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.

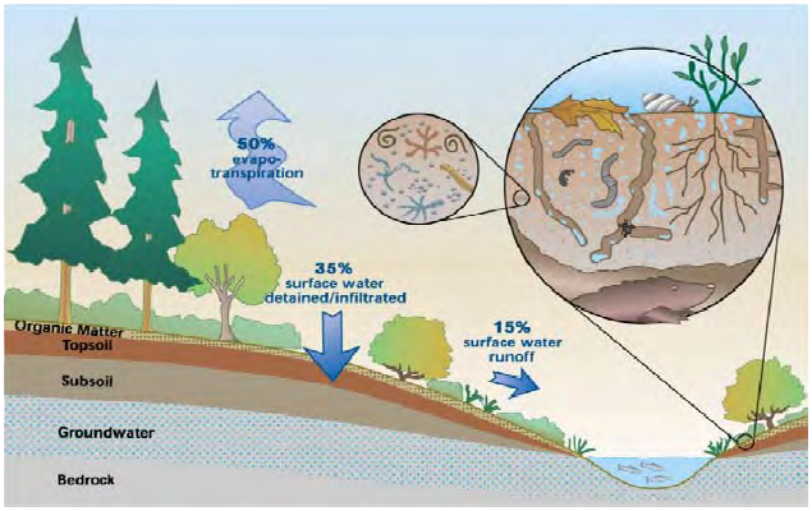

Figure 2-2. Pre-Urbanization Water Cycle and Soil Conditions (FISRWG, 1998; adapted by E. Berntsen, 2009)

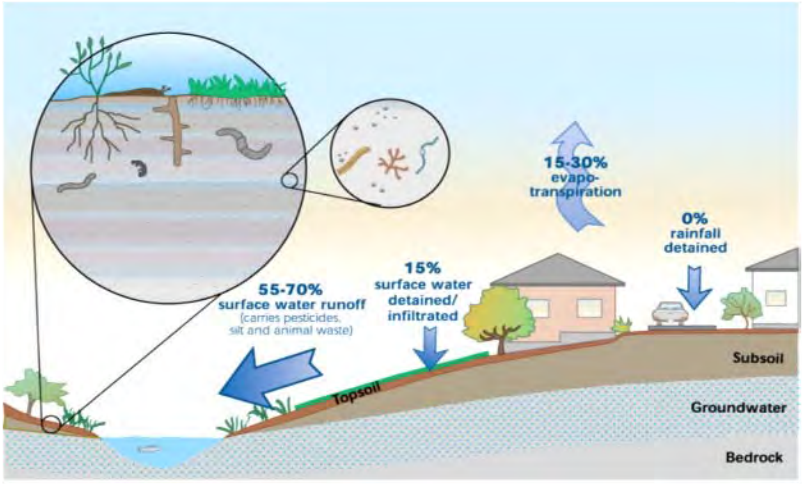

Figure 2-3. Post-Urbanization Water Cycle and Soil Conditions (FISRWG, 1998; adapted by E. Berntsen, 2009)

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).

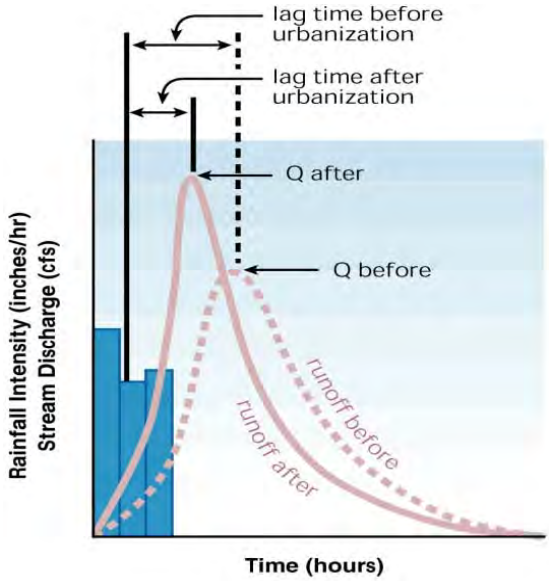

Figure 2-4. Comparison of Runoff Before and After Urban Development

(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.

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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 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

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 that 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

Developers/Builders
Reduces land clearing and grading costs
Reduces infrastructure costs (streets, curbs, gutters, sidewalk)
Reduces stormwater management costs
Increases lot yields
Increases lot and community marketability
Municipalities
Protects regional flora and fauna
Balances growth needs with environmental protection
Reduces municipal infrastructure and utility maintenance costs (streets, curbs, gutters, sidewalks, storm sewers)
Helps satisfy environmental regulations related to water quality and climate change
Potentially reduces localized flooding
Fosters public/private partnerships
Property Owners
Preserves and protects amenities that can translate into higher value, more marketable homes and livable communities
Reduces energy demand and costs due to temperature regulating trees and vegetation
Potentially reduces localized flooding
Protects water quality – public health benefit
Reduces infrastructure costs which can be passed onto property owners
Compliance with stormwater regulations
Improved public relations associated with implementing green building strategies
Environment
Preserves integrity of ecological and biological systems
Protects site and regional water quality by reducing sediment, nutrient, and toxic loads to water bodies
Reduces impacts to local terrestrial and aquatic plants and animals
Preserves trees and natural vegetation
Reduces demands on water supply and encourages natural groundwater recharge

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[1], 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

[1] 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.

> ***"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***

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 contaminates from air and rainfall.

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 the 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

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 thorough 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.

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 l 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

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).

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)

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

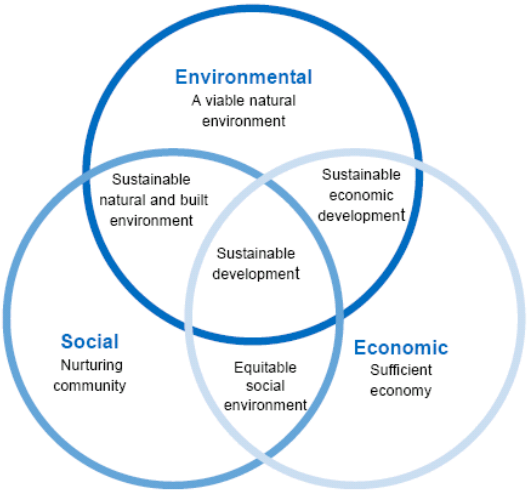
Natural open space and trails are typically attractive to potential home buyers. Various LID projects and smart growth studies have found that clustered housing with open space appreciated in value at a higher rate than conventionally designed subdivisions. For example, in Amherst and Concord, MA, clustered 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).

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). 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

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.

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

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).

- 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.***

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 and 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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