's activities, including development of plans and guidance documents, compliance monitoring, and outreach, are funded primarily through three sources: the City of Reno's Sanitary Sewer Fund, the City of Sparks' Sanitary Sewer Fund and Stormwater Utility, and Washoe County and NDOT's General Fund accounts.

The state's Regional Water Planning Commission (RWPC) also contributed financial resources to the development of the Stormwater Quality Management Program. This entity was created in 1995 by state legislation, to serve as a forum for the planning and coordination of water use, flood control, and wastewater management. Revenue is derived through a surcharge of 1.5 percent applied to each customer's water bill.

To develop the Program, the Committee hired a consulting team, led by Kennedy/Jenks Consultants. Fourteen public workshops were conducted between May 2000 and September 2001 to research, discuss, and develop required elements of the program. The NDEP also participated in the program development process. The resulting document included a detailed description of plans and implementation action steps for each element, anticipated staff requirements, quantifiable goals to track progress, and a detailed implementation schedule through 2007. By December 2001, the document had been approved by each of the participating permittees.

### Implementation Success—From "Zero to 60" in Response to an EPA Mandate

In January 2002, the Committee hit a "bump in the road" that, in retrospect, significantly accelerated permittees' implementation of a very well-organized, multi-faceted approach to water quality management.

EPA conducted an audit of the Program, interviewing staff from Community Development, Municipal Operations, Environmental Control, and other departments to assess compliance with requirements of the Phase I permit. EPA representatives expected to find a fully implemented program - not just a Program plan - and was particularly concerned that inspection programs for construction

and industrial sites had not yet been implemented. Further, the implementation schedule for the Program indicated that full implementation would not be achieved until 2004 or 2005—two to three years away.

In August 2002, permittees were directed to accelerate the schedule for Program implementation with specific emphasis placed on implementing inspection programs for construction and industrial sites by July 2003. Initially, this seemed like a nearly impossible challenge, given that the Committee relied on each co-permit-holder's Public Works staff as in-kind resources. Committee staff, however, took it as a challenge, and took the issue to the Reno and Sparks City Councils, the Washoe County Board of Commissioners, and the Regional Water Planning Commission (RWPC), explaining the situation in a series of presentations. The RWPC agreed to contribute just over \$175,000 for the development of two manuals: one addressing construction site BMPs, the other addressing structural BMP controls, which would provide a foundation for the next phases of program implementation.

To maximize visibility and buy-in, the construction BMP handbook development process included extensive participation from the developer/builder/contractor community,



Vegetated swale at Costco parking lot (Image courtesy of Sue Donaldson)

including the local Builders' Association, Associated General Contractors, and professional organizations representing the engineering and design communities (for example, the American Society of Civil Engineers).

As a next step, checklists were developed that identified requirements for obtaining a construction permit and for implementing on-site BMPs for the duration of construction. Administrative charges for construction permits were revised, so that longer-duration projects, projects with extreme risks of erosion (due to steep slopes), and projects in closer proximity to a floodplain, paid more to compensate for their (potentially) greater impact. An inspection program was developed that relied on cross-training Washoe County and City of Reno Public Works inspectors, City of Sparks Community development inspectors, and Nevada Department of Transportation inspectors. Regulatory staff at NDEP also conduct inspections at construction sites.

### Structural BMP Controls

The implementation of structural BMPs in areas of new development and significant redevelopment was also fast-tracked. Development of a structural BMP manual was initiated in April 2003, with a public workshop held in May. The manual was completed on schedule in Fall 2003, and approved for implementation beginning in January 2004. It provides written guidance and training to local government staff, project designers, developers and structural BMP owners regarding the design, operation, inspection and maintenance of structural controls.

### Land Use Planning and Low Impact Development Tools

Though EPA did not require that the SWPCC accelerate the development of land use planning and low impact development tools, Committee staff viewed them as critical components of the program, given the rapid pace of development in the Truckee Meadows region. By mid-2005, a draft Low Impact Development Handbook was developed, which outlines principles for land use planning that minimize runoff and protect water quality. It also incorporates a set of tools, including new site design requirements (e.g. riparian setbacks and calculation of impervious coverage), land conservation tools (e.g., conservation easements and deed restrictions) and public outreach methods to encourage land use planning designs that protect water quality.

### Public Outreach

As the Program began to "ramp up" and guidance documents were developed and written, the Committee also accelerated its public outreach campaign. A [new website for the RSQMP](#) was developed that provides a central location for learning about the program; downloading guidance documents, forms, and worksheets; learning about training opportunities; and posting news and meeting agendas.

The Committee also formed an important partnership with the [NEMO-Nevada program](#), operated through the University of Nevada Cooperative Extension Service. The Cooperative Extension program operates a [public outreach program referred to as "Water Wise,"](#) hosted on KRNV Channel 4. Cooperative Extension also hosts a revolving series of public information sessions to educate area residents on water quality concerns and the role of both structural BMPs and Low Impact Development, in protecting water quality. Focused training sessions are also held on a regular basis for members of the construction and landscape contractor industry (primarily focused on the construction discharge program) and for engineers and landscape architects (focused on low impact development and structural BMPs). NEMO-Nevada has also sought speakers from across the country to provide practical lessons from other communities with similar climates and soil conditions.

### Conclusion

The 2002 EPA mandate proved to be an important "tipping point" in building momentum for the Truckee Meadows region's adoption of a comprehensive Regional Stormwater Quality Management Program. Members of the Stormwater Permit Coordinating

Committee followed through, making the initial investment in preparing necessary manuals and guidance documents and insisted on completing these both on a very aggressive schedule so they would be ready for implementation. They did this through a transparent process that involved major developer and builder stakeholders, in addition to the public. The Committee was also fortunate to contract with a local engineering consultant who was knowledgeable about, and supportive of, landscape-based water quality treatment and low-impact development techniques to develop the guidance documents. The emphasis on public outreach, and the strong partnership with NEMO-Nevada and Cooperative Extension was also an important asset in raising awareness in both professional circles and with the general public.



"Rain garden" in residential neighborhood

Momentum is definitely building in the Truckee Meadows region. In 2006, a municipal street improvements project in the City of Reno incorporated infiltration tree boxes into the streetscape component, to "pilot-test" this approach to capturing storm runoff from the roadway. Vegetated swales and rain gardens are being incorporated into retail settings and new community design. Though the Committee would suggest that much more remains to be done, their aggressive and timely response to EPA's mandate, as well as their attention to public outreach have allowed them to make rapid and meaningful progress in a relatively short amount of time.

#### Additional Information

[Truckee Meadows Regional Stormwater Quality Management Program](#)

[NEMO-Nevada](#)

[University of Nevada Cooperative Extension](#)

[City of Las Vegas Stormwater Quality Management Committee](#)

The Stormwater Quality Management Committee is committed to the development and implementation of stormwater pollution monitoring, control and outreach efforts within the Las Vegas Valley

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WERF research examines the social, economic, and environmental aspects of challenges confronting wastewater and stormwater facilities.  
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# Truckee River Friendly Landscaping Program

## Case Study (2/10/2012)

In 2010, the Truckee River Friendly Landscape program was established as a voluntary program implemented by the Truckee River Watershed Council (TRWC) in partnership with the Sierra Nevada Alliance and the Tahoe Resources Conservation District for existing residences. The intent of this incentive-based program is to help redesign existing residential landscaped areas to better mimic their natural surroundings and reduce sediment load that flows into the Truckee River. This is achieved by installing Best Management Practices (BMPs) which includes structural or non structural methods that prevent or reduce the movement of sediment, nutrients, pesticides, and other pollutant from the land to surface water. Donner Lake, Tahoe/Donner (Alder Creek and Tahoe Creek), and residences along the main Truckee River are the areas targeted by this program.

The TRWC works cooperatively with willing homeowners to help implement BMPs. The types of services provided by this program may include any one or a combination of the following:

- Structural materials for erosion control and water quality improvements.
- Plant materials for the purposes of soil stabilization or restoration.
- Technical assistance on designing and installing the various erosion control measures recommended on the homeowner's property. Technical assistance may also include planting techniques, soil and microclimate considerations.
- The Truckee River Watershed Council may monitor the effectiveness of various treatment systems and determine which improvements, if any, may be needed in the future. The site may also be utilized for demonstration purposes.

When a homeowner is interested in the program, a conservation assistant will meet with the homeowner to conduct a site evaluation and prepare a Development Treatment Workbook specifically prepared for the site. The homeowner will also contact their local fire professional for a fire defensible space inspection. The conservation assistant will review the results of the fire defensible space inspection to ensure that any recommended improvements will compliment with a fire defensible space program. If the homeowner agrees to participate in the project, a license agreement is signed by the Truckee River Watershed Council and the homeowner specifying the terms of the contract and granting the TRWC right of entry to the property. The homeowner has until December 2013 to implement at least 80 percent of the workbook in order to qualify for the Rebate Program, which has been established to assist homeowners with implementation expenses. TRWC will stay in contact with the homeowner to answer any questions and to also encourage completion of their project. Funding for the pilot program is available until December 2013.

The Truckee River Friendly Landscaping Program has enrolled 78 homeowners since the start of the program. As of the writing of this case study, none of the homeowners have had sufficient time to complete their projects. This case study will be periodically updated to provide feedback on the program's success.

Contact: Andy Otto, River Friendly Landscaping Program, Phone: 530-550-8760, ext. 3

[aotto@truckeeriverwc.org](mailto:aotto@truckeeriverwc.org)

<http://www.truckeeriverwc.org/river-friendly-landscaping/rfl-overview>



Before

Above: Before

Below: After

This landscape project included slope stabilization as well as armoring below the dripline and beneath the deck.



After

This landscape project included slope stabilization as well as armoring below the dripline and beneath the deck.

# Cedar House Hotel / Truckee, California

## Case Study (2004-2006)

**Site Use and & Protection Measures Before & During Construction:** One year before construction, the owner completed grading, drainage, and construction of 3 retention ponds to retain runoff. The retention ponds filter sediment and contaminants and allow water to percolate. The largest pond is 40' by 20' and 12' deep. Each pond has a sandy bottom. Paved areas are sloped toward the middle to runoff into the retention ponds.



**Outdoor Water Efficiency Measures in Project:** The green roof is underlain by five layers of fabric and drain channels. It is re-seeded each year. Water draining off the green roof goes through gutters down a hanging chain to the landscaping below. Water is dispersed from the chain in a circle with a diameter of 2-3 feet. The landscaping has an outward facing slope to maximize use of the runoff for irrigation. Subsurface perforated pipes direct water to gardens down slope.



A rock gabion wall on the perimeter of the property extends 3-4 feet below the ground. The rocks in the gabions filter subsurface flows. Permeable pavers cover the restaurant's patio area.

Designer: Ken Meffin, Rough & Ready, CA

Builder: Owners: JB Construction, Grass Valley, CA.

Contact: Jeff Baird

Owner / Cedar House Hotel

Phone: (530) 559-5254

Email: [patty@cedarhousesporthotel.com](mailto:patty@cedarhousesporthotel.com)

# UC Davis Tahoe City Field Station / Tahoe City, California

## Case Study (10/12/2011)

The UC Davis Tahoe City Field Station (aka Historic Fish Hatchery) building utilizes a number of innovative LID practices that were implemented on the Hatchery property when the building was renovated, including an underground infiltration system, rock-lined swales, slotted channel drains, drip-line trenches, riprap and paver infiltration areas.



Paver Infiltration Walkway



Vegetation under drip lines infiltrates roof runoff



Drip line rock armoring increases infiltration of roof runoff



Rock-lined swale

Contact: Alan C. Heyvaert, Ph.D.  
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**APPENDIX D PLANNING AND REGULATORY FRAMEWORK FOR LID**

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# **Appendix D: Planning and Regulatory Framework for LID and Recommendations for Counties and Cities to Address LID<sup>1</sup>**

## **1.0 Introduction**

Low Impact Development (LID) is a relatively new practice in California and Placer County. As such, LID is not yet well integrated into the state and local planning processes. For example, very few general plans - the foundation of the California planning process - specifically address LID, and subsequently, LID is not addressed (or inconsistently addressed) in later phases of the planning process. Such is the case in Placer County. This Guidebook offers guidance for incorporating LID into project and site planning and serves as a valuable educational tool for planners and designers in the public and private sector. But in order to be successful and realize the full range of environmental protection benefits, LID must also be addressed at the broader community planning scale.

Currently, the State Water Resources Control Board and California Regional Water Quality Control Boards (collectively known as the Water Boards) are driving the use of LID measures in new and redevelopment projects through National Pollutant Discharge Elimination System (NPDES) permits, total maximum daily load (TMDL) mandates, and/or 401 water quality certification requirements. The U.S. EPA is also encouraging LID and has published several related LID and smart growth guidance documents.

## **2.0 Current Planning Framework for LID**

### **LID and General Plans**

Although California has a variety of regional plans, including Regional Blueprints such as that adopted by the six-county Sacramento Area Council of Governments (SACOG), the cornerstone of the California planning process is the General Plan. The General Plan process is defined by California Government Code Sections 65000-66037, which delegate most local land use decisions to individual cities and counties across the state. Each county and incorporated city is required to adopt “a comprehensive long term general plan for physical development.”

General Plans include development goals and policies and lay the foundation for land use decisions made by planning commissions, county boards of supervisors and city councils. General Plans must contain text sections and maps or diagrams illustrating the general distribution of land uses, circulation systems, open space, environmental hazard areas, and other policy statements that can be illustrated. The California Government Code specifies that General Plans must contain seven mandatory elements: circulation, conservation, housing, land use, noise, open-space, and safety. Local governments may also voluntarily adopt other elements addressing topics of local interest. Cities and counties could adopt an

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<sup>1</sup> Most of the information in this appendix is an adaptation of Appendix B in the Southern California LID Manual, available from the California Stormwater Quality Association (CASQA) LID web portal at [www.casqa.org](http://www.casqa.org). Additional information about integrating LID into municipal stormwater permit programs was adapted from the Low Impact Development Center (<http://www.lowimpactdevelopment.org/lidphase2>.)

optional water element in their general plans, but few have done so. Instead, water has most often been partially addressed in either the mandatory conservation element or in optional natural resources or public facilities elements. Water is frequently addressed only in terms of water supply and/or water conservation.

## **LID, Zoning and Municipal Codes**

California law establishes zoning as a regulatory mechanism to implement general plans. Zoning is adopted by ordinances and must be consistent with general plans. Under a zoning ordinance, development is required to comply on a lot-by-lot basis with specific enforceable standards. Zoning ordinances specify categories of land use and associated standards such as minimum lot size, maximum building heights, and minimum building setbacks. Zoning ordinances can include overlay zones that provide additional standards for specified areas such as historic districts, wetlands, and other areas deemed to require extra protection.

Traditional zoning is often referred to as Euclidian zoning after the United States Supreme Court decision that affirmed the legality of zoning to separate land uses. Separation of uses became widespread as zoning gained popularity. LID is not specifically addressed in traditional zoning, but some of the standards included in specific zones can provide significant barriers to implementations of LID practices. For example, setback requirements between structures on adjacent lots (typically established for fire safety reasons) may prevent the clustering of buildings to minimize impervious surfaces and preserve natural areas.

Currently, the planning profession and many communities are experimenting with a different approach to zoning that provides more flexibility regarding building areas within particular zones combined with more stringent regulation of design elements such as architecture, landscaping, and pedestrian-friendly circulation systems. This type of zoning can help to implement smart growth, as was made possible by the approval in 2004 of Assembly Bill 1268, which allowed the use of form-based codes in the state. Form-based codes provide the flexibility to address LID and, in fact, invite the inclusion of detailed LID design elements.

In addition to zoning, municipalities also have a variety of other codes and ordinances that impact the amount of impervious cover and may create barriers for effective implementation of LID practices. To study this situation, the Local Government Commission and Ventura County secured grant funding in 2007 to conduct a review and analysis of Ventura County's codes. This review focused on two overarching questions:

1. Which code (or combinations of codes) drives creation or prevention of excess land disturbances and impervious cover at the regional, community, or neighborhood level?
2. Which aspects of the code (or combination of codes) drive creation or prevention of excess land disturbance and impervious surface at the parcel, lot, or site level (in particular, directly connected impervious surfaces)?

The analysis examined code impacts on several drivers of overall imperviousness in watersheds, including open space, infill and redevelopment, compact design use mix, streets and mobility, parking,

and site planning and environmental design. Within each category, the review included an overview of the land development elements and how they are typically treated within codes and ordinances as well as sample language and discussion of its relevance. In addition to zoning codes, the review examined other codes that impact development in Ventura County, including, the State Streets and Highway Code; building codes; circulation codes; County Fire Protection District codes, standards, and ordinances; open space and growth management ordinances; plumed watercourse setback ordinances; subdivision ordinances; water quality ordinances; transfer of development rights (TDR) programs; floodplain management regulations; land development standards; landscape standards; and local road standards. The study concluded that the codes that have the most widespread impact on imperviousness and implementation of LID practices are the zoning codes, landscape codes, parking codes, and subdivision codes. (Anderson, 2008).

More recently, the City of Bothell in Washington State completed a comprehensive analysis of its municipal codes in 2011 and found barriers to LID techniques such as narrow road widths and sidewalks, reduced setbacks, curbless roads (to allow stormwater to enter swales), and conservation easements. (Bothell, 2011).

Placer County and the local government agencies in the county have not been required to incorporate LID into their municipal codes to date, but future NPDES permit and TMDL requirements are anticipated to require this. Larger municipalities in the San Francisco Bay Area and Southern California are already grappling with this (see Los Angeles Municipal Code case study).

#### **Los Angeles Municipal Code**

The City of Los Angeles is amending the Los Angeles Municipal Code to incorporate LID. The code will be amended to “expand the applicability of the existing [stormwater development] requirements by providing stormwater and rainwater LID strategies for planning, and construction of development and redevelopment projects that require building permits” (LA DPW, 2010).

Under the City’s LID ordinance any development / re-development will be required to capture and manage stormwater runoff through onsite infiltration, capture and reuse, evapotranspiration, and high efficiency bio-filtration/retention BMPs to the maximum extent feasible. A LID Plan shall be prepared and submitted for the City’s Department of Public Works, Bureau of Sanitation for review and approval.

Prior to implementing the LID Ordinance, the Department of Public Works, Bureau of Sanitation will update the current “Development Best Management Practices Handbook” to incorporate an LID Section. The handbook currently provides guidance for developers required to address stormwater impacts. Under the LID Section of the handbook, strategies and techniques to comply with the LID requirements for stormwater management will be included to guide homeowners and developers. In addition, the LID Section will address those instances where LID requirements cannot be fully implemented onsite. Homeowners and developers may opt for offsite mitigation or an in-lieu fee, which would be used later to assist the City in implementing a water quality improvement project within the same subwatershed.

### 3.0 LID and the California Environmental Quality Act (CEQA)

#### LID and the Purpose of CEQA

California-based LID practitioners are concerned that the absence of references to LID principles in the California Environmental Quality Act (CEQA) puts LID at a disadvantage in the state<sup>2</sup>. The question of the relationship between CEQA and LID is similar to the questions that have been asked about the relationship between CEQA and the New Urbanist argument, as detailed by Cindy van Empel in her article, "CEQA and New Urbanist Development."<sup>3</sup> Van Empel concluded that the problem is due to varying interpretations of CEQA, rather than with the structure of CEQA itself. CEQA's primary purpose is, in part, to maintain a quality environment, with significant consideration given to preventing environmental damage (PRC §21000). As stated in the CEQA Guidelines (CCR §15002), the basic purposes of CEQA are to inform decision makers of environmental impacts, identify ways to reduce impacts, prevent environmental damage where feasible, and disclose to the public why an agency decides to approve a project in spite of its impacts. CEQA is essentially a disclosure law.

#### LID in CEQA Guidelines

As noted in the CEQA Guidelines, the ideal timeframe for CEQA implementation is as early in the planning process as possible to "enable environmental considerations to influence project program and design and yet late enough to provide meaningful information for environmental assessment" [CCR §15004(b)]. As general plan development is the earliest planning stage, LID should be incorporated into general plans in California. Any subsequent municipal planning must be consistent with a municipality's general plan. In the case that a planning document is inconsistent with the general plan, a general plan amendment must be adopted such that the general plan remains the consistent guiding document for planning in a municipality. Incorporation of LID into general plans would provide support for its principles at the foundational level of development planning, and would serve to link LID with CEQA Guidelines.

LID should be incorporated into General Plans in California

In order to support a municipality's preferred development pattern, it should establish significance thresholds that are consistent with general plan goals, objectives, and policies. Significance thresholds establish the framework for evaluation of impacts. They are similar to objectives or performance standards in that they provide a baseline measure against which proposals can be compared. In most impact categories, municipalities and their departments establish their own significance criteria to reflect agency or municipality goals. The standard Initial Study Checklist, Appendix G of the CEQA Guidelines, indicates that the significance of an impact is a primary concern. The lead agency of a planning process is generally responsible for establishing significance thresholds that further its objectives and that are supported by substantial evidence (CCR §15064.7).

<sup>2</sup> PRC §21000 et seq and CCR §15000 et seq

<sup>3</sup> van Empel, C., 2008. "CEQA and New Urbanist Development." *The Environmental Monitor*, Association of Environmental Professionals, Winter 2008. Sacramento, CA.

Recognition of LID in significance thresholds is another important means of incorporating LID into the planning process. If LID differs substantially from prevailing development policies, new significance thresholds will need to be established. Failure to create new significance thresholds that recognize LID will add time and expense to the development process in the form of additional CEQA review.

Policies and significance thresholds can be structured to require additional environmental review if a particular proposal does not comply with the general plan. Conversely, an agency can encourage a particular development pattern by minimizing the amount of environmental review needed for that development type. General plan policies, significance thresholds, and mitigation measures can be structured to support a preferred development type. The combination of general plan policies and adopted significance thresholds can greatly influence development patterns to favor those aligned with agency or municipality goals.

Recognition of LID in significance thresholds is another important means of incorporating LID into the planning process.

### **Addressing LID Through CEQA**

To ensure that LID is more universally addressed and incorporated, some LID practitioners have suggested that the State Office of Planning and Research (OPR) issue a CEQA technical guidance paper on LID similar to the one released addressing greenhouse gas emissions. In response to AB 32, SB 97, and lawsuits regarding the lack of attention to greenhouse gas emissions in EIRs, OPR's technical guidance document on greenhouse gas emissions includes informal guidance regarding the steps lead agencies should take to address climate change in their CEQA documents. This document serves as a powerful tool for lead agencies and CEQA practitioners. LID practitioners contend that a technical guidance document on LID following the same model would make it easier to measure the use and usefulness of LID and ensure its widespread application and consideration.

In addition, some LID practitioners recommend that the CEQA Guidelines be modified to suggest questions specifically related to LID principles, such as hydromodification, and to address LID mitigation measures and where they fit in the CEQA process (one approach is illustrated in Figure D-1).

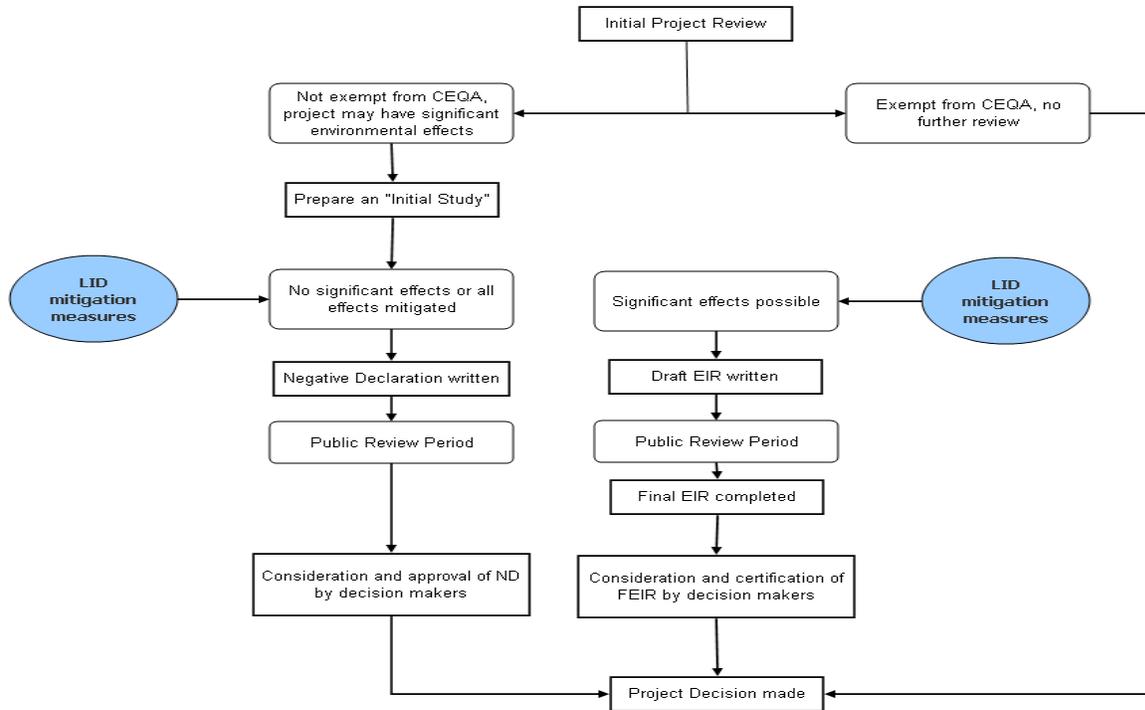


Figure D-1. An Approach for Addressing LID in the CEQA Process.  
 Source of base diagram: California Planning Guide: An Introduction to Planning in California;  
 Governor's Office of Planning and Research, 2005

## 4.0 LID is Driven by Water Quality Regulation

### LID in the State Water Board's Strategic Plan

The use of LID measures in California is driven by water quality regulations and promoted by the Ocean Protection Council. The State Water Resources Control Board's formal adoption of its *Strategic Plan Update 2008-2012* restates the Board's vision of "a sustainable California made possible by clean water and water availability for both human use and resource protection." The update contains a sustainability principle and value that states, "we commit to enhancing and encouraging sustainability within the administration of Water Board programs and activities by promoting water management strategies such as low impact development, considering the impacts of climate change in our decision-making, and coordinating with governmental, non-profit, and private industry, and business partners to further strategies for sustainability."

The *Strategic Plan Update* supports various determinations by the State Water Board in Resolution No. 2008-0030 Requiring Sustainable Water Resources, such as:

*Directs Water Boards' staff to require sustainable water resources management such as LID and climate change considerations, in all future policies, guidelines, and regulatory actions;*

*Directs Regional Water Boards to aggressively promote measures such as recycled water, conservation, and LID Best Management Practices where appropriate and work with Dischargers to ensure proposed compliance documents include appropriate, sustainable water management strategies; and*

*Directs Water Boards' staff to coordinate with partners from other government agencies, non-profit organizations, and private industry and business to further enhance and encourage sustainable activities within the administration of Water Board programs and activities.*

## **LID Municipal Stormwater Permits**

The "LID" terminology may be relatively new to Placer County, but the underpinnings of LID have existed in the county for several years, particularly in the Lake Tahoe Region, where stormwater quality and quantity controls have been part of the solution for minimizing the discharge of sediments and associated pollutants to the lake. In the Tahoe Region, the Lahontan Regional Water Quality Control Board has been requiring BMPs to filter and treat stormwater and reduce runoff in compliance with the Phase I NPDES stormwater permit<sup>4</sup>. For western Placer County (including Foresthill and Colfax) and the Truckee River Basin, stormwater treatment and LID requirements are anticipated via the renewal of the Phase II NPDES stormwater general permit by the State Water Board. In fact, such draft requirements were included in the June 2011 draft general permit. The new requirements are in addition to existing provisions mandating that the county require new and redevelopment to treat site runoff.

Many municipal permits in the state already contain specific LID and hydromodification requirements. The major emphasis of the LID requirements in the southern California municipal permits is on reduction of impervious area in order to facilitate infiltration and reduce urban runoff. In the case of the Sacramento Phase I area-wide stormwater permit, Sacramento County and six cities are tasked with the responsibility of developing design and maintenance criteria and establishing minimum standards for the use of LID practices. They are also required to develop technical guidance for reference by municipal employees and private sector practitioners involved with the implementation of LID practices.

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<sup>4</sup> Information on the County's NPDES Permit Programs can be found at:  
<http://www.placer.ca.gov/Departments/Works/StrmWtr/StrmWtrAbout.aspx>

### **How Can LID Be Used to Build More Effective Municipal Stormwater Programs?**

LID controls are well-suited for use by Phase II communities. LID reduces stormwater volumes and peak stormwater runoff rates as well as provides stormwater pollutant removal. Therefore, it is an ideal approach to provide post-construction runoff control as required by the six minimum controls and pollutant removals to the maximum extent practicable standard. LID offers the opportunity to address the full range of watershed protection criteria not fully managed by end-of-pipe stormwater controls.

LID also simultaneously addresses community issues of aesthetics and land use. The numerous vegetated LID techniques instituted throughout a community increase green space and improves the aesthetics of urban and suburban areas. This facet of LID allows it to be integrated into the community planning process. Overall land use dedicated to stormwater management is decreased with LID as the size of large stormwater catchment basins is reduced or eliminated and replaced with micro-scale management practices.

LID can be used to satisfy five of the six minimum requirements of the Phase II rule:

- Public education and outreach
- Public participation / involvement
- Illicit discharge connection and elimination
- Construction site runoff control
- Post-construction runoff control
- Pollution prevention / good housekeeping

Related to post-construction runoff control, the foundation of LID is attempting to replicate pre-development hydrology in a developed environment. One of the primary benefits of LID is the ability to limit the volume and peak flow rates of stormwater discharges by utilizing the processes of infiltration, detention, interception, and evapotranspiration. The processes employed by LID provide effective runoff control and have been used to meet hydrologic regulatory requirements.

-Adapted from Low Impact Development Center, [www.lowimpactdevelopment.org](http://www.lowimpactdevelopment.org)

### **State Stormwater Grant Programs Encourage LID**

Not only are the State Water Resources Control Board and the Ocean Protection Council promoting LID through strategic plans and resolutions, they are structuring grant funding guidelines to facilitate construction of low impact development projects. Section 4 of Assembly Bill 739 (Statutes of 2007, Chapter 610, Laird) inserted language into the Public Resources Code specifying that funds shall be available *“for assistance in implementing low-impact development and other onsite and regional practices, on public and private lands, that seek to maintain predevelopment hydrology for existing and new development and redevelopment projects.”*

Furthermore, the Stormwater Advisory Task Force, as part of its discussion of possible uses of the State Water Board’s Prop 84 stormwater grant program funds, considered evaluation of LID regulatory barriers and studies of how to implement LID on a watershed basis. The Task Force concluded that the focus of the funding should be on implementation of LID capital improvement projects in order to achieve something meaningful. However, up to 10% of the available grant funds have been allocated to finance the planning and monitoring necessary for successful design selection and implementation of

capital projects. Integrated Regional Water Management Plans (IRWMPs) and watershed plans could be funded, as could studies to revise municipal ordinances, regulations, and site design standards to clearly allow and encourage the use of LID measures. The State Water Board's stormwater grant program solicitation was published in October 2011 and the first round of funding is anticipated for award in 2012.

## **5.0 Recommendations for Counties and Cities to Incorporate LID into the Planning Process**

### **Start with the Ahwahnee Water Principles**

*The Ahwahnee Principles for Resource-Efficient Communities* was written in 1991 by the California Local Government Commission (LGC) and has served as a planning blueprint for the Smart Growth movement. The concept was for the principles to guide elected officials in developing compact, mixed use, walkable and transit-oriented communities as an alternative to existing urban and suburban sprawl patterns. The *Ahwahnee Principles for Economic Development* (1997) and the *Ahwahnee Water Principles* (2005) were later added to expand upon and complement the original Ahwahnee Principles.

There are nine Community Principles and five Implementation Principles identified in the *Ahwahnee Water Principles*. These can be generally grouped into the following four categories<sup>5</sup>:

1. Growing in a water-wise manner
2. Water-friendly neighborhood/site-scale planning and design strategies
3. Water conservation approaches to make the most efficient use of existing water supplies; and
4. A set of corollary guidelines that can help put the nine community principles into action through strategies for implementing practical steps to make the physical changes necessary to ensure water stability.

According to the *Ahwahnee Water Principles*:

- Natural resources such as wetlands, flood plains, recharge zones, riparian areas, open space, should be identified, preserved, and restored as valuable assets for such uses as flood protection and water quality improvement.
- Water holding areas, including creek beds, recessed athletic fields should be incorporated into urban landscapes.
- Landscaping should be designed to reduce water demand, retain runoff, and recharge groundwater.
- Permeable surfaces should be used for hardscape, with impervious surfaces minimized, so that land is available to absorb storm water, reduce polluted urban runoff, recharge groundwater and reduce flooding.

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<sup>5</sup> The Ahwahnee Principles can be found at the Local Government Commission's website: [http://www.lgc.org/ahwahnee/h2o\\_principles.html](http://www.lgc.org/ahwahnee/h2o_principles.html).

- Dual plumbing should be used to allow the use of greywater for landscape irrigation in new development.
- Community design should maximize use of recycled water for landscape irrigation, toilet flushing, and commercial/industrial uses, with purple pipe installed in new construction and redevelopment in anticipation of future recycled water use.
- Water conservation technologies for new construction and retrofit should be incorporated in new construction and redevelopment.
- Maximize locally available, drought-proof water supplies (i.e. groundwater treatment and brackish water desalination).

The Implementation Principles encourage the participation of water supply agencies, city and county officials, watershed councils, Local Agency Formation Commissions (LAFCOs), special districts, and other stakeholders sharing watersheds to take advantage of the benefits of watershed-level planning. They note the importance of working with water supply agencies early in the planning and land use decision-making process in order to understand technology, demographics, and growth projections and incorporate them into the planning process. In addition, the Implementation Principles stress prioritization and implementation of multi-benefit and integrated projects before others and the importance of keeping the public informed and involved in the process from inception. Projects should be evaluated to inform and improve future plans and practices.

### **Incorporate LID into General Plans**

There are several viable methods of incorporating LID into general plans. One approach would involve amending existing general plan elements to incorporate LID principles, goals, and policies. Since water is most often addressed in the required conservation element, appropriate principles, goals, and policies could be added to this element. The January 2008 report prepared for the Ocean Protection Council entitled *“State and Local Policies Encouraging or Requiring Low Impact Development in California”* recommends that a state LID statute should provide language for incorporating low impact development into the mandatory land use and conservation elements of general plans. In addition, since the land use element is the focus of local land use decisions, language on low impact development should also be added to the element. When water is addressed in another element, such as an optional natural resources or water element, LID language should be added to that element.

A second approach would be to develop a new water element. Not many such optional elements have been adopted in California; however, the 2003 edition of the State of California General Plan Guidelines contains a detailed discussion of optional water elements. OPR stated,

*“Given the importance of water to the state’s future, a community would be well served to create a separate water element, in conjunction with the appropriate water supply and resource agencies, in which each aspect of the hydrologic cycle is integrated into a single chapter of the general plan. With recent law that requires land use decisions to be linked to water availability, a water element takes on increased importance.”*

An optional element, such as a water element, can be amended at any time, which is important since LID is an evolving practice. To assist local governments in developing water elements, the LGC included a

model water element as appendix to its July 2006 publication, *The Ahwahnee Water Principles, A Blueprint for Regional Sustainability*.

The model water element proposed by the LGC includes sample policies grouped into three sections: 1) Watershed protection and management; 2) Protecting and improving water quality; and 3) Managing supply and demand of water resources. The model element was designed to provide a policy framework to address the links between water and land use. It builds upon the Ahwahnee Water Principles.

### **Address LID Through Specific Plans**

One of the most potentially useful planning tools to promote and facilitate LID may be the specific plan. A specific plan is a very flexible tool for systematically implementing general plans. Specific plans must be consistent with Section 65450-65457 of the California Government Code. These provisions require that specific plans be consistent with the general plans of the jurisdictions that adopt them. The range of issues addressed and the area covered by specific plans is left to the discretion of the decision-making body of the city or county adopting the plan. Once a specific plan is adopted, all zoning regulations, all public works projects, and all subsequent subdivision and development must be consistent with the specific plan.

Section 65451 of the Government Code specifies the structure of a specific plan. The information that is to be presented by text and diagram includes the distribution, location and extent of land uses within the area covered by the plan. Specific plans also include:

*“(2) The proposed distribution, location, and extent and intensity of major components of public and private transportation, sewage, water, drainage, solid waste disposal, energy, and other essential facilities proposed to be located within the area covered by the plan and needed to support the land uses described in the plan.*

In addition, the specific plans contain:

*“(3) The Standards and criteria by which development will proceed, and standards for the conservation, development, and utilization of natural resources, where applicable,”  
and*

*“(4) A program of implementation measures including regulations, programs, public works projects, and financing measures necessary to carry out paragraphs (1), (2), and (3).*

Since specific plans are flexible and scalable by design, they can be used in different ways to implement LID. If adopted by resolution, a specific plan is a policy document. If adopted by ordinance, a specific plan would be a regulatory document. An overlay specific plan could be adopted either by resolution or ordinance to address only the LID issue. Alternatively, a specific plan could be adopted to address the comprehensive development or redevelopment of a defined area and include LID requirements among the standards and implementation measures applicable to the area. The City of San Bernardino is developing a model specific plan for watershed sustainability that should be a useful reference for other municipalities wishing to incorporate LID into specific plans (see case study below).

### **San Bernardino's Experience Incorporating LID Into Specific Plans**

An example specific plan is being prepared for a portion of the City of San Bernardino as part of the Inland Empire Sustainable Watershed Program (IESWP), a Proposition 50 grant project funded through the CalFed Watershed Program of the California Department of Water Resources. This project, "*The Model Specific Plan for Watershed Sustainability*" was designed to "develop a guide for how urban planners can use land use design to create LID-friendly specific plans that implement LID at a community scale. This approach leverages the efficiency and opportunity of scale to streamline the MS4 storm water runoff permit compliance process.

The IESWP is a capacity building program to increase participation in watershed planning and management in the upper Santa Ana River watershed. It targets land use planners and decision-makers, the development community, and residents by providing products, resources, and forums that encourage the incorporation of watershed and low impact development approaches into the planning and development process.

### **Address LID Through Conditions of Approval**

One method of addressing LID as early as possible in the planning process and of tracking implementation of LID practices would be to develop and apply both standard and non-standard conditions of approval. Most jurisdictions apply conditions of approval to the approval of development projects. These conditions often relate to a broad range of topics, including grading, drainage, landscaping, and water quality. Conditions of approval normally state what is to be done, who is to do it, when it is to be done, and who is responsible for determining compliance. Conditions are applied to discretionary planning permits and subdivision maps at different levels in the approval process and may be repeated at subsequent levels of approval when they would be informative to applicants or municipal staff.

Many jurisdictions have developed water quality conditions of approval. Such conditions often relate to pollution prevention during construction and planning for the installation of post-construction structural and non-structural water quality control measures.

New conditions of approval requiring consideration of, and planning for, implementation of low impact development measures could be added to the lists of conditions of approval. LID conditions of approval should be applied as early as possible in the project approval process and repeated at subsequent levels of approval to ensure compliance, timely implementation, and long-term maintenance.

## **6.0 Recommendations for Counties and Cities to Incorporate LID into Municipal Codes and Ordinances**

### **Amend Municipal Codes to Address LID**

Municipal codes can relate to low impact development in several ways. Cities and counties can adopt separate LID ordinances to require the use of LID principles in development projects and provide standards for the use of LID. An LID ordinance can specify when LID implementation plans are due and can specify compliance with criteria and standards in a manual or guidance document that can be updated as new information becomes available and as experience with implementation and maintenance of LID measures is gained.

Municipal codes may contain barriers to LID implementation. The magnitude of the barriers in existing ordinances will vary with the purpose of implementing LID measures. If the primary purpose for implementing LID measures is to reduce runoff to improve water quality or to improve flood control, the barrier in existing ordinances may be less difficult to overcome than if the purpose is to achieve a broad watershed protection and enhancement goal.

Many types of codes and ordinances can influence the implementation of LID. Different codes may impact LID differently at different scales. At the site scale, building codes, landscape codes, parking codes, and zoning ordinances can influence site coverage, building dimension, parking requirements and landscaping. Parking codes have received special attention because vehicle parking is a major component of the built environment. These issues are discussed in detail in the January 2008 Tetra Tech analysis of *“State and Local Policies Encouraging or Requiring Low Impact Development in California”* and in an analysis of watershed-based planning strategies completed for Ventura County by the Local Government Commission, referenced previously in this appendix.

Removing barriers to LID in existing codes, including zoning codes, is likely to be a time consuming process and vary from jurisdiction to jurisdiction. Perceived barriers to implementation of LID measures are often the result of the needs and experience of multiple departments within a municipality. These departments have promoted standards to facilitate achieving a variety of goals and responsibilities. Not all perceived barriers will need to be removed from existing codes. It may be easier, at least initially, to use overlay zones or specific plans to facilitate implementation of LID practices in both new development and redevelopment projects. As more experience is gained with implementation of LID, standards could be modified in consultation with the departments that promoted the standards that are perceived by stormwater managers to be barriers to LID.

### **Institutional Barriers to LID and Economic Incentives to Encourage Its Use**

Pilot installations, full-scale developments, and academic research have shown LID to be a technologically feasible and effective stormwater management approach. Current impediments to broader application of LID are often institutional barriers – zoning or regulatory policies that discourage or limit its use. Despite these obstacles, municipalities need to press on and should review applicable codes and regulations for opportunities to encourage the use of LID (some examples are provided below). Municipalities should streamline the permit process. Waivers for the small land disturbances typical of LID are a regulatory option available in many jurisdictions and go a long way in streamlining the permitting process. Applicable guidelines should also be reviewed to confirm that they allow for on-lot stormwater management and do not prohibit such practices.

Some of the largest impediments to the implementation of LID are the often unintentional zoning and code barriers, such as those explicitly requiring curb and gutter or prohibiting open channel conveyances. These zoning ordinances and codes require obtaining a waiver to implement LID practices, greatly lengthening the development and construction process. Additionally, local plumbing codes, like those requiring downspouts to be directly connected to collection systems unintentionally prevent downspout disconnection efforts and the use of on-site stormwater management.

A number of municipalities have developed economic incentive programs for developers, homeowners, or commercial property owners that use LID. As stormwater utilities are being created in municipalities to fund stormwater control programs, some jurisdictions are incorporating provisions designed to encourage alternate stormwater controls. Portland, Oregon and Orlando, Florida provide a reduction in the stormwater utility rate for commercial properties with on-site stormwater management. Several municipalities subsidize downspout disconnection programs, either providing a cash incentive to homeowners and community groups or having municipal personnel provide the service for free.

-Low Impact Development Center, 2011 ([www.lowimpactdevelopment.org](http://www.lowimpactdevelopment.org))

### **Adopt or Amend Ordinances to Facilitate LID**

One direct way to use city and county codes to facilitate LID is to adopt specific LID ordinances to require the use of LID principles in development projects. This approach has been followed by the County of Los Angeles (see below). Another approach is to amend existing stormwater ordinances to address LID.

### **The County of Los Angeles' Experience Amending Codes to Address LID**

The County of Los Angeles added a chapter to the Title 12 Environmental Protection of the Los Angeles County Code. This chapter is entitled Low Impact Development (LID) Standards; its stated purpose is to require the use of LID principles in development projects. The chapter states, *"LID builds on conventional design strategies by utilizing every softscape and hardscape surface in the development to perform a beneficial hydrologic function by retaining, detaining, storing, changing the timing of, or filtering stormwater and urban runoff."* The ordinance requires that comprehensive LID plans that demonstrate compliance with an LID Standards Manual be submitted for review and approval by the Department of Public Works. It also specifies that urban and stormwater runoff quantity and quality control standards will be established in the LID Standards Manual that is to be updated and maintained by the Department of Public Works. For subdivisions, the LID plans must be approved prior to tentative map approval. For all other development, an LID plan must be approved prior to issuance of a grading permit or, where a grading permit is not required, prior to issuance of a building permit.

The Subdivision and Planning Zoning Titles of the Los Angeles County Code were amended to add reference to the Low Impact Development Title. In addition, the County adopted ordinances for green building and drought-tolerant landscaping. All three ordinances apply to all administrative and all discretionary projects.

## **7.0 Achieving Compliance with Other Regulations Through Implementation of LID**

### **LID and Implementation of Senate Bill (SB) 375**

Senate Bill 375, adopted and signed into law in 2008, uses the climate change goals of AB 32 to promote Smart Growth. It was the product of a two-year process that resulted in a compromise that was generally supported by the California Building Industry Association, major environmental organizations, and the League of California Cities.

A summary of SB 375 produced by the Association of Bay Area of Governments (ABAG) states that the bill, in part, *"requires metropolitan planning organizations to include sustainable communities strategies in their regional transportation plans for the purpose of reducing greenhouse gas emissions, aligns planning for transportation and housing, and creates specified incentives for the implementation of the strategies."*

A major objective of the bill is to reduce greenhouse gas emissions from cars and light duty trucks. The bill uses the annual distribution of transportation funds by the State as a compliance incentive. The emphasis of the regional planning requirements in SB 375 is to link land use planning to transportation planning and housing element requirements.

A key element of the bill that could be used to promote low impact development is the requirement that each Metropolitan Planning Organization (MPO) in California must develop and adopt a sustainable communities strategy as part of its regional transportation plan. Certain future transportation planning and programming activities would then be required to be consistent with the sustainable communities

strategy. The bill also requires that the State Air Resources Control Board review each MPO's sustainable communities strategy to determine whether the strategy, if implemented, would achieve the greenhouse gas emission reduction targets. In addition, certain MPO transportation planning and programming activities must be consistent with the sustainable communities strategy.

Although the sustainable communities strategies are focused on reduction of greenhouse gases and contain no specific LID or water quality requirements, they will present opportunities to promote LID. One of the requirements of the strategy documents is to "identify the general location of uses, residential densities and building intensities within the region." MPOs are also authorized to "adopt a framework for a subregional sustainable communities strategy or alternative subregional planning strategy to address the integral land use, transportation, economic, air quality, and climate policy relationships." Planning departments and water quality programs could work with MPOs to get LID and watershed management included in sustainable community strategies.

For information on SACOG's accomplishments related to developing sustainable communities strategies, see: <http://www.sacog.org/sustainable/about/>.

### **LID and Water Efficient Landscape Ordinances (AB 1881)**

Assembly Bill 1881 required the Department of Water Resources to develop a Model Water Efficient Landscape Ordinance<sup>6</sup> in order to improve the efficiency of water use for irrigation in the state. This model ordinance was either adopted by local agencies by January 2010 or the agencies developed their own equivalent ordinance (some agencies, such as Placer County, adopted the state model and some are currently working towards a tailored ordinance for this area). The ordinance will apply to new and existing projects, and will require the use of water efficient landscaping practices. Application of LID design principles should help communities and water agencies meet the requirements, because LID naturally leads to water efficient landscaping through the capture and reuse of rainfall, promotion of infiltration onsite, and the use of climate-appropriate plantings.

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<sup>6</sup> The State DWR model ordinance can be found here: <http://www.owue.water.ca.gov/landscape/ord/updatedOrd.cfm/>.

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**APPENDIX E RESOURCES FOR MORE INFORMATION**

# LINKS FOR PLACER LOW IMPACT DEVELOPMENT GUIDEBOOK

## Top Low Impact Development Links

CASQA California LID Portal

<http://www.casqa.org/LID/tabid/240/Default.aspx>

International Stormwater Best Management Practices (BMP) Database

<http://www.bmpdatabase.org/>

Low Impact Development Center

<http://www.lowimpactdevelopment.org/links.htm>

Low Impact Development (LID) Urban Design Tools Website

<http://www.lid-stormwater.net/>

Puget Sound Partnership Stormwater & Low Impact Development (LID)

<http://www.psp.wa.gov/stormwater.php>

US EPA Low Impact Development (LID) Site

<http://www.epa.gov/owow/NPS/lid/>

Water Sensitive Urban Design Program

<http://www.wsud.org/>

WERF Low Impact Development

[http://www.werf.org/AM/Template.cfm?Section=Search&Template=/CustomSource/KnowledgeAr  
eas/GetTaggedContent.cfm&TagId=180](http://www.werf.org/AM/Template.cfm?Section=Search&Template=/CustomSource/KnowledgeAreas/GetTaggedContent.cfm&TagId=180)

## Other Useful Links

### Local Links (Tahoe Area)

Low Impact Development: Projects and Guidance

<http://www.reno.gov/Index.aspx?page=996>

TRPA Stormwater Management Program

<http://www.tahoebmp.org/>

### California Links

CASQA California LID Portal

<http://www.casqa.org/LID/tabid/240/Default.aspx>

Low Impact Development – Sustainable Storm Water Management

[http://www.waterboards.ca.gov/water\\_issues/programs/low\\_impact\\_development/](http://www.waterboards.ca.gov/water_issues/programs/low_impact_development/)

Ordinances for Green Building, LID, and Drought-Tolerant Landscaping – LA County

[http://planning.lacounty.gov/assets/upl/data/ord\\_green-building-final-ordinances.pdf](http://planning.lacounty.gov/assets/upl/data/ord_green-building-final-ordinances.pdf)

Sacramento Stormwater Quality Partnership

<http://www.beriverfriendly.net/>

### **Other State Links**

University of Connecticut National NEMO LID Network  
[clear.uconn.edu/tools/lidmap](http://clear.uconn.edu/tools/lidmap)

Massachusetts Smart Growth/ Smart Energy Toolkit (LID)  
[http://www.mass.gov/envir/smart\\_growth\\_toolkit/pages/mod-lid.html](http://www.mass.gov/envir/smart_growth_toolkit/pages/mod-lid.html)

Michigan Low Impact Development Site  
<http://www.semco.org/lowimpactdevelopment.aspx>

North Carolina State University LID Site  
<http://www.ces.ncsu.edu/depts/agecon/WECO/ncsulid/>

Puget Sound Partnership Stormwater & Low Impact Development (LID)  
<http://www.psp.wa.gov/stormwater.php>

University of Washington Center for Urban Water Resources  
<http://depts.washington.edu/cuwrm/>

Washington State Department of Ecology  
<http://www.ecy.wa.gov/programs/wq/wqhome.html>

Urban Land Institute  
<http://www.uli.org/>

## **APPENDIX F TOOLS FOR PLANNING, SELECTING AND DESIGNING LID STRATEGIES FOR PROJECTS IN PLACER COUNTY**

**LID Planning and Design Process Overview Flowchart**

**LID Planning and Design Checklist**

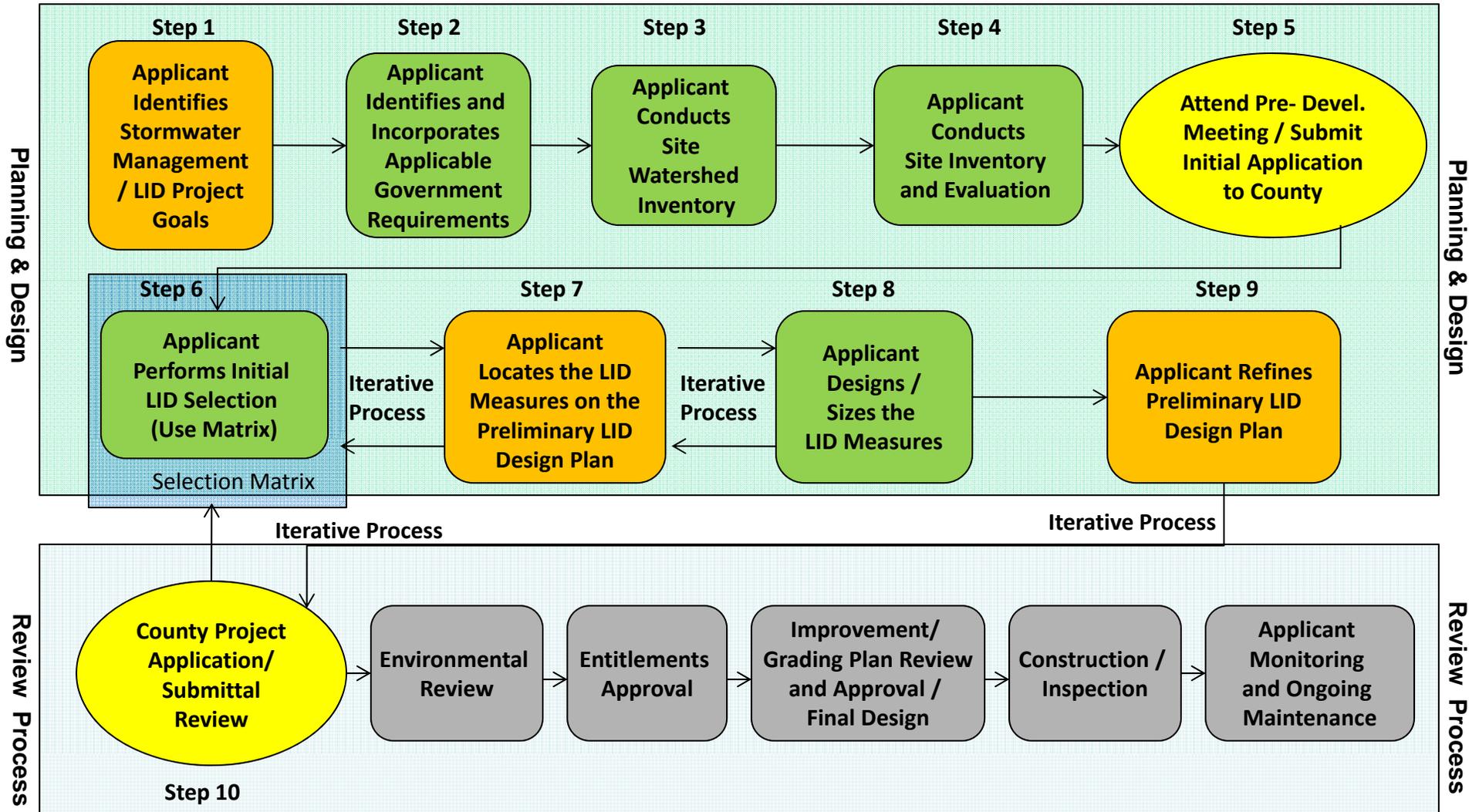
**LID Selection Matrix**

**LID Site Design (SD) Measure Fact Sheets (4)**

**LID Runoff Management (RM) Measure Fact Sheets (8)**

# Figure 3-1. Low Impact Development (LID) Planning and Design Process Overview

(Use this Flowchart in conjunction with LID Planning and Design Checklist)



Note: This is "ideal case", not typical of all projects. Actual LID process is more iterative than shown, but the LID process has been displayed in a linear fashion to more easily identify steps of the LID design process.

# Placer County LID Guidebook

## LID Planning and Design Checklist

The information provided in this checklist pertains specifically to integration of Low Impact Development (LID) principles into the development project planning and design process. This checklist represents one part of the typical overall planning process and is not intended to replace or supersede any required County procedures. The LID planning and design steps described herein may reference other related processes, studies, permits or submittals that may be required for environmental compliance, but it is not intended to replace or supersede those elements.



### Getting Started

Prior to completing this checklist, complete the following Placer County planning documents if applicable (*having these completed forms in hand will be helpful when completing the LID Checklist*):

- Initial Project Application
- Exemption Verification (if applicable)
- Standard or Minor Environmental Questionnaire

*Check with County planning staff early in the planning process to verify which requirements apply to the project.*

### Basic Project Information

Project Name: \_\_\_\_\_  
Project Owner: \_\_\_\_\_ Project Designer: \_\_\_\_\_  
Project Address/City/Zip Code: \_\_\_\_\_

Total Size (ac): \_\_\_\_\_ Approx. Area Disturbed (ac): \_\_\_\_\_

Zoning: \_\_\_\_\_

Project Type: (check all that apply)

- |  |  |   |
|--|--|---|
| <input type="checkbox"/> New Development           | <input type="checkbox"/> Redevelopment |   |
| <input type="checkbox"/> Single Family Residential | <input type="checkbox"/> Commercial    | <input type="checkbox"/> Public/Institutional |
| <input type="checkbox"/> Multi-Family Residential  | <input type="checkbox"/> Industrial    | <input type="checkbox"/> Roadway              |

Phasing – is the project part of a larger phased development?  yes  no

If so, describe: \_\_\_\_\_

### Projects with Limited LID Potential or Special Requirements

If any of the following situations apply to the project, LID potential may be limited or the project may be subject to special requirements.

- Detached single-family home projects that are not part of a larger plan of development
- Small commercial/industrial development
- Retrofit/redevelopment project
- Previous soil and/or groundwater contamination (e.g., Brownfields)
- Project will use existing on-site or immediate off-site stormwater drainage system
- Located in the Tahoe Regional Planning Agency's (TRPA's) jurisdiction
- Subject to Total Maximum Daily Load (TMDL) or other water quality regulatory requirements
- Subject to a Community Enhancement Program (CEP)

*Obtain copies of this checklist and other applicable documents from Placer County Planning Services Division (in person or on-line at:*

<http://www.placer.ca.gov/Departments/CommunityDevelopment/Planning.aspx>

## STEP 1 - Identify Stormwater Management and LID Project Goals

What are the stormwater management goals for the proposed project?  
*(check all that apply)*

- Improve Water Quality/Reduce Pollution in Runoff
- Flood Control/Reduce Peak Flows
- Reduce Runoff from the Site
- Eliminate Runoff from the Site (Retain on site)

### Step 1

**Applicant  
Identifies  
Stormwater  
Management  
/ LID Project  
Goals**

If known, what are the stormwater management/LID strategies for the proposed project?  
*(check all that apply)*

- Infiltration
- Groundwater Recharge
- Retention
- Detention
- Disconnection of Runoff from Roofs/Impervious Surfaces
- On-Site Capture and Re-Use of Rain Water
- On-Site Capture and Re-Use of Runoff
- No Stormwater Discharge From the Site
- Other: \_\_\_\_\_
- Other: \_\_\_\_\_

*The types of LID strategies selected for the project will be influenced by site conditions such as soil type and slope/topography (see Step 4)*

## STEP 2 - Identify and Incorporate Applicable Government Requirements

### Step 2

**Applicant  
Identifies and  
Incorporates  
Applicable  
Government  
Requirements**

All projects are subject to the following Placer County requirements:

- General Plan
- Zoning Ordinance
- Land Development Manual
- Stormwater Management Manual
- Placer County General Specifications
- Subdivision Ordinance (PCC 16.04)
- Street Improvement Ordinance (PCC 12.08)
- Grading, Erosion and Sediment Control Ordinance (PCC 15.48)
- Flood Damage Prevention Ordinance (PCC 15.52)

Identify the additional local land use policy documents, plans, ordinances, requirements and guidelines that are applicable to the project.

*(check all that apply and provide document names)*

*Check with  
County Planning  
Services Division  
staff to verify  
which  
requirements  
apply to the  
project*

- Community Plan(s): \_\_\_\_\_
- Specific Plan(s): \_\_\_\_\_
- Master Plan: \_\_\_\_\_
- Master Use Permit: \_\_\_\_\_
- Design/Landscape Guidelines: \_\_\_\_\_
- Water Conservation: \_\_\_\_\_
- Other: \_\_\_\_\_



*Note: It is critical to review applicable documents checked above before proceeding with LID design. In case of conflict between other requirements and this Guidebook, the other requirements shall prevail.*

Regional/State/Federal Policies, Plans, Requirements or Guidelines - List all that apply to the project:

Regional (e.g., regional land use plans, watershed plans, etc.)

- \_\_\_\_\_
- \_\_\_\_\_

State (e.g., NPDES permits, 401 certifications, fire code, integrated regional water management, Title 24 accessibility, etc.)

- \_\_\_\_\_
- \_\_\_\_\_

Federal (e.g., Section 404, Endangered Species Act, ADA)

- \_\_\_\_\_
- \_\_\_\_\_

*In the event of  
conflict between  
other regulatory  
requirements and  
this Guidebook,  
the other  
requirements  
shall prevail.*



*Note: It is critical to review and understand applicable requirements listed above before proceeding with LID design. In case of conflict between other requirements and this Guidebook, the other requirements shall prevail.*

### STEP 3 - Conduct Site Watershed Inventory

### Step 3

Check the correct answer for each question and add responses if known:



- | Yes                      | No                       |  |
|--------------------------|--------------------------|--|
| <input type="checkbox"/> | <input type="checkbox"/> | Are there natural water bodies/waterways present on the site?<br>If yes, describe/name: _____  |
| <input type="checkbox"/> | <input type="checkbox"/> | Will the project site drainage/runoff discharge to a municipal storm drain system?<br>If yes, provide municipality name: _____   |
| <input type="checkbox"/> | <input type="checkbox"/> | Will the project site discharge to off-site receiving waters (e.g., creek, stream, river, lake, wetland)?<br>If yes, describe/name: _____<br><input type="checkbox"/> direct discharge <input type="checkbox"/> indirect discharge |
| <input type="checkbox"/> | <input type="checkbox"/> | Is the site's receiving water a 303d listed/impaired waterway, or a tributary to such a waterway?<br>If yes, describe: _____   |
| <input type="checkbox"/> | <input type="checkbox"/> | Are there existing or planned Total Maximum Daily Loads (TMDLs) for the receiving waters?<br>If yes, describe: _____   |
| <input type="checkbox"/> | <input type="checkbox"/> | Are there any known immediate downstream flooding problems?<br>If yes, describe: _____   |
| <input type="checkbox"/> | <input type="checkbox"/> | Is there run-on from neighboring properties that must be managed on the project site?<br>If yes, describe: _____<br>If yes, are there any known problems with the run-on?<br>If yes, describe: _____                               |
| <input type="checkbox"/> | <input type="checkbox"/> | Is additional development anticipated for the surrounding/adjacent area that could impact future hydrologic conditions on the site?<br>If yes, describe: _____   |
| <input type="checkbox"/> | <input type="checkbox"/> | Is additional development anticipated for the surrounding/adjacent area that could lead to further opportunities (e.g., partnerships in multi-site or regional water quality or quantity controls)?<br>If yes, describe: _____     |
| <input type="checkbox"/> | <input type="checkbox"/> | Are there other issues that could affect design of stormwater management measure for the site?<br>If yes, describe: _____<br>_____<br>_____  |

*The municipal storm drain system is defined as a conveyance or system of conveyances, including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains owned or operated by a state, county, city, special district, etc.*

## STEP 4 - Conduct Site Inventory and Evaluation

### Step 4

Perform a site visit to observe physical site features and identify potential barriers and opportunities for using LID. Use this checklist to record observations and measurements and note the locations of the features on a topographic map of the project site, or the preliminary project site plan, if available.

**Applicant  
Conducts  
Site Inventory  
and Evaluation**



*Note: Most LID runoff management measures are intended to manage water for small contributing drainage areas. If the site is greater than 5 acres, you will likely need to divide the site into separate drainage areas to each be served by one or more LID runoff management measures.*

### Identify Physical Site Conditions

Identify and note key physical site conditions on the site map/plan; for example:

- Existing lot lines, lease areas and easements
- Proposed lot lines, lease areas, and easements
- Major and minor hydrologic features, including 100-year floodplain (FEMA and/or fully developed, unmitigated floodplain), seeps, springs, closed depression areas, drainage swales, and contours.

### Identify Physical Constraints/Potential Barriers to Using LID

Do any of these **physical constraints** apply to the project site? *(check all that apply and note location on the site map/plan)*

- Soils with low infiltration (e.g., clays)
- Soils with high infiltration (e.g., rocky soils, cobbles)
- Slope > 25%
- Shallow depth to groundwater (< 10 feet)
- Project within 100-year floodplain/flood hazard area
- Sensitive water features that need to be protected (e.g., wetlands)
- Existing stormwater conveyance and/or treatment facilities (on-site and off-site)
- Areas with known or suspected contaminated soils and/or groundwater
- Aquifer and wellhead protection areas on or adjacent to the site
- Power lines/major underground utilities (e.g., buried natural gas lines)
- Areas subject to high flow conditions
- Dense overhead foliage (shade considerations for vegetative growth)
- Project space constraints based on preliminary site plan (if known)
- Other: \_\_\_\_\_
- Other: \_\_\_\_\_
- Other: \_\_\_\_\_

## Identify Opportunities for LID

Do any of these **opportunities** apply to the project site? (*check all that apply and note location on the site map/plan*)

Feature (Existing or Proposed)	LID/Site Design Opportunities
<input type="checkbox"/> Natural vegetation and environmentally sensitive areas (areas that may support habitat)	<input type="checkbox"/> Preservation of natural pervious areas to infiltrate/filter stormwater <input type="checkbox"/> Protect sensitive areas - during and after construction <input type="checkbox"/> Preserve open space by clustering buildings in a smaller area <input type="checkbox"/> Locate trash facilities away from these areas
<input type="checkbox"/> Riparian areas, natural swales, drainages, depressions	<input type="checkbox"/> Configure site to take advantage of natural site topography and avoid unnecessary cut and fill that will change the hydrologic regime <input type="checkbox"/> Bioretention/filtration of stormwater to reduce runoff and remove pollutants <input type="checkbox"/> Infiltration/groundwater recharge <input type="checkbox"/> Evapotranspiration <input type="checkbox"/> Flowpath disconnection <input type="checkbox"/> Snow storage
<input type="checkbox"/> Soils with good/moderate infiltration capacity (e.g., NRCS Types A and B)	<input type="checkbox"/> Configure site to locate LID measures such as infiltration, bioretention and pervious pavement in areas with well-drained soils (place buildings and other impervious features in other areas of the site if possible)
<input type="checkbox"/> Exposed, bare areas	<input type="checkbox"/> Revegetation, reforestation to restore infiltration/filtration functions
<input type="checkbox"/> Existing stormwater conveyance and/or treatment facilities	<input type="checkbox"/> Analyze existing stormwater treatment facilities for potential to treat additional runoff
<input type="checkbox"/> Existing impervious areas that can be converted to pervious areas	<input type="checkbox"/> Replace with pervious/ permeable pavement (e.g., porous concrete, asphalt or paving stones) <input type="checkbox"/> Use alternative driveways (e.g., with center strip of plants/DG, subject to fire approval)
<input type="checkbox"/> Buildings/ Lots	<input type="checkbox"/> Minimize individual lot size <input type="checkbox"/> Concentrate/cluster uses and lots <input type="checkbox"/> Configure lots/development to avoid sensitive natural areas and conform to natural topography <input type="checkbox"/> Integrate stormwater management/LID with lot/building layout to mitigate impacts from buildings and other impervious surfaces <input type="checkbox"/> Use rain barrels and/or cisterns to store rainwater for lot irrigation
<input type="checkbox"/> Rooftops	<input type="checkbox"/> Consider vegetation for rooftops, walls and adjacent areas to filter, evapotranspire rainwater, reduce runoff and shade/insulate buildings <input type="checkbox"/> Disconnect downspouts from piped storm drain system <input type="checkbox"/> Route roof runoff (rainfall/snowmelt) to vegetated areas for infiltration/filtration <input type="checkbox"/> Route roof runoff to dry wells or pervious areas for infiltration <input type="checkbox"/> Route roof runoff to rain barrels/cisterns for storage and re-use
<input type="checkbox"/> Parking lots, sidewalks, driveways	<input type="checkbox"/> Utilize permeable pavement (with or without underdrains, depending on soil type) for pedestrian and low traffic vehicular areas such as parking and alleyways ( <i>subject to fire approval</i> ) <input type="checkbox"/> Use vegetation in medians and islands within turnaround areas to

Feature (Existing or Proposed)	LID/Site Design Opportunities
<input type="checkbox"/> Parking lots, sidewalks, driveways (cont'd)	infiltrate/filter stormwater (rain and snowmelt, subject to fire approval) <input type="checkbox"/> Disconnect drives/walkways/small impervious areas to natural areas <input type="checkbox"/> Consider underground cisterns to detain water to reduce peak runoff flows or store water for re-use <input type="checkbox"/> Use minimum standards for road width ( <i>subject to fire approval</i> ) <input type="checkbox"/> Use cul-de-sacs and turnarounds at minimum standard width <input type="checkbox"/> Use minimum standards for driveway lengths and widths <input type="checkbox"/> Use minimum standards for parking ratios <input type="checkbox"/> Consider shared parking potential (e.g., shared driveways) <input type="checkbox"/> Tuck parking under buildings (tuck-under parking)
<input type="checkbox"/> Green Space/ Site Landscaping/ Road and Parking Lot Medians	<input type="checkbox"/> Connect open space/sensitive areas with larger community greenways plan <input type="checkbox"/> Connect upstream features with drainage features that infiltrate, treat, and convey stormwater <input type="checkbox"/> Determine which areas are viable for snow storage <input type="checkbox"/> Disconnect runoff flow paths with vegetation wherever possible

**STEP 5 - Attend Pre-Development Meeting / Submit Initial Application to County**

**Step 5**



Prior to scheduling the pre-development meeting or submitting the initial planning application to the Planning Services Division, the following tasks are recommended (check off when completed):

Review the following if available (if not available before the pre-development meeting, planning staff will ask for these types of reports to be prepared after the meeting):

- A **soils report** prepared by a licensed geotechnical engineer or licensed engineering geologist. The report shall identify infiltration capability, natural stormwater conveyance, depth to groundwater and geologic hazard areas.
- An **inventory of existing native vegetative** cover by a licensed landscape architect, arborist or qualified biologist, identifying any forest areas on the site, species and condition of ground cover and shrub layer, tree species and canopy cover.
- A **streams, wetland, and water body inventory and classification** report by a qualified biologist showing wetland and buffer boundaries, if present.
- Stormwater best management practices plan** prepared by a licensed civil engineer.

Based on the previous steps 2-4, summarize any issues associated with:

- Hydrologic Features \_\_\_\_\_
- Soils/Grading \_\_\_\_\_
- Vegetation \_\_\_\_\_
- Wetlands \_\_\_\_\_
- Flooding \_\_\_\_\_
- Groundwater \_\_\_\_\_
- Other \_\_\_\_\_

Re-evaluate the stormwater management/LID project goals originally developed in Step 1 and adjust page 2 of the checklist as needed to reflect the site opportunities and constraints.

Check with the Planning Services Division to determine which of these agencies/groups needs to be consulted during or after meeting (*check all that apply*):

- Planning Services
- Engineering and Surveying Department
- Environmental Engineering and Utilities (Special Districts)
- Environmental Health Services
- CalFire
- Building Services
- Facility Services-Parks
- Department of Public Works

## Step 6 –Perform Initial LID Selection (Use LID Selection Matrix)



*In this step in the process, use the results from the site evaluation (Step 4) to determine which LID design concepts are viable, and which concepts are not feasible for the project site. This evaluation may result in a need to revisit and revise any preliminary site design in an iterative fashion.*

Use the LID Selection Matrix (at the end of this checklist) and the 12 associated fact sheets in Chapter 4 of the LID Guidebook to consider and initially select Site Design (SD) measures and LID Runoff Management (RM) measures for the project.

### LID Site Design Measures:

- SD-1: Protect Natural Conditions and Sensitive Areas
- SD-2: Optimize Site Layout
- SD-3: Control Pollutants at Source
- SD-4: Integrate Eco-Friendly Landscaping

### LID Runoff Management Measures:

- LID 1: Stormwater Disconnection
- LID 2: Rainwater and Snowmelt Harvesting
- LID 3: Infiltration Trench / Dry Well
- LID 4: Bioretention
- LID 5: Vegetated Filter Strip
- LID 6: Vegetated Swale
- LID 7: Permeable Pavement
- LID 8: Green Roof

Plan ahead for short and long-term maintenance needs and identify likely responsible party to provide the maintenance, as well as funding mechanism to pay for such maintenance to ensure optimum performance (*consider consulting maintenance personnel before design is complete*)

## Step 6

**Applicant  
Performs Initial  
LID Selection  
(Use Matrix)**

### *Iterative Process*

**Step 6. SELECT LID Measure**  
**Step 7. LOCATE LID Measure**  
**Step 8. SIZE LID Measure; if feature does not work, then go back to Step 6 to select another LID measure.**

*Site design measures are typically non-structural and relate to the layout of the site, whereas the LID measures are structural in nature and have associated construction/installation and maintenance costs.*

## STEP 7 – Locate the LID Measures on the Preliminary LID Design Plan

Use the information from Steps 4, 5 and 6 to locate the LID features on the Preliminary LID Design Plan. Sketch a design concept that distributes the LID measures appropriately on the project site, including notes on how the LID measures connect to on-site and/or off-site stormwater drainage systems.

Keep these ideas in mind as you locate LID measures on the LID Design Plan:

- Preserve and utilize existing natural/vegetated areas as much as possible
- Minimize site disturbance, building footprints and impervious areas
- Locate new impervious features on previously disturbed areas or over areas of the site with clay/impervious soils, shallow groundwater table, known pollution, etc.
- Disconnect all impervious surfaces (roofs, roads, driveways, patios, etc.) and direct flow to vegetated areas
- Manage stormwater runoff (including rainfall and snowmelt) and pollutants as close to the source as possible to minimize costs of storm drain pipes and other conveyance features
- Consider LID runoff management measures that can capture/manage stormwater from adjacent impervious areas
- Consider multipurpose benefits of stormwater management/LID techniques/facilities. For example:
  - Preserved or new natural areas can provide habitat for wildlife and increase aesthetic value for the community
  - Recreation areas can be located in networks of open space or green corridors or dual-purpose detention facilities
  - Pervious parking areas can be combined with sub-surface detention facilities such as cisterns and/or infiltration chambers
  - Developments integrated with natural areas and/or community open space can have higher property values
  - Adding interpretive signage can provide educational value
- Estimate construction and maintenance costs

### Step 7

**Applicant  
Locates the LID  
Measures on the  
Preliminary LID  
Design Plan**

#### ***Iterative Process***

*Step 6. SELECT LID Measure  
Step 7. LOCATE LID Measure  
Step 8. SIZE LID Measure; if  
feature does not work, then  
go back to Step 6 to select  
another LID measure.*

## STEP 8 – Design/Size the LID Measures

Perform engineering design and calculations to develop the structural LID components. The calculation methodology and design should be consistent with the County’s recommended or accepted design criteria for stormwater management, including volume/peak rate control, water quality treatment, and any other factors specified by the agency. Additionally, the fact sheets in Chapter 4 of the Guidebook will be helpful.

### Step 8

**Applicant  
Designs /  
Sizes the  
LID Measures**

#### *Iterative Process*

*Step 6. SELECT LID Measure  
Step 7. LOCATE LID Measure  
Step 8. SIZE LID Measure; if  
feature does not work, then  
go back to Step 6 to select  
another LID Measure.*

## STEP 9 – Refine Preliminary LID Design Plan Based on Stormwater Management Objectives

Developing a stormwater management program using LID principles and practices is a dynamic process. Evaluate the design to see if it meets project stormwater management objectives.

### Step 9

**Applicant Refines  
Preliminary LID  
Design Plan**

## STEP 10 – County Project Application/ Submittal Review

Submit the application to the County for evaluation of the LID design to determine if it is acceptable. If the County requires revisions, go back to Step 6 and repeat the LID selection and design process.

### Step 10

**County Project  
Application/  
Submittal  
Review**

**>>END OF LID CHECKLIST**

# Low Impact Development Selection Matrix for Placer County Guidebook

Low Impact Development (LID) Measure		Site Condition Factors <sup>(a)</sup>								Runoff Control			Pollutant Control				Implementation				Ancillary Benefits																		
		Minimum Infiltration Rate Requirement	Minimum Head Requirement	Setback Distance Requirement	Slope > 25%	Minimum Depth to Groundwater Limitation	Substantial Additional Footprint	Vector Concerns	Long Life Expectancy, >= 20 years	Provides Detention / Impoundment Storage	Increases SW Runoff Travel Time	Reduces Volume of Overall SW Runoff	Metals Reduction	Nutrient Reduction	Oil and Grease/ Hydrocarbon Reduction	Sediment Reduction	Temperature Reduction	Construction Cost (\$ / cf) <sup>(b)</sup>	Construction Cost (\$ / feature) <sup>(c)</sup>	Annual O&M Cost (\$) <sup>(d)</sup>	Reduces Public Agency Maintenance Costs	High Elevation Winter Conditions <sup>(e)</sup>	Provides Evapotranspiration (ET)	Provides Habitat	Promotes GW Recharge	Provides Shade (Reduces Heat Island Effect)	Reduces Greenhouse Gases	Reduces Energy Use	Aesthetically Pleasing	Reduces Downstream Erosion and Flooding	Enhances Property Value								
ID	<b>LID Site Design (SD) Measures</b>	Site Condition Factors do not limit the application of Site Design Measures																																					
SD-1	Protect Natural Conditions and Sensitive Areas																																						
SD-2	Optimize Site Layout																																						
SD-3	Control Pollutants at Source																																						
SD-4	Integrate Eco-Friendly Landscaping																																						
	<b>LID Runoff Management (RM) Measures</b>																																						
RM-1	Stormwater Disconnection	X				X	X	X																															
RM-2	Rainwater and Snowmelt Harvesting			X	X			X										\$\$\$	\$\$	\$\$																			
RM-3	Infiltration Trench / Dry Well	X	X	X		X		X	X									\$\$\$	\$\$	\$\$\$																			
RM-4	Bioretention		X	X				X										\$\$	\$\$\$	\$\$																			
RM-5	Vegetated Filter Strip			X		X	X	X	X									\$	\$	\$																			
RM-6	Vegetated Swale	X	X	X		X	X	X	X									\$	\$	\$\$																			
RM-7	Permeable Pavement	X	X	X		X			X									\$\$	\$\$\$	\$\$\$																			
RM-8	Green Roof							X	X									\$\$\$	\$\$\$	\$\$\$																			

Notes: Information presented in this matrix is based on published, national literature and is intended for planning purposes only. Check References section of the LID Guidebook for sources of data.

Other Best Management Practices (BMPs) such as detention basins and constructed wetlands are not considered "small scale controls" and therefore are not included in this Guidebook.

During large storm events (when groundwater and soil is saturated), these measures will provide little, if any, hydraulic management.

(a) Specific rates and distances for each site condition factor are provided in SD and RM fact sheets.

(b) Construction Cost (\$ / cf) (2006 dollars)                      \$ = < \$3                                      \$\$ = \$3 - \$15                                      \$\$\$ = > \$15

(c) Construction Cost (\$ / feature) (2006 dollars)                      \$ = \$0 - \$10,000                                      \$\$ = \$10,000 - \$50,000                                      \$\$\$ = > \$50,000

(d) Annual O&M Cost (\$ / feature) (2006 dollars)                      \$ = < \$1,000                                      \$\$ = \$1,000 - \$5,000                                      \$\$\$ = > \$5,000

(e) Relative effectiveness ratings are based on comparison of the various practices to each other for use in High Sierra, rather than comparing the practices used in High Sierra to those on the valley floor.

# Protect Natural Conditions

PLACER COUNTY LOW IMPACT DEVELOPMENT **GUIDEBOOK**



Fact Sheet SD-1

Protect Natural Conditions is a site design measure that can be applied to most projects, and includes preserving natural areas such as riparian buffers and tree clusters; protecting environmentally sensitive areas and designated open space; protecting natural drainage features; and minimizing soil compaction during site clearing and grading.

## Planning and Design Strategies

Site design to preserve natural conditions is guided by these general strategies:

- Protect as much of the existing natural/vegetated areas of the site as possible
- Protect environmentally sensitive areas and designated open space
- Preserve and use existing natural drainage features and flow paths whenever possible. If not possible, restore these features to pre-project conditions
- Minimize soil compaction during and after construction

### Protect Natural Conditions

**Riparian Buffer:** Riparian buffer areas are important elements of local communities' green infrastructure and/or LID tool box. These areas are critical to the biological, chemical, and physical integrity of our waterways. Riparian buffer areas protect water quality by cooling water, stabilizing banks, mitigating flow rates, and providing for pollution and sediment removal by filtering overland sheet runoff before it enters the water. The Environmental Protection Agency defines buffer areas as, "areas of planted or preserved vegetation between developed land and surface water, [which] are effective at reducing sediment and nutrient loads."

**Trees and Tree Clusters:** Tree conservation at development sites will help to maintain a natural hydrologic regime. If tree conservation is not an option, plant new trees in pervious areas of development sites. Tree clusters planted in turf grass or barren ground can reduce stormwater runoff volume and peak flow, improve water quality, generate organic soils, absorb greenhouse gases, create wildlife habitat, and provide shading to mitigate temperature increases at development sites.

### Protect Environmentally Sensitive Areas and Designated Open Space

**Open Space:** Open space areas are generally defined through zoning where urban development is not permitted. These areas may be used for parks, parkways, etc.

**Environmentally Sensitive Areas:** Environmentally sensitive features include waters of the state such as wetlands, vernal pools, seasonal and perennial creeks; as well as habitat for endangered or threatened species.

### Preserve Natural Drainage Features

A main goal of LID is to maintain or mimic a site's pre-project hydrologic regime. Preserving natural drainage features, such as swales, depressions, and watercourses, and utilizing the site's natural topography will minimize site disturbance. The natural vegetation in these features will filter, slow and infiltrate stormwater runoff to protect water quality. Designers can use natural drainage features to reduce or eliminate the need for structural underground drainage systems. In areas where natural drainage features need to be modified or piped to accommodate the development, approval must be obtained from the appropriate permitting and resource agencies.

### Minimize Soil Compaction

Minimizing soil compaction is the practice of protecting and minimizing damage to existing soil quality and permeability caused by land development activities. Minimizing soil compaction will sustain and maintain infiltration rates for various LID features. It is also possible to enhance soil composition with soil amendments and mechanical restoration after it has been damaged (see fact sheet SD-4).

## OPPORTUNITIES AND BENEFITS

- Protecting of natural areas and riparian buffers (if present) will improve water quality and reduce runoff velocities and flows through filtration and infiltration, enhance site aesthetics, and provide habitat.
- Owning residences with natural and aesthetic value can lead to higher property values.
- Using riparian buffers can provide a canopy to reduce water temperature and deter growth of invasive aquatic vegetation, and prevent shoreline and bank erosion.
- Protecting trees and tree clusters offers many benefits. Trees absorb, filter and evapotranspire rainwater; sequester carbon and create oxygen which reduces greenhouse gases and provides cleaner air; and provides shade to reduce surface and runoff temperatures. Tree roots enhance infiltration capacity of the soil.
- Protecting natural drainage features and working with the existing site topography will maximize natural hydrological functions and reduce the need for cut and fill, structural stormwater conveyance facilities, and associated costs.
- Minimizing soil compaction maintains the site's natural infiltration capacity and maintains a healthy soil environment for vegetation.



Right: Signs help to raise public awareness and understanding about the need for and benefits of protecting natural resources. Photo Credit: Stefan Schuster, CDM

# PROTECT NATURAL CONDITIONS

## Design Elements

### Protect Natural Conditions

- **Identify and protect riparian buffers:** Identify and map riparian buffer areas on the site and specify setback distances and other methods for physical protection (e.g., orange protective fencing and signs) on the site plan. Consult with the local permitting agency about environmental overlay zones and any other special requirements that may apply.
- **Preserve and/or reintroduce trees and tree clusters:** Design the site plan to preserve existing trees where possible. On larger sites, install tree protection (e.g., orange protective fencing and signs) approximately 50 feet outside of the drip line (canopy) of the tree. If trees are not present at a site, design the site plan to incorporate additional trees and/or tree clusters as appropriate. A tree cluster consists of 3 or more trees and is installed using 3 feet of backfill that is compatible with site soils. Plant native trees that are salt tolerant species in areas that will receive snow melt from roadways, parking lots, or snow storage piles. Plant native trees that can withstand frequent inundation (flooding) if shallow depth to groundwater is present.

### Protect Environmentally Sensitive Areas and Designated Open Space

- **Designated Open Space:** Identify and map designated open space areas on the site. Preserve and/or create as much open space as possible. Examples of increasing the amount of open space are clustering buildings and incorporating open space as overflow parking. Open space area runoff is typically not as polluted as runoff from impervious surfaces. Isolate runoff from open space areas and use them as self-treatment areas, which are areas that use natural processes to remove pollutants from stormwater. Refrain from using pesticides or quick-release synthetic fertilizers to minimize contaminants in runoff from self-treating areas directly to the storm drain system or other receiving water.
- **Environmentally Sensitive Areas:** Identify and map environmentally sensitive areas on the site. Avoid these areas during construction, and install protection (e.g., orange protective fencing and signs) surrounding them.

### Protect Natural Drainage Features

- Identify and map drainage features (e.g., swales, channels, ephemeral streams, depressions, etc.) and specify setback distances and other methods for physical protection of these features (e.g., orange protective fencing and signs). Use existing natural drainage features, if present, to convey stormwater where appropriate. Distribute non-erosive surface flow to natural drainage features, and keep non-erosive channel flow within drainage pathways. If existing drainage modifications are required, then restore modified drainages to pre-development conditions to the extent practicable. If no natural drainage features are present, use topographic features to design stormwater conveyance to minimize cut and fill requirements.

### Minimize Soil Compaction

- Minimize soil compaction throughout project construction. Limit areas of heavy equipment, and keep heavy equipment in these areas. Following construction, aerate and plow these areas if possible to increase infiltration back to pre-development standards. Enhance soil composition with soil amendments to restore it after it has been damaged.

## Limitations

- The use of trees and tree clusters may be limited by available space, underground utilities, overhead powerlines, and shallow depth to water table (found within 3 feet of the surface).
- Soil compaction minimization may be difficult to implement on smaller sites.

## References

C.3 Stormwater Technical Guidance. San Mateo PPP, 2010.  
 Massachusetts LID Toolkit, 2007.  
 SEMCOG, LID Manual for Michigan, 2008.



Protect the root zones of trees from compaction and damage by keeping the natural area under the canopy (inside the drip line) clear.  
 Photo Credit: Carmel Brown



Diagram of site stormwater treatment and discharge. Source ACCWP, 2010

Below: Preservation of native trees or reforestation, particularly use of tree clusters, provides a wide range of water and air quality benefits while adding aesthetic value  
 Photo Credit: Carmel Brown



# Optimize Site Layout



Optimize Site Layout is a site design measure for minimizing the site footprint that can be applied to all projects, and is accomplished using strategies such as minimizing total disturbed area, reducing the amount of impervious surfaces and integrating stormwater management features with buildings and vegetation. Key considerations include taking advantage of pre-project natural site conditions and looking for opportunities to install features that can serve multiple purposes.

## Planning and Design Strategies

Once natural conditions and features on a site have been protected (see Fact Sheet SD-1), consider these strategies to optimize site layout and reduce environmental impacts of the development:

**Minimize Total Disturbed Area.** Lay out the site and building footprint(s) to minimize the amount of site clearing and grading (cut and fill) needed. This process will, in turn, reduce the erosion potential and amount and cost of erosion and sediment controls needed during construction. One way to minimize disturbed area is to concentrate development on smaller lots on a portion of the site, while leaving other areas as open or community space. "Cluster development" like this can help to avoid sensitive and constrained areas, such as steep slopes, water bodies and floodplains, without sacrificing building units.

**Reduce Impervious Surfaces.** Look for opportunities to reduce impervious surfaces so that the site features act more like a natural sponge to absorb and reduce runoff. This approach means reducing the building footprint (e.g., multi-story instead of single story), decreasing width of private roads, creating smaller parking lots and utilizing alternative driveway designs, all subject to approval of the permitting agencies. The strategy also includes using pervious pavement instead of using conventional impervious pavement.

**Integrate Stormwater Management Features with Buildings, Landscaping and Recreation Uses.** Coordinate placement of stormwater management features with buildings and vegetation and find opportunities for multi-purpose uses, such as detention basins that can function as recreational fields in drier summer months.



**Village Homes in Davis, California (built in 1975) is a good example of a LID cluster development that provides community open space/ gardens and natural treatment of stormwater in drainage swales without flooding. About 800 residents enjoy the close community connections and home resale value here have consistently been higher than similar developments in the area.**

Photo Credit: Michael Corbett

## OPPORTUNITIES AND BENEFITS

- Minimizing site disturbance, building footprints and other impervious areas maintains more natural areas that promote filtration, infiltration and evapotranspiration of stormwater and reduce runoff volumes and peak rates
- Reduced disturbance of the site and use of clustered development and multi-use features can result in less grading and structural storm drain infrastructure and associated costs
- Less clearing and grading lowers the potential for sediments to be carried off the site in runoff to local streams where it can impair habitat
- Clustered development allows space for community gardens, parks, recreational trails and/or open spaces
- New impervious features can be located over problematic areas of the site such as those with clay/impervious soils, shallow groundwater table, and known contamination
- Recreation areas can be located in networks of open space or green corridors or combined with stormwater management features (e.g., dual-purpose detention basins)
- Pervious parking areas can be combined with sub-surface detention facilities such as cisterns

## Limitations

- Check with the local fire control agency and engineering department for restrictions about use of permeable paving materials for roadways, driveways and fire access lanes (also see Fact Sheet LID-7)
- Clustering may be difficult to achieve on small, constrained development sites

**A narrow road along Fallen Leaf Lake, Lake Tahoe, CA**

Photo Credit: Bill C.



## OPTIMIZE SITE LAYOUT

### Design Elements

#### Minimize Disturbed Areas

- Configure lots/development to avoid sensitive natural areas and conform to natural topography
- Preserve open space and natural conditions by clustering lots, buildings and uses in a smaller area of the site
- Locate features (e.g., site access points, driveways) to minimize impacts to sensitive environmental features
- Indicate on the site plan where exposed, bare areas that can be revegetated to enhance infiltration and slow runoff
- For redevelopment projects, plan to convert existing impervious areas to pervious areas whenever possible

#### Reduce Impervious Surfaces

##### Building Lots

- Use minimum standards for driveway lengths and widths, subject to permitting agencies' approval
- Reduce front yard setbacks to allow for shorter driveways, but allow a minimum of 20 feet length for driveway parking
- Consider alternative driveway styles, such as Hollywood driveways (vegetated center strip), permeable paving (see fact sheet LID-7) and shared driveways
- Use alternative materials for sidewalks, walkways and patios such as pavers or decomposed granite

##### Parking Lots

- Design parking lots for average annual demand instead of seasonal/infrequent peak demand
- Install overflow parking areas constructed of pervious paving materials for seasonal peak demand
- Use minimum standards for allowable parking ratios
- Analyze parking lot layout to reduce impacts, including use of narrowed one-way circulation traffic lanes, varied parking stall orientations and permeable paving materials in low-traffic areas
- Arrange for shared parking where possible, particularly when adjoining land uses have different hours of operation (e.g., commercial building and church)
- Construct parking areas/ garages under buildings

##### Streets

- Use minimum standards for road width, subject to permitting agencies' approval
- Avoid use of cul-de-sacs or design cul-de-sacs at the minimum standards for width and turning radius, subject to fire approval
- Integrate stormwater management with complete street design to create low impact "green streets"

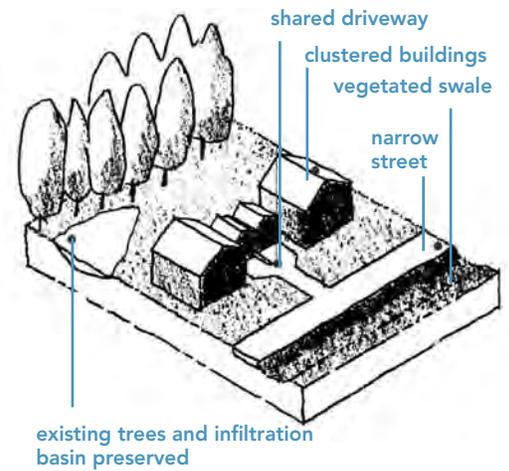
#### Integrate Stormwater Management Features with Buildings, Landscaping and Recreational Uses

- Integrate stormwater management techniques (see LID fact sheet series) with lot/building layout to treat runoff from buildings and other impervious surfaces
- Locate LID features such as infiltration, bioretention and pervious pavement in areas with well-drained soils (configure the site plan to place buildings and other impervious features in other areas of the site if possible)
- Consider vegetation for rooftops (see Fact Sheet LID-8), walls and adjacent areas to filter, evapotranspire rainwater and snowmelt, reduce runoff and shade/insulate buildings
- Use vegetation in medians and circulation areas to infiltrate/filter stormwater (rain and snowmelt)

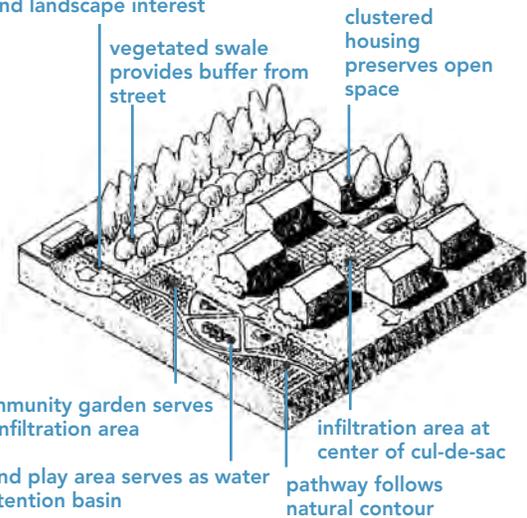
#### References

BASMAA, *Start at the Source*, 1999.

SEMCOG, *LID Manual for Michigan*, 2008.



footbridge provides connectivity and landscape interest



community garden serves as infiltration area

sand play area serves as water retention basin

infiltration area at center of cul-de-sac

pathway follows natural contour

Examples of optimizing site layout for residential areas. Adapted from Start at the Source (BASMAA, 1999)

### CONSTRUCTION CONSIDERATIONS

Provide instructions to the owner or contractor with the site plans to minimize impacts during construction. For example:

- Obtain coverage under the State's Construction General Permit if the project will disturb one or more acres (including parking and staging areas)
- Minimize construction traffic/soil disturbance areas and stabilize as needed to prevent sediment tracking off the site
- Minimize and control construction stockpiling and storage areas and use erosion and sediment controls to keep sediments from traveling off the site in runoff
- Cover/protect newly installed pervious pavements until construction is complete to keep fine construction and landscaping sediments from clogging void spaces

# Control Pollutants at the Source

PLACER COUNTY LOW IMPACT DEVELOPMENT **GUIDEBOOK**



Fact Sheet SD-3

Control Pollutants at the Source is a site design measure that can be applied to all projects, and includes designing materials storage and housekeeping site features to keep water from contacting pollutants (for example, putting roofs over storage areas) and to keep pollutants from contacting water (for example, locating areas with a likelihood of generating pollutants away from storm drains and water bodies).

## Planning and Design Strategies

The following are general strategies/design considerations related to activities that are common to storage and work areas at commercial and industrial sites, such as garbage and recycling, maintenance, and loading. These activities can have a significant negative impact on stormwater quality, and special attention should be paid to the siting and design of the activity area. Evaluate local ordinances affecting the use of the site and specific areas of the site, as many local jurisdictions have specific requirements. In the case of conflict, the local requirements shall prevail.



**Pollutant source areas such as trash enclosures should be set on concrete and covered with roofs to prevent pollutants from being carried to storm drains and streams.**

- **Prevent water from contacting work and storage areas.** Design the site to prevent water (including rainfall, stormwater runoff and runoff, and other water generated during site activities [e.g., washwater]) from entering/passing through loading areas, maintenance yards/buildings, storage areas, fueling areas and other work places before it reaches storm drains. Example strategies include: using roofs and locating pollutant source areas away from storm drain inlets. The objective is to prevent the discharge of water laden with pollutants to surface waters or sensitive resource areas.
- **Prevent pollutants from contacting surfaces that come into contact with water.** Design the site to keep pollutants from contacting surfaces that will come into contact with water (including rainfall, stormwater runoff and runoff, and other water generated during site activities [e.g., washwater]). Although pollution control is largely an operational element, there are a number of features that can be designed into a project that function as source controls once the project is completed. Example strategies include: marking new drain inlets with “no dumping” messages, posting informational signs, placing outdoor material and trash storage areas away from storm drain inlets, plumbing wash areas to the sanitary sewer, and permanently protecting slopes and channels from erosion.

## OPPORTUNITIES AND BENEFITS

- Managing stormwater runoff (including rainfall and snowmelt) and pollutants as close to the source as possible can minimize costs of storm drain pipes and other conveyance features.
- Controlling pollution at the point of generation is less costly than treating the runoff to remove the pollutants and may reduce or eliminate the need for treatment.
- Source controls will reduce potential for illegal pollutant discharges to the storm drain or local waterway.



**Erosion Control & Veg Fence; Northstar CSD Administration Building.** Photo Credit: PR Design & Engineering



## Limitations

- Effectiveness of source control measures will depend not only on good site design but on behaviors by those using the site after construction is complete. Prior to final acceptance of the project, provide instructions for operation and maintenance for the new property owners. In the case of commercial sites, also provide guidelines for site personnel training.
- Sometimes the solution for stormwater pollution prevention is to direct water to the sanitary sewer. However, check with the local sanitary sewage system operator for restrictions on quality and quantity of allowed discharges. Additional fees may apply.
- Check with the local fire control agency for restrictions about use of dead end sumps for containing spills (will depend on nature of potential pollutants).
- Check with local solid waste hauler for height restrictions on roofs and overhangs for loading docks and trash enclosures.

## CONTROL POLLUTANTS AT THE SOURCE

### Design Elements

Site design to control pollutant sources is guided by the following general principles:

- Locate the storage and work areas away from hose bibs, storm drains, water bodies and sensitive natural areas of the site. If the work area is adjacent to or directly upstream from a storm drain or landscaped drainage feature (e.g. bioswale), debris or liquids from the work area can migrate into the stormwater system.
- Create an impermeable surface, such as concrete or asphalt where potential pollutants are stored. A concrete surface is more expensive, but is generally less permeable and will typically last longer than asphalt, as vehicle fluids can either dissolve asphalt or can be absorbed by the asphalt and released later. Porous pavement, discussed elsewhere in the LID Guidebook, should not be used in high traffic areas and areas that have the potential to generate pollutants.
- Cover the storage or work area with a roof. This prevents rain from falling on the work area and becoming polluted runoff.
- Berm or mounding around the perimeter of the area to prevent water from adjacent areas to flow on to the surface of the work area (runon) and to prevent spills from migrating away from the area. In this way, the amount of polluted runoff is minimized.
- Directly connect runoff. Unlike other areas of the site where runoff disconnection would be recommended to reduce site runoff, the runoff from outdoor work, storage and vehicle/equipment wash areas may need to be directly connected to the sanitary sewer, dead end sumps or other specialized containment systems. This would allow the more highly concentrated pollutants from these areas to receive special treatment that removes pollutants. Obtain approval for such features from the appropriate sanitary sewage or other agency (see Limitations).
- Locate and design garbage and recycling areas properly. In addition to the above strategies, other factors must be considered for these areas. They must be sited so that receptacles are accessible for collection by standard collection trucks, yet out of the way so as not to disturb the aesthetics of the site. Consult with the local waste hauler and plan an adequate space for the sizes of trash and recycling receptacles. For food and restaurant establishments, design segregated areas for tallow bin storage, away from trash and recycling. Do not place storm drains or hose bibs inside trash, recycling and/or tallow bin storage areas. In cases where water cannot be diverted from the enclosure (such as areas located within a low spot), a self contained drainage system should be included, subject to approval of the local permitting agency. Provide signage and operation and maintenance instructions for sweeping, litter control, and spill cleanup to the new property owner/operator.

The "Start at the Source Design Guidance Manual for Stormwater Quality Protection", first published in 1999, continues to be the best guide available today for designing a site to control sources of pollution.  
[http://www.flowstobay.org/bs\\_new\\_development.php](http://www.flowstobay.org/bs_new_development.php)



Hose bibs and pollutant source areas such as vehicle/equipment washing areas should be located away from storm drain inlets to reduce the threat of pollution.



Marking storm drain inlets with permanent "no dumping" messages is a simple way to educate the public about stormwater pollution



### TYPICAL STORMWATER POLLUTANTS AND SOURCES:

**Sediment.** Roads, parking lots, and roofs are common sources of sediment due to wear. Unstabilized landscaped areas and streambanks, unprotected slopes and bare dirt areas also contribute. Sediment is a main component of total suspended solids (TSS), and is detrimental to aquatic life because it can clog fish gills, cover spawning gravels and create turbid conditions which affect photosynthesis. Sediment also transports other pollutants that attach to soil particles, so sediment control practices will help reduce most other pollutants in this list as well.

**Organic Compounds.** These compounds are derived from automotive fluids, pesticides, and fertilizers. Organic compounds often attach to soil particles.

**Nutrients.** Nutrients include nitrogen, phosphorus, and other organic compounds which can be found in organic litter, green waste, fertilizers, food waste, sewage and sediment. Excess nutrients impact creek health and impair use of water in lakes and other water supply sources by promoting excessive growth of algae or vegetation (i.e. eutrophication). As the vegetation dies off, it robs the waterway of dissolved oxygen, essential for fish and other aquatic life.

**Metals.** Sources of trace metals (copper, lead, cadmium, chromium, nickel, and zinc) can include motor vehicles, roofing and construction materials, chemicals and sediments. Trace metals can be toxic to aquatic organisms and, in accumulated quantities, can contaminate drinking water supplies.

**Bacteria and viruses.** Sources include animal excrement (found in areas where pets are often walked), sanitary sewer overflow, and trash handling areas (dumpsters). Bacteria and viruses may pose public health and safety concerns to drinking water and recreational water bodies.

**Oil and Grease.** Some sources of oil and grease include motor vehicles, food service establishments, and fueling stations. Oil and grease act as carriers for heavy metals and contain hydrocarbon compounds, which even at low concentrations may be toxic to aquatic organisms.

### References

CASQA California Stormwater BMP New Development and Redevelopment, 2003.  
 KJ, The Truckee Meadows Structural Controls Design Manual, 2007.

# Integrate Eco-Friendly Landscaping



Integrate Eco-Friendly Landscaping is a site design measure that can be applied to most projects, including small urban infill projects and sites with steep slopes or clay soils. It entails locating and specifying various features on the site plan and construction specifications, such as: locations and types of native and climate appropriate vegetation that will require less maintenance, water, fertilizers and pesticides; soil amendments where needed to create functional soil conditions that will sustain vegetation; and water efficient irrigation for landscaped areas.

## Planning and Design Strategies

Several strategies can be used to integrate eco-friendly landscaping on the project site to reduce environmental impacts of the development. Due to the non-structural nature of these solutions, they can be very cost-effective:

### Specify and Properly Locate Native and Climate Appropriate Grasses, Plants and Trees:

Native plants are eco-friendly because they were originally a natural part of the landscape. Native plants typically require less water, are slower growing and require less maintenance. Additionally, local native species are tolerant to dry summers and diurnal temperature fluctuations. Reforesting with trees and tree clusters will provide many benefits including improved air and water quality and reduced greenhouse gases.

**Plan for Functional Soil Conditions:** Soil amendments can help restore soil properties to pre-project conditions by reversing the loss of organic matter and compaction. Amendments can make clay soils suitable to receive and filter/infiltrate site runoff. Soil amendments consist of fibrous materials such as peat, wood chips, and hardwood bark; humus such as compost and aged manure; and inorganic materials such as vermiculite and perlite. The practice can increase infiltration rates, plant survival rates and health, enhance root growth, provide erosion stabilization, and decrease need for irrigation and fertilization.

**Design a Water-Efficient Site:** The first step in creating a water-efficient site is to eliminate or limit the amount of vegetation that requires frequent watering (e.g., turf, non-native grasses and shrubs). After that, specify water efficient landscape irrigation systems (e.g., evapotranspiration (ET) controllers, timers and drip irrigation) to reduce future water use by the property owners/tenants.



Eco-friendly landscaping

Photo Credit: David Roberts Landscape

## OPPORTUNITIES AND BENEFITS

- Eco-friendly landscaping provides a wide range of benefits, including improved water and air quality, reduced greenhouse gases, water and energy conservation, and reduction of waste to the landfill.
- Native grasses and plants typically require less water and are slower growing and require less maintenance. They can provide pollutant removal and reduce stormwater flows.
- Protecting trees and tree clusters offers many benefits. Trees absorb, filter and evapotranspire rainwater; sequester carbon and create oxygen which reduces greenhouse gases and provides cleaner air; and provides shade to reduce surface and runoff temperatures. Tree roots enhance infiltration capacity of the soil.
- Revegetation and reforestation can restore filtration, infiltration and groundwater recharge functions.
- Vegetated areas can provide habitat for wildlife and increase aesthetic value for the community.
- Amended soils can yield moderate increases in infiltration rates from 2 to 10 times over unamended soil rates and reduce the need to irrigate and fertilize the landscaping.

## Limitations

- Native plants and trees can be slower growing and can take longer to establish than other plants.
- Maximum slope for using soil amendments is typically 10%, unless geotextile matting is provided.
- Do not plant trees in areas with shallow groundwater (less than 3 feet).
- Tree selection and use may be limited on constrained sites with overhead power lines and/or underground utilities and on dense infill sites with high building lot coverage and minimum setbacks.



Vegetation and Mulch Treatments

Photo Credit: Dana Olson, Tahoe RCD

# INTEGRATE ECO-FRIENDLY LANDSCAPING

## Design Elements

### Specify and Properly Locate Native and Climate Appropriate Grasses, Plants, and Trees

Select grasses, plants and trees that are appropriate for the site and its intended use, considering sun exposure and shade conditions, climate, soils, drainage, and irrigation/maintenance needs. Refer to a recommended plant/tree list in Appendix A.

#### Grasses and Plants

- Select hydrophilic plants/grasses for areas that will be more frequently inundated (e.g., in stormwater planters and swales, see Fact Sheets LID-4 and 6).
- Consider the expected life and future size and root zone of the mature species when locating plants in landscaped areas, and space the plants appropriately. If additional information is needed, visit a native plant demonstration garden or view photos of full-grown plants on the internet.

#### Trees

- Involve an arborist in the design process.
- Consider the future size/canopy and root zone of the fully-grown mature species when locating trees on the site, providing proper clearance from building foundations, pavement and overhead/underground utilities. Ideally, provide a setback of 10 to 15 feet from the expected 10-year canopy to overhead lines.
- The total soil area to be excavated for tree root balls is typically two cubic feet per square foot of future canopy cover at maturity.
- Use root guards and structural soil in areas near underground utilities and pavement, and streets.

### Plan for Functional Soil Conditions

- Test the soil and infiltration rates prior to preparing the landscape plan.
- For sites with permeable soils (typically infiltration rates greater than 1 in/hr), specify protection of native topsoil in place or stock it in a protected area of the site until building construction is complete and landscaped areas are ready.
- Specify soil amendments before planting when infiltration rates are less than 1 in/hr, or even in cases where native soils are good quality. Soil amendments are particularly important for trees in soils with low infiltration capacity.
- Prepare construction specifications for preparing soils on the site. For example:
  - Scarify or till existing soils to a depth of 15 inches and add 4 to 6 inches of well-aged compost to achieve organic matter content in the range of 8 to 13%.
  - Stabilize amended soil areas with groundcovers, perennial grass species, trees or other herbaceous plants. Use geotextile matting in sloped areas.
  - Use orange fencing to designate and protect amended soil areas from compaction during construction and plant perimeter shrubs or trees for long term protection from vehicle and heavy foot traffic.

### Design a Water-Efficient Site

- Divide landscape areas into hydrozones that have varying irrigation requirements.
- Select irrigation systems that can be configured to water less frequently, but for longer periods of time to provide dry periods between watering and enhance rooting depth.
- Specify use of drip irrigation to convey water via a mild pressure distribution system, enhance infiltration and plant uptake, and prevent overspray/overwatering and runoff.
- Develop a water balance to determine seasonal irrigation needs, based on local ET rates and efficiency factors.

### References

SSQP, *River Friendly Landscape Guidelines*, 2007.  
SEMCOG, *LID Manual for Michigan*, 2008.

## INSTALLATION AND MAINTENANCE CONSIDERATIONS

- Specify ideal season for spreading native grass seed (typically in the early fall or early spring) and planting woody vegetation and trees (typically in early spring).
- Plan for temporary irrigation if needed.
- Provide maintenance instructions for the plant establishment period (up to 2 years) and thereafter.



**Before: Bare Areas in Tahoe area**

Photo Credit: Dana Olson, Tahoe RCD



**After: Revegetation and Mulching**

Photo Credit: Dana Olson, Tahoe RCD

## GENERAL DESCRIPTION

Stormwater disconnection is a technique that reduces the volume of stormwater delivered to storm drains by disconnecting the runoff from roofs, impervious areas on the site and minor roads and redirecting the runoff to permeable areas (e.g., vegetation) that promote runoff filtration and infiltration. Design variations include:

- Rooftop direct runoff and downspout disconnection
- On-site (driveway, walkway, small parking areas, and patio) disconnection
- Minor road runoff disconnection via curb cuts and curb removal

## PLANNING AND DESIGN STRATEGIES

### GENERAL GUIDELINES

COMPONENT	GUIDELINE
<b>Rooftop Direct Runoff and On-Site Disconnection</b>	
<b>Site Layout</b>	Building Setback – 20' Drainage Area – Average is 500 sf; maximum is 1,000 sf Topography – 10% maximum
<b>Design Criteria</b>	Impervious/Porous Ratio – 2:1 maximum Slope – Must discharge to a gradual slope away from the building at 1% to 5% Soil – Amend soils with infiltration rates less than 1 in/hr or use an underdrain Water Table – 2' minimum separation, 10' minimum separation for infiltration devices Design water surface elevation below the road subbase
<b>Conveyance and Overflow</b>	Level Spreading Device – Place a level spreading device (e.g., pea gravel diaphragm) or energy dissipating device (e.g., splash pad) at the downspout discharge location to distribute runoff evenly over the pervious area
<b>Minor Road Disconnection</b>	
<b>Site Layout</b>	Available Space – Minimum disconnection flow length: 60' Drainage Area – 1 ac maximum per unit Topography – 10% maximum
<b>Design Criteria</b>	Soil – Amend soils with infiltration rates less than 1 in/hr Water Table – 2' minimum separation
<b>Materials</b>	Vegetation – Intervals of vegetated areas are dictated by the design storm, road slope, sinuosity, location and other factors. An initial target distance of 20' can be used for both road length and vegetative flow path length.

Curb Cut, Sierra Tract 1b, South Lake Tahoe, CA. Credit: Eric Friedlander, CSLT



## DESIGN STRATEGIES

- **Reduce amount and peak of stormwater flow.** Where possible, use shallow unchannelized flow in lieu of piped discharge to increase the time of concentration of flow.
- **Direct flow into stabilized vegetated areas for infiltration and detention.** Flow can also be diverted from impervious surfaces via sheet flow to these vegetated areas.
- **Use curb cuts and curb removal for minor road runoff disconnection.** Peak flow can be attenuated using one of the strategies below: Disconnect runoff in streets by removing part of a curb and allow for infiltration into a depression or planter box; Install curb cuts at intervals and route flows through street and vegetated areas in an alternating fashion.

## BENEFITS

- Applicable with limited space constraints and under all soil conditions
- Reduces runoff volume and peak flow, provides infiltration and disconnects flow path
- Provides treatment of sediment, nutrients, metals, O&G and temperature
- Water Quantity: Reduces runoff volume and peak flow, provides infiltration and disconnects flow path
- Water Quality: Provides treatment of sediment, nutrients, metals, and temperature
- Relatively low construction and O&M cost and ease of maintenance
- Promotes groundwater recharge, and is aesthetically pleasing
- Conserves water and promotes groundwater recharge, and is aesthetically pleasing
- Takes advantage of already-required landscape areas; no additional space required
- Can reduce size of downstream stormwater quality treatment measures by reducing the volume required to treat
- Allows for tree preservation in areas requiring pavement
- Vegetated areas provide green space

## LIMITATIONS

- Potential for vector concerns due to standing water in vegetated features
- Water barrier will be required where porous material abuts regular asphalt/concrete pavement and there is concern about water infiltrating the regular pavement subbase
- Subsurface infiltration devices may eventually clog with sediment, requiring costly reconstruction
- Soil permeability may limit applicability of subsurface infiltration structures
- Do not use on sites with a likelihood of O&G or other hazardous spills
- Some very rocky/granite soils may allow for only limited infiltration

## COLD CLIMATE CONSIDERATIONS

- **Depth of Freeze:** Insert underground components below the frost line to prevent frost heave and prevent water from freezing in pipes. Reduced soil infiltration will likely occur during winter months.
- **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months. Little or no roof runoff may occur during winter months.
- **Length of Growing Season:** Select cold climate appropriate plants for vegetated areas.
- **Rain on Snow Events:** Higher runoff volumes may occur during these events.
- **Snow Depth:** Select vegetation to withstand expected snow depths. Incorporate snow volume estimates when sizing storage volumes. Road deicers may cause additional sediment and/or pollutant loads during winter months.

## CONSTRUCTION CONSIDERATIONS

- **Soil Disturbance and Compaction:** Allow only vehicular traffic necessary for construction on the pervious areas where flow will be discharged. If vehicle traffic is unavoidable, then the pervious area should be tilled to a depth of 1' to loosen the compacted soil.
- **Erosion and Sediment Control:** If possible, direct construction runoff away from the proposed discharge location. After the contributing drainage area and the discharge location are stabilized and vegetated, remove erosion and sediment control structures.
- **Standing Water and Ponding:** Test areas to be vegetated to verify that standing water infiltrates or evaporates within 48 hours following a runoff event. When longer ponding periods are observed, improve soil infiltration by dethatching, aerating, tilling, regrading and/or adding compost.

## OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Irrigate and maintain vegetated areas to maintain infiltration and filtering capacity.
- Periodically check for clogging of any subsurface pipes or infiltration systems and repair as needed.
- Develop a maintenance agreement with property owners or managers to ensure that downspouts remain disconnected and the pervious area remains pervious.
- If ponding of water for longer than 48 hours occurs, the pervious area should be dethatched and aerated.
- If ponding persists, regrading or tilling to reverse compaction and/or addition of compost to improve soil moisture retention may be required.



Left: Downspout routed through sinuous gravel-lined decorative stormwater feature. Photo credit: Carrie Pak, CWS.

Below: Roof runoff flows to energy dissipator under gutter downspout. South Lake Tahoe, CA. Photo credit: Dana Olson, TRCD



## REFERENCES

- See Section 4.4 in the text for more information.
- *Low Impact Development Approaches Handbook*, 2009. CWS, *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- TRCA, *Low Impact Development Stormwater Management Planning and Design Guide*, 2010.
- SEMCOG, *Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers*. 2008.

## GENERAL DESCRIPTION

Rainwater and snowmelt harvesting consists of collecting, conveying and storing rainfall and snowfall for future indoor and outdoor uses. The purpose of this harvesting is to collect high quality water to offset potable water demands. The rain or snow that falls upon an impervious surface (e.g. roof, driveway, or walkway) is collected and conveyed into a storage tank (e.g. rain barrel or cistern). With minimal pretreatment (e.g., gravity filtration or first-flush diversion), the captured rainwater or snowmelt can be used for outdoor non-potable water uses such as irrigation and pressure washing, or in the building to flush toilets or urinals.

## PLANNING AND DESIGN STRATEGIES

### GENERAL GUIDELINES

COMPONENT	GUIDELINE
<b>Site Layout</b>	<p>Available Space – Place storage tanks underground, indoors, on roofs, or adjacent to buildings, outside of County ROW</p> <p>Building Setback – Make tanks water tight to avoid ponding or saturation of soils within 10' of building foundations</p> <p>Drainage Area – Dependent upon conveyance and storage tank sizing</p> <p>Topography – Influences the placement of the storage tank and design of the distribution and overflow systems</p>
<b>Design Criteria</b>	<p>Head – Locate rain barrels or above ground cisterns with gravity distribution systems up-gradient from irrigated areas</p> <p>Soil – Locate underground cisterns in native, rather than fill soil for stability</p> <p>Utility/Tree Clearance – Utilities may constrain the location of underground storage tanks</p> <p>Water Table – Can be used under various depth to water ranges</p>
<b>Pretreatment</b>	<p>Pretreat runoff to remove debris, dust, leaves, and other debris</p> <p>Use Leaf and mosquito screens (1 mm mesh size), first-flush diverter, or in-tank filter</p> <p>Use settling compartment for tanks over 2,500 gallons</p>
<b>Conveyance and Overflow</b>	<p>Rain barrels use head and gravity to feed hoses via a tap and spigot</p> <p>Use a water pump for underground cisterns. Indoor systems usually require a pump, pressure tank, back-up water supply line and backflow preventer</p> <p>Include an overflow system in the design (outflow pipe = inflow pipe size)</p>
<b>Storage</b>	<p>Tank size varies based on rainfall and snowfall frequencies and totals, end-use of water, the catchment surface area, aesthetics, and budget</p> <p>Storage tanks range in size from rain barrels for residential land uses (typically 50 to 100 gallons), to large cisterns (200-400 gallons) for industrial, commercial and institutional land uses</p> <p>Use opaque, potable or food-grade structurally sound materials to construct storage tanks</p> <p>Install tanks in locations where native soils or building structures can support the load from the stored water</p> <p>Childproof rain barrels and cisterns and seal against mosquitoes</p>
<b>Materials</b>	<p>Roof – Metal roofs are recommended</p> <p>Downspouts and Eavestroughs – Materials include PVC pipe, vinyl, aluminum and galvanized steel</p> <p>Do not use lead as solder</p>

## DESIGN STRATEGIES

- **Reduce volume of stormwater runoff** by directing downspout to a rain barrel with gravity distribution, routing multiple downspouts to a cistern and pump to reuse water, or collecting flows from impervious areas. Roof can also be used for snow storage, prior to snowmelt collection.
- **Reduce potable water demands** by using diverted and stored stormwater in lieu of potable water. Stored rain water and snowmelt can be used for non-potable uses, such as, landscaping, flushing toilets, and powerwashing.
- **Reuse stormwater prior to pollutant contamination**, as rainwater or snowmelt at the source is much cleaner than downstream runoff. Water from the roof or from low traffic areas is of higher quality and can be reused readily.

## BENEFITS

- Applicable with limited space constraints and under all soil conditions
- Reduces runoff volume and peak flow and disconnects flow path
- Does not add additional pollutants to runoff
- Relatively low construction and O&M cost and ease of maintenance
- Conserves water and promotes groundwater recharge
- Managing stormwater runoff (including rainfall and snowmelt) and pollutants close to the source can minimize costs of conveyance features
- Cisterns can be combined with pervious parking areas
- Rainwater harvesting systems can help reduce demand on municipal treated water supplies
- Reduced loads delay expansion of treatment and distribution systems, conserve energy used for pumping and treating water and lower consumer water bills
- It is estimated that these applications alone can reduce household municipal water consumption by up to half
- Where site designs permit, cisterns may be quite large, and shared by multiple households, achieving economies of scale
- Can be retrofitted into existing property

## LIMITATIONS

- Potential vector concerns should be addressed by using filter screens and keeping storage tanks covered.
- The stormwater volume/peak discharge rate benefits of cisterns and rain barrels depend on the amount of storage available at the beginning of each storm. One rain barrel may provide a useful amount of water for garden irrigation, but it will have little effect on overall runoff volumes, especially if the entire tank is not drained in between storms.
- Greater effectiveness can be achieved by having more storage volume and by designing the system with a continuous discharge to an infiltration mechanism, so that there is always available volume for retention.
- Rain barrels and cisterns offer no primary pollutant removal benefits. However, this water is often cleaner than downstream runoff.
- The water collected is for nonpotable uses only.
- Immediate use of harvested water is preferred to storage.

## COLD CLIMATE CONSIDERATIONS

- **Depth of Freeze:** Pipes are at risk for frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
- **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Little or no roof runoff may occur during winter months.

To prevent ice accumulation and damage during winter, place first-flush diverters or in-ground filters in a temperature controlled environment, bury below the local frost penetration depth or insulate or equip with heat tracing. Do the same with dual use cisterns and conveyance pipes leading to cisterns. Tank placement is recommended on the south side of the building. Insulate the tank outlet hose to the pump or services with mineral wool mat or molded insulation foam.

## CONSTRUCTION CONSIDERATIONS

- **Soil Disturbance and Compaction:** Allow only vehicular traffic necessary for construction on the pervious areas where flow will be discharged. If vehicle traffic is unavoidable, then the pervious area should be tilled to a depth of 1' to loosen the compacted soil.
- **Erosion and Sediment Control:** If possible, direct construction runoff away from the proposed discharge location. After the contributing drainage area and the discharge location are stabilized and vegetated, remove erosion and sediment control structures.
- **Standing Water and Ponding:** Test areas to be vegetated to verify that standing water infiltrates or evaporates within 48 hours following a runoff event. When longer ponding periods are observed, improve soil infiltration by dethatching, aerating, tilling, regrading and/or adding compost.

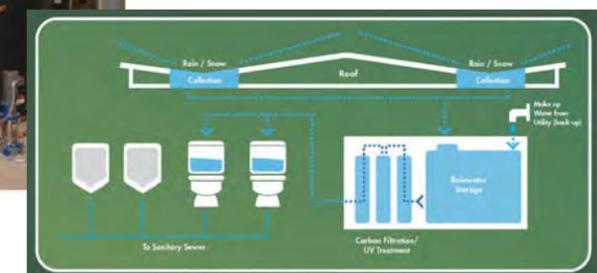
## OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Maintenance requirements for rainwater harvesting systems vary according to use
- Systems that are used to provide supplemental irrigation water have relatively low maintenance requirements, while systems designed for indoor uses have much higher maintenance requirements.
- Perform regular inspections every six months during the spring and fall seasons to keep leaf screens, eavestroughs and downspouts free of leaves and other debris; check screens and patch holes or gaps; clean and maintain first flush diverters and filters, especially those on drip irrigation systems; inspect and clean storage tank lids, paying special attention to vents and screens on inflow and outflow spigots; and replace damaged system components as needed.
- If screening is not sufficient to deter mosquitoes, use vegetable oil to smother larvae, or use mosquito dunks or pellets containing larvicide.



Left: TCES Rainwater Harvesting System with UV, Photo Credit: Heather Segale, TERC

Below: Water Capture System, Credit: Heather Segale, TERC



## REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- MAPC, *Mass LID Toolkit*, 2007.
- CASQA, *California Stormwater Best Management Practice Handbook, New Development and Redevelopment*, 2003.
- UDFCD, *Best Management Practices*, 1999.

## GENERAL DESCRIPTION

Dry wells and infiltration trenches store water in the void (pore) space between crushed stone or gravel where the water slowly percolates downward into the subsoil. An overflow outlet is needed for runoff from large storms that cannot be fully infiltrated by the trench or dry well.



Driveway runoff conveyed by slotted channel drain to infiltration system  
Photo Credits: Dana Olson, TRCD



Sloped driveway conveys runoff to infiltration trench

## CONSTRUCTION CONSIDERATIONS

- **Soil Disturbance and Compaction:** Before site work begins, clearly mark areas for dry well pits. Only allow vehicular traffic used for construction close to the strip.
- **Erosion and Sediment Control:** Do not use infiltration practices as a sediment control device during construction. Direct construction runoff away from the proposed filter strip site. After the site is vegetated, remove erosion and sediment control structures.

## PLANNING AND DESIGN STRATEGIES

### GENERAL GUIDELINES

COMPONENT	GUIDELINE
<b>Site Layout</b>	Building Setback – 20' minimum distance Drainage Area – <5ac maximum per unit Topography – 5% maximum contributing slope Install outside of County ROW
<b>Design Criteria</b>	Soil – Infiltration rates of existing site soils must be a minimum of 0.5 in/hr and a maximum of 2.4 in/hr, or use an underdrain Slope – do not apply on slopes greater than 20 percent Utility/Tree Clearance – do not locate under tree drip lines; Consider removing all trees within 10' Water Table – 10' minimum separation Wellhead Protection – 100' setback from potable water wells Maximum trench depth recommended is 10" The maximum depth of the stone in the dry well pit is 5'
<b>Infiltration Rate</b>	Drill borings to determine infiltration rate (one boring at each dry well, two borings at each infiltration trench), with additional borings at 50 feet intervals Determine the infiltrative capacity using a double-ring infiltrometer Base trench/drywell sizing on the slowest rate Do not use trenches or dry wells where soils are >30% clay or >40% silt clay
<b>Pretreatment</b>	Remove sediment prior to treatment to prevent reduction of infiltration capacity Vegetated filter strip, Vegetated swale, and Bioretention are all suitable pretreatment measures
<b>Conveyance and Overflow</b>	Inlet pipes are typically perforated pipe connected to a standard non-perforated pipe or eavestrough The overflow outlet can be the perforated pipe inlet that backs up and discharges to a splash pad and pervious area at grade or can be a pipe that is at the top of the gravel layer and is connected to a storm sewer Outlet pipes must have capacity equal to or greater than the inlet. Use distribution pipes with perforations of 0.5" that are capped at least 1 foot short of the wall of the trench or well
<b>Materials</b>	The dry well should be filled with uniformly-graded, washed 2" diameter stone with a 40% void capacity Trench should be filled with washed 3/4" to 1 1/2" drain rock Add optional horizontal layer of geotextile fabric layer 2"-6" below the trench surface to reduce sediment Non-woven filter cloth should be used to line the trench to prevent the pore space between the stones from being blocked by surrounding native material Trim tree roots flush with the trench sides in order to prevent puncturing or tearing the filter fabric Use an HDPE underdrain pipe that has a perforated, smooth interior, and minimum inside diameter of 4". Perforated pipe should run lengthwise through the dry well Install containment borders using pressure treated lumber, recycled composites, brick, stone, cobble, or other landscape edging material

### DESIGN STRATEGIES

- **Reduce peak discharge rate and total runoff volume** by infiltrating a portion of stormwater generated on-site, which will result in modest groundwater recharge.

### BENEFITS

- Reduce stormwater runoff volume, including most of the runoff from small frequent storms
- Reduce peak discharge rates by retaining the first flush of stormwater runoff and creating longer flow paths for runoff
- Reduce the size of more expensive downstream stormwater management structures

### LIMITATIONS

- Potential vector concerns due to standing water during infiltration
- Cannot receive untreated stormwater runoff, except roof- top runoff. Pretreatment is necessary to prevent premature failure that results from fine sediment, and to prevent potential groundwater contamination due to nutrient, salts, and hydrocarbons
- Can not be used to treat runoff from portions of the site that are not stabilized, and might result in erosion
- Rehabilitation of failed infiltration trenches requires complete reconstruction
- Difficult to use in slowly permeable soils or in fill areas

### COLD CLIMATE CONSIDERATIONS

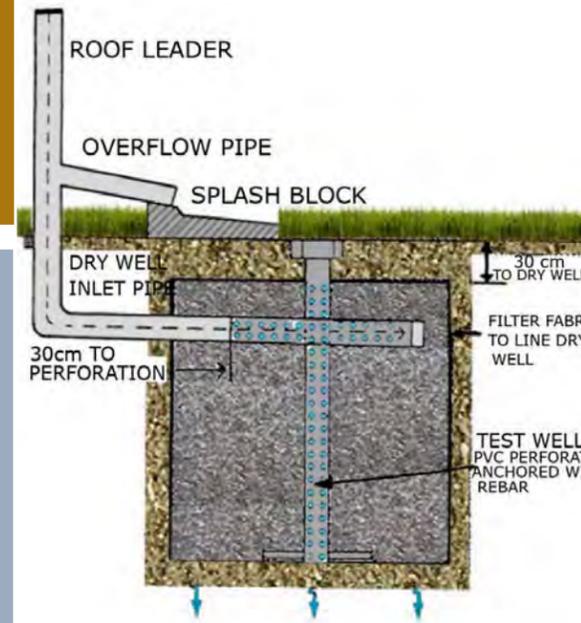
- **Depth of Freeze:** Pipes are at risk for freezing and/or frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
- **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months.
- **Rain on Snow Events:** Higher runoff volumes may occur during these events. To prevent ice accumulation and damage during winter, place conveyance pipes below the local frost penetration depth and/or insulate pipes. Increase depth of feature to keep stored runoff below frost line. Incorporate snow volume estimates when sizing storage volumes. Due to increased sediment and pollutant loads do not treat snow that has been exposed to deicers without pretreatment.



Infiltration Trench contoured along house  
Photo Credit: TRCA, 2010

## OPERATIONS AND MAINTENANCE CONSIDERATIONS

- After construction, inspect after every major storm for the first few months to ensure stabilization and proper function.
- On a monthly basis, remove sediment and oil/grease from pretreatment devices, overflow structures, and the surface of infiltration trenches.
- Semi-annually, check observation wells 3 days after a major storm. Failure to percolate within this time period indicates clogging.
- Semi-annually, inspect pretreatment devices and diversion structures for structural damage.
- If ponding occurs on the surface of an infiltration trench, remove and replace the topsoil or first layer of stone and top layer of filter fabric.
- Upon failure, perform total rehabilitation of the trench to maintain a storage capacity within 2/3 of the design treatment volume and 72-hour exfiltration rate.



Credit: TRCA, 2010



Dry Rock Dry Well  
Photo Credit: Dana Olson, TRCD

## REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- Massachusetts *LID Toolkit*, 2007.
- TRCD and NTCD, *Drip Line Infiltration Trench*, 2006.

## GENERAL DESCRIPTION

Bioretention areas (raingardens, tree pits, planters, and curb extensions) are planted depressions that store and filter rainwater to enhance water quality. Stormwater runoff flows into the cell and slowly percolates through the soil (which acts as a filter) and into the groundwater; some of the water is also taken up by the plants. Bioretention areas are usually designed to allow shallow ponding, with an overflow outlet to prevent flooding during heavy storms.

## PLANNING AND DESIGN STRATEGIES

### GENERAL GUIDELINES

COMPONENT	GUIDELINE
<b>Site Layout</b>	Available Space – Minimum dimensions 15' wide by 40' long Building Setback – If no impermeable liner, minimum 10' setback Drainage Area – Typically 1,000 sf to 1 ac Topography – Contributing slopes between 1 to 5%
<b>Design Criteria</b>	Freeboard – Allow 3" of freeboard above ponding depth to prevent flooding to adjacent parking areas Head – 3' minimum vertical distance from invert to inflow point Inlets and outlets should be located as far apart as possible Soil – Infiltration rates of existing site soils must be a minimum of 0.5 in/hr and a maximum of 2.4 in/hr, or use an underdrain Slope – Do not apply on slopes greater than 20 percent Water Table – Minimum 5' separation Wellhead Protection – Minimum separation of 100' from potable water supply wells
<b>Pretreatment</b>	Pre-treatment measures include, grass filter strip, and vegetated swale May also be used to infiltrate overflow from infiltration trench/drywell or rainwater harvesting
<b>Conveyance and Overflow</b>	The inflow conveyance may consist of, downspout, sheet flow, curb cuts, covered drain, or pop-up emitters. Overflow can either be diverted by: <ul style="list-style-type: none"> <li>• Sizing curb openings to capture only the water quality volume while higher flows remain in the gutter</li> <li>• Utility landscaping type inlets or standpipes with trash guards as overflow devices</li> <li>• Using a pre-treatment chamber with a weir design that limits flow to the filter bed area</li> </ul>
<b>Storage</b>	Snow can be stored in shallow depressions Water can be stored in pool areas
<b>Materials</b>	Vegetation – Planting plan generally includes one tree or shrub per 50 s.f. of bioretention area, and at least 3 species each of native herbaceous perennials, shrubs, and trees. Select plants that tolerate intermittent flooding, occasionally saline conditions, and extended dry periods. Filter medium – 85% sand, 10% fines, 5% organic matter Mulch layer – Shredded hardwood or bark Geotextile: Should be woven monofilament or non-woven needle punched fabrics. Woven slit film and non-woven heat bonded fabrics should not be used as they are prone to clogging. Gravel: Washed 2" diameter stone should be used to surround the underdrain and for the gravel drainage layer

## DESIGN STRATEGIES

- **Provide water quality treatment through filtration:** Bioretention areas treat stormwater runoff by passing it through a mixture of sand, soil, and organic material.
- **Increase groundwater recharge through infiltration:** Bioretention areas allow infiltration to occur over an extended time period to enhance overall infiltration.
- **Reduce peak discharge rates and total runoff volume:** Bioretention areas may be used to store excess stormwater when the downstream infiltration system has been surcharged.
- **Improve site landscaping:** Bioretention areas are typically installed in commercial, institutional, and residential sites in spaces that are traditionally pervious and landscaped.

## BENEFITS

- Properly designed cells remove suspended solids, metals, and nutrients, and can infiltrate an inch or more of rainfall.
- Can provide excellent pollutant removal and recharge for the "first flush" of stormwater runoff
- Increase groundwater recharge as compared to a conventional "pipe and pond" approach
- Low-tech, decentralized bioretention areas are also less costly to design, install, and maintain than conventional stormwater technologies that treat runoff at the end of the pipe.
- Bioretention areas enhance the landscape in a variety of ways: they improve the appearance of developed sites, provide wind breaks, absorb noise, provide wildlife habitat, and reduce the urban heat island effect.

## LIMITATIONS

- Potential vector concerns due to standing water in vegetated features
- Not suitable for locations where the seasonally high groundwater table is near the surface
- Clogging may be a problem in areas with high sediment loads in runoff
- Vegetation may require irrigation

## COLD CLIMATE CONSIDERATIONS

- **Depth of Freeze:** Pipes are at risk for freezing and/or frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
  - **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months.
  - **Length of Growing Season:** Select cold climate appropriate plants for vegetated areas.
  - **Rain on Snow Events:** Higher runoff volumes may occur during these events.
  - **Snow Depth:** Select vegetation to withstand expected snow depths.
- To prevent ice accumulation and damage during winter, place conveyance pipes below the local frost penetration depth and/or insulate pipes. Size facilities for coldest temperature removal rates (decreased biological activity, settling etc.), expect enhanced removal during non-winter months.
- Incorporate snow volume estimates when sizing storage volumes. Road deicers may cause additional sediment and/or pollutant loads during winter months.



**Left: Flow-through-Planter**

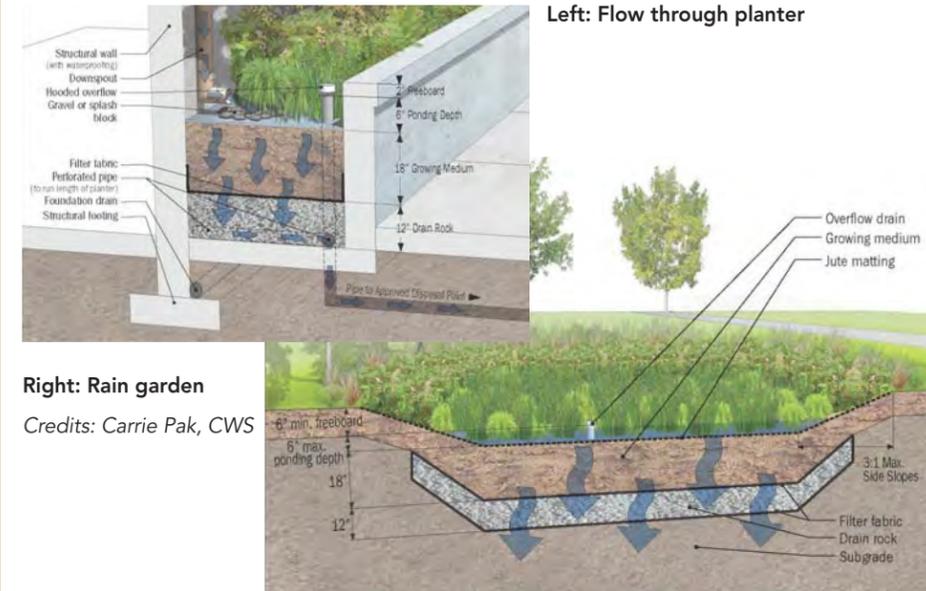
Photo Credit: Ed Armstrong, Foothill

**Right: Rain Garden**  
Photo Credit: Dana Olson, TRCD



## CONSTRUCTION CONSIDERATIONS

- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded, seeded, and/or planted areas with suitable erosion control materials.
- For planters flush with the surrounding landscape, install sediment controls (staked straw wattles) around the planter to prevent high sediment loads from entering during construction activities.
- Focus on erosion and sediment control, materials elevation, and landscape stabilization during Construction Inspection.



**Left: Flow through planter**

**Right: Rain garden**

Credits: Carrie Pak, CWS

## OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Inspect pretreatment devices and bioretention cells regularly for sediment build-up, structural damage, and standing water.
- Inspect soil and repair eroded areas monthly. Re-mulch void areas as needed. Remove litter and debris monthly.
- Treat diseased vegetation as needed. Remove and replace dead vegetation twice per year.
- Remove invasive species as needed to prevent these species from spreading into the bioretention area.
- Replace mulch every two years, in the early spring.
- Upon failure, excavate bioretention area, scarify bottom and sides, replace filter fabric and soil, replant, and mulch.

## REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- CASQA, *California Stormwater Best Management Practice Handbook, New Development and Redevelopment*, 2003.
- UDFCD, *Best Management Practices*, 1999.

POLLUTANT	% REMOVAL
TSS	75-90
TP	70-80
TN	65-80
ZINC	75-80
LEAD	75-80
ORGANICS	75-90
BACTERIA	75-90

## GENERAL DESCRIPTION

Vegetated filter strips (buffer strips and grass filter strips) are gently sloping, densely vegetated areas that treat runoff as sheet flow from adjacent impervious areas. They slow runoff velocity, filter out suspended sediment, provide some infiltration into underlying soils and are effective as a pretreatment practice. Vegetation may be comprised of a variety of trees, shrubs and groundcovers to add aesthetic value as well as water quality benefits. Vegetated Filter Strips provide a convenient area for snow storage and treatment, and are particularly valuable due to their capacity for snowmelt infiltration.



**Vegetated filter strip**  
Photo Credit: Carrie Pak, CWS

## CONSTRUCTION CONSIDERATIONS

- **Soil Disturbance and Compaction:** Clearly show the limits of disturbance on all construction drawings. Before site work begins, clearly mark areas for filter strips and protect them by using acceptable signage and silt fencing. Isolate construction vehicular traffic so that other traffic does not come near the filter strip.
- **Erosion and Sediment Control:** Direct construction runoff away from the proposed filter strip site. If used for sediment control during construction, regrade and revegetate after construction is finished.



## PLANNING AND DESIGN STRATEGIES

### GENERAL GUIDELINES

COMPONENT	GUIDELINE
<b>Site Layout</b>	Available Space – Ratio of drainage area and footprint = 6:1. Minimum 20' in direction of flow, 60' maximum for impervious surfaces, and 100' maximum for pervious surfaces Building Setback – 10' minimum separation
<b>Design Criteria</b>	Soil – All soil types Slope – Specify slopes should be between 1% and 15%, though slopes less than 5% are preferred. Design the top and toe of the slope to be as flat as possible. Water Table – Minimum 3' separation Sheet flow must be maintained across strips Vegetation – Requires dense vegetation minimum of 2" to 4" tall Normal velocity should be <1.0 ft/s for design flow, with maximum permissible velocity of 3.0 ft/s for peak discharge during 10-yr storm
<b>Pretreatment</b>	Functions well as a pretreatment device
<b>Conveyance and Overflow</b>	Use a cement level spreader or pea gravel diaphragm at the top of the slope. Filter strips can be designed with a pervious berm of sand and gravel at the toe of the slope. This feature provides an area for shallow ponding at the bottom of the filter strip. Runoff ponds behind the berm and gradually flows through outlet pipes in the berm. The volume ponded behind the berm should be equal to the water quality volume.
<b>Storage</b>	Snow can be stored on feature
<b>Materials</b>	Soil – If soils on the filter strip site are highly compacted, or of such low fertility that vegetation cannot become established, they should be tilled to a depth of 1' and amended with compost to achieve an organic content of 8 to 15% by weight or 30 to 40% by volume. Vegetation – Select vegetation that can withstand calculated flow velocities, and both wet and dry periods. Also consider depth to groundwater and choose facultative wetland species if appropriate.

### DESIGN STRATEGIES

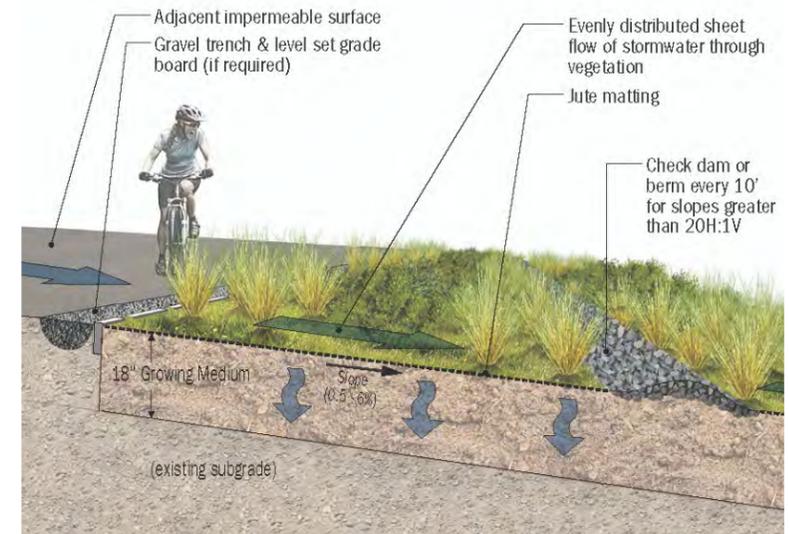
- **Reduce peak discharge rate and total runoff volume:** Vegetated filter strips redirect stormwater from pervious areas and slow the flow due to increased roughness in the vegetation.
- **Provide snow storage areas:** Grass filter strips provide areas where snow can be stored.

### BENEFITS

- **Provide runoff pretreatment by trapping, filtering and infiltrating particulates and associated pollutants.** Effectiveness depends largely on the quantity of water treated, the slope and length of the filter strip, the type of vegetation, and the soil infiltration rate
- **Reduce runoff velocities and increase the time of concentration as compared to channelized flow,** resulting in a reduction of erosion and peak discharge rates

### LIMITATIONS

- Because filter strips infiltrate runoff to groundwater, they could be inappropriate at stormwater "hotspots" (such as gas stations) with higher potential pollutant loads. Combine them with other LID features to ensure adequate treatment of polluted runoff prior to discharge.
- Channelization and premature failure may result from poor design, imprecise construction, or lack of maintenance. Proper design requires a great deal of finesse, and slight problems in the construction, such as improper grading, can render the practice less effective in terms of pollutant removal.
- Filter strips have low removal rates for nutrients, so use them in conjunction with other LID features.
- Filter strips often require lots of space, making them often infeasible in urban environments where land prices are high.
- Vegetation may require irrigation.



**Vegetated filter strip profile** Credit: Carrie Pak, CWS

## OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Inspect level spreader monthly and remove built-up sediment.
- Inspect vegetation monthly for rills and gullies and correct. Fill any depressions or channels. Seed or sod bare areas.
- In the year following construction, inspect the filter strip regularly to ensure that grass has established. If not, replace with an alternative species. Allow natural succession by native grasses and shrubs if it occurs.
- Mow grass, as rarely as 2-3 times per year, to maintain 4" to 6" of dense grass cover. Grass clippings should be collected and composted elsewhere. Provide a minimum of fertilizer only when necessary. Mow when the soil is dry and firm to prevent rutting.
- Semi-annually, remove sediment that has accumulated to prevent berms or channels.

## REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
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## COLD CLIMATE CONSIDERATIONS

- **Depth of Freeze:** Pipes are at risk for freezing and/or frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
- **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months.
- **Length of Growing Season:** Select cold climate appropriate plants for vegetated areas.
- **Rain on Snow Events:** Higher runoff volumes may occur during these events
- **Snow Depth:** Select vegetation to withstand expected snow depths.

Install pipes components below the frost line to prevent frost heave and preventing water from freezing in pipes. Size facilities for coldest temperature removal rates (decreased biological activity, settling etc.), expect enhanced removal during non-winter months. Road deicers may cause additional sediment and/or pollutant loads during winter months.



**Vegetated filter strip traffic island**  
Photo Credit: Carrie Pak, CWS

## GENERAL DESCRIPTION

Vegetated swales are essentially bioretention cells that are configured as linear channels.

They are stormwater conveyance and soil filter systems that temporarily store and then filter the desired water quality volume. Stormwater is conveyed slowly through a vegetated swale due to roughness associated with plants, where it can pool behind shallow check dams. Stormwater is treated by filtering through the soil bed which can then flow to an underdrain, which conveys treated runoff back to the conveyance system further downstream.

## PLANNING AND DESIGN STRATEGIES

### GENERAL GUIDELINES

COMPONENT	GUIDELINE
<b>Site Layout</b>	Available Space – Footprint 5% to 15% of drainage area. Swale length > culvert length, Minimum swale length 100' Building Setback – Minimum 10' setback Drainage Area – Maximum drainage area 5 ac Topography – Do not apply in areas with adjacent slopes of 5% or greater or in areas with highly erodible soils
<b>Design Criteria</b>	Head – Elevation drop needed between inflow and outflow Soil – Minimum infiltration rate of 0.5 in/hr and a maximum of 2.4 in/hr, or use an underdrain Water Table – Minimum 2' separation Wellhead Protection – Minimum separation of 100' from potable water supply wells Shape – a trapezoidal or parabolic shape is preferable for aesthetic, maintenance and hydraulic reasons Bottom Width – 2' to 8' Side Slopes – Max 3:1 Swale Longitudinal Slope: Moderately flat with a slope between 1% and 2% is recommended. Slopes of up to 4% can be utilized, if check dams are used. It should be wide enough for maintenance access.
<b>Pretreatment</b>	Pre-treatment measures include, grass filter strip, and bioretention May also be used to infiltrate flow from roadway disconnection, infiltration trench/drywell or rainwater harvesting
<b>Conveyance and Overflow</b>	Inflow controls include: <ul style="list-style-type: none"> <li>Gravel diaphragm (sheet flow) at the end of pavement, perpendicular to the flow path. Select gravel that is clean and washed.</li> <li>Rip rap and/or dense vegetation (channel flow) can be used on smaller swales</li> </ul> Dry swales should be designed for a max velocity of 1 ft/s for the water quality design storm. The swale should also convey the locally required design storm (usually the 10 yr storm) at non-erosive velocities. Check dams at 50' intervals (<2' drop) help to maximize retention time, increase infiltration, promote particulate settling, and decrease flow velocities. Check dams are not necessary with very low longitudinal slopes. Provide scour protection below check dam.
<b>Storage</b>	Snow can be stored in shallow depressions Water can be stored behind check dams
<b>Materials</b>	Filter Media – soil mixture should be 85% sand, 10% soil fines, and 5% organic matter. Underdrain – Use a soil bed depth of 2' to 3' with a gravel/pipe underdrain system. The minimum interface between the underdrain gravel and the underlying soil should be 0.5'. Vegetation – Select salt-tolerant, native grasses, herbaceous plants, or trees that can withstand both wet and dry periods. Use taller and denser grasses, though the species is less important than good stabilization.

## DESIGN STRATEGIES

- Provide water quality treatment through filtration:** Vegetated swales treat stormwater runoff by conveying it through a rough vegetated pathway, where flow can infiltrate through a soil medium.
- Increase groundwater recharge through infiltration:** Vegetated swales allow infiltration to occur over an extended duration of time. Small check dams can be added perpendicular to the flow to add infiltration or step pools.
- Reduce peak discharge rates and total runoff volume:** Vegetated swales may be used to store excess stormwater when the downstream system has been surcharged.
- Provide a location for snow storage:** Vegetated swales provide an area for snow storage, where snow can be infiltrated as it melts.

## BENEFITS

- Swales help to control peak discharges by reducing runoff velocity, lengthening flow paths, and increasing time of concentration.
- Infiltration through the natural substrate helps to reduce total stormwater runoff volume.
- Swales provide effective pretreatment for downstream BMPs by trapping, filtering and infiltrating particulates and associated pollutants.
- Swales accent the landscape and may help to satisfy landscaping and greenspace requirements.
- Swales can provide a location for snow storage during winter months.
- Roadside swales effectively keep stormwater flows away from street surfaces.
- Construction may cost less than conventional curb and gutter systems.

## LIMITATIONS

- Potential vector concerns due to standing water in vegetated features
- Effectiveness decreased by compacted soils, frozen ground conditions, short grass heights, steep slopes, large storm events, high discharge rates, high velocities and short runoff contact time
- Effectiveness may be limited in areas where gophers or other burrowing animals are abundant
- Use swales carefully on industrial sites or areas of higher pollutant concentrations. If used, use them as part of a "treatment train" that includes other treatment features.
- Swales not effective at reducing soluble nutrients such as phosphorous
- In some places, the use of swales is restricted by law; many local municipalities may require curb and gutter systems in residential areas.
- Vegetation may require irrigation
- Swales take up more site area than conventional curb and gutter systems

## COLD CLIMATE CONSIDERATIONS

- Depth of Freeze:** Pipes are at risk for freezing and/or frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
- Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months.
- Length of Growing Season:** Select cold climate appropriate plants for vegetated areas.
- Rain on Snow Events:** Higher runoff volumes may occur during these events.
- Snow Depth:** Select vegetation to withstand expected snow depths.

To prevent ice accumulation and damage during winter, place conveyance pipes below the local frost penetration depth and/or insulate pipes. Size facilities for coldest temperature removal rates (decreased biological activity, settling etc.), expect enhanced removal during non-winter months. Incorporate snow volume estimates when sizing storage volumes. Road deicers may cause additional sediment and/or pollutant loads during winter months.

## CONSTRUCTION CONSIDERATIONS

- Prevent soil compaction by locating vegetated swales outside the limit of disturbance until construction of the swale begins.
- Do not locate vegetated swales in areas where sediment basins were located during construction, as the concentration of fines will prevent post-construction infiltration.
- To prevent sediment from clogging the surface of a vegetated swale, divert stormwater away from the swale until the drainage area is fully stabilized.
- Used clean and washed gravel for the underdrain, if present, so that no fines are present in the material.
- Rapidly stabilize the swale channel and side slopes with biodegradable geotextile blankets and seeding before bringing the swale "on-line".

## OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Develop permits for vegetated swales that specify schedules and responsibility for inspection and maintenance.
- Inspect on a semi-annual basis: Assess slope integrity, soil moisture, vegetative health, soil stability, compaction, erosion, ponding, and sedimentation.
- Mow at least once per year, but do not cut grass shorter than the design flow depth because the effectiveness of the vegetation in reducing flow velocity and pollutant removal may be reduced. Grass cuttings should be removed from the swale and composted.
- Remove accumulated sediment when it is 3" deep or higher than the turf, to minimize potential concentrated flows and sediment resuspension.
- Irrigate only as necessary to prevent vegetation from dying.
- Apply fertilizers and pesticides minimally.
- Reseed periodically to maintain dense turf.
- Remove trash or obstructions that cause standing water.
- Prevent off-street parking or other activities that can cause rutting or soil compaction.



**Vegetated Swales in Tahoe**

Left: Photo Credit: Dana Olson, TRCD

Right: Photo Credit: Allen Breuch, Placer County



## REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- MAPC, *Mass LID Toolkit*, 2007.
- CASQA, *California Stormwater Best Management Practice Handbook, New Development and Redevelopment*, 2003.
- UDFCD, *Best Management Practices*, 1999.

POLLUTANT	% REMOVAL
TSS	60-95
TP	5-45
TN	16-65
NITRATE	25-65
METALS	20-90
ORGANICS	75-90
BACTERIA	75-90

## GENERAL DESCRIPTION

Permeable paving allows rainwater to percolate through the paving and into the ground before it runs off. This approach reduces stormwater runoff volumes and minimizes the pollutants introduced into stormwater runoff from parking areas. All permeable paving systems consist of a durable, load bearing, pervious surface overlying a crushed stone base that stores rainwater before it infiltrates into the underlying soil. Permeable paving techniques include porous asphalt, pervious concrete, paving stones, and manufactured "grass pavers" made of concrete or plastic. Permeable paving may be used for walkways, patios, plazas, driveways, parking stalls, and overflow parking areas.

## PLANNING AND DESIGN STRATEGIES

### GENERAL GUIDELINES

COMPONENT	GUIDELINE
<b>Site Layout</b>	Available Space – Impervious areas should not exceed 2x the permeable pavement area Building Setback – Minimum 10' setback Drainage Area – Impervious areas should not exceed 2x the permeable pavement area Topography – Typical 1% to 5% slope. Maximum slope of contributing area: 20%
<b>Design Criteria</b>	Head – Minimum vertical distance between inflow and outlet is 1.5' to 3' Soil – Soils with infiltration less than 1 in/hr will need underdrain Utility/Tree Clearance – Consult local utilities for design guidance Water Table – Minimum separation of 3' Wellhead Protection – Minimum separation of 100' from potable water supply wells
<b>Conveyance and Overflow</b>	Underdrain – Construct with 4" perforated pipes Terminate outflow pipe 1' short of side of opening for base
<b>Storage</b>	Can be used for snow storage if snow is free of pollutants (e.g. sediment, oil) that may clog pavement Water can be stored in base course below permeable pavement prior to infiltration/runoff
<b>Materials</b>	Base Course – Reservoir layer of 1" to 2" crushed stone; depth to be determined by storage required and frost penetration depth Choice of base material is a compromise between stiffness, permeability, and storage capacity Use angular crushed rock material with a high surface friction to prevent traffic compaction and rutting Filter Course – 2" thick layer of 0.5" crushed stone is applied over the base course Geotextile fabric may be laid at the top of the filter layer to trap sediment and pollutants. Vegetation – select durable grass varieties and install by plug, seed, or sod
<b>Pervious Concrete Specs</b>	NO4-RG-S7 Proven to have the best freeze-thaw durability after 300 freeze- thaw cycles 28 day compressive strength = 5.5MPa to 20MPa Void Ratio = 14% to 31% Permeability= 35in/hr to 800in/hr
<b>Permeable Paver Specs</b>	Pavers to meet minimum material and physical properties set forth in the ASTM C 936 Pigment on concrete pavers must conform to ASTM C979 Max allowable breakage – 5% Min paver thickness 3" (vehicular) and 2.5" (pedestrian) Joint width max 0.6" (pedestrian)

## DESIGN STRATEGIES

- **Provide water quality treatment through filtration:** Permeable pavement acts as a filter to remove particulate matter from stormwater.
- **Increase groundwater recharge through infiltration:** Permeable pavement allows infiltration to occur.
- **Reduce peak discharge rates and total runoff volume:** The portion of flow that is filtered through the permeable pavement will reduce the overall amount of stormwater flowing downstream.
- **Infiltrate into storage areas:** Permeable pavement can be used to infiltrate stormwater into underground cisterns or storage areas (infiltration galleries)

## BENEFITS

- Permeable paving can infiltrate as much as 70% to 80% of annual rainfall.
- Porous pavement can reduce peak discharge rates significantly by diverting stormwater into the ground and away from the pipe-and-pond stormwater management system.
- Grass pavers can improve site appearance by providing vegetation.
- Porous paving increases effective developable area on a site because portions of the stormwater management system are located underneath the paved areas, and the infiltration provided by permeable paving can significantly reduce the need for large stormwater management structures on a site.

## LIMITATIONS

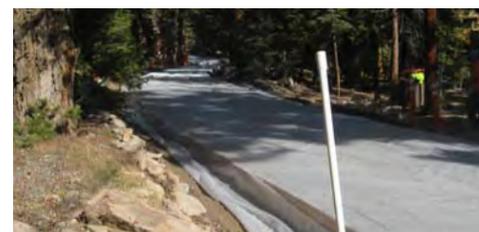
- Typically not to be applied on streets with speeds greater than 30 mph or streets with high traffic loads
- Permeable paving can be prone to clogging from sand and fine sediments that fill void spaces and the joints between pavers.
- In cold climates, the potential for frost heave may be a concern for the use of permeable paving. Some design manuals recommend excavating the base course to below the frost line, but this may not be necessary in rapidly permeable soils. In addition, the dead air and void spaces in the base course provide insulation so that the frost line is closer to the surface.
- Snow plows can catch the edge of grass pavers and some paving stones. Rollers should be attached to the bottom edge of a snowplow to prevent this problem.
- Permeable paving should not receive stormwater from other drainage areas, especially any areas that are not fully stabilized.

## COLD CLIMATE CONSIDERATIONS

- **Depth of Freeze:** Pipes are at risk for freezing and/or frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
- **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months.
- **Rain on Snow Events:** Higher runoff volumes may occur during these events. To prevent frost heave, increase depth of aggregate base to keep stored runoff below frost line. Incorporate snow volume estimates when sizing storage volumes. Do not use road deicers on permeable paving or allow contact with runoff that has been exposed to road deicers, to prevent clogging from added sediment load. Raise blades or add rollers on snow removal equipment in order to prevent damage to permeable pavement.



Base layer during construction



After pouring Photo Credits: Stefan Schuster, CDM

## CONSTRUCTION CONSIDERATIONS

- Fully protect treatment area throughout construction
- Compact aggregate with a minimum 10 ton steel drum
- Avoid extremely high and low temperatures during construction
- Test materials onsite
- Consult industry reps should be consulted for specifications on batching and placement
- Construct as one of the last items to be built on a development site, after most heavy construction vehicles are finished and after the majority of the landscaping work is completed.

## OPERATIONS AND MAINTENANCE CONSIDERATIONS

- The blade of the snow plow should be set 1 inch higher than normal when plowing on these surfaces. When contamination is an issue, do not direct snow piles and melt toward these systems.
- Post signs identifying porous pavement areas
- Minimize use of salt or sand during winter months
- Keep landscaped areas well-maintained and prevent soil from being transported onto the pavement
- Clean the surface using vacuum sweeping machines
- For paving stones, periodically add joint material (sand) to replace material that has been transported
- Monitor regularly to ensure that the paving surface drains properly after storms
- Do not reseal or repave with impermeable materials
- Inspect the surface annually for deterioration
- Grass pavers may require periodic reseedling to fill in bare spots
- Clean out drainage pipes and structures within or draining to the subsurface bedding beneath porous pavement at regular intervals



Leveling



Finished Project  
Photo Credits: PR Design & Engineering

## REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- MAPC, *Mass LID Toolkit*, 2007.
- UDFCD, *Best Management Practices*, 1999.

POLLUTANT	% REMOVAL
TSS	70-90
TP	40-55
TN	10-20
ZINC	40-80
LEAD	60-70
ORGANICS	75-90
BACTERIA	75-90

## GENERAL DESCRIPTION

Green roofs, also known as “living roofs” or “eco-roofs,” consist of a layer of vegetation and soil installed on top of a conventional flat or sloped roof. Green roofs are touted for their benefits to cities, as they can improve energy efficiency, reduce heat island effects, and create urban green space for passive recreation or aesthetics. Hydrologically speaking, the green roof assembly acts like a lawn or meadow by storing rainwater in the soil and pond areas. Excess rainfall flows to underdrains and overflow points and is conveyed in a typical building drainage system. After a storm, stored water either evaporates or is evapotranspired by the plants.



**Cedar Hotel Vegetated Roof**  
Photo Credit: Cedar House Sport Hotel

## PLANNING AND DESIGN STRATEGIES

### GENERAL GUIDELINES

COMPONENT	GUIDELINE
<b>Site Layout</b>	Available Space – Limited to rooftop Drainage Area – Green rooftops are designed to capture rainfall directly onto the surface Topography – Green rooftops may be installed on roofs with slopes up to 10%
<b>Design Criteria</b>	Soil – Soils with adequate infiltration rates (1 in/hr) Load – Roof structure must be able to support soil and plants of the green roof assembly, and maintenance staff accessing the roof. Slope – Can be used on roof slopes up to 10%. ASTM International released the following Green Roof standards in 2005: <ul style="list-style-type: none"> <li>• E2396-05 Standard Test Method for Saturated Water Permeability of Granular Drainage Media;</li> <li>• E2397-05 Standard Determination of Dead Loads and Live Loads associated with Green Roof Systems;</li> <li>• E2398-05 Standard test method for water capture and media retention of geocomposite drain layers for green roof systems;</li> <li>• E2399-05 Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems; and</li> <li>• E2400-06 Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems.</li> </ul>
<b>Conveyance and Overflow</b>	The drainage system includes a porous drainage layer and a geosynthetic filter mat to prevent fine soil particles from clogging the porous media. The drainage layer can be made up of gravels or recycled-polyethylene materials that are capable of water retention and efficient drainage. The depth of the drainage layer depends on the load bearing capacity of the roof structure and the stormwater retention requirements. The porosity of the drainage layer should be greater than or equal to 25%.
<b>Materials</b>	Waterproof Membrane – Modified asphalts (bitumens), synthetic rubber (EPDM), hypolan (CPSE), and reinforced PVC Modified asphalts usually require a root barrier, while EPDM and reinforced PVC generally do not Common european membrane design is a 60-80 mil PVC singleply roof system Growing Medium – Typically a mixture of sand, gravel, crushed brick, compost or organic matter combined with soil, 3” to 6” in depth, increasing the roof load by 16 lb/sqft to 35 lb/sqft when fully saturated Do not use growing media that contain phosphorus rich fertilizers or excessive nutrient levels Vegetation – Use low-growing, spreading perennial or self-sowing annuals that are drought tolerant including: sedum, delospermum, sempervivium, creeping thyme, allium, phloxes, anttenaria, ameria, and abretia Vegetation may be planted as vegetation mats, plugs or potted plants, sprigs (cuttings), or seeds

### DESIGN STRATEGIES

- **Reduce peak discharge rates and total runoff volume:** The portion of flow that is collected by a green roof will reduce the overall amount of stormwater flowing downstream.
- **Reduce heating and cooling costs through roof insulation:** Green roofs provide cooling effects through soil, plant, and water mixture on the roof which provides insulation.

### BENEFITS

- Green roofs reduce peak discharge rates by retaining runoff and creating longer flow paths. Research indicates that peak flow rates are reduced by 50% to 90% compared to conventional roofs, and peak discharge is delayed by an hour or more.
- Green roofs lower heating and cooling costs because the trapped air in the underdrain layer and in the root layer help to insulate the roof of the building. During the summer, sunlight drives evaporation and plant growth, instead of heating the roof surface. During the winter, a green roof can reduce heat loss by 25% or more.
- Because green roofs shield roof membranes from intense heat and direct sunlight, the entire roofing system has a longer lifespan than conventional roofs.
- The presence of a green roof helps to reduce air temperatures around the building, reducing the “heat island” effect and reducing the production of smog and ozone, which forms in the intense heat (175 degrees F) over large conventional roofs. The vegetation on green roofs also consumes carbon dioxide and increases the local levels of oxygen and humidity.
- Green roofs have demonstrated aesthetic benefits that can increase community acceptance of a high-visibility project; they may also add value to the property if marketed effectively.

### LIMITATIONS

- Load restrictions are usually the main limitation for green roofs in retrofit applications. A professional structural engineer must assess the necessary load reserves and design a roof structure that meets state and local codes.
- Slopes greater than 15% require a wooden lath grid or other retention system to hold substrate in place until plants form a thick vegetation mat.
- Green roofs should not be used where groundwater recharge is a priority, such as in aquifer recharge areas or watersheds experiencing low-flow stresses.
- The initial construction cost is higher than conventional roofs.
- Vegetation may require irrigation

### COLD CLIMATE CONSIDERATIONS

- **Extreme and Sustained Cold Temperature:** Permanent pool ice covering, reduced biological activity
  - **Length of Growing Season:** Select cold climate appropriate plants for vegetated areas.
- Size facilities for coldest temperature removal rates (decreased biological activity, settling etc.), but will see enhanced removal during non-winter months. Select climate appropriate vegetation.

## CONSTRUCTION CONSIDERATIONS

- Use an experienced professional green roof installer to install the green roof designed by an architect (or landscape architect) who must work with contractor to ensure that the waterproofing membrane installed is appropriate for use under a green roof assembly.
- Construct conventional green roof assemblies in sections for easier inspection and maintenance access to the membrane and roof drains.
- Green roofs can be purchased as a complete system from specialized suppliers who distribute all the assembly components, including the waterproofing membrane. Alternatively a professional landscape architect can design a customized green roof and specify different suppliers for each component of the system.

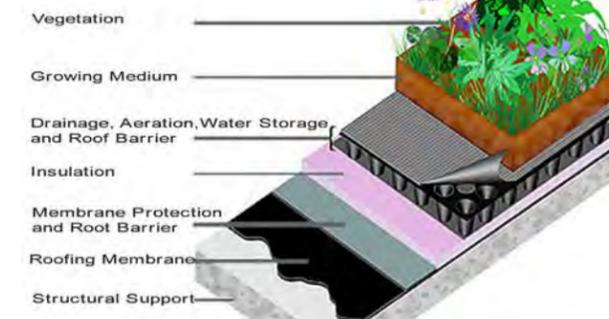
## OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Green roofs require some support during establishment and then yearly maintenance thereafter. Irrigate plants or sprigs until established, and additional plants or sprigs added to ensure good plant coverage if necessary. With drought-resistant vegetation, irrigation of an extensive green roof is rarely necessary after the two-year establishment period.
- Weed and mulch during the establishment period and periodically thereafter over the life of the roof. Remove any woody plants which become established on the roof.
- If necessary (many roofs can survive on deposition of airborne nitrogen and biomass breakdown), apply a slow-release fertilizer once a year will ensure continued vigorous growth of the vegetation. Do not use soluble nitrogen fertilizers and compost due to the potential for nutrient and bacteria export.



**Above: California Academy of Sciences Green Roof**  
Photo Credit: California Academy of Sciences

**Green Roof Layers**  
Credit: TRCA



## REFERENCES

- See Section 4.4 in the text for more information.
- CWS, *LID Approaches Handbook*, 2009.
- *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
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