Drought Response Outreach Program for Schools Technical Assistance
GA# 14-474-550

GUIDANCE FOR DESIGN AND CONSTRUCTION OF VEGETATED LOW IMPACT DEVELOPMENT PROJECTS

CALIFORNIA Water Boards
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS

drops
Drought Response Outreach Program for Schools

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COUNCIL FOR WATERSHED HEALTH

About Drought Response Outreach Program for Schools (DROPS) Technical Assistance

The State Water Resources Control Board (SWRCB) developed the concept of the Drought Response Outreach Program for Schools Technical Assistance to increase the number of grant applicants applying for Drought Response Outreach Program for Schools (DROPS) funding and to support the development of technically-sound and competitive grant applications. The State Water Board awarded grant funding to the Council for Watershed Health to convene and manage a Technical Assistance Team (TA Team) to provide technical assistance to interested school districts and schools. During the grant application period, technical assistance focused on the development of concept level project proposals that emphasized Low Impact Development (LID) principles to capture, treat, and retain stormwater. Applicants submitted a short application to SWRCB requesting technical assistance. The SWRCB prioritized technical assistance for Disadvantaged Schools, which are often the least likely to have adequate resources or expertise to develop competitive grant proposals. Forty-eight schools received technical assistance, resulting in the identification and evaluation of more than 500 potential LID projects for school campuses. In addition to concept design development, the TA Team developed and presented two webinar presentations on LID for schools. The TA Team also provided post-grant award technical assistance to school districts needing supplemental support to refine their DROPS projects. This document will help guide DROPS Project teams and other schools toward successful LID projects on schools campuses throughout California. For more information about DROPS visit: http://www.waterboards.ca.gov/water_issues/programs/grants_loans/drops/

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Contents

Introduction **1**

Design of Vegetated LID Projects 3

Design 1: Establish the Project Team 3

Design 2: Review Existing Information 5

Design 3: Select the Performance Design Type 5

Design 4: Determine the Project Dimensions (i.e. sizing) 7

Design 5: Ensure Stormwater Can Enter and Exit the Project 9

Design 6: Protect Adjacent Structures from Stormwater Intrusion 11

Design 7: Use Ponding Depth and Check Dams to Enhance Infiltration 11

Design 8: Use Appropriate Plants and Landscaping Materials 12

Design 9: Determine the Irrigation Approach 15

Design 10: Avoid Sediment and Erosion Problems 16

Design 11: Consider Pedestrian Circulation and Use 16

Construction of Vegetated LID Projects 18

Construction 1: Review the Project Design with the Construction Team 18

Construction 2: Prepare for Different Construction Techniques and Material Requirements 19

Construction 3: Make Sure Proper Protections are in Place and Check the Native Soil Condition 19

Construction 4: Conduct Excavation, Placement of Materials and Set Elevations 20

Construction 5: Complete Construction 21

Attachment 1: Vegetated Stormwater LID Examples 22

Attachment 2: Vegetated Stormwater Project Check List 36

Introduction

Low Impact Development: Improving How We Manage Stormwater

Stormwater runoff is created when rainwater falls on impervious surfaces such as roads, rooftops and parking lots. Urban areas generate large amounts of stormwater runoff that does not infiltrate into the surrounding soil but is generally conveyed downstream via underground pipes or surface ditches. The downstream impacts of stormwater runoff can be significant including flooding and damage to our lakes, rivers, streams, and ocean. Urban stormwater also carries pollutants such as metals, oil/grease, pesticides, and fertilizers that are harmful to downstream aquatic life and impact recreational uses such as swimming and fishing. However, stormwater runoff can be a valuable resource for our communities and when managed correctly, stormwater can be used to reduce such impacts. The State Water Resources Control Board (SWRCB) continues to implement programs to reduce stormwater pollution and advocates the use of Low Impact Development, or LID, to manage stormwater runoff as a valuable resource.

Low Impact Development, or LID, is a stormwater management approach that mimics nature by capturing, treating, and infiltrating runoff *on-site*. LID strategies such as rain gardens, permeable pavement, and bioswales help to reduce stormwater runoff volumes and pollutants and therefore protect our valuable water resources.

Unlike conventional stormwater management, which is generally achieved through use of underground pipes, vaults, and detention ponds, the use of LID, especially in vegetated-type designs, provide many economic, environmental, and social benefits. The terms "LID" and "Green Infrastructure" are sometimes used interchangeably to communicate how the use of vegetation and soils in urban environments provide benefits related to water quality, air quality, energy use, water conservation, groundwater recharge, wildlife habitat, and community health and recreation.

Why Is Low Impact Development Important For Our Schools?

As public places, schools can model sustainable stormwater management for the whole community. The simple act of building LID projects mimics natural processes, values healthy soils, and shares the beauty and resiliency of climate appropriate plants.

- School sites often have expansive impervious areas that can be retrofitted with water absorbing and water saving landscapes.

- School LID projects can demonstrate successful landscape designs that can be replicated throughout the community, reducing flooding and improving stormwater quality.

- Use of California-friendly landscapes, often comprised of native and drought-tolerant plants and trees reduce water consumption and irrigations costs, as well as provide shade and habitat for pollinators and beneficial insects.

- As teaching institutions, schools are ideal locations to foster an environmental stewardship among children and adults by integrating the principles of sustainable water resource management into learning curriculum.

Design and Construction of Vegetated LID Projects: How to Use This Document

This guidance document provides an overview of design and construction considerations for vegetated LID projects such as bioretention areas and rain gardens. Vegetated LID designs are the most common type of LID project. They are cost-effective and provide many benefits to the community and environment. These include but are not limited to stormwater management, improved air quality, decreased heat island effect, improved community aesthetic, and increased biological diversity. Vegetated LID designs can range in complexity from simple rain gardens to engineered bioretention systems. Selecting the LID project type and design often depends on many factors such as budget, space constraints, and performance goals.

This document focuses on some of the critical design and construction elements that are necessary for a successful project. Ideally, the Project Team will review the entire document, refer to the LID examples in Attachment 1, and use the check list provided in Attachment 2 to facilitate discussion and ensure that design and construction elements are adequately addressed. The information in this document is not intended to be exhaustive nor does it replace the need for a qualified and knowledgeable design and construction team.

Figure 1. The City of Atascadero Zoo LID Parking Lot Project includes vegetated bioretention facilities that capture, treat and infiltrate stormwater runoff. Signage and pathways promote an educational experience.

Design of Vegetated LID Projects

The design phase creates the blueprint for the finished project and involves considerations that may not be familiar to those new to LID projects. The following sections outline some key design elements required for a successful project. Photos and images to illustrate the design concepts are included in Attachment 1.

Design 1: Establish the Project Team

A strong Project Team is critical for success. LID projects are multi-faceted and require input from a variety of individuals to support successful design, construction, long-term performance, and educational value. Project Team members may include:

- Landscape architects to provide input on context-appropriate design and outdoor space planning strategies, help with hardscape material choices, and recommend appropriate plant palettes.
- Civil engineers to conduct the necessary hydrologic design calculations and identify engineered design elements.
- Geotechnical engineers to provide input related to soils and potential issues associated with nearby structures.
- Facility and grounds personnel who are knowledgeable regarding use of existing spaces, areas prone to flooding, and long-term operations and maintenance requirements.
- Education and communication specialists and teachers who can enrich the learning experience during project design, construction and after project completion.

While not every member of the Project Team needs to be an LID expert, the individual(s) leading the design work should have some on-the-ground experience with the design and construction of LID projects. When possible, seek design review from individuals with LID expertise who can troubleshoot design concepts and plans. Ultimately, a good Project Team is comprised of individuals who can contribute their insight and knowledge to help create a project that will benefit the environment and community for many years.

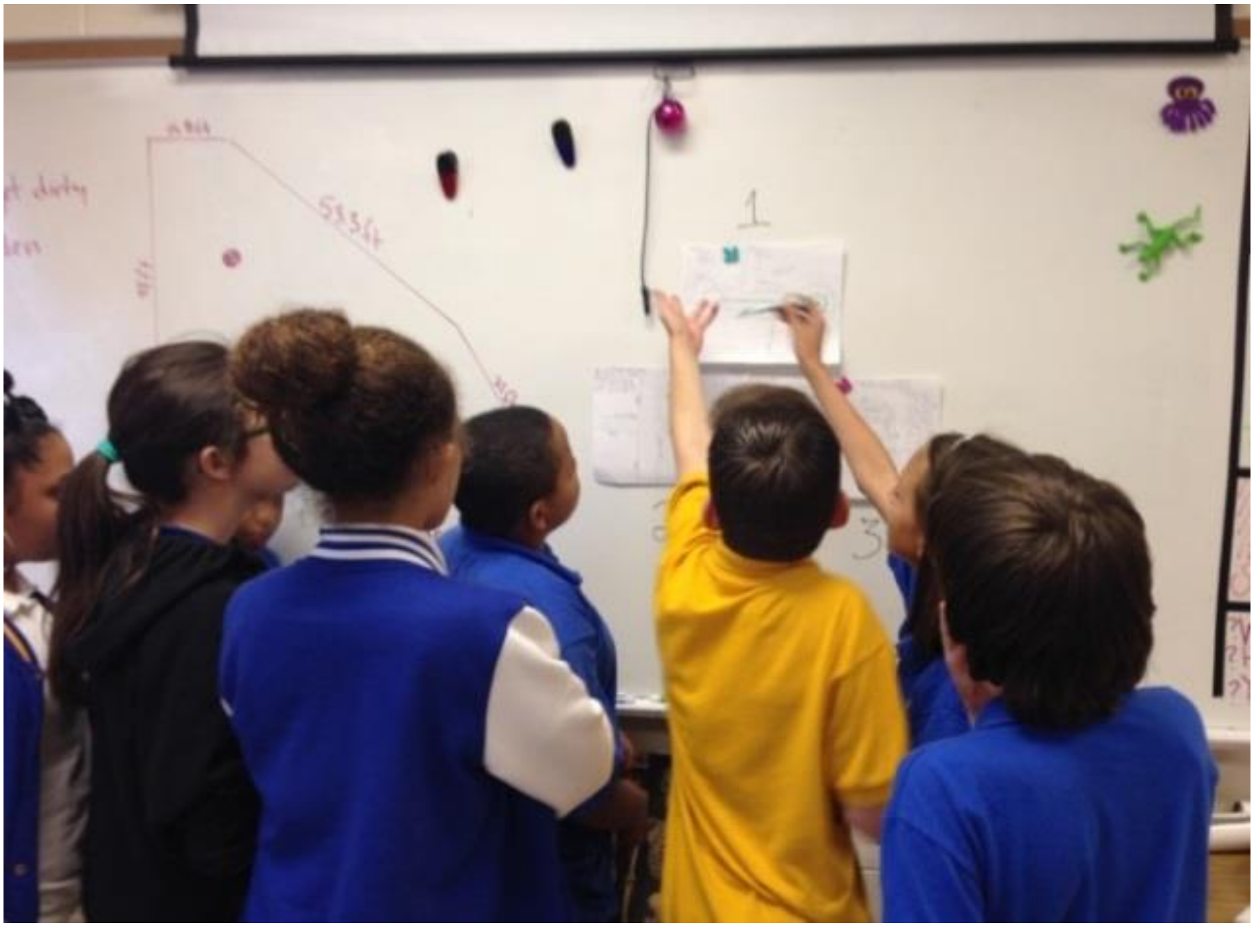


Figure 2: LID projects are wonderful place-based learning opportunities. Including students in the design and construction process will create a richer experience for everyone. In this photo, students from Hillsborough County Public Schools take part in a "Campus Green Infrastructure Challenge" to debate their design ideas and recommendations. Photo courtesy of Ryan C. Locicero (c) 2014 raingardens.us and supported by National Science Foundation grant No. 1200682 and 1156905.

Design 2: Review Existing Information

The Project Team should review any existing information related to the project as a critical first step prior to launching into the actual design. Even in situations where the project parameters have been conceptually defined and documented, it is not uncommon for Project Team members to initially have differing perspectives or levels of understanding regarding the project. For example, if the project includes a numeric water quality performance requirement such as often exists with grant-funded projects, the team needs to fully understand this requirement as this information will influence both the design and the nature of the completed project. Similarly, the Project Team should review relevant reports or information such as geotechnical documents or required setbacks (e.g., from buildings or creeks).

The Project Team should also check the accuracy of any stated contributing drainage areas (i.e. square footage) that will contribute stormwater runoff to the project as this value determines the amount of stormwwater runoff that must be managed within the project. Existing information may also provide insight regarding project constraints and opportunities that can influence the project type, location, or even feasibility. A design workshop can be a helpful way to refine the project objectives, conceptually address project constraints and opportunities, and provide a means to bring together the Project Team with key stakeholders to initiate the project.

Design 3: Select the Performance Design Type

LID projects mimic how rainwater moves through the natural environment. To do this, LID designers focus on capturing, slowing, and infiltrating stormwater runoff generated by our urban environment (e.g. streets, roofs, parking lots). LID projects designed to infiltrate stormwater runoff provide a dual benefit: pollutant removal and volume reduction. Several factors can influence whether a project will provide water quality treatment only (i.e. no volume reduction benefit) or both pollutant removal and volume reduction benefit. This distinction drives the project design so it's critical that the Project Team determines the following for each individual LID project:

- Will the LID project provide water quality treatment *only*?
  OR
- Will the LID project provide both water quality treatment *and* volume reduction?

A short description of each design type follows.

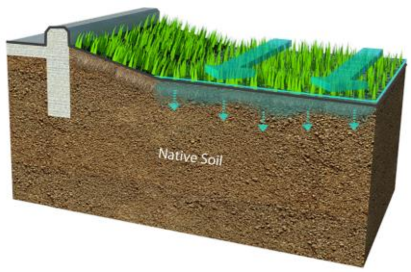


Figure 3. A bioswale facility removes pollutants primarily through filtration and settling as stormwater moves over the surface of the vegetated area. Infiltration into the native soil is negligible if a liner is used.

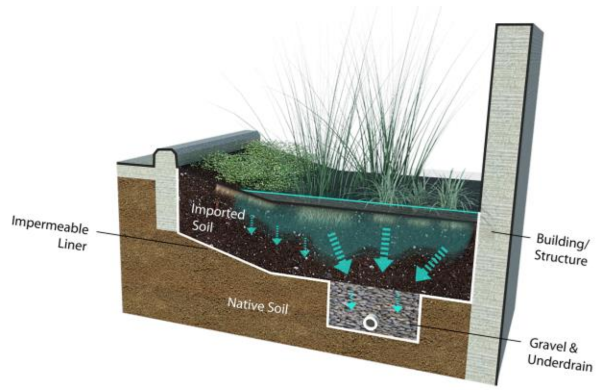


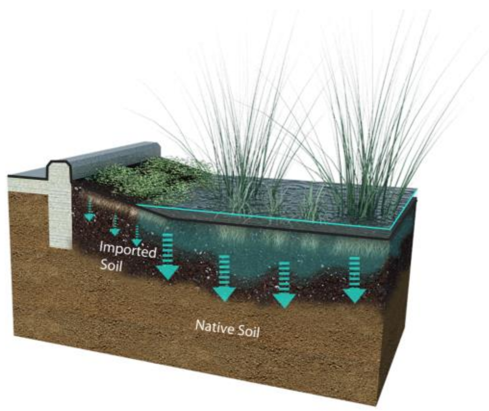
Figure 4. A bio-filtration facility infiltrates stormwater through a special soil media designed to remove pollutants. Treated stormwater is then routed through an underdrain to exit the system. Infiltration into the native soil is negligible or non-existent if a liner is used to protect foundations.

Water Quality Treatment-Only

LID projects remove urban pollutants such as oil/grease, metals, pesticides/herbicides, bacteria, and sediment. Water quality treatment-only designs are most appropriate where there is a strong reason not to infiltrate stormwater into the native soils due to soil contamination, nearby existing utility vaults, building foundations, etc. Water quality treatment-only design types capture a specified volume of stormwater runoff within the project, but there is little to no infiltration into the native soils (i.e. the soils underlying the project). Instead, stormwater may be directed across the vegetated surface where pollutants are removed through settling and filtering processes (Figure 3), or downward through a specialized soil media designed to remove pollutants after which the treated stormwater is routed out of the system through an underdrain (Figure 4). In both cases, the stormwater volume is not significantly reduced and exits the facility.

Water Quality Treatment and Volume Reduction

LID projects designed to provide water quality treatment and volume reduction must capture and hold stormwater for a sufficient period to allow the desired amount of infiltration to occur (Figures 5, 6). LID designers use a variety of techniques to promote infiltration including maximizing the overall square footage and allowable ponding depth (typically no greater than 6 inches) to capture and infiltrate stormwater. The use of subsurface crushed rock layers act as stormwater reservoirs that hold stormwater and allow infiltration into the underlying soil. The project's underlying, or



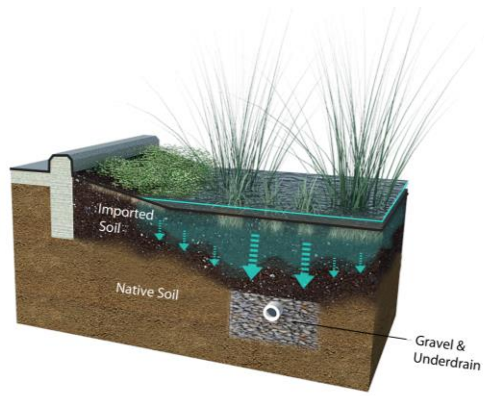


Figure 5. A rain garden or bioretention facility without an underdrain infiltrates the entire design storm to provide both stormwater quality treatment and volume reduction. Special soil media for treatment is not required.

Figure 6. A bioretention facility with an underdrain is used when the native underlying soils do not adequately infiltrate, and additional subsurface storage is needed to manage the design storm. The underdrain also reduces excessive ponding duration that can occur due to the poor infiltration. Specialized soil media is used to ensure that any stormwater exiting via the underdrain has been adequately treated.

native, soils will greatly influence the required project dimensions needed to meet the infiltration performance requirements. For example, clay or highly compacted soils do not infiltrate as well as sandy soils and consequently, projects located over poorly infiltrating soils will need to be sized larger to meet the same performance goals as projects located over highly infiltrative soils.

Design 4: Sizing - Determine the Project Dimensions

Detailed sizing guidance is beyond the scope of this document. The project design engineer needs to use the appropriate LID sizing tools, models or other computational methods to determine the project sizing dimensions to achieve the numeric water quality performance objective. An example of a commonly used numeric water quality performance objective is "treat runoff from storm events up to and including the 85th percentile, 24-hr storm event"1. These storm events represent relatively small storms that cumulatively account for the majority of annual rainfall. From a stormwater management perspective, capturing and treating all the small storm events will result in the removal of the majority of annual pollutants that are associated with urban runoff. In determining the sizing dimensions for an LID project, the numeric water quality performance

[1] The 85th percentile, 24-hr storm event is a statistical value by which 85 percent of all annual storms are equal to, or less than a specific storm size. The 85th percentile, 24-hr storm event varies by region due to climate and precipitation variance. For example, the 85th percentile, 24-hr storm event for the City of Gonzales, CA is 0.7 inch.

Figure 7. LID projects can vary in the level of engineering that is needed to provide the desired performance. When space and conditions allow, designers should strive to use simple designs such a rain garden design.

Figure 8. Space constraints may call for a more compact design such as a bioretention planter. For the same performance objective, simple rain garden type designs tend to cost less than the more engineered bioretention or biofiltration type designs. However, this will depend on several factors including cost of land, materials used for the project and long-term maintenance requirements.

objective is the primary factor that defines project size and the project type (i.e. water quality treatment-only or, treatment and volume reduction).

Sizing calculations must account for the amount of runoff that will be directed to the project as well as precipitation that falls directly on the project. The design team should take into consideration the available space for the project. Where feasible (e.g., space, soil conditions, setbacks) the project team should strive for simple vegetated stormwater designs. Simple designs, such as rain gardens, require less excavation, less infrastructure (e.g., pipes, overflow units), and less materials (e.g., specialized soils) than more highly engineered designs (e.g., bioretention). However, simple designs usually require more square footage to meet the same performance objective as compared to a more highly engineered design (Figure 7, 8).   When there is sufficient space to consider different sizing options, the design engineer will often go through an iterative process with the project team to find the preferred project footprint (e.g., square footage) to align with the project performance objectives, available budget, desired aesthetic, and acceptable long-term maintenance requirements.

Design 5: Ensure Stormwater Can Enter and Exit the Project

The goal of an LID project is to capture stormwater so that it can be treated and ideally, infiltrated into the native soils. It is frustrating to construct an LID project only to find that stormwater runoff does not enter the facility. If the project is intended to accept runoff from contributing impervious surfaces, the design must indicate how stormwater will be directed toward and then captured by the project. Similarly, an overflow strategy is needed to remove stormwater when infiltration cannot occur or when the capacity of the facility is exceeded as may occur in large storm events. The design element of directing stormwater movement is often referred to as "routing" and can be imagined as the route, or path, the stormwater will follow to enter, flow through, and exit the project. Also, there may be instances where one stand-alone LID facility might not be able to manage a defined amount of stormwater runoff and it may be necessary to have several inter-connected LID landscape systems in place. Several of the methods describe below are cost-effective ways to route stormwater from one LID project to another and provide educational opportunities.
Routing stormwater into the LID project:

- Check the elevation grade from the source of the stormwater runoff to the project. The stormwater runoff needs to transition from a higher elevation to a lower elevation without any "uphills" in-between. This includes runoff flowing over surfaces such as asphalt, landscape, or where subsurface pipes are used to route stormwater. Common design strategies use passive overland sheet flow, concrete valley gutters, trench drains, and runnels.

- The project design plans need to show specific elevation grades for routing runoff into the facility including grade elevation for entry points, such as curb cuts. The final elevation grades of the soil within the facility should be set lower than the entry point to avoid creating a barrier.

- There are many types of curb cuts that allow surface flow from paved areas to enter the LID project. These include standard curb cuts, curb cuts with side walls, flush curbs, and grated curb cuts. The design conditions will help determine the appropriate type and number of curb cuts needed to adequately allow water into the project.

- Roof runoff can be routed to the LID project in a variety of ways. One common method is to disconnect existing exterior roof downspouts at the base of the building. Once disconnected, runoff can enter directly into a project located adjacent to buildings or be directed away from the building toward a project farther away using design strategies mentioned above.

- Scuppers are outlets in the side of a building that can be used to direct flow vertically from buildings to an adjacent LID project. Care should be taken to ensure that runoff flows directly into the LID facility. Also carefully consider possible erosion of soil that may result from the vertical drop of water and the potential for children to interact with the water.

Routing stormwater out of the LID project:

- Stormwater can be directed out of the project by use of a passive surface design or through some type of piped overflow and/or underdrain system.

- Conveyance of stormwater from the project must be done in a manner that does not affect project performance or cause downstream or adjacent area problems, such as flooding or pedestrian hazards.
- Passive design takes advantage of surface grade to allow excess stormwater to exit the system at a lower point than where it entered. Passive design is generally preferred where adequate infiltration rates do not cause nuisance ponding within the facility and may be the only choice where there is no opportunity to connect to an existing underground stormwater conveyance system. Even with piped infrastructure in place, it is a good design measure to have a defined passive surface overflow in place. Passive design can allow overflow via sheet flow, through a defined curb cut, a surface channel, or a trench drain.

- Overflow inlets and underdrains may be needed to avoid extended ponding duration where the native soil limits infiltration rates. Care should be taken with underdrain design to avoid conveying all stormwater runoff out of the system when infiltration into the native soil is desired. Overflow devices and underdrains usually require connection to an existing piped stormwater conveyance system.

- The size of the overflow inlet should be proportional to the overall amount of runoff being managed. It is common to have either too large of an overflow inlet that takes up valuable space within the landscape or, an undersized overflow system that cannot accept larger storm events.

Examples of Routing Techniques that can be used for individual projects or to link multiple LID projects:

- Trench drain systems are designed to convey stormwater runoff within a shallow channel (usually 6 inches in depth or less) while maintaining unimpeded American with Disabilities Act pedestrian or vehicular access. Trench drain grates can vary considerably in size and shape, as well as material choice and patterns.

- Concrete valley gutters are commonly used in California to convey surface runoff. However, the conventional approach is conveying stormwater to storm drain inlets. These concave shaped, shallow, concrete gutters can also route water to LID projects or connect them. Concrete valley gutters are a cost-effective means to convey runoff and they can also be used to incorporate art or interpretive signage.

- Runnels are small-scale open channels with vertical depth used to convey stormwater runoff. They are essentially a trench drain without the grate on top. Runnels can be made of any durable element such as concrete, brick, metal, or stone. They are often used to route stormwater runoff from disconnected downspouts to adjacent LID landscapes and can even be terraced to allow water to cascade in areas with steeper grades.

Design 6: Protect Adjacent Structures from Stormwater Intrusion

LID projects are often placed near or adjacent to other urban infrastructure such as roads, parking lots, buildings, sidewalks and play areas. Often, the LID project will receive stormwater runoff from these surfaces. Designers must take care to protect any existing structures and infrastructure from damage due to the capture and infiltration of stormwater runoff. During project design, make sure to:

- Use a ten foot distance between an LID project and a building as a general rule-of-thumb for protecting building foundations from infiltrated stormwater.
- Consider use of vertical moisture barriers/liners, deep curbs[2], underdrains, and trench dams.
- Consult a geotechnical engineer for advice with any concerns regarding water intrusion.

Design 7: Use Ponding Depth and Check Dams to Enhance Infiltration

LID projects are designed to capture stormwater from small to moderate size storm events, allowing the water to infiltrate. To achieve this, the surface of the project must be recessed to capture and hold the stormwater. Check dams, berms and weirs can complement a recessed design to enhance infiltration. Check dams and weirs are the “speed bumps” for stormwater management and are essentially small barriers designed and strategically placed perpendicular to the runoff flow within an LID facility to slow the flow, control the depth of water retained, or both. Weirs are essentially check dams but have defined notches or openings to control the amount of stormwater retention and the location of flow.

Tips for designing the recessed area of the project:

- Where possible, use gradual slopes to achieve the change in grade necessary to create a recessed area for ponding.

[2] Deep curbs are also used to protect asphalt street edges and parking lots from collapse that can occur due to the uncompacted nature of the adjacent LID project soils, which do not provide the same structural stability as compacted soils.

- The maximum ponding depth within the project should not exceed 6 inches. However, the maximum ponding depth may vary depending on factors such as safety in areas used by children and grading conditions.

- Avoid ponded water in excess of 48 hours after a storm event to avoid creating a mosquito breeding environment.

- In areas where space is limited, the use of low walls is a good option to achieve a transition in grade. Hardscape elements such as concrete rock or metal can be used to construct these low walls.

- When creating the soil grade, the ideal graded slope to retain strong plant growth, reduce erosion, and reduce irrigation runoff is a 4:1 slope, with a maximum slope of 3:1. For example, in a 4:1 slope, for every 4 feet of horizontal distance there is a 1 foot drop in grade.

Tips for using check dams and weirs:

- Check dams should retain stormwater at relatively shallow depths, with a maximum ponding depth of 6 inches of stormwater during storm events.

- Check dams are particularly useful in landscapes with moderate longitudinal slopes. They can also be placed within landscapes that have little or no longitudinal slope in order to promote infiltration. However, this should be done only where soil conditions are conducive to infiltration or where there is an underdrain system.

- Both check dams and weirs can be made from a variety of durable construction materials such as rock, concrete, metal or wood.

- The number and spacing of check dams is largely dependent on the stormwater management goals of a project and the particular site conditions. For projects with longitudinal slopes of 4 percent or less, check dams should be placed at least every 25 feet. In steeper conditions, check dams will need to be placed at a greater frequency and may need to be made from the most durable hardscape materials to withstand the forces of the water.

Design 8: Use Appropriate Plants and Landscaping Materials

LID projects are highly functional and beautiful landscapes. Plants and trees provide function, habitat, and aesthetic appeal. However, to achieve stormwater quality management goals, there are some considerations that differ from conventional landscape design, including selection of appropriate plants, soils, and mulches. Another important decision is the method used for irrigation to support plant establishment as well as long-term survivability. This section provides some guidance related to landscape materials and irrigation.

Plants:

- LID projects will have different planting zones based on the type of design used. LID projects that are designed with a side slope condition have two planting zones: dry and seasonally wet. Shrubs, groundcovers, and perennials that thrive in drier conditions should be placed on the upper portions of the side slopes while the seasonally wet tolerant plants, such as sedges and rushes, are best suited for the low, flat bottom zone of the LID project. LID projects that have a flat-bottom condition without a side slope (e.g., stormwater planters) have only one planting zone and should only be planted with seasonally wet-tolerant plant material.

- In most areas of California, the options for plant types that will be located within the ponding zone are fewer than those that will be located outside the ponding zone. For both zones, select plant types that are appropriate to the climate and region.

- Plants chosen for seasonally wet zone conditions should also have some level of drought tolerance in order to minimize, or potentially eliminate, the need for supplemental irrigation during dry periods after the plant establishment period. Prioritize selection of plants that are California native, low-maintenance, drought-tolerant, and non-invasive.

- Regardless of the chosen plant palette, it is important to design and install the plant material at an appropriate density. LID projects are commonly installed with too few plants and this condition allows weeds to overtake the landscape in a short period of time. A well-designed LID project, with the appropriate plant density, should have no bare ground showing after a two-year plant establishment period, which will reduce the need for weeding.

- In general, choose lower-growing plants types that do not exceed three feet in height. Low-growing plants preserve site lines, and tend to be more aesthetically and functionally preferable for LID projects. In addition, low-growing plant varieties help to reduce ongoing maintenance by eliminating the need for plant trimming.

Trees:

- Trees provide additional community and environmental benefits and project design process should include an evaluation of whether trees can be integrated into the project. It is important to determine whether those responsible for the project's long term maintenance are prepared and able to care for trees associated with the project.

- Smaller container trees can often quickly adapt to site conditions and can be a better choice than planting larger container trees.

- Provide sufficient space for tree growth to reduce tree mortality and replacement costs.

- Trees should be located at least five feet from facility inlets to avoid erosion of soils around the root ball.

- Trees located where there are seasonally wet soils and potential ponding must be able to tolerate these conditions. Some trees may tolerate periodic shallow ponding, especially if native soils allow water to infiltrate quickly.

- If space allows, plant trees outside of the area that will experience stormwater ponding. By locating trees outside the ponding zone, the number of tree species choices for the project area is greater.

- Avoid specifying trees with invasive roots.
- LID projects can be located alongside existing mature trees if the species can tolerate wetter conditions and as long as the root zone of the tree is not disturbed.

Soil and Mulch:

- Many sites, especially retrofit conditions, have little or no organic material within the soil structure because they have been paved over and compacted for many years. When needed, amend native soils with organic material to increase infiltration, promote healthy plant growth and support the microbiological processes beneficial for the removal of certain types of pollutants.

- Bioretention facilities often use a specialized soil mix to enhance infiltration, remove pollutants, and support plant health. The general mixture is comprised of 60 – 70 percent sand and 30 – 40 percent compost. Some specifications have a reduced compost percentage and use an approximate 65 percent sand, 20 percent sandy loam and 15 percent compost mixture.

- When importing a new soil mix into an LID project, it is important to follow a soil preparation procedure to ensure the ability for water to soak into the soil and to provide the best conditions for plants to grow. Design plans should call for the native soil to be scarified or rototilled to break up any soil compaction during construction. When the new soil mix is imported, it should be introduced in 6 inch lifts and blended into the native soil. This helps create a smooth gradient of soil blending between the native soil and the imported soil. Design plans and specifications should indicate compaction of imported soil should only be by foot or a landscape roller.

- Mulch material can be made of organic material (e.g., bark mulch, organic compost) or inorganic material (e.g. pea gravel). For organic mulches, care should be taken to use a weed-free source. Bark mulch has a tendency to float and move during the initial storm events and is more appropriately placed on flat and gently sloped areas. The movement of mulch tends to decrease over time as the mulch settles, decomposes and the plants mature to cover the ground. Pea gravel mulch is a good choice for only the lowest grades of stormwater facilities or areas that experience high velocities of runoff and have a higher potential for erosion. Pea gravel tends not to move during storm events, does provide some moisture retention for root zones, and it allows for easier removal of sediment accumulation. Design plans should specify final grades taking into account that a 2-3 inch mulch layer would ultimately be added to the final grade. It is important to consider these final grades so that curb cuts or other means for water to enter the landscape is not obstructed by a mulch layer.

Design 9: Determine the Irrigation Approach

LID projects will need to be irrigated during the plant establishment period, which is typically two to three years. After this period, supplemental irrigation may be needed especially during drought conditions. Some considerations regarding irrigation:

- Plant in fall, when temperatures are cooler and plants can take advantage of the winter rain to establish their roots; this can help reduce costs and the need for irrigation.

- An efficient irrigation system can help establish a new landscape during the dry season and provide supplemental irrigation to established landscapes during extended drought periods. The project designer should include an irrigation plan for the establishment period as well as a long-term irrigation system if one is desired after the plant establishment period. A long-term irrigation system must be in compliance with the California Model Water Efficient Ordinance. This will require most types of LID projects with new landscapes to use a drip irrigation system.

- Document the irrigation needs during the plant establishment period and the necessary irrigation adjustments for post-establishment. Be sure to determine appropriate application rates, avoid overwatering sandy soils and be aware that excessive watering may result in unwanted discharges where an underdrain system is present.
- The Project Team should consult with appropriate individuals (e.g. school district facility personnel, irrigation consultants) to determine the irrigation plan that will achieve the highest efficiency and water savings.

- If a long-term irrigation system will not be built into the project, extra care must be taken in plant selection to choose plants that can do well with little (e.g. via water trucks) or no supplemental water during the dry season.

Design 10: Avoid Sediment and Erosion Problems

Stormwater runoff that is routed to an LID project can enter the facility at a high velocity and may also be carrying sediment. The project design must include elements to avoid erosion within the facility as well as excess sedimentation that can cause clogging. A few tips for erosion and sediment control:

- Where there is a substantial volume and velocity of flow at entry points, pea gravel or cobble can be used at the entry points to reduce the potential for erosion. These features can also help to capture sediment.
- Avoid over-use of decorative cobble throughout the LID project. This can impede infiltration and become a maintenance problem resulting in weeds and widespread sediment accumulation.
- While rain gardens and bioretention are designed to remove sediment from stormwater, excessive amounts can clog the system. Determine whether a separate sediment removal feature such as a forebay is needed.

Design 11: Consider Pedestrian Circulation and Use

When siting LID projects, there should be careful consideration regarding pedestrian circulation. The project design should account for pedestrian movement to address public safety and also to deter people from walking through the project, which can compact soils and damage plants. In some cases, pedestrian circulation and the LID project may be in direct conflict. Some pedestrian circulation design tips include:

- Where an LID project is located along pedestrian areas such as sidewalks, there will be a grade change and care should be taken to make these grade transitions safe and noticeable for pedestrians. The construction of gentle slopes of soil and plant material, as well as concrete curbs and low-profile rails may be used to create a detectable edge at the change in grade.
- Changes in soil grade adjacent to pedestrian walkways are best accommodated by using a 4:1 side slope condition from the walking surface to the completed grade of the stormwater facility.
- A flat grade soil perimeter around all or a portion of the project can act as a safety border between pedestrians and any downward slope changes.
- Where a vertical grade transition of more than 6 inches is needed near the project perimeter, a low-railing or raised concrete curb to alert pedestrians of the grade change is recommended.

- LID projects located in parking lots are often a special challenge for addressing pedestrian circulation, especially as there is a tendency for people to cut across a landscaped area to reach their destination, which will result in trampled plants, compacted soil, and increased erosion in the LID project. The project design may require pedestrian bridges, pathways, walkways or other means for people to walk safely alongside or across the stormwater facilities. Care should also be taken in the transition of grades in the corners between bridges and walkways. Depending on the amount of grade change from bridges and walkways, raised detectable edges can be placed along the edges to increase safety.

- Trench drains are another design approach that can be integrated with a walkway to allow stormwater to enter or exit the LID project while accommodating safe pedestrian movement.

- The project design may include features for passive recreation and educational use including sidewalks, pathways, viewing and seating areas which must safely accommodate individuals as well as student groups.

Construction of Vegetated LID Projects

Construction of LID projects is different from what most contractors have experienced. Critical to successful construction is educating those responsible for construction regarding the unique nature of the design. The following sections outline some key construction elements required for a successful project. Photos and images to illustrate the design concepts are included in Attachment 2.

Construction 1: Review the Project Design with the Construction Team and Stay Involved

The project will likely include unique design features and materials. Additionally, LID projects typically involve non-traditional infrastructure and placement of infrastructure in a way that may seem incorrect to the contractor (e.g. raised overflow inlets). Examples include curbs cuts, check dams, raised overflow inlets, specialized plants and trench drain walkways. Good communication between the design team and construction team increases the likelihood of a successful project and is often overlooked and insufficiently budgeted. Too often, an LID design passes to the construction contractor without transition or support for on-going communication and oversight from those knowledgeable concerning the intended design. A few tips on communication prior to and during, the construction phase:

- Consider ways in which information can be shared from the design phase to support the construction phase. For example, for projects that go out for bid for construction, a pre-bid meeting can help share various aspects of the project design with potential contractors.

- Members of the design team should review the project design plans, drawings, specifications and intended water quality functions with those who will be responsible for project construction. A technically informed member of the Project Team should be available during the construction phase to answer questions from the contractor, respond to substitution requests, and ensure construction is being conducted correctly.

- Review should also include any information concerning the site conditions including soils, utility locations, and features requiring protection such as trees.

- Vegetated LID features will likely have several different elevation points that must work together to function properly e.g., gutter inlet, top of curb, adjacent surfaces, finished grade in the facility, overflow elevation. Make sure the construction team understands the required final elevation for each constructed element before starting construction.

- Solicit input from the construction team on ways to improve the design or reduce costs.

Construction 2: Prepare For Different Construction Techniques and Material Requirements

Prior to initiating construction, some advance planning may be required to obtain specialized materials or expertise. Consider:

- LID projects often include special soils, plants, or pervious pavement materials to enhance infiltration and treatment. Deviating from the design such as changing soils, plants, aggregate, or lowering inlets, may result in a lower performing or failed project. Any desired material changes need to be approved by the design team or project manager.

- Determine the time needed to obtain special materials such as bioretention soils, plants, porous concrete, and pervious pavers. Verify that suppliers can meet the specifications for materials as substitutions may be limited, or in some cases, not allowed.

- Clarify what is required for projects that include a maintenance or warranty period for landscape maintenance, plant replacement, and sediment and debris removal.

- Ensure workers are skilled or certified in any required specialized practices that may be required for the project such as construction of deep curbs.

Construction 3: Make Sure Proper Protections are in Place and Check the Native Soil Condition

Construction best management practices (BMPs) are used to protect the facility and the public during construction activities. These BMPs are typically put in place prior to initiating construction. This is also an opportune time to check the condition of the existing soils at the site. Keep in mind:

- Ensure construction BMPs are in place to protect the LID facility from unwanted sediment, flows or compaction due to foot traffic or machinery. This might include temporary fencing, erosion control straw bales, signage or other measures to both protect the site and reduce any impact the site might have to the surrounding area during construction.

- Protect existing trees. Excavation for LID features may cross into tree drip lines or critical root zones. The project could require special procedures to protect the tree and consultation with an arborist may be advisable.

- Inspect existing soil conditions to determine if there needs to be any changes made to the imported soil mix specified in the plans. This is important for designs that do not specify bioretention soil mix. This may be needed if the design team could not assess the existing soil conditions during the design phase.

Construction 4: Conduct Excavation, Placement of Materials and Set Elevations

The method and sequencing of construction is very important for vegetated LID projects where the placement of plants, soils and infrastructure all work together for proper function. A few construction tips:

- Place machinery performing excavation adjacent to, not inside of, the LID project. This is done to prevent compaction of soils that are intended to infiltrate stormwater.

- If amended soil or bioretention soil will be used, be sure to apply in separate lifts (approximately 6 inches per lift).

- The design plans should not include the use of filter fabric. It clogs and reduces the performance of the project. Ensure the landscape contractor does not inadvertently add filter fabric to the LID facility.

- When underdrains are used, correct placement and orientation of the pipe perforations is essential.

  - Install underdrains with perforations facing down. Underdrain discharge elevation should be near the top of the aggregate layer and they need to connect to an approved discharge point. Ensure finished elevations move water from the point of entry to the discharge.

  - Ensure correct placement aligns with expected project function. Underdrains located at the lowest elevation of the LID project drain all the water while underdrains installed at a higher elevation allow more retention and infiltration of stormwater into underlying soils.

- Landscape contractors need to follow the landscape design because some or all of the plants are selected to tolerate stormwater ponding and using the correct plants and their placement is critical. Improper plant type or placement can result in plant die-off.

- The construction contractor should coordinate with the landscape contractor to ensure that final grades are maintained upon completion of plant and mulch installation. When constructing the LID project, the grade of the soil should be left 2 inches below the desired finish grade to allow for a layer of mulch. If the finish grade of the LID project is constructed without taking into account a mulch layer, the finished grade will be too high and will prevent runoff from entering the LID project.

- Prior to pouring any concrete or asphalt elements, ensure accurate grades and elevations for routing runoff into the LID project are correct.

- Install plants as soon as possible following final grading to help stabilize the project soils.

Construction 5: Complete Construction

Once the project is essentially constructed, there are a few more items to address before the facility is ready to accept stormwater runoff:

- Block the inlets to the LID projects until plants are sufficiently established to withstand stormwater flows.

- Protect LID features from runoff during construction as upstream drainage areas may contribute unwanted sediment and flow, and the LID feature may not be stabilized.

- When the LID project cannot be blocked off because of flooding hazards, either install a temporary storm drain inlet/pipe system, temporarily cover the facility with filter fabric, or install additional upstream BMPs.

- Review plant establishment requirements and set the appropriate irrigation schedule during plant establishment.

Once construction is complete, the project owner should be provided with the operations and maintenance manual specific to the project or similar documentation that outlines protocols for ensuring the LID features continue to perform as designed, including guidance on plant care and replacement. Development of the operations and maintenance manual should be initiated as part of the design process and include input from those who will be responsible for long-term project maintenance.

Attachment 1: Vegetated Stormwater LID Examples

Attachment 1: Typical Curb Cut Examples

Figure A-1

KEVIN ROBERT PERRY

This is a standard 18" wide curb cut with 45 degree chamfered edges. Note that the layer of pea gravel to dissipate energy.

Figure A-2

KEVIN ROBERT PERRY

This curb cut allows water to enter using a trench drain. Also note the concrete wings that hold back the adjacent soil grade.

Figure A-3

KEVIN ROBERT PERRY

This school plaza space has no raised curbs. Runoff sheet flows into a slightly recessed stormwater planter.

Figure A-4

KEVIN ROBERT PERRY

Runoff from a parking lot flows over a flush curb between vehicle wheelstops.

Figure A-5

KEVIN ROBERT PERRY

This parking lot has a curb cut located at every other parking stall to allow runoff to enter a landscaped swale.

Attachment 1: Typical Downspout Disconnection Examples

Figure A-6

KEVIN ROBERT PERRY

These school building downspouts convey runoff with a concrete runnel away from the building to a stormwater planter.

Figure A-7

KEVIN ROBERT PERRY

This metal runnell allows water from a building downspout to be conveyed to a small rain garden.

Figure A-8

KEVIN ROBERT PERRY

This building downspout disconnection system uses a trench drain to convey water to stormwater planter through a sidewalk zone.

Figure A-9

KEVIN ROBERT PERRY

A close-up view of the concrete runnel as water enters the landscape.

Figure A-10

KEVIN ROBERT PERRY

An artistic way of allowing runoff from a building to cascade to a rain garden.

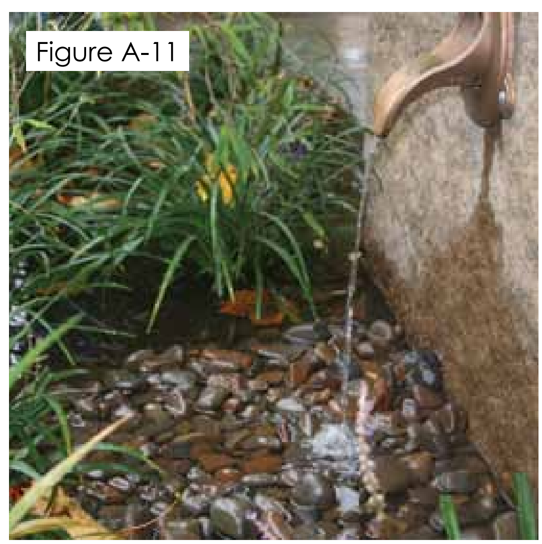


Figure A-11

KEVIN ROBERT PERRY

A downspout scupper within a building column allows runoff to enter a rain garden.

Attachment 1: Typical Checkdam and Weir Examples

Figure A-12

KEVIN ROBERT PERRY

A clear plexiglass check dam is placed within a rain garden to retain exactly a maximum of 6" of runoff.

Figure A-13

KEVIN ROBERT PERRY

Simple check dams made of different sizes of stacked rock can help slow the flow and retain water upstream.

Figure A-14

KEVIN ROBERT PERRY

The use of thin-profile metal check dams placed at this parking lot planter help hold back 3-4" of water.

Figure A-15

KEVIN ROBERT PERRY

A metal check dam with defined weir openings directs water flow.

Figure A-16

KEVIN ROBERT PERRY

A close up view of one of the weir openings during dry conditions.

Figure A-17

KEVIN ROBERT PERRY

A close up view of a weir opening directing water flow during a storm event.

Attachment 1: Typical Pedestrian Circulation Considerations

Figure A-18

KEVIN ROBERT PERRY

Students helping to build a swale are using a wood template that determines an exact 4:1 soft grade transition from the sidewalk.

Figure A-19

KEVIN ROBERT PERRY

This boardwalk allows pedestrians to cross over a large rain garden area.

Figure A-20

KEVIN ROBERT PERRY

Metal grates are used as pedestrian bridges to cross a school's stormwater planter.

Figure A-21

KEVIN ROBERT PERRY

Low-profile railings help protect people from vertical changes in grade.

Figure A-22

KEVIN ROBERT PERRY

Raised curbs can help define safe pedestrian movement.

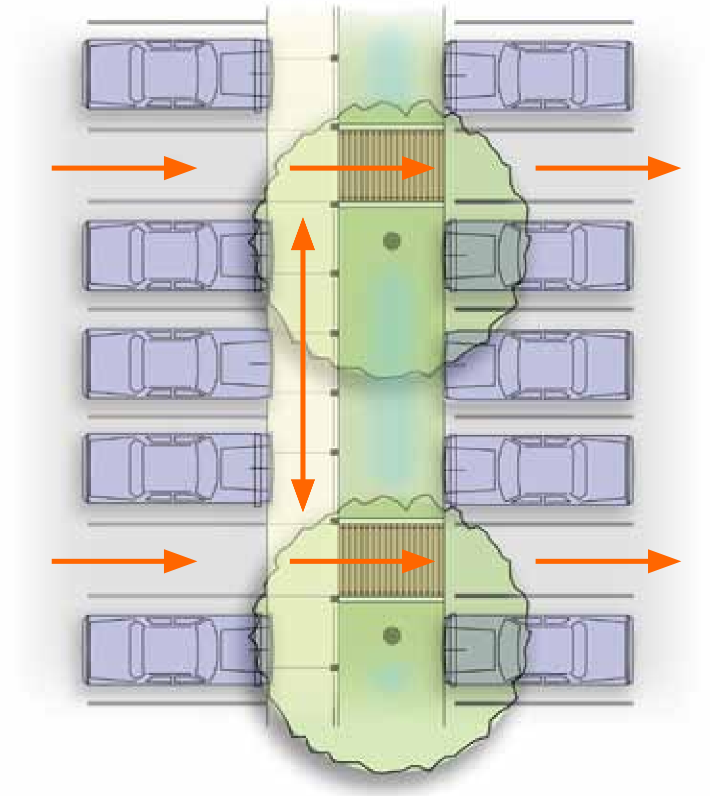
Figure A-23

KEVIN ROBERT PERRY

Where there is more that 6" drop in grade, low-profile edge rails can be used to protect pedestrians.

Attachment 1: Typical Pedestrian Circulation Considerations

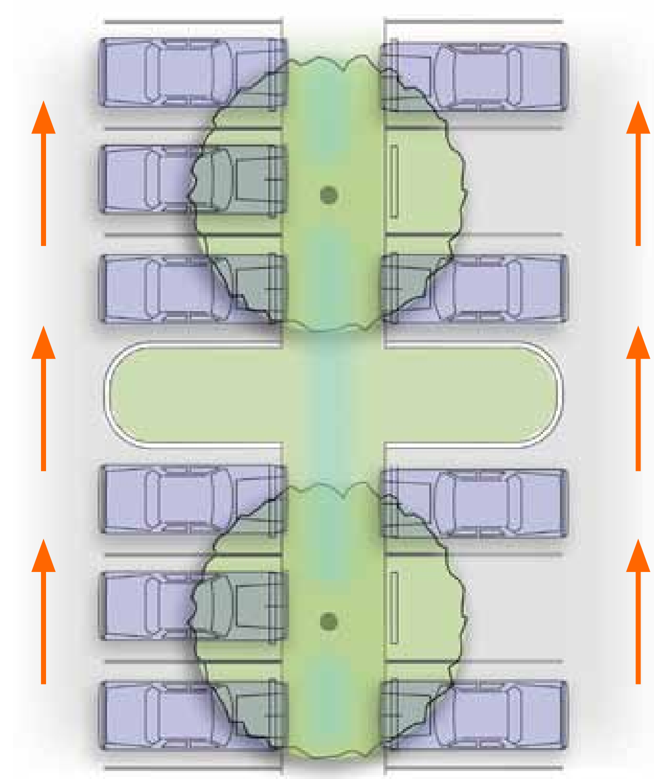
Figure A-24



Perpendicular Pedestrian Flow

(Pedestrian circulation is perpendicular to a stormwater facility alignment)

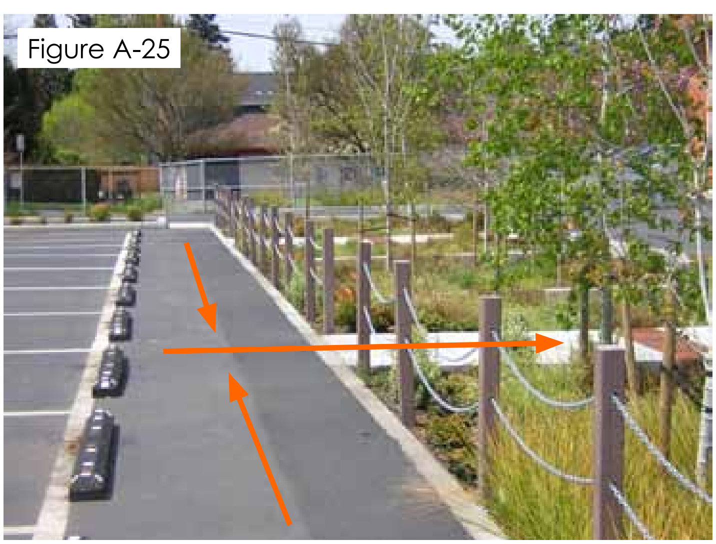
Figure A-26



Parallel Pedestrian Flow

(Pedestrian circulation is parallel to a stormwater facility alignment)

Figure A-25



KEVIN ROBERT PERRY

With good design, this swale has several walkways that allow pedestrians to access their destination without walking through the landscape area.

Figure A-27

KEVIN ROBERT PERRY

With poor circulation design, people have trampled this vegetated swale to the point where the landscape is beginning to die and soil is being compacted.

Figure A-28

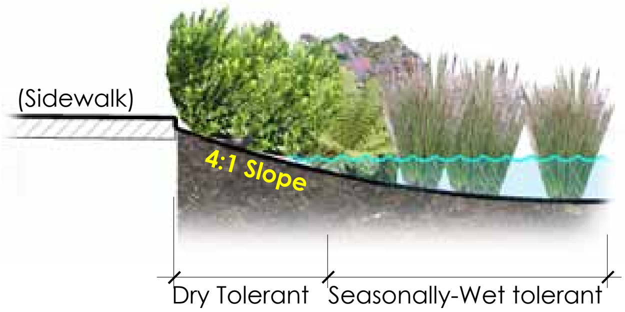
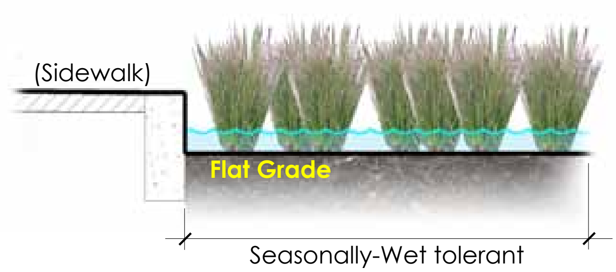


Figure A-31



Typical Side Slope and Flat-Bottom Planting Condition

Typical Flat-Bottom Planting Condition

Figure A-29

KEVIN ROBERT PERRY

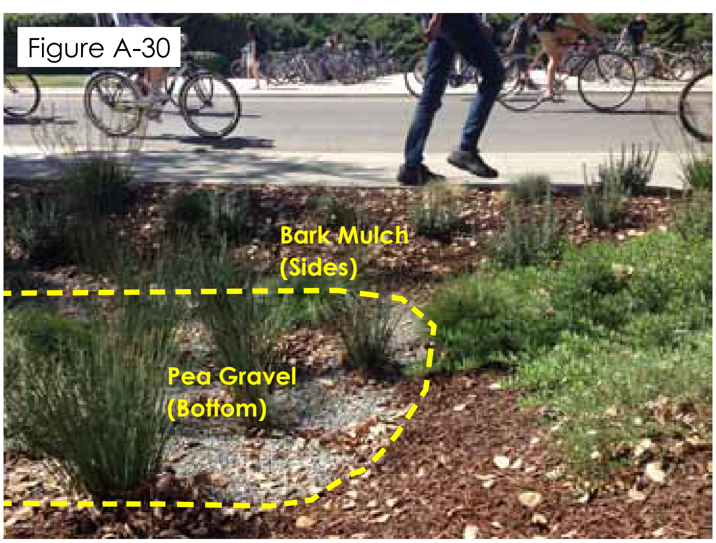
Stormwater facilities that have side slope conditions will need to have dry tolerant plants along the side slopes and seasonally-wet plants within the bottom.

Figure A-32

KEVIN ROBERT PERRY

Flat bottom stormwater facilities such as planters that have no side slopes will need plants material that can tolerate seasonally wet and dry conditions.

Figure A-30



KEVIN ROBERT PERRY

Using pea gravel at the bottom of stormwater facilities can act as a mulch as well as for energy dissipation. Bark mulch can be used along side slope conditions.

Figure A-33

KEVIN ROBERT PERRY

Trees are an integral part of Low-Impact Development. Trees roots help soak up water and can be placed in many kinds of stormwater facilities.

Figure A-34

KEVIN ROBERT PERRY

The gaps between granite pavers conveys surface runoff into a stormwater planter.

Figure A-35

KEVIN ROBERT PERRY

A heavy duty steel trench drain channel conveys surface runoff to a landscaped swale.

Figure A-36

KEVIN ROBERT PERRY

A shallow concrete valley gutter conveys surface runoff from a parking lot into a rain garden.

Figure A-37

KEVIN ROBERT PERRY

A trench drain connects two stormwater planters through a sidewalk zone.

Attachment 1: Bad Examples of Stormwater Overflow Inlet Placement

LOW IMPACT DEVELOPMENT INITIATIVE (CENTRALCOASTLIDI.ORG)

This overflow inlet incorrectly placed against a curb cut forcing water to enter the overflow before it enters the landscape.

LOW IMPACT DEVELOPMENT INITIATIVE (CENTRALCOASTLIDI.ORG)

This overflow inlet is incorrectly placed flush with the soil surface and in line of the water flow path. No water can interact with the landscape.

CANNONCORP ENGINEERING

A bioretention system with correct curb cut placement and raised overflow inlet elevations to allow the brief ponding of water.

KEVIN ROBERT PERRY

A rain garden with a series of weirs that allow for the brief ponding of water during storm events.

Attachment 1: Typical Soil Preparation Construction Procedures

Figure A-42

KEVIN ROBERT PERRY

The native soil condition in this planter is scarified to break up any compaction from the excavation process.

Figure A-43

KEVIN ROBERT PERRY

New imported topsoil is placed and mix with the native soil condition.

Figure A-44

CANNONCORP ENGINEERING

Bioretention construction showing the placement of soil. Note that heavy equipment is located outside the facility to avoid any soil compaction. Also note the vertical liner installed to prevent lateral stormwater movement toward the adjacent street.

Figure A-45

KEVIN ROBERT PERRY

The final grade of the soil is lightly compacted by a roller or feet only.

Figure A-46

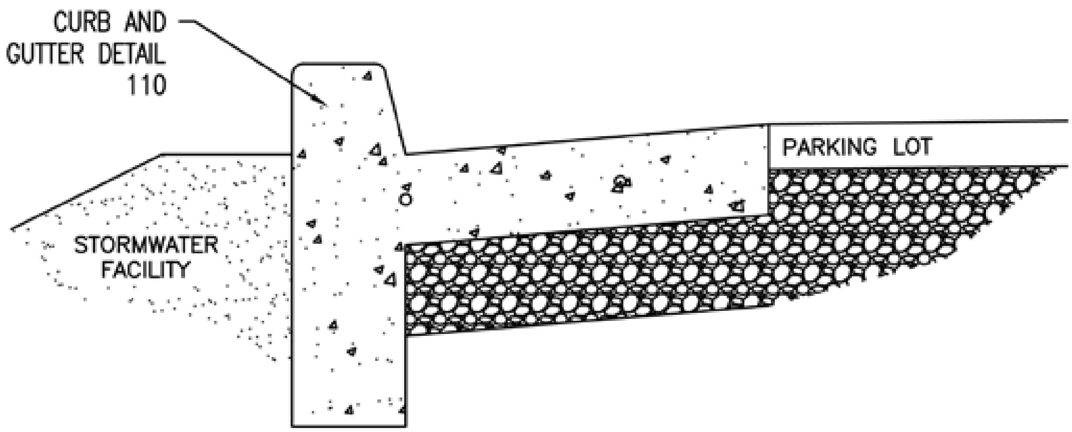
Sand bags protect runoff from entering the landscape until it is ready.

Figure A-47

KEVIN ROBERT PERRY

Close up detail of the impermeable liner attachment to a curb face.

Figure A-48



Curb and gutter detail showing deep curb used to improve stabilization and integrity of the adjacent parking lot. Engineering detail from the Low Impact Development website (centralcoastlidi.org).

Figure A-49

KEVIN ROBERT PERRY

Installation of a deep curb to prevent lateral migration of stormwater into the street subgrade.

Attachment 1: Bad Examples of Using River Rock Cobbles


Figure A-50

KEVIN ROBERT PERRY

Intended to dissipate the energy of flowing water, this incorrect placement of river rock cobble at the entry curb cut is creating a sediment dam and is actually blocking runoff from entering the landscape.


Figure A-51

LOW IMPACT DEVELOPMENT INITIATIVE (CENTRALCOASTLIDI.ORG)

Example of excessive use of decorative cobble which fills with sediment, reduces infiltration, and is challenging to maintain.

KEVIN ROBERT PERRY

This concrete forebay at the end of a trench drain helps slow runoff and collect sediment before it enters the landscape.

KEVIN ROBERT PERRY

This concrete splash pad dissipates energy from as water drops vertically from the trench drain.

Attachment 2: LID Project Design and Construction Checklist

As your project moves through design to construction, a checklist can help ensure that major design and construction concepts are addressed. Going through the process of a checklist can also facilitate team communication to ensure that everyone has the same understanding regarding project assumptions, design parameters, etc. The following checklist captures the key design and construction elements described in the main document. If unclear as to what the question pertains to, refer back to the corresponding section in the main document.

DESIGN CHECKLIST		
Section	**Questions**	**Answers**
Design 2	Has the Project Team reviewed the project objectives, any relevant documents, studies, etc.?	
Design 3	Is the Project Team clear on the intended project performance(e.g., treatment only or treatment/infiltration to native soils)	
Design 4	Have the project dimensions been determined that meet the performance goals?	
Design 5	Have the methods for routing of stormwater into and out of, the facility been determined? If linking more than one LID project, does the design adequately route runoff from one facility to the next without causing downstream flooding or negative impacts to pedestrians?	
Design 6	Does the design include measures to protect any adjacent structures such as roads, buildings and sidewalks from stormwater intrusion?	
Design 7	Does the design adequately allow for stormwater to pond to better allow for capture and infiltration?	
Design 8	Have the correct materials been specified such as soil and plants? Has correct density and placement of plants been defined? Has correct placement of soil been defined?	
Design 9	Has the method of irrigation for plant establishment been determined? How will plants receive water in the long-term?	
Design 10	Does the design identify and incorporate sufficient measures for sediment and erosion control such as use of forebays, pea gravel, splash guards, etc.?	
Design 11	Does the design sufficiently address pedestrian circulation and safety? Does the design incorporate measures to protect the project from unwanted foot traffic across soils and plants? Does the project incorporate opportunities for passive recreation and teaching opportunities?	

CONSTRUCTION CHECKLIST		
Section	**Questions**	**Answers**
Construction 1	Has the Project Team reviewed the project design with those responsible for construction? Has a Project Team member been identified to provide continuity and support during the construction phase?	
Construction 2	Is the construction team aware of the special materials that may be needed for the project such as LID plants, bioretention soils or other materials that may be difficult to obtain?	
Construction 2	Is the construction team aware of special construction techniques or placement that may be required such as curb cuts, raised overflow inlets, and trench drain walkways?	
Construction 3	Is the construction team prepared to place the appropriate construction Best Management Practices in place to protect the facility during construction as well as limit sedimentation and erosion due to construction?	
Construction 3	Has the condition of the native soil been evaluated prior to construction to determine if any soil amendments are necessary?	
Construction 4	Is the correct soil being used for the project and applied correctly?	
Construction 4	If underdrains are used, are they being placed in the facility correctly to ensure proper function?	
Construction 4	Does the landscape contractor or similar understand the planting requirements especially as relates to ponding vs. non-ponding area?	
Construction 4	Have all final grades been reviewed, checked and being built correctly?	
Construction 5	Has the proper protection been put in place to project the project (e.g., plants) while establishing?	
Construction 5	If an irrigation system is specified, have the correct irrigation amounts and frequencies been established?	
Construction 5	Has a project Operations and Maintenance document been provided to the project owner?	