APPENDIX F TOOLS FOR PLANNING, SELECTING AND DESIGNING LID STRATEGIES FOR PROJECTS IN PLACER COUNTY

LID Planning and Design Process Overview Flowchart

LID Planning and Design Checklist

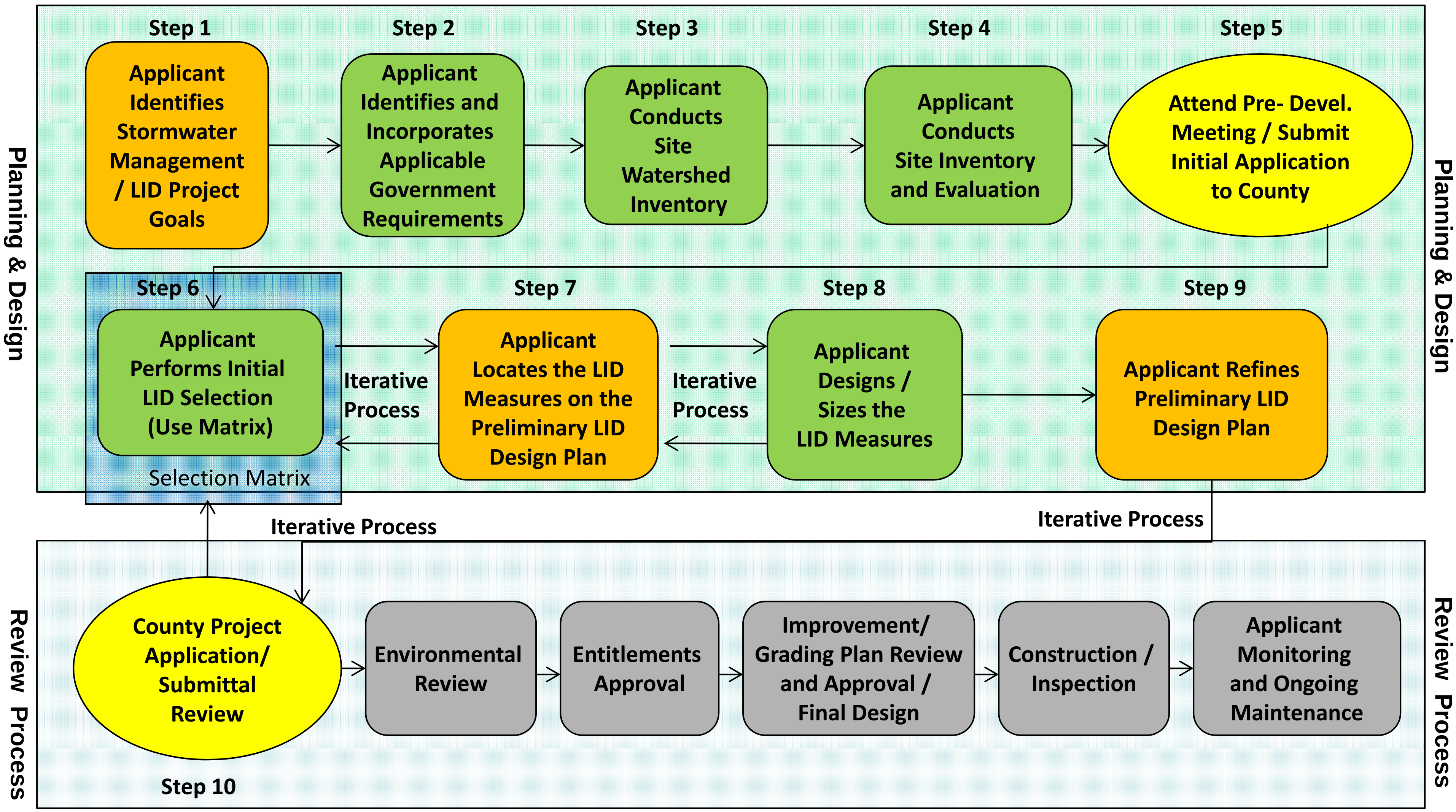
LID Selection Matrix

LID Site Design (SD) Measure Fact Sheets (4)

LID Runoff Management (RM) Measure Fact Sheets (8)

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

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



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

Revised March 2012

Placer County LID Guidebook

LID Planning and Design Checklist

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

Getting Started

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

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

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

Basic Project Information

Project Name: ____

Project Owner: ______________________________Project Designer: _______________________

Project Address/City/Zip Code: ____

____

Total Size (ac): _______________________Approx. Area Disturbed (ac): _________________________

Zoning: ____

Project Type: (check all that apply)

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

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

If so, describe: ____

Projects with Limited LID Potential or Special Requirements

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

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

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

STEP 1 - Identify Stormwater Management and LID Project Goals

Step 1

Applicant Identifies Stormwater Management / LID Project Goals

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

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

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

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

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

STEP 2 - Identify and Incorporate Applicable Government Requirements

Step 2

Applicant Identifies and Incorporates Applicable Government Requirements

All projects are subject to the following Placer County requirements:

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

Identify the additional local land use policy documents, plans, ordinances, requirements and guidelines that are applicable to the project.
(check all that apply and provide document names)

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

- ❑ Community Plan(s): ____
- ❑ Specific Plan(s): ____
- ❑ Master Plan: ____
- ❑ Master Use Permit: ____
- ❑ Design/Landscape Guidelines: ____________________________________
- ❑ Water Conservation: ____
- ❑ Other: ____

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

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

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

- ❑ ____
- ❑ ____

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

- ❑ ____
- ❑ ____

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

- ❑ ____
- ❑ ____

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

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

STEP 3 - Conduct Site Watershed Inventory

Step 3

Applicant Conducts Site Watershed Inventory

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

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

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

STEP 4 - Conduct Site Inventory and Evaluation

Step 4

Applicant Conducts Site Inventory and Evaluation

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

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

Identify Physical Site Conditions

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

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

Identify Physical Constraints/Potential Barriers to Using LID

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

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

Identify Opportunities for LID

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

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

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

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

Step 5

Attend Pre-Development Meeting / Submit Initial Application to County

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

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

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

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

❑ Hydrologic Features____
❑ Soils/Grading____
❑ Vegetation____
❑ Wetlands____
❑ Flooding ____
❑ Groundwater ____
❑ Other ____

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

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

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

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

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

Step 6

Applicant Performs Initial LID Selection (Use Matrix)

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

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

LID Site Design Measures:

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

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

LID Runoff Management Measures:

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

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

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

Step 7

Applicant Locates the LID Measures on the Preliminary LID Design Plan

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

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

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

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

STEP 8 – Design/Size the LID Measures

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

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

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

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

STEP 10 – County Project Application/ Submittal Review

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

>>END OF LID CHECKLIST

Low Impact Development Selection Matrix for Placer County Guidebook

Legend:
- ● Very Effective
- ◐ Moderately Effective
- ○ Mildly Effective
- X Applicable
- (shaded) Not Applicable

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

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

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

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

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

(b) Construction Cost ($ / cf) (2006 dollars)	$ = < $3	$$ = $3 - $15	$$$ = > $15
(c) Construction Cost ($ / feature) (2006 dollars)	$ = $0 - $10,000	$$ = $10,000 - $50,000	$$$ = > $50,000
(d) Annual O&M Cost ($ / feature) (2006 dollars)	$ = < $1,000	$$ = $1,000 - $5,000	$$$ = >$ 5,000

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

Protect Natural Conditions

PLACER COUNTY LOW IMPACT DEVELOPMENT **GUIDEBOOK**

Fact Sheet SD-1

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

Planning and Design Strategies

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

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

Protect Natural Conditions

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

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

Protect Environmentally Sensitive Areas and Designated Open Space

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

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

Preserve Natural Drainage Features

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

Minimize Soil Compaction

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

OPPORTUNITIES AND BENEFITS

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

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

PROTECT NATURAL CONDITIONS

Design Elements

Protect Natural Conditions

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

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

Protect Environmentally Sensitive Areas and Designated Open Space

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

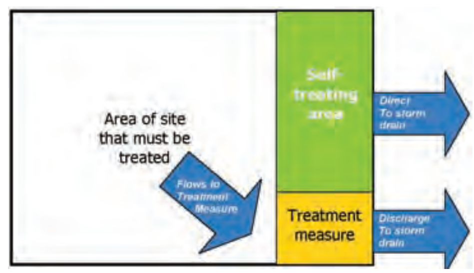


Diagram of site stormwater treatment and discharge. Source ACCWP, 2010

Protect Natural Drainage Features

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

Minimize Soil Compaction

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

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

Limitations

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

References

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

Optimize Site Layout

PLACER COUNTY LOW IMPACT DEVELOPMENT **GUIDEBOOK**

Fact Sheet SD-2

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

Planning and Design Strategies

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

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

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

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

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

OPPORTUNITIES AND BENEFITS

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

Limitations

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

A narrow road along Fallen Leaf Lake, Lake Tahoe, CA
Photo Credit: Bill C.

OPTIMIZE SITE LAYOUT

Design Elements

Minimize Disturbed Areas

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

Reduce Impervious Surfaces

Building Lots

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

Parking Lots

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

Streets

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

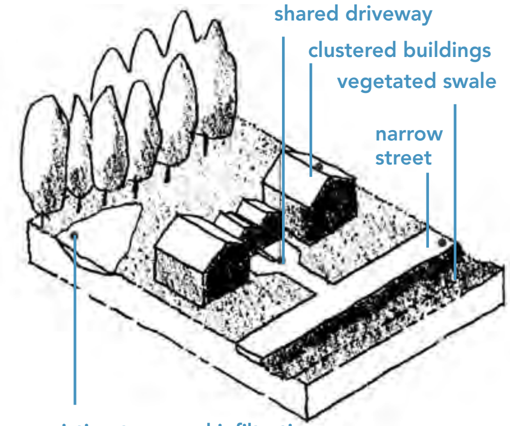
Integrate Stormwater Management Features with Buildings, Landscaping and Recreational Uses

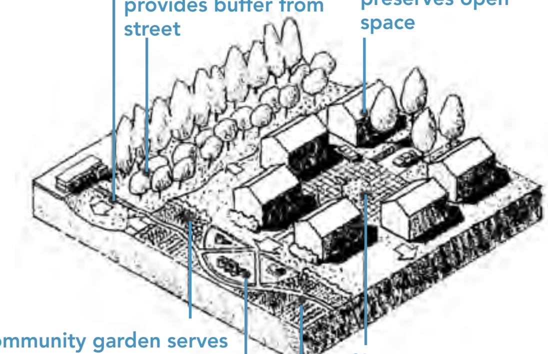
- Integrate stormwater management techniques (see LID fact sheet series) with lot/ building layout to treat runoff from buildings and other impervious surfaces
- Locate LID features such as infiltration, bioretention and pervious pavement in areas with well-drained soils (configure the site plan to place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

References

BASMAA, *Start at the Source*, 1999.

SEMCOG, *LID Manual for Michigan*, 2008.





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

CONSTRUCTION CONSIDERATIONS

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

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

Control Pollutants at the Source

PLACER COUNTY LOW IMPACT DEVELOPMENT **GUIDEBOOK**

Fact Sheet SD-3

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

Planning and Design Strategies

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

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

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

OPPORTUNITIES AND BENEFITS

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

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

Limitations

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

CONTROL POLLUTANTS AT THE SOURCE

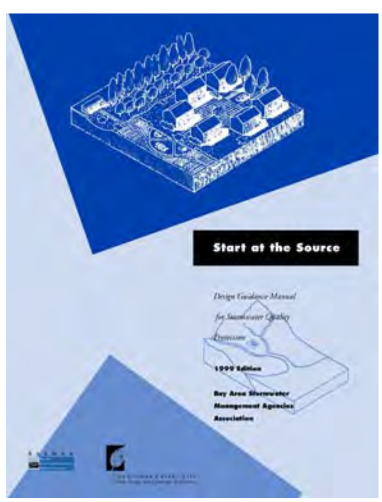
Design Elements

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

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

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

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



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

References

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

TYPICAL STORMWATER POLLUTANTS AND SOURCES:

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

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

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

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

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

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

Integrate Eco-Friendly Landscaping

PLACER COUNTY LOW IMPACT DEVELOPMENT **GUIDEBOOK**

Fact Sheet SD-4

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

Planning and Design Strategies

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

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

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

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

Eco-friendly landscaping
Photo Credit: David Roberts Landscape

OPPORTUNITIES AND BENEFITS

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

Limitations

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

Vegetation and Mulch Treatments
Photo Credit: Dana Olson, Tahoe RCD

INTEGRATE ECO-FRIENDLY LANDSCAPING

Design Elements

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

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

Grasses and Plants

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

Trees

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

Plan for Functional Soil Conditions

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

Design a Water-Efficient Site

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

References

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

INSTALLATION AND MAINTENANCE CONSIDERATIONS

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

Before: Bare Areas in Tahoe area
Photo Credit: Dana Olson, Tahoe RCD

After: Revegetation and Mulching
Photo Credit: Dana Olson, Tahoe RCD

SW Flowpath Disconnection

PLACER COUNTY LOW IMPACT DEVELOPMENT GUIDEBOOK

Fact Sheet RM-1

GENERAL DESCRIPTION

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

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

PLANNING AND DESIGN STRATEGIES

GENERAL GUIDELINES

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

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

DESIGN STRATEGIES

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

BENEFITS

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

LIMITATIONS

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

COLD CLIMATE CONSIDERATIONS

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

CONSTRUCTION CONSIDERATIONS

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

OPERATIONS AND MAINTENANCE CONSIDERATIONS

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

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

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

REFERENCES

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

GENERAL DESCRIPTION

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

PLANNING AND DESIGN STRATEGIES

GENERAL GUIDELINES

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

DESIGN STRATEGIES

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

BENEFITS

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

LIMITATIONS

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

COLD CLIMATE CONSIDERATIONS

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

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

CONSTRUCTION CONSIDERATIONS

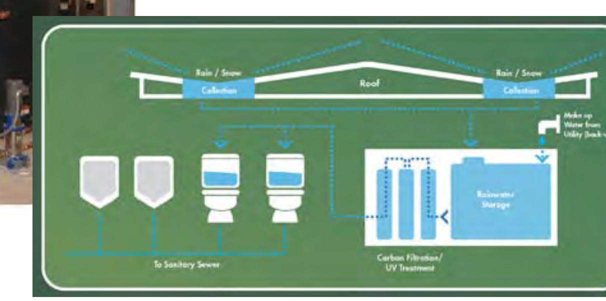
- **Soil Disturbance and Compaction:** Allow only vehicular traffic necessary for construction on the pervious areas where flow will be discharged. If vehicle traffic is unavoidable, then the pervious area should be tilled to a depth of 1' to loosen the compacted soil.
- **Erosion and Sediment Control:**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

OPERATIONS AND MAINTENANCE CONSIDERATIONS

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

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

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



REFERENCES

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

Rainwater and Snowmelt Harvesting

Fact Sheet RM-2

PLACER COUNTY LOW IMPACT DEVELOPMENT GUIDEBOOK

Infiltration Trench and Dry Well

Fact Sheet RM-3

GENERAL DESCRIPTION

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

PLANNING AND DESIGN STRATEGIES

GENERAL GUIDELINES

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

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

Sloped driveway conveys runoff to infiltration trench

DESIGN STRATEGIES

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

BENEFITS

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

LIMITATIONS

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

COLD CLIMATE CONSIDERATIONS

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

To prevent ice accumulation and damage during winter, place conveyance pipes below the local frost penetration depth and/or insulate pipes. Increase depth of feature to keep stored runoff below frost line. Incorporate snow volume estimates when sizing storage volumes. Due to increased sediment and pollutant loads do not treat snow that has been exposed to deicers without pretreatment.

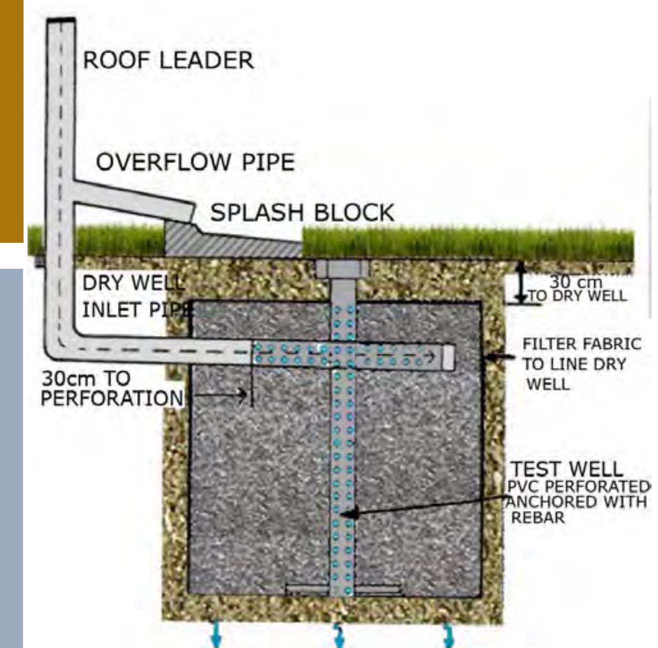
Infiltration Trench contoured along house
Photo Credit: TRCA, 2010

CONSTRUCTION CONSIDERATIONS

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

OPERATIONS AND MAINTENANCE CONSIDERATIONS

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



Credit: TRCA, 2010

Dry Rock Dry Well
Photo Credit: Dana Olson, TRCD

REFERENCES

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

GENERAL DESCRIPTION

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

PLANNING AND DESIGN STRATEGIES

GENERAL GUIDELINES

COMPONENT	GUIDELINE
Site Layout	Available Space – Minimum dimensions 15′ wide by 40′ long Building Setback – If no impermeable liner, minimum 10′ setback Drainage Area – Typically 1,000 sf to 1 ac Topography – Contributing slopes between 1 to 5%
Design Criteria	Freeboard – Allow 3″ of freeboard above ponding depth to prevent flooding to adjacent parking areas Head – 3′ minimum vertical distance from invert to inflow point Inlets and outlets should be located as far apart as possible Soil – Infiltration rates of existing site soils must be a minimum of 0.5 in/hr and a maximum of 2.4 in/hr, or use an underdrain Slope – Do not apply on slopes greater than 20 percent Water Table – Minimum 5′ separation Wellhead Protection – Minimum separation of 100′ from potable water supply wells
Pretreatment	Pre-treatment measures include, grass filter strip, and vegetated swale May also be used to infiltrate overflow from infiltration trench/drywell or rainwater harvesting
Conveyance and Overflow	The inflow conveyance may consist of, downspout, sheet flow, curb cuts, covered drain, or pop-up emitters. Overflow can either be diverted by: • Sizing curb openings to capture only the water quality volume while higher flows remain in the gutter • Utility landscaping type inlets or standpipes with trash guards as overflow devices • Using a pre-treatment chamber with a weir design that limits flow to the filter bed area
Storage	Snow can be stored in shallow depressions Water can be stored in pool areas
Materials	Vegetation – Planting plan generally includes one tree or shrub per 50 s.f. of bioretention area, and at least 3 species each of native herbaceous perennials, shrubs, and trees. Select plants that tolerate intermittent flooding, occasionally saline conditions, and extended dry periods. Filter medium – 85% sand, 10% fines, 5% organic matter Mulch layer – Shredded hardwood or bark Geotextile: Should be woven monofilament or non-woven needle punched fabrics. Woven slit film and non-woven heat bonded fabrics should not be used as they are prone to clogging. Gravel: Washed 2″ diameter stone should be used to surround the underdrain and for the gravel drainage layer

DESIGN STRATEGIES

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

BENEFITS

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

LIMITATIONS

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

COLD CLIMATE CONSIDERATIONS

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

To prevent ice accumulation and damage during winter, place conveyance pipes below the local frost penetration depth and/or insulate pipes. Size facilities for coldest temperature removal rates (decreased biological activity, settling etc.), expect enhanced removal during non-winter months.

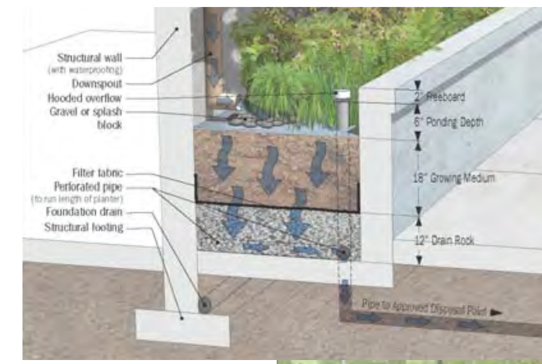
Incorporate snow volume estimates when sizing storage volumes. Road deicers may cause additional sediment and/or pollutant loads during winter months.

Left: Flow-through-Planter
Photo Credit: Ed Armstrong, Foothill

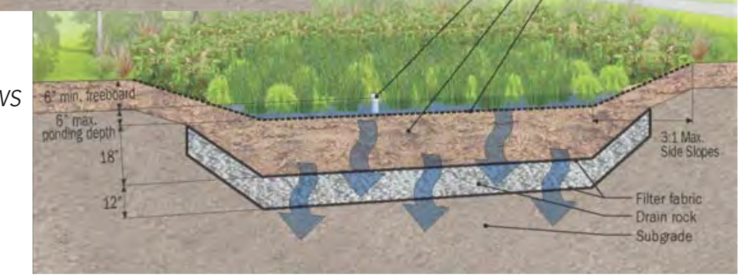
Right: Rain Garden
Photo Credit: Dana Olson, TRCD

CONSTRUCTION CONSIDERATIONS

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



Left: Flow through planter



Right: Rain garden

Credits: Carrie Pak, CWS

OPERATIONS AND MAINTENANCE CONSIDERATIONS

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

REFERENCES

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

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

Bioretention

Vegetated Filter Strip

PLACER COUNTY LOW IMPACT DEVELOPMENT GUIDEBOOK

Fact Sheet RM-5

GENERAL DESCRIPTION

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

Vegetated filter strip
Photo Credit: Carrie Pak, CWS

PLANNING AND DESIGN STRATEGIES

GENERAL GUIDELINES

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

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

DESIGN STRATEGIES

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

BENEFITS

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

LIMITATIONS

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

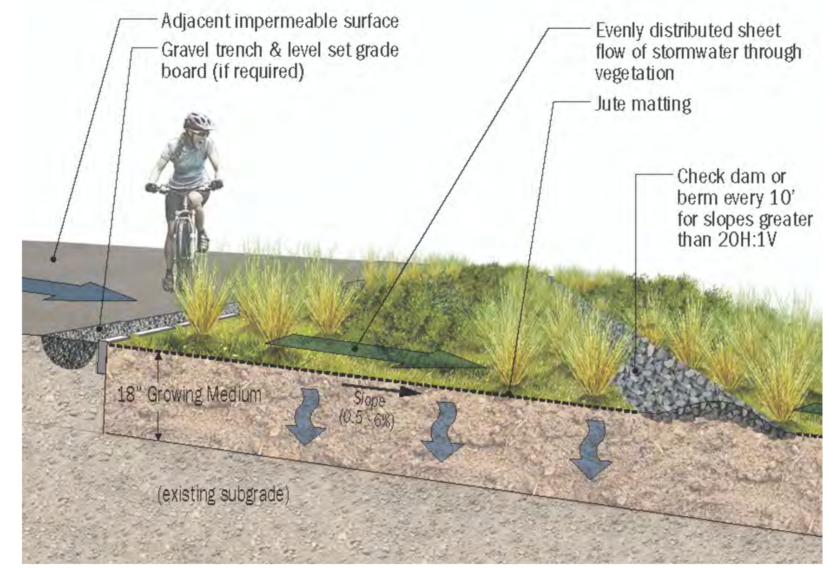
COLD CLIMATE CONSIDERATIONS

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

Install pipes components below the frost line to prevent frost heave and preventing water from freezing in pipes. Size facilities for coldest temperature removal rates (decreased biological activity, settling etc.), expect enhanced removal during non-winter months. Road deicers may cause additional sediment and/or pollutant loads during winter months.

CONSTRUCTION CONSIDERATIONS

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



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

OPERATIONS AND MAINTENANCE CONSIDERATIONS

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

REFERENCES

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

GENERAL DESCRIPTION

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

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

PLANNING AND DESIGN STRATEGIES

GENERAL GUIDELINES

COMPONENT	GUIDELINE
Site Layout	Available Space – Footprint 5% to 15% of drainage area. Swale length > culvert length, Minimum swale length 100' Building Setback – Minimum 10' setback Drainage Area – Maximum drainage area 5 ac Topography – Do not apply in areas with adjacent slopes of 5% or greater or in areas with highly erodible soils
Design Criteria	Head – Elevation drop needed between inflow and outflow Soil – Minimum infiltration rate of 0.5 in/hr and a maximum of 2.4 in/hr, or use an underdrain Water Table – Minimum 2' separation Wellhead Protection – Minimum separation of 100' from potable water supply wells Shape – a trapezoidal or parabolic shape is preferable for aesthetic, maintenance and hydraulic reasons Bottom Width – 2' to 8' Side Slopes – Max 3:1 Swale Longitudinal Slope: Moderately flat with a slope between 1% and 2% is recommended. Slopes of up to 4% can be utilized, if check dams are used. It should be wide enough for maintenance access.
Pretreatment	Pre-treatment measures include, grass filter strip, and bioretention May also be used to infiltrate flow from roadway disconnection, infiltration trench/drywell or rainwater harvesting
Conveyance and Overflow	Inflow controls include: • Gravel diaphragm (sheet flow) at the end of pavement, perpendicular to the flow path. Select gravel that is clean and washed. • Rip rap and/or dense vegetation (channel flow) can be used on smaller swales Dry swales should be designed for a max velocity of 1 ft/s for the water quality design storm. The swale should also convey the locally required design storm (usually the 10 yr storm) at non-erosive velocities. Check dams at 50' intervals (<2' drop) help to maximize retention time, increase infiltration, promote particulate settling, and decrease flow velocities. Check dams are not necessary with very low longitudinal slopes. Provide scour protection below check dam.
Storage	Snow can be stored in shallow depressions Water can be stored behind check dams
Materials	Filter Media – soil mixture should be 85% sand, 10% soil fines, and 5% organic matter. Underdrain – Use a soil bed depth of 2' to 3' with a gravel/pipe underdrain system. The minimum interface between the underdrain gravel and the underlying soil should be 0.5'. Vegetation – Select salt-tolerant, native grasses, herbaceous plants, or trees that can withstand both wet and dry periods. Use taller and denser grasses, though the species is less important than good stabilization.

DESIGN STRATEGIES

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

BENEFITS

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

LIMITATIONS

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

COLD CLIMATE CONSIDERATIONS

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

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

CONSTRUCTION CONSIDERATIONS

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

OPERATIONS AND MAINTENANCE CONSIDERATIONS

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

Vegetated Swales in Tahoe
Left: Photo Credit: Dana Olson, TRCD
Right: Photo Credit: Allen Breuch, Placer County

REFERENCES

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

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

Vegetated Swale

Permeable Pavement

PLACER COUNTY LOW IMPACT DEVELOPMENT GUIDEBOOK

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

GENERAL DESCRIPTION

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

PLANNING AND DESIGN STRATEGIES

GENERAL GUIDELINES

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

DESIGN STRATEGIES

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

BENEFITS

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

LIMITATIONS

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

COLD CLIMATE CONSIDERATIONS

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

To prevent frost heave, increase depth of aggregate base to keep stored runoff below frost line. Incorporate snow volume estimates when sizing storage volumes. Do not use road deicers on permeable paving or allow contact with runoff that has been exposed to road deicers, to prevent clogging from added sediment load. Raise blades or add rollers on snow removal equipment in order to prevent damage to permeable pavement.

Base layer during construction

After pouring *Photo Credits: Stefan Schuster, CDM*

CONSTRUCTION CONSIDERATIONS

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

OPERATIONS AND MAINTENANCE CONSIDERATIONS

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

Leveling

Finished Project
Photo Credits: PR Design & Engineering

REFERENCES

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

GENERAL DESCRIPTION

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

PLANNING AND DESIGN STRATEGIES

GENERAL GUIDELINES

COMPONENT	GUIDELINE
Site Layout	Available Space – Limited to rooftop Drainage Area – Green rooftops are designed to capture rainfall directly onto the surface Topography – Green rooftops may be installed on roofs with slopes up to 10%
Design Criteria	Soil – Soils with adequate infiltration rates (1 in/hr) Load – Roof structure must be able to support soil and plants of the green roof assembly, and maintenance staff accessing the roof. Slope – Can be used on roof slopes up to 10%. ASTM International released the following Green Roof standards in 2005: • E2396-05 Standard Test Method for Saturated Water Permeability of Granular Drainage Media; • E2397-05 Standard Determination of Dead Loads and Live Loads associated with Green Roof Systems; • E2398-05 Standard test method for water capture and media retention of geocomposite drain layers for green roof systems; • E2399-05 Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems; and • E2400-06 Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems.
Conveyance and Overflow	The drainage system includes a porous drainage layer and a geosynthetic filter mat to prevent fine soil particles from clogging the porous media. The drainage layer can be made up of gravels or recycled-polyethylene materials that are capable of water retention and efficient drainage. The depth of the drainage layer depends on the load bearing capacity of the roof structure and the stormwater retention requirements. The porosity of the drainage layer should be greater than or equal to 25%.
Materials	Waterproof Membrane – Modified asphalts (bitumens), synthetic rubber (EPDM), hypolan (CPSE), and reinforced PVC Modified asphalts usually require a root barrier, while EPDM and reinforced PVC generally do not Common european membrane design is a 60-80 mil PVC singleply roof system Growing Medium – Typically a mixture of sand, gravel, crushed brick, compost or organic matter combined with soil, 3" to 6" in depth, increasing the roof load by 16 lb/sqft to 35 lb/sqft when fully saturated Do not use growing media that contain phosphorus rich fertilizers or excessive nutrient levels Vegetation – Use low-growing, spreading perennial or self-sowing annuals that are drought tolerant including: sedum, delospermum, sempervivium, creeping thyme, allium, phloxes, anntenaria, ameria, and abretia Vegetation may be planted as vegetation mats, plugs or potted plants, sprigs (cuttings), or seeds

Cedar Hotel Vegetated Roof
Photo Credit: Cedar House Sport Hotel

DESIGN STRATEGIES

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

BENEFITS

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

LIMITATIONS

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

COLD CLIMATE CONSIDERATIONS

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

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

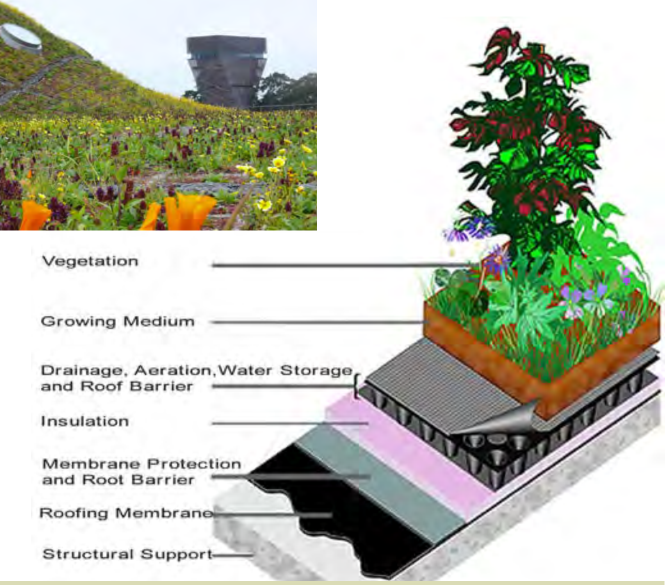
CONSTRUCTION CONSIDERATIONS

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

OPERATIONS AND MAINTENANCE CONSIDERATIONS

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

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



Green Roof Layers
Credit: TRCA

REFERENCES

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

PLACER COUNTY LOW IMPACT DEVELOPMENT GUIDEBOOK

Green Roof

Fact Sheet RM-8