LOW IMPACT DEVELOPMENT TOOLKIT

PREPARED FOR THE CITY OF GLENDALE, ARIZONA

LOW IMPACT DEVELOPMENT TOOLKIT

PREPARED FOR THE CITY OF GLENDALE

GLENDALE AZ

BY THE TEAM OF:

LOGAN SIMPSON

Dibble Engineering

WITH FUNDING FROM:

WIFA

WATER INFRASTRUCTURE FINANCE AUTHORITY

APRIL 2015

Example of a traditional stormwater system: An 84" stormwater pipe installed down the center of Main Street, Mesa, AZ 1968

"The downtown core area has a large amount of impervious surface, and is served by a mature, traditional stormwater system, typical of cities across Arizona.

By implementing and evaluating how LID techniques can impact this 'typical' area, the City can find ways to manage its stormwater in more effective and sustainable ways."

TABLE OF CONTENTS

Foreword

The Cities of Mesa and Glendale, with a grant from the Water Infrastructure Finance Authority of Arizona (WIFA), have partnered to develop this Low Impact Development (LID) Toolkit, with the support of consulting planners and designers and the input of city agencies. The Toolkit is intended to identify current stormwater management practices and national and regional LID best practices, ultimately providing a living document with simple, updatable tools, that can guide the city and their businesses and residents, toward more sustainable stormwater design practices.

While the Cities of Mesa and Glendale are distinct entities with their own development and stormwater management challenges, goals and policies, there are enough similarities - in their maturity, development potential, geography and proximity to the metro area - that practices and recommendations from this effort can be readily applied in both communities, as well as elsewhere in the Valley. Representatives from both cities' engineering, transportation, planning, environmental, and parks agencies generously contributed their ideas, concerns and challenges.

City policies can either encourage or discourage the use of LID tools. As with other cities in the Valley, Mesa and Glendale have adopted a modified form of Maricopa Association of Governments (MAG) standards for guiding development policy and implementing public works projects. Some practices in this toolkit may require additional review and coordination with the city before being acceptable for use.

The Cities' role in this effort is to lead by example -- by providing funding for pilot projects in highly visible areas to increase public awareness, by updating and supporting policies that encourage more sustainable stormwater management, and by considering the integration of LID into all municipal projects.

Introduction

Low Impact Development (LID) is a sustainable approach to stormwater management that utilizes the landscape to absorb storm runoff, reducing offsite flows that can contribute to flooding and infrastructure costs. The goal of LID is to mimic and sustain predevelopment hydrologic regime by using techniques that are included in this Toolkit. LID can be used to divert, store and utilize stormwater runoff to support native and designed landscapes. They can be utilized to supplement, and sometimes reduce the need for, traditional methods for stormwater management. While conventional methods often channelize and pipe runoff away from development, LID methods utilize this water close to its source, to support vegetation and reduce runoff volume.

LID is adaptable to a wide range of land use types and project scales. Breaking down developed areas into their constituent components – private property and public realm; buildings, paved areas and landscape – presents a way to organize potential actions to implement LID. That is the goal of this Toolkit.

Increased stormwater runoff is directly related to the amount of impervious surfaces in a given area and to how land is developed and improved. Improvements in managing stormwater can have multiple benefits for cities and their residents and businesses. LID actions can be taken by governments, organizations and private interests. The benefits of LID have been published for many national and local examples, and are supported by the Environmental Protection Agency (EPA) in its Municipal Separate Storm Sewer System (MS4) requirements.

Direct Benefits

- Detains stormwater close to its source, potentially reducing runoff volume and velocity downstream.
- Collects sediment and reduces pollutants in storm-water runoff.
- Utilizes stormwater to support native vegetation and landscape improvements.

Indirect Benefits

- Reduces irrigation water requirements for landscape areas.
- Reduces impacts on existing stormwater infrastructure and the need for new channels and pipes.
- Is compatible with the protection and restoration of natural systems, which supports climate resiliency.
- Complements site improvements for human activities.
- Provides and sustains habitat for wildlife.
- Supports tree canopy growth for increased shade, which can significantly decrease urban heat-island effects.
- Adds value to property through efficient use of space and resources.
- Provides multiple-use opportunities, such as open space and landscaping, that improve a community's quality of life.

Project overview

Focus Area

While LID tools can be scaled to all types of development that create stormwater runoff, this study focuses on the urbanized downtown core area. In these areas the intensity and diversity of land uses provide a multitude of opportunities for incorporation of LID strategies into existing and upcoming redevelopment projects. In addition, the downtown core area has a large amount of impervious surface, and is served by a mature, traditional stormwater system, typical of cities across Arizona.

By implementing and evaluating how LID techniques can impact this "typical" area, the City can find ways to manage its stormwater in more effective and sustainable ways. The ultimate goal for utilizing LID strategies is to reduce stormwater impacts on natural systems, reduce capital and maintenance costs of stormwater infrastructure, and increase quality of life and property value for community residents and businesses by improving streets, parks and even home landscapes.

Scope

The three main components of the LID Toolkit are:

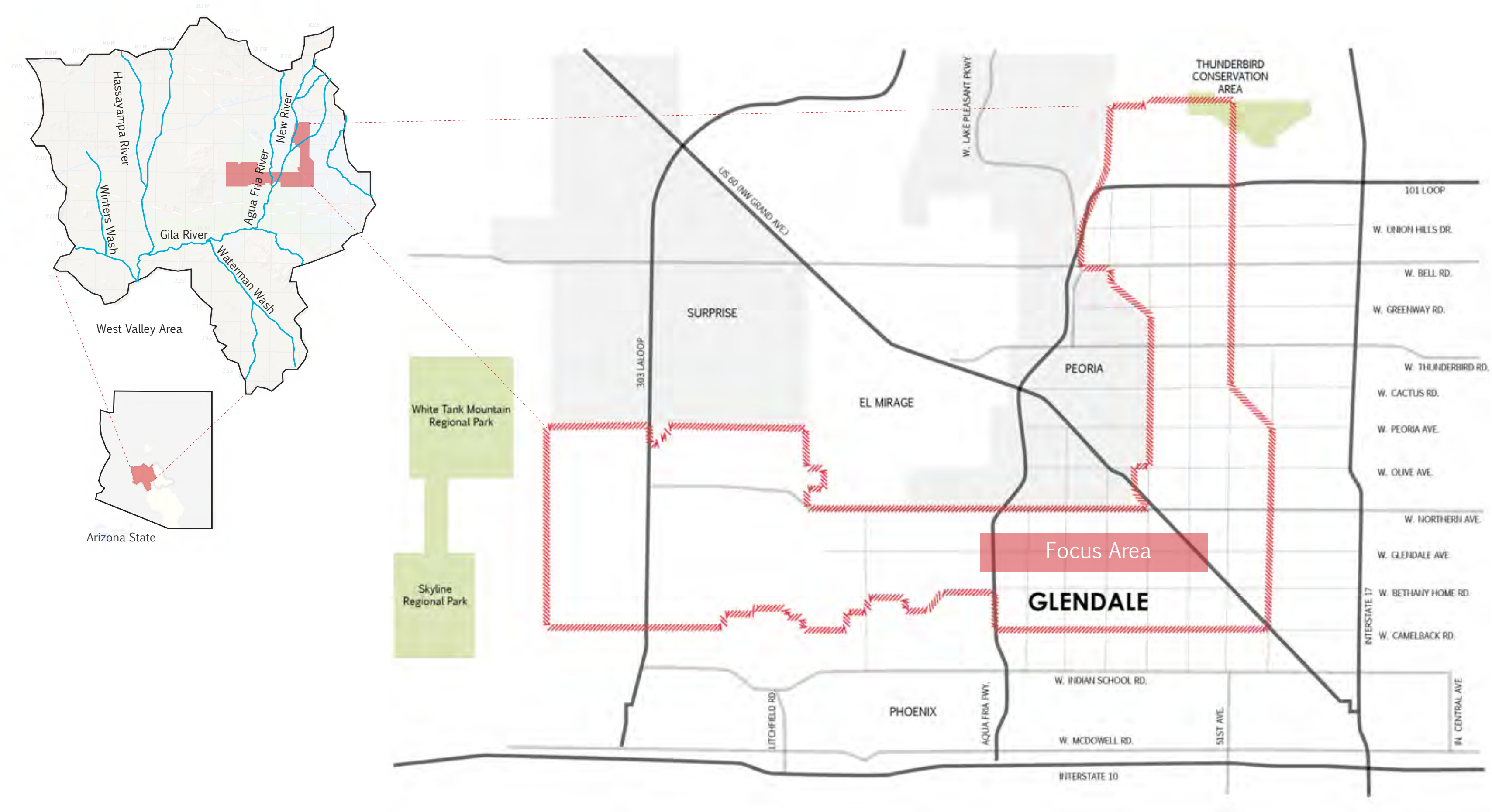
- The LID Toolkit in Chapter 2 includes a user-friendly catalogue of tools including the description, installation methods, and maintenance needs for each LID practice.
- Best practices in Chapter 3 includes examples of current practices compared with LID best practices that can be used in new or existing development.
- Case studies in Chapter 4 includes supporting information for local and national case studies of LID implementation and City-specific data.

Uses

The LID Toolkit can be used to:

- Assess current construction methods to determine where LID methods should be used to improve stormwater management.
- Review and assess current city policies, codes, regulations and checklists to determine which updates are required to enable and encourage the implementation of LID techniques.
- Educate City agencies, residents, businesses, and developers about the advantages and benefits of LID.
- Immediately enhance the built environment by implementing LID projects that use ecologically friendly and aesthetically pleasing design solutions that provide multiple benefits for the community.
- Identify appropriate LID standard engineering details as part of site development planning.

City-wide map



City-Wide Map

Glendale is located about 9 miles northwest of downtown Phoenix, mostly within the watershed of the Agua Fria River. There are several freeways through the City that create barriers to surface water movement, and where stormwater is conveyed into traditional channel and pipe stormwater systems.

The centralized project focus area was selected to be representative of a typical urban and suburban developed area in Glendale. This area is characterized by mature development and infrastructure with a large amount of impervious surfaces, and numerous opportunities to implement LID techniques in adaptive or new infill redevelopment projects.

Rain garden at Glendale's
Main Library, 2014

"The Toolkit is developed to be compatible with urban and suburban development methods and building codes."

LID Toolkit

Chapter 2

LID TOOLKIT DIAGRAM

SOURCE

ORIGIN OF STORMWATER RUNOFF

PARKING & STREETS	HARDSCAPE AREAS	STRUCTURE RUNOFF	LANDSCAPE AREAS	ALTERNATIVE SOURCES

ACTION

METHOD OF MANAGING STORMWATER RUNOFF

CONVEY	FILTER	INFILTRATE	EVAPO-TRANSPORATE	STORE	REUSE

TOOLS / TECHNICAL VARIATIONS

MEANS TO ACCOMPLISH ACTIONS

GREEN STREET	VEGETATED SWALE	BIORETENTION	PERMEABLE PAVING	CONSTRUCTED WETLANDS	INFILTRATION & UNDERDRAINS	GREEN ROOF	RAINWATER HARVESTING	LANDSCAPE*
Standard Curb Cut	Meandering or Linear	Vegetated Retention Basin	Stabilized Aggregate	Constructed Wetlands	Infiltration & Underdrains	Rooftop Garden	Cisterns Above Ground	Tree Preservation
Curb Cut with Sidewing	Restored Wash	Bioretention Cell	Porous Asphalt			Downspout Disconnection	Cisterns Below Ground	Soil Amendment
Concrete Flush Curb		Planter	Porous Concrete					Impervious Surface Reduction
Grated Curb Cut			Structural Grids					Plant Selection
Curb Cut with Sediment Capture			Permeable Pavers					
Wheelstop Curb								

* Not in tookit because it is applicable to many other tools

Source

The tools included in this document have been collected, reviewed and refined from many sources, including research of professional organizations, onsite observation and research of project data provided by cities and other resources. The EPA has published several guides to LID that describe the various LID methods that have been developed and implemented throughout the country. Not-for-profit interest groups, such as the Watershed Management Group, have documented several examples that have been implemented in the desert Southwest.

While not intended to be all-inclusive, this LID Toolkit provides a representative cross section of best management practices (BMPs) that can be deployed in Maricopa County, Mesa, Glendale and throughout the region.*

Tools

As described in the LID Toolkit Diagram, each tool is categorized by its context within a site or system, and by which action(s) the tool is intended to perform with respect to the stormwater it manages.

The Toolkit is developed to be compatible with urban and suburban development methods and building codes. For the purposes of this document, tools that are appropriate in developed or developing areas, and consistent with current or proposed city policies, will be the focus.

Technical Variations

Many of the BMP techniques illustrated in the LID Toolkit have multiple variations and/or site specific adaptations. The arid region in which we live, requires special understanding and care when implementing these techniques. Within the appropriate site and project context, LID tools can be effectively deployed to achieve cities' stormwater management goals.

Other context and site related issues that must be considered when applying the LID Toolkit to a stormwater management system include:

- Knowledge of local codes and regulations.
- Anticipating high intensity storms exceeding the capacity of stormwater facilities.
- Intermittent rainfall requiring vegetation to have access to supplemental irrigation.
- Periods of drought and/or extreme heat requiring adapted and highly tolerant vegetation.
- Extreme temperatures and/or daily temperature fluctuations leading to expansion and contraction and affecting installation parameters.
- Advantages and constraints associated with the type and use of local and regional materials.
- Dust and debris accumulation between storms.

* The LID Toolkit is not intended to address all of the requirements of local, state, regional, and other codes, regulations, and standards. Additional research and analysis will be required for each project, feature and site.

GUIDE TO READING THE TOOLKIT PAGES

Functions

Many LID tools provide a specific function related to stormwater, and some of them can perform several functions. The function intended by the designer is often a determining factor in the selection of which tool/technique to use in the design.

Flow Control
-the regulation of stormwater runoff flow rates.

Detention
-the temporary storage of stormwater runoff in underground vaults, ponds, or depressed areas to reduce peak flow rates.

Retention
-the storage of stormwater runoff on-site to allow for suspended solids to settle.

Filtration
-the sequestration of sediment from stormwater runoff through a porous medium such as sand, a fibrous root system, or a human-made filter.

Infiltration
-the vertical movement of stormwater runoff through soil, recharging groundwater.

Treatment
-processes that use plant materials, natural phytoremediation and/or bacterial colonies to metabolize contaminants in stormwater runoff.

Benefits

LID tools can provide benefits that go beyond stormwater management. By managing stormwater close to its source, they can nourish a healthy stand of vegetation, which provides interest in the landscape, reduces water and energy use, and reduces the cost of stormwater infrastructure and contaminants downstream. The following icons identify the indirect benefits associated with each LID practice.

Shade
-promotes vegetated shade

Habitat
-provides wildlife habitat area

Recreation
-creates recreational areas

Aesthetics
-enhances aesthetics

Design
-encourage creative solutions to stormwater manage

Education
-provides learning opportunity

Heat Island
-mitigates heat island effects

Infrastructure
-reduces impact on existing or future infrastructure

Location

Some LID tools are specific to certain locations and types of development. Other tools can be used in multiple locations and be adapted to different development types. It is important to assess which locations and applications each tool is appropriate for during the design process. The locations and development types identified by the following icons are intended to be scalable. For instance, the landscaped yard around a residence can be considered similar to the site area around a small business or school. Open space can describe a park, or a large landscaped area on the campus of an institution or corporate facility.

Street Buffer
-landscaped area between street and building

Pedestrian Path
-designed walkway for pedestrians

Street Median
-distinct island in middle of road designed to guide traffic

Driveway
-private vehicular accessway

Parking Island
- distinct island in parking area designed to guide traffic

Parking Lot
-designated area for parking

Residential Landscape
-unpaved and hardscape areas outside homes

Parks and Open Space
-large contiguous landscape areas for public or common use

Nonresidential Building
-buildings without residential uses

Nonresidential Landscape
-unpaved and hardscape areas outside non-residential buildings

Parking Shading
-trees or structures that provide shade

Residential Building
-buildings with residential uses

Description

This section includes a description of the type of tool, the materials used to construct or implement it, its potential uses, and the category that the tool fits within. When applicable it also includes definitions of key terms commonly associated with the technique.

Installation *

This section describes common installation methods, including locations for use, typical material, and common steps needed. Each application of any LID tool should be designed and constructed on a site-by-site and project-by-project basis, consistent with approved City standards and guidelines.

Maintenance

This section describes general management and maintenance items that users should take into account when considering the application of LID tools. The long term functionality of LID practices is crucial to their value in any design, and proper maintenance is key to their functionality. Site-specific conditions may increase the type and frequency of maintenance. A complete understanding of required maintenance from an operations and cost perspective is critical to making informed design choices when evaluating each tool.

Images

The images on each LID Toolkit page are of representative installations that use the tool described on that page. Each tool can have several variations as described in the LID Toolkit introduction. The intent is not to recreate the exact installation shown in the image, but to provide examples that can be adapted to city standards, site context, the project and regional climate influences.

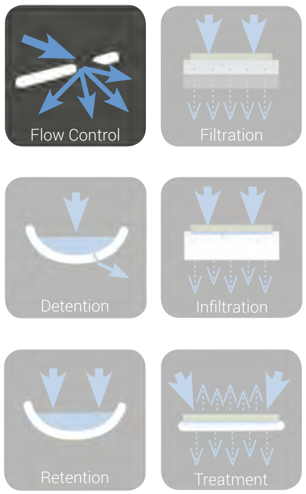
Resources and Details

Links to other resources that can provide additional information about the application and operation of certain tools are denoted by a footnote at the bottom of the LID Toolkit page, with the full reference provided in the Document Resources section of the Appendix. Several existing City and MAG details related to LID, along with relevant details currently being used in these areas, are included in the Appendix.

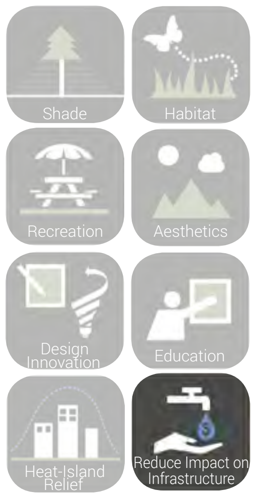
* The LID Toolkit is not intended to address all of the requirements of local, state, regional, and other codes, regulations, and standards. Additional research and analysis will be required for each project, feature and site.

Green Street - Standard Curb Cut

Functions



Benefits



Location

Curb cuts control stormwater flow from streets to LID facilities.

Description

- Curb cuts are openings created in a curb to allow stormwater from an impervious surface, such as roads, parking lots, or hardscape areas, to flow into a lower landscaped storage and infiltration area.
- The curb cut is a useful tool for retrofitting existing development with green infrastructure practices without major reconstruction.
- Since curb cut openings are perpendicular to the flow of stormwater on the street, they will usually collect only a portion of the water flowing along the gutter. If attenuating stormwater flows along the street is the goal, place multiple curb cuts at intervals along the street.

Installation

- Openings should be at least 18 inches wide, but up to 36 inches is preferred for ease of maintenance.
- Locate curb cut openings at low points and space them based upon stormwater velocity and volume, and the capacity of the area behind curb for detention, infiltration and access to overflow systems.
- The curb cut can either have vertical or angled sides. The design intent is to create a smooth transition from the paved surface to full curb height.
- Curb cuts work well with relatively shallow stormwater facilities that do not have steep side slopes that might erode.
- Set the elevation of the bottom of the curb cut to maximize flow into the landscape area.
- A drop in grade should occur between the curb cut entry point and the finished grade of the landscape area to allow for passage of sediment.
- Small amounts of hand placed rip-rap can be used on the LID facility side of the curb cut opening to reduce the potential for erosion in landscaped areas.
- Example of standard curb cut detail in Best Practice chapter, page 39.

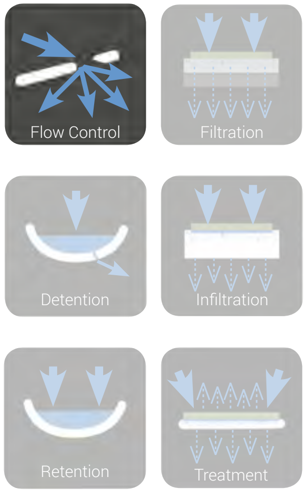
Maintenance

- Regularly clear curb cuts of any debris and sediment that prevents the free flow of stormwater (1-2 times per year and after storm events).
- Periodically check rip rap areas for signs of erosion damage. Repair and reinforce as necessary (annually and after storm events).

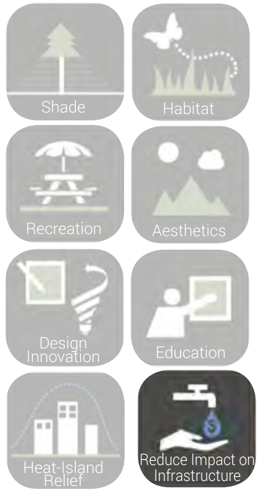
Footnote: #1

Green Street – Curb Cut with Sidewings

Functions



Benefits



Location

Curb cuts direct stormwater from street to landscape areas.

Description

- Curb cuts are openings created in a curb to allow stormwater from an impervious surface, such as roads, parking lots, or hardscape areas, to flow into a lower landscaped storage and infiltration area.
- The curb cut is a useful tool for retrofitting existing development with green infrastructure practices without major reconstruction.
- Since curb cut openings are perpendicular to the flow of stormwater on the street, they will usually collect only a portion of the water flowing along the gutter. If attenuating stormwater flows along the street is the goal, place multiple curb cuts at intervals along the street.
- The sidewing addition conveys stormwater a greater distance, and can reduce the potential for erosion behind the curb or close to the paved surface.

Installation

- Openings should be at least 18 inches wide, and sidewings can be parallel or tapered.
- Locate openings at low points and space them based on amount of water being received along curb, and the area available for detention, infiltration, and access to overflow drains.
- Sidewings work well to guide stormwater greater distances and with stormwater facilities that have steep side slopes.
- Slope the bottom of the curb cut and trench toward the landscape area. The slope should be flat enough to keep flow velocities low and steep enough to keep sediment moving (between 1% and 5% slope).
- A drop in grade should occur between the curb cut entry point and the finished grade of the landscape area to allow for passage of sediment.
- Small amounts of hand placed rip-rap can be used outside the curb cut opening to reduce the potential for erosion in landscaped areas.

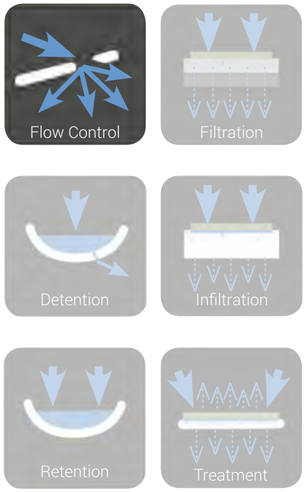
Maintenance

- Regularly clear curb cuts and sidewings of any debris and sediment that prevents the free flow of stormwater (1-2 times per year and after storm events).
- Periodically check rip rap areas for signs of erosion damage. Repair and reinforce as necessary (annually and after storm events).

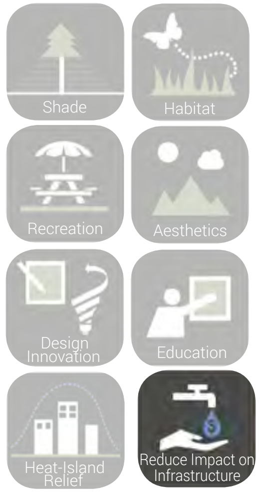
Footnote: #2

Green Street - Grated Curb Cut

Functions



Benefits



Location

Grates allow stormwater to pass through while proving an accessible pedestrian route.

Description

- Grated curb cuts allow stormwater to be conveyed under a pedestrian walkway. Curb-cut openings are described in previous sections to allow stormwater from impervious surfaces to flow into a landscaped area.
- The grated curb cut is a useful tool for urban areas where there is heavy pedestrian traffic and the need for handicap accessible routes adjacent to streets and parking areas.
- Grated curb cuts should only be used where there is not enough vertical distance to install a scupper. Where they are used, only decorative heavy duty, accessible, precast gratings should be permitted.

Installation

- The grated curb cut opening should ideally be 18 inches wide; enough to minimize the potential for clogging.
- Grates should be compliant with the Americans with Disabilities Act (ADA) and have adequate slip resistance.
- Grates should be anchored in a way that deters removal or theft.
- A drop in grade should occur between the grated curb cut channel and the finish grade of the landscaped area to allow for the passage of sediment. Permanent or temporary erosion control may be necessary where concentrated runoff from the channel is deposited into the landscaped area.

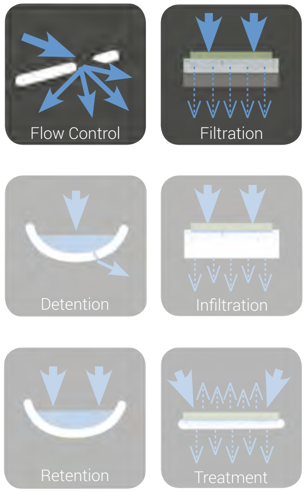
Maintenance

- Regularly clear grated curb cuts of debris and sediment that may prevent the free flow of stormwater (1-2 times per year and after storm events).
- Periodically check for damage to grate and structural support system that may cause ponding of water or impede accessible pedestrian routes.
- It may be necessary to remove grates to clear sediment and debris.

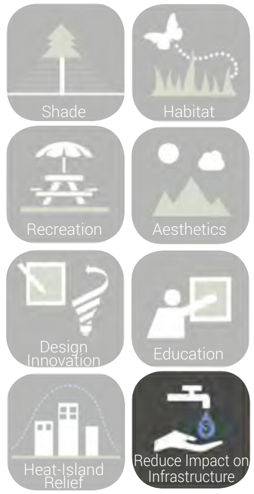
Footnote: #4

Green Street – Curb Cut with Sediment Capture

Functions



Benefits



Location

Sediment capture can be open or covered.

Description

- Sediment removal poses a considerable challenge in the maintenance of green infrastructure sites. In the arid Southwest, high proportions of bare soil are common, resulting in high rates of erosion and sedimentation. Sediment capture can address this issue.
- Sediment catchments capture and collect sand and fine soils at the entrance to bioretention areas, removing them from stormwater. Sediment removal can significantly extend the functional life of these features.
- The area for sediment capture can be designed for easier cleanout.

Installation

- Use sediment capture in areas where higher than normal sediment loads are expected.
- Excavate at least 12 inches from the inside of the curb cut, and at least 2 feet square by 8 inches deep. The capture device can either be open or covered with a grate.
- A concrete curb, or steel edge, several inches in height, may be used to separate the capture area from the adjacent landscape detention area or basin, and anchor the grate.
- A berm, several inches in height, may be used to separate the capture area from the adjacent landscape detention area or basin. Plant the berm with native groundcover plantings to stabilize it and allow it to filter stormwater pollutants.

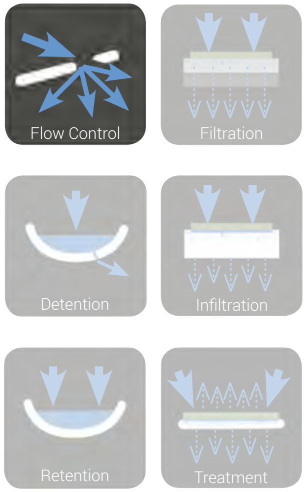
Maintenance

- Check sediment capture device to ensure that the stormwater inlet does not become blocked (before and after rainy seasons and after large storm event).
- Regularly remove sediment from the bottom of the facility (frequency depends on sedimentation rates, but at least once a year).
- Check apron, slopes, edges, etc. for erosion and repair/reinforce as needed (annually and after storm events).

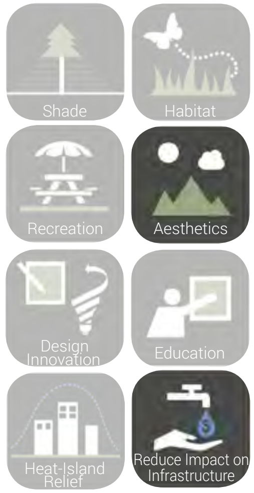
Footnote: #5

Green Street – Concrete Flush Curb

Functions



Benefits



Location

Flush curbs allow stormwater to sheet drain to landscape areas.

Description

- Concrete flush curbs allow stormwater to runoff impervious surfaces directly into landscaped areas and stormwater facilities. Stormwater flow is distributed more evenly which reduces the potential for erosion and clogging along a pavement edge.

Installation

- Top of concrete curb should be installed flush with the pavement surface, with allowances for subgrade compaction and future settlement.
- A drop in grade should occur between the top of the flush curb and the finished grade of the landscaped area to allow for passage of sediment and debris to drop out.
- Utilize temporary erosion control measures when seeding or planting adjacent areas to reduce the potential for erosion.
- A wider surface area and contrasting color for the flush curb provides an important visual cue when used on roads, driveways and bicycle paths.
- This tool will be considered on a case by case basis for street rights-of-way.

Maintenance

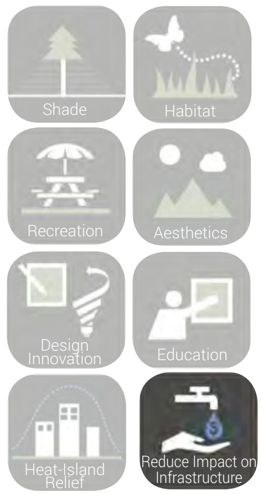
- Check the flush curb for signs of damage or settlement causing ponding or concentration of stormwater runoff.
- Check landscape edge condition for signs of rilling or erosion and repair or reinforce as needed (annually).
- Remove sediment and debris from landscape area outside of flush curb that may cause water to pond or backup.

Footnote: #6

Green Street – Wheelstop Curb

Functions

Benefits



Location

Wheelstops allow sheet drainage to pass into landscape areas.

Description

- Wheelstop Curbs are formed sections of curb with gaps between them. They allow stormwater from adjacent impervious surfaces, like parking lots, to flow into adjacent planting areas.
- In flush, or no curb parking areas, poured-in-place wheelstop curbs can be used to define openings and protect infiltration and planting areas.

Installation

- Space poured-in-place wheel stop curbs as needed for parking/traffic conditions while allowing water to flow into vegetated areas.
- Poured-in-place wheel stop curbs are most common in parking lot applications, but they can also be applied in certain street conditions.
- Provide a minimum of 6 inches of space between the poured-in-place wheelstop curb edge and edge of asphalt paving to provide structural support for the wheel stop.
- Securely anchor poured-in-place wheelstop curbs using foundations or other support to ensure that they resist vehicle impact and overturning.
- A concrete flush curb is advised along the edge of pavement for structural support of poured-in-place wheel stop curbs and visual demarcation of parking area or driveway edge.

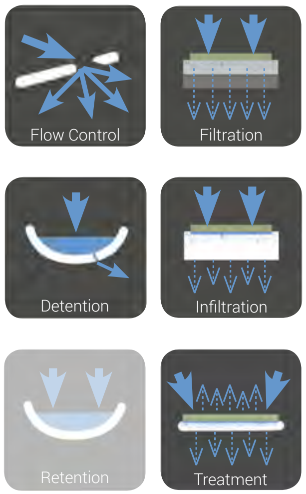
Maintenance

- Poured-in-place wheelstop curbs have similar maintenance requirements as other poured concrete curbs. Unless they are firmly anchored they can be dislodged creating unsightly and dangerous conditions. They should be checked regularly for cracking and settlement and repaired or replaced as necessary.

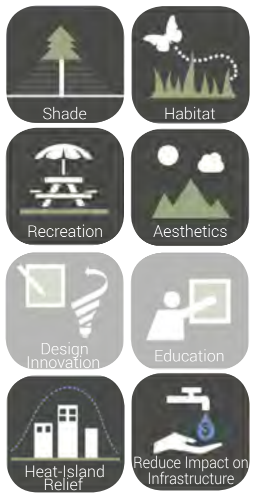
Footnote: #3

Vegetated Swale - Meandering or Linear

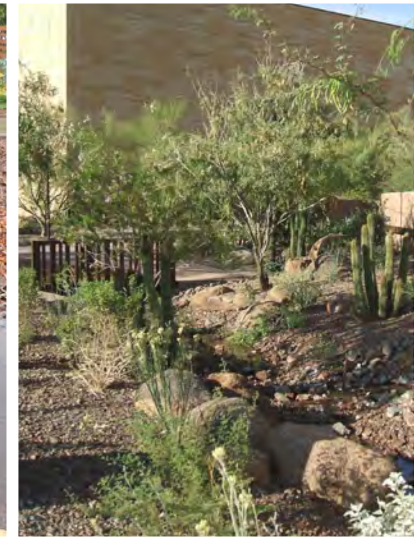
Functions



Benefits



Location



Vegetated swales accept stormwater for conveyance, storage and infiltration.

Description

- Vegetated swales are stormwater runoff conveyance systems that provide an alternative to piped storm sewers.
- They can absorb low flows and direct runoff from heavy rains to storm sewer inlets or directly to surface waters.
- Vegetated swales improve water quality by enhancing infiltration of the first flush of stormwater runoff and promoting infiltration of storm flows they convey.
- Costs vary greatly depending on size, plant materials, and site considerations. Vegetated swales are generally less expensive when used in place of underground piping.

Installation

- Deep-rooted native plants are preferred to promote water infiltration and reduce erosion and maintenance requirements.
- Evaluate site soil conditions. Ideally soil infiltration rates should be greater than one-half inch per hour. Soil Amendments may be needed to achieve ideal infiltration rates.
- Side slopes should not exceed 4:1. Slopes adjacent to walkways or accessible hardscape areas should not exceed 6:1. In suburban contexts, a meandering installation should be used. Linear installations are appropriate in urban contexts.
- Refer to building codes for maximum depths allowed without requiring a guard rail. In any case, a vertical drop of more than 30 inches will require a guard rail installation.
- Current engineering standards require all swales that detain stormwater to completely drain within 36 hours.

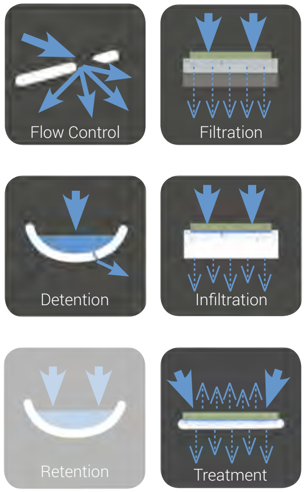
Maintenance

- Vegetation in the swale will require regular maintenance such as removal of debris and dead branches, and occasional pruning.
- Supplemental irrigation may be required to maintain healthy landscape plants.
- Removal of sediment and regrading will be necessary to maintain the swale shape and volume over time. As with plant waste, sediment should be removed and disposed of properly.

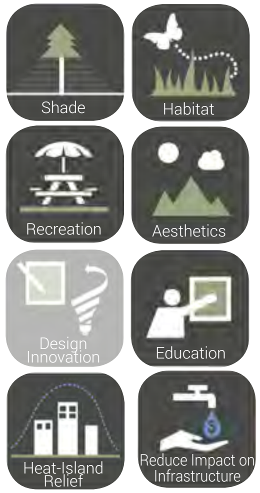
Footnote: #7

Vegetated Swale – Restored Wash

Functions



Benefits



Location

Restored washes maintain hydrology, reducing infrastructure costs.

Description

- The natural Sonoran Desert consists of washes that flood infrequently yet allow established native riparian plants to flourish.
- Wash restoration follows natural drainage patterns and supports a healthy naturalistic landscape palette, requiring little or no supplemental irrigation.
- Restored washes provide natural beauty, wildlife habitat and recreation opportunities that are valuable to city residents.
- Restoring washes recreates riparian systems while accommodating flood protection.

Installation

- Channel alignments and side slopes must be designed in close coordination with civil engineers to ensure that restored washes convey while minimizing erosion damage.
- Employ erosion control and channel stabilization techniques that encourage upland and riparian vegetation to establish over time.
- Provide access for regular inspection and maintenance efforts.

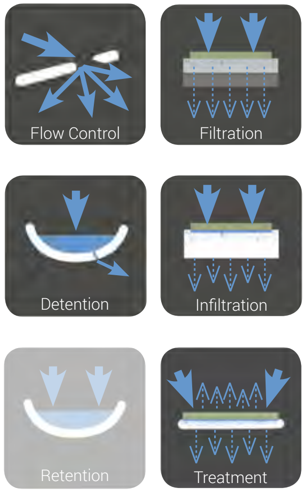
Maintenance

- Responsive and well-timed maintenance activities are critical to the success of any ecosystem restoration project, particularly within the first 5 years after construction, during initial plant establishment. This time period is referred to as the short-term maintenance period. During this time, plants are most susceptible to drought, competition by weeds and herbivory (browsing by wildlife), all of which can influence the overall success of a project.
- Short-term site maintenance includes supplemental planting and seeding, checking and repairing irrigation lines, weed and erosion control, and remedying mosquito problems.
- The irrigation system should be designed so that it can be turned off after a 2-3 year plant establishment period.
- Long-term maintenance activities include repairing erosion, continued weed control, thinning invasive species such as desert broom and controlling mosquitoes.
- Restored washes have unique maintenance needs due to native and riparian vegetation and the potential for soil erosion. These areas must have a maintenance plan executed by experienced professionals.

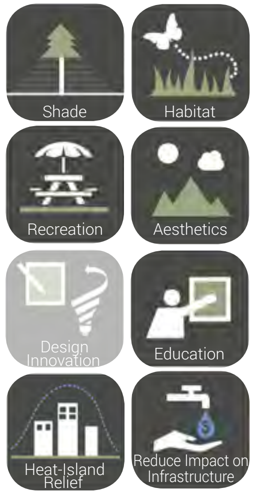
Footnote: #8

Bioretention – Vegetated Retention Basin

Functions



Benefits



Location

Bioretention areas detain stormwater while enhancing the landscape.

Description

- Bioretention basins are shallow depressions in the landscape that typically include plants and a mulch layer or ground cover. Porous soils allow stormwater to infiltrate and supply plants with needed water.
- In addition to increased groundwater recharge, bioretention basins can improve water quality during smaller, more frequent storm events. In addition to removing sediments coming off paved areas, pollutants can also be removed through absorption into plantings and evaporation.
- Bioretention basins, can be used in residential settings, often referred to as rain gardens, to accept runoff from a roof or other impervious surface.

Installation

- Creative shaping and planting of bioretention basins can utilize soil excavated from the basin to accommodate sloping berms.
- Adding hand placed stones where stormwater enters the basin from a curb cut, pipe or downspout can help dissipate concentrated flows and reduce erosion.
- Vegetation should be selected based on local microclimate and soil conditions. Plants should be set in the ground so the surface soil is level with the bottom of the basin. Once the plants are installed, the area should be mulched to retain soil moisture and reduce erosion.
- Basin side slopes should not exceed 4:1 in all cases. Where adjacent to walkways or accessible hardscape areas they should not exceed 6:1.
- In suburban installations an irregular or meandering shape may be most appropriate. Other geometric configurations are appropriate in a more urban context.
- Current engineering standards require all basins that detain stormwater to completely drain within 36 hours.

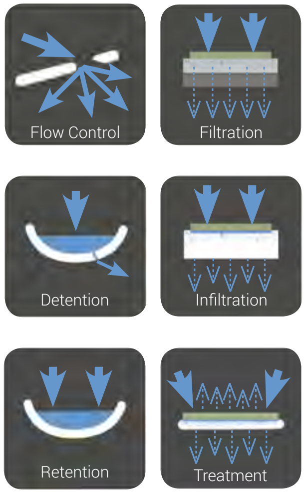
Maintenance

- Plantings should get regular adequate supplemental irrigation until fully established (normally two full growing seasons). Maintain landscaped areas including pruning shrubs to remove dead material and encourage new growth. The roots of healthy vegetation will improve the function of the bioretention basin/rain garden.
- Regularly check for erosion, remove sediment and debris (vegetative litter as well as trash).
- Long-term maintenance activities include repairing erosion, continued weed control, thinning invasive species such as desert broom and controlling mosquitoes.

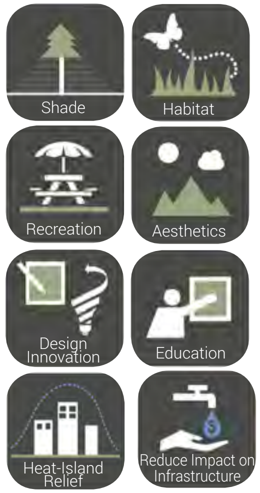
Footnote: #9

Bioretention - Bioretention Cell

Functions



Benefits



Location

Bioretention cells fit into constrained urban site.

Description

- Bioretention cells are shallow depressions with a designed soil mix and plants adapted to the local climate and soil conditions. These are used in more urban conditions and where subsoils are porous and allow infiltration into the subgrade.
- Bioretention cells capture and infiltrate stormwater into the ground below the cell and have an overflow that carries excess stormwater to a discharge point.
- Bioretention cells that do not infiltrate stormwater into the ground and include an underdrain, are called bioretention planters.

Installation

- Bioretention cell bottoms should be relatively flat and not lined. The bottom surface should be loosened several inches deep prior to placing the bioretention soil mix. The cell bottom area should be designed based on the ability of the soil to freely drain into the subgrade.
- Stormwater enters the bioretention cell by surface flow or pipe inlet. A pre-settling area can be a rocky or vegetated sediment capture area designed to protect the bioretention cell by slowing incoming flows at the point of entry.
- A minimum depth of specially graded soil is necessary for the proper function of a bioretention cell.
- An appropriate surface mulch layer should be selected to reduce weed establishment, regulate soil moisture and temperature, and add organic matter to the soil.

- Stormwater ponding above the cell provides storage for storm flows, settles out particulates such as sediment, and provides for uptake and filtering of pollutants within the cell.
- Plants used must be drought tolerant, and suitable for occasional saturation.
- Overflow for the bioretention cell should transport excess stormwater to an approved discharge point.

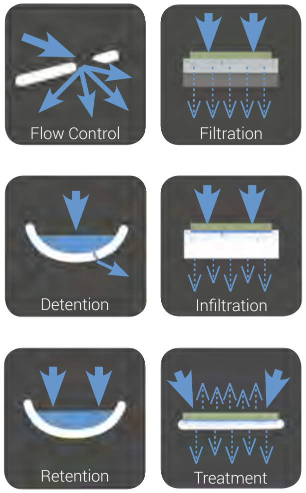
Maintenance

- Regularly check bioretention cells for blockages from debris and sediment. Remove sediment and debris and dispose of properly.
- Maintain landscape by replacing dead vegetation, pruning healthy vegetation and removing weeds regularly. Do not use herbicides in stormwater facilities.
- Bioretention soil may need to be replaced if soil percolation rates fall below the design flow capacity, Check percolation rates if bioretention cells are not draining within 36 hours, or have been contaminated by sediment inflows.

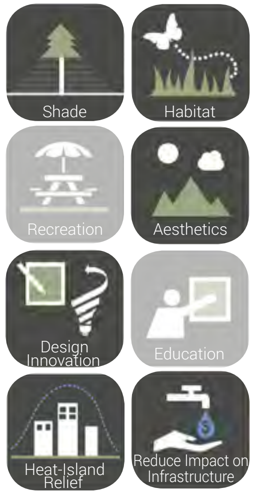
Footnote: #10

Bioretention - Planters

Functions



Benefits



Location

Bioretention planters provide stormwater storage and promote healthy growth of trees and plants.

Description

- Bioretention planters are landscape planters that also store stormwater in porous planting soils and above the soil surface. Planters may be raised above ground or can be set flush with or even below the ground surface. They capture runoff from downspouts or overflow from rain barrels.
- There are several types of bioretention planters including:
  - Structural soils or Silva Cells.
  - Raised flow-through planter boxes.
  - In-ground planter boxes.
- Like bioretention swales and rain gardens, planter boxes sustain healthy plants with a minimum of supplemental irrigation, while improving the quality of stormwater runoff and reducing runoff volume.

Installation

- Calculate stormwater volume capacity by using the soil volume and pore space in each planter.
- Planters should be installed on a flat subgrade and surface grade to maximize storage.
- Planting mix soil should be carefully selected and tested to provide proper physical composition, adequate drainage and organic matter to support designated plantings. Planting soil should be at least 18" deep; contain no more than 20% compost, and be a desert-appropriate mix.
- Soils should be placed at a width and depth to accommodate the mature size of specified plantings. A subgrade gravel layer can be used to add storage capacity.

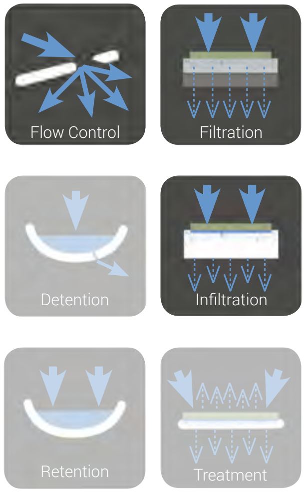
Maintenance

- Bioretention planters should be checked annually to maintain optimum storage, and drainage functions.
- Following storm events, planters should be inspected to ensure that standing water is not present in the planter for more than 36 hours.
- Monitor health of vegetation and maintain them using best landscape maintenance practices. Prune and replace plants as necessary.
- Herbicides should not be used in bioretention planters.
- Special consideration should be taken when replanting in bioretention planters that have structured soils or Silva Cells.

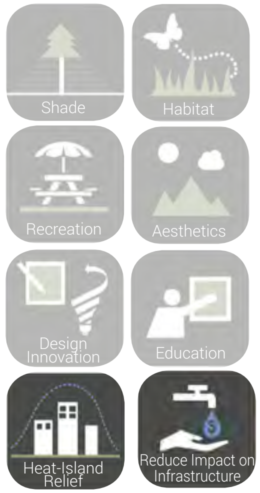
Footnote: #11

Permeable Paving - Stabilized Aggregate

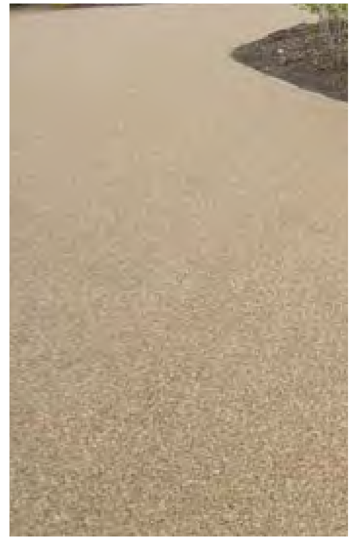
Functions

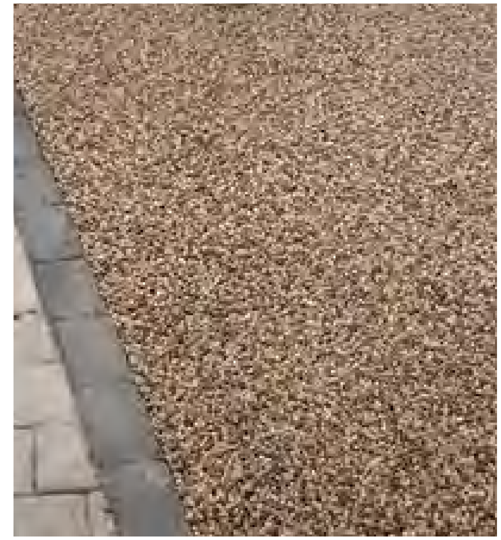


Benefits



Location





Stabilized aggregate reduces storm runoff from paved low-traffic areas.

Description

- Stabilized aggregate is a mixture of compacted stone aggregate and a binder, used to pave driveways, footpaths and other accessible landscape areas.
- Unlike traditional paving it allows surface water to penetrate into the subgrade, reducing (or eliminating) runoff, and providing significant storage volume.
- Stabilized aggregate should be used in areas that do not have high volumes of vehicular traffic, or are used intermittently for event parking or fire lanes. A compacted and graded sub-base, consisting of porous stone layers, can be utilized for additional storage.

Installation

- Stabilized aggregate paving requires a well compacted base. Crushed rock is placed in layers that allow rapid infiltration of surface water.
- The surface layer can consist of a variety of colored and textured aggregates designed to meet aesthetic choices and required flow characteristics. Binders can be mixed on site or remotely, and applied by hand or with specially designed mixing equipment depending on design requirements.
- The finished surface should be relatively flat (less than 2% slope) and screeded to form a smooth, level surface without loose stones.

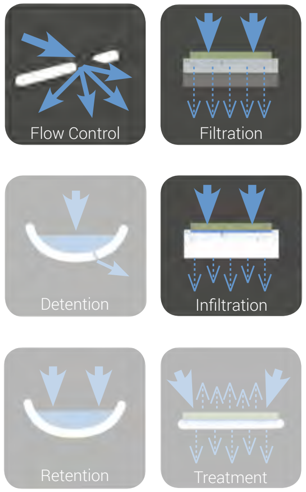
Maintenance

- Stabilized aggregate should be checked regularly for signs of settlement, fissuring or ponding. Sediment can clog pores and reduce its effectiveness for stormwater absorption.
- Repair damaged or cracked sections immediately as they occur.
- Regular maintenance is essential to maintain the functionality of the pavement and drainage system.

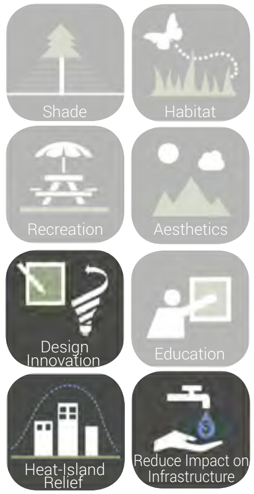
Footnote: #12

Permeable Paving - Porous Asphalt

Functions



Benefits



Location

Porous asphalt paving is a runoff-reducing option for paving areas and driveways.

Description

- Porous asphalt consists of standard asphalt pavement in which the fines have been screened and removed, creating void spaces that make it highly permeable to water.
- Porous asphalt reduces the velocity and volume of stormwater runoff delivered into the storm sewer systems and can reduce contaminants in runoff prior to its discharge to the storm sewer system.
- Porous asphalt should be used in areas that do not have high volumes of traffic, or are used intermittently for event parking or fire lanes. A compacted and graded sub-base, consisting of porous stone layers, can be utilized for stormwater storage.

Installation

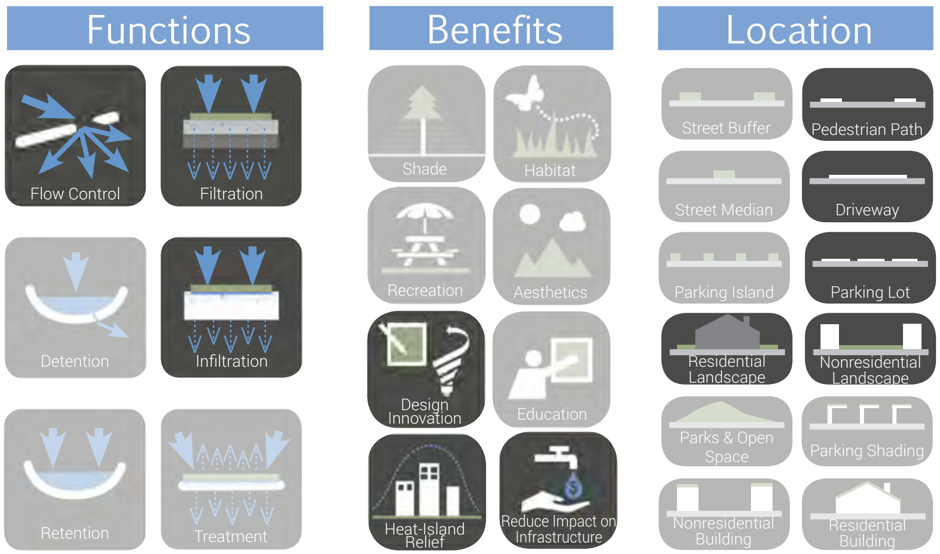
- The porous asphalt mix must be designed and installed by an experienced contractor. Poor materials and/or installation can result in a higher risk of failure.
- The design for porous asphalt consists of several layers, including a compacted sub-base, geotextile, a reservoir stone aggregate, a filter and surfacing, applied with a paving spreader and roller.
- Porous asphalt is normally set flush with adjacent pavements or grades, and contained by concrete curbs or other types of edging to ensure the structural stability of edges.
- The subgrade reservoir should allow for drainage to the stormwater system, especially if the subgrade does not allow adequate infiltration. Underdrain tile or piping is sometimes necessary to achieve proper drainage.

Maintenance

- Maintenance includes the regular vacuuming of surface areas to remove sediment and minimize clogging. With regular maintenance porous asphalt can have a service life of at least 10 years.
- Porous asphalt should be checked periodically for settlement and cracking, and damaged areas repaired to match the original pavement design.

Footnote: #13

Permeable Paving - Porous Concrete




Porous concrete can reduce runoff in sidewalks and plaza areas.

Description

- Single size aggregate, also know as porous concrete, consists of a special mix design with void spaces that make it highly permeable.
- Aggregates are normally screened to provide particles that can fall within narrow limits to ensure porosity,.
- About 30% to 40% of the material is void space, and its permeability is often measured in hundreds of inches per hour.
- Porous concrete reduces the velocity and volume of stormwater runoff delivered into the storm sewer system and can reduce contaminants in runoff prior to its discharge to the storm sewer system.

Installation

- The porous concrete mix must be designed and installed by an experienced contractor. There is a high degree of risk of failure associated with poor materials and/or installation.
- The design for porous concrete consists of several layers, including a compacted sub-base, geotextile, a reservoir stone aggregate, and poured surfacing layer, formed with a screed finish.
- Porous concrete is normally set flush with adjacent pavements or grades.
- The subgrade reservoir should allow for drainage to the stormwater system through underdrain tile or piping, especially if the subgrade does not allow adequate infiltration. Underdrain tile or piping is sometimes necessary to achieve proper drainage.

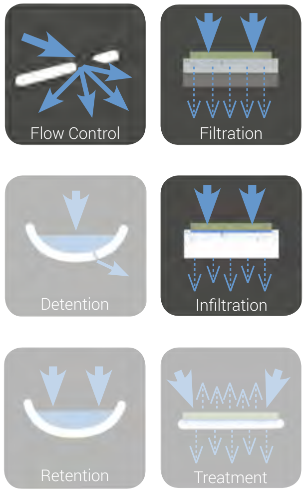
Maintenance

- Maintenance includes the regular vacuuming of surface areas to remove sediment and minimize clogging. With regular maintenance, porous concrete can have a service life of at least 20 years.
- Porous concrete should be checked periodically for settlement and cracking, and damaged areas repaired to match the original pavement design.

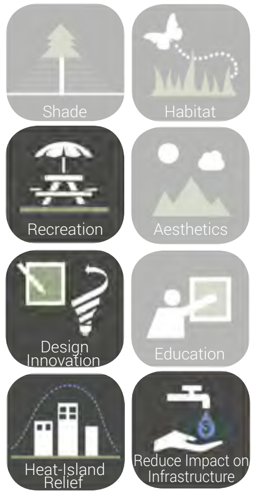
Footnote: #14

Permeable Paving - Structural Grids

Functions



Benefits



Location

Structural grid paving reduces runoff in parking areas and firelanes.

Description

- Structural Grid Systems, also referred to as geocells, consist of plastic, concrete or metal interlocking units that allow water to infiltrate through large openings filled with aggregate stone, or topsoil and turf grass. “Grasscrete” products are one type of structural grid system.
- Structural grid systems can be used in areas that can carry low volumes of traffic, or are used intermittently for event parking or fire lanes. A compacted and graded permeable sub-base, consisting of porous stone or soil layers, provides stormwater storage and landscape cover.

Installation

- Existing soils are removed to a depth that accommodates the desired stormwater storage volume. Compact the subgrade, install geotextile fabric, and install drainage filter stone to desired grade.
- Install edge retention and place bedding layer over the geotextile. The structural grid is then placed on the screed bedding layer so that the paver cells sit flat on the surface.
- For grass surfaces, pavers are filled with a topsoil root zone mix to finished grade prior to implementing a normal seeding or sodding, fertilizing and watering program.
- For a gravel surface, angular gravel or aggregate is installed in lieu of topsoil and sod (or seed).

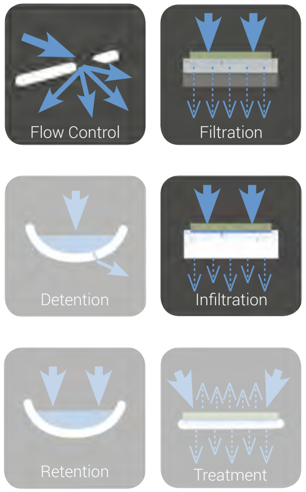
Maintenance

- For turf finishes, keep traffic off of geogrid surface until sod or seed has had adequate time to establish. Use landscape maintenance best practices for turfgrass areas.
- Regularly check for dislodged, settled or damaged grid cells, and remove and replace as required. Replenish the top course sod or aggregate as needed.

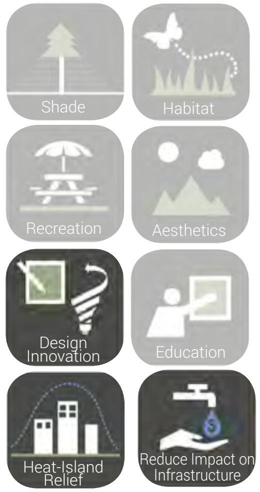
Footnote: #15

Permeable Paving - Permeable Pavers

Functions



Benefits



Location

Permeable paving is an attractive way to provide runoff reduction in paving and pedestrian areas.

Description

- Permeable pavers are comprised of precast concrete unit pavers designed to be set on a compacted base and highly permeable setting bed with joints filled with sand or fine gravel.
- Water enters the joints between the unit pavers and flows through an open-graded base, to infiltrate into the subgrade or be carried out into the storm system via underdrain piping.
- The void spaces in the subbase store water and infiltrate it back into the subgrade, or allow it to evaporate providing local air cooling.
- The sand joints provide surface permeability and helps filter stormwater sediments and pollutants.

Installation

- A stable compacted subbase is essential for any flexible pavement such as porous pavers. The depth of rock and gravel must be capable of holding rainwater long enough for the soil underneath to absorb it.
- Excavate to required subgrade depth, compact subsoil using a roller or vibratory compactor, and install geotextile fabric.
- Prepare base material and compact using a roller or compactor. Install the crushed rock in separate layers and recompact. Install bedding layer and then paving stones with edge restraints.

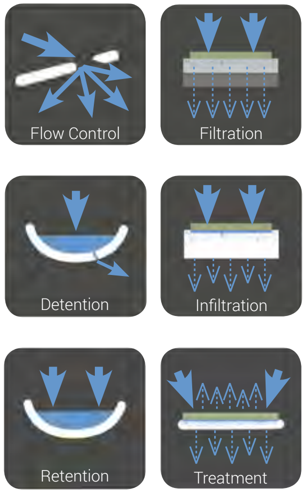
Maintenance

- Inspect pavers regularly for settlement and broken pavers. Replace broken pavers immediately to prevent structural instability. Pavers can be removed individually and replaced during utility work.
- Do not pressure wash concrete unit pavers. Sweeping and vacuuming should be performed when paver areas are dry.
- Although a more expensive option for permeable pavement, concrete unit pavers are the most effective at reducing runoff and are often the most aesthetically pleasing option.

Footnote: #16

Constructed Wetlands

Functions



Benefits

Location

Constructed wetlands provide aesthetic and educational benefits while they utilize plants to remove contaminants and provide wildlife habitat.

Description

- Constructed wetlands for water treatment can be complex, integrated systems of water, plants, animals, microorganisms, and the environment.
- Wetlands provide a number of functions and values including: water quality improvements, flood storage and reducing stormwater surface runoff, cycling of nutrients and other materials, creation of wildlife habitat, recreation, education and research, aesthetics and landscape enhancement.
- Under certain conditions, constructed wetlands can be used to mitigate impacts to natural wetlands and be traded in a wetlands mitigation bank.

Installation

- Constructed wetlands are generally built on uplands and outside of floodplains or floodways in order to avoid damage to natural wetlands and other aquatic resources.
- Wetlands are constructed by excavating, backfilling, grading, diking and installing water control structures to establish desired hydraulic flow patterns.
- If the site has highly permeable soils, an impervious, compacted clay liner is usually installed and the original soil placed over the liner.

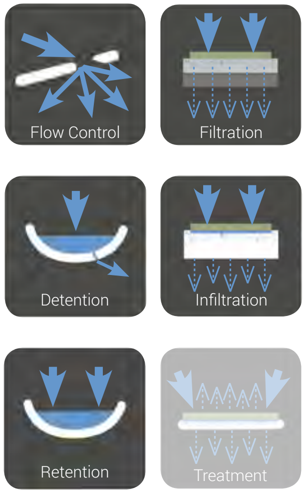
Maintenance

- Constructed wetlands must have a maintenance plan and be maintained by an experienced professional. Privately owned facilities often require an easement, deed restriction, or other legal measure to prevent neglect or removal.
- During the first growing season, vegetation should be inspected every 2 to 3 weeks. Inspections should assess the vegetation, erosion, flow channelization, bank stability, inlet/outlet conditions, and sediment/debris accumulation.
- Once established, properly designed and installed constructed wetlands should require little maintenance. They should be inspected at least biannually and after major storms.

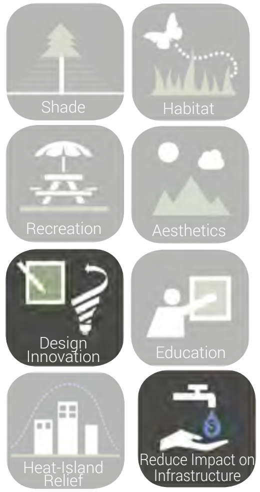
Footnote: #17

Infiltration & Underdrains

Functions



Benefits



Location

Drainfields provide for a large volume of stormwater storage and promote groundwater recharge.

Description

- Infiltration drainfields are used to store larger amounts of onsite stormwater, allowing it to infiltrate into subsoils and recharge groundwater.
- Drainfields supplement other LID tools to help control large runoff events, and reduce impacts on downstream infrastructure.
- A drainfield system is normally comprised of a pre-filtration structure, a manifold system, and underdrain pipes installed in porous stone bedding.

Installation

- Infiltration drainfields are not generally used on slopes greater than 5 percent, and work best when the site is as flat as possible. The infiltration rate below the bottom of the stone reservoir should be at least 1/2 inch per hour.
- Drainage volumes and areas are highly variable. System design should be performed by a licensed engineer. Drainage time for the design storm ranges from a minimum of 12 hours to a maximum of 72 hours, with the ideal being 24 hours.
- Excavate and grade to minimize soil compaction. Divert stormwater runoff away from site before and during construction. A typical infiltration cross section comprises of a graded stone reservoir consisting of coarse stone (washed), and sand filters.
- Pre-filtration is often used to treat runoff from contributing areas before it reaches the drainfield.
- A dispersion manifold is placed in the upper portions of the infiltration drainfield to evenly distribute stormwater runoff over the largest possible area.

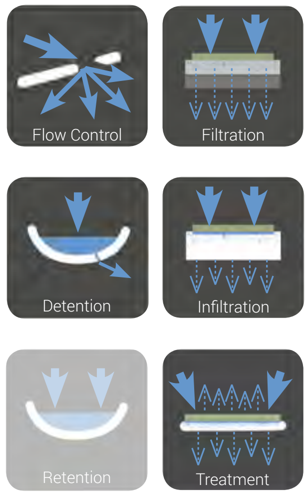
Maintenance

- The pre-filtration facility should be checked regularly, and after major storm events, for debris and sediment that might affect system function.
- The inlet and outlet pipes should be inspected regularly for debris and clogging.
- Sediment should be cleaned out when it depletes more than 10 percent of system capacity.

Footnote: #18

Green Roofs - Rooftop Garden

Functions



Benefits

Location

Green roofs store and utilize stormwater to reduce runoff from building sites.

Description

- A green roof or Xeriscape living roof is when the roof of a building or structure is at least partially covered with a growing medium and vegetation planted over a waterproofing membrane. It may also include a root barrier, drainage mat and irrigation system.
- There are two types of green roofs: Intensive and Extensive. The difference is in the depth of soil and the ability to support simple groundcover planting (intensive) versus larger materials such as trees and shrubs (extensive).
- Green roofs provide stormwater storage and absorption, reduce runoff from buildings, and insulate buildings from solar gain and heat loss.

Installation

- The intended function of a green roof will have a significant effect on its design.
- The height of the roof above grade, its exposure to wind, orientation to the sun and shading by surrounding buildings will all impact types of materials used and maintenance requirements. Views to and from the roof will also determine where elements are located for maximum effect.
- Professionals must be consulted for the design and construction of the green roof. A qualified architect, structural engineer, landscape architect and facility maintenance personnel are critical to the success of a green roof project.
- Access to the green roof site is crucial - not only for installation and maintenance, but also for delivery of materials, soil and plants.

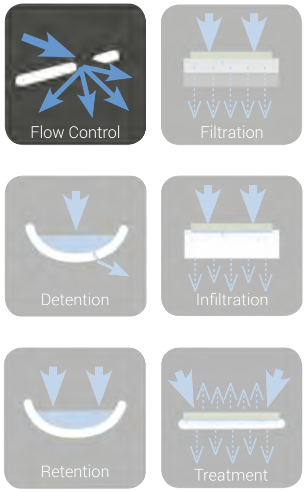
Maintenance

- Vegetation will require supplemental irrigation and only very hardy plants should be used in our desert environment. Depending on whether the green roof is extensive or intensive, required plant maintenance will range from two to three yearly inspections to check for weeds or damage, to weekly visits for irrigation, pruning, and replanting.
- Both plant maintenance and maintenance of the waterproofing membrane are required.
- To ensure continuity in the warranty and the maintenance requirements, the building architect, structural engineer and/or owner should specify and maintain everything up to and including the waterproof membrane. The green roof designer and installer is only responsible for those items above the waterproof membrane, including soils, drainage and plantings.

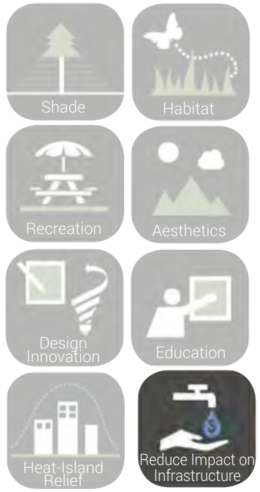
Footnote: #19

Green Roofs - Downspout Disconnection

Functions



Benefits



Location

Disconnecting a downspout allows rainwater to supplement irrigation in the landscapes.

Description

- Downspout disconnection is the practice of directing rainwater from the rooftop into a landscaped yard instead of into a piped system or into the street.
- Downspouts can direct stormwater to landscape areas where it is stored and used to irrigate landscape plants or infiltrate into the ground.

Installation

- Direct downspout extensions away from building foundations or adjacent properties to avoid structural damage or nuisance flooding.
- Firmly anchored splash blocks or hand placed rock can be installed to direct downspout drainage to landscaped areas.
- Ensure that the offsite overflow is sufficiently lower than the building floor elevation to reduce the potential for building flooding.

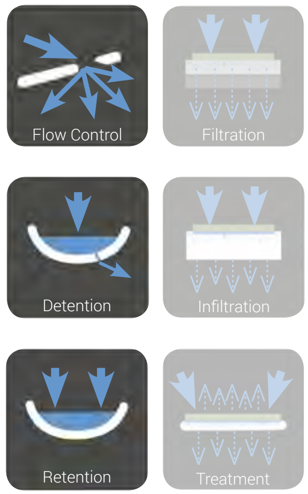
Maintenance

- Clean gutter at least twice a year, and more often if there are overhanging trees. Make sure gutters are pitched to direct water to downspouts.
- Caulk leaks and holes. Make sure roof flashing directs water into the gutters. Look for low spots or sagging areas along the gutter line and repair with spikes or place new hangers as needed.
- Check and clear elbows or bends in downspouts to prevent clogging. Each elbow or section of the downspout should funnel into the one below it. All parts should be securely fastened together.
- Maintain landscaping so that there is positive drainage away from all structures. Don't build up grade, soils, groundcover mulches, or other materials near the building that might inhibit positive drainage.

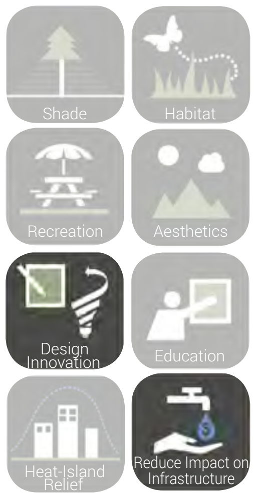
Footnote: #20

Rainwater Harvesting - Cisterns above Ground

Functions



Benefits



Location


Cisterns can store rainwater to be re-used for future landscape irrigation.

Description

- An aboveground rainwater harvesting system captures stormwater runoff, often from a rooftop, and stores the water for later use.
- A rainwater harvesting system consists of four main components including a gutter system that collects runoff from the rooftop and directs it into the cistern, a cistern that stores runoff for later use, an overflow pipe that allows excess runoff to leave the cistern in a controlled manner, and an outlet pipe, sometimes connected to a pump, that draws water from the bottom of the cistern for irrigation use.

Installation

- The most commonly available cisterns are made of plastic, fiberglass, or galvanized metal. The size of the rainwater cistern can have the greatest impact on system cost and performance. Several factors must be considered, including contributing rooftop area, rainfall patterns and anticipated usage.
- The primary constraint in selecting a cistern location is the position of the gutter downspouts. It is generally easiest and most cost effective to place the cistern near an existing downspout. When possible, locate the cistern near the site where water will be used.
- A building, stone or gravel backfill or a poured concrete pad, may be required to provide structural support to an aboveground cistern.
- Some type of overflow or bypass is required to release water when the cistern has reached its capacity.
- To draw water from the cistern, some type of faucet or outlet pipe must be installed.
- An existing gutter system can be easily modified to direct rainwater into a cistern.

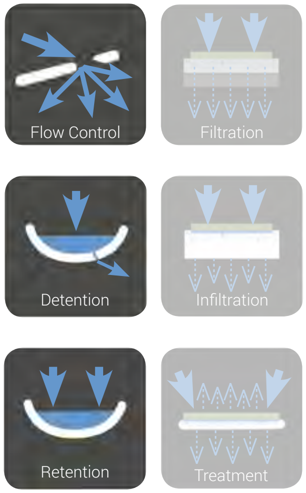
Maintenance

- Regularly check the gutters to make sure debris is not entering the rainwater harvesting system.
- Inspect the screens annually to make sure debris is not collecting on the surface and that there are not holes allowing mosquitoes or other insects to enter the cistern.
- Clean the inside of the cistern twice a year to prevent buildup of debris. Clean out debris twice a year, preferably prior to the beginning of each rainy season.
- Cisterns should be fully enclosed or have screens to prevent mosquito breeding.

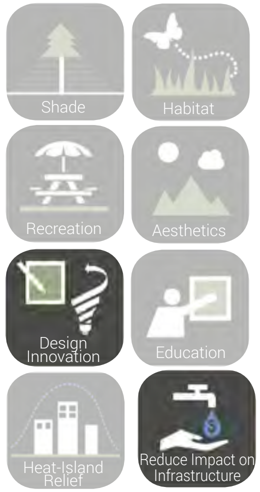
Footnote: #21

Rainwater Harvesting - Cisterns below Ground

Functions



Benefits



Location

Underground cisterns provide storage areas for rainwater reuse.

Description

- A system of gutters and downspouts directs the rainwater collected by the roof to an underground storage cistern. The underground cistern may be preferable where surface space is limited.
- The cistern can supply water to the landscape through a standard pump and pressurized plumbing system.

Installation

- The storage capacity of a rainwater cistern depends on several factors, including the amount of rainfall available for use, the roof-catchment area available for collecting rainfall, the daily water requirements and costs.
- The roof catchment area to be used as the collection surface is usually predetermined by the size of the existing structures and roof area. However, when planning a rainwater collection system from the ground up, the size of the catchment can be designed to suit domestic water needs.
- Cisterns should be located as close as possible to the building or where the water is to be used. They may be incorporated into building structures, such as in basements or under porches. Foundation walls can be used for structural support as well as for containment of stored rain water.
- Cisterns can be constructed from a variety of materials including reinforced concrete, cinder blocks, brick or stone set with mortar and plastered with cement on the inside, ready-made steel tanks, precast concrete tanks, and fiberglass. Cast-in-place reinforced concrete is often the best option for underground cisterns.

Maintenance

- Using a first-flush diverter or sediment trap will reduce sediment inputs into the cistern.
- Check gutter connections every three to four months and after intense rainfall to check for leaking or damage. Clean gutters of leaves and debris as needed and at least prior to each rainy season.
- Maintain pumps or filters used in the rainwater harvesting system in accordance with manufacturer’s recommendations.

Footnote: #22

"Curb cuts allow stormwater from rain events to collect in landscape areas before they enter drain inlets, lowering peak and total runoff in stormwater systems downstream."

Mesa Urban
Garden Retrofit,
Mesa, AZ 2014

Best Practices

Existing Technique - Catch Basin

Current Practice

Catch Basins are normally located at low points in a paved gutter, transferring surface stormwater runoff from streets and parking areas into subgrade pipes, where they are conveyed to outlets at basins, washes or rivers.

Catch Basins often include a sump at the bottom which collects sediment and trash and requires regular maintenance to prevent clogging. Since Catch Basins are concrete structures, they convey nearly 100% of the runoff that enters them into the piped stormwater system.

Catch Basins have been used for centuries to capture surface water and convey it into underground pipes.

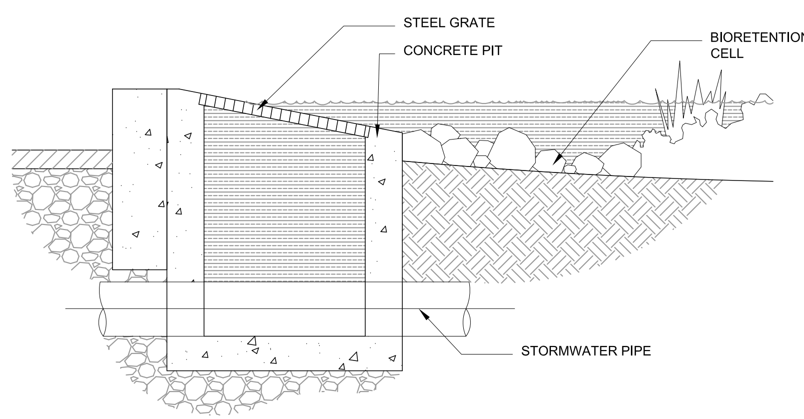
Best Practice - Bioretention Cell

Recommended LID Option

Bioretention Cells allow stormwater to collect in landscape areas and only overtop the basin through the grate when stormwater reaches a certain level. This allows stormwater to infiltrate in the landscape area, supporting vegetation and reducing the need for supplemental irrigation.

Sediment and trash are allowed to settle out in the recessed landscape areas in a basin, where they are visible and can be easily removed by maintenance personnel.

A Bioretention Cell with sloped grate and sediment capture in landscaped area



Bioretention Cell Detail

Existing Technique - Impervious Pavement

Current Practice

Impervious (not porous) surfaces proliferate in urbanized areas, and are the largest contributor to peak stormwater runoff during storm events.

More than 90% of stormwater that lands on the surface of a rooftop, paved street or parking area, will run off into storm sewers or adjacent properties, often causing erosion and flooding in larger storm events.

To mitigate offsite runoff, city code requires new development to retain all stormwater from a 100-year, 2-hour storm event on site. A variety of LID techniques can be used for on-site retention.

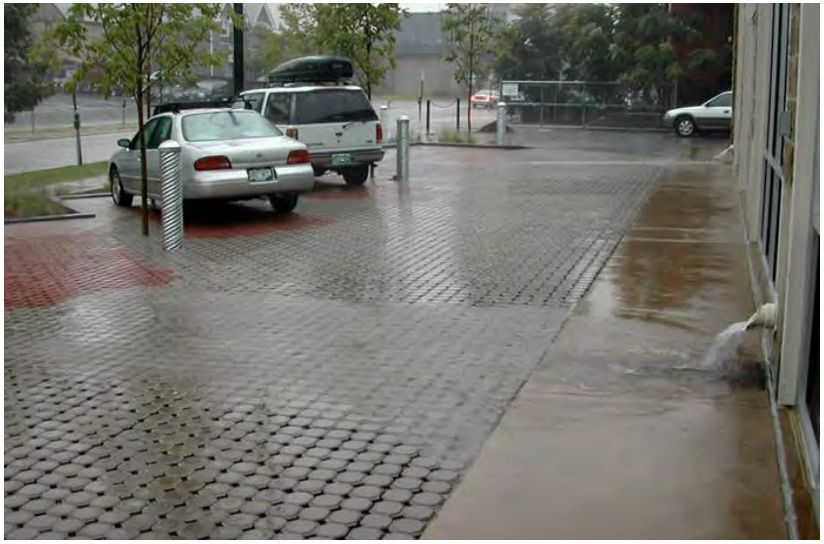
Impervious pavements are typical in urbanized areas, but result in increased volume and velocity of stormwater runoff, affecting downstream hydrology.

Best Practice - Permeable Paving

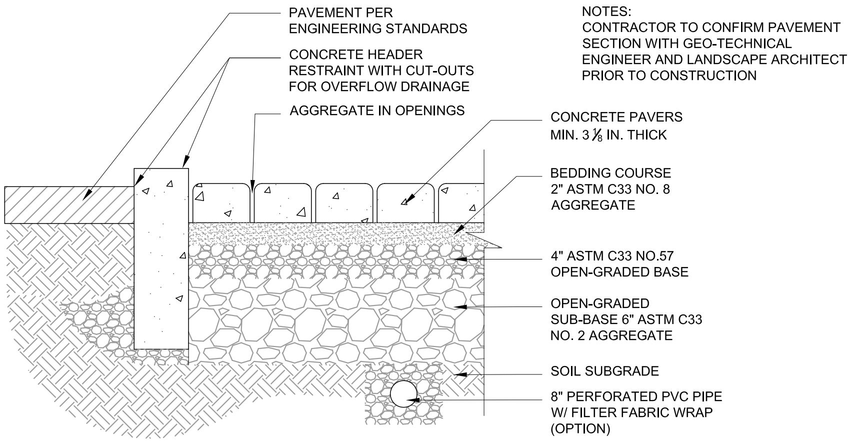
Recommended LID Option

Permeable paving has many potential applications, especially in lower traffic areas, such as sidewalks, parking areas, parallel or diagonal parking strips, alleys, and driveways.

There are several types of permeable pavements, each with their own advantages and disadvantages. Porous pavers (as shown) have a proven track record, adding aesthetic value while providing the ability to convey and store most storm events into a subgrade stone storage layer. Porous asphalt and concrete have been used in limited applications, and must be carefully selected, mixed and regularly cleaned to be successful.



Permeable Pavement can capture most stormwater runoff.



Permeable Pavement Detail

Existing Technique - Raised Curb

Current Practice

Raised curbs work with gutters to concentrate and convey stormwater from one impervious surface to another. They are an important part of traditional stormwater infrastructure design, and in many locations curb and gutter systems are the only means of conveying stormwater into downstream areas.

Curbs also provide an important physical and visual cue for drivers to keep vehicles on the road or parking area, and out of protected areas such as sidewalks and planting areas.

Existing Standard Curbs keep stormwater out of landscaped areas.

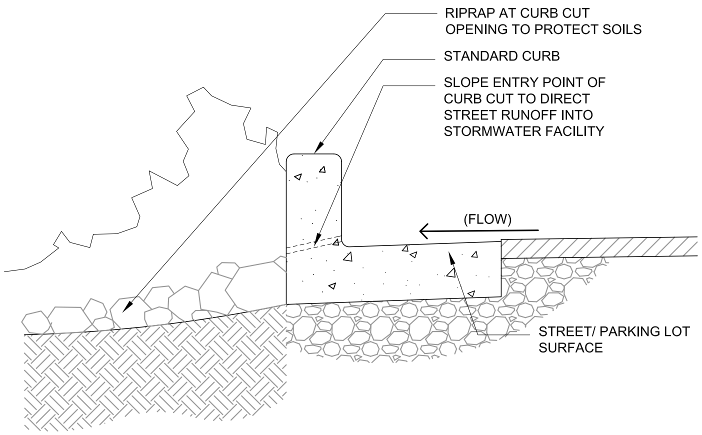
Best Practice - Curb Cuts

Recommended LID Option

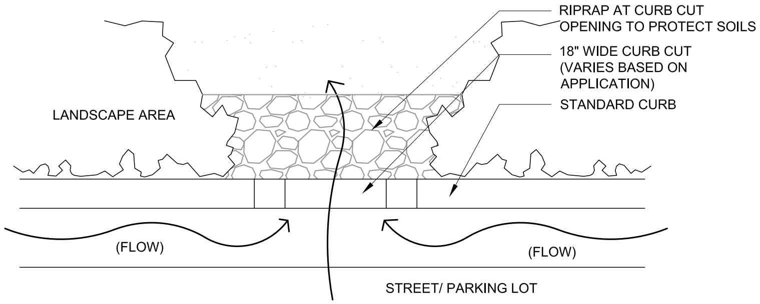
Curb Cuts in normal raised curbs provide conveyance routes for stormwater runoff to enter landscaped areas. Often located at low points in a street or parking area, curb cuts allow stormwater from rain events to collect in landscape areas before they enter drain inlets, lowering peak and total runoff in stormwater systems downstream.

Stormwater runoff into landscape areas provides the added benefits of collecting sediment and sustaining vegetation growth, including street trees and native desert plantings, while reducing irrigation demand from potable water sources.

A Standard Curb Cut allows runoff to enter a lower landscaped area.



Standard Curb Cut Detail (Section)



Standard Curb Cut Detail (Plan)

Existing Technique - Curb and Gutter

Current Practice

Curbs, gutters and drain inlets are traditional ways to convey surface stormwater from paved impervious surfaces to a below grade piped system, where stormwater runoff is handled.

Standard "gray infrastructure" practices such as this treat stormwater as wastewater, to be efficiently moved, along with sediments and pollutants, from its source to an outfall some distance away.

Existing standard curb and gutter conveys stormwater to a piped system underground.

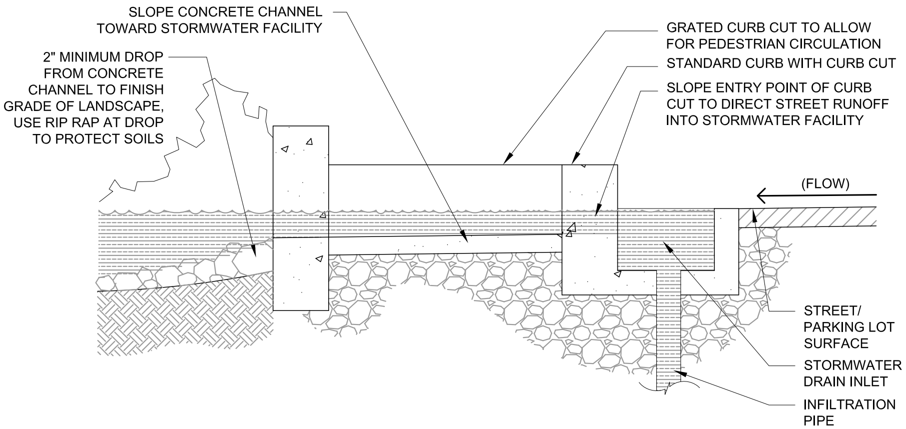
Best Practice - Grated Curb Cuts

Recommended LID Option

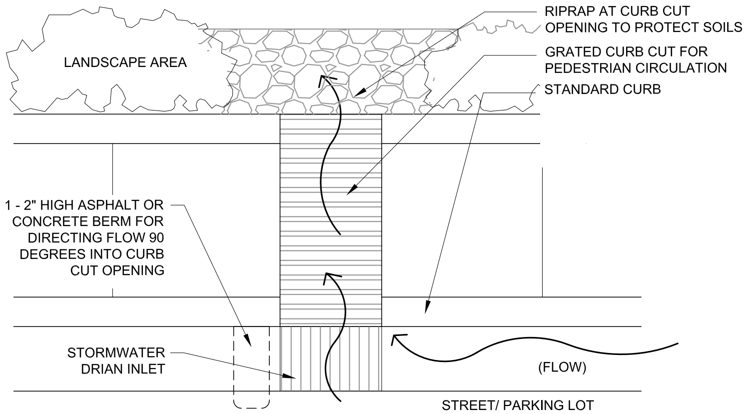
Grated Curb Cuts convey surface stormwater into landscape areas, where smaller events can be detained, sediments and pollutants captured, and vegetation sustained by the supplemental water received when it rains.

Grated Curb Cuts are fabricated of poured-in-place concrete and include a removable precast or ornamental metal grate at the surface grade to allow for pedestrian traffic. Where the drop-off is greater than might be expected at the back of the sidewalk, a low raised curb can be added to keep pedestrians and wheelchairs on the sidewalk.

A Grated Curb Cuts conveys stormwater across a sidewalk



Grated Curb Cut Detail (Section)



Grated Curb Cut Detail (Plan)

Existing Technique - Standard Tree Planters

Current Practice

Street trees are a valuable amenity in our desert climate, providing cooling shade, pedestrian scale and aesthetics that greatly increases the attractiveness of public streets, shopping areas, plazas, courtyards and parking areas.

Conventional street planting practices restrict the area for tree roots to expand, limiting a tree's ability to grow to its full mature size. Root zones are often limited by highly compacted soils below adjacent pavements, and the ability of irrigation systems to provide enough water to support their growth over time.

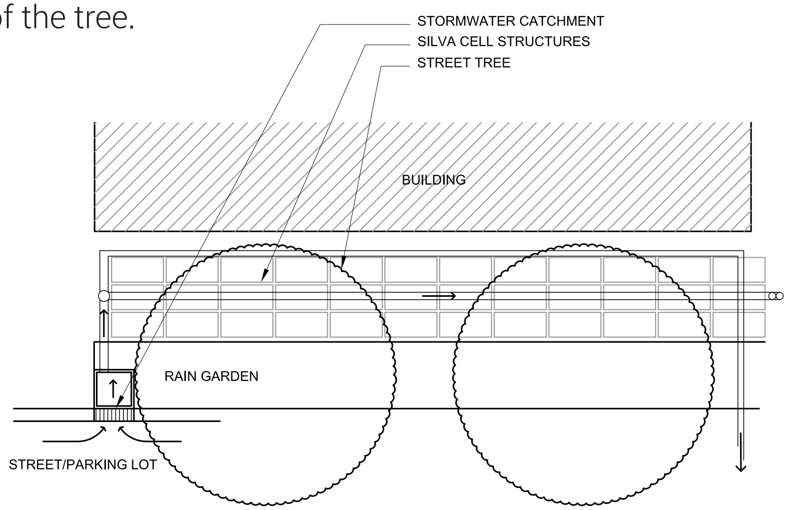
The growth potential and lifespan of trees can be restricted by standard tree planters due to impervious surfaces and compacted subgrades.

Best Practice - Bioretention Planter

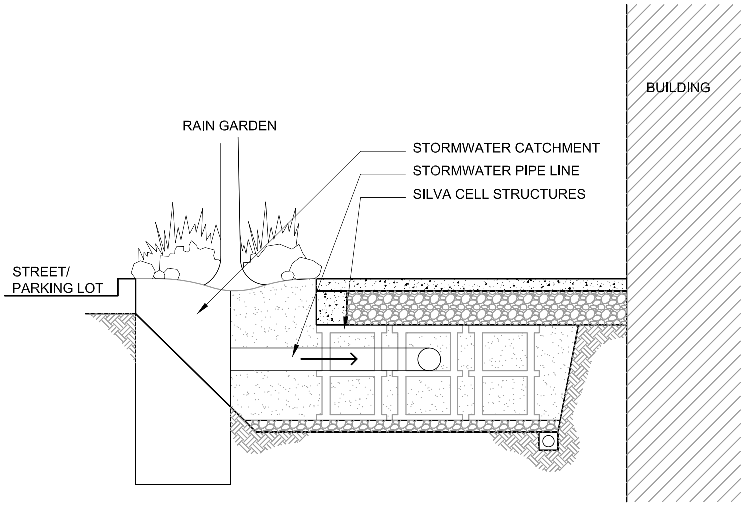
Recommended LID Option

Recent innovations in structural soils and Silva Cells permit urban street trees to be placed in subgrade structures that expand their roots zones below adjacent pavements. Since trees will only grow as large as their roots can expand, ample soil nutrients, oxygen and water are necessary to support that growth. Bioretention Planters support sustained growth of healthier trees. As an added benefit larger subsoil areas, with well-drained soils and healthy root systems, can accommodate increased absorption of stormwater runoff and use the natural uptake and transpiration of the tree.


Silva Cell tree structures used for LID purposes in Burbank, CA (courtesy Silva Cell Products).



Bioretention Planter Detail (Plan)



Bioretention Planter Detail (Section)

Footnote: #24

Existing Technique - Downspouts Connected to Storm Drains

Current Practice

Stormwater from impervious building roof areas are often conveyed directly to the street or stormwater system.

Landscaped areas around buildings normally use potable water to irrigate vegetation that will not otherwise survive in our desert environment.

Landscapes do not always take advantage of the water available from stormwater runoff from adjacent impervious surface such as rooftops, sidewalks and driveways.

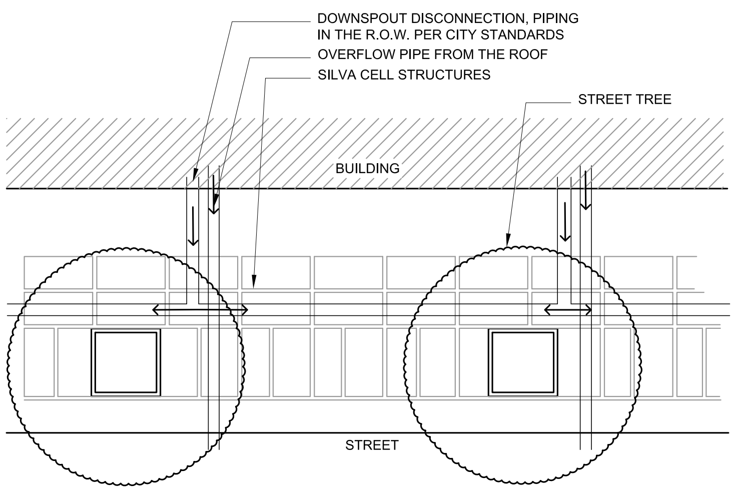
Best Practice - Disconnected Downspouts

Recommended LID Option

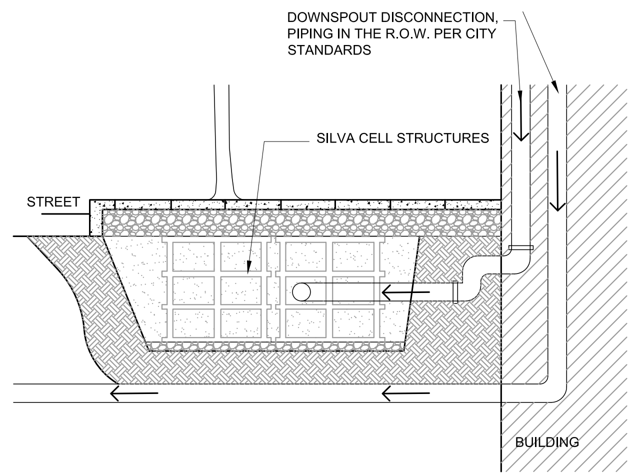
Rooftop stormwater can be conveyed to planted areas in adjacent landscapes by disconnecting downspouts, or by piping directly into Bioretention Planters as shown in the detail below.

As an added benefit, well-drained soils and healthy root systems can accommodate increased capacity of stormwater runoff into a subgrade reservoir, which can absorb it using the natural uptake and transpiration of trees, and infiltration into subsoils.

Disconnected downspouts, with or without subgrade connections supplement irrigation of landscape planters.



Disconnected Downspout to Bioretention Planter Detail (Plan)



Disconnected Downspout to Bioretention Planter Detail (Section)

Footnote: #25

Museum of the West,
Scottsdale, AZ 2015
Note: Winter months
when trees are
dormant.

"The bioswale provides much needed green space and supports trees whose shade also helps mitigate the heat island effect in this urban environment."

Supporting Information

Case Study - Taylor Mall

City of Phoenix and Arizona State University Downtown Campus

Data

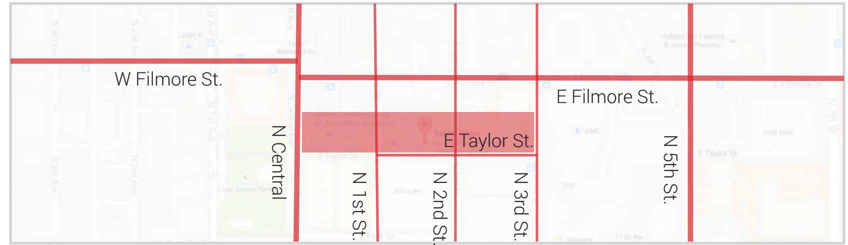
- Location: Taylor Street and 3rd Street, Phoenix, AZ
- Size: 100,000 SF, or approximately 2 acres
- Owner: City of Phoenix
- Completed: September, 2007

Project Specifications

- At the heart of the downtown ASU campus, this project serves as an outdoor classroom for students wanting to learn about current green building techniques. Its use of permeable pavement surfaces, water harvesting techniques, local and native materials, and its demonstrated reduction of the urban heat island effect by providing shade, are examples of these techniques. The project also uses recycled air conditioner condensate (stored in a cistern) to create an oasis effect, making water visible and celebrating its importance in our arid climate, and supporting the beauty and diversity of Sonoran Desert vegetation.
- 2nd Street to 3rd Street: The existing street was removed and replaced with a narrower road with permeable paver parking bays. Curb cuts installed along the north side of the street collect street stormwater into a bioswale. The bioswale provides much needed green space and supports Palo Brea trees whose shade also helps mitigate the heat island effect in this urban environment.
- Central Ave to 1st Street: Previously completely covered with an asphalt parking lot, vehicle traffic was removed with the exception of fire and loading access. Impervious surfaces were reduced by using porous concrete, stabilized decomposed granite and unit pavers. A continuous bioswale through the project collects and distributes stormwater for reducing potable water use in the landscape.

Estimated Cost

- Estimated Cost of stormwater project: up to $5 million (Public funding: local)
- Related Information: Project covers 3 blocks of downtown Phoenix



which spans from Central Avenue to 3rd Street. From Central to 1st Street, landscape cost approx. $850,000.; from 1st Street to 2nd Street: cost unknown; from 2nd Street to 3rd Street: approx. $750,000.

Summary

Performance Measures: 1. Stormwater reduction performance analysis: no data available, but would assume at least 50% of the stormwater is retained on site. 2. Community and economic benefits that have resulted from the project: as part of the new campus, this area has been completely renovated with the addition of student housing, renovated structures which now house classrooms, reduction of street width resulting in a pedestrian corridor which now links students and downtown visitors to adjacent entertainment avenues and a central park.

DESIGN FEATURES: The bioswale was inspired by the historic canals that once traversed this area just south of Taylor Street. Canals were integral to the setting of this region and were used to move and regulate water throughout the community. This project was an opportunity to re-envision the canals as stormwater and air conditioning condensate collection points from the adjacent structures for use in the landscape. Curb cuts were included along the street and sidewalk to collect stormwater. Air conditioner condensate is re-directed to a beautiful rectangular natural cast-in-place cistern. The water feature nourishes the landscape and provides a visual story of our connection to nature.

LID Practices Utilized

- Curb cuts
- Vegetated swale
- Permeable pavers
- Permeable paving
- Cistern

Footnote: #25

Water features can harvest rainfall, making water visible and celebrating its importance in an arid climate.

Grated curb cuts convey stormwater from pavement into planting areas.

Porous pavers and permeable pavement at the pedestrian walkway allows infiltration and reduces offsite runoff.

Standard curb cuts open up planting areas to receive stormwater flow.

CASE STUDY
– SCOTT AVENUE REVITALIZATION

SCOTT AVENUE, FROM BROADWAY TO 14TH STREET, TUCSON, AZ

Data

- Location: Scott Avenue, from Broadway to Cushing/14th Street
- Size: Three blocks; approximately 1/4 mile long
- Owner: City of Tucson Department of Transportation
- Completed: May, 2009

Project Specifications

- The majority of the benefits are derived from the large number of trees included in the project that obtain some of their water needs from stormwater harvest basins and curb cuts.
- Sonoran Desert vegetation provides shade to the adjacent walkways and a reduction in the urban heat island effects. A portion of the Presidio Trail, an historic walking trail throughout downtown, was highlighted with glass aggregate pavers and solar powered paver lights.

Estimated Cost

- Estimated construction: $37 million
- Funding Source: City of Tucson
- Maintenance: City of Tucson Downtown Partnership

Summary

FINISHED PROJECT DESCRIPTION: Scott Avenue is an attractive, shady pedestrian scaled streetscape. Sidewalks are a comfortable 8' wide minimum; they accommodate crowds attending the theater due to their spacious width and the tree canopies provide climate control. Landscape is lush but comprised of native materials. The natives have low water requirements which are supplemented by water harvesting practices which capture significant flows from rainfall events. New site furnishings include benches, bicycle racks, trash/recycling receptacles and drinking fountains. Solar powered art created a welcoming statement at the entrance to Scott Avenue. These gateway features illustrate through pictures and text the historic and cultural significance of Scott Avenue.

DESIGN FEATURES: Pedestrians were the focus of the design. The pavement section was narrowed from 55' curb to curb, to a varied 22' to 33' width. This allows for wider sidewalks and pedestrian walkways. Water harvesting was an integral part of the design, not an add on. The harvesting principles supplemented the plant water requirements, but also mitigated storm events by decreasing water in the street. New, more comprehensive and energy efficient street and pedestrian lighting was installed, fitted with white lighting for better color rendition.

LID Practices Utilized

- Vegetated swales
- Curb cuts
- Bioretention planters
- Native vegetation/canopy

Footnote: #26

Sidewalks are comfortable as the mature tree canopies provide ample shade.

Curb cuts at the street edge capture significant flows during rainfall events.

Arid LID landscape is comprised of native materials, such as contoured berms, groundcovers and native plants.

CASE STUDY - TEMPE TRANSPORTATION CENTER

200 E 5TH STREET, TEMPE, AZ

Data

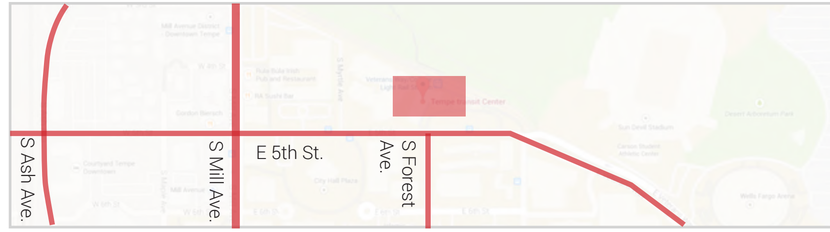
- Location: Tempe, AZ
- Size: up to 5 acres
- Owner: City of Tempe, Arizona
- Completed: 2008

Project Specifications

- The Transportation Center, Courtyard and Transit Center represent a confluence of transportation modes including light rail, bicycle, neighborhood and regional transit, and pedestrian. Located in the heart of Downtown Tempe, the transit center serves the light rail station, provides a bicycle valet and maintenance service, is within walking distance of Arizona State University and Downtown Tempe and provides access to regional bus routes and extensive neighborhood circulators. The building is certified LEED Platinum and includes a vegetated green roof. Stormwater is collected under the bus plazas for reuse to irrigate the roof and transit center plaza trees and plants.
- This project was an initiative by the City of Tempe to promote green building and infrastructure.
- It involved redevelopment of an existing 2-acre surface parking lot with minimal landscape.

Estimated Cost

- Estimated Cost: $200,000 (design)
- Publicly funded



Summary

Stormwater reduction performance analysis: 100% retention in underground storage tanks; approx. 20% siphoned off, filtered and stored for irrigation purposes. Local codes prohibit use of all the water: greywater system not allowed for irrigation use, even to the vegetated roof which has restricted access; stormwater retention must be fully drained within 36 hours per local codes even if underground.

Community and economic benefits that have resulted from the project: This project provides access to a light rail station by bus, pedestrian or bicycle; it has created 2 new businesses - a Bike Cellar and adjacent restaurant; it provides office space for city staff; leasable space on the third floor is available to private organizations; retail space is available for a restaurant or retail shop.

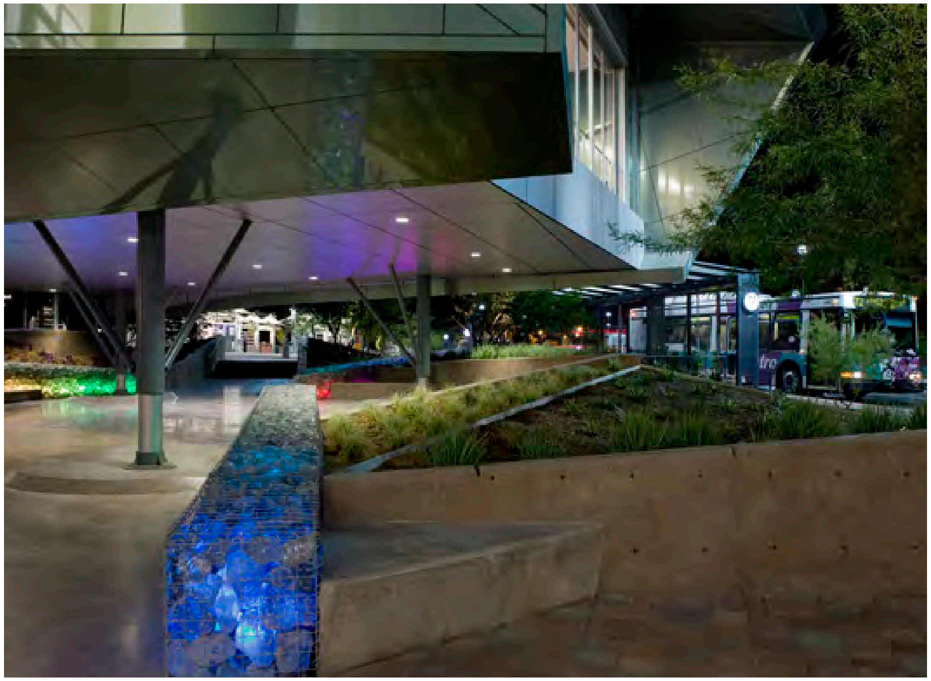
LID Practices Utilized

- Green roof
- Cistern
- Permeable pavers

Footnote: #27

Green roofs absorbs rainwater, provides insulation and creates wildlife habitat. It also helps to lower adjacent air temperature, mitigating the heat island effect.

Native tree canopies provide cooling in the plaza area.



Native materials, used in urban forms, help create a gathering area for people using the Tempe Transit Center.

Shade structures at transit stations can harvest rainwater and use it to nourish a green wall.

CASE STUDY
– UNIVERSITY OF ARIZONA CAPLA

COLLEGE OF ARCHITECTURE, PLANNING AND LANDSCAPE ARCHITECTURE, TUCSON, AZ

Data

- Location: 1040 N. Olive Road, UA campus
- Size: 0.21 Acres (9,066 sq. ft.)
- Owner: Arizona Board of Regents on behalf of University of Arizona CAPLA (College of Architecture +Planning + Landscape Architecture)
- Completed: 2007

Project Specifications

- CHALLENGE: CAPLA faculty wanted an interpretive learning experience with a range of materials. A fun oasis and attraction for existing and future students, and professors of the CAPLA program. Parking lot runoff all seemed to drain to future building entry space.
- SOLUTION: A new entry and garden/outdoor classroom to provide cleansing biosponge garden for adjacent runoff and discarded building water.
- PERFORMANCE MEASURES: 1. Use local materials. 2. Conserve water by totally integrating building mechanical systems waste water: roof runoff, drinking fountain greywater, university well 'blow off' (backwash from well's sand filter) and HVAC condensate, into landscape. 3. Create sustainable livable space. 4. Reduce urban heat island (UHI) effect 5. Reduce flooding around building.

Estimated Cost

- Estimated Cost: $650,000 (planting, irrigation, lighting)
- CONSTRUCTION: Hardscape constructed for approx. $200,000.

Summary

FINISHED PROJECT DESCRIPTION: 1) Reclaimed 1.2 acres of parking lot to create a Sonoran Desert biotic community landscape; 2) Native fauna introduced (endangered fish and frogs) or immigrated (road runner; gray fox) have thrived; 3) Repopulation and active predation activities have been observed; 4) Establishment period (first 3-5 years) reduced potable water use by 83% (280,000 gallons annually); 5) After establishment, use of potable water should be eliminated; and 6) Reused brick and concrete, salvaged from the partial building demolition, to line the Desert Riparian channels.

DESIGN FEATURES: 1) Stormwater runoff is reduced significantly in the landscape; 2) Landscape fully integrated with building mechanical systems; 3) ET rates integrated into high efficiency drip irrigation system; 4) Significant terrestrial and aquatic habitat created; 5) Utilizes up to 250 gallons/day of well water backwash that previously went to stormwater drainage system; 6) High efficiency drip irrigation system is controlled by monitoring ET rates; and 7) 11,500 gallon water tank (7' diameter x 38' tall)

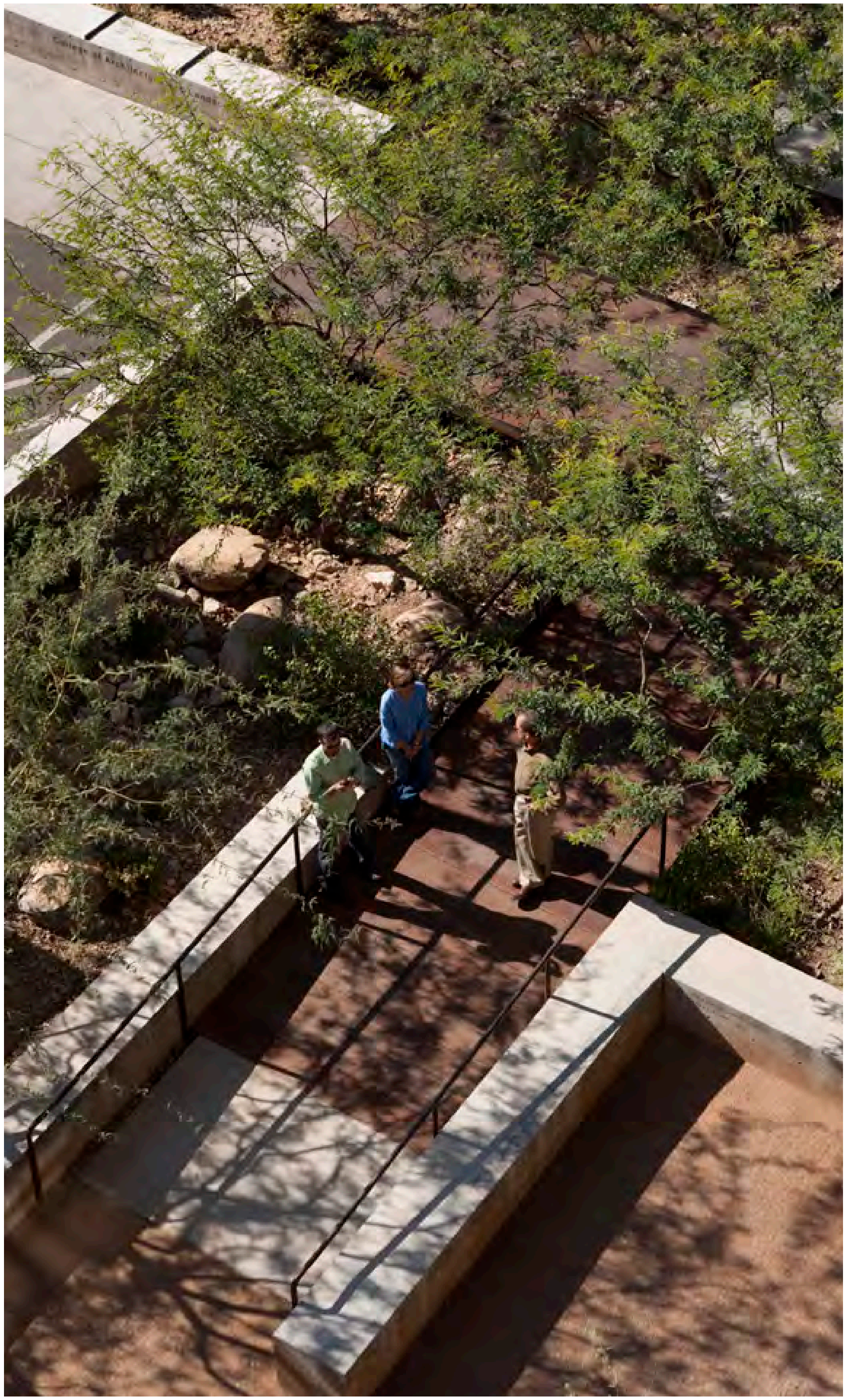
LID Practices Utilized

- Permeable pavement
- Disconnect impervious surfaces
- Cisterns or underground cisterns
- Native vegetation/canopy
- Infiltration techniques
- Use of condensate

Footnote: #28

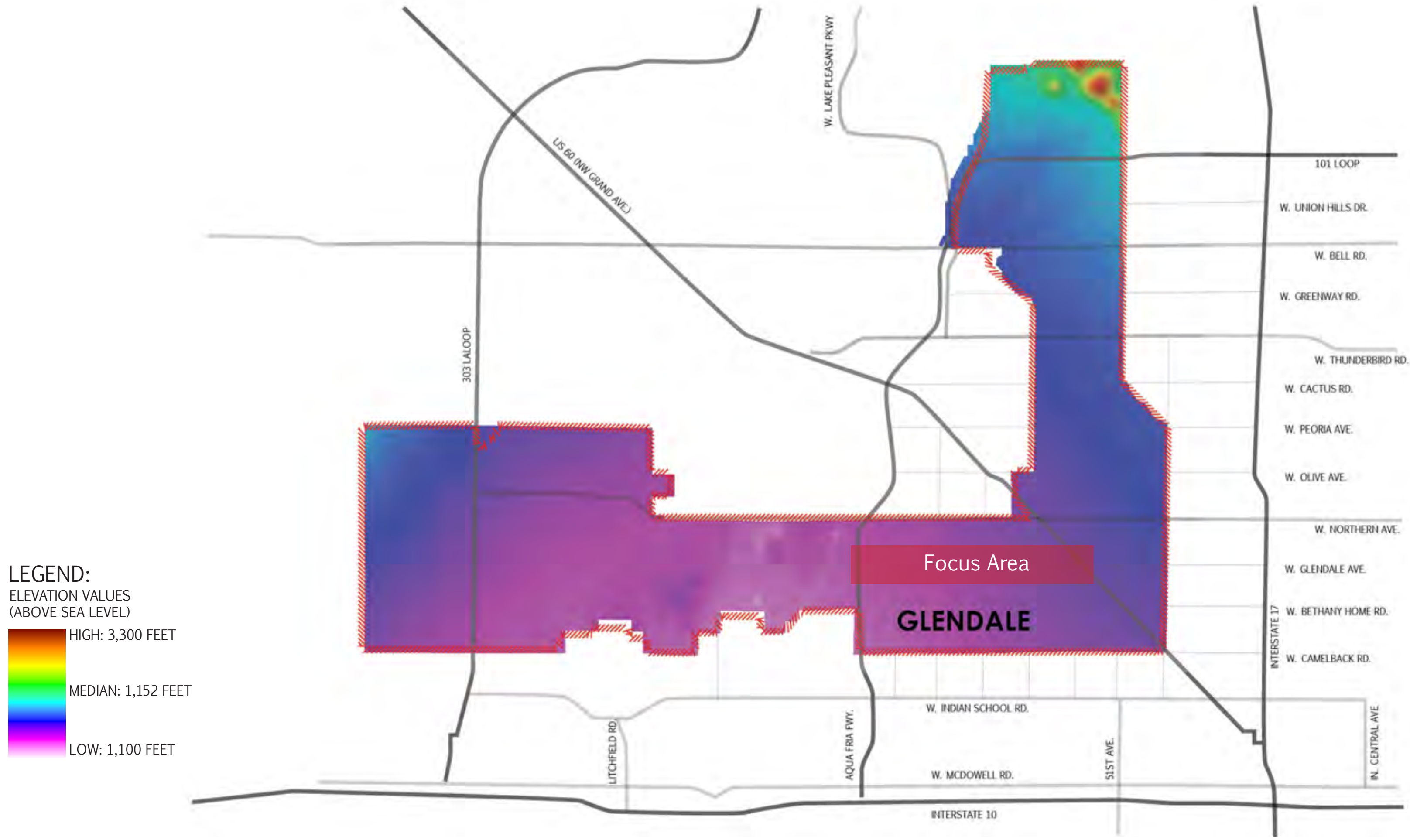
A new entry and garden/outdoor classroom provide cleansing gardens for adjacent buildings and pavement runoff.

Stormwater runoff is reduced significantly because of the landscape and is fully integrated with building mechanical systems.



Pedestrian walkways provide shady comfort.

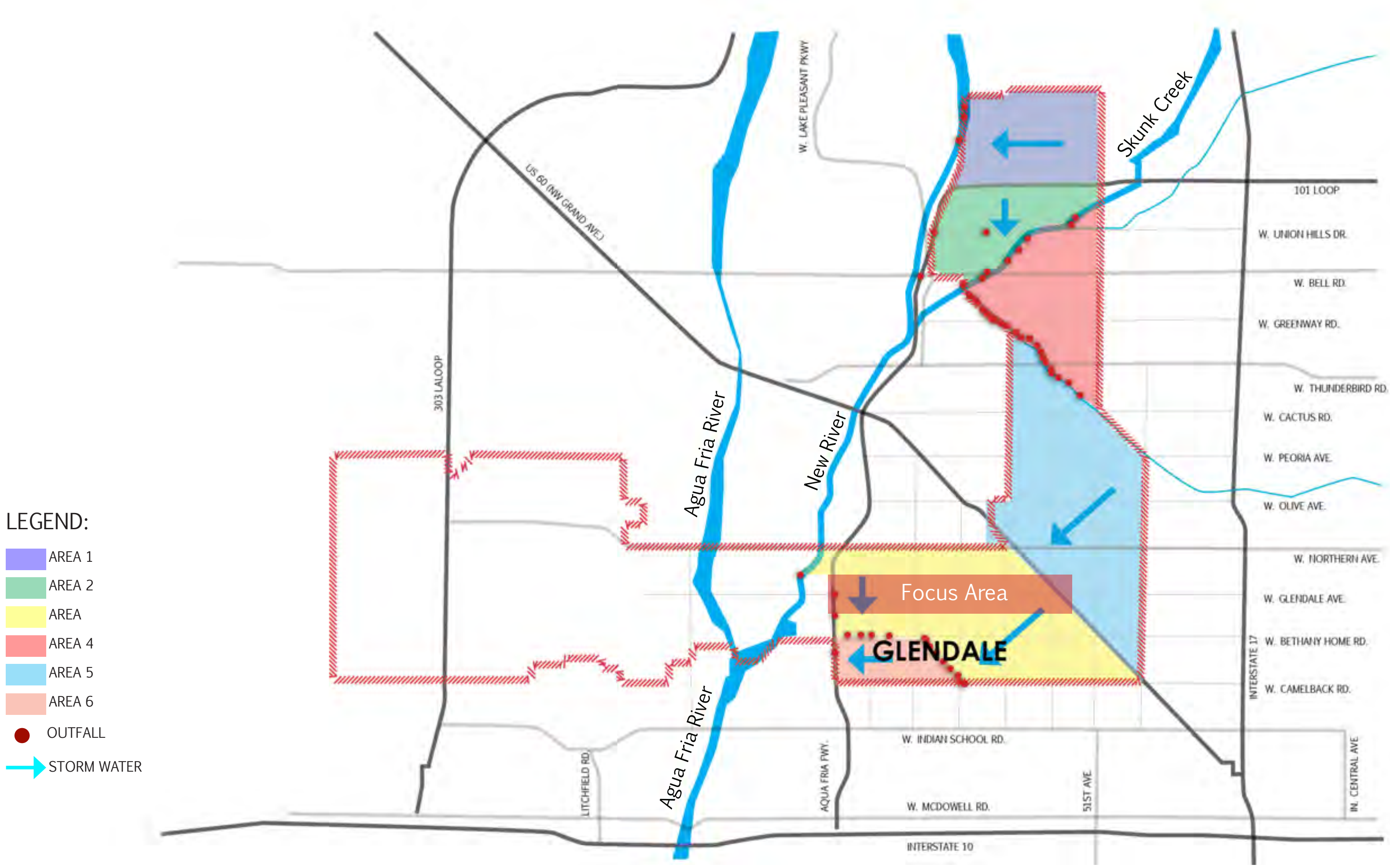
City-wide elevation map



City-wide Elevation Map

This map shows the surface elevation change from high points to low points within the city's municipal planning area. In the eastern segments of the City surface water generally flows from northeast to southwest. In the west it flows east to the Aqua Fria River.

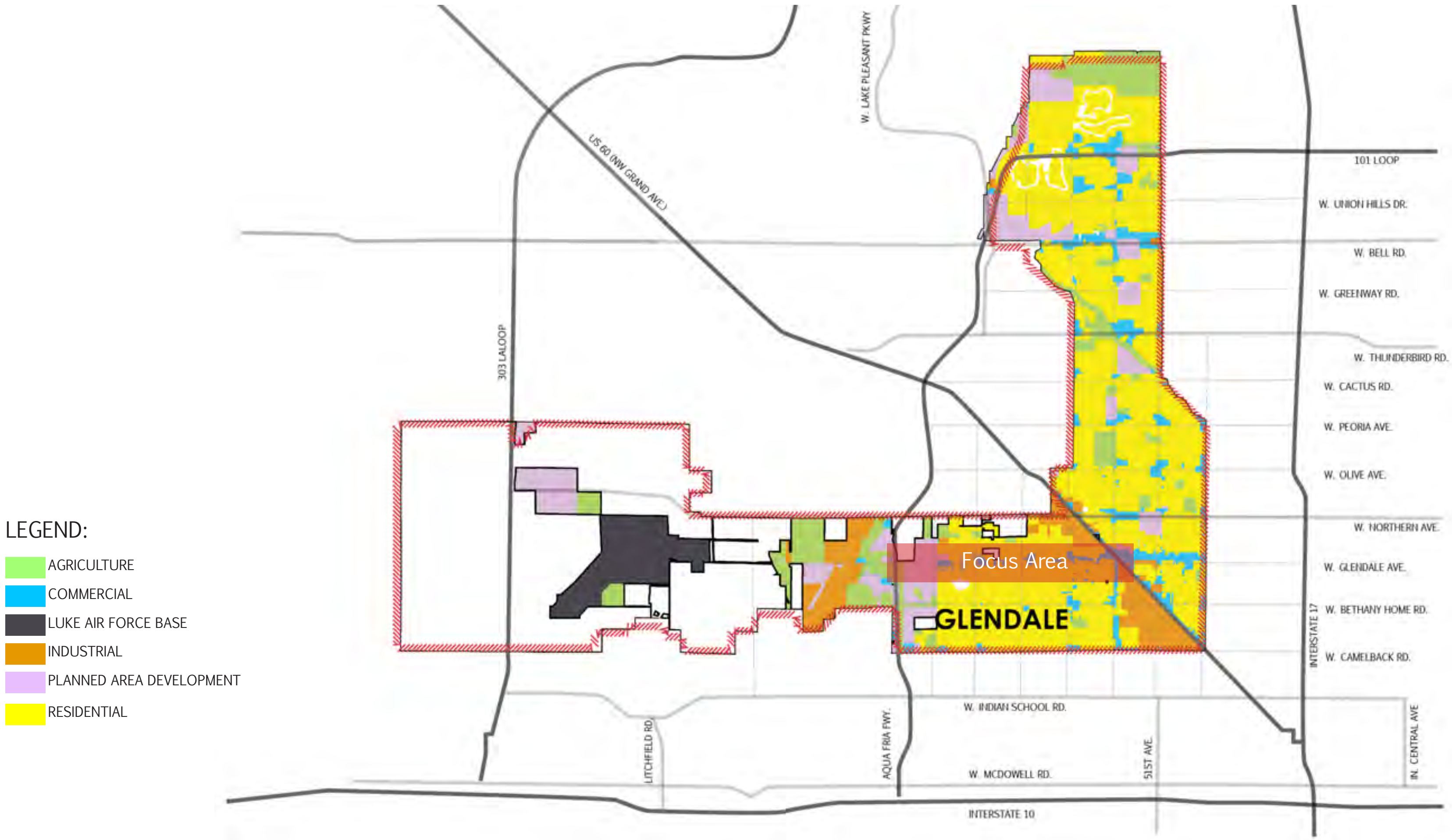
City-wide stormwater drainage map



City-wide Stormwater Drainage Map

Surface stormwater flows are interrupted by development in the watershed, including buildings, highways, and canals. These developments increase runoff and function as barriers that collect stormwater and convey it through channels and underground pipes. The stormwater system directs water, as well as sediment and pollutants, from the pipes to outfall locations, where they enter natural water courses. This map depicts major barriers and outfalls in the City, including US 60/Grand Avenue, the 101 and 303 Freeways, major canals, and rivers that affect urban surface hydrology.

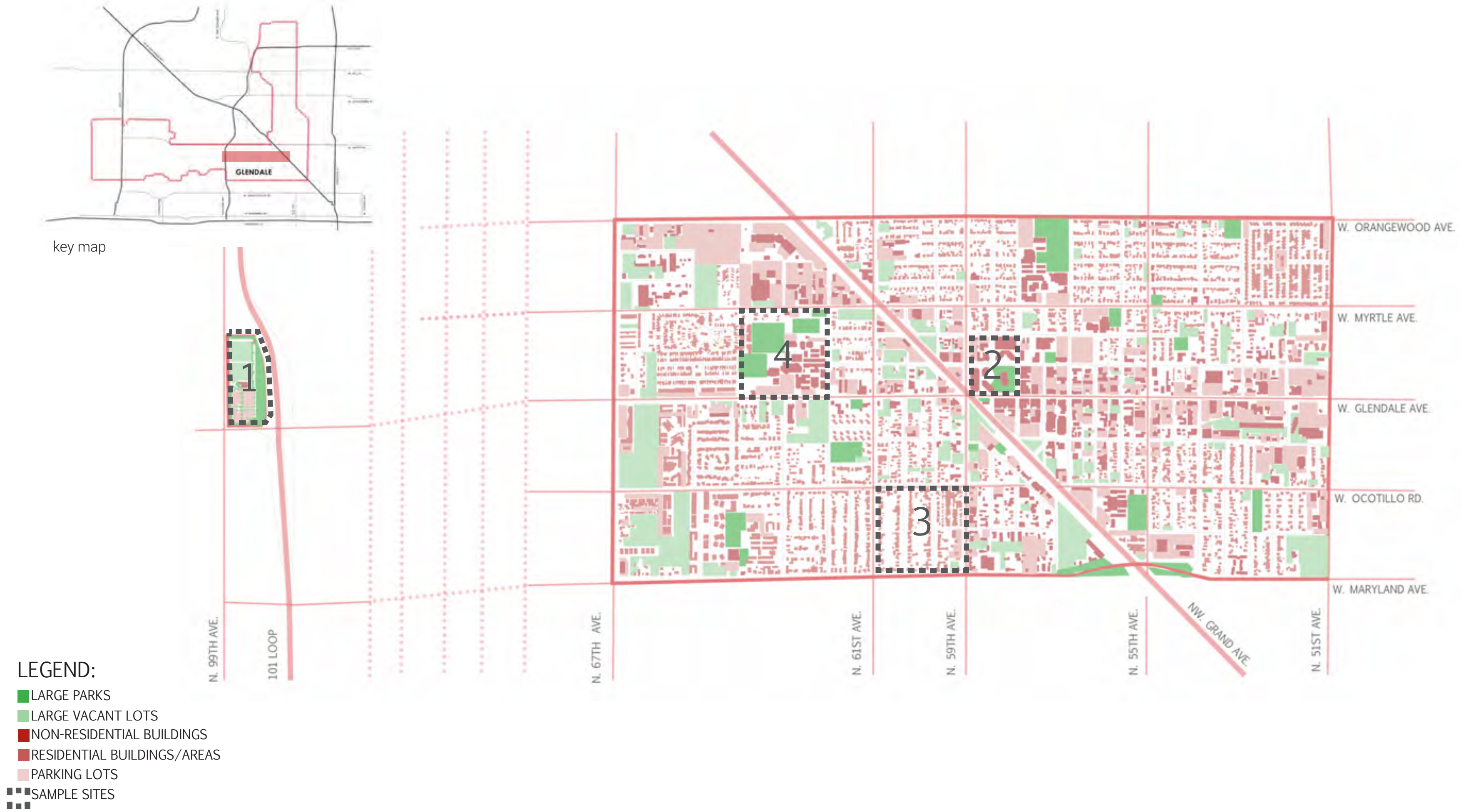
City-wide Land-use map



City-wide Land Use Map

Land uses within the city range from residential to industrial and from high density to low. Different combinations of land use type and density will influence the selection of stormwater management tools. The mixed-use high-density downtown and entertainment district area was selected for the project focus area because it covers several varieties of land uses and redevelopment opportunities to test different tool kit application scenarios.

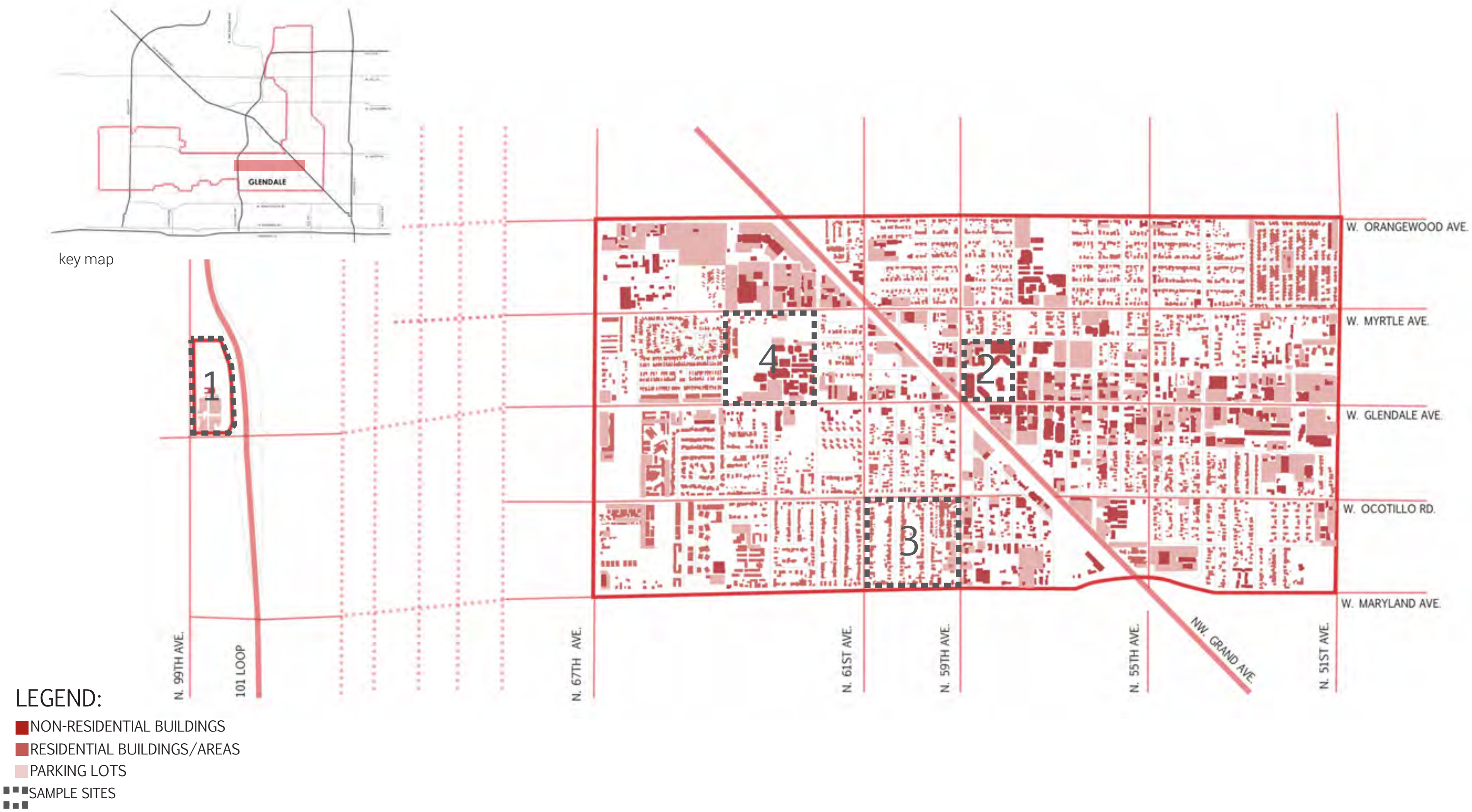
FOCUS AREA



Sample Sites in Focus Area

Within the focus area, four sample sites were selected for stormwater catchment calculation study and analysis. Each of these areas has different land use characteristics and site features. The sample areas include a parking lot, a city government block, a residential area, and an institutional area.

FOCUS AREA: IMPERVIOUS SURFACES



Impervious Area

This map shows the general distribution of impervious areas from development, such as pavements for roads and parking, and residential and commercial building rooftops within the focus area. Impervious surfaces shed rainwater, contributing to increased runoff volume and velocities during storm events. Increased peak and total stormwater runoff can contribute to flooding, erosion, sedimentation, and property damage if not properly managed. Conventional piped conveyance systems designed to handle these peaks, are a costly part of the city's stormwater infrastructure.

FOCUS AREA: PERVIOUS SURFACES

Pervious Area

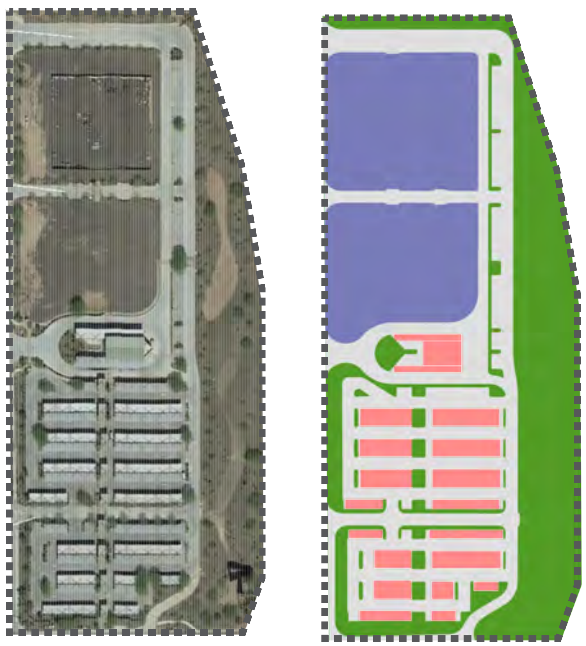
This map identifies larger areas within the downtown focus area, where much of the surface area is open space or landscaped. In these pervious areas, stormwater infiltrates through porous soils and is absorbed by vegetation, so that stormwater runoff behaves much like it did prior to development. Landscaped areas are able to store and infiltrate stormwater, reducing peak and total surface flows during storm events, and treating it to remove sediment and pollutants. Landscaped areas also provide multiple benefits that reduce urban heat islands by providing shade, and add value to neighborhoods by providing recreation opportunities and planted buffers.

SAMPLE SITE 1: PARKING LOTS

key map

Glendale averages 9.14 inches per year according to the National Weather Service. Rainfall amounts fluctuate widely during the year. A month by month breakdown can be found in the Appendix.

Surface runoff coefficients represent the relative perviousness of the groundcover with 1.0 being completely impervious (all stormwater runs off) to 0.0 (nothing runs off).



Rainwater Catchment Surfaces
Scale: 1"=400'

Potential Rainwater Harvesting

	Rainfall Amount (Yearly)	Surface Coefficient	Catchment Area (square foot)	Total Yield of Harvested Rainwater (Gallons)
Roof	9.23	0.95	*60,000*	*327, 767*
Vegetated Area	9.23	0.17	*216,000*	*211, 151*
Parking & Road	9.23	1	*352,000*	*2, 024, 102*
Vacant Lots	9.23	0.6	*174,000*	*600, 320*

The table above represents the approximate volume of stormwater that currently runs off, and is available for rainwater harvesting each year, given existing conditions in the area. Total volume of runoff is calculated as:

Rainfall (in) x Catchment Area (sq ft) x Runoff Coefficient x 0.623* = Total Yield

(*0.623 converts inches-square feet to gallons)

Portions of the Park and Ride site utilize Porous Pavements, which are not included in runoff calculations. For complete calculations please see the tables in the Appendix.

Site Description

Glendale Park and Ride located at West Glendale Avenue and 101 freeway loop, serves as a parking lot and transportation center for the city of Glendale. The study area shown on the map is about 18 acres (802,000 sf).

Site Conditions

- Building Roof area: The site has 388 car spaces with 345 covered. The total roof area is about 1.5 acres (**60,000 sf**).
- Parking areas and roads: The site has 8 acres (**352,000 sf**) of road and parking area without cover in total.
- Vegetated area: The total vegetated area is about 5 acres (**216,000 sf**), including parking lots islands, street landscapes and one large storm water basin area.
- Vacant lots: There are two pieces of undeveloped land on the site, which occupy about 4 acres (**174,000 sf**).

Data Analysis

- As the catchment calculation table on the previous page illustrates, total impervious surface (including roof, parking, and road areas) will collect approximately 2 million gallons of rainwater each year.
- Vegetated areas and vacant lots generally compose the remaining (pervious) surface areas which collect approximately 1 million gallons of water yearly.
- To slow and clean surface flows during storm events, while harvesting rainwater for the benefit of landscape areas, impervious surfaces can be reduced and connected to LID landscape areas.

Potential LID Strategies

Several LID strategies could be applied in this area to achieve reductions in stormwater flows, and improvements in water quality:

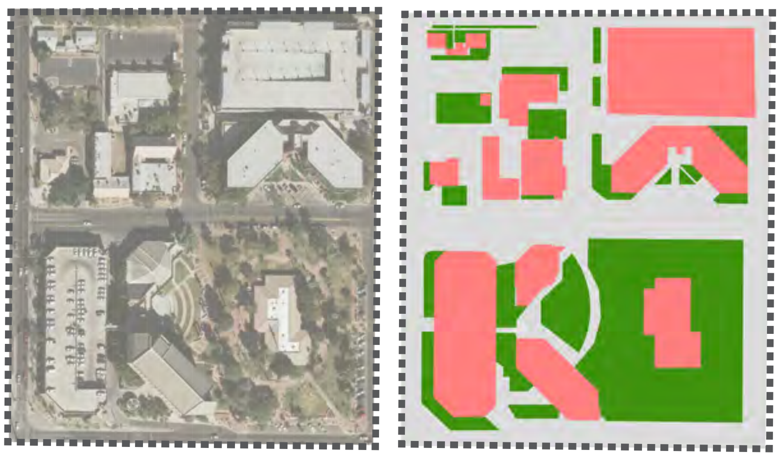
- Curb cuts: modifying existing curbs in parking and street landscape areas to collect surface water from adjacent pavements. This will allow quick and inexpensive ways to implement LID and rainwater harvesting.
- Vegetated swales: creating vegetated swales to guide runoff from paved areas to storm sewer inlets, can improve water quality by slowing and filtering storm runoff and provide interesting landscape treatments that support denser stands of vegetation.
- Bioretention areas: creating shallow depressions in landscape areas that typically include plants and ground cover will provide increased groundwater recharge and pollutant treatment.
- Infiltration and under drains: As part of a localized stormwater solution, drain-fields can promote storm water infiltration into subsoils. These drain-fields can reduce offsite stormwater runoff by storing and infiltrating it onsite.
- Cisterns: Above- or belowground, cisterns capture stormwater runoff from impervious surfaces, such as building rooftops, and store rainwater for later landscape irrigation use.

SAMPLE SITE 2: GOVERNMENT CENTER

key map

Glendale averages 9.14 inches per year according to the National Weather Service. Rainfall amounts fluctuate widely during the year. A month by month breakdown can be found in the Appendix.

Surface runoff coefficients represent the relative perviousness of the groundcover with 1.0 being completely impervious (all stormwater runs off) to 0.0 (nothing runs off).



Rainwater Catchment Surfaces
Scale: 1"=400'

Potential Rainwater Harvesting

	Rainfall Amount (Yearly)	Surface Coefficient	Catchment Area (square foot)	Total Yield of Harvested Rainwater (Gallons)
Roof	9.23	0.95	*200, 059*	*1, 092, 877*
Vegetated Area	9.23	0.17	*172, 000*	*168, 138*
Parking & Road	9.23	1	*317, 910*	*1, 828, 075*

The table above represents the approximate volume of stormwater that currently runs off, and is available for rainwater harvesting each year, given existing conditions in the area. Total volume of runoff is calculated as:

Rainfall (in) x Catchment Area (sq ft) x Runoff Coefficient x 0.623* = Total Yield

(*0.623 converts inches-square feet to gallons)

For complete calculations please see the tables in the Appendix.

Site Description

The site is constituted by government blocks and commercial blocks, which is located at West Glendale Avenue and North 58th Avenue. The study area shown on the map is about 16 acres (**690,000 sf**).

Site Conditions

- Building Roof areas: The total roof area of the site is about 5 acres (**200,000 sf**), which is comprised of institutional buildings.
- Parking areas and roads: The site has approximately 7 acres (**318,000 sf**) of paved road and parking areas.
- Vegetated areas: The total landscape area is approximately 4 acres (**172,000 sf**), including parking lot islands, streetscapes and lawn areas.

Data Analysis

- As the table on the previous page illustrates, total impervious surface (including roof, parking, and road areas) will collect approximately 3 million gallons of rainwater each year. Most of this water normally bypasses the site through piped drainage systems.
- Vegetated areas and vacant lots generally compose the remaining (pervious) surface areas which collect approximately 168,000 gallons of water yearly.
- In order to slow and clean surface flows during storm events, while harvesting rainwater for the benefit of landscape areas, impervious surfaces can be reduced and connected to LID landscape areas.

Potential LID Strategies

Several LID strategies could be applied in this area to achieve reductions in stormwater flows, and improvements in water quality:

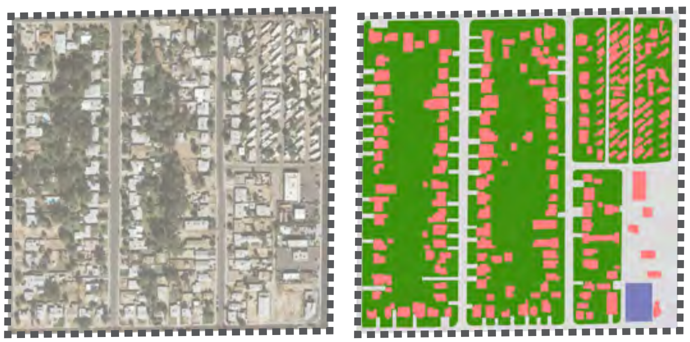
- Curb cuts: modifying existing curbs in parking and street landscape areas to collect surface water from adjacent pavements. This will allow quick and inexpensive ways to implement LID and rainwater harvesting.
- Vegetated swales: creating vegetated swales to guide runoff from paved areas to storm sewer inlets, can improve water quality by slowing and filtering storm runoff and provide interesting landscape treatments that support denser stands of vegetation.
- Bioretention areas: creating shallow depressions in landscape areas that typically include plants and ground cover will provide increased groundwater recharge and pollutant treatment.
- Permeable paving: replacing existing impervious pavements with porous paving, especially in parking areas and driveways, can provide additional storage and reduce runoff into stormwater systems. It also filters first-flush contaminants prior to discharge and helps recharge groundwater.
- Infiltration and under drains: As part of a localized stormwater solution, drain-fields can promote storm water infiltration into subsoils. These drain-fields can reduce offsite stormwater runoff by storing and infiltrating it onsite.
- Cisterns: Above or below ground, cisterns capture stormwater runoff from impervious surfaces, such as a building rooftops, and store rainwater for later landscape irrigation use.

SAMPLE SITE 3: RESIDENTIAL NEIGHBORHOOD AREA

key map

Glendale averages 9.14 inches per year according to the National Weather Service. Rainfall amounts fluctuate widely during the year. A month by month breakdown can be found in the Appendix.

Surface runoff coefficients represent the relative perviousness of the groundcover with 1.0 being completely impervious (all stormwater runs off) to 0.0 (nothing runs off).



Rainwater Catchment Surfaces
Scale: 1"=800'

Potential Rainwater Harvesting

	Rainfall Amount (Yearly)	Surface Coefficient	Catchment Area (square foot)	Total Yield of Harvested Rainwater (Gallons)
Roof	9.23	0.9	*343, 000*	*1, 775, 114*
Vegetated Area	9.23	0.17	*1, 047, 000*	*1, 023, 494*
Parking & Road	9.23	0.9	*333, 000*	*1, 723, 362*
Vacant Lots	9.23	0.6	*18, 000*	*62, 103*

The table above represents the approximate volume of stormwater that currently runs off, and is available for rainwater harvesting each year, given existing conditions in the area. Total volume of runoff is calculated as:

Rainfall (in) x Catchment Area (sq ft) x Runoff Coefficient x 0.623* = Total Yield

(*0.623 converts inches-square feet to gallons)

For complete calculations please see the tables in the Appendix.

Site Description

The site is one of the typical residential areas, which is located at West Ocotillo Road and 59th Avenue. The study area shown on the map is about 40 acres (**1,741,000 sf**) including residential buildings, residential landscapes and community driveways.

Site Conditions

- Building Roof areas: The total roof area is about 7 acres (**343,000 sf**). The materials used for residential rooftops are usually different than for nonresidential building rooftops. They can absorb more water and the coefficient will be a little bit lower.
- Parking areas and roads: The site has 8 acres (**333,000 sf**) of road and parking which is mainly the community driveways.
- Vegetated area: The total vegetated area is about 24 acres (**1,047,000 sf**), mainly constituted by residential landscapes.
- Vacant lots: There is one piece of undeveloped land on the site, which occupies about 0.5 acre (**18,000 sf**).

Data Analysis

- As the table on the previous page illustrates, total impervious surface (including roof, parking and road areas) will collect approximately 3.5 million gallons of rainwater each year. Most of this water normally bypasses the site through piped drainage systems.
- Vegetated areas generally comprise the remaining (pervious) surface areas which collect approximately 1 million gallons of water yearly. Much of this area is in residential yards which have a high potential for integrating LID techniques.
- In order to slow and clean surface flows during storm events, while harvesting rainwater for the benefit of landscape areas, impervious surfaces should be reduced and connected to landscape areas. As much of the area is privately owned, opportunities exist in front yards, homeowners association common land and public parks and open space.

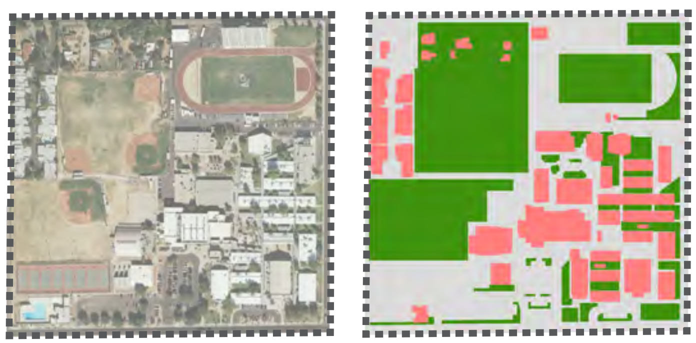
Potential LID Strategies

Several LID strategies could be applied in this area to achieve reductions in stormwater flows, and improvements in water quality:

- Curb cuts: modifying existing curbs in parking and street landscape areas to collect surface water from adjacent pavements. This will allow quick and inexpensive ways to implement LID and rainwater harvesting.
- Vegetated swales: creating vegetated swales to guide runoff from paved areas to storm sewer inlets, can improve water quality by slowing and filtering storm runoff and provide interesting landscape treatments that support denser stands of vegetation.
- Rain Gardens: creating shallow depressions in landscape areas in front yards and common areas, include plants and ground covers that provide stormwater detention, water quality treatment and groundwater recharge.
- Permeable paving: used in driveways and parking areas, porous pavements can provide additional storage and reduce runoff into stormwater systems.
- Infiltration and underdrains: As part of a localized stormwater solution, drain-fields can promote storm water infiltration into subsoils. These drain-fields can reduce offsite stormwater runoff by storing and infiltrating it onsite.
- Cisterns: These have a more limited application in residential uses due to the size required and given our intermittent rains. Storage and distribution of rainwater over an extended period of time can be accomplished through creative grading and storage options.

SAMPLE SITE 4: INSTITUTIONAL BLOCK AREA

key map



Rainwater Catchment Surfaces
Scale: 1"=800'

Glendale averages 9.14 inches per year according to the National Weather Service. Rainfall amounts fluctuate widely during the year. A month by month breakdown can be found in the Appendix.

Surface runoff coefficients represent the relative perviousness of the groundcover with 1.0 being completely impervious (all stormwater runs off) to 0.0 (nothing runs off).

Potential Rainwater Harvesting

	Rainfall Amount (Yearly)	Surface Coefficient	Catchment Area (square foot)	Total Yield of Harvested Rainwater (Gallons)
Roof	9.23	0.95	*317, 000*	*1, 731, 700*
Vegetated Area	9.23	0.17	*679, 000*	*663, 756*
Parking & Road	9.23	1	*842, 000*	*4, 841, 744*

The table above represents the approximate volume of stormwater that currently runs off, and is available for rainwater harvesting each year, given existing conditions in the area. Total volume of runoff is calculated as:

Rainfall (in) x Catchment Area (sq ft) x Runoff Coefficient x 0.623* = Total Yield

(*0.623 converts inches-square feet to gallons)

For complete calculations please see the tables in the Appendix.

Site Description

Glendale High School is located at West Glendale Avenue and North 62nd Avenue. The study area shown on the map is about 42 acres (**1,838,000 sf**), which includes insititutional buildings, several parking lots, and sports fields.

Site Conditions

- Building Roof areas: The total roof area of the site is about 7 acres (**317,000 sf**), which is constituted mainly by institutional buildings and several residential buildings.
- Parking and road area: The site has 19 acres (**842,000 sf**) of road and parking area.
- Vegetated area: The total vegetated area is about 16 acres (**679,000 sf**), including parking lot islands, street landscapes, residential landscapes and two large lawn sports fields.

Data Analysis

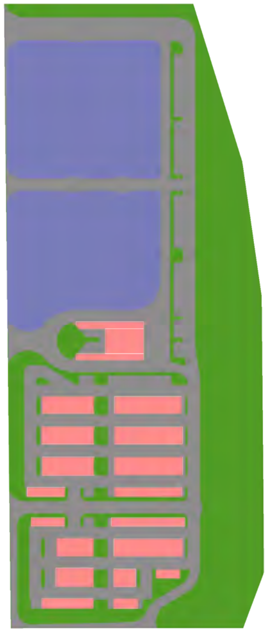
- As the table on the previous page illustrates, total impervious surface (including roof, parking and road areas) will collect approximately 7 million gallons of rainwater each year. Most of this water normally bypasses the site through piped drainage systems.
- Vegetated areas generally comprise the remaining (pervious) surface areas which collect approximately 679,000 gallons of water yearly. Landscape setbacks and buffers in these areas require a significant amount of management and maintenance.
- In order to slow and clean surface flows during storm events, while harvesting rainwater for the benefit of landscape areas, impervious surfaces should be reduced and connected to landscape areas. Large areas exist where LID techniques can be easily implemented on private properties where owners want to reduce their costs of stormwater management.

Potential LID Strategies

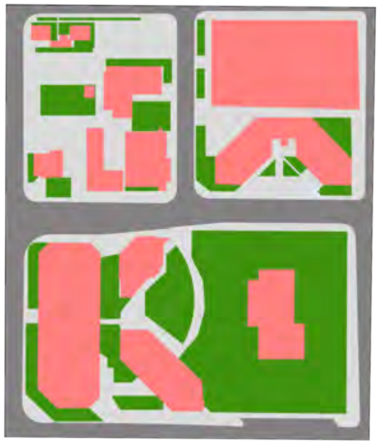
Several LID strategies could be applied in this area to achieve reductions in stormwater flows, and improvements in water quality:

- Curb cuts: modifying existing curbs in parking and driveway landscape areas to collect surface water from adjacent pavements. This will allow quick and inexpensive ways to implement LID and rainwater harvesting.
- Vegetated swales: creating vegetated swales to guide runoff from paved areas to storm sewer inlets, can improve water quality by slowing and filtering storm runoff and provide interesting landscape treatments that support denser stands of vegetation.
- Bioretention areas: creating shallow depressions in landscape areas that typically include plants and ground cover will provide increased groundwater recharge and pollutant treatment.
- Permeable paving: replacing existing impervious pavements with porous paving, especially in parking areas and driveways, can provide additional storage and reduce runoff into stormwater systems. It also filters first-flush contaminants prior to discharge and helps recharge groundwater.
- Infiltration and under drains: As part of a localized stormwater solution, drain-fields can promote storm water infiltration into subsoils. These drain-fields can reduce offsite stormwater runoff by storing and infiltrating it onsite.
- Cisterns: Especially well adapted in industrial and commercial use areas, above or below ground cisterns capture stormwater runoff from impervious surfaces, such as a building rooftops, and store rainwater for later landscape irrigation use.

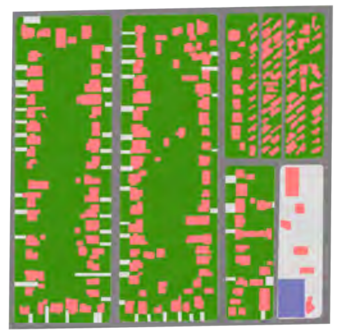
SAMPLE SITE 5: PUBLIC STREETS



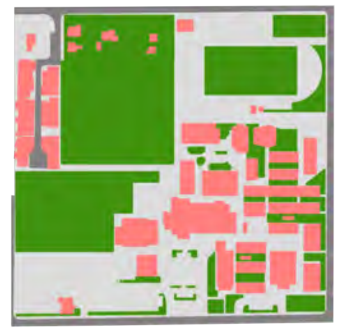
Sample Site 1
Parking Lot Area
Scale: 1"=400'



Sample Site 2
Government Block Area
Scale: 1"=400'



Sample Site 3
Residential Neighborhood Area
Scale: 1"=800'



Sample Site 4
Institutional Block Area
Scale: 1"=800'

Potential Rainwater Harvesting

	Rainfall Amount (Yearly)	Surface Coefficient	Catchment Area (square foot)	Total Yield of Harvested Rainwater (Gallons)
Site 1	9.23	1	***252, 000***	***2, 024, 102***
Site 2	9.23	1	***145, 000***	***833, 792***
Site 3	9.23	0.9	***250, 000***	***1, 293, 815***
Site 4	9.23	1	***147, 000***	***845, 293***

Glendale averages 9.14 inches per year according to the National Weather Service. Rainfall amounts fluctuate widely during the year. A month by month breakdown can be found in the Appendix.

Surface runoff coefficients represent the relative perviousness of the groundcover with 1.0 being completely impervious (all stormwater runs off) to 0.0 (nothing runs off).

The table on left represents the approximate volume of stormwater that currently runs off, and is available for rainwater harvesting each year, given existing conditions in the area. Total volume of runoff is calculated as:

Rainfall (in) x Catchment Area (sq ft) x Runoff Coefficient x 0.623* = Total Yield

(*0.623 converts inches-square feet to gallons)

For complete calculations please see the tables in the Appendix.

Public Streets Description

Public streets are generally under the control of the City. Study of stormwater catchment in these areas will help the City better understand how existing stormwater systems can be improved through LID practices.

Public Streets Conditions

- Public Streets in Sample Site 1 = 8 acres (352,000 sf).
- Public Streets in Sample Site 2 = 3 acres (147,000 sf).
- Public Streets in Sample Site 3 = 6 acres (250,000 sf).
- Public Streets in Sample Site 4 = 3 acres (145,000 sf).

Data Analysis

- The existing public streets in the four sample site areas are assumed to be impervious surfaces. Most of the stormwater collected by these surface areas normally flows into the piped stormwater system, or is evaporated from ponding areas.
- In order to slow and clean surface flows during storm events, while harvesting rainwater for the benefit of landscape areas, impervious surfaces should be connected to landscape areas. In public streets, opportunities exist within landscape buffers and tree strips, and medians. Modifications to streets to encourage these practices can be combined with traffic calming and streetscape beautification.

Potential LID Strategies

Several LID strategies could be applied in this area to achieve reductions in stormwater flows, and improvements in water quality:

- Curb cuts: modifying existing curbs in parking and street landscape areas to collect surface water from adjacent pavements. This will allow quick and inexpensive ways to implement LID and rainwater harvesting.
- Vegetated swales: creating vegetated swales to guide runoff from paved areas to storm sewer inlets, can improve water quality by slowing and filtering storm runoff and provide interesting landscape treatments that support denser stands of vegetation.
- Bio-retention areas: creating shallow depressions in landscape areas that typically include plants and ground cover will provide increased groundwater recharge and pollutant treatment.
- Permeable paving: replacing existing impervious pavements with porous paving, especially in parking areas and driveways, can provide additional storage and reduce runoff into stormwater systems. It also filters first flush contaminants prior to discharge and helps recharge groundwater.

DOCUMENT RESOURCES

Footnote	Page	Resource Link
1-6	10-15	http://flowstobay.org/files/greenstreets/pg132-136ch5.pdf
7	16	http://www.lakeforestca.gov/civica/filebank/blobdload.asp?BlobID=6549
8	17	http://www.streamdynamics.us/
		http://watershedmg.org/tech-trainings/urban-streams
		http://webcms.pima.gov/cms/one.aspx?portalId=169&pageId=687544
9	18	http://www.clearcreeksolutions.info/ftp/public/publications/WWHM4PlanterBox.pdf
10	19	http://www.seattle.gov/DPD/Publications/CAM/cam532.pdf
11	20	http://www.lastormwater.org/wp-content/files_mf/planterboxes7313.pdf
		http://www.clearcreeksolutions.info/ftp/public/publications/WWHM4PlanterBox.pdf
12	21	http://www.lifetimepavers.com/gravellok_full_brochure2011.pdf
13	22	http://www.dauphincd.org/swm/BMPfactsheets/Porous%20Asphalt%20fact%20sheet.pdf
14	23	http://www.perviouspavement.org/materials.html
15	24	http://www.typargeosynthetics.com/products/porous-paving/bodpave-85-porous-pavers.html
16	25	http://www.icpi.org/permeable
		http://www.wikihow.com/Install-Permeable-Pavers
17	26	http://www.epa.gov/owow/wetlands/pdf/ConstructedW.pdf
		http://water.epa.gov/type/wetlands/restore/upload/constructed-wetlands-handbook.pdf
		http://www.bfenvironmental.com/pdfs/ConstrWetlands.pdf
18	27	http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_infltdrn.pdf
19	28	http://www.cmhc-schl.gc.ca/en/inpr/bude/himu/coedar/upload/Design-Guidelines-for-Green-Roofs.pdf
20	29	http://www.dwsd.org/downloads_n/announcements/general_announcements/downspout_disconnect_ brochure.pdf
		http://www.rwra.org/wp-content/uploads/2012/03/Owensboro-Downspout-Disconnect-Guidelines.pdf
21	30	http://www.cityofchicago.org/city/en/depts/water/supp_info/conservation/downspout_disconnection.html
		http://www.ces.ncsu.edu/depts/agecon/WECO/documents/WaterHarvestHome2008.pdf

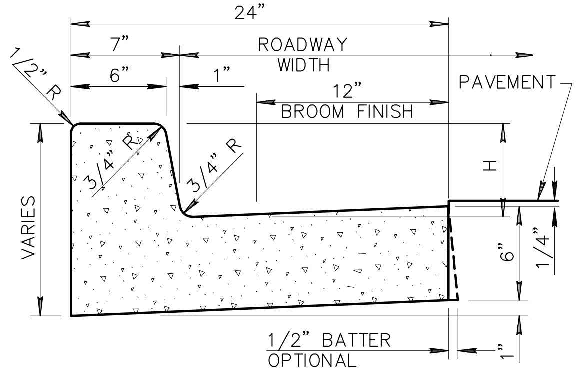
DOCUMENT RESOURCES

Footnote	Page	Resource Link
22	31	http://extension.psu.edu/natural-resources/water/drinking-water/cisterns-and-springs/rainwater-cisterns-design-construction-and-water-treatment
23-24	43,45	http://www.deeproot.com/products/silva-cell/landing-page/sc
25	48	http://www.asla.org/uploadedFiles/CMS/Advocacy/Federal_Government_Affairs/Stormwater_Case_Studies/Stormwater%20Case%20361%20Taylor%20Mall%20-%20City%20of%20Phoenix%20and%20Arizona%20State%20University%20Downtown%20Campus,%20Phoenix,%20AZ.pdf
26	50	http://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Flood%20Control/Floodplain%20Management/Low%20Impact%20Development/lid-case-studies-201401.pdf
27	52	http://www.asla.org/uploadedFiles/CMS/Advocacy/Federal_Government_Affairs/Stormwater_Case_Studies/Stormwater%20Case%20369%20Tempe%20Transportation%20Center,%20Tempe,%20AZ.pdf
28	54	http://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Flood%20Control/Floodplain%20Management/Low%20Impact%20Development/lid-case-studies-201401.pdf

Museum of the West,
Scottsdale, AZ
2015
Note: Winter months when trees are dormant.

"Downspouts can direct stormwater to landscape areas where it is stored and used to irrigate landscape plants or infiltrate into the ground."

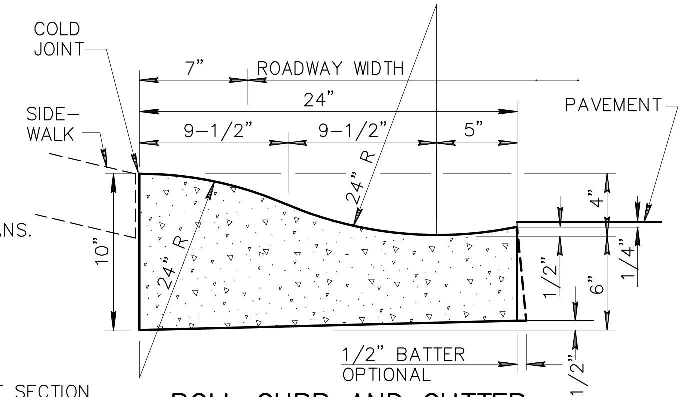
APPENDIX



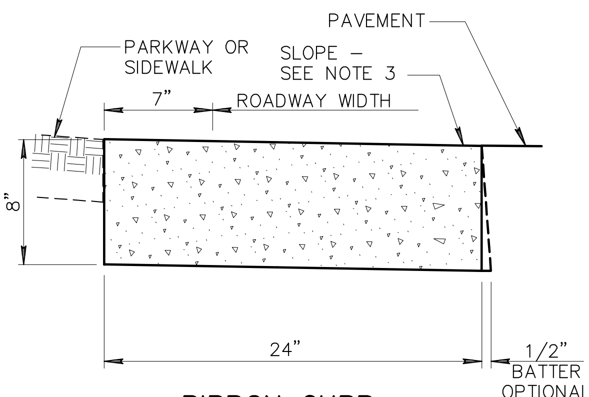
VERTICAL CURB AND GUTTER
(TYPE A)

NOTES: (TYPE A)

1. ALL EXPOSED SURFACES TO BE TROWEL FINISHED EXCEPT AS SHOWN. SEE SECT. 340.
2. H=6" OR AS SPECIFIED ON PLANS.
3. CONTRACTION JOINT SPACING 10' MAXIMUM.
4. EXPANSION JOINTS AS PER SECT. 340.
5. CLASS 'B' CONCRETE PER 725.
6. WHEN THE ADJACENT PAVEMENT SECTION SLOPES AWAY FROM THE GUTTER, THE SLOPE OF THE GUTTER PAN SHALL MATCH PAVEMENT CROSS SLOPE.



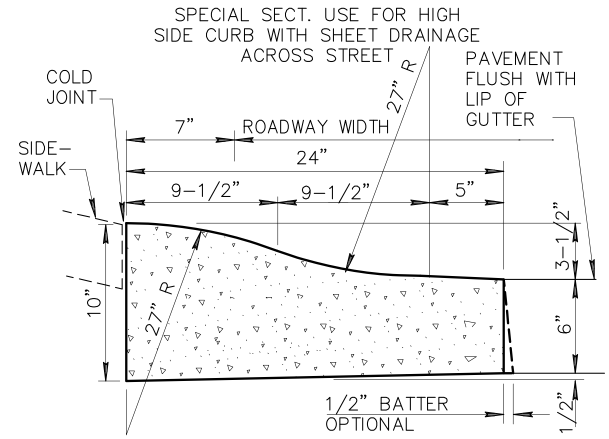
ROLL CURB AND GUTTER
(TYPE C)



RIBBON CURB
(TYPE B)

NOTES: (TYPE B)

1. CONSTRUCT CURB AND INSTALL 1/2" MASTIC EXPANSION JOINTS, A.S.T.M. D-1751. SECT. 340.
2. BROOM FINISH ALL SURFACES.
3. RIBBON CURB MAY SLOPE TOWARDS PAVEMENT OR PARKWAY AS INDICATED ON PLANS.
4. CONTRACTION JOINT SPACING 10' MAXIMUM.
5. CONCRETE SHALL BE CLASS 'B' PER SECT. 725 AND INSTALLED PER SECT. 505.



(TYPE D)

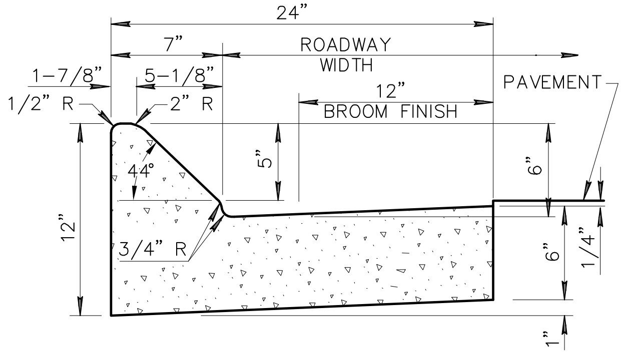
NOTES: (C & D)

1. ALL WORK AND MATERIALS SHALL CONFORM TO SECT. 304, 505 AND 725. BROOM FINISH TO EXPOSED SURFACE.
2. CONTRACTION JOINT SPACING 10' MAXIMUM.
3. EXPANSION JOINTS AS PER SECT. 340.
4. CLASS 'B' CONCRETE PER 725.

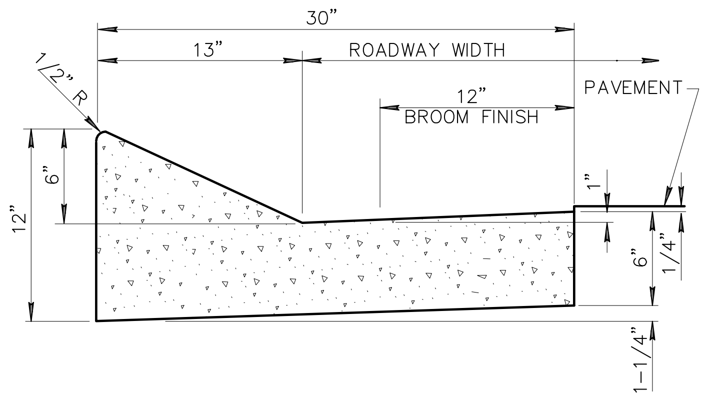
DETAIL NO.	MARICOPA ASSOCIATION of GOVERNMENTS	STANDARD DETAIL ENGLISH	CURB AND GUTTER TYPES A, B, C AND D	REVISED	DETAIL NO.
220-1				01-01-2007	220-1

http://www.azmag.gov/Communications/publications.asp

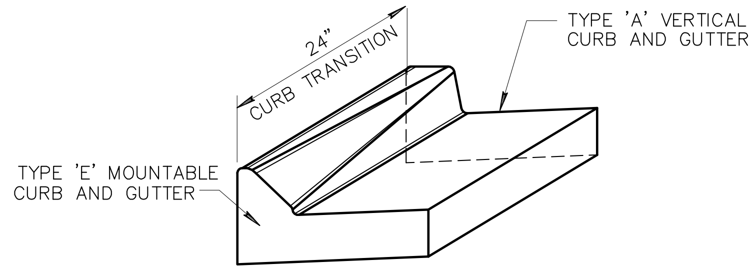
Current State-of-Practice detail



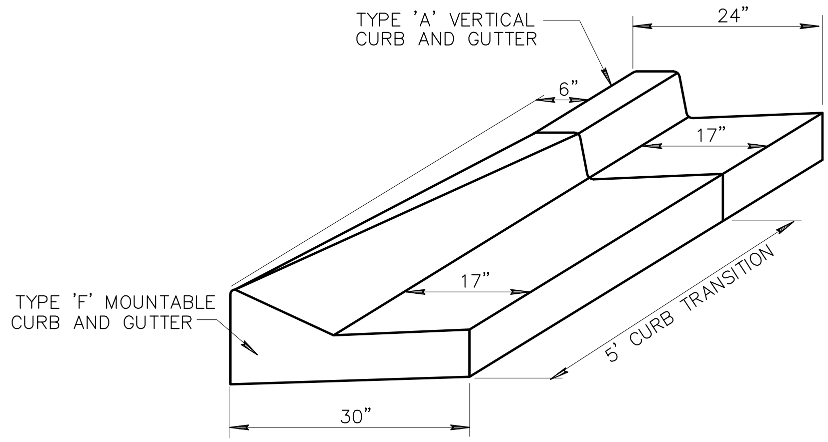
MOUNTABLE CURB AND GUTTER (TYPE E)



MOUNTABLE CURB AND GUTTER (TYPE F)



CURB TRANSITION TYPE 'E' TO TYPE 'A'



CURB TRANSITION TYPE 'F' TO TYPE 'A'

NOTES: (E & F)

1. ALL EXPOSED SURFACES TO BE TROWEL FINISHED EXCEPT AS SHOWN. SEE SECT. 340.
2. CONTRACTION JOINT SPACING 10' MAXIMUM.
3. EXPANSION JOINTS PER SECT. 340.
4. CLASS 'B' CONCRETE PER SECT. 725.
5. WHEN THE ADJACENT PAVEMENT SECTION SLOPES AWAY FROM THE GUTTER, THE SLOPE OF THE GUTTER PAN SHALL MATCH THE PAVEMENT CROSS SLOPE.

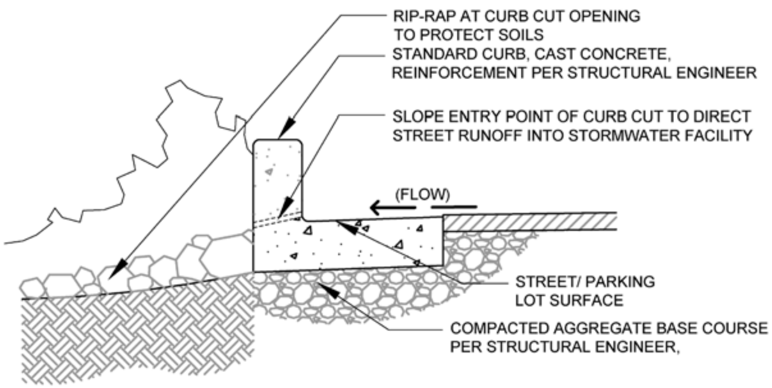
DETAIL NO.				REVISED	DETAIL NO.
220-2	MARICOPA ASSOCIATION of GOVERNMENTS	STANDARD DETAIL ENGLISH	CURB AND GUTTER TYPES E AND F	01-01-2007	220-2

http://www.azmag.gov/Communications/publications.asp

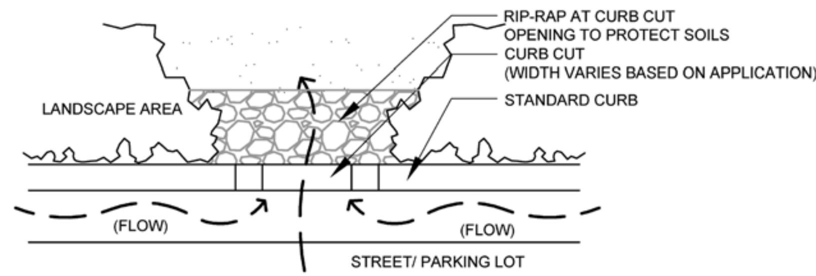
LOW IMPACT DEVELOPMENT DETAIL

NOTES

1. RIP-RAP AREA AND ROCK SIZE VARY PER SITE CONDITIONS. CONSULT PROJECT LANDSCAPE ARCHITECT.



STANDARD CURB CUT - SECTION VIEW



STANDARD CURB CUT - PLAN VIEW

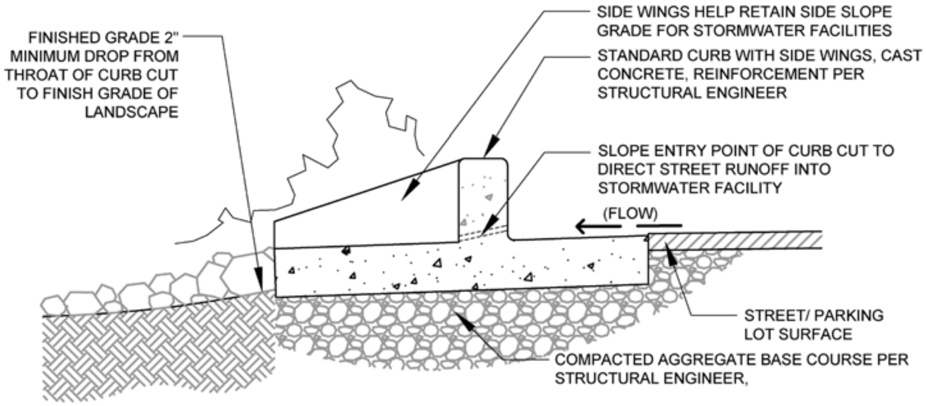
NOT TO SCALE

STANDARD CURB CUT

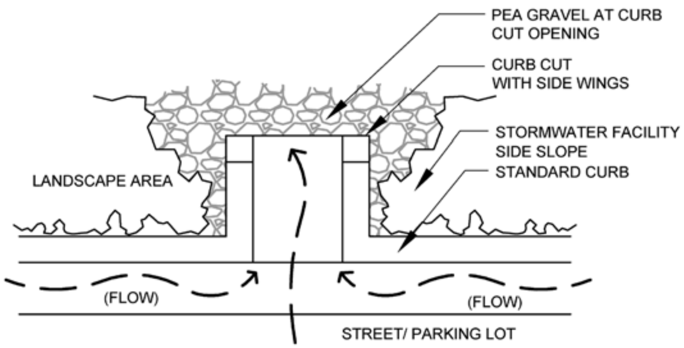
DETAIL NO. XXX

NOTES

1. RIP-RAP AREA AND ROCK SIZE VARY PER SITE/PROJECT. CONSULT PROJECT LANDSCAPE ARCHITECT.



STANDARD CURB CUT WITH SIDE WINGS - SECTION VIEW



STANDARD CURB CUT WITH SIDE WINGS - PLAN VIEW

STANDARD CURB CUT WITH SIDE WINGS

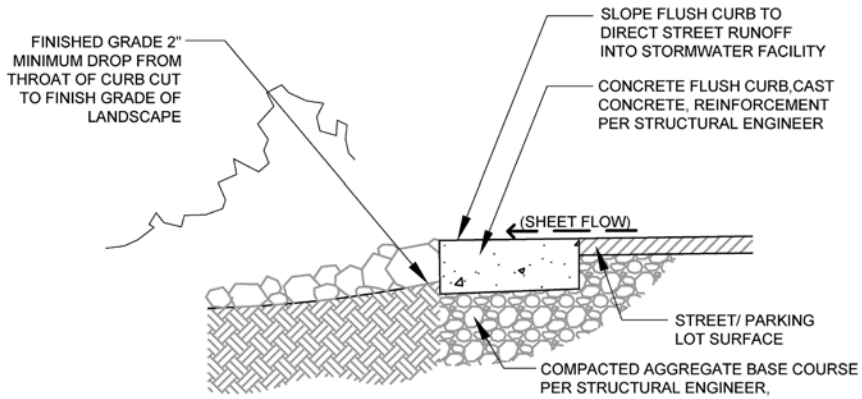
DETAIL NO. XXX

NOT TO SCALE

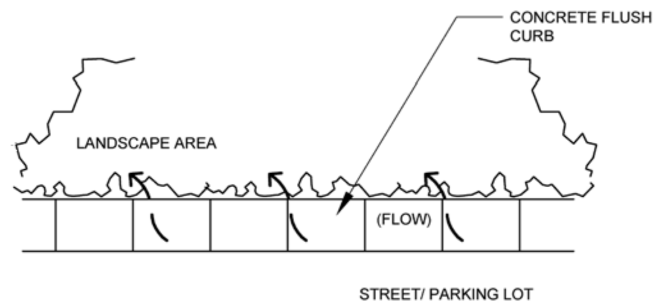
LOW IMPACT DEVELOPMENT DETAIL

NOTES

1. RIP-RAP AREA AND ROCK SIZE VARY PER SITE/PROJECT. CONSULT PROJECT LANDSCAPE ARCHITECT.



CONCRETE FLUSH CURB - SECTION VIEW



CONCRETE FLUSH CURB - PLAN VIEW

NOT TO SCALE

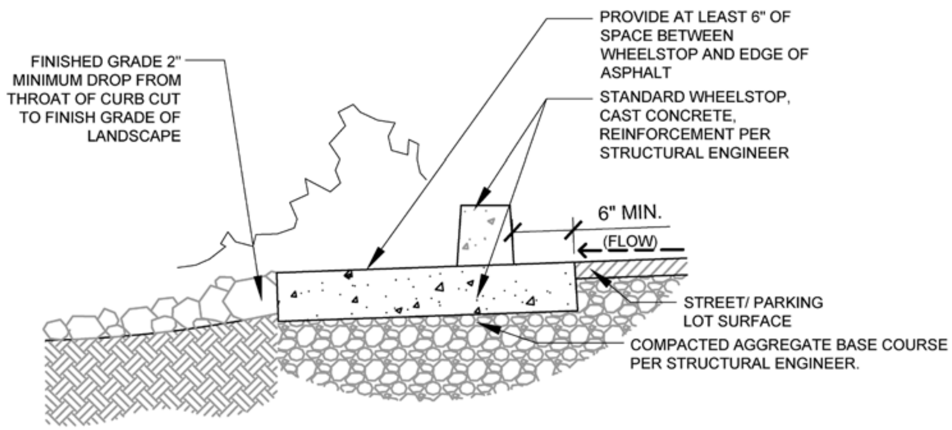
LOGANSIMPSON

CONCRETE FLUSH CURB

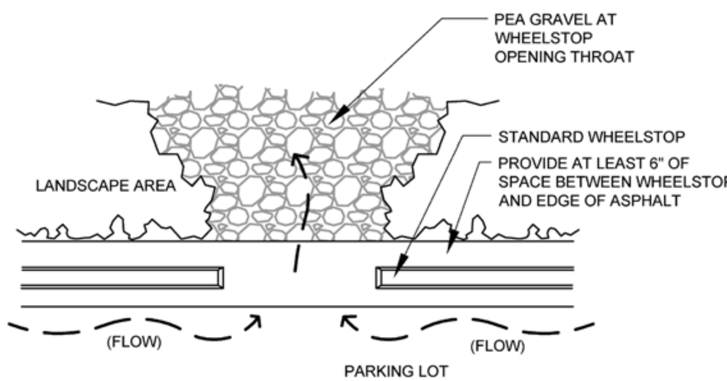
DETAIL NO. XXX

NOTES

1. RIP-RAP AREA AND ROCK SIZE VARY PER SITE/PROJECT. CONSULT PROJECT LANDSCAPE ARCHITECT.



WHEELSTOP CURB - SECTION VIEW



WHEELSTOP CURB - PLAN VIEW

WHEELSTOP CURB

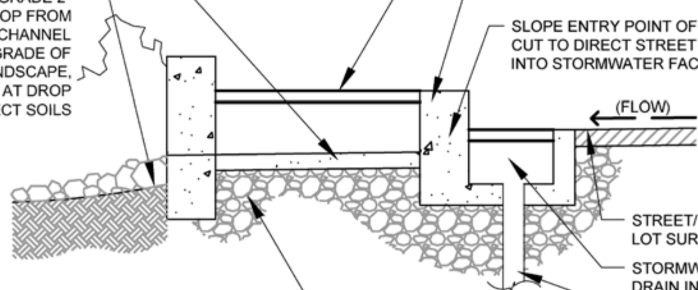
DETAIL NO. XXX

NOT TO SCALE

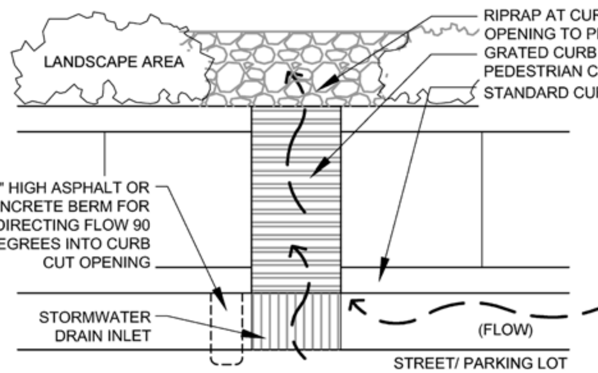
LOW IMPACT DEVELOPMENT DETAIL

NOTES

1. RIP-RAP AREA AND ROCK SIZE VARY PER SITE/PROJECT. CONSULT PROJECT LANDSCAPE ARCHITECT.



GRATED CURB CUT - SECTION VIEW



GRATED CURB CUT - PLAN VIEW

NOT TO SCALE

LOGANSIMPSON

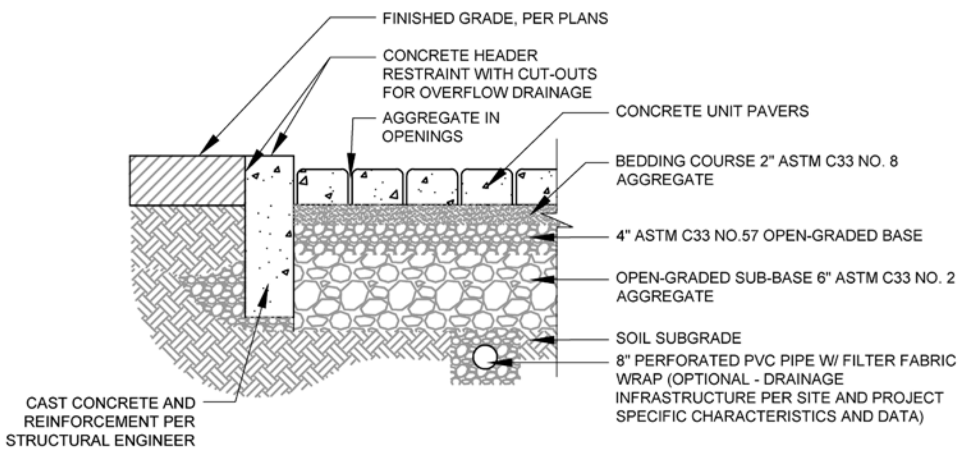
GRATED CURB CUT

DETAIL NO. XXX

LOW IMPACT DEVELOPMENT DETAIL

NOTES

1. CONSULT SITE GEOTECHNICAL REPORT AND CIVIL ENGINEER FOR PROJECT SPECIFIC SUBGRADE REQUIREMENTS.
2. CONTRACTOR TO CONFIRM PAVEMENT SECTION WITH GEO-TECHNICAL ENGINEER AND LANDSCAPE ARCHITECT PRIOR TO CONSTRUCTION



PERMEABLE CONCRETE PAVEMENT - SECTION VIEW

NOT TO SCALE

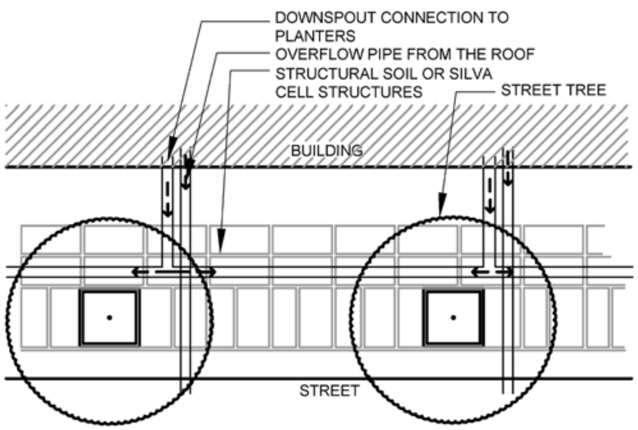
PERMEABLE PAVEMENT

DETAIL NO. XXX

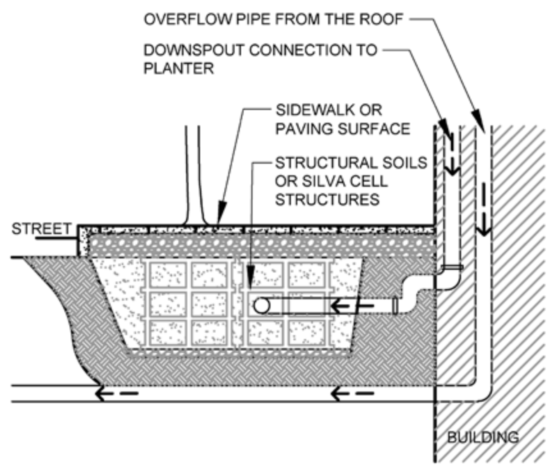
LOW IMPACT DEVELOPMENT DETAIL

NOTES

1. COORDINATE LOCATION AND SIZE OF BUILDING DOWNSPOUTS WITH CIVIL ENGINEER
2. FINISHED GRADE MATERIAL CAN VARY PER LANDSCAPE ARCHITECT



STRUCTURAL SOIL OR SILVA CELL PLANTER WITH RAIN LEADERS - PLAN VIEW



STRUCTURAL SOIL OR SILVA CELL PLANTER WITH RAIN LEADERS - SECTION VIEW

NOT TO SCALE

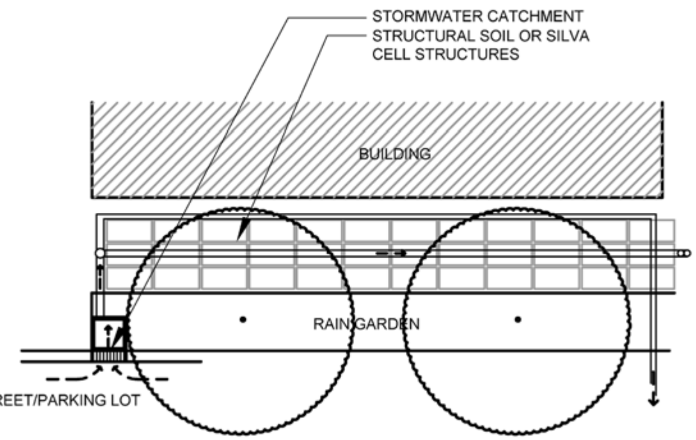
LOGANSIMPSON

STRUCTURAL SOIL OR SILVA CELL - RAIN LEADER

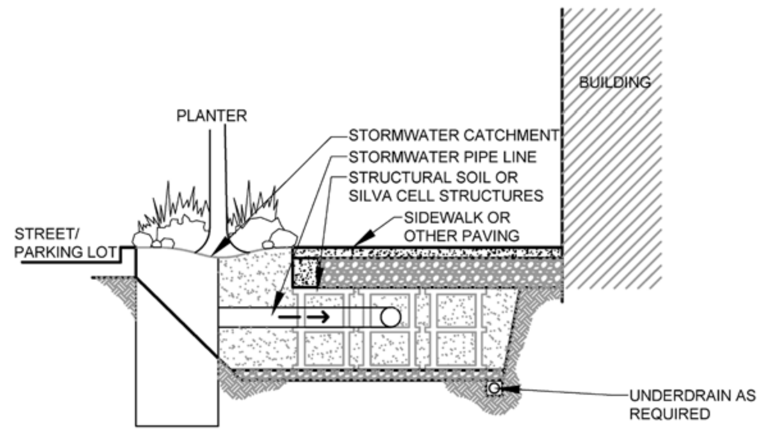
DETAIL NO. XXX

NOTES

1. LOCATION, TYPE, AND SIZE OF STORMWATER CATCHMENT PER CIVIL ENGINEER, COORDINATED WITH LANDSCAPE ARCHITECT
2. DIMENSIONS AND DEPTH OF ASSOCIATED RAIN GARDEN CAN VARY PER SITE/PLAN, CONSULT LANDSCAPE ARCHITECT



STRUCTURAL SOIL OR SILVA CELL PLANTER - PLAN VIEW



STRUCTURAL SOIL OR SILVA CELL PLANTER - PLAN VIEW

NOT TO SCALE

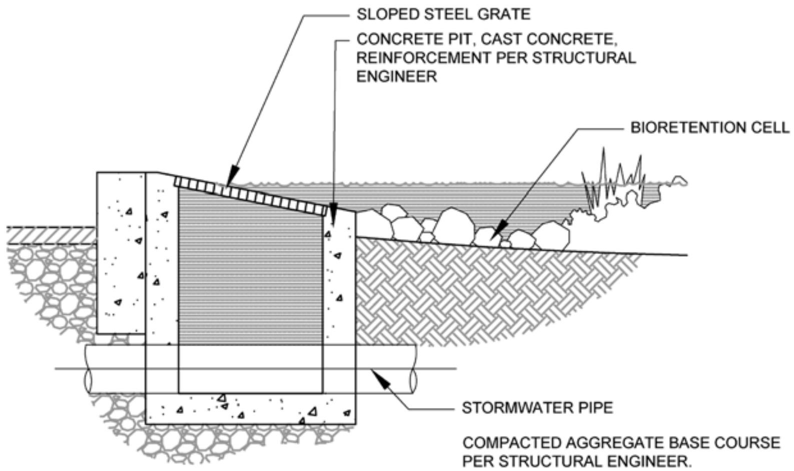
LOGANSIMPSON

STRUCTURAL SOIL OR SILVA CELL

DETAIL NO. XXX

NOTES

1. CONSULT SITE GEOTECHNICAL REPORT AND CIVIL ENGINEER FOR PROJECT SPECIFIC SUBGRADE REQUIREMENTS.
2. CONTRACTOR TO CONFIRM PAVEMENT SECTION WITH GEO-TECHNICAL ENGINEER AND LANDSCAPE ARCHITECT PRIOR TO CONSTRUCTION



BIORETENTION CELL - CATCH BASIN

NOT TO SCALE

LOGANSIMPSON

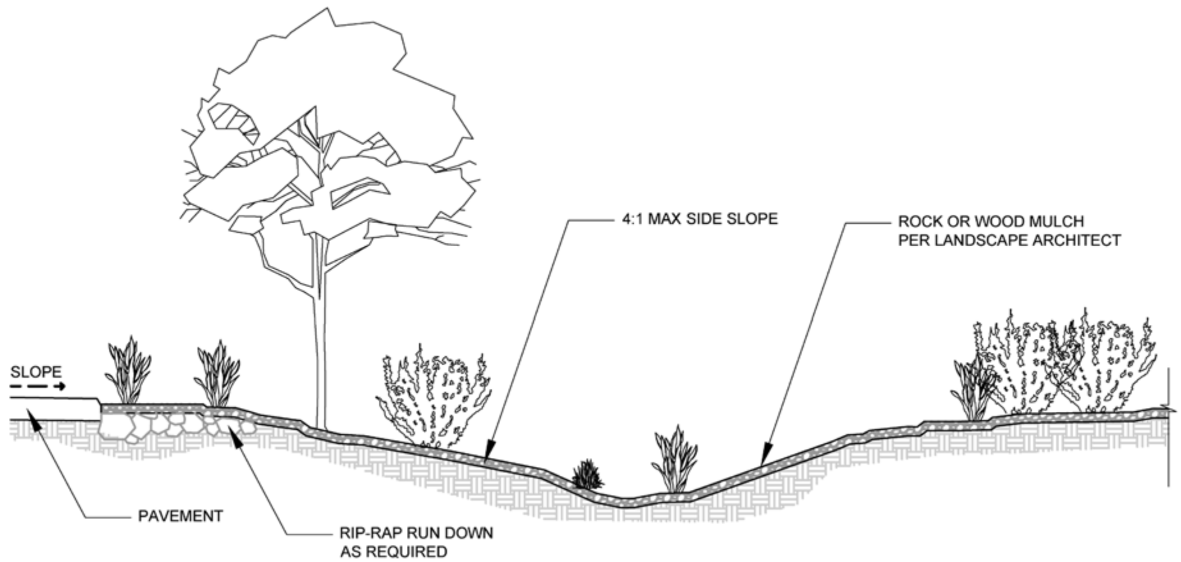
BIORETENTION CELL - CATCH BASIN

DETAIL NO. XXX

LOW IMPACT DEVELOPMENT DETAIL

NOTES

1. SLOPE TO DRAIN WITHIN 36 HOURS AFTER STORM.



VEGETATED BIOSWALE - SECTION

VEGETATED BIOSWALE

DETAIL NO.
XXX

NOT TO SCALE

CALCULATION TABLES - SAMPLE SITE 1 PARKING LOT AREA

Roof	Inches of Rainfall	Gallons / Square foot	Square Footage of Catchment	Gross Gallons of Rainfall/ Month	Runoff Coefficient for the Surface	Total Monthly Yield of Harvested Rainwater in Gallons
January	1.01	0.62923	60,000	37753.8	0.95	35866.11
February	0.99	0.61677	60,000	37006.2	0.95	35155.89
March	1.19	0.74137	60,000	44482.2	0.95	42258.09
April	0.33	0.20559	60,000	12335.4	0.95	11718.63
May	0.17	0.10591	60,000	6354.6	0.95	6036.87
June	0.06	0.03738	60,000	2242.8	0.95	2130.66
July	0.89	0.55447	60,000	33268.2	0.95	31604.79
August	1.14	0.71022	60,000	42613.2	0.95	40482.54
September	0.89	0.55447	60,000	33268.2	0.95	31604.79
October	0.81	0.50463	60,000	30277.8	0.95	28763.91
November	0.77	0.47971	60,000	28782.6	0.95	27343.47
December	0.98	0.61054	60,000	36632.4	0.95	34800.78
Totals						327766.53

Vegetated Area	Inches of Rainfall	Gallons / Square foot	Square Footage of Catchment	Gross Gallons of Rainfall/ Month	Runoff Coefficient for the Surface	Total Monthly Yield of Harvested Rainwater in Gallons
January	1.01	0.62923	216,000	135913.68	0.17	23105.3256
February	0.99	0.61677	216,000	133222.32	0.17	22647.7944
March	1.19	0.74137	216,000	160135.92	0.17	27223.1064
April	0.33	0.20559	216,000	44407.44	0.17	7549.2648
May	0.17	0.10591	216,000	22876.56	0.17	3889.0152
June	0.06	0.03738	216,000	8074.08	0.17	1372.5936
July	0.89	0.55447	216,000	119765.52	0.17	20360.1384
August	1.14	0.71022	216,000	153407.52	0.17	26079.2784
September	0.89	0.55447	216,000	119765.52	0.17	20360.1384
October	0.81	0.50463	216,000	109000.08	0.17	18530.0136
November	0.77	0.47971	216,000	103617.36	0.17	17614.9512
December	0.98	0.61054	216,000	131876.64	0.17	22419.0288
Totals						211150.6488

Runoff Coefficient:
1. Roof (metal, gravel asphalt, shingle, fiberglass, mineral paper): High 0.95/Low 0.9
2. Paving (concrete, asphalt): High 1.00/Low 0.90
3. Soil (flat, bare): High 0.75/Low 0.2; Soil (flat, heavy soil): High 0.6/Low 0.1
4. Lawn (flat, sandy soil): High 0.1/Low 0.05; Lawn (flat, heavy soil): High 0.17/Low 0.13

Parking Lots/ Roads	Inches of Rainfall	Gallons / Square foot	Square Footage of Catchment	Gross Gallons of Rainfall/ Month	Runoff Coefficient for the Surface	Total Monthly Yield of Harvested Rainwater in Gallons
January	1.01	0.62923	352,000	221488.96	1	221488.96
February	0.99	0.61677	352,000	217103.04	1	217103.04
March	1.19	0.74137	352,000	260962.24	1	260962.24
April	0.33	0.20559	352,000	72367.68	1	72367.68
May	0.17	0.10591	352,000	37280.32	1	37280.32
June	0.06	0.03738	352,000	13157.76	1	13157.76
July	0.89	0.55447	352,000	195173.44	1	195173.44
August	1.14	0.71022	352,000	249997.44	1	249997.44
September	0.89	0.55447	352,000	195173.44	1	195173.44
October	0.81	0.50463	352,000	177629.76	1	177629.76
November	0.77	0.47971	352,000	168857.92	1	168857.92
December	0.98	0.61054	352,000	214910.08	1	214910.08
Totals						2024102.08

Vacant Lots	Inches of Rainfall	Gallons / Square foot	Square Footage of Catchment	Gross Gallons of Rainfall/ Month	Runoff Coefficient for the Surface	Total Monthly Yield of Harvested Rainwater in Gallons
January	1.01	0.62923	174,000	109486.02	0.6	65691.612
February	0.99	0.61677	174,000	107317.98	0.6	64390.788
March	1.19	0.74137	174,000	128998.38	0.6	77399.028
April	0.33	0.20559	174,000	35772.66	0.6	21463.596
May	0.17	0.10591	174,000	18428.34	0.6	11057.004
June	0.06	0.03738	174,000	6504.12	0.6	3902.472
July	0.89	0.55447	174,000	96477.78	0.6	57886.668
August	1.14	0.71022	174,000	123578.28	0.6	74146.968
September	0.89	0.55447	174,000	96477.78	0.6	57886.668
October	0.81	0.50463	174,000	87805.62	0.6	52683.372
November	0.77	0.47971	174,000	83469.54	0.6	50081.724
December	0.98	0.61054	174,000	106233.96	0.6	63740.376
Totals						600330.276

Note: vacant lots are undeveloped and may change with development

CALCULATION TABLES - SAMPLE SITE 2 GOVERNMENT AND COMMERCIAL AREA

Roof	Inches of Rainfall	Gallons / Square foot	Square Footage of Catchment	Gross Gallons of Rainfall/ Month	Runoff Coefficient for the Surface	Total Monthly Yield of Harvested Rainwater in Gallons
January	1.01	0.62923	200,059	125883.1246	0.95	119588.9683
February	0.99	0.61677	200,059	123390.3894	0.95	117220.87
March	1.19	0.74137	200,059	148317.7408	0.95	140901.8538
April	0.33	0.20559	200,059	41130.12981	0.95	39073.62332
May	0.17	0.10591	200,059	21188.24869	0.95	20128.83626
June	0.06	0.03738	200,059	7478.20542	0.95	7104.295149
July	0.89	0.55447	200,059	110926.7137	0.95	105380.378
August	1.14	0.71022	200,059	142085.903	0.95	134981.6078
September	0.89	0.55447	200,059	110926.7137	0.95	105380.378
October	0.81	0.50463	200,059	100955.7732	0.95	95907.98451
November	0.77	0.47971	200,059	95970.30289	0.95	91171.78775
December	0.98	0.61054	200,059	122144.0219	0.95	116036.8208
Totals						1092877.404

Vegetated Area	Inches of Rainfall	Gallons / Square foot	Square Footage of Catchment	Gross Gallons of Rainfall/ Month	Runoff Coefficient for the Surface	Total Monthly Yield of Harvested Rainwater in Gallons
January	1.01	0.62923	172,000	108227.56	0.17	18398.6852
February	0.99	0.61677	172,000	106084.44	0.17	18034.3548
March	1.19	0.74137	172,000	127515.64	0.17	21677.6588
April	0.33	0.20559	172,000	35361.48	0.17	6011.4516
May	0.17	0.10591	172,000	18216.52	0.17	3096.8084
June	0.06	0.03738	172,000	6429.36	0.17	1092.9912
July	0.89	0.55447	172,000	95368.84	0.17	16212.7028
August	1.14	0.71022	172,000	122157.84	0.17	20766.8328
September	0.89	0.55447	172,000	95368.84	0.17	16212.7028
October	0.81	0.50463	172,000	86796.36	0.17	14755.3812
November	0.77	0.47971	172,000	82510.12	0.17	14026.7204
December	0.98	0.61054	172,000	105012.88	0.17	17852.1896
Totals						168138.4796

Runoff Coefficient:

1. Roof (metal, gravel asphalt, shingle, fiberglass, mineral paper): High 0.95/Low 0.9
2. Paving (concrete, asphalt): High 1.00/Low 0.90
3. Soil (flat, bare): High 0.75/Low 0.2; Soil (flat, heavy soil): High 0.6/Low 0.1
4. Lawn (flat, sandy soil): High 0.1/Low 0.05; Lawn (flat, heavy soil): High 0.17/Low 0.13

Parking Lots/ Roads	Inches of Rainfall	Gallons / Square foot	Square Footage of Catchment	Gross Gallons of Rainfall/ Month	Runoff Coefficient for the Surface	Total Monthly Yield of Harvested Rainwater in Gallons
January	1.01	0.62923	317,910	200038.5093	1	200038.5093
February	0.99	0.61677	317,910	196077.3507	1	196077.3507
March	1.19	0.74137	317,910	235688.9367	1	235688.9367
April	0.33	0.20559	317,910	65359.1169	1	65359.1169
May	0.17	0.10591	317,910	33669.8481	1	33669.8481
June	0.06	0.03738	317,910	11883.4758	1	11883.4758
July	0.89	0.55447	317,910	176271.5577	1	176271.5577
August	1.14	0.71022	317,910	225786.0402	1	225786.0402
September	0.89	0.55447	317,910	176271.5577	1	176271.5577
October	0.81	0.50463	317,910	160426.9233	1	160426.9233
November	0.77	0.47971	317,910	152504.6061	1	152504.6061
December	0.98	0.61054	317,910	194096.7714	1	194096.7714
Totals						1828074.694

CALCULATION TABLES - SAMPLE SITE 3 NEIGHBORHOOD AREA

Roof	Inches of Rainfall	Gallons / Square foot	Square Footage of Catchment	Gross Gallons of Rainfall/ Month	Runoff Coefficient for the Surface	Total Monthly Yield of Harvested Rainwater in Gallons
January	1.01	0.62923	343,000	215825.89	0.9	194243.301
February	0.99	0.61677	343,000	211552.11	0.9	190396.899
March	1.19	0.74137	343,000	254289.91	0.9	228860.919
April	0.33	0.20559	343,000	70517.37	0.9	63465.633
May	0.17	0.10591	343,000	36327.13	0.9	32694.417
June	0.06	0.03738	343,000	12821.34	0.9	11539.206
July	0.89	0.55447	343,000	190183.21	0.9	171164.889
August	1.14	0.71022	343,000	243605.46	0.9	219244.914
September	0.89	0.55447	343,000	190183.21	0.9	171164.889
October	0.81	0.50463	343,000	173088.09	0.9	155779.281
November	0.77	0.47971	343,000	164540.53	0.9	148086.477
December	0.98	0.61054	343,000	209415.22	0.9	188473.698
Totals						1775114.523

Parking Lots/ Roads	Inches of Rainfall	Gallons / Square foot	Square Footage of Catchment	Gross Gallons of Rainfall/ Month	Runoff Coefficient for the Surface	Total Monthly Yield of Harvested Rainwater in Gallons
January	1.01	0.62923	333,000	209533.59	0.9	188580.231
February	0.99	0.61677	333,000	205384.41	0.9	184845.969
March	1.19	0.74137	333,000	246876.21	0.9	222188.589
April	0.33	0.20559	333,000	68461.47	0.9	61615.323
May	0.17	0.10591	333,000	35268.03	0.9	31741.227
June	0.06	0.03738	333,000	12447.54	0.9	11202.786
July	0.89	0.55447	333,000	184638.51	0.9	166174.659
August	1.14	0.71022	333,000	236503.26	0.9	212852.934
September	0.89	0.55447	333,000	184638.51	0.9	166174.659
October	0.81	0.50463	333,000	168041.79	0.9	151237.611
November	0.77	0.47971	333,000	159743.43	0.9	143769.087
December	0.98	0.61054	333,000	203309.82	0.9	182978.838
Totals						1723361.913

Vegetated Area	Inches of Rainfall	Gallons / Square foot	Square Footage of Catchment	Gross Gallons of Rainfall/ Month	Runoff Coefficient for the Surface	Total Monthly Yield of Harvested Rainwater in Gallons
January	1.01	0.62923	1,047,000	658803.81	0.17	111996.6477
February	0.99	0.61677	1,047,000	645758.19	0.17	109778.8923
March	1.19	0.74137	1,047,000	776214.39	0.17	131956.4463
April	0.33	0.20559	1,047,000	215252.73	0.17	36592.9641
May	0.17	0.10591	1,047,000	110887.77	0.17	18850.9209
June	0.06	0.03738	1,047,000	39136.86	0.17	6653.2662
July	0.89	0.55447	1,047,000	580530.09	0.17	98690.1153
August	1.14	0.71022	1,047,000	743600.34	0.17	126412.0578
September	0.89	0.55447	1,047,000	580530.09	0.17	98690.1153
October	0.81	0.50463	1,047,000	528347.61	0.17	89819.0937
November	0.77	0.47971	1,047,000	502256.37	0.17	85383.5829
December	0.98	0.61054	1,047,000	639235.38	0.17	108670.0146
Totals						1023494.117

Vacant Lots	Inches of Rainfall	Gallons / Square foot	Square Footage of Catchment	Gross Gallons of Rainfall/ Month	Runoff Coefficient for the Surface	Total Monthly Yield of Harvested Rainwater in Gallons
January	1.01	0.62923	18,000	11326.14	0.6	6795.684
February	0.99	0.61677	18,000	11101.86	0.6	6661.116
March	1.19	0.74137	18,000	13344.66	0.6	8006.796
April	0.33	0.20559	18,000	3700.62	0.6	2220.372
May	0.17	0.10591	18,000	1906.38	0.6	1143.828
June	0.06	0.03738	18,000	672.84	0.6	403.704
July	0.89	0.55447	18,000	9980.46	0.6	5988.276
August	1.14	0.71022	18,000	12783.96	0.6	7670.376
September	0.89	0.55447	18,000	9980.46	0.6	5988.276
October	0.81	0.50463	18,000	9083.34	0.6	5450.004
November	0.77	0.47971	18,000	8634.78	0.6	5180.868
December	0.98	0.61054	18,000	10989.72	0.6	6593.832
Totals						62103.132

Runoff Coefficient:

1. Roof (metal, gravel asphalt, shingle, fiberglass, mineral paper): High 0.95/Low 0.9
2. Paving (concrete, asphalt): High 1.00/Low 0.90
3. Soil (flat, bare): High 0.75/Low 0.2; Soil (flat, heavy soil): High 0.6/Low 0.1
4. Lawn (flat, sandy soil): High 0.1/Low 0.05; Lawn (flat, heavy soil): High 0.17/Low 0.13

Note: vacant lots are undeveloped and may change with development

CALCULATION TABLES - SAMPLE SITE 4 INSTITUTIONAL BLOCK

Roof	Inches of Rainfall	Gallons / Square foot	Square Footage of Catchment	Gross Gallons of Rainfall/ Month	Runoff Coefficient for the Surface	Total Monthly Yield of Harvested Rainwater in Gallons
January	1.01	0.62923	200,059	125883.1246	0.95	119588.9683
February	0.99	0.61677	200,059	123390.3894	0.95	117220.87
March	1.19	0.74137	200,059	148317.7408	0.95	140901.8538
April	0.33	0.20559	200,059	41130.12981	0.95	39073.62332
May	0.17	0.10591	200,059	21188.24869	0.95	20128.83626
June	0.06	0.03738	200,059	7478.20542	0.95	7104.295149
July	0.89	0.55447	200,059	110926.7137	0.95	105380.378
August	1.14	0.71022	200,059	142085.903	0.95	134981.6078
September	0.89	0.55447	200,059	110926.7137	0.95	105380.378
October	0.81	0.50463	200,059	100955.7732	0.95	95907.98451
November	0.77	0.47971	200,059	95970.30289	0.95	91171.78775
December	0.98	0.61054	200,059	122144.0219	0.95	116036.8208
Totals						1092877.404

Parking Lots/ Roads	Inches of Rainfall	Gallons / Square foot	Square Footage of Catchment	Gross Gallons of Rainfall/ Month	Runoff Coefficient for the Surface	Total Monthly Yield of Harvested Rainwater in Gallons
January	1.01	0.62923	317,910	200038.5093	1	200038.5093
February	0.99	0.61677	317,910	196077.3507	1	196077.3507
March	1.19	0.74137	317,910	235688.9367	1	235688.9367
April	0.33	0.20559	317,910	65359.1169	1	65359.1169
May	0.17	0.10591	317,910	33669.8481	1	33669.8481
June	0.06	0.03738	317,910	11883.4758	1	11883.4758
July	0.89	0.55447	317,910	176271.5577	1	176271.5577
August	1.14	0.71022	317,910	225786.0402	1	225786.0402
September	0.89	0.55447	317,910	176271.5577	1	176271.5577
October	0.81	0.50463	317,910	160426.9233	1	160426.9233
November	0.77	0.47971	317,910	152504.6061	1	152504.6061
December	0.98	0.61054	317,910	194096.7714	1	194096.7714
Totals						1828074.694

Vegetated Area	Inches of Rainfall	Gallons / Square foot	Square Footage of Catchment	Gross Gallons of Rainfall/ Month	Runoff Coefficient for the Surface	Total Monthly Yield of Harvested Rainwater in Gallons
January	1.01	0.62923	172,000	108227.56	0.17	18398.6852
February	0.99	0.61677	172,000	106084.44	0.17	18034.3548
March	1.19	0.74137	172,000	127515.64	0.17	21677.6588
April	0.33	0.20559	172,000	35361.48	0.17	6011.4516
May	0.17	0.10591	172,000	18216.52	0.17	3096.8084
June	0.06	0.03738	172,000	6429.36	0.17	1092.9912
July	0.89	0.55447	172,000	95368.84	0.17	16212.7028
August	1.14	0.71022	172,000	122157.84	0.17	20766.8328
September	0.89	0.55447	172,000	95368.84	0.17	16212.7028
October	0.81	0.50463	172,000	86796.36	0.17	14755.3812
November	0.77	0.47971	172,000	82510.12	0.17	14026.7204
December	0.98	0.61054	172,000	105012.88	0.17	17852.1896
Totals						168138.4796

Runoff Coefficient:

1. Roof (metal, gravel asphalt, shingle, fiberglass, mineral paper): High 0.95/Low 0.9
2. Paving (concrete, asphalt): High 1.00/Low 0.90
3. Soil (flat, bare): High 0.75/Low 0.2; Soil (flat, heavy soil): High 0.6/Low 0.1
4. Lawn (flat, sandy soil): High 0.1/Low 0.05; Lawn (flat, heavy soil): High 0.17/Low 0.13