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SUBJECT: **Pueblo Alto & Mile Hi Neighborhoods Drainage Study**
Toolkit of Small-Scale Stormwater Management Techniques

I. Study Background

The City of Albuquerque (City) contracted Bohannan Huston, Inc. (BHI) to perform the Pueblo Alto and Mile Hi Neighborhoods Drainage Study (under the Pueblo Alto Drainage Analysis and Outreach Efforts on-call Task Order) in response to ongoing drainage issues across the subject neighborhoods. In addition to the development of this toolkit, this study consists of an extensive outreach process, identification and evaluation of techniques for the subject neighborhoods, and preparation of a summary report. **Figure 1 – Study Area Map** shows the neighborhoods included in the current study. The intent of the resulting study summary report is to become a resource for City staff in considering future stormwater improvement projects. At this time, it is unknown if the current study will lead directly to improvements.

II. Toolkit Purpose

This toolkit identifies small-scale, localized stormwater management techniques that may be specifically applicable to the Pueblo Alto and Mile Hi neighborhoods as well as other neighborhoods across the Northeast Heights of Albuquerque. This toolkit is intended as an introduction to the small-scale techniques and establishes terminology for use by study participants and stakeholders. It is intentionally brief and means to provide a basic understanding of the advantages and limitations of each technique. This toolkit is also intended to serve as a resource for City staff and consultants when considering these techniques elsewhere in Albuquerque.

Toolkit users who wish to learn more about these techniques may consult the attached reference documents for more detailed, technical information.

III. Stormwater Management Techniques

The five (5) small-scale stormwater management techniques presented below were selected through an initial assessment of the Pueblo Alto and Mile Hi neighborhoods and based on their potential applicability to existing neighborhoods in the Northeast Heights. Neighborhoods in the Northeast Heights tend to be mostly developed, with moderately steep slopes, adequate infiltration, limited excess right-of-way, and limited open space.

IV. Co-Benefits of Green Stormwater Infrastructure (GSI)

The techniques included in this toolkit are a combination of green stormwater infrastructure (GSI) practices and other practices that can be incorporated with GSI as part of an overall project. GSI can generally be described as constructed features that leverage ecological functions of natural systems to provide ecosystem services (including capturing, cleaning, and infiltrating stormwater, among other services). GSI practices provide a myriad of “co-benefits” beyond the noted stormwater benefits, including but not limited to:

- Reduction of urban heat island and climate change impacts
- Increased tree canopy and improved air quality
- Traffic calming
- Improved physical and mental health
- Pollinator habitat
- Reduced potable water use
- Increased property values

Additional information about GSI and the techniques presented in this toolkit can be found in the attached reference documents.

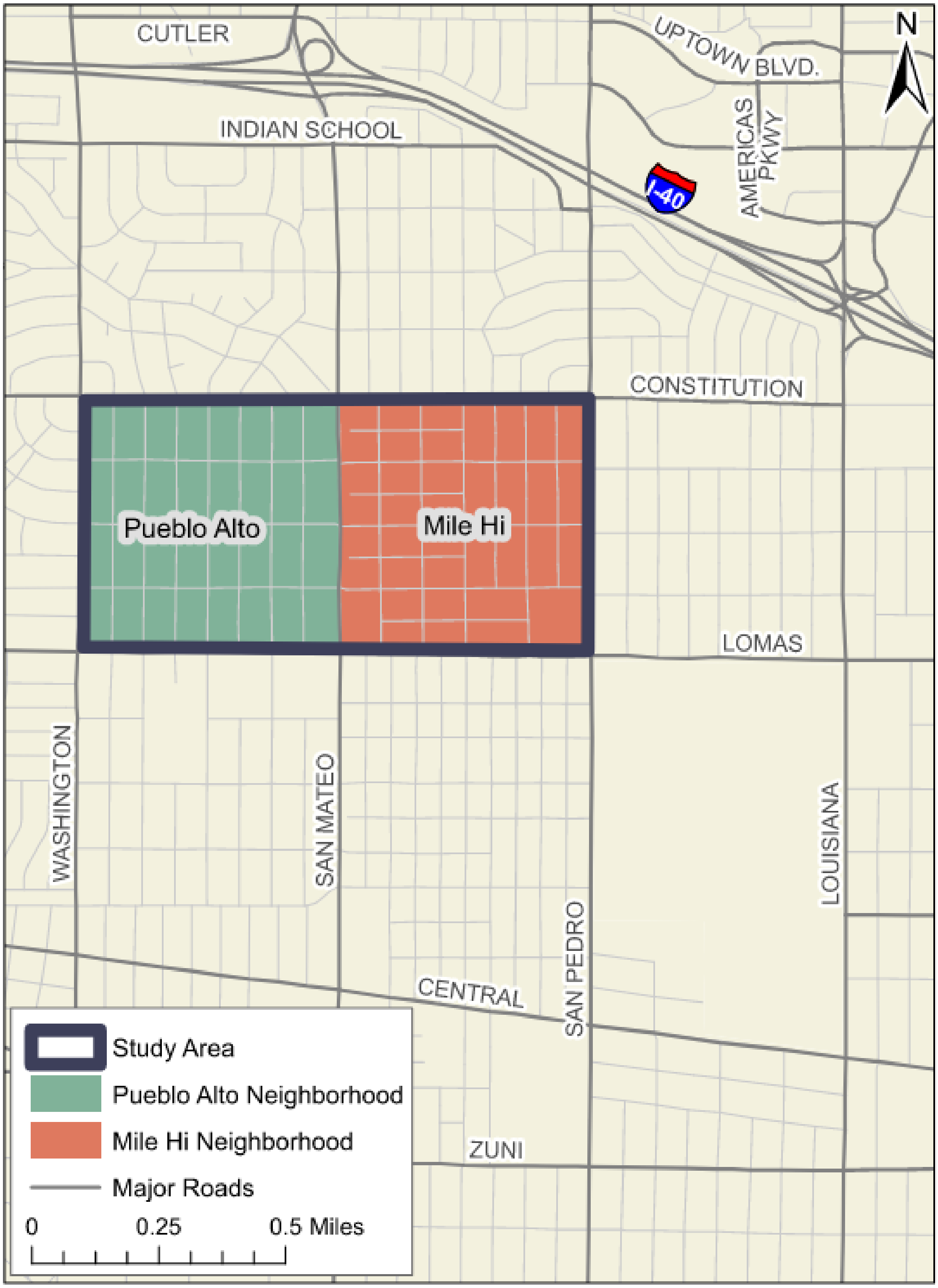


Figure 1 – Study Area Map

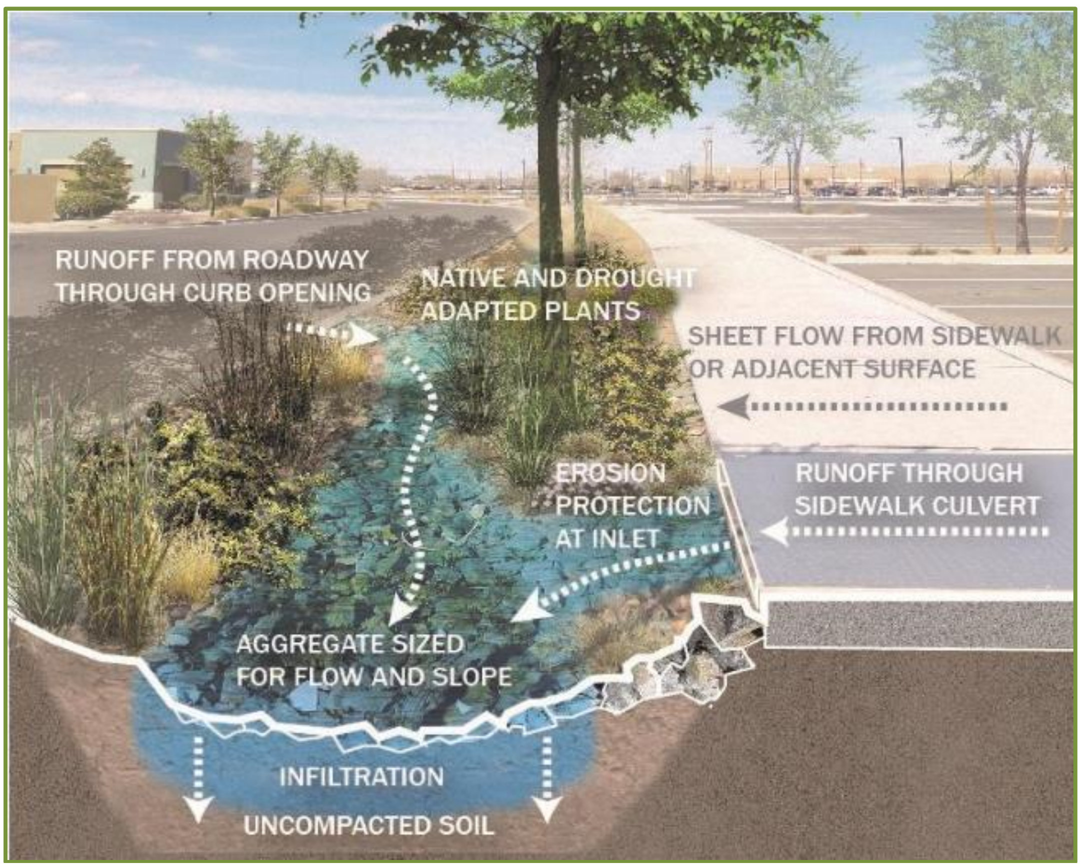
A. Stormwater Harvesting Basin

Description	• GSI practice consisting of a shallow, vegetated basin designed for capture and infiltration of stormwater runoff to support vegetation and improve water quality.
Advantages	• Captures and infiltrates runoff • Improves water quality • Reduces runoff volumes
Limitations	• Limited storage depth (typically 6”-9”) and volume
Maintenance	• Inspect after storms greater than ¼” (at least twice each year) • Remove trash, sediment
Other Considerations	• Recommended infiltration rate of at least 0.5-inch/hour • Irrigation or temporary watering should be provided for plant establishment • Overflow and erosion protection required

(Credit: *Bernalillo County GSI LID Standards,* 2021)

B. Bioswale

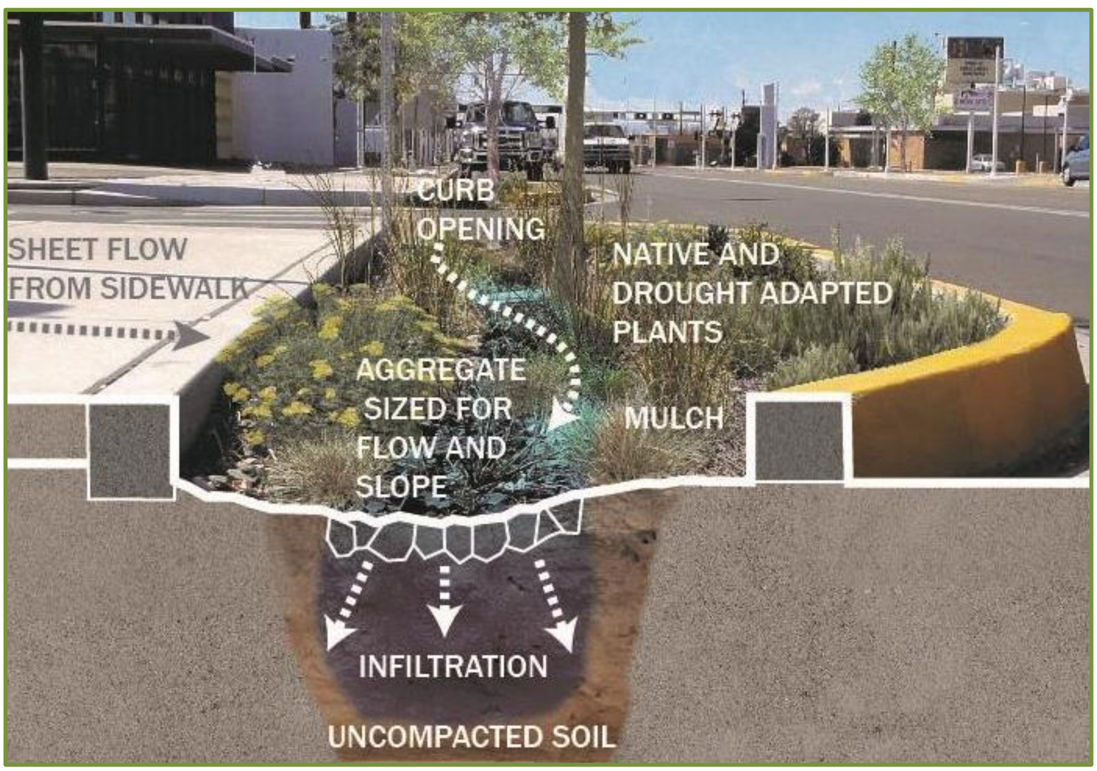
Description	• GSI practice consisting of a shallow, linear feature designed to improve water quality by conveying, slowing, and treating runoff; allows pollutants to settle out and promotes infiltration.
Advantages	• Slows runoff velocity and increases infiltration • Improves water quality • Compact footprint
Limitations	• Generally not appropriate where slopes are greater than 5% without tiered/stepped design • Minimal reduction to runoff volume or flowrate for large storms
Maintenance	• Inspect after storms greater than ¼" (at least twice each year) • Remove trash, sediment
Other Considerations	• Irrigation or temporary watering should be provided for plant establishment • Can be used in a depressed median or parkway application • Erosion protection required at concentrated inlets and outlets



(Credit: *Bernalillo County GSI LID Standards,* 2021)

C. Stormwater Bumpout

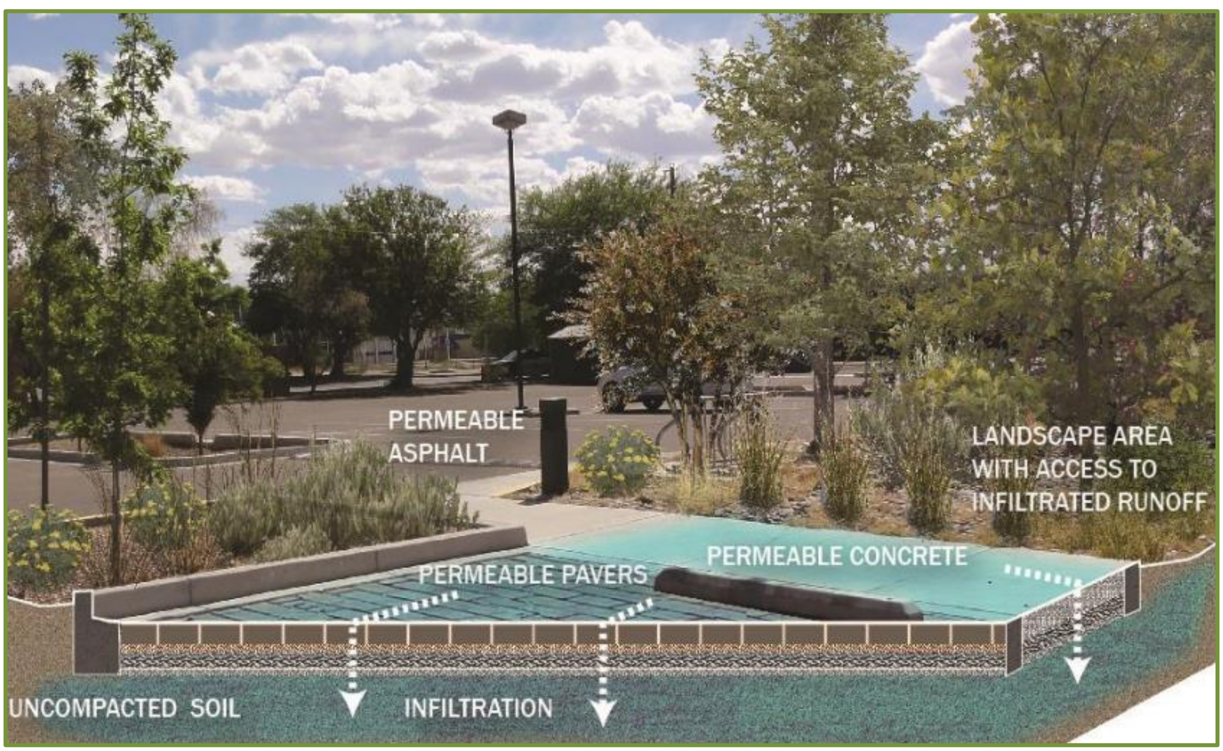
Description	• An area for infiltration and green stormwater infrastructure intervention created when the curb and gutter is moved out into the portion of the roadway normally reserved for parking. Otherwise known as 'bulbouts', 'chicanes', and 'curb extensions'.
Advantages	• Calms traffic • Can be retrofitted into existing street, where appropriate • Slows runoff velocity and increases infiltration • Improves water quality
Limitations	• Reduces streetside parking • Limited storage depth (typically 6"-9") and volume
Maintenance	• Inspect after storms greater than ¼" (at least twice each year) • Remove trash, sediment
Other Considerations	• Maximize infiltration rates • Irrigation or temporary watering should be provided for plant establishment • Erosion protection required at concentrated inlets and outlets • Best for low-speed roadways and parking lots • Impact on street flow capacity should be considered



(Credit: *Bernalillo County GSI LID Standards,* 2021)

D. Permeable Pavement

Description	• Paving material that allows stormwater to move through the pavement's surface to a storage layer below, allowing infiltration into the underlying soil. Material options include porous asphalt, pervious concrete, pavers, and various plastic products for reinforcing gravel or grass.
Advantages	• Increases infiltration rates • Reduces runoff volumes and rates
Limitations	• Can clog – should not be used with sediment-heavy runoff • Should not be used with regular winter salting or sanding • Not for heavy or high-speed (>30mph) traffic areas • Specialized maintenance equipment is needed
Maintenance	• Inspect after storms greater than ¼" (at least twice each year) • Remove sediment • Routine and long-term maintenance with high-performance, regenerative air vacuuming
Other Considerations	• Generally for use in low to moderate-vehicular use areas • Subgrade infiltration rate and strength impacts pavement design • ADA requirements should be considered carefully

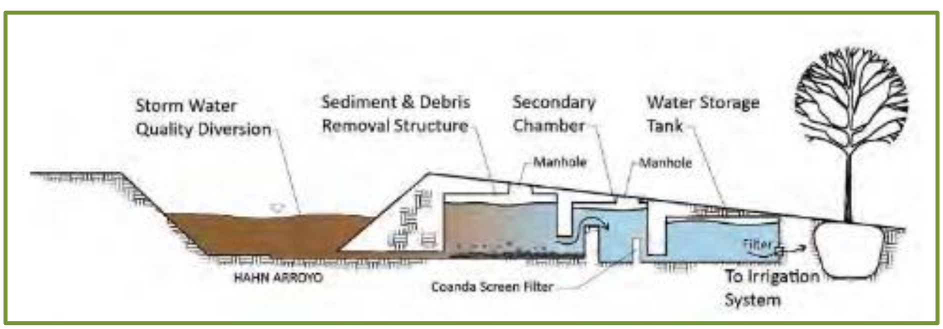


(Credit: *Bernalillo County GSI LID Standards,* 2021)

E. Underground Storage and Infiltration Systems

Description	• Various manufactured systems that capture and temporarily store stormwater collected from surrounding impervious surfaces.
Advantages	• Reduces runoff rates and volumes • Can incorporate water quality features • Useful when limited surface storage area is available
Limitations	• Relatively high cost • Inspection and maintenance are more difficult than other techniques in toolkit • Specialized maintenance equipment is needed
Maintenance	• Inspect monthly and after major storm events • Remove sediment using vacuum truck
Other Considerations	• Best used when stormwater has a low sediment load • Include sufficient access points • Include emergency overflow

(Credit: *NMDOT NPDES,* 2020)



(Credit: *NMDOT NPDES,* 2020)

V. Ideas for Application of Techniques

The graphics below present various ways in which GSI and other small-scale stormwater management techniques can be incorporated into a project. Design of these techniques should consider the project site characteristics as further described in the *Bernalillo County GSI/LID Standards*, Chapter 6 (Attachment A to this toolkit).

Bioswales and stormwater bumpouts generally lend themselves to use along roadways in the Northeast Heights of Albuquerque, particularly residential roadways. Stormwater harvesting areas can be implemented within relatively flat areas, including along roadways. Permeable pavement and underground storage systems can be utilized in a variety of settings with careful design considerations for existing utilities, constructability, and maintainability, but come at a higher cost.

A. Roadside Improvements Behind Existing Curbs or Sidewalks

Techniques presented in this toolkit can be retrofitted along roadways behind existing curb or behind existing sidewalk. Retrofits beyond the existing curb or sidewalk need to consider existing ROW width, existing utilities, and private improvements that may be constructed in public ROW, among other design considerations, but can be possible.

The graphic example below shows a conceptual stormwater harvesting basin behind an existing sidewalk, assuming there is adequate ROW for such a feature, integrated with other techniques to create a cohesive system.

(Credit: *Bernalillo County GSI LID Standards,* 2021)

B. Roadside Improvements as part of a Road Diet

Road diets involve the reduction in the number and/or narrowing of travel lanes to improve safety and make space for other improvements. The "before and after" example below shows a portion of 4th Street Revitalization, Phase 1 in the Village of Los Ranchos.


(Credit: Photos by BHI)

C. Pocket Parks

A pocket park is a small local park that is generally integrated into a neighborhood and provides health, social, and environmental benefits and can help manage and treat stormwater. Pocket parks can use stormwater harvesting basins to lower landscape irrigation costs and stormwater runoff rates.

Before: Palo Verde Pocket Park is a barren lot, October 2014.

After: Palo Verde Pocket Park is transformed with broad basins, meandering pathways, and a mix of native trees and shrubs, October 2016.

(Credit: *Watershed Management Group GI for Desert Communities*)

VI. Summary

This toolkit provides an introduction to small-scale stormwater management techniques that could be considered in the Pueblo Alto and Mile Hi neighborhoods, and elsewhere in the Northeast Heights of Albuquerque. The technique comparison matrix provided below can be used to help identify when and where these techniques may be appropriate.

Stormwater Technique Comparison Matrix

	Stormwater Harvesting Basin	Bioswale	Stormwater Bumpout	Permeable Pavement	Underground Storage and Infiltration
Cost	$	$	$$	$$	$$$
Stormwater Capture Potential	++	+	+	+	+++
GSI Co-Benefits[1]	+++	+++	+++	++	+
Ease of Implementation[2]	+++	+++	++	+	+
Maintenance Requirements	Low	Low	Low	Moderate	Moderate

1. "GSI Co-Benefits" is an assessment of the relative number and impact of co-benefits (described in Section IV of this toolkit) that could be created by each technique.
2. "Ease of Implementation" is an assessment of the relative complexity of each technique, acknowledging that less complex infrastructure systems are generally preferable. Increased complexity could be due to utility conflicts, right-of-way (ROW) limitations, design requirements, etc.

Key: Most favorable (dark green) → Least favorable (light green)

This toolkit was prepared by: Bohannan Huston, Inc. (Vince Steiner – Drainage Engineer; Rob Salazar)

RS/VCS/ab

Attachments

- Attachment A – *Bernalillo County Green Stormwater Infrastructure Low Impact Development Standards* (September 2021)
- Attachment B – *NMDOT National Pollutant Discharge Elimination System Manual - Appendix A* (December 2020)
- Attachment C – *Green Infrastructure for Desert Communities* (Watershed Management Group, January 2017)
- Attachment D – *Greater Phoenix Metro Green Infrastructure Handbook* (January 2019)
- Attachment E – *Sonoran Desert Green Infrastructure Resource Library* (2020)
- Attachment F – *Pocket Park Toolkit*

ATTACHMENT A

BERNALILLO COUNTY GREEN STORMWATER INFRASTRUCTURE LOW IMPACT DEVELOPMENT STANDARDS

SEPTEMBER 2021

GREEN STORMWATER INFRASTRUCTURE

LOW IMPACT DEVELOPMENT STANDARDS

BERNALILLO COUNTY
STATE OF NEW MEXICO

Bernalillo County
Green Stormwater Infrastructure / Low Impact Development Standards

September 2021

Bohannan Huston

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Introduction

Overview

Green Stormwater Infrastructure (GSI) and Low-Impact Development (LID) are approaches to stormwater management that mimic natural processes to improve water quality and mitigate environmental impacts, among other benefits. This document identifies Best Management Practices (BMPs) for GSI/LID that are appropriate for the arid environment of the Middle Rio Grande Valley and provides guidance for designers on the implementation of BMPs.

The *Green Stormwater Infrastructure / Low Impact Development Standards* also support Bernalillo County's Stormwater Quality Ordinance and represent an increased commitment on the part of the County toward the goal of broad implementation of GSI/LID. Though guidelines for the use of GSI/LID BMPs have been provided in the past, this document contains additional guidance and best practices for design and maintenance, as well as detailed drawings depicting County requirements. Users should note that this document constitutes an update to the *Bernalillo County Green Stormwater Infrastructure: Low Impact Strategies for Desert Communities*.

In particular, this document is intended to make it easier for design professionals to reference best practices. In addition to the locations and contexts in which GSI/LID is appropriate, this document outlines Bernalillo County regulatory requirements and provides detailed information to support sound GSI/LID BMP design and construction in Bernalillo County's arid environment. The guidance should be applied to new development and redevelopment projects, as well as roadway corridors.

Key Definitions

Green Stormwater Infrastructure (GSI) is a method of sustainable stormwater management that focuses on treating stormwater runoff prior to it entering rivers, streams, aquifers, and other waterways by leveraging the ecological functions of living, natural systems.

Low Impact Development (LID) refers to design and development practices that work with nature to reduce the stormwater runoff volume generated and minimize or eliminate adverse impacts to stormwater quality.

Best Management Practices (BMPs) refer to the proven techniques that may be applied to successfully manage stormwater runoff and improve water quality.

Purpose of GSI/LID Standards

Advance Best Practices in Stormwater Management and Pollution Reduction: GSI/LID, as reflected in this document and the Bernalillo County Technical Standards, is a set of methods that detain, disperse, attenuate, infiltrate, and/or filter stormwater runoff from impervious surfaces such as streets, sidewalks, rooftops, and parking areas. The intent of GSI/LID practices is to mimic predevelopment hydrology by managing stormwater as close to where it falls as possible.

Implementation of GSI/LID makes Bernalillo County an increasingly desirable place to live by improving community aesthetics, mitigating impacts from changing climate, improving air quality, increasing tree canopy, and improving stormwater quality. Bernalillo County also encourages GSI/LID as a means of meeting Federal Municipal Separate

Storm Sewer System (MS4) National Pollutant Discharge Elimination System (NPDES) Permit requirements.

Bernalillo Country Requirements: Bernalillo County requires that GSI/LID be considered as part of all site development plans. These plans are subject to review by Bernalillo County staff, who are also available to provide guidance during the site plan development process. Per the MS4 permit requirements, developers **must** address on-site stormwater quality volume. GSI/LID BMPs can be used to meet those requirements. Developers are required to submit a **post-construction evaluation form** as part of the Grading & Drainage Plan that states the ways in which GSI/LID were considered.

The process and procedures that developers and project designers must follow in the implementation of GSI/LID BMPs is contained in Section 3: Regulatory Requirements for Implementing GSI/LID BMPs.

Integration with Bernalillo County Technical Standards: This document was developed in conjunction with the update to the Bernalillo County Technical Standards, completed in 2021. The Technical Standards provide design requirements and considerations for transportation and site infrastructure in unincorporated areas of Bernalillo County. Whereas the Technical Standards provide guidance on appropriate locations for GSI/LID BMPs, this document provides direction on the specific application of GSI/LID BMPs within those appropriate locations.

Enhance Public Understanding and Increase Application of GSI/LID: An important objective of this document is to improve the public's understanding and expectations about what GSI/LID is and what it looks like, as ecologically responsible designs may differ from people's expectations. Bernalillo County strives to be a leader in sustainable design and infrastructure, and it is the intent of the County that the techniques and guidance provided in this document may be applicable for other agencies and developers in the Middle Rio Grande Valley.

Intended Users

This document is a guide for both private development and publicly-funded projects in the installation of GSI/LID BMPs. For **private developers**, the GSI/LID Standards serve to explain the County review process and provide guidance on appropriate BMPs. For **Bernalillo County staff** and consultants, this document is specifically intended as a resource for inclusion of GSI/LID BMPs in publicly-funded projects.

Contents of the GSI/LID Standards Document

Regulatory Requirements: Bernalillo County regulatory environment and review process

General Considerations: Appropriate GSI/LID BMP selection, maintenance considerations, use of mulch, and other best practices for design and construction

BMP Technical Guidance Sheets: Definitions, general design and maintenance guidance as well as appropriate application locations

Standard Drawings: Detailed guidance on the design and construction of BMPs

Treatment Train Guidance: Examples of how BMPs can be used in combination (i.e. treatment trains)

Plant List: Identification of native and drought-tolerant plants that are appropriate for GSI/LID locations across Bernalillo County

Mulch: Guidance on types, preferred use, and best practices for mulch.

1 | Locations for GSI/LID BMPs

General Application for GSI/LID BMPs

GSI/LID BMPs included in this document can be used in various applications, including in public infrastructure projects, in roadway rights-of-way and medians, public facility parking lots, and as part of public and private site developments (e.g. building sites, community centers, etc.). The application of GSI/LID BMPs may vary depending on site conditions and project needs.

Commercial applications include GSI/LID BMPs that address stormwater runoff from impervious surfaces, such as parking lots, roadways, sidewalks, and rooftops, as well as incorporation into on-site landscaping and stormwater management facilities (e.g. detention ponds). Projects in the **public right-of-way** also produce runoff from impervious surfaces and should incorporate BMPs into roadway medians, landscape/buffer zones, open spaces, and alongside trail facilities.

GSI/LID is also appropriate in **residential settings**, and Bernalillo County offers incentive programs for the use of rain barrels and cisterns. See the Bernalillo County website for additional information. For more information on rainwater harvesting on a residential scale go to www.bernco.gov/rainwater.

The typical applications listed in the following sections are not intended to be an exhaustive set of practices, and other techniques may be approved by Bernalillo County upon review. As examples, stormwater planters, tree boxes and infiltration chambers are typically manufactured proprietary GSI/LID solutions; these are not detailed in the Bernalillo County GSI/LID standard drawings and technical guidance sheets but are techniques that Bernalillo County encourages designers to consider.

Considerations by Road Type

Urban type roads typically manage stormwater through curb and gutter and may include medians and landscape buffers. As such, there are a variety of opportunities for the application of GSI/LID BMPs.

Figure 1: Urban Type Road

Source: K. Bronson, Bernalillo County

Rural type roads do not typically feature curb and gutter, though some techniques, such as bioswales and stormwater harvesting basins, are appropriate. See the Bernalillo County Technical Standards for additional information on road types.

Figure 2: Rural Type Road: 2nd St Albuquerque, NM

Source: K. Bronson, Bernalillo County

Typical Locations for GSI/LID BMPs

Roadway Median

Medians may be landscaped to increase roadway aesthetics, improve safety, and provide traffic calming benefits. Medians are conducive to GSI/LID interventions as they can easily be modified as low points where stormwater can be collected and treated. By modifying the curb and lowering the grade, stormwater can enter the basin from the roadway. Given their linear characteristics, medians are also conducive to conveyance to other stormwater management installations.

Typical applications include:

- Bioswale
- Stormwater Harvesting Basin
- Check Dam
- Depressed Median
- Curb Openings with Sediment Traps

Figure 3: Roadway Median Example: Tucson, AZ

Source: K. Bronson, Bernalillo County

Landscape/Buffer Zone

Landscape/buffer zones are generally located between the sidewalk and the curb along a roadway. GSI/LID BMPs may also be applied at bumpouts or curb extensions located at intersections or mid-block locations. These areas provide safety and traffic calming benefits and are typically landscaped to improve aesthetics and enhance the pedestrian experience. These structures are conducive to GSI/LID BMPs as they can easily be modified as low points where stormwater can be collected. By using curb openings and lowering the grade, stormwater can enter the landscape/buffer zones from the roadway or other impervious area. Given their linear characteristics, landscape/buffer zones are also to conducive conveyance to other stormwater management installations.

Typical applications include:

- Bioswale
- Infiltration Trench
- Stormwater Tree Box*
- Stormwater Planter*
- Stormwater Bumpout
- Curb Openings with Sediment Traps

**Not included in BMPs since the designs are proprietary.*

Figure 4: Landscape Buffer Zone Examples

Source: K. Bronson; Left: 2nd St, Bernalillo County; Right: Central Ave, Albuquerque, NM

Source: J. Luna, Bernalillo County; Central Ave, Albuquerque, NM.

Landscaped Parking Areas

Parking areas offer opportunities for stormwater management as they typically include landscape strips and basins utilized for on-site stormwater management. Similar to medians and roadside buffers, landscaped areas in parking lots can easily be modified as low points where stormwater can be collected. By using curb openings and lowering the grade, stormwater can enter the BMPs from drive aisles and parking stalls. Additionally, angled parking, which can accommodate more parking spaces in a smaller area, can be used to reduce impervious area.

Typical applications include:

- Bioswale
- Infiltration Trench
- Stormwater Bumpout

Figure 5: Landscaped Parking Area Example

Source: S. Osterman; Las Estancias, South Valley, Bernalillo County

Site Development Applications

GSI/LID interventions should be considered and can be applied on most development and redevelopment sites to enhance community aesthetics and manage stormwater as close to where it falls as possible. Public facilities where GSI/LID may be considered include community centers, government buildings, libraries, and schools, which all typically feature landscaped areas. Typical applications for site development contexts include:

- Stormwater Harvesting Basin
- Bioswale
- Permeable Pavement
- Check Dam
- Infiltration Trench

Figure 6: Site Development Applications

Source: Left: BHI/MRWM; Smith Brasher Hall, CNM; Right: S. Osterman, Las Estancias in Bernalillo County Albuquerque, NM

2 | Benefits of Implementing GSI/LID Best Management Practices

The fundamental goal in implementing GSI/LID BMPs is to reduce the amount of stormwater runoff and pollution reaching surface waters and adversely impacting the watershed. In this way, GSI/LID is a direct means of complying with the County's MS4 Permit.

GSI/LID practices are designed to address smaller rainfall events by creating a "break" in directly connected impervious areas (DCIA). DCIAs account for the majority of stormwater runoff in developed areas; by breaking up impervious areas, such as parking lots with landscape areas that feature GSI/LID BMPs, stormwater runoff from smaller rain events can be reduced or eliminated.

Direct Benefits

Direct benefits of GSI/LID include slowing the flow of water during and after rainfall events (i.e. **peak flow attenuation**), thus **reducing erosion** and promoting **sediment capture** to ensure that landscaping and stormwater management areas remain durable and functional over the long-term. GSI/LID BMPs also **improve water quality by filtering and removing pollutants** and capturing floatables, trash, and other debris.

By adding landscaped areas that mimic natural conditions, GSI/LID increases infiltration and groundwater recharge. Collectively, BMPs promote healthier waterways and improve overall stormwater quality.

Co-Benefits

In addition to stormwater management and pollution reduction, GSI/LID provides a range of co-benefits that positively affect sustainability and overall quality of life in communities.

Water Conservation

A sustainable landscape design in an arid region like Bernalillo County includes GSI/LID. Rainwater harvesting reduces or eliminates use of potable water for irrigation. In contrast to typical landscaping, GSI/LID encourages the use of native/drought-tolerant plants rather than plants that need supplemental irrigation. Although many plants require supplemental irrigation during the establishment period (generally 3-5 years), incorporating GSI/LID in landscaping can provide significant long-term water savings.

Reduce Urban Heat Island and Climate Change Impacts

The presence of landscaped areas can reduce the impacts of climate change and urban heat island effect by minimizing the paved surfaces that absorb and re-emit heat from the sun. Landscaped areas that include trees provide shade and cooling in urban areas.

Increased Tree Canopy and Improved Air Quality

Trees used in GSI/LID features contribute to improved air quality and heat island impact mitigation, as well as increased shade, habitat creation, and general livability for residents.

Create Wildlife Habitat

GSI/LID installations replicate native environments outside of the urban area, creating small pockets of wildlife habitat in urban areas. The use of native plant species in landscaping support local fauna and improve biodiversity.

Traffic Calming

GSI/LID techniques can be integrated into medians and buffer areas to provide traffic calming and safety benefits. Landscape areas between the sidewalk and roadway travel lanes provide a buffer between motorists and pedestrians, while street trees and vegetation have been shown to reduce travel speeds and crash rates.


Source: NACTO, Urban Street Stormwater Guide

Improved Physical and Mental Health Outcomes

At a neighborhood scale, GSI/LID provides opportunities for physical activity while also improving mental health by reducing stress and promoting cognition. Additionally, installation of GSI/LID BMPs can address social equity when applied in communities that lack access to parks and green spaces.

Environmental Justice

Environmental Justice means all people, regardless of race, color, national origin, or income are entitled to equal protection from environmental risks. Communities with environmental justice issues often face a disproportionate share of adverse environmental impacts from industrial and governmental operations and polices, which can result in issues such as heat island, industrial pollution, air pollution, and health impacts. Green stormwater infrastructure can provide social, environmental, and economic benefits to these communities by creating a healthier environment where people live and work.

Aesthetics

Well-designed GSI/LID BMPs can create visually interesting pockets of green space to enhance community aesthetics. GSI/LID can also provide social benefits when BMPs are integrated into outdoor recreation areas and other gathering places.

3 | Regulatory Requirements for Implementing GSI/LID

Regulatory Context

The US Environmental Protection Agency (EPA) issued the Middle Rio Grande NPDES MS4 Permit in 2014. In addition to general requirements to mitigate the presence of pollutants in stormwater runoff, the MS4 Permit requires all new development and redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale, to retain and treat the stormwater quality volume on-site. This requirement applies to both public projects and private developments. Projects must also evaluate for opportunities to use GSI/LID techniques in the site design.

In 2016, Bernalillo County passed the Stormwater Quality Ordinance, Chapter 38, Article IV, to establish stormwater management requirements for the unincorporated area of Bernalillo County. The ordinance requires all new development and redevelopment projects that disturb greater than or equal to one acre – including projects less than one acre that are part of a larger common plan of development or sale – include BMPs to manage the stormwater quality design volume on-site (Section 4).

In addition, all projects that retain or detain stormwater are subject to the rule from the Office of the State Engineer that all waters must infiltrate or be released from detention within 96 hours. Additional information can be found in the *Green Infrastructure Implementation in New Mexico* document developed by the New Mexico Environment Department in coordination with the Office of the State Engineer.

Bernalillo County Review Process

Bernalillo County requires submittal of the *Stormwater Post-Construction Green Stormwater Infrastructure / Low Impact Development Best Management Practices Evaluation Form* for new development and redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale. The form is available on the Bernalillo County website (www.bernco.gov/postconstruction).

When is GSI/LID Required?

GSI/LID BMPs are **required** for all new development and redevelopment projects that disturb greater than or equal to one acre**.** GSI/LID BMPs are **encouraged** for all new development and redevelopment projects that disturb less than or equal to one acre.

In addition to the guidance contained in this document, Bernalillo County staff is available to consult with developers and site designers on the appropriate application of GSI/LID BMPs. Bernalillo County encourages developers to consider GSI/LID BMPs early in the site development process and to incorporate GSI/LID into grading and drainage plans. Additional information on the County review process can be found in Section 6: GSI/LID BMP Design and Construction.

4 | Stormwater Quality Design Storm and Design Volume

Under the MS4 Permit and the Bernalillo County Stormwater Quality Ordinance (Chapter 38), the stormwater quality design volume (SWQV) that must be treated and managed onsite. The SWQV is calculated using the 90th percentile rain event for new development projects and the 80th percentile rain event for redevelopment projects.

The SWQV calculation is determined as follows and the storm rainfall depths are summarized in Table 1:

- **New Development** –The 90th percentile rainfall depth (0.615 inches) multiplied by the new development impervious and compacted areas.
- *Retained Volume = 0.615 inches * impervious and compacted areas.* **Redevelopment** - The 80th percentile rainfall depth (0.48 inches) multiplied by the additional redevelopment impervious and compacted areas. *Retained Volume = 0.48 inches * new impervious and compacted areas.*

All stormwater runoff from a site must receive stormwater quality treatment and all BMPs must be sized for the SWQV for the tributary area. If a BMP is sized for the SWQV for the entire site, then the designer must ensure that it collects runoff from the entire site and is not limited to a portion of the site. More often, site runoff is collected at multiple locations requiring multiple properly sized BMPs.

See the Standard Drawings and Table 3 for stormwater quality volume design data required for project plans for GSI/LID BMPs.

Table 1: Stormwater Quality Design Storm by Development Type

Development Type	Percentile Event	Rainfall Depth
New Development	90^{th}	0.615"
Redevelopment	80^{th}	0.48"

Source: *Estimating Predevelopment Hydrology in the Middle Rio Grande Watershed, New Mexico* (EPA Publication Number 832-R-14-007, Tetra Tech, 2014)

5 | GSI/LID Best Management Practices

General Overview

This section highlights the most common and most appropriate GSI/LID BMPs for application in unincorporated Bernalillo County given the arid environment and desire to conserve water.

Table 2 presents the GSI/LID BMPs that are included in this document, along with typical benefits associated with these techniques. Each BMP is profiled below in a **technical guidance sheet** that contains a graphic depiction, design considerations, maintenance needs, appropriate locations and context, and complementary techniques, as well as a **standard drawing** that indicates preferred design specifications and construction methods.

It is important to note that the appropriate GSI/LID BMP may vary from the provided guidance depending on site specific conditions and the site location within the Middle Rio Grande region. Site features and conditions, as well as design considerations, should inform the selection of appropriate GSI/LID BMPs.

The BMPs presented in this section are not intended to be an exhaustive set of practices, and other techniques may be approved by Bernalillo County upon review. As examples, stormwater planters, tree boxes and infiltration chambers are typically manufactured proprietary GSI/LID solutions; these are not detailed in the Bernalillo County GSI/LID standard drawings and technical guidance sheets but are techniques that Bernalillo County encourages designers to consider. Designers may consult the document *Bernalillo County Green Stormwater Infrastructure: Low Impact Design Strategies for Desert Communities* for additional techniques and guidance.

GSI/LID BMPs designed in accordance with the standard drawings in this document and properly located/applied will be approved by Bernalillo County. Any design modifications to the standard drawings and the Technical Standards will be reviewed and evaluated on a project-by-project basis.

Table 2: Summary of Benefits by BMP

	Reduces or Regulates Runoff Rate or Volume	Filters out Pollutants	Increases Infiltration	Captures Debris, Floatables, & Sediment	Reduce Urban Heat Island Effect	Promotes Evaporation / Transpiration
Curb Opening with Sediment Trap				✓		
Stormwater Harvesting Basin	✓	✓	✓	✓	✓	✓
Stormwater Bumpout	✓	✓	✓	✓	✓	✓
Bioswale	✓	✓	✓		✓	✓
Depressed Median	✓	✓	✓		✓	✓
Infiltration Trench	✓	✓	✓			
Check Dam	✓		✓	✓		
Outlet Control Structure	✓			✓		
Permeable Pavement	✓	✓	✓		✓	

Application of BMPs and Treatment Trains

GSI/LID BMPs can be used alone or in conjunction with other treatments. However, GSI/LID BMPs are most effective when used in various combinations – called treatment trains – that are tailored to a given site. A stormwater treatment train helps to maximize infiltration of stormwater and capture pollutants in stormwater runoff before they reach the downstream receiving waters, thus providing better overall results compared to use of a single BMP. A treatment train can consist of multiple installations of one type of GSI/LID BMP (e.g. stormwater harvesting basins) or multiple BMPs (e.g. swales and check dams).

Considerations for ADA Compliance

All GSI/LID BMP installations should meet ADA requirements – need to rephrase. Will have some installations that are not completely ADA compliant and that's ok. Should word to suggest that ADA compliance as feasible. Designers should review and consider the intent of the ADA requirements when selecting BMPs for locations where pedestrians may be present.

Figure 7 (page 33) and Figure 8 (page 34) are examples of treatment trains that show how BMPs can function together to manage stormwater runoff. The treatment train in Figure 7 illustrates how permeable pavement, curb openings with sediment traps, a stormwater bumpout, and an infiltration trench collectively provide an effective GSI/LID installation adjacent to a roadway or parking lot. The treatment train in Figure 8 shows a combination of a bioswale, check dam, and stormwater harvesting basin as a GSI/LID solution that could fit into many development designs.

GSI-01

CURB OPENING

CURB OPENING

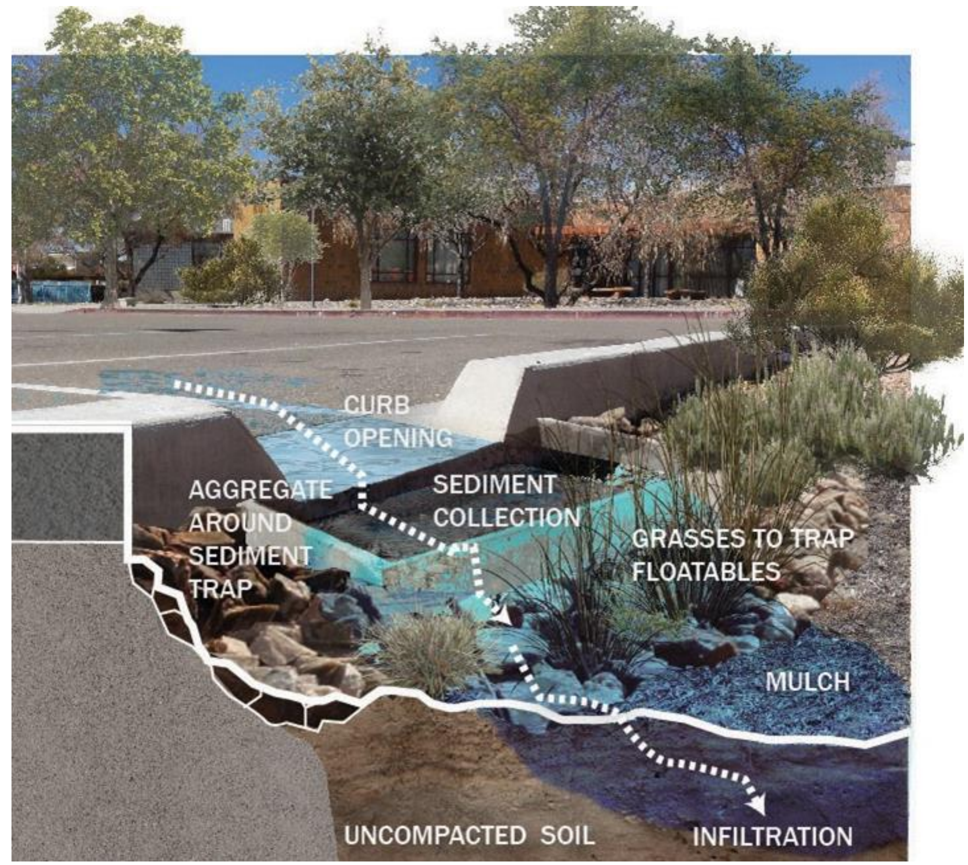
An opening in a curb to allow stormwater from an impervious surface, such as roads, parking lots, or hardscape areas, to flow into an infiltration area. Typical design includes a sediment trap located behind the curb opening.

DESIGN CONSIDERATIONS

- Can be used to retrofit existing projects, as well as constructed with new projects. Retrofit application will require sawcut & removal of existing curb & gutter.
- Curb opening length should be 2-feet minimum to prevent clogging.
- A sediment trap is recommended to facilitate maintenance.
- A minimum 2-inch elevation drop should be provided from the curb opening flowline to the finished grade at back of curb, to ensure positive drainage.
- Erosion protection must be provided downstream of the sediment trap.
- Size & place erosion protection as needed for design storm velocity & slope stabilization.
- Utilize the AASHTO Roadside Design Guide when placing & designing curb openings adjacent to travel ways.

MAINTENANCE

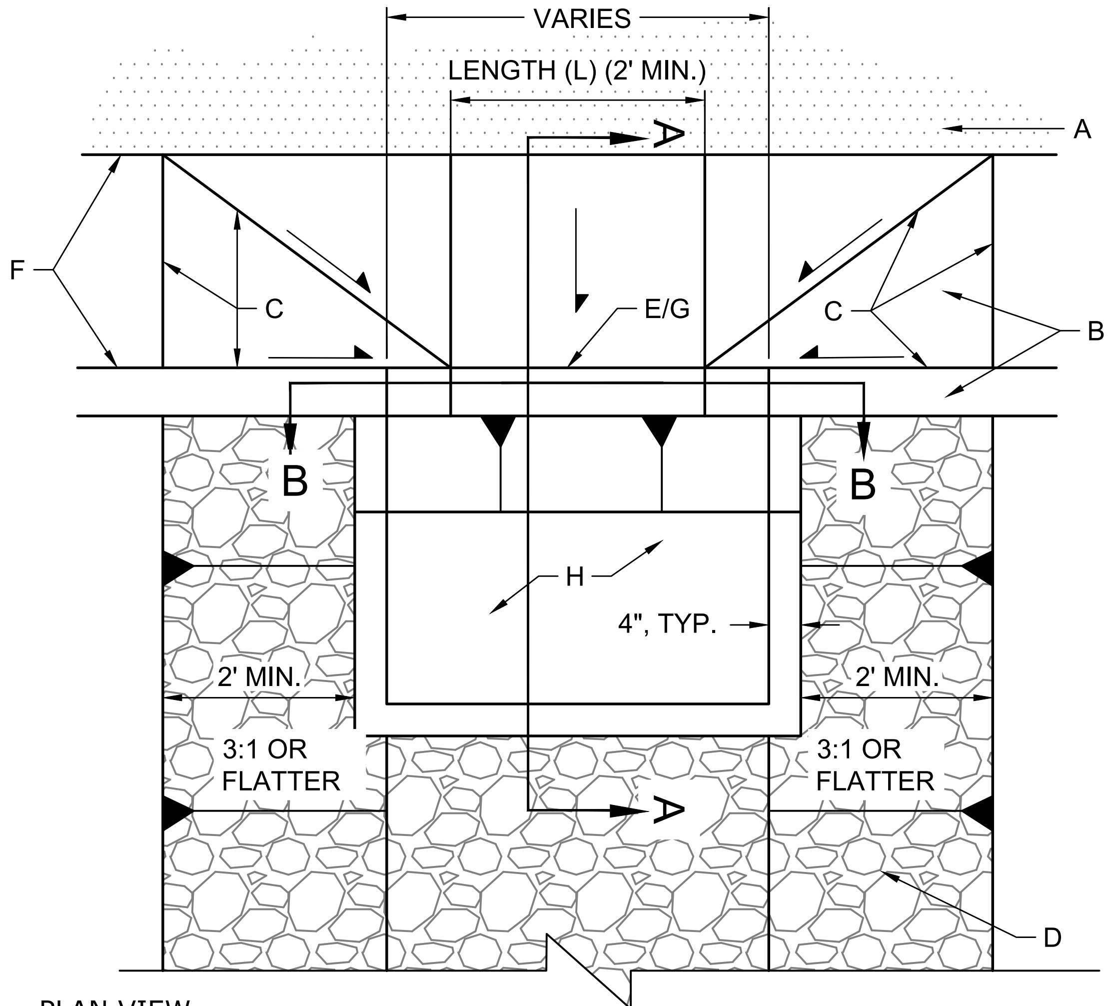
- Inspect after storms > 0.25-inches, recommend inspections minimum of twice per year.
- Remove debris, trash & accumulated sediment from curb opening & sediment trap.
- Check for & repair erosions issues.
- Routinely check curb opening for damage from vehicle strikes & repair, as necessary.



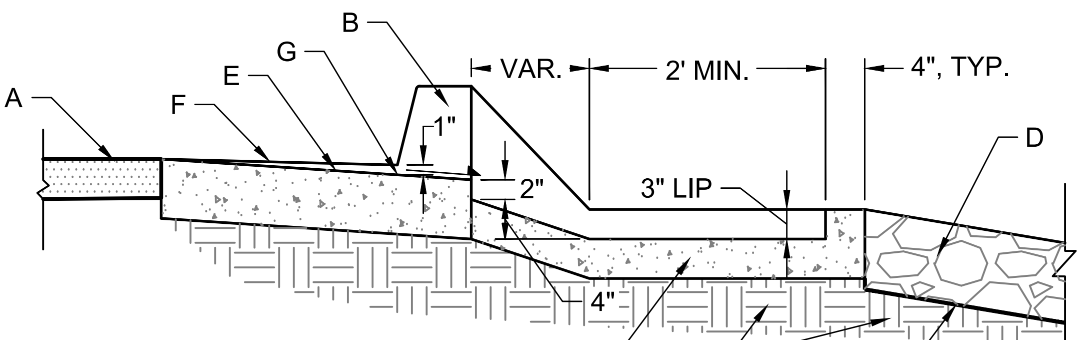
WHERE TO USE

✓	Urban Type Road
	Rural Type Road
✓	Streetside
✓	Parking
✓	Residential Development
✓	Commercial/Institutional Development

FUNCTIONS WITH



PLAN VIEW



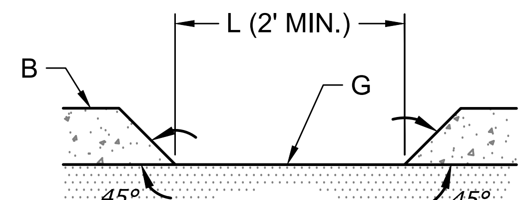
SECTION A-A

GENERAL NOTES:

1. SEE TECHNICAL GUIDANCE SHEET FOR DESIGN GUIDANCE AND CONSIDERATIONS.
2. CURB OPENING LENGTH (L) SHALL BE PROVIDED ON PROJECT PLANS (2' MIN.).
3. SEDIMENT TRAP SHOULD BE DESIGNED FOR CONTRIBUTING WATERSHED/SEDIMENT LOAD AND DESIGN HYDRAULIC CONDITIONS. DIMENSIONS SHOWN ARE FOR TYPICAL APPLICATION AND MAY BE MODIFIED BY PROJECT PLANS.
4. DETAIL AS SHOWN ASSUMES NEW CONSTRUCTION. MAY BE MODIFIED FOR RETROFIT CONSTRUCTION OF CURB OPENING.

CONSTRUCTION NOTES:

A. ADJACENT ROADWAY/PARKING SURFACE.
B. CURB OR CURB AND GUTTER PER PROJECT PLANS. STANDARD C&G PER COUNTY STANDARD DWG 2415A SHOWN.
C. GUTTER TRANSITION PER COUNTY STANDARD DWG 2207 OR AS MODIFIED PER PROJECT PLANS.
D. RIPRAP RUNDOWN OR EROSION PROTECTION. LAYOUT, DIMENSIONS, AND RIPRAP SIZE/THICKNESS PER PROJECT PLANS.
E. DEPRESSED GUTTER AT CURB OPENING.
F. NORMAL GUTTER.
G. POINT OF MEASUREMENT FOR CURB OPENING FLOWLINE ELEVATION.
H. CONCRETE SEDIMENT TRAP, 4" THICK. DIMENSIONS (LENGTH & WIDTH) PER PROJECT PLANS.
I. SUBGRADE BELOW SEDIMENT TRAP AND RIPRAP COMPACTED TO 95% MAX DENSITY.
J. NON-WOVEN GEOTEXTILE FILTER CLOTH BETWEEN RIPRAP AND SUBGRADE.



SECTION B-B

COUNTY OF BERNALILLO

REVISIONS

CURB OPENING

GSI-01

APR 2021

GSI-02

STORMWATER HARVESTING BASIN

STORMWATER BASIN

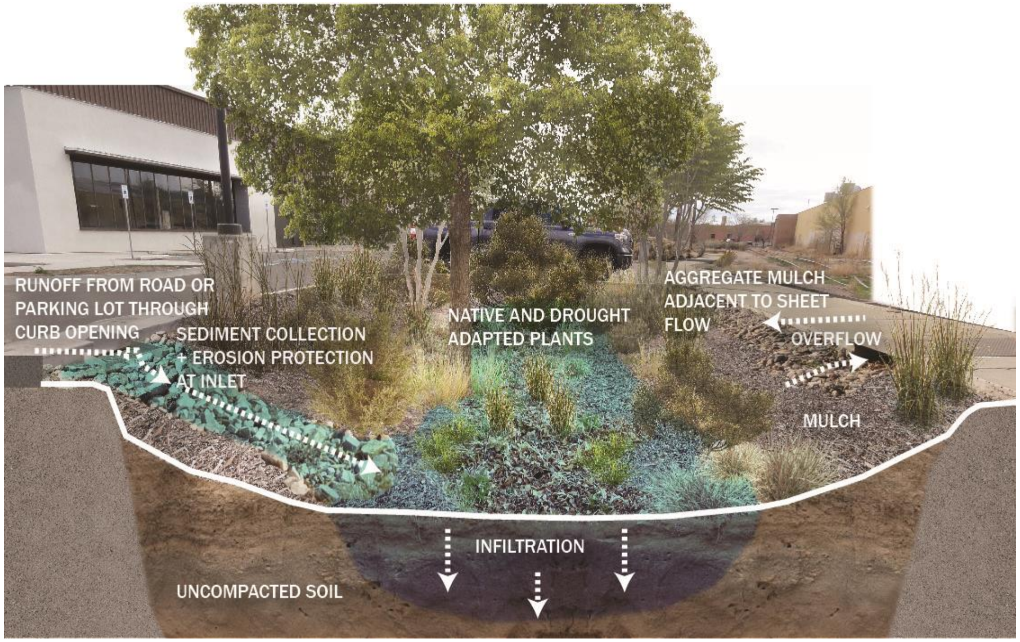
A stormwater retention basin designed for capture and infiltration of stormwater runoff to support vegetation, regulate discharge rates, and improve water quality.

DESIGN CONSIDERATIONS

- Consider depth to the groundwater table & bedrock – refer to Section 6, General Design Principles.
- Recommend infiltration rate greater than 0.5-inch/hr. Infiltration testing should be conducted at the proposed basin bottom elevation. An underdrain may be required if the infiltration rate is less than 0.5-inch/hr.
- Ponded surface water shall infiltrate or be released from detention within 96 hours or less, if required by local ordinances.
- To maximize infiltration, do not compact bottom during or after construction & ensure that the bottom is scarified per the standard drawing.
- Size & place erosion protection as needed for design storm velocity & slope stabilization.
- Overflow structure required & shall be sized for the 100-yr. discharge or design report shall demonstrate that the basin retains the 100-yr., 24-hr. contributing runoff.
- Consider a sediment trap at concentrated inflows.
- Place plants according to elevation zone & inundation zone. Do not place plants where inlet(s) or overflow will be impacted.
- Include an irrigation system for plant establishment.

MAINTENANCE

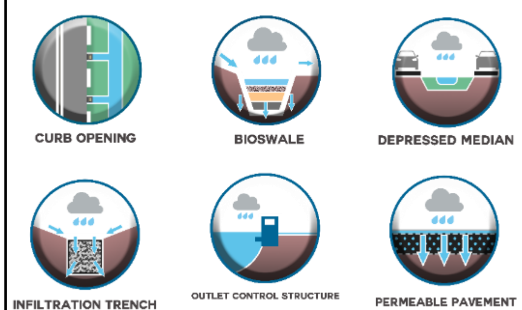
- Inspect after storms > 0.25-inches, recommend inspections minimum of twice per year.
- Remove debris, trash & accumulated sediment. The accumulated sediment should be removed if it inhibits vegetation or reduces the basin capacity.
- Check for & repair erosions issues.
- Add & redistribute organic mulch as needed.
- Prune & replace plants as needed.
- Leave organic debris in place to biodegrade.
- Remove invasive species.

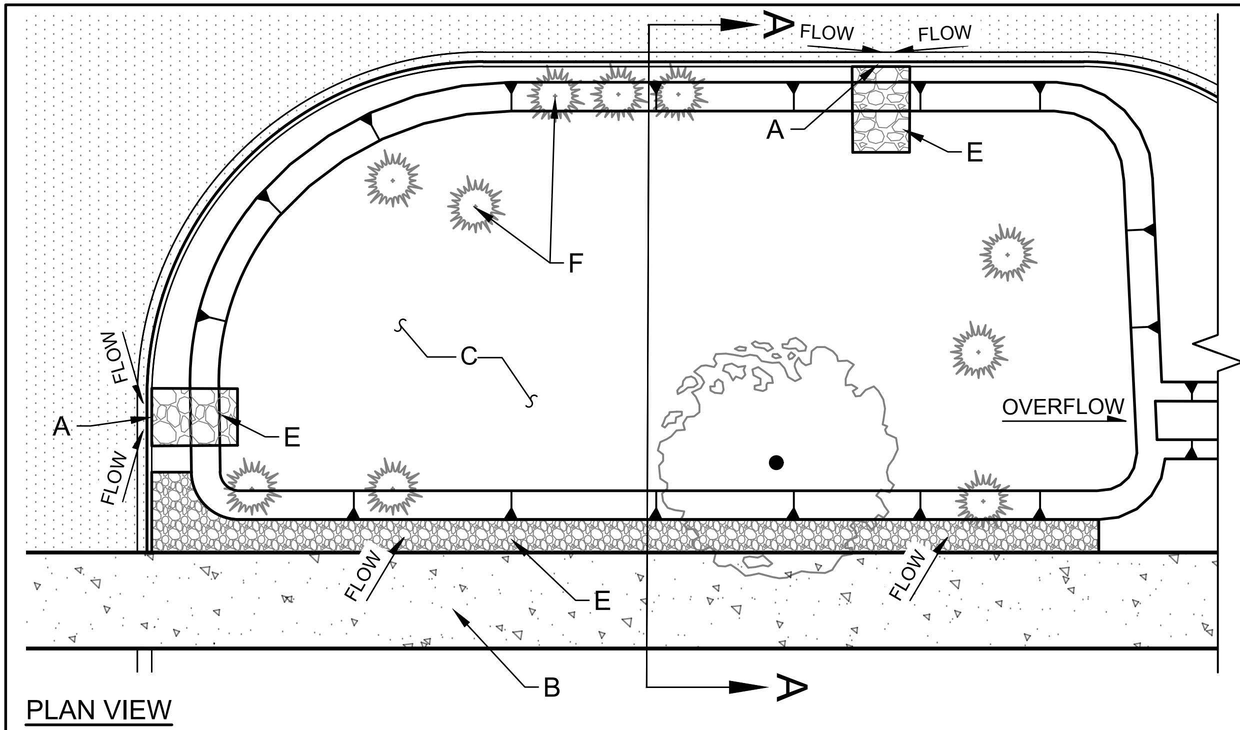


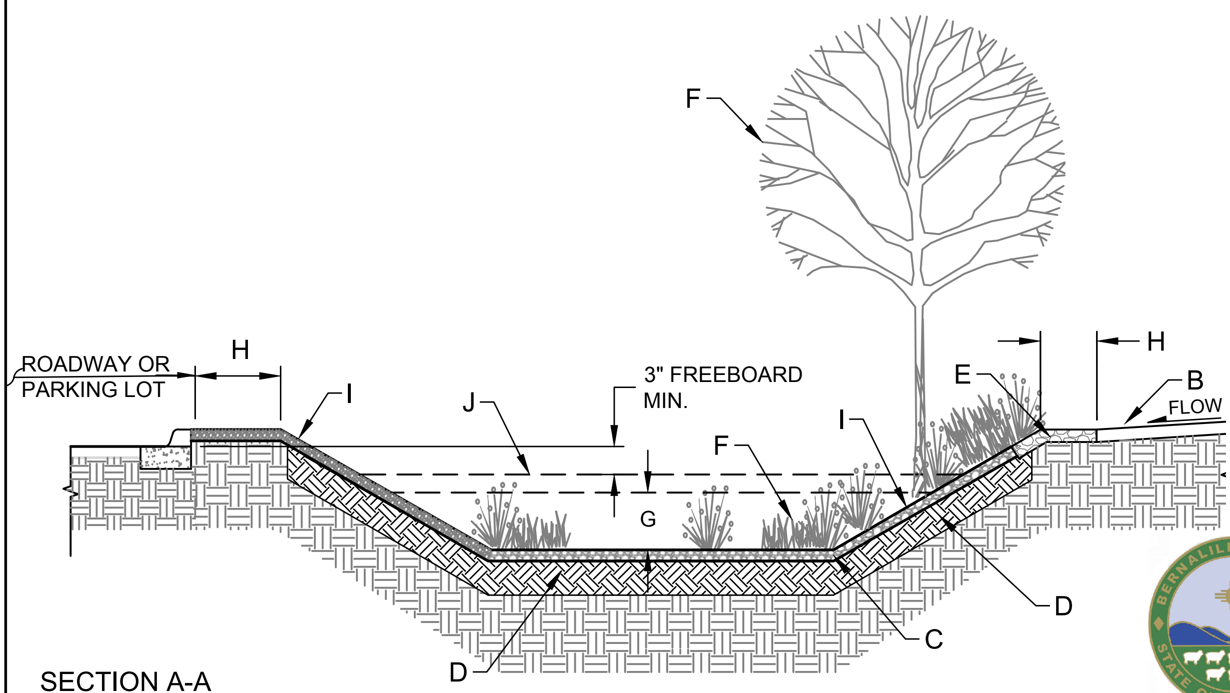
WHERE TO USE

✓	Urban Type Road
✓	Rural Type Road
✓	Streetside
✓	Parking
✓	Residential Development
✓	Commercial/Institutional Development

FUNCTIONS WITH







GENERAL NOTES:

1. SEE TECHNICAL GUIDANCE SHEET FOR DESIGN GUIDANCE AND CONSIDERATIONS.
2. OVERFLOW REQUIRED & SHALL BE SIZED FOR 100-YEAR PEAK DISCHARGE OR DESIGN REPORT SHALL DEMONSTRATE BASIN RETAINS 100-YEAR, 24-HOUR CONTRIBUTING RUNOFF.
3. NO PLANTINGS IMPACTING FLOW CAPACITY SHALL BE PLACED AT CONCENTRATED FLOW INLETS OR OVERFLOW.
4. TREES AND SHRUBS SHOULD BE LOCATED IN ACCORDANCE WITH INUNDATION ZONE AND ELEVATION ZONE. SEE BERNALILLO COUNTY GSI PLANT LIST FOR GUIDANCE.
5. MULCH TYPE AND LOCATION PER PROJECT PLANS SHALL BE INFORMED BY EVALUATION OF HYDRAULIC CONDITIONS AND MAY BE USED FOR EROSION PREVENTION, SLOPE STABILIZATION, OR DESIGN PREFERENCE. ORGANIC MULCH MAY BE USED WHERE DESIGN VELOCITY IS LESS THAN 1 FPS.
6. AVOID COMPACTION OF BASIN BOTTOM DURING AND AFTER CONSTRUCTION TO MAINTAIN INFILTRATION RATE

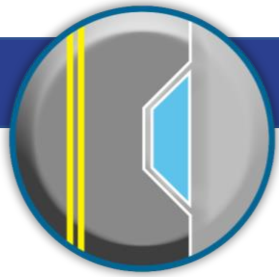
CONSTRUCTION NOTES:

A. CURB OPENING PER COUNTY STD DWG GSI-01.
B. SIDEWALK , PATH, OR OTHER HARDSCAPE DRAINING TO BASIN.
C. ORGANIC OR INORGANIC MULCH PER PROJECT PLANS. PLANS SHALL SPECIFY MULCH TYPE, THICKNESS, AND LOCATION.
D. SCARIFY SUBGRADE TO DEPTH OF 12", MIN.
E. EROSION PROTECTION AT FLOW INLET. TYPE & DIMENSIONS PER PROJECT PLANS. COMPACT SUBGRADE BELOW EROSION PROTECTION TO 95% OF MAX DENSITY.
F. PLANTS PER PROJECT PLANS.
G. 9" MAXIMUM PONDING DEPTH & DEPTH FOR CALCULATING STORMWATER QUALITY VOLUME (SWQV). MEASURED FROM BASIN BOTTOM TO OVERFLOW ELEVATION.
H. 2' STEP OUT WHEN BASIN ALONG ROADWAY. 1' SETBACK ALONG OTHER PEDESTRIAN ROUTES.
I. 3H:IV SIDE SLOPE OR FLATTER TYP.
J. WATER SURFACE AT 100-YEAR OVERFLOW DEPTH. FREEBOARD MEASURED FROM OVERFLOW WATER SURFACE TO TOP OF BASIN OR LOWEST INFLOW ELEVATION (WHICHEVER IS LOWEST).

REVISIONS	COUNTY OF BERNALILLO
	STORMWATER HARVESTING BASIN
	GSI-02 APR 2021

GSI-03

STORMWATER BUMPOUT



STORMWATER BUMPOUT

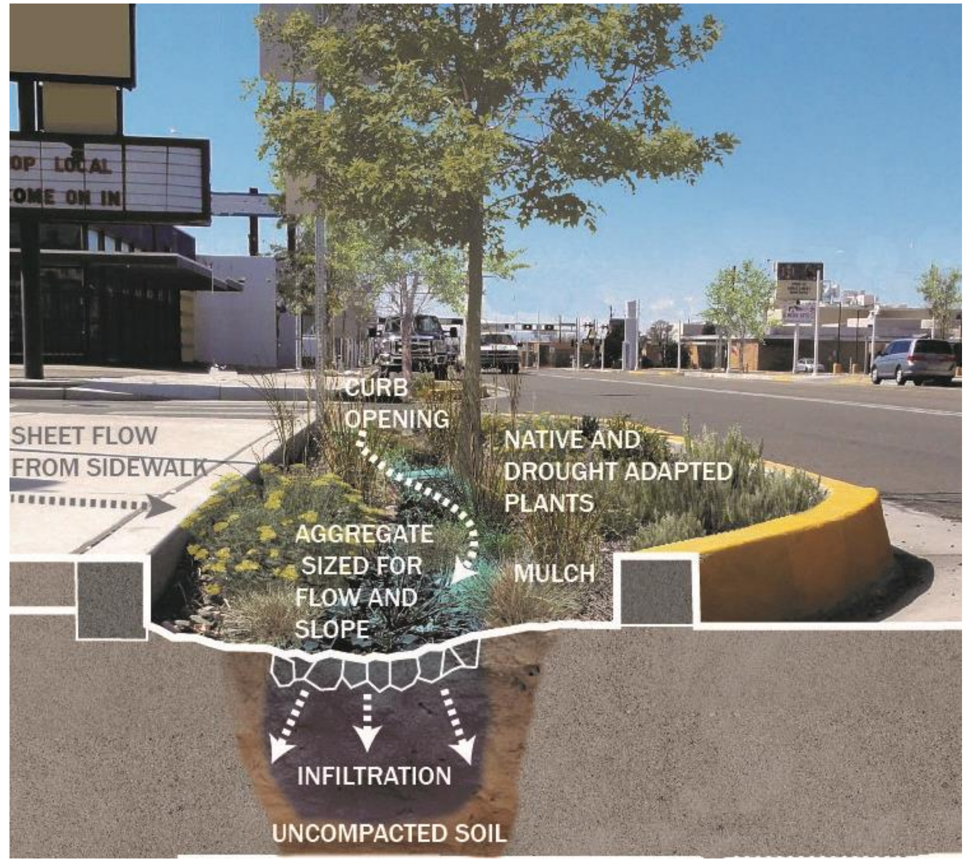
An area for infiltration and green infrastructure interventions created when the curb and gutter is moved out into the portion of the roadway normally reserved for parking. Otherwise known as 'bulbouts' or 'chicanes'.

DESIGN CONSIDERATIONS

- Can be used to retrofit existing projects, as well as constructed with new projects. Retrofit application will require sawcut & removal of existing curb, gutter, & pavement.
- Stormwater bumpouts can function as mid-block traffic calming structures.
- To maximize infiltration, do not compact bottom during or after construction & ensure that the bottom is scarified per the standard drawing.
- Place sediment trap at inlet as shown in curb opening GSI-01 standard drawing.
- Size & place erosion protection as needed for design storm velocity.
- Place plants according to elevation zone & inundation zone. Do not place plants where inlet(s) or outlet will be impacted.
- Include an irrigation system for plant establishment.
- Select plants that allow for vehicle clearances & sight triangles.
- Utilize the AASHTO Roadside Design Guide when placing & designing stormwater bumpouts adjacent to travel ways.

MAINTENANCE

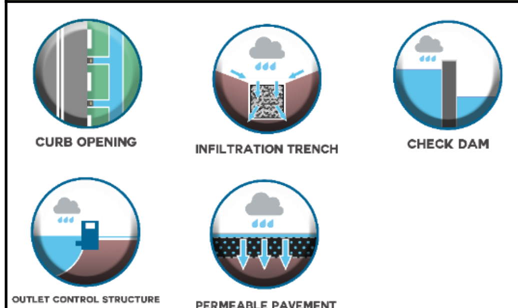
- Inspect after storms > 0.25-inches, recommend inspections minimum of twice per year.
- Remove debris, trash & accumulated sediment. The accumulated sediment should be removed if it inhibits vegetation or reduces the bumpout capacity.
- Check for & repair erosions issues.
- Add & redistribute organic mulch as needed.
- Prune & replace plants as needed. Prune plants to maintain vehicle clearances & sight triangles.
- Leave organic debris in place to biodegrade.
- Remove invasive species.

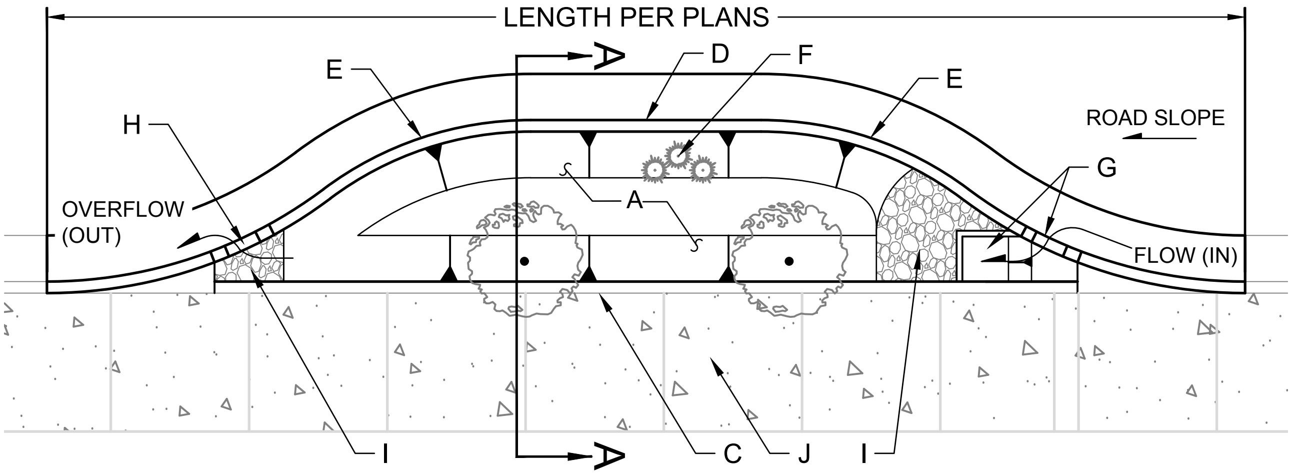


WHERE TO USE

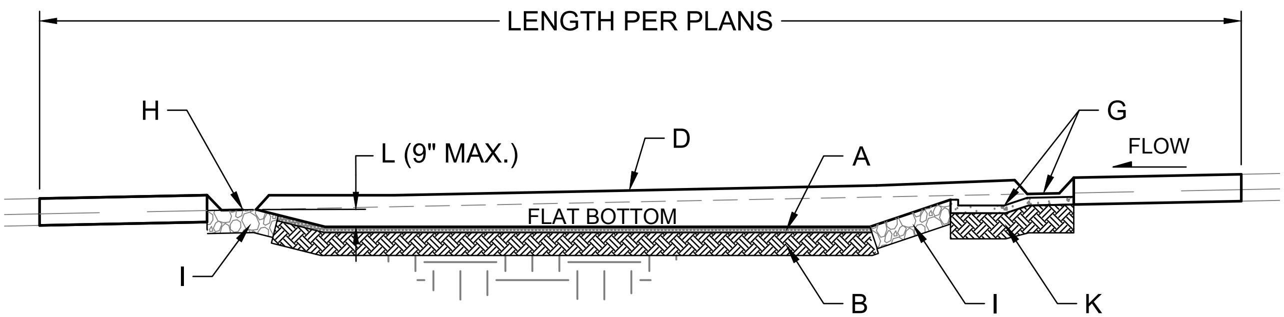
✓	Urban Type Road
✓	Rural Type Road
✓	Streetside
✓	Parking
✓	Residential Development
✓	Commercial/Institutional Development

FUNCTIONS WITH

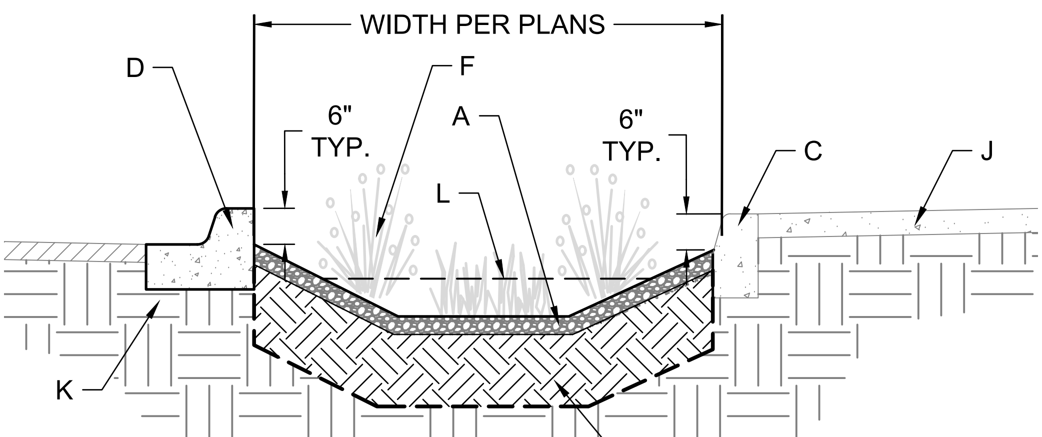




PLAN VIEW



PROFILE VIEW



SECTION A-A

GENERAL NOTES:

1. SEE TECHNICAL GUIDANCE SHEET FOR DESIGN GUIDANCE AND CONSIDERATIONS.
2. TREES AND SHRUBS SHOULD BE LOCATED IN ACCORDANCE WITH INUNDATION ZONE AND ELEVATION ZONE. SEE BERNALILLO COUNTY GSI PLANT LIST FOR GUIDANCE.
3. MULCH TYPE AND LOCATION PER PROJECT PLANS SHALL BE INFORMED BY EVALUATION OF HYDRAULIC CONDITIONS AND MAY BE USED FOR EROSION PREVENTION, SLOPE STABILIZATION, OR DESIGN PREFERENCE. ORGANIC MULCH MAY BE USED WHERE DESIGN VELOCITY IS LESS THAN 1 FPS.

CONSTRUCTION NOTES:

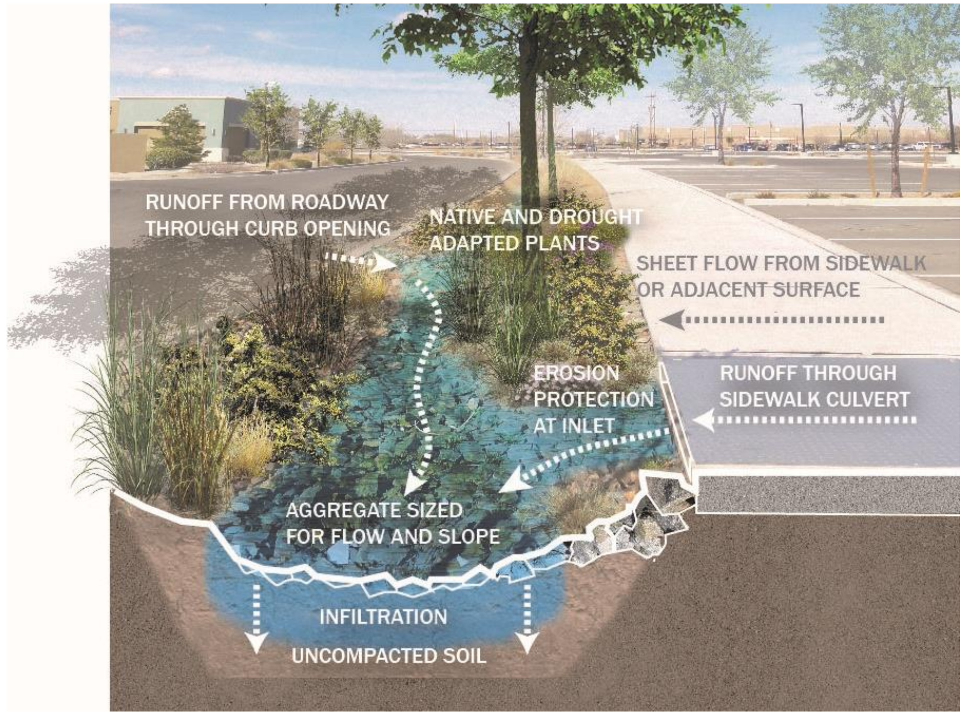
A. ORGANIC OR INORGANIC MULCH PER PROJECT PLANS. PLANS SHALL SPECIFY MULCH TYPE, THICKNESS, AND LOCATION.
B. SCARIFY SUBGRADE TO DEPTH OF 12", MIN.
C. HEADER CURB OR EXISTING CURB (SAWCUT AND REMOVE GUTTER PAN FLUSH WITH CURB FACE).
D. STANDARD CURB AND GUTTER PER COUNTY STANDARD DRAWING 2415A.
E. RADIUS PER PROJECT PLANS, 10' MIN.
F. PLANTS PER PROJECT PLANS.
G. CURB OPENING AND SEDIMENT TRAP PER COUNTY STD DWG GSI-01.
H. CURB OPENING AT OVERFLOW PER COUNTY STD DWG GSI-01 (NO SEDIMENT TRAP).
I. RIPRAP EROSION PROTECTION. COMPACT SUBGRADE BELOW EROSION PROTECTION TO 95% OF MAX DENSITY. REFER TO PROJECT PLANS FOR DIMENSIONS
J. SIDEWALK AT BACK OF CURB.
K. COMPACTED SUBGRADE BELOW C&G AND PAVEMENT.
L. 9" MAXIMUM PONDING DEPTH & DEPTH FOR CALCULATING STORMWATER QUALITY VOLUME (SWQV). MEASURED FROM BASIN BOTTOM TO OVERFLOW ELEVATION.

	COUNTY OF BERNALILLO
REVISIONS	STORMWATER BUMPOUT
	GSI-03 APR 2021

GSI-04

BIOSWALE

A shallow, linear or curvilinear feature designed to improve water quality by conveying, slowing, and treating runoff; allows pollutants to settle out and promotes infiltration.



DESIGN CONSIDERATIONS

- Meandering swale design encouraged.
- Consider depth to the groundwater table & bedrock – refer to Section 6, General Design Principles.
- Recommend infiltration rate greater than 0.5-inch/hr. An underdrain may be required if the infiltration rate is less than 0.5-inch/hr.
- To maximize infiltration, do not compact bottom during or after construction & ensure that the bottom is scarified per the standard drawing.
- Size & place erosion protection as needed for design storm velocity & slope stabilization.
- Recommended max. longitudinal slope of 5% to minimize potential for erosive flow velocities.
- Consider a sediment trap at concentrated inflows.
- Place plants according to elevation zone & inundation zone. Do not place plants where inlet(s) or outlet will be impacted.
- Include an irrigation system for plant establishment.

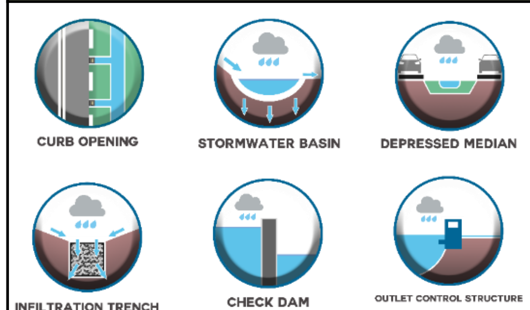
MAINTENANCE

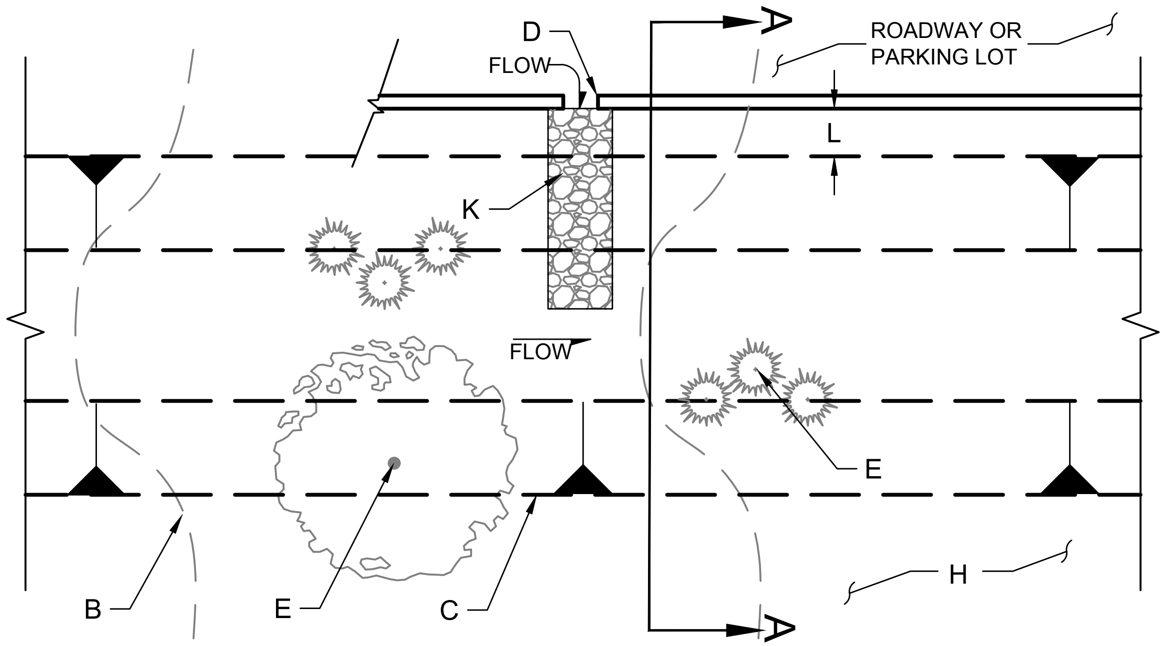
- Inspect after storms > 0.25-inches, recommend inspections minimum of twice per year.
- Remove debris, trash & accumulated sediment. The accumulated sediment should be removed if it inhibits vegetation or reduces the bioswale capacity.
- Check for & repair erosions issues.
- Add & redistribute organic mulch as needed.
- Prune & replace plants as needed.
- Leave organic debris in place to biodegrade.
- Remove invasive species.

WHERE TO USE

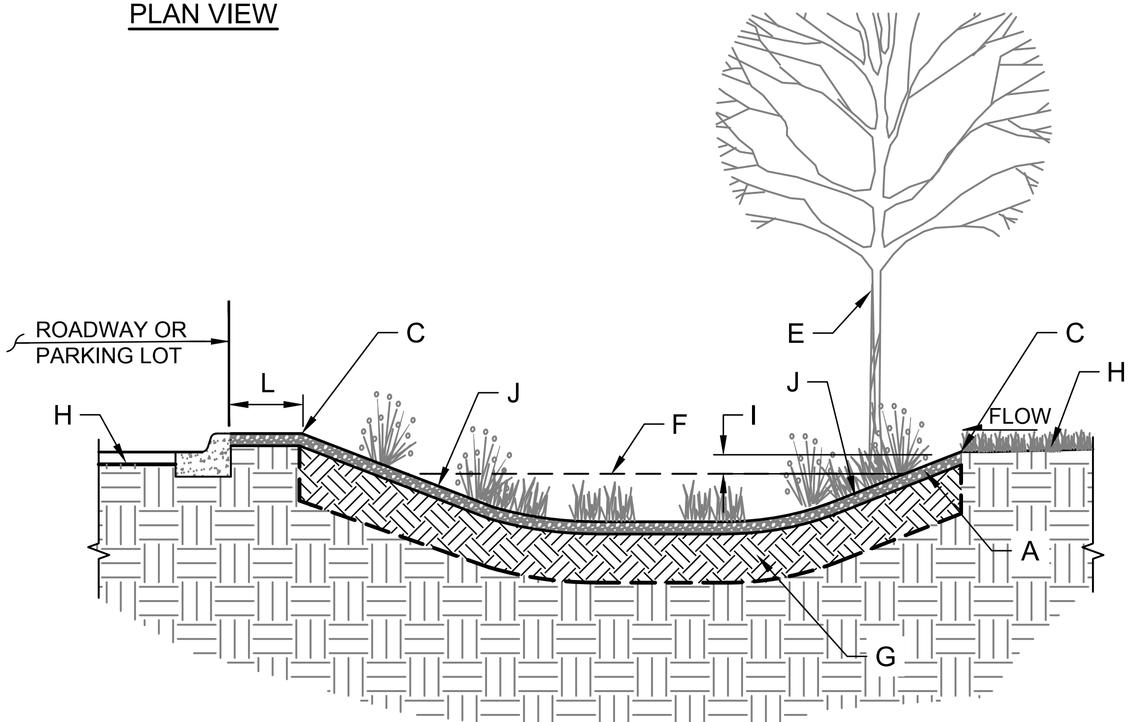
✓	Urban Type Road
✓	Rural Type Road
✓	Streetside
✓	Parking
✓	Residential Development
✓	Commercial/Institutional Development

FUNCTIONS WITH





PLAN VIEW



SECTION A-A

GENERAL NOTES:

1. SEE TECHNICAL GUIDANCE SHEET FOR DESIGN GUIDANCE AND CONSIDERATIONS.
2. TREES AND SHRUBS SHOULD BE LOCATED IN ACCORDANCE WITH INUNDATION ZONE AND ELEVATION ZONE. SEE BERNALILLO COUNTY GSI PLANT LIST FOR GUIDANCE.
3. CHECK DAMS PER COUNTY STD DWG GSI-07 SHALL BE PROVIDED WHEN DESIGN STORM VELOCITY EXCEEDS 3 FPS. REFER TO PROJECT PLANS.
4. MULCH TYPE AND LOCATION PER PROJECT PLANS SHALL BE INFORMED BY EVALUATION OF HYDRAULIC CONDITIONS AND MAY BE USED FOR EROSION PREVENTION, SLOPE STABILIZATION, OR DESIGN PREFERENCE. ORGANIC MULCH MAY BE USED WHERE DESIGN VELOCITY IS LESS THAN 1 FPS.
5. STABLE GRASS LINING MAY BE USED IN PLACE OF MULCH PER PROJECT PLANS.
6. AVOID COMPACTION OF BIOSWALE BOTTOM DURING AND AFTER CONSTRUCTION TO MAINTAIN INFILTRATION RATE.

CONSTRUCTION NOTES:

A. ORGANIC OR INORGANIC MULCH PER PROJECT PLANS. PLANS SHALL SPECIFY MULCH TYPE, THICKNESS, AND LOCATION.

B. CONCEPTUAL DESIGN CONTOUR.

C. TOP OF BIOSWALE/CHANNEL/DITCH.

D. CURB OPENING PER COUNTY STD DWG GSI-01.

E. PLANTS PER PROJECT PLANS.

F. WATER SURFACE AT DESIGN STORM FLOW DEPTH

G. SCARIFY SUBGRADE TO DEPTH OF 12", MIN.

H. ADJACENT SURFACES MAY VARY.

I. 3" FREEBOARD, MIN.

J. 3H:1V SIDE SLOPE OR FLATTER, TYP.

K. EROSION PROTECTION AT FLOW INLET. COMPACT SUBGRADE BELOW EROSION PROTECTION TO 95% OF MAX DENSITY. REFER TO PROJECT PLANS FOR DIMENSIONS AND DETAILS.

L. 2' STEP OUT WHEN BIOSWALE ALONG ROADWAY. 1' SETBACK ALONG OTHER PEDESTRIAN ROUTES. CROSS SLOPE SHALL MATCH SHOULDER OR 2% MAX.

REVISIONS	COUNTY OF BERNALILLO
	BIOSWALE
	GSI-04 APR 2021

GSI-05

DEPRESSED MEDIAN

DEPRESSED MEDIAN

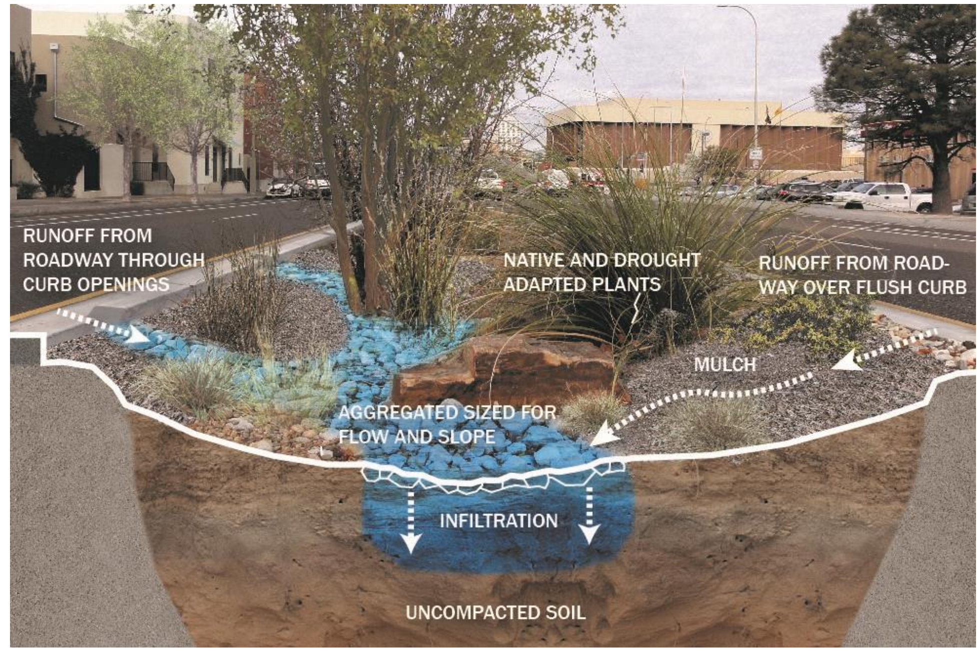
A linear or curvilinear shallow depression located in the roadway median designed to improve water quality by conveying, slowing, and treating runoff; allows pollutants to settle out and promotes infiltration.

DESIGN CONSIDERATIONS

- Consider depth to the groundwater table & bedrock – refer to Section 6, General Design Principles.
- Recommended max. longitudinal slope of 5% to minimize potential for erosive flow velocities.
- Recommend infiltration rate greater than 0.5-inch/hr. An underdrain may be required if the infiltration rate is less than 0.5-inch/hr.
- To maximize infiltration, do not compact bottom during or after construction & ensure that the bottom is scarified per the standard drawing.
- Size & place erosion protection as needed for design storm velocity & slope stabilization.
- Consider a sediment trap at concentrated inflows.
- Place plants according to elevation zone & inundation zone. Do not place plants where inlet(s) or outlet will be impacted.
- Include an irrigation system for plant establishment.
- Select plants that allow for vehicle clearances & sight triangles.
- Utilize the AASHTO Roadside Design Guide when placing & designing depressed medians adjacent to travel ways.

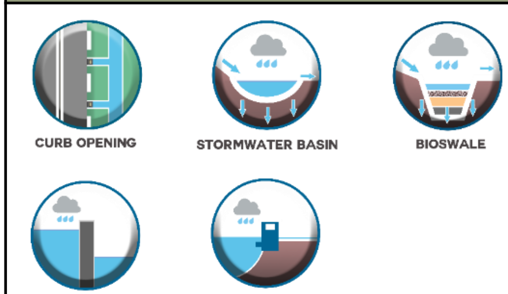
MAINTENANCE

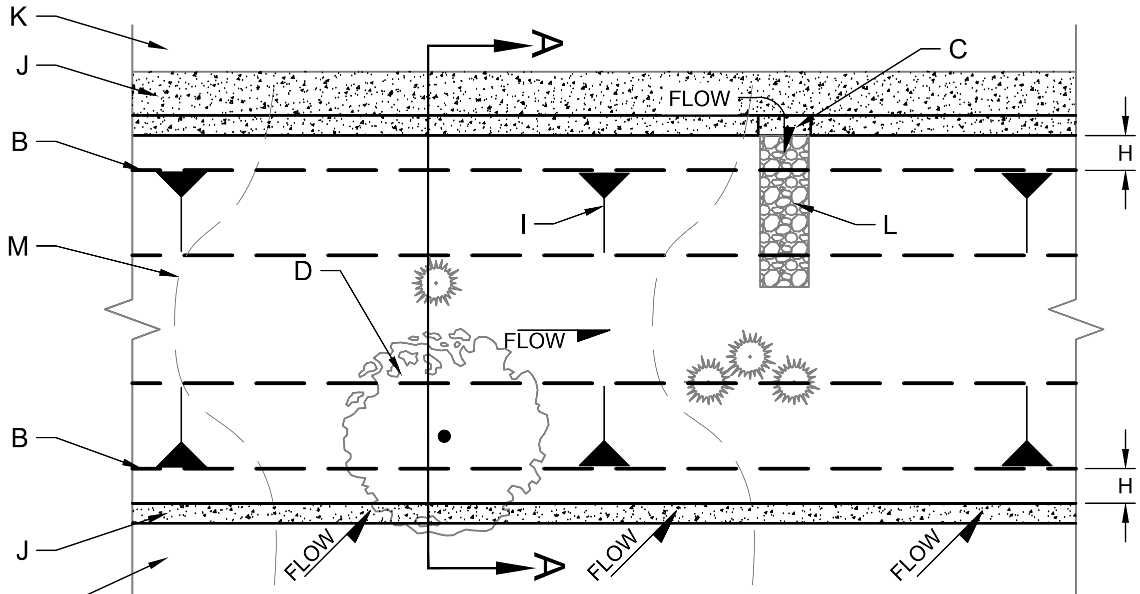
- Inspect after storms > 0.25-inches, recommend inspections minimum of twice per year.
- Remove debris, trash & accumulated sediment. The accumulated sediment should be removed if it inhibits vegetation or reduces the median capacity.
- Check for & repair erosions issues.
- Add & redistribute organic mulch as needed.
- Prune & replace plants as needed. Prune plants to maintain vehicle clearances & sight triangles.
- Leave organic debris in place to biodegrade.
- Remove invasive species.



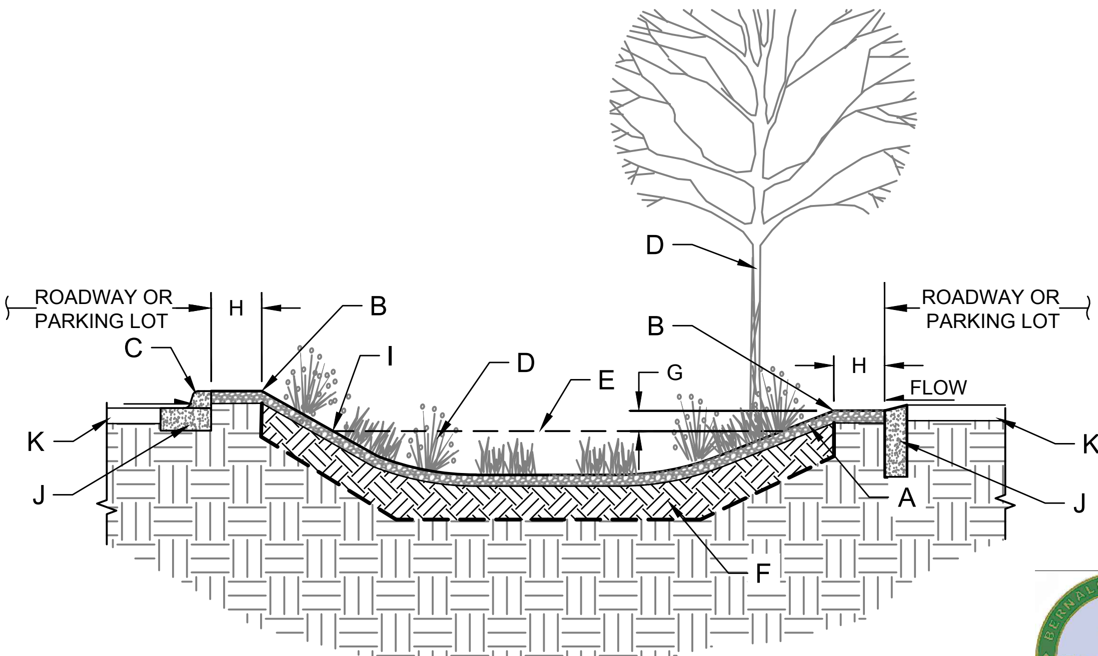
WHERE TO USE	
✓	Urban Type Road
✓	Rural Type Road
✓	Streetside
✓	Parking
✓	Residential Development
✓	Commercial/Institutional Development

FUNCTIONS WITH





PLAN VIEW



SECTION A-A

GENERAL NOTES:

1. SEE TECHNICAL GUIDANCE SHEET FOR DESIGN GUIDANCE AND CONSIDERATIONS.
2. TREES AND SHRUBS SHOULD BE LOCATED IN ACCORDANCE WITH INUNDATION ZONE AND ELEVATION ZONE. SEE BERNALILLO COUNTY GSI PLANT LIST FOR GUIDANCE.
3. CROSS SLOPE OF SHOULDER BEHIND FLUSH CURB SHOULD BE STEEPER THAN LONGITUDINAL SLOPE TO DIRECT FLOW TO DEPRESSED MEDIAN.
4. CHECK DAMS PER COUNTY STD DWG GSI-07 SHALL BE PROVIDED WHEN DESIGN STORM VELOCITY EXCEEDS 3.0 FPS. REFER TO PROJECT PLANS.
5. MULCH TYPE AND LOCATION PER PROJECT PLANS SHALL BE INFORMED BY EVALUATION OF HYDRAULIC CONDITIONS AND MAY BE USED FOR EROSION PREVENTION, SLOPE STABILIZATION, OR DESIGN PREFERENCE. ORGANIC MULCH MAY BE USED WHERE DESIGN VELOCITY IS LESS THAN 1 FPS.

CONSTRUCTION NOTES:

A. ORGANIC OR INORGANIC MULCH PER PROJECT PLANS. PLANS SHALL SPECIFY MULCH TYPE, THICKNESS, AND LOCATION.
B. TOP OF BIOSWALE/CHANNEL/DITCH.
C. CURB OPENING PER COUNTY STD DWG GSI-01.
D. PLANTS PER PROJECT PLANS.
E. WATER SURFACE AT DESIGN STORM FLOW DEPTH.
F. SCARIFY SUBGRADE TO DEPTH OF 12", MIN.
G. 3" FREEBOARD, MIN.
H. 2' STEP OUT WHEN USED ALONG ROADWAY. 1' SETBACK ALONG OTHER PEDESTRIAN ROUTES. CROSS SLOPE PER PROJECT PLANS.
I. 3H:1V SIDE SLOPE OR FLATTER, TYP.
J. CONCRETE STANDARD CURB AND GUTTER OR FLUSH HEADER CURB PER COUNTY STANDARD DWG 2415A/B. REFER TO PROJECT PLANS.
K. ADJACENT PARKING/ROAD SURFACES.
K. EROSION PROTECTION AT FLOW INLET. COMPACT SUBGRADE BELOW EROSION PROTECTION TO 95% OF MAX DENSITY. REFER TO PROJECT PLANS FOR DIMENSIONS AND DETAILS.
L. CONCEPTUAL DESIGN CONTOUR.

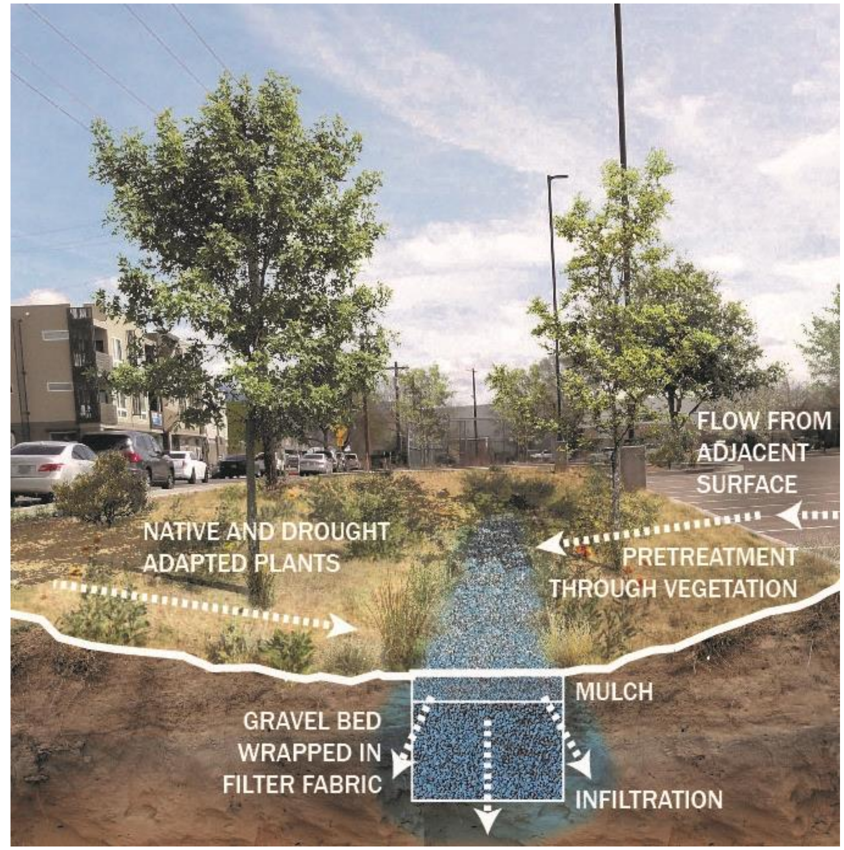
COUNTY OF BERNALILLO	
REVISIONS	DEPRESSED MEDIAN
	GSI-05 APR 2021

GSI-06

INFILTRATION TRENCH

INFILTRATION TRENCH

A linear excavated area that is lined with filter fabric and filled with rock in order to create additional space for runoff to collect and infiltrate into adjacent permeable soils.



DESIGN CONSIDERATIONS

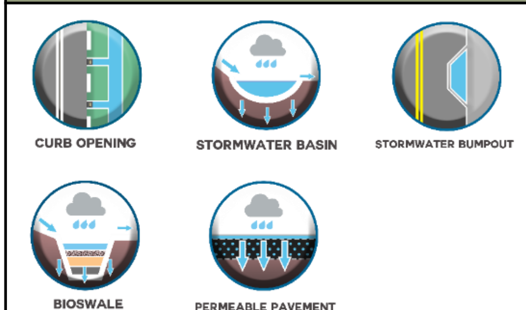
- Recommend stormwater runoff pretreatment (filter strips, sediment traps, etc.) to prevent sediment from clogging the infiltration trench.
- Porous gravel material provides additional retention capacity prior to infiltration into the subsurface.
- Consider depth to the groundwater table & bedrock – refer to Section 6, General Design Principles.
- Recommend infiltration rate greater than 0.5-inch/hr. An underdrain may be required if the infiltration rate is less than 0.5-inch/hr.
- To maximize infiltration, do not compact bottom during or after construction & ensure that the bottom is scarified per the standard drawing.
- Consider a sediment trap at concentrated inflows.
- Vegetation may <u>not</u> be grown on the infiltration trench. Plantings adjacent to the infiltration trench are encouraged so that vegetation may utilize the infiltrated stormwater; plants should not inhibit maintenance of the infiltration trench.

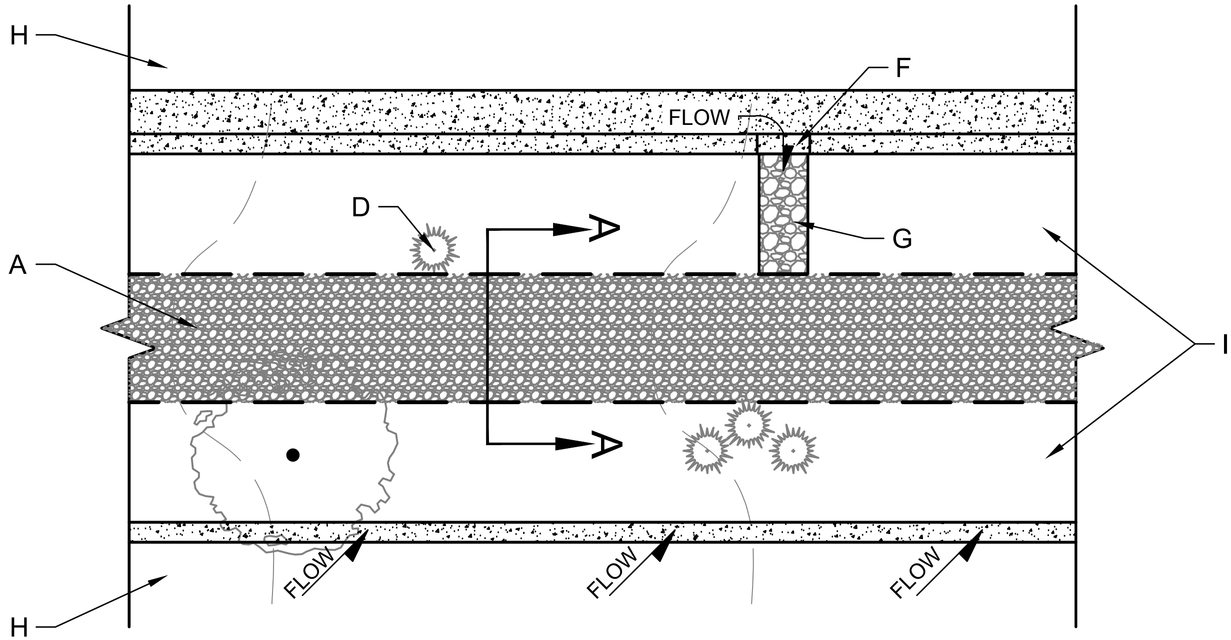
MAINTENANCE

- Inspect after storms > 0.25-inches, recommend inspections minimum of twice per year.
- Remove debris, trash & accumulated sediment, especially at pretreatment locations.
- Prune & replace adjacent plants as needed.
- Remove invasive species.
- If infiltration rates have decreased substantially, major maintenance may be performed by removing, cleaning, & replacing the top gravel layer or removing the gravel & replacing any clogged filter fabric.

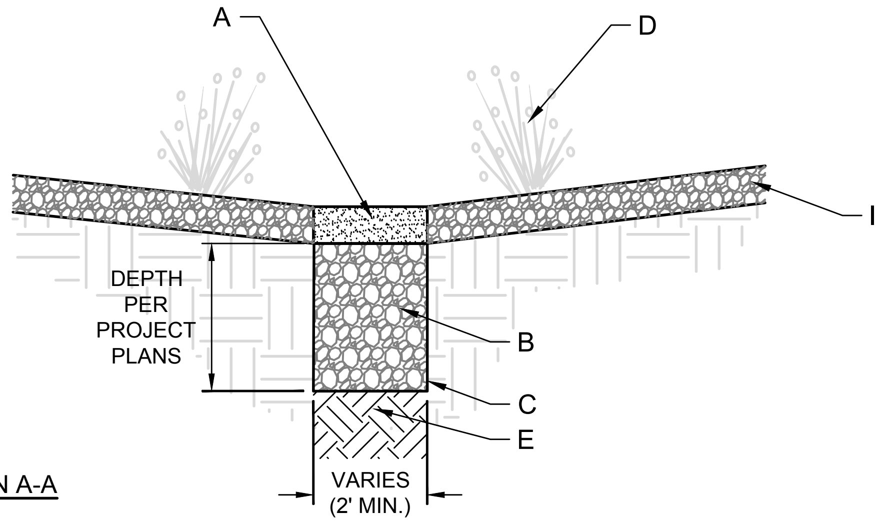
WHERE TO USE	
✓	Urban Type Road
✓	Rural Type Road
✓	Streetside
✓	Parking
✓	Residential Development
✓	Commercial/Institutional Development

FUNCTIONS WITH





PLAN VIEW



SECTION A-A

GENERAL NOTES:

1. SEE TECHNICAL GUIDANCE SHEET FOR DESIGN GUIDANCE AND CONSIDERATIONS.
2. RESERVOIR LAYER WIDTH AND DEPTH SHALL BE PROVIDED ON PROJECT PLANS. CONSIDER IN-SITU SUBSURFACE CONDITIONS AND OTHER SITE CONSTRAINTS.
3. ALL STONE SHALL BE DOUBLE-WASHED, SUFFICIENT TO REMOVE DUST AND OTHER COATINGS.

CONSTRUCTION NOTES:

A. FILTER LAYER, CLEAN GRAVEL PER PROJECT PLANS. 3" THICK MINIMUM.
B. RESERVOIR LAYER, ASTM #2 OR AS SPECIFIED ON PROJECT PLANS.
C. NON-WOVEN GEOTEXTILE FILTER CLOTH AROUND GRAVEL RESERVOIR LAYER, ALL SIDES (INCLUDING BETWEEN RESERVOIR LAYER AND FILTER LAYER).
D. PLANTS PER PROJECT PLANS.
E. SCARIFY SUBGRADE BELOW RESERVOIR LAYER TO DEPTH OF 12", MIN.
F. CURB OPENING PER COUNTY STD DWG GSI-01.
G. EROSION PROTECTION AT FLOW INLET. COMPACT SUBGRADE BELOW EROSION PROTECTION TO 95% OF MAX DENSITY. REFER TO PROJECT PLANS FOR DIMENSIONS AND DETAILS.
H. ADJACENT PARKING/ROAD/ HARDSCAPE SURFACES.
I. ORGANIC OR INORGANIC MULCH PER PROJECT PLANS. PLANS SHALL SPECIFY MULCH TYPE, THICKNESS, AND LOCATION.

	COUNTY OF BERNALILLO
REVISIONS	INFILTRATION TRENCH
	GSI-06 APR 2021

GSI-07

CHECK DAM

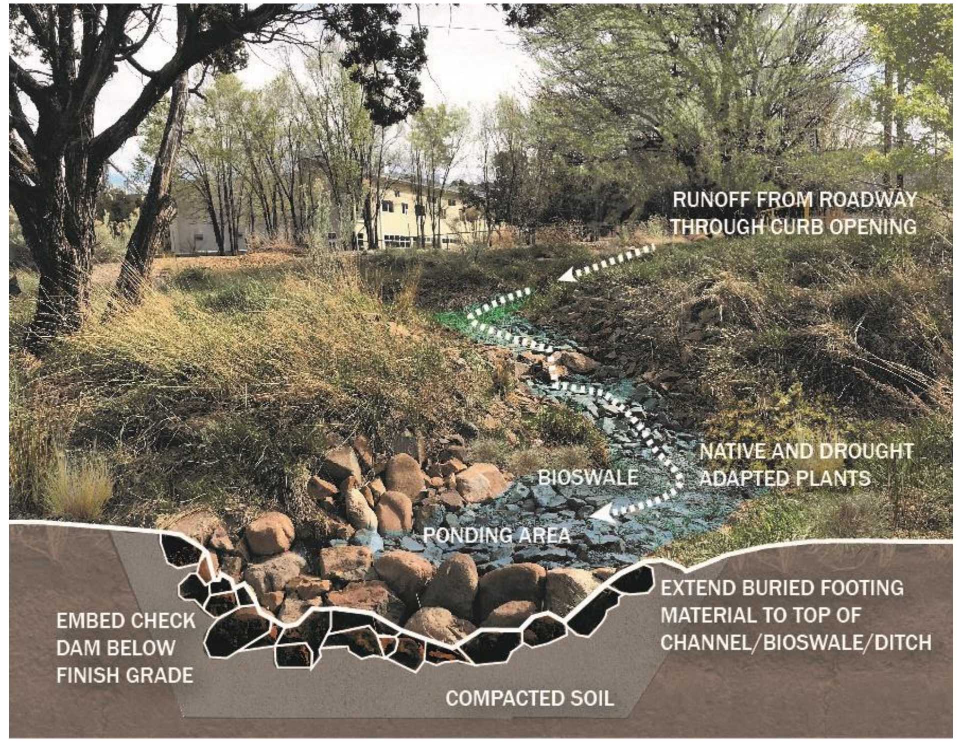
A shallow, typically permeable control placed perpendicular to the flow of water within a drainage feature that slows the flow, increasing infiltration as well as retaining sediment & debris.

DESIGN CONSIDERATIONS

- Check dams shall be installed when the design storm velocity exceeds 3 feet-per-second (fps).
- Most effective when used in series, spaced at regular intervals.
- Recommended check dam max. height of 18-inches.
- Recommended max. longitudinal slope of 5% to minimize potential for erosive flow velocities.
- Check dams can be comprised of angular gravel or stone, other aggregates such as clean, broken concrete, wood, metal, or compacted soil. The standard drawing is specific to gravel, cobble, clean broken concrete, or other suitable aggregate; if other materials are used the design will vary from the standard drawing.
- Size & place check dam materials as needed for design storm velocity & slope stabilization per project plans.

MAINTENANCE

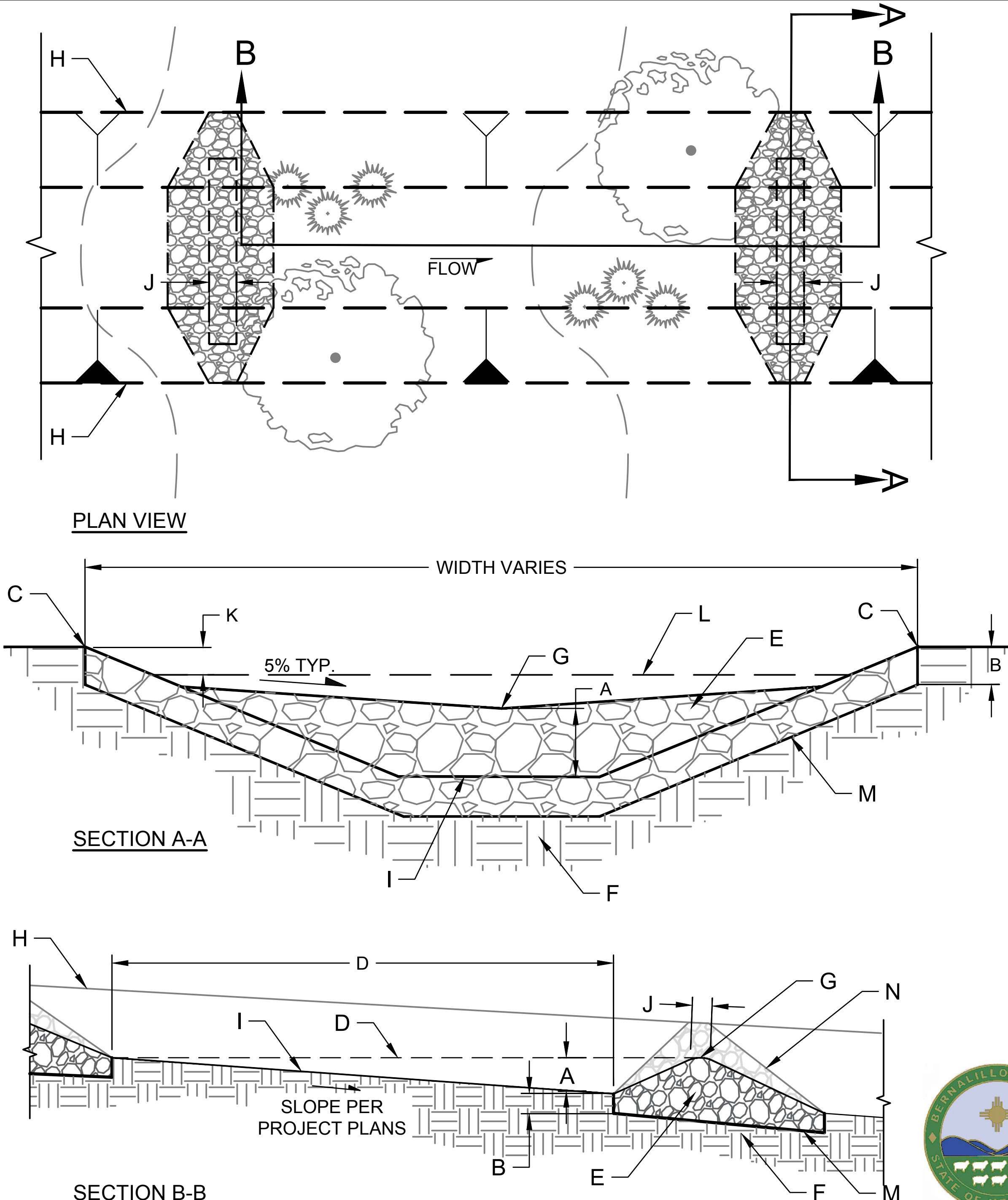
- Inspect after storms > 0.25-inches, recommend inspections minimum of twice per year.
- Remove debris, trash & accumulated sediment. Remove sediment if over half of the original check dam height.
- Check for & repair erosions issues; look for flanking & scour issues.
- Restore dislodged or washed out check dams to their original configuration.



WHERE TO USE

✓	Urban Type Road
✓	Rural Type Road
✓	Streetside
✓	Parking
✓	Residential Development
✓	Commercial/Institutional Development

FUNCTIONS WITH



GENERAL NOTES:

1. SEE TECHNICAL GUIDANCE SHEET FOR DESIGN GUIDANCE AND CONSIDERATIONS, INCLUDING DISCUSSION OF OTHER ALLOWABLE MATERIALS.

CONSTRUCTION NOTES:

A. HEIGHT PER PROJECT PLANS.

B. CHECK DAM EMBEDDED BELOW FINISHED GRADE, 6" MIN.

C. EXTEND CHECK DAM TO TOP OF CHANNEL/BIOSWALE/DITCH TO PREVENT FROM BEING FLANKED.

D. SPACE CHECK DAMS SUCH THAT THE DOWNSTREAM WEIR ELEVATION IS AT OR ABOVE THE TOE ELEVATION OF THE NEXT UPSTREAM WEIR.

E. GRAVEL, COBBLE, CLEAN BROKEN CONCRETE, OR OTHER SUITABLE AGGREGATE, SIZED TO WITHSTAND DESIGN STORM FLOW CONDITIONS.

F. COMPACT SUBGRADE BELOW CHECK DAM BASE TO 95% OF MAX DENSITY.

G. WEIR ELEVATION, 9" (MIN) BELOW ADJACENT TOP OF BIOSWALE/CHANNEL/DITCH.

H. TOP OF BIOSWALE/CHANNEL/DITCH.

I. DESIGN FLOWLINE ELEVATION OF BIOSWALE/CHANNEL/DITCH.

J. 12" WIDE SHELF, MIN.

K. 3" FREEBOARD, MIN.

L. WATER SURFACE AT DESIGN STORM FLOW DEPTH OVER CHECK DAM.

M. NON-WOVEN GEOTEXTILE FILTER CLOTH BETWEEN RIPRAP AND SUBGRADE.

N. 3H:1V SIDE SLOPE OR FLATTER, TYP.

	COUNTY OF BERNALILLO
REVISIONS	CHECK DAM
	GSI-07 APR 2021

GSI-08

OUTLET CONTROL STRUCTURE

OUTLET CONTROL STRUCTURE

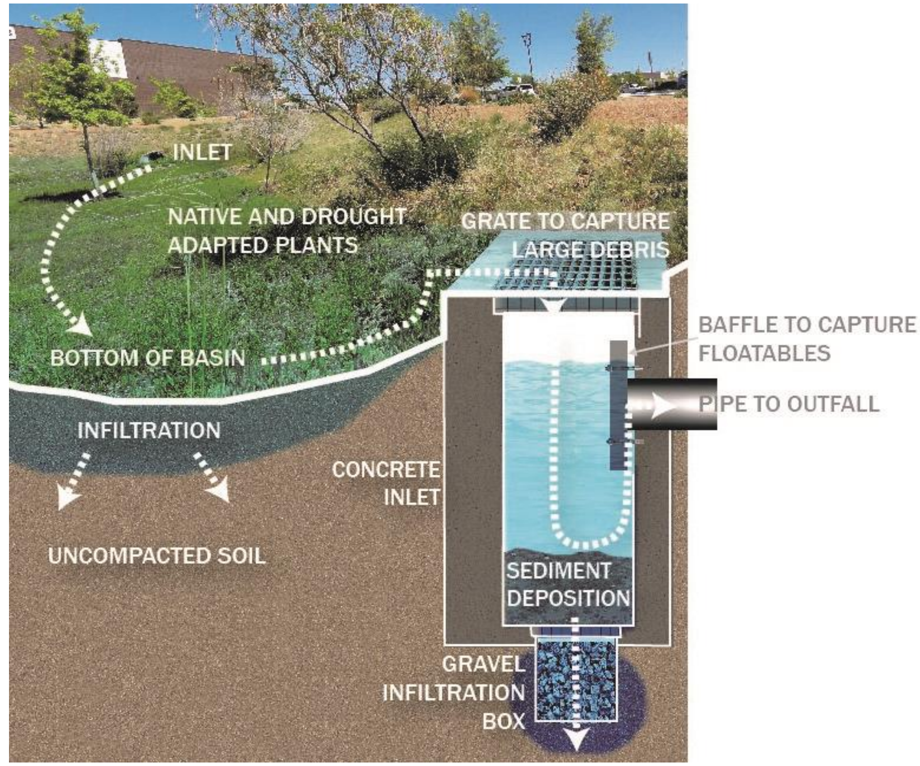
A structure placed at the discharge point from a BMP or detention pond designed to regulate the release of stormwater and facilitate capture of sediment & floatables.

DESIGN CONSIDERATIONS

- Outlet control structures allow for ponding within multiple GSI BMPs & should be designed to provide an outlet for larger storm events that exceed the capacity the BMP.
- The raised structure, as well as the sump/baffle design, allow trash, debris & sediment to drop out of the stormwater within the BMP.
- The structure should be located at the downstream end of a drainage facility & the outfall must connect to a downstream collection system, such as a storm drain, basin, channel, or arroyo.
- Maintenance access to the outlet control structure should be considered & provided during design.

MAINTENANCE

- Inspect after storms > 0.25-inches, recommend inspections minimum of twice per year.
- Remove debris, trash & accumulated sediment from the inlet grate & structure sump. A vacuum truck may be needed for the structure sump maintenance.
- Encroaching vegetation should be pruned or removed to maintain a min. of 2-foot landscape buffer from the structure.

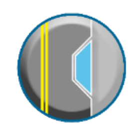


WHERE TO USE

✓	Urban Type Road
✓	Rural Type Road
✓	Streetside
✓	Parking
✓	Residential Development
✓	Commercial/Institutional Development

FUNCTIONS WITH

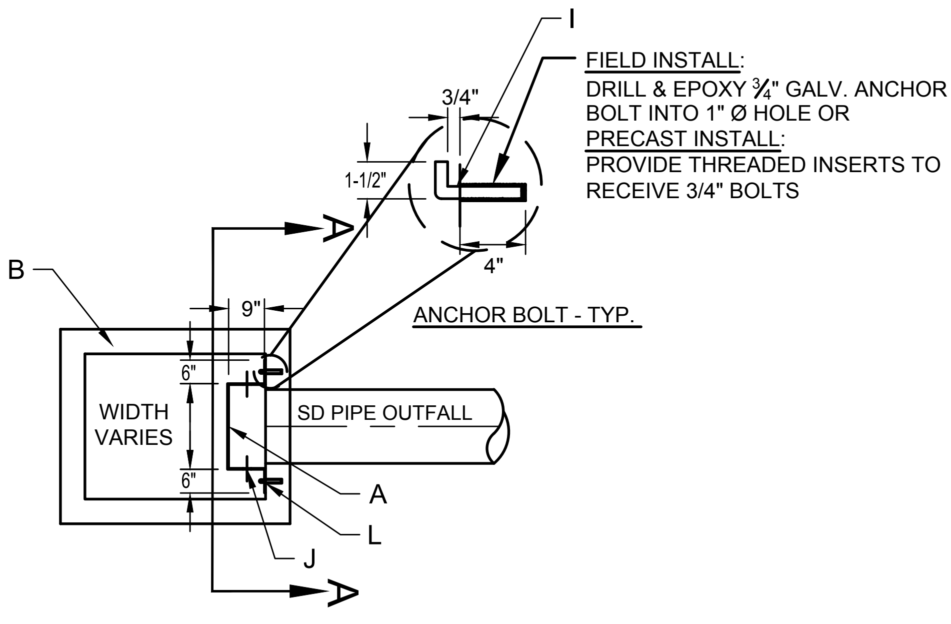
STORMWATER BASIN



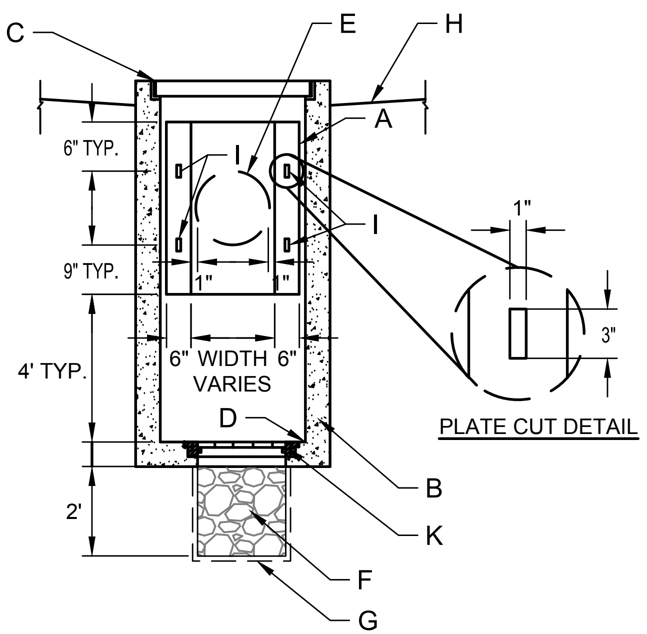
STORMWATER BUMPOUT

BIOSWALE

DEPRESSED MEDIAN



PLAN VIEW



SECTION A-A

GENERAL NOTES:

1. SEE TECHNICAL GUIDANCE SHEET FOR DESIGN GUIDANCE AND CONSIDERATIONS.
2. OUTLET CONTROL PLATE DIMENSIONS AND INLET SUMP DEPTH SHOULD BE DESIGNED FOR CONTRIBUTING WATERSHED/SEDIMENT LOAD AND DESIGN HYDRAULIC CONDITIONS. DIMENSIONS SHOWN ARE FOR TYPICAL APPLICATION AND MAY BE MODIFIED BY PROJECT PLANS.
3. AS APPROVED BY ENGINEER, ALTERNATIVE MANUFACTURED BAFFLE MAY BE USED.

CONSTRUCTION NOTES:

A. 3/16" ALUMINUM BAFFLE. WIDTH PER PLAN.
B. CONCRETE DROP INLET. TYPE AND SIZE PER PROJECT PLANS.
C. INLET GRATE ELEVATION PER PROJECT PLANS.
D. INLET SUMP ELEVATION PER PROJECT PLANS.
E. STORM DRAIN OUTFALL PIPE. SIZE AND INVERT ELEVATION PER PROJECT PLANS.
F. GRAVEL INFILTRATION BOX, ASTM #57 STONE.
G. NON-WOVEN GEOTEXTILE FILTER CLOTH AROUND GRAVEL, ALL SIDES.
H. FINISHED GROUND AT INLET. ELEVATION PER PROJECT PLANS.
I. RECTANGULAR CUT INTO PLATE TO HANG ON ANCHOR BOLT.
J. LIFTING HOLE, BOTH SIDES OF BAFFLE. 2" DIA. HOLE CUT INTO PLATE 4.5" FROM WALL, 2" (MIN.) FROM TOP OF BAFFLE.
K. ROUND STEEL GRATE AND FRAME (12" DIAMETER MIN.) IN BOTTOM OF INLET SUMP. GRATE TYPE/MANUFACTURER PER PROJECT PLANS.
L. 1/8" THICK NEOPRENE WASHER AT ANCHOR BETWEEN PLATE TO CONCRETE WALL CONTACT AREA.

	COUNTY OF BERNALILLO
REVISIONS	OUTLET CONTROL STRUCTURE
	GSI-08 APRIL 2021

GSI-09

PERMEABLE PAVEMENT

PERMEABLE PAVEMENT

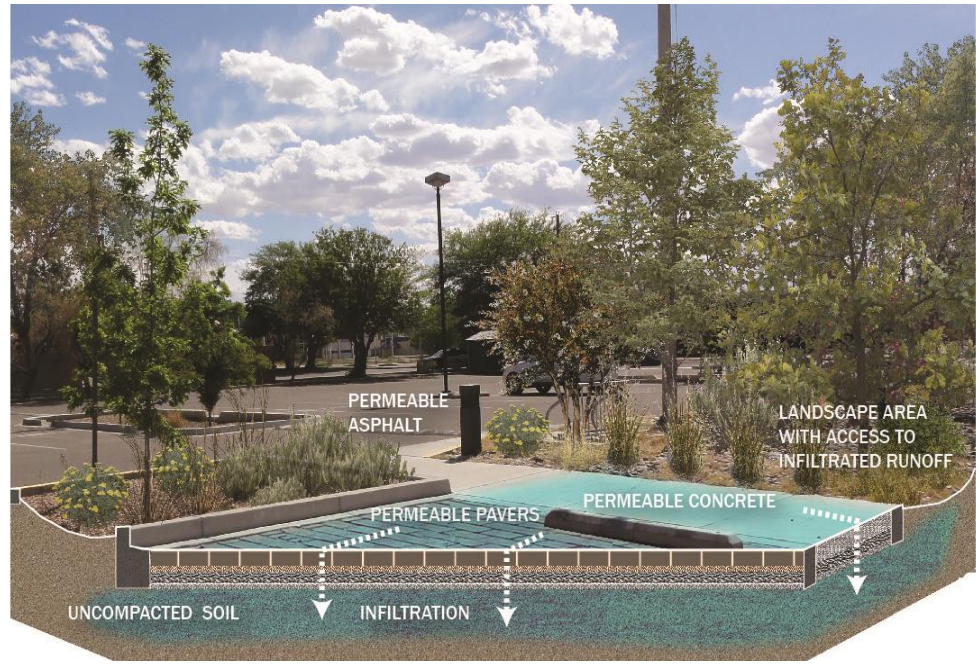
Paving material that allows stormwater to move through the pavement's surface to a storage layer below, allowing infiltration into the underlying soil. Includes, but is not limited to, permeable interlocking pavers, asphalt, and concrete.

DESIGN CONSIDERATIONS

- Other pavement types than shown on the standard drawing may be considered, such as permeable gutter systems or porous asphalt, pending approval by the County.
- Control of sediment is important to maintain the pavement permeability; offsite stormwater runoff should not be sediment laden.
- Consider concrete curb for edge support & to help keep unwanted sediment off the pavement.
- Pavement design shall address both stormwater retention, geotechnical, & structural pavement design requirements.
- Consider depth to the groundwater table & bedrock – refer to Section 6, General Design Principles.
- Recommended max. longitudinal slope of 5%. Slopes greater than 2% require subsurface check dams.

MAINTENANCE

- Inspect after storms > 0.25-inches, recommend inspections minimum of twice per year. Watch for sediment washout or deposition on the pavement.
- Remove accumulated sediment & debris from pavement using manufacturer's recommended maintenance approach & schedule. Superficial dirt does not necessarily clog the pavement, however, repeatedly ground in dirt by tires can lead to clogging.
- Routine & long-term maintenance, using high performance, regenerative air vacuuming to maintain the hydraulic function, are typically required. Mechanical broom type sweepers are typically not recommended.
- Pavements should not receive regular winter salt or sanding.
- Seal coating or repaving are not appropriate for permeable pavements.



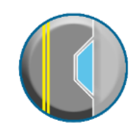
WHERE TO USE

✓	Urban Type Road
	Rural Type Road
✓	Streetside
✓	Parking
✓	Residential Development
✓	Commercial/Institutional Development

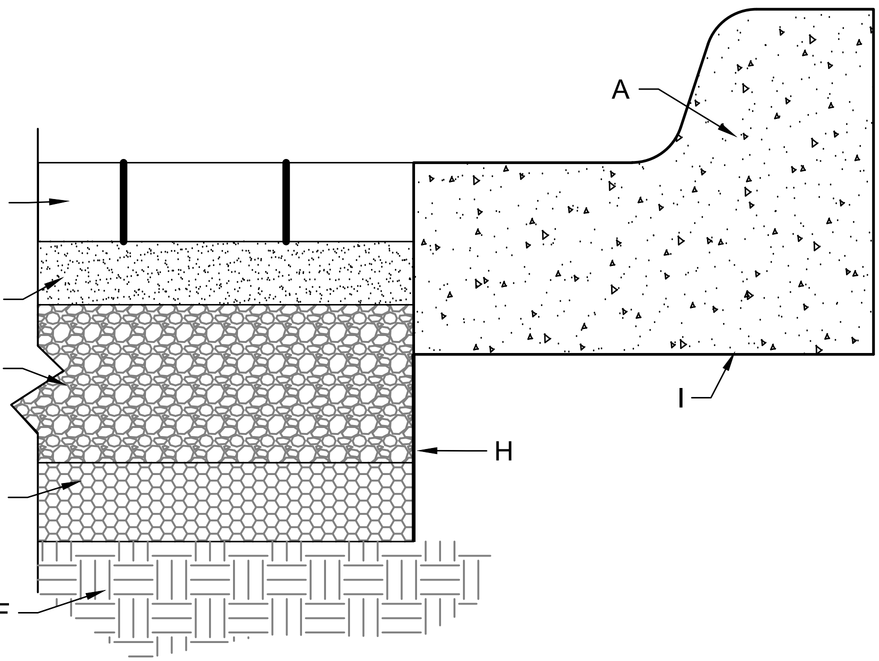
FUNCTIONS WITH


CURB OPENING

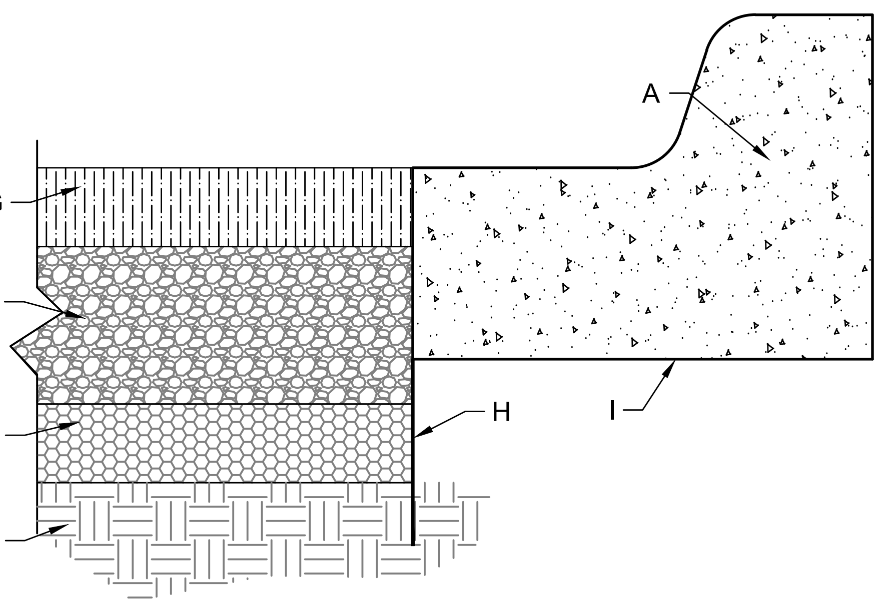

STORMWATER BASIN


STORMWATER BUMPOUT


INFILTRATION TRENCH



PERMEABLE PAVERS - TYPICAL SECTION



PERVIOUS CONCRETE - TYPICAL SECTION

GENERAL NOTES:

1. SEE TECHNICAL GUIDANCE SHEET FOR DESIGN GUIDANCE AND CONSIDERATIONS.
2. TYPICAL SECTIONS ARE PROVIDED FOR GENERAL GUIDANCE. LAYER DEPTHS ARE PROJECT/SITE SPECIFIC AND SHALL BE DESIGNED BASED ON GEOTECHNICAL RECOMMENDATIONS AND LOADING/STRUCTURAL REQUIREMENTS.
3. RESERVOIR LAYER THICKNESS SHALL BE PROVIDED ON PROJECT PLANS. THICKNESS SHALL BE DETERMINED BASED ON STORMWATER QUALITY VOLUME (SWQV) RETENTION REQUIREMENTS AND STRUCTURAL PAVEMENT DESIGN REQUIREMENTS.
4. SYSTEM SHALL BE DESIGNED TO DRAIN THE DESIGN STORM WITHIN 96 HOURS. UNDERDRAIN MAY BE CONSIDERED IF IN-SITU SOILS ARE NOT CONDUCIVE TO INFILTRATION (GENERALLY LESS THAN 0.2 IN/HR).
5. BOTTOM OF RESERVOIR LAYER SHOULD BE DESIGNED AS FLAT AS POSSIBLE (0% PREFERRED). SUBSURFACE CHECK DAMS IN RESERVOIR LAYER REQUIRED IF SURFACE SLOPE EXCEEDS 2%.
6. ALL STONE SHALL BE DOUBLE-WASHED, SUFFICIENT TO REMOVE DUST AND OTHER COATINGS.
7. NON-WOVEN GEOTEXTILE FILTER FABRIC SHALL BE PLACED ON THE SIDES OF OPEN-GRADED STONE LAYERS AT THE EDGES OF SYSTEM (WHERE NO OTHER EDGE RESTRAINT PROVIDED) TO PREVENT MIGRATION OF ADJACENT FINE MATERIAL.
8. AGGREGATE SIZES IN CONSCTRUCTION NOTES ARE PER ASTM D448-STANDARD CLASSIFICATION FOR SIZES OF AGGREGATE FOR ROAD AND BRIDGE CONSTRUCTION.

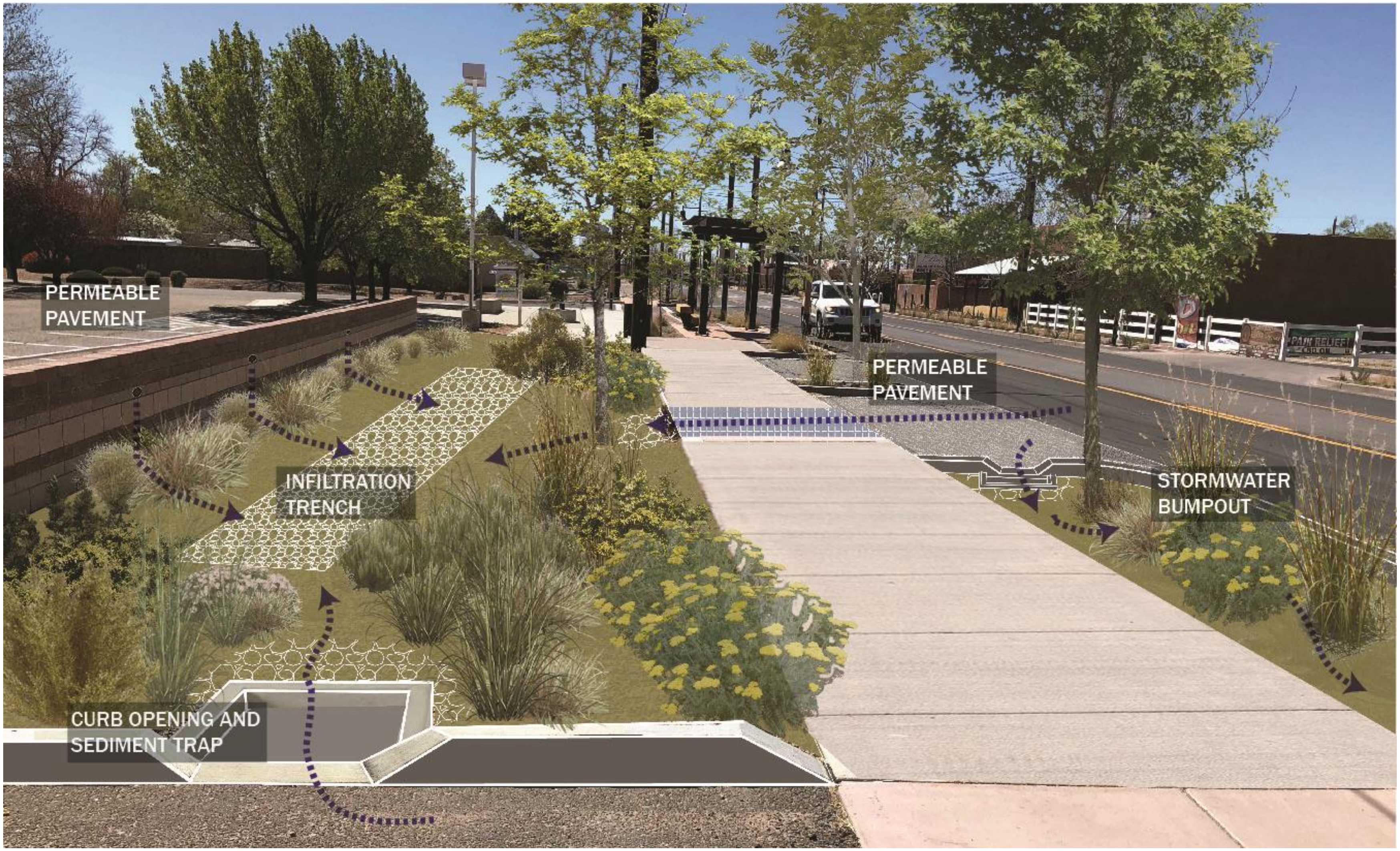
CONSTRUCTION NOTES:

A. CONCRETE CURB OR OTHER EDGE RESTRAINT PER PROJECT STANDARD CURB AND GUTTER PER COUNTY STANDARD DRAWING 2415A SHOWN
B. CONCRETE PAVER (MIN. THICKNESS IS 3-1/8" FOR VEHICULAR TRAFFIC, 2-3/8" FOR PEDESTRIAN AREAS). JOINTS SHALL BE FILLED WITH ASTM #8 STONE OR AS RECOMMENDED BY MANUFACTURER.
C. BEDDING/FILTER LAYER, 2" THICK ASTM #8 STONE OR AS RECOMMENDED BY MANUFACTURER.
D. RESERVOIR LAYER, ASTM #2 PER PROJECT PLANS. THICKNESS PER PROJECT PLANS (6" MIN.).
E. SUBBASE LAYER , ASTM #57 STONE. WHEN OMITTED, PROVIDE GEOTEXTILE FILTER FABRIC BELOW RESERVOIR LAYER.
F. UNCOMPACTED SUBGRADE.
G. PERVIOUS PORTLAND CEMENT CONCRETE, THICKNESS PER PROJECT PLANS (6" MIN.).
H. NON-WOVEN GEOTEXTILE FABRIC ALONG SIDE OF STONE LAYERS WHERE NO OTHER EDGE RESTRAIN PROVIDED.
I. COMPACTED SUBGRADE

REVISIONS	COUNTY OF BERNALILLO	
	PERMEABLE PAVEMENT	
	GSI-09	APR 2021

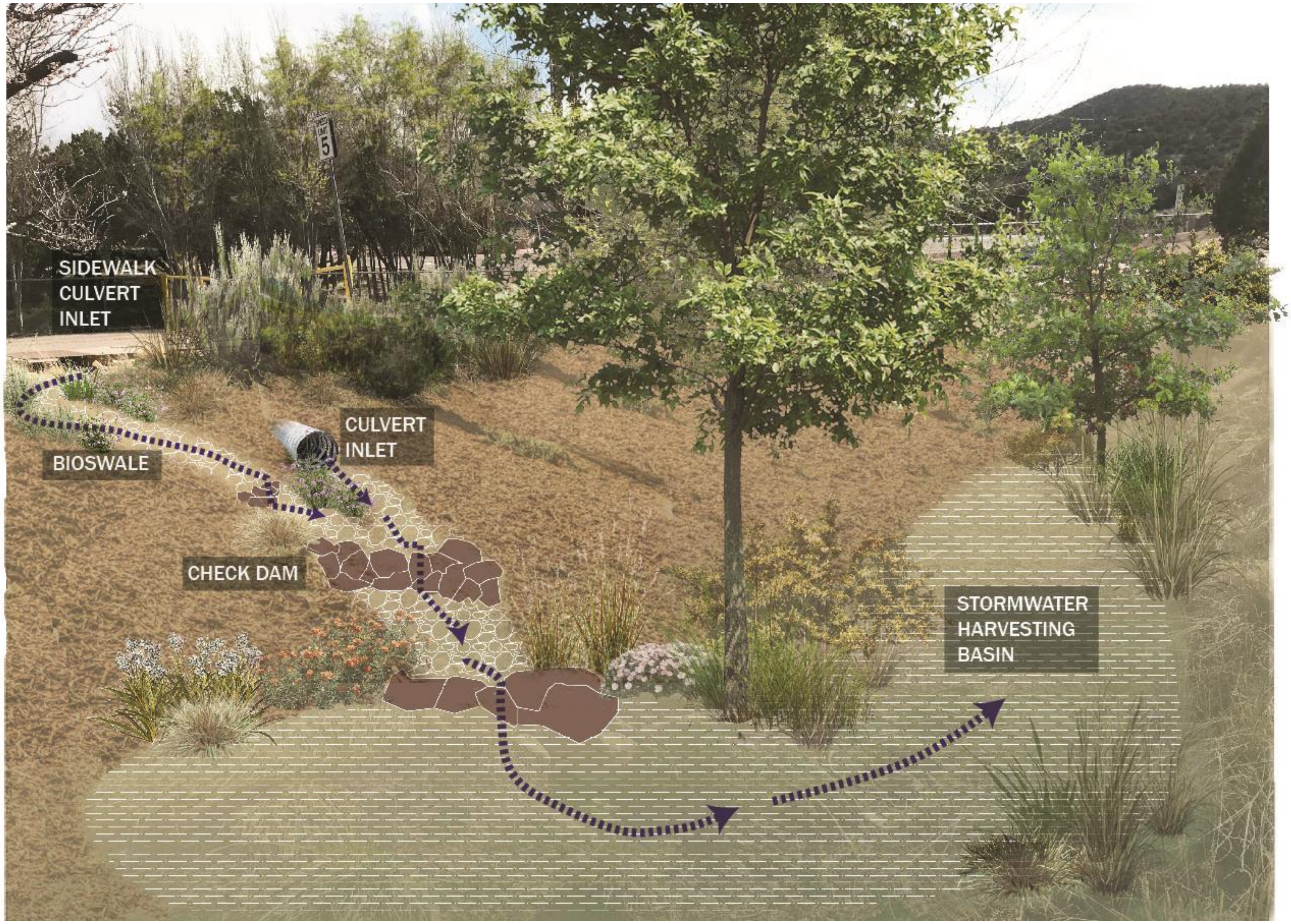
TREATMENT TRAIN EXAMPLE

Figure 7: Example Treatment Train #1 of GSI/LID BMPs



TREATMENT TRAIN EXAMPLE

Figure 8: Example Treatment Train #2 of GSI/LID BMPs



6 | Design and Construction

Though the appropriate GSI/LID BMPs may vary based on location, there are common design considerations and construction practices that apply whenever GSI/LID BMPs are implemented. This section outlines various considerations that developers and designers should account for prior to design, project approval, and construction.

County Review Process

Private developers and designers are encouraged to meet with Bernalillo County staff as part of a **pre-application meeting** early in the site development process regarding the incorporation of GSI/LID BMPs into their projects. The applicant should contact the Planning staff at Planning and Development Services to request the pre-application meeting. Planning staff will set up the meeting with applicable staff on the Case Review Committee from Bernalillo County Planning, Zoning, Building, Public Works Development Review, Transportation, and Natural Resources, as well as ABCWUA.

Bernalillo County requires that GSI/LID and stormwater quality BMPs be incorporated into the **grading and drainage plan**. Applicants should maintain communication with Bernalillo County staff throughout the design process to ensure that goals are met in the final design. Early consideration of GSI/LID can also provide savings and benefits for developers and designers as it can be more complicated and expensive to integrate GSI/LID BMPs after the grading and drainage plan and landscaping plans have been submitted for County review.

Frequent communication within the project team, from the beginning of the project and throughout design and construction, is an integral component in the development process and can ensure successful and cost-efficient outcomes for the project. The project team can include some or all of the following: project owner(s), engineers, landscape designers/architects, general contractors, and landscape maintenance practitioners.

Steps in the Bernalillo County Review Process Associated With GSI/LID

1. Pre-application meeting (recommended)
2. Submit grading and drainage plan and post-construction form
3. Review by County Natural Resource Services staff for proposed GSI/LID and stormwater quality BMPs
4. Recommendations/revisions from existing plans; optional meeting with County staff
5. Approval of grading and drainage plan
6. Submit building permit application inclusive of landscape plan
7. Review by County Natural Resource Services staff to ensure proposed landscaping aligns with approved grading and drainage plan, Stormwater Quality and Water Conservation Ordinances, and GSI Standards
8. Recommendations/revisions from existing plan
9. Approval of landscape plan

General Design Principles

The following general principles should be applied in the design of GSI/LID BMPs:

- Design GSI/LID conveyances to slow down runoff, promote infiltration, and provide filtration to remove pollutants.
- Reduce impervious surfaces to the greatest extent practicable. Impervious surfaces collect and retain pollutants, including oil and grease, as well as increase the heat island effect.
- Consider maintenance access needs during design. Communicate with maintenance personnel during the design process to ensure maintenance requirements are met.
- When sediment and debris accumulation is anticipated in the GSI/LID BMP, incorporate an upstream sediment trap, trash/debris screens, and/or planning for additional required maintenance.
- Design appropriately sized erosion protection, especially at concentrated flow locations.
- Design GSI/LID BMPs to ensure infiltration by avoiding soil compaction of pervious areas and around vegetation, performing on-site infiltration rate tests, and using soil amendments, if needed, to improve infiltration.
- In general, infiltration rates greater than 0.5 inches/hour are recommended for BMPs. Infiltration testing should be conducted at the proposed bottom elevations of the BMP. An underdrain may be needed if the infiltration rate is less than 0.5 inches/hour.
- Consider the depth to the groundwater table and bedrock below each BMP; an underdrain may be needed if the groundwater table and/or bedrock are shallow and will impact infiltration within the BMP.
- Consider the location of existing utilities.
- Inlets or outlets to GSI/LID BMPs cannot flow directly through handicap accessible ramps or handicap parking spaces.
- Follow setback requirements from property lines, as indicated in the County zoning code.
- Coordinate with the project design team and utility owners on required setbacks from buildings/foundations, septic tanks, utility lines, etc.
- For GSI/LID BMPs immediately adjacent to travel ways, consult the AASHTO Roadside Design Guide when placing and designing BMPs.

Define Maintenance Requirements and Responsibilities

It is important to consider irrigation and maintenance requirements prior to the design of GSI/LID BMPs as these requirements will differ from typical landscaping. The pre-application meeting is an opportunity for developers to meet with Bernalillo County staff and learn about maintenance requirements associated with different BMPs. Additional information on maintenance can be found in Section 7: GSI/LID BMP Maintenance.

BMP Overflow Control Design Requirements

GSI/LID BMPs should be designed to accommodate larger, higher-intensity storm events that exceed the storage capacity of the GSI/LID BMP. The following should be incorporated into BMP overflow design:

- The design capacity of the overflow structure shall be for the 100-year peak outflow rate.
- Erosion protection for the emergency spillway must be considered during design and must be sufficient for the flow velocity and flow expansion downstream of the overflow structure.
- Overflow structures must be designed to safely convey flows to downstream drainage facilities or other County approved discharge location.

Plant Selection Considerations

Designers should consider the planting approach during the design process, as plants are a key element to successful GSI/LID applications. Regionally adapted plants should be selected based on temperature tolerance, soil types, and water needs.

Arid region applications that incorporate vegetation as part of the BMP may require supplemental irrigation to support the vegetation during an establishment period. See **Section 9** for guidance on plant selection and the establishment period.

Soil Protection During Construction

It is important to maintain soil permeability and to limit compaction during construction. Best practices to protect soil conditions during construction include:

- Protect the GSI/LID BMP installation area, landscaped areas, and areas that will be left undeveloped from construction equipment that could compact soils and reduce soil permeability.
- Reserve existing topsoil and reuse to ensure a healthy growth medium for plant establishment.
- Remove excess sediment that results from construction activities as accumulated sediment limits infiltration and is a primary reason that GSI/LID BMPs fail to operate as designed.
- Scarifying soils after construction is recommended to reduce compaction and promote infiltration.
- Impervious area construction should be completed, and pervious areas stabilized, before runoff is allowed to enter an infiltration BMP.

Standard Drawings

The County review process includes comparison of proposed designs against the standard drawings in these technical standards to ensure that the designs are buildable and appropriately selected and located. Table 4 lists the typical design data that the County requires on project plans for each GSI/LID BMP included in this document. See Section 5 for Standard Drawings for each of the BMPs recommended by Bernalillo County.

Table 3: Design Data Required for GSI/LID BMPs

BMP	Standard Drawing Number	GSI/LID Standard Drawing	GSI/LID BMP Design Data Required on Project Plans
 CURB OPENING	GSI-01	Curb Opening	• Curb opening length (L) – 2-ft. minimum. • Identify if sediment trap is required. • Sediment trap dimensions, if required. • Riprap rundown/erosion protection dimensions, stone size, and riprap thickness. • Elevation of flowline at curb opening and elevation at bottom of sediment trap or adjacent BMP. • Gutter transition, if different from county standard drawing 2207.
 STORMWATER BASIN	GSI-02	Stormwater Harvesting Basin	• Erosion protection type and dimensions; if riprap, provide stone size and riprap thickness. • Ponding depth for SWQV – 9-in. maximum. See standard Drawing for calculation method. • Water surface elevation at 100-year overflow depth. See standard drawing for calculation method. • Freeboard measurement – 3-in. minimum. See standard drawing for calculation method. • Mulch type, thickness, and location.
 STORMWATER BUMPOUT	GSI-03	Stormwater Bumpout	• Bumpout radius – 10-ft. minimum. • Bumpout dimensions. • Riprap/erosion protection dimensions, stone size, and riprap thickness. • Design storm velocity. • Ponding depth for SWQV – 9-in. maximum. See standard drawing for calculation method. • Mulch type, thickness, and location.
 BIOSWALE	GSI-04	Bioswale	• Design storm velocity; if velocity is greater than 3 fps, check dam(s) required. • Freeboard measurement – 3-in. minimum. See standard drawing for calculation method. • Erosion protection type and dimensions; if riprap, provide stone size and riprap thickness. • Mulch type, thickness, and location.

BMP	Standard Drawing Number	GSI/LID Standard Drawing	GSI/LID BMP Design Data Required on Project Plans
	GSI-05	Depressed Median	• Design storm velocity – if velocity greater than 3 fps, check dam(s) required. • Freeboard measurement – 3-in. minimum. See standard drawing for calculation method. • Erosion protection type and dimensions; if riprap, provide stone size and riprap thickness. • Mulch type, thickness, and location.
	GSI-06	Infiltration Trench	• Filter layer and reservoir layer dimensions. • Filter layer and reservoir layer stone size. • Erosion protection type and dimensions; if riprap, provide stone size and riprap thickness. • Mulch type, thickness, and location.
	GSI-07	Check Dam	• Check dam height. • Check dam shelf width. • Depth embedded below grade – 6-in. minimum. • Elevations for top of check dam weir. • Elevation at top of bioswale/channel/ditch at check dam location. • Aggregate type and size or specification (sized for design storm flow conditions). • Freeboard measurement – 3-in. minimum. See standard drawing for calculation method.
	GSI-08	Outlet Control Structure	• Concrete drop inlet type and size • Elevations for inlet grate and inlet sump. • Storm drain outfall size and invert elevation.
	GSI-09	Permeable Pavement	• Pavement type and thickness. • Reservoir layer thickness – 6-in. minimum. • Subbase layer thickness, if applicable.

7 | GSI/LID BMP Maintenance

Maintenance Responsibilities

Maintenance for GSI/LID along **roadways and in the public right-of-way** that are installed by a developer as part of a site improvement project is generally the responsibility of Bernalillo County, unless agreements exist with a homeowners association or other entity. Where GSI/LID BMPs are located in the public right-of-way, the Bernalillo County review process will consider whether the proposed elements are consistent with the County's maintenance practices.

Maintenance for GSI/LID on **private property** is the responsibility of the landowner.

Maintenance Benefits from GSI/LID

Native and drought-tolerant plants in GSI/LID BMPs require resources during the establishment period, but maintenance needs (e.g. pruning) and water usage over the long-term are typically lower than for typical landscaping installations.

Maintenance Best Practices

The following are best practices to ensure proper maintenance of GSI/LID BMPs:

- Conduct inspections of GSI/LID BMPs at a minimum of once per year or more, as well as after storms greater than 0.25 inches.
- Remove debris, trash, and accumulated sediment regularly from pretreatment structures and GSI/LID BMPs. Accumulated sediment limits infiltration and is a primary reason that GSI/LID BMPs fail to operate as designed.
- Inspect and repair erosion issues. Areas subject to erosion include side slopes, riprap rundowns, concentrated flow locations, areas of high velocity flow, or areas where human traffic may disturb the vegetation.
- Some GSI/LID BMPs may require use of specialized equipment for maintenance, such as permeable pavement and outlet control structures. See the technical guidance sheets for maintenance guidance.
- Prune and replace plants as needed. Remove invasive plant species.
- Irrigate regularly during plant establishment period (see Section 9 for establishment period guidance). Once plants are established, irrigate only as necessary.
- Leave organic debris in place to biodegrade whenever feasible. This practice promotes healthy soils.
- If a neat or uniform appearance is desired, the surface can be lightly raked or a 1-inch layer of organic mulch can be applied. See Section 8 for additional guidance on the use of mulch.

- BMPs that are seeded and feature grass cover should typically not be mowed more than once a year.

Other Maintenance Considerations

The party responsible for maintaining the BMP may also consider including educational information regarding the function and benefits of GSI/LID for the general public.

Signs may be posted within or adjacent to the BMP to clarify maintenance requirements and to ensure that no equipment is used that might compact the soils within the BMP.

8 | Mulch in GSI/LID BMPs

Benefits and Preferred Materials

Mulch serves to stabilize the surface and reduce evaporation from the soil and is a critical component of GSI/LID installations. **Organic mulch**, which contributes to pollutant treatment and containment through filtration and development of a healthy soil microbiome, should be used wherever possible. By contrast, rock and inorganic mulch materials such as gravel, gravel mulch, pebbles, lava rock, or crushed rock, contributes less to the treatment of runoff, or to the biological health of soil and plants, while also storing and releasing heat.

Staining from runoff is not as apparent on organic mulch as it is for rock and inorganic mulch.

Key Definition: Soil Microbiome

The soil microbiome is the dynamic community of microorganisms associated with plants and soil. This community includes bacteria, archaea, and fungi. The composition of any particular microbiome is influenced by myriad factors, including: environmental, soil physical properties, nutrient availability, and plant species.

Preferred mulch materials are shredded, partially composted woody mulch, installed at 3-inch depth. Shredded wood mulch locks together, making it more resistant to floating or blowing away. Mulch that is partially composted contains healthy bacteria and fungi that contribute to soil health. Runoff from a few storms will activate soil fungi which will “glue” the soil to the mulch, making it non-floatable.

Best Practices in Use of Mulch

Below are best practices to follow when using mulch with GSI/LID BMPs within Bernalillo County's arid climate.

- Organic mulch of 3-inch in depth should last at least three years; mulch may be top-dressed annually to freshen the appearance. If the BMP receives frequent or high-volume flows, mulch may need to be refreshed more frequently.
- Leaf litter does not need to be removed from the surface of areas with organic mulch.
- Avoid organic mulch products containing bark chips, or products that are likely to blow away, such as pecan shells.
- Keep all mulch at least 4 inches away from the base of new trees and plants.
- If seeding an area, hydromulch or a thin layer of small rock mulch (less than 1.5 inches) is recommended over drill seeding or hand broadcast seeding. Follow Section 632 of the NMDOT Standard Specifications for Highway and Bridge Construction.

Use of Rock and Inorganic Mulch

Inorganic mulch is not preferred, though may be appropriate in some contexts. If inorganic mulch is necessary, install a 3-inch depth of chipped wood mulch below the inorganic mulch wherever possible, OR install weedblock fabric. Other considerations include:

- Use rock and inorganic mulch materials where velocity exceeds 1 foot-per-second (fps). Inorganic mulch requirements (e.g. rock size and thickness) shall be informed by evaluation of hydraulic conditions for the GSI/LID BMP.
- Chipped (non-composted) wood mulch is recommended to be used under rocks and inorganic mulch materials as it will degrade more slowly than shredded, partially composted wood mulch.
- Do not use rock and inorganic mulch containing fine grains. This can create additional sediment accumulation around infiltration features, clogging soils and decreasing infiltration.
- If rock and inorganic mulch is used, plan for maintenance to remove sediment and debris from the mulch; weeds will grow in sediment that accumulates in the rock and inorganic mulch.
- Dark-colored rock and inorganic mulch materials, such as basalt, are preferred for areas that will be stained by urban runoff. Light-colored rock and inorganic mulch materials are preferred for other areas because it attracts less heat than dark colored materials.

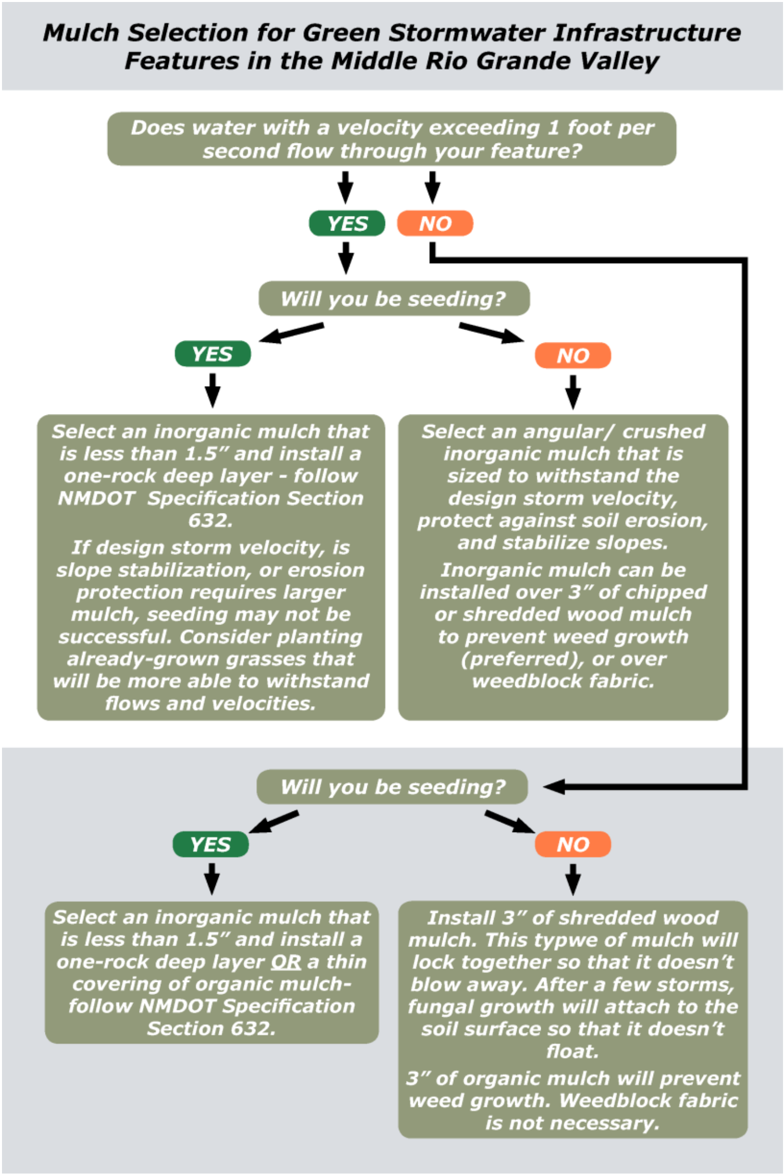
Figure 9: Preferred Mulch Types

Source: Soilutions; Right: Forest Floor Mulch; Left: Native Mulch

Use of Weedblock

Use of weedblock / geotextile fabric for weed control is not a preferred practice in GSI/LID features because it separates stormwater runoff from the soil and plant roots with which it needs direct contact for pollutant treatment. Weedblock fabric is not necessary under a 3-inch depth or greater of organic mulch. Most weedblock fabrics are only permeable when fully saturated. This means that runoff from small storm events may not reach plant roots and soil microbes. In addition, weedblock fabric can become obsolete when sediment accumulates on top of the fabric and weeds grow. Rather than using weedblock, appropriately applied shredded wood mulch is effective for preventing weed growth while also supporting healthy soils and plants.

Figure 10: Mulch Selection for GSI/LID BMPs



9 | GSI/LID Plant Selection

General Considerations

Plants in GSI/LID features are an important part of an engineered system. Soil pore space and organic material created by plant roots maintain and improve infiltration rates for stormwater. Plant roots stabilize soil and reduce erosion. Plants provide shade and habitat while making the GSI/LID feature more aesthetically attractive and regionally unique, which increases public acceptance. Appendix A provides a list of plants appropriate for use in and around GSI/LID BMPs in the Middle Rio Grande Valley.

GSI/LID features should include at least three species within each plant type (i.e. tree, shrub, perennial, grass) to ensure that some species will live in the event of extreme drought or insect infestation. Species diversity is also critical for wildlife habitat.

Steps in Plant Selection Process

1. Identify ecological biome
2. Determine elevation zone
3. Identify location in GSI/LID BMP (high ground, transition zone, inundation zone)

Plants must be appropriately selected and maintained for the GSI/LID BMP to function properly. To aide in plant selection, the plant list is organized by ecological biome, elevation zone, inundation zone, and plant type (trees, shrubs, perennials, and grasses). The Plant List Components and Selection section below provides steps on using the plant list during GSI/LID BMP design.

Figure 11 provides a flow chart outlining how to use the plant selection criteria in the plant list in Appendix A to identify appropriate plants for the GSI/LID BMP.

Criteria for Plant List

- Can survive without irrigation after establishment
- Ability to stabilize soil
- Heat, drought, and cold tolerant
- Non-invasive
- Appropriate for GIS/LID inundation zones

Plant List Components & Selection

Ecological Biome

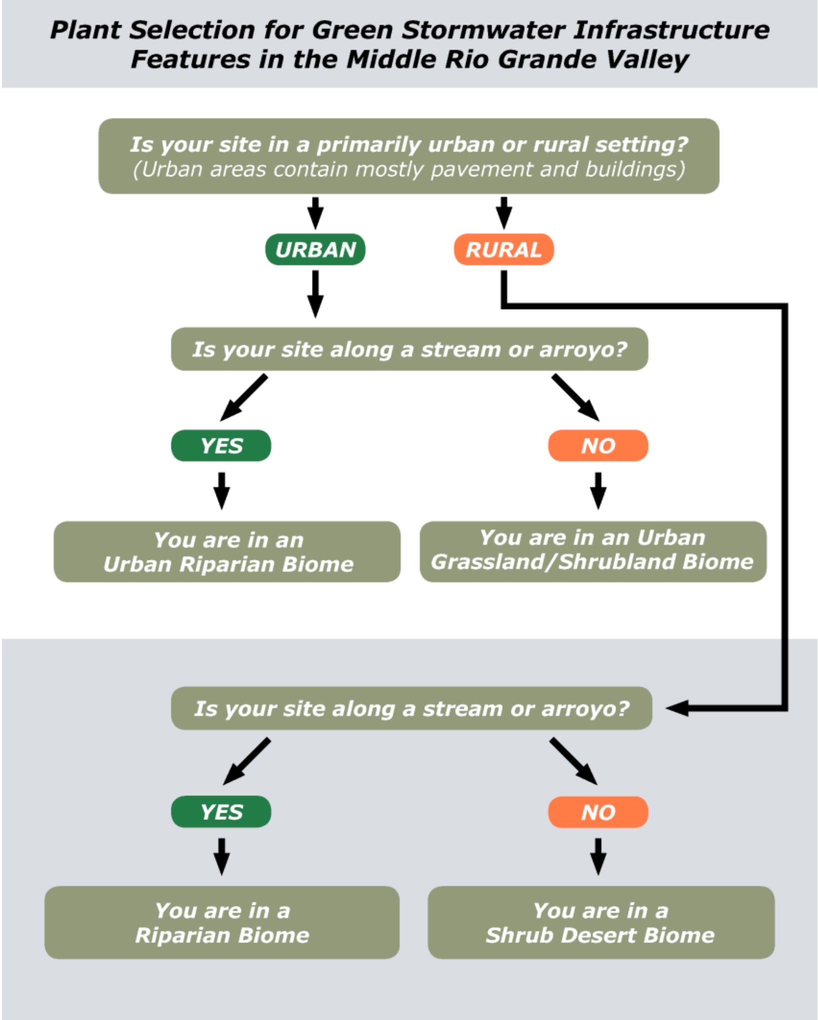
The **first step** in using the plant list is to determine the biome location of the GSI/LID BMP. See Figures 11 and 12 and Table 4 to determine the ecological biome for the project.

Across all elevation zones, four general biome categories are recognized for simplified plant selection: two are urban and two are non-urban. Within *urban areas*, the two biomes are **Urban Ephemeral Riparian**, which is the biome in and around unpaved arroyos, and **Urban Grassland/ Shrubland**. In *non-urban areas*, the two primary biomes are **Shrub Desert Grassland** and **Riparian**. Riparian biomes occur along acequias, ditches, the Rio Grande and Tijeras Creek, while other areas can generally be classified as Shrub Desert Grassland. Non-urban locations include the East Mountains, North Albuquerque Acres, the North and South Valleys, and other areas of unincorporated Bernalillo County.

Table 4: Ecological Biomes in the Middle Rio Grande

Biome	Urban	Rural	Stream or Arroyo
Urban Ephemeral Riparian	✓		✓
Urban Desert Grassland / Shrubland	✓		
Shrub Desert Grassland		✓	
Riparian		✓	✓

Figure 11: Plant Selection Flow Chart



Elevation Zone

The **second step** in using the plant list involves identifying the elevation zone, which can be determined by locating the project area within one of the five (5) zones depicted in Figure 12 and Figure 13.

Elevation, soil types, and annual precipitation amounts vary within the Middle Rio Grande watershed, which affects plant species selection. Five elevation zones, or areas of similar elevation and climate, run north-south through the Middle Rio Grande watershed:

1. West Mesa (west of Coors Blvd)
2. Valley (between Coors Blvd and Edith Blvd)
3. East Mesa (from Edith Blvd to Juan Tabo Blvd)
4. Foothills (Juan Tabo Blvd to the National Forest)
5. East Mountains (along NM 14 and NM 337)

Figure 12: Elevation Zones across Bernalillo County

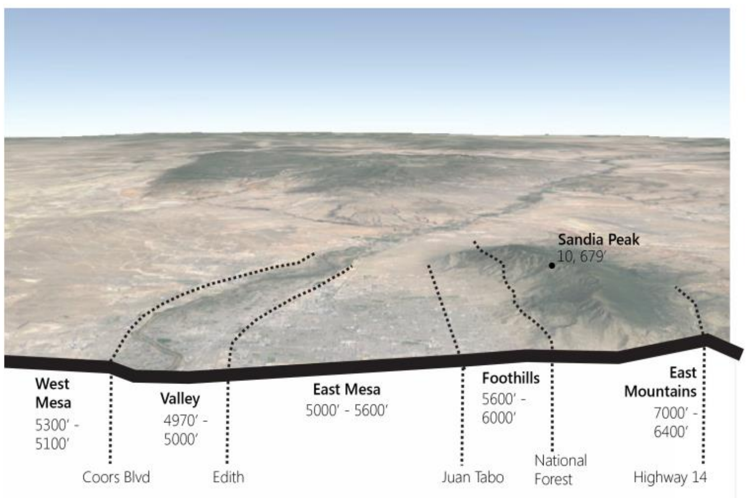
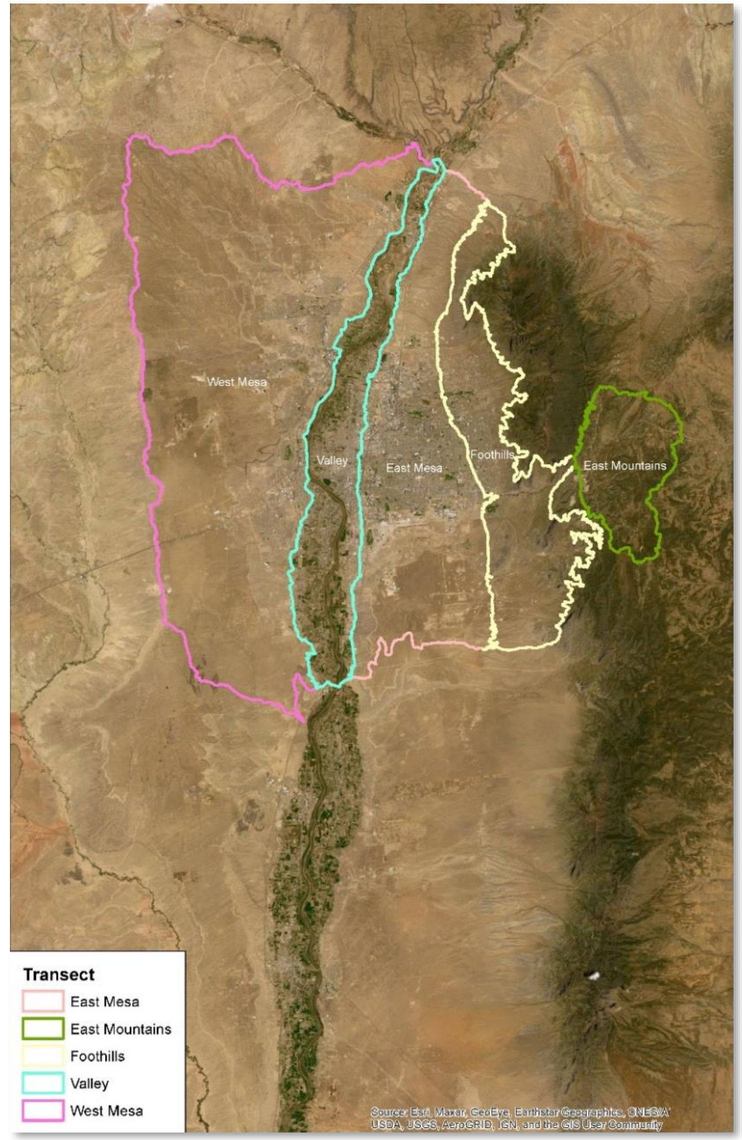


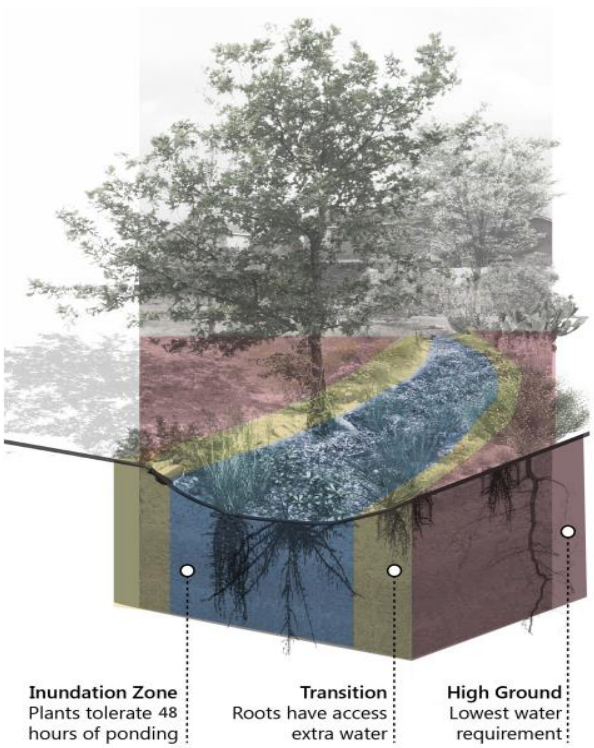
Figure 13: Geographic Area for Elevation Zones



Inundation Zone

The **third step** for using the plant list is determining the planting location within the BMP to identify the inundation zone. Plant selection must be appropriate for the inundation, or wetness, zone in the GSI/LID feature. The location features around the BMP include the inundation zone at the bottom of the basin or swale, the transition area along the sides, and high ground at the top of the GSI/LID BMP (see Figure 14).

Figure 14: Inundation Zones within GSI/LID BMPs



The depth of the inundation zone will be unique to and determined by the hydraulics of the GSI/LID BMP. The capacity, drainage outfall, and permeability of the soils will all impact how deep the water ponds within and how quickly it drains from a BMP. Most drought-adapted plants require good drainage, including those that can tolerate temporary inundation. If an infiltration feature does not drain within 48 hours, even inundation-tolerant plants may not survive.

Transition Zone

The transition zone is typically located on the side slopes of the BMP, above the inundation zone and below the top of the slope for the BMP, and refers to the area where capillary rise no longer moves water upwards through the soil from the inundation zone. The extent of the transition zone could vary for very deep GSI/LID BMPs; in these situations the high ground may extend down the side slopes.

Plant Species Diversity

GSI/LID features should include at least three species within each plant type (i.e. tree, shrub, perennial, grass) to ensure that some species will live in the event of extreme drought or insect infestation. Species diversity is also critical for wildlife habitat.

Runoff Requirements for Trees

Each tree on the plant list should receive runoff from at least 1,500-3,500 sq. ft. of impervious surface (i.e. concrete or asphalt) to survive without irrigation after establishment. Lower water use trees, such as desert willow and mesquite, require closer to 1,500 sq. ft., while higher water use trees, such as cottonwood and Arizona sycamore, require upwards of 3,500 sq. ft.

Planting Recommendations

The following procedures should be followed to promote plant growth with GSI/LID BMPs:

- Protect soil from compaction or scarify soil before planting.
- Nursery-grown plants should be planted in the fall (i.e. October and November) to promote root establishment and minimize irrigation needs. Fall planting of nursery-grown plants is preferred as it gives plants five to six months for root growth before warm temperatures and winds stress new plants.
- Seeds should be planted in early fall because the soil is still warm and soil moisture is present, while intense storms that wash away seeds are less likely. Follow Section 632 of the NMDOT Standard Specifications for Highway and Bridge Construction for weather limitations for seeding.

Establishment Periods

To achieve water conservation benefit from GSI/LID, plants in GSI/LID features should be drought-adapted and generally able to survive without irrigation, once established. Depending on species selection and site factors, continued irrigation may be needed for trees. While in some conditions tree species may not need irrigation beyond establishment, trees merit continued, efficient irrigation because of the multitude of benefits they return to the community. Supplemental irrigation for all plant types may also be required during periods of prolonged drought. Table 5 outlines establishment periods by plant category under normal precipitation conditions. Table 6 provides guidelines for plant establishment guidelines for GSI/LID features.

Table 5: Arid Environment Establishment Periods

Plant Type	Establishment Period
Trees	10-15 years
Shrubs	3-5 years
Perennials/grasses	1-2 years

Table 6: Establishing Guidelines for GSI/LID Features

Are you Planting Trees?
Yes
You will need to irrigate for 10 to 15 years to establish a healthy tree. This range depends on available precipitation, selected species, soil health, reflected heat, and time of planting. This range assumes that each tree receives runoff from between 1,500 to 3,500 sq ft of impervious surface. A durable irrigation system is recommended (PVC pipe and bubblers). Drip systems generally do not last more than 8 years. If you are also planting shrubs/smaller plants, consider putting them on a sperate irrigation zone so that the shrub zone can be turned off while the tree zone continues to be active. It is also possible to cap bubblers for shrubs after they are established (3-5 years) while leaving bubblers for trees active for at least 10-15 years.
No
Shrubs require at least 3-5 years of irrigation for establishment. This range depends on available precipitation, selected species, soil health, reflected heat, and time of planting. A drip system may be sufficient to meet established irrigation needs for shrub perennials, although it will require consistent maintenance to ensure functionality for 3-5 years. If you are seeding, installing a temporary spray irrigation system will greatly improve results. Depending on available precipitation, spray irrigation may only be needed for 1 year. Wildflowers and grasses respond to precipitation, but may go dormant without soil moisture. If continuous growth/ blooms are desired, irrigation will be necessary.

Appendix: Plant List

Bernalillo County maintains a plant list on the Residential Rainwater Harvesting page of its website (www.bernco.gov). The plant lists provided below reflect preferred plants by biome and transect and inundation zones as of July 2020 for the following plant types:

- Trees
- Shrubs
- Perennials
- Grasses

Trees

Botanical Name	Common Name	Mature Size (Height x Spread)	Biome				Transect and Infiltration Zone (I = inundation, T = transition, H= high ground)					Evergreen / Semi-	Notes
			Urban Ephemeral Riparian	Urban Grassland/ Shrubland	Shrub Desert Grassland	Riparian	West Mesa	Valley	East Mesa	Foothills	E. Mntn		
TREES													
*Acacia syn Senegalia greggii**	Catclaw acacia	10' x 15'	X	X	X	X	I, T	I, T	I, T	-	-		Fast grower, good barrier plant, marginally cold hardy
Celtis laevigata'-reticulata	Netleaf hackberry	25' x 25'	X	X	X	X	I, T	I, T	I, T	I, T,H	I, T,H		Small red fruits in fall
Cercis mexicana	Mexican redbud	20' x 15'	X	X		X	-	I, T	-	-	-		May be difficult to transplant.
Chilopsis linearis	Desert willow	20' x 25'	X	X	X	X	I,T,H	I,T,H	I,T,H	I,T,H	-		Blooms summer and fall
Crataegus ambigua	Russian hawthorn	15' x 20'	X			X	-	-	-	-	I		May require supplemental water
*Juniperus chinensis 'Keteleeri'**	Keteleeri juniper	15' x 10'	X	X	X		T	T,H	T	T,H	T,H	E	A more heat-tolerant Juniper
*Juniperus monosperma**	One-seed juniper	15' x 20'		X	X		T,H	T,H	T,H	T,H	T,H	E	Only plant female of species
Koelreuteria paniculata	Golden rain tree	20' x 20'	X			X	-	I,T	I	I,T	I,T		Attracts box elder bugs
Maclura pomifera	Osage orange	25' x 25'	X	X	X	X	-	I,T	I,T	I,T	I,T		Orange-size green fruits on female trees
*Pinus eldarica**	Afghan pine	40' x 20'	X	X	X		T	T	T	T	-	E	Protect from inundation
*Pinus pinea**	Italian stone pine	60' x 50'	X	X			T	T	T	-	-	E	Protect from inundation
Pistacia chinensis	Chinese pistache	40' x 20'	X			X	I	I	I	I,T	I,T		
Platanus mexicana	Mexican sycamore	50' x 30'				X	-	I	-	I	-		Included on this list on a trial basis
Platanus wrightii	Arizona sycamore	60' x 70'				X	-	I	-	I	I		Requires plentiful and consistent runoff
*Populus deltoides var. wislizenii**	Rio Grande cottonwood	50' x 60'				X	-	I	-	-	I,T		Premier wildlife habitat
Prosopis glandulosa	Honey mesquite	25' x 30'	X	X	X	X	I,T,H	I,T,H	I,T,H	-	-		Yellow flowers in summer
Prosopis pubescens	Screwbean mesquite	20' x 20'	X	X	X	X	I,T,H	I,T,H	I,T,H	-	-		
Quercus arizonica	Arizona white oak	25' x 25'	X			X	-	I,T	I,T	-	-	E	Included on this list on a trial basis
Quercus fusiformis	Escarpment live oak	25' x 30'	X			X	-	I,T	I,T	I,T	-	E	Texas native
Quercus gambelii	Gambel oak	25' x 25'	X			X	-	I,T	-	I,T	I,T,H		Requires supplemental water during drought
Quercus muhlenbergii	Chinquapin oak	40' x 50'	X			X	-	I,T	-	I,T	I,T		Texas native
Quercus turbinella	Scrub live oak	18' x 20'	X			X	-	I,T	I,T	I,T	I,T	E	Native in Sandia Mountains
*Rhus lanceolata**	Prairie flameleaf sumac	15' x 20'	X			X	-	I,T	I	I,T	I,T		Fast growing, can form thickets
*Robinia neomexicana**	New Mexico locust	25' x 15'	X	X	X	X	-	I,T	I,T	I,T	I,T		Thorny, thicket forming, requires consistent runoff, poisonous seeds, pink flowers in Spring
Salix gooddingii	Goodding's willow	25' x 25'				X	-	I	-	-	-		Riparian only, high water needs
Sapindus saponaria var. drummondii	Western soapberry	30' x 30'	X			X	-	I,T	I	I,T	I,T		Slow grower, white flowers in summer followed by inedible fruits
Styphnolobium japonicum	Japanese pagoda tree	35' x 25'	X			X	I,T	I,T	I,T	I,T	I,T		White flowers in summer
Ulmus parvifolia (and hybrids)	Lacebark elm	40' x 30'	X			X	-	I,T	I	I,T	I,T		Non-invasive, elm beetle resistant
Vitex agnus castus	Chaste tree	20' x 20'	X			X	I,T	I,T	I,T	-	-		
*Ziziphus jujuba**	Jujube	25' x 25'	X	X	X	X	I,T	I,T	I,T	I,T	I,T		Thicket-forming barrier plant

Notes:
More testing is needed on Gymnocladus dioica (questionable drought tolerance) and Ulmus propinqua (potentially invasive).
Several additional trees were considered for this list and not included because of concerns with heat and-or drought tolerance: Celtis occidentalis, Gleditsia triacanthos, Juglans major and nigra, Juniperus scopulorum, Prunus cistena, and Quercus buckleyi.
In general, trees provide important habitat for birds and pollinators. Conifers (pines and junipers on this list) do not provide the same benefit to pollinators that most deciduous trees do.
** indicates tree is not recommended as street trees because of growth habit, thorns, fruit production, or root development.*

Shrubs

Botanical Name	Common Name	Mature Size (Height x Spread)	Biome				Transect and Infiltration Zone (I = inundation, T = transition, H= high ground)					Wildlife Value		Evergreen / Semi-	Notes
			Urban Ephemeral Riparian	Urban Grassland/ Shrubland	Shrub Desert Grassland	Riparian	West Mesa	Valley	East Mesa	Foothills	E. Mntn	Pollinator	Bird		
SHRUBS															
Amorpha canescens	Leadplant	3' x 3'	X	X	X	X	I	I	I	I	I,T	X			
Amorpha fruticosa	False indigo	10' x 10'	X			X	-	I	-	-	I,T	X			Phytoremediator for lead and perchlorate
Anisacanthus wrightii	Desert honeysuckle	5' x 4'	X	X	X	X	I,T	I,T	I,T	I,T	-	X	X		Bright red'-orange flowers in early summer and when well watered
Arctostaphylos x coloradoensis	Chieftain or Panchito manzanita	2' x 4'	X	X	X		T,H	T,H	T,H	T,H	T,H	X	X	E	Requires good drainage
Artemisia filifolia	Sand sage	4' x 4'	X	X	X		T,H	T,H	T,H	T,H	T,H		X	E	Requires good drainage, only give one year establishment irrigation
Artemisia tridentata	Big sage	4' x 4'	X	X	X		I,T,H	-	I,T,H	I,T,H	I,T,H	X	X	E	
Atriplex canescens	Fourt-winged saltbush	5' x 7'	X	X	X	X	T,H	T,H	T,H	T,H	T,H		X	E	Allergen-producing, use sparingly, will reseed, salt tolerant
Atriplex lentiformis	Quail bush	8' x 8'	X	X	X	X	T	T	T	T	-		X	E	Good for large spaces
Baccharis salicifolia	Mulefat	8' x 6'	X			X	I,T	I,T	I,T	-	-	X		SE	Sticky foliage
Baccharis salicina	Seep willow	6' x 6'	X			X	-	I,T	-	-	-	X	X	SE	Locally native
Baccharis sarathroides	Desert broom	10' x 10'	X	X		X	I,T,H	T,H	I,T,H	-	-	X	X	SE	
Baccharis 'Starn Thompson'	Starn Thompson broom	4' x 5'	X	X	X	X	-	I,T	-	I,T	-			E	Sterile cultivar
Buddleia marrubifolia	Wooly butterfly bush	4' x 4'	X	X	X	X	T,H	T,H	T,H	-	-	X	X	SE	
Caesalpinia giliesii	Yellow brd of paradise	5' x 5'	X	X	X	X	T,H	T,H	T,H	T,H	-	X	X		
Caryopteris x clandonensis	Blue mist spirea	4' x 4'	X	X		X	I	I	I	I,T	I,T	X			
Cercocarpus breviflorus	Hairy mountain mahogany	10' x 8'	X	X		X	-	-	T	T,H	T,H	X	X	SE	Slow growing
Cercocarpus ledifolius	Curlleaf mountain mahogany	10' x 12'	X	X		X	-	-	T	T,H	T,H	X	X	E	Slow growing
Cercocarpus montanus	Mountain mahogany	8' x 10'	X	X		X	-	-	T	T,H	T,H	X	X	SE	Slow growing
Chamaebatiaria millefolium	Fernbush	6' x 8'	X	X	X	X	I,T	I,T	I,T	I,T	I,T,H	X	X		
Dalea capitata	Sierra gold dalea	1' x 3'	X	X	X	X	T	T	T	-	-		X	SE	Very heat tolerant
Ephedra nevadensis	Nevada jointfir	4' x 4'	X	X	X		T,H	-	T,H	T,H	-	X	X	E	
Ephedra viridis	Green ephedra	2' x 4'	X	X	X		T,H	-	T,H	T,H	-	X	X	E	
Ericameria larcifolia	Turpentine bush	3' x 4'	X	X	X		I,T,H	I,T,H	I,T,H	I,T,H	I,T,H	X		E	Fall-blooming, important late-season nectar source for bees
Ericameria nauseosa	Chamisa'- Rabbitbrush	5' x 8'	X	X	X		I,T,H	I,T,H	I,T,H	I,T,H	I,T,H	X	X	E	Flowers have foul odor
Eriogonum fasciculatum	Flat-top buckwheat	1' x 2'	X	X	X		T,H	-	T,H	T,H	-	X	X		
Eriogonum wrightii	Wright's buckwheat	1' x 2'	X	X	X		T,H	-	T,H	T,H	-	X	X		
Fallugia paradoxa	Apache plume	6' x 7'	X	X	X	X	I,T,H	I,T,H	I,T,H	I,T,H	I,T,H	X	X	SE	
Forestiera neomexicana	New Mexico olive	12' x 12'	X	X		X	-	I,T	I,T	I,T,H	I,T,H	X	X		
Garrya wrightii	Wright's silktassel	6' x 6'	X	X		X	T,H	T,H	T,H	T,H	T,H			E	
Hesperaloe parivflora	Red yucca	3' x 3'	X	X	X		T,H	T,H	T,H	T,H	T,H	X	X	E	
Krascheninnikovia lanata	Winterfat	3' x 3'		X	X		I,T,H	I,T,H	I,T,H	I,T,H	I,T,H		X	SE	
Larrea tridentata	Creosote bush	6' x 6'	X	X	X		T,H	-	T,H	-	-	X	X	E	Yellow flowers in spring and winter
Leucophyllum spp	Texas ranger	3-6' x 3-6'	X	X	X	X	T,H	T,H	T,H	-	-	X		SE	Best species: *L. langmaniae* 'Lynn's Legacy' and 'Rio Bravo', *L.frutescens* 'Compacta' and 'Green Cloud', *L. revolutum* 'Houdini'
Lycium andersonii	Anderson wolfberry	6' x 6'	X	X	X	X	I,T,H	I,T,H	I,T,H	I,T,H	-	X	X	E	Salt tolerant
Mahonia haematocarpa	Red mahonia'- barberry	6' x 5'	X	X	X	X	I,T,H	I,T,H	I,T,H	I,T,H	I,T,H	X	X	E	Yellow flowers in spring followed by red berries
Mahonia trifoliata	Algerita	6' x 8'	X	X	X		I,T,H	I,T,H	I,T,H	I,T,H	I,T,H	X	X	E	Yellow flowers in spring followed by red berries
Nolina microcarpa	Beargrass	5' x 7'		X	X		T,H	T,H	T,H	T,H	-	X	X	E	
Nolina nelsonii	Blue nolina	8' x 4'		X	X		T,H	T,H	T,H	-	-	X		E	
Nolina texana	Beargrass	3' x 3'		X	X		T,H	T,H	T,H	T,H	T,H	X	X	E	Locally native
Prunus americana	Wild plum	10' x 10'	X			X	I	I	I	I,T	I,T	X	X		
Prunus besseyi	Western sand cherry	5' x 5'	X	X	X	X	T,H	T,H	T,H	T,H	T,H	X	X		
Prunus besseyi 'Pawnee Buttes'	Pawnee Buttes sand cherry	2' x 6'	X	X	X	X	T,H	T,H	T,H	T,H	T,H	X	X		Groundcover variety of Western sand cherry
Prunus virginiana var melanocarpa	Western choke cherry	10' x 10'	X	X		X	-	I,T	I	I,T	I,T	X	X		Select from local provenance
Purshia mexicana	Cliff Rose	8' x 8'	X	X	X		T,H	-	T,H	T,H	T,H	X	X	E	Fragrant
Purshia tridentata	Antelope bitterbrush	5' x 5'	X	X	X		T,H		T,H	T,H	T,H	X	X	SE	
Rhus glabra ' Cismontana'	Compact smooth sumac	5' x 7'	X	X		X	-	I,T	I,T	I,T,H	I,T,H	X	X		Thicket-forming
Rhus microphylla	Littleleaf sumac	8' x 9'	X	X	X	X	I,T	I,T	I,T	I,T,H	I,T,H	X	X		
Rhus trilobata	Three leaf sumac	6' x 6'	X	X	X	X	I,T,H	I,T,H	I,T,H	I,T,H	I,T,H		X		Locally native
Rhus trilobata 'Autumn Amber'	Prostrate three-leaf sumac	2' x 6'	X	X	X	X	I,T,H	I,T,H	I,T,H	I,T,H	I,T,H		X		Groundcover variety of Three leaf sumac (locally native)
Salix exigua	Coyote willow	5' x 3'				X	-	I	I	I	I	X	X		Root sprouts, bank stabilizer
Salvia chamaedryoides	Mexican blue sage	1' x 2'	X	X			-	T	T	T	-	X		SE	Does well in clay
Salvia greggii	Autumn or Cherry sage	2' x 3'	X	X	X	X	I,T	I,T	I,T	I,T	I,T	X	X	SE	Brittle, blooms from spring to fall
Salvia officianialis	Culinary sage	2' x 3'	X	X	X	X	I,T	I,T	I,T	I,T	I,T	X		SE	Can be used for cooking
Salvia pachyphylla	Mojave sage	2' x 3'		X	X		-	T	T	T,H	T,H	X		SE	
Salvia rosmarinus	Rosemary	3' x 3'	X			X	T	T	T	-	-	X		E	
Santolina chamaecyparissus	Grey santolina	2' x 3'	X	X			T	T	T	T	T			E	
Santolina virens	Green santolina	2' x 3'	X	X			T	T	T	T	T			E	
Teucrium aroanium	Gray creeping germander	4" x 2'	X	X		X	T	T	T	T	T	X		E	
Teucrium chamaedrys	Wall germander	2' x 2'	X	X		X	I,T	I,T	I,T	I,T	I,T	X		E	
Vauquelinia californica ssp	Arizona rosewood	12' x 10'	X	X			T,H	T,H	T,H	T,H	-	X	X	E	Does well with high winds

Notes: Several additional shrubs were considered for this list and not included because of concerns with heat and/or drought tolerance, including Rhus aromatica 'Gro-Low', Buddleia davidii, and Lavandula spp.,

Perennials

Botanical Name	Common Name	Mature Size (Height x Spread)	Biome				Transect and Infiltration Zone (I = inundation, T = transition, H= high ground)					Wildlife Value		Notes
			Urban Ephemeral Riparian	Urban Grassland/ Shrubland	Shrub Desert Grassland	Riparian	West Mesa	Valley	East Mesa	Foothills	E. Mntn	Pollinator	Bird	
HERBACEOUS PERENNIALS AND ANNUAL WILDFLOWERS														
Achillea millefolium	Common yarrow	1' x 1'	X	X	X	X	-	I,T	I,T	I,T	I,T	X		
Artemisia frigida	Fringed sage	1' x 1'	X	X	X		I,T,H	I,T,H	I,T,H	I,T,H	I,T,H		X	
Artemisia ludoviciana	Prairie sage	2' x 3'	X	X	X	X	-	I,T,H	I,T,H	I,T,H	I,T,H	X		Spreads by rhizomes
Asclepias speciosa	Showy milkweed	3' x 1'	X			X	I	I,T	I,T	I,T	I,T	X	X	
Asclepias subverticillata	Horsetail milkweed	2' x 2'	X	X	X	X	I	I	I	I	I,T	X		
Baileya radiata	Desert marigold	1' x 1'	X	X	X		T,H	T,H	T,H	T,H	T,H	X	X	Biennial, prolific reseeder
Berlandiera lyrata	Chocolate flower	1' x 2'	X	X	X	X	T,H	-	T,H	T,H	T,H	X	X	Will reseed
Calylophus hartwegii	Sundrops	1' x 2'	X	X	X		T	-	T	T,H	T,H	X		
Centranthus ruber	Red Valerian	2' x 2'	X	X	X	X	I,T	I,T	I,T	I,T	I,T,H	X		Tolerant of a variety of conditions, will reseed
Cirsium neomexicanum	New Mexico thistle	6' x 2'	X	X	X		I,T,H	I,T,H	I,T,H	I,T,H	I,T,H	X	X	Locally native, non-invasive
Cleome serrulata	Rocky Mountain beeplant	3' x 3'	X	X	X	X	I,T	I,T	I,T	I,T	I,T,H	X	X	Annual, available as seed
Datura wrightii	Sacred datura	2' x 6'	X	X	X	X	I,T,H	I,T,H	I,T,H	I,T,H	I,T,H	X	X	All parts of plant are toxic, only plant in inaccessible basins.
Epilobium canum	Hummingbird trumpet	1' x 3'	X			X	-	I,T	-	I,T	I,T	X	X	
Euphorbia rigida	Gopher spurge	2' x 3'	X	X	X		T	T	T	T	-	X		Handle with caution- sap can burn skin. Will reseed
Gaillardia aristata	Blanketflower	1' x 1'	X	X	X		T,H	T,H	T,H	T,H	T,H	X		Reseeds readily
Glandularia gooddingii	Goodding's verbena	1' x 1'	X			X	T	T	T	T	T	X		Requires water to bloom
Glandularia rigida	Sandpaper verbena	2' x 4'	X	X	X	X	T	T	T	-	-	X		
Helianthus annuus	Common sunflower	4-6' tall	X	X	X	X	-	I,T,H	-	-	I,T,H	X	X	Annual, great for birds, bees, and butterflies (available as seed), phytoremidator of hydrocarbons and metals
Helianthus petiolaris	Prairie sunflower	4' x 4'	X	X		X	I,T,H	I,T,H	I,T,H	I,T,H	I,T,H	X	X	Annual, great for birds, bees, and butterflies (available as seed)
Hymenoxys acaulis	Angelita daisy	1' x 1'	X	X	X		T,H	T,H	T,H	T,H	T,H	X		Reblooms throughout spring and summer
Linum lewisii	Blue flax	2' x 2'	X	X		X	I,T,H	I,T,H	I,T,H	I,T,H	I,T,H	X		
Melampodium leucanthum	Blackfoot daisy	1' x 2'		X	X		T,H	-	T,H	T,H	T,H	X	X	Long-lived, will reseed
Mirabilis multiflora	Desert four o'clock	2' x 3'	X	X	X	X	T,H	-	T,H	T,H	T,H	X		Will reseed
Monarda fistulosa	Wild beebalm	2' x 2'	X	X	X	X	-	-	-	I,T,H	I,T,H	X		
Nepeta racemosa	Catmint	2' x 2'	X	X		X	T	T	T	T	T	X		Blooms spring to fall
Oenthera caespitosa	White tufted evening primrose	1' x 2'	X	X	X	X	T,H	T,H	T,H	T,H	T,H	X		Short-lived, but reseeds readily
Oenothera speciosa	Mexican evening primrose	1' x 2'	X	X	X	X	I,T	I,T	I,T	I,T	I,T	X	X	Needs some water and sunlight to bloom
Oenothera lindheimeri	Gaura	3' x 3'	X			X	I,T	I,T	I,T	I,T	I,T	X		
Penstemon ambiguus	Sand penstemon	2' x 2'	X	X	X		I,T,H	I,T,H	I,T,H	I,T,H	I,T,H	X	X	Usually available as seed
Penstemon thurberi	Thurber's penstemon	2' x 2'	X	X	X		I,T,H	I,T,H	I,T,H	I,T,H	-	X	X	
Psilotrophe tagetina	Wooly paperflower	1' x 2'		X	X		T,H	T,H	T,H	T,H	T,H	X		
Ratibida columnifera	Mexican hat	1' x 1'	X	X	X	X	I,T,H	I,T,H	I,T,H	I,T,H	I,T,H	X	X	
Salvia darcyi	Vermillion Bluffs sage	3' x 3'	X	X		X	-	T	T	T	T	X	X	Great for hummingbirds
Sphaeralcea spp	Globemallow	2' x 2'	X	X	X	X	I,T,H	I,T,H	I,T,H	I,T,H	I,T,H	X	X	Short-lived, reseeds
Symphyotrichum ericoides	White heath aster	2' x 2'	X	X	X	X	-	I,T,H	-	I,T,H	I,T,H	X		Bosque native
Zinnia acerosa	Desert zinnia	1' x 1'	X	X	X		T,H	-	T,H	T,H	-	X	X	
Zinnia grandiflora	Prairie zinnia	0.5' x 1'	X	X	X		T,H	-	T,H	T,H	T,H	X	X	

Notes: Penstemons require well drained soils and do not tolerate inundation. The Penstemons listed above (ambiguus and thurberi) are the exceptions that have been observed to tolerate some inundation. However, there are many Penstemons (including eatonii, parryi, pinifolius, pseudospectabilis, strictus, and superbus) that may do well in areas around GSI features. If conditions are favorable, they will reseed themselves into wetter soil.

Grasses

Botanical Name	Common Name	Mature Size (Height x Spread)	Biome				Transect and Infiltration Zone (I = inundation, T = transition, H= high ground)					Wildlife Value		Notes
			Urban Ephemeral Riparian	Urban Grassland/ Shrubland	Shrub Desert Grassland	Riparian	West Mesa	Valley	East Mesa	Foothills	E. Mntn	Pollinator	Bird	
GRASSES														
Andropogon gerardii	Big bluestem	4' x 2'				X	-	I,T	-	I,T	I,T	X	X	Salt tolerant , phytoremediation of hydrocarbons, some heavy metals, and PCBs (through accumulation)
Aristida purpurea	Purple three-awn	1' x 1'		X	X		T,H	T,H	T,H	T,H	T,H	X	X	Available as seed, good for erosion control and reclamation
Bouteloua curtipendula	Sideoats grama	2' x 2'	X	X	X		T,H	T,H	T,H	T,H	T,H	X	X	
Bouteloua gracilis	Blue grama	2' x 2'	X	X	X		T,H	T,H	T,H	T,H	T,H	X	X	Helps to break down hydrocarbons
Distichlis spicata	Desert saltgrass	2' tall, spreading				X	I	I	I	I	I	X	X	Available as seed, high salt tolerance, higher water needs, mat forming
Elymus elymoides	Squirreltail	1' x 1'	X	X	X		T,H	T,H	T,H	T,H	T,H			Seed heads can be dangerous for pets, good for reclamation
Elymus lanceaolatus ssp psammophilus	Streambank wheat	1' x 2'	X	X	X	X	-	I,T	-	I,T	I,T			Sod-forming
Eragrostis trichodes	Sand lovegrass	3' x 3'	X	X	X		T,H	T,H	T,H	T,H	T,H	X		
Festuca glauca	Blue fescue	1' x 1'					-	-	-	-	T			
Muhlenbergia asperifolia	Alkali muhly/Scratchgrass	2' x 2'	X	X	X	X	-	I,T	-	-	-			Salt tolerant
Muhlenbergia capillaris	Regal mist	3' x 3'	X			X	I,T	-	I,T	I,T	I,T		X	High salt tolerance
Muhlenbergia emersleyi	Bull grass	3' x 3'	X			X	I,T	I,T	I,T	I,T	-	X	X	
Muhlenbergia lindheimerii	Autumn glow muhly	5' x 5'	X			X	I,T	I,T	I,T	I,T	-		X	
Muhlenbergia porteri	Bush muhly	1' x 3'	X	X	X		T,H	T,H	T,H	T,H	T,H		X	Usually available as seed
Muhlenbergia rigens	Deer grass	4' x 4'	X	X	X	X	I,T	I,T	I,T	I,T	I,T	X	X	
Muhlenbergia rigida	Nashville muhly	2' x 3'	X	X	X	X	I,T	I,T	I,T	I,T	I,T	X		
Nassella tenuissima	Mexican feather grass	2' x 2'	X	X	X	X	I,T,H	I,T,H	I,T,H	I,T,H	I,T,H			Will reseed. Only plant where spreading is desired.
Panicum obstusum	Vine mesquite	2', spreading	X	X	X	X	I,T	I,T	I,T	I,T	I,T	X		Available as seed, mat forming
Panicum virgatum	Switchgrass	3' x 2'	X			X	-	I	-	-	I,T	X	X	
Pascopyrum'-Agropyron smithii	Western wheat grass	2' x 2'	X			X	-	I,T	-	I,T	I,T,H		X	Helps to break down hydrocarbons, can crowd out wildflowers, tolerates poor drainage
Pleuraphis jamesii	Galleta grass	1' x 1'	X	X	X		T,H	T,H	T,H	T,H	T,H	X	X	
Schizachyrium scoparium	Little bluestem	2' x 2'	X	X	X	X	I,T,H	T,H	I,T,H	I,T,H	T,H	X	X	Helps to break down hydrocarbons
Sorghastrum nutans	Indiangrass	4' x 2'	X			X	I,T	I,T	I,T	I,T	I,T	X	X	Helps to break down hydrocarbons, tolerates poor drainage
Sporobolus airoides	Alkali sacaton	2' x 2'	X	X	X	X	I,T,H	I,T,H	I,T,H	I,T,H	I,T,H	X	X	Tolerates salinity and inundation
Sporobolus cryptandrus	Sand dropseed	2' x 2'		X	X		T,H	T,H	T,H	T,H	T,H	X	X	
Sporobolus wrightii	Giant sacaton	5' x 5'	X			X	I,T	I,T	I,T	I,T	I,T	X	X	Tolerates salinity and inundation

BERNALILLO COUNTY
STATE OF NEW MEXICO

ATTACHMENT B

NMDOT NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM MANUAL – APPENDIX A

National Pollutant Discharge Elimination System Manual

STORMWATER MANAGEMENT GUIDELINES FOR CONSTRUCTION, MS4, AND INDUSTRIAL ACTIVITIES

Revision 3 12/2020

New Mexico DEPARTMENT OF TRANSPORTATION
MOBILITY FOR EVERYONE

Permits for Clean Water
NPDES

National Pollutant Discharge Elimination System Manual

STORMWATER MANAGEMENT GUIDELINES FOR CONSTRUCTION, MS4, AND INDUSTRIAL ACTIVITIES

Revision 3
December 2020

New Mexico Department of Transportation
Environmental Bureau
PO Box 1149
Santa Fe, New Mexico 87504-1149

FORWARD

This December 2020 edition of the *Stormwater Management Guidelines for Construction, MS4, and Industrial Activities* is to be used as guidance for addressing National Pollutant Discharge System (NPDES) requirements for stormwater runoff from construction projects, municipal separate storm sewer system (MS4) areas, and industrial activities. The Manual is designed to be used in all parts of the state of New Mexico, both in urban and rural areas. This Manual was created to provide NPDES stormwater compliance guidance for the New Mexico Department of Transportation (NMDOT) and other government agency staff, design engineers, planners, landscape architects, and developers for use on both public and private projects.

The use of this Manual is encouraged for any entity that has the potential to generate stormwater runoff through either construction, MS4, or industrial activities with exposure to stormwater.

This revision to the NPDES Manual was necessitated by multiple regulatory NPDES changes, including:

- 2017 Construction General Permit (CGP) as modified 2019, dated June 27, 2019;
- 2014 General Permit for the Middle Rio Grande Watershed MS4s in New Mexico – #NMR04A000, currently in administrative continuance; and
- Multi-Sector General Permit (MSGP) for Stormwater Discharges from Industrial Activities – 2015 MSGP and Proposed 2020 MSGP. The 2015 MSGP is currently under administrative continuance.

In addition to the regulatory changes, this Manual revision includes a new, separate MS4 section (refer to Section II). The revision also updates Appendix A - Best Management Practice (BMPs) and includes BMPs with a focus on Green Stormwater Infrastructure (GSI) and Low Impact Development (LID). Appendix A is intended to encourage the use of, as well as assist with understanding and choosing appropriate BMP practices, including GSI.

This Manual is intended to provide guidance in meeting the current NPDES regulations for General Permits; however, changes in regulatory prerogatives of state and federal agencies and other affected parties may be more recent that the information presented in this Manual. The user should be aware of and verify if updated regulatory information supersede information within this Manual. This Manual does not address obtaining a site-specific, individual NPDES Permit, where required.

Comments regarding the content of this Manual are welcome and should be addressed to:

MS4 Program Manager, Environmental Bureau
New Mexico Department of Transportation
P.O. Box 1149
Santa Fe, NM 87504-1149

ACKNOWLEDGEMENTS

The Manual revision was performed by the New Mexico Department of Transportation (NMDOT) Environmental and Drainage Design Bureaus with the assistance of Bohannan Huston, Inc., Daniel B. Stephens & Associates, Dekker/Perich/Sabatini, and Sites Southwest.

The original Manual was the result of a collaborative effort between the NMDOT and the following agencies:

- City of Albuquerque,
- Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA),
- University of New Mexico (UNM),
- Southern Sandoval County Arroyo Flood Control Authority (SSCAFCA),
- City of Rio Rancho,
- Bernalillo County, and
- New Mexico Environment Department (NMED) Surface Water Quality Bureau.

NMDOT led the updates to the Manual in 2012 and 2020 (current). This 2020 Manual revision has been provided for review to the original collaborative agencies listed above as well as to:

- Amigos Bravos,
- Arid LID Coalition,
- Associated Contractors of New Mexico (ACNM), through which 814 Solutions LLC provided review comments,
- Middle Rio Grande Technical Advisory Group, which includes most of the original collaborative member agencies listed above,
- City of Santa Fe,
- Santa Fe County,
- City of Farmington,
- San Juan County,
- City of Las Cruces,
- Town of Mesilla,
- New Mexico State University (NMSU),
- City of Sunland Park,
- City of Anthony, and
- Doña Ana County.

The statewide feedback and collaborative contributions received are greatly appreciated and have been reviewed and reflected in the Manual, where applicable.

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APPENDICES

ACRONYMS

AIM	Additional Implementation Measures
AMAFCA	Albuquerque Metropolitan Arroyo Flood Control Authority
BMP	Best Management Practice
CDX	Central Data Exchange, an EPA Electronic Reporting System
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CGP	Construction General Permit
CN	Curve Number
COA	City of Albuquerque
CWA	Clean Water Act
DMR	Discharge Monitoring Report
DPM	Development Process Manual
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FR	Federal Register
GSI	Green Stormwater Infrastructure
GWQB	Ground Water Quality Bureau, Division of NMED
LANL	Los Alamos National Laboratory
LID	Low Impact Development
MCM	Minimum Control Measure
MEP	Maximum Extent Practicable
MRG	Middle Rio Grande
MS4	Municipal Separate Storm Sewer System
MSGP	Multi-Sector General Permit
NEC	No Exposure Certification
NeT	NPDES Electronic Reporting Tool
NMAC	New Mexico Administrative Code
NMDOT	New Mexico Department of Transportation
NMED	New Mexico Environment Department
NMSU	New Mexico State University
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NOT	Notice of Termination
NPDES	National Pollutant Discharge Elimination System
NRC	National Response Center

ACRONYMS

NRCS	Natural Resources Conservation Service
OSE	Office of the State Engineer
OSHA	Occupational Safety and Health Administration
PDE	NMDOT Project Development Engineer
POTW	Publicly Owned Treatment Works
ROW	Right-of-Way
RQ	Reportable Quantity
RUSLE	Revised Universal Soil Loss Equation
SCP	Sediment Control Plan, refer also to TESCP
SSCAFCA	Southern Sandoval County Arroyo Flood Control Authority
SIC	Standard Industrial Classification
SWMP	Stormwater Management Plan
SWPPP	Stormwater Pollution Prevention Plan
TESCP	Temporary Erosion and Sediment Control Plan (term specific to NMDOT)
The Services	U.S. Fish and Wildlife Service and National Marine Fisheries Services
TMDL	Total Maximum Daily Load
UA	Urbanized Area
UNM	University of New Mexico
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WLA	Waste Load Allocation

REFERENCES

City of Albuquerque. (2020). *Development Process Manual (DPM).* Albuquerque: City of Albuquerque.

EPA 2017 Construction General Permit (as modified in 2019) – Website link includes the NPDES General Permit for Discharges from Construction Activities (as modified), appendices, and fact sheet.

EPA NPDES Middle Rio Grande Watershed Based MS4 Permit – Website link has NPDES General Permit for the Middle Rio Grande Watershed MS4s, #NMR04A000 (2014), Fact Sheet, and MS4 Annual Report Form.

EPA NPDES Stormwater General Permit for Discharges from Small MS4s in New Mexico – Website link has NPDES General Permit for Discharges from Small MS4s in New Mexico, #NMR040000 (2007), Fact Sheet, Proposal to Reissue NMR040000 (2015), and 2015 Draft General Permit for Discharges from Small MS4s in New Mexico:

EPA NPDES Multi Sector General Permit (MSGP) for Stormwater Discharges from Industrial Activity – Website link has an overview of the program, 2015 MSGP, and Proposed 2020 MSGP. The 2015 MSGP is currently under administrative continuance.

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GLOSSARY OF TERMS

Throughout the Manual, the reader will find references to specific terms. To understand the process and goal of the stormwater program, these specific terms are listed below with definitions.

Arid Area – Areas with an average annual rainfall of 0 to 10 inches.

Best Management Practices (BMPs) – Management measures or practices used to protect air, soil, or water quality or reduce the potential for pollution associated with stormwater runoff. BMPs may be a structural device or non-structural practice, including processes, land use alternatives, activities, or physical structures.

Bioretention – The use of ecological processes incorporating vegetation and organic soils to treat and infiltrate stormwater runoff. In addition to transpiring and infiltrating significant stormwater volumes, vegetation and healthy soil can enhance pollutant removal from stormwater, improve permeability, and provide ecological and aesthetic value. Examples of bioretention practices include bioswales, raingardens, tree trenches, and contour swales. Also known as bioinfiltration.

Construction General Permit (CGP) – This refers to the NPDES General Permit for Discharges from Construction Activities. This is an umbrella permit that authorizes the discharge of stormwater (and certain authorized non-stormwater discharges) from construction sites that disturb one (1) or more acres of land, and from smaller sites that are part of a larger, common plan of development or sale that will ultimately disturb one (1) or more acres of land.

Detention Facility – A pond or stormwater facility that holds or detains runoff in a basin for a limited time, releasing it very slowly and allowing much of the sediment to drop out.

Evapotranspiration – The process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants.

Gray Stormwater Infrastructure – Traditional "gray" stormwater infrastructure is designed to quickly move stormwater away from the built environment and includes concrete, curbs, gutters, drains, piping, and collection systems that ultimately discharge untreated stormwater into a local water body.

Green Stormwater Infrastructure (GSI) – A method of stormwater management that is as sustainable, environmentally friendly, and cost-effective as possible. GSI focuses on creating ecosystems to treat polluted stormwater runoff prior to it entering aquifers, streams, or other waterways. On-site management of stormwater is the first choice, with neighborhood or regional management options as the next preferable solutions.

Impervious Surface – A material or layer that prevents fluid from passing through. Typical examples are roofs, asphalt surfaces, sidewalks, and concrete structures.

Low Impact Development (LID) – A method of building design and community development with the intention of keeping stormwater runoff as uncontaminated as possible. “Slow it down, spread it out, soak it in” is the motto of LID. Spreading stormwater out reduces both the speed of the stormwater and erosion. Allowing the stormwater to soak into the ground recharges underground aquifers and fosters environmental growth.

Minimum Control Measures (MCM) – minimum control measures include six elements that, when implemented in concert, are expected to result in significant reductions of pollutants discharged into receiving waterbodies from MS4s. The standard six minimum control measures that must be included in MS4 SWMPs include: 1) Construction Site Stormwater Runoff Control; 2) Post-Construction Stormwater Management in New Development and Redevelopment; 3) Pollution Prevention and Good Housekeeping for Municipal Operations; 4) Illicit Discharges and Improper Disposal; 5) Public Education and Outreach on Stormwater Impacts; and 6) Public Involvement/Participation.

Multi-Sector General Permit (MSGP) – This refers to the NPDES Multi-Sector General Permit for Stormwater Discharges Associated with Industrial Activity. This is an umbrella permit under which certain Standard Industrial Classification (SIC) industries may be granted a permit to discharge stormwater associated with industrial activities by notifying EPA of their intent to do so, in compliance with the regulatory provisions of the General Permit.

Municipal Separate Storm Sewer System (MS4) – A conveyance or system of conveyances (including roads with drainage systems and municipal streets) that is “owned or operated by a state, city, town, borough, county, parish, district, association, or other public body designed or used for collecting or conveying stormwater.”

National Pollutant Discharge Elimination System (NPDES) – The national program for administering and regulating Sections 307, 318, 402, and 405 of the Clean Water Act. The EPA administers the NPDES program through issuance and enforcement of permits that authorize discharges to waters of the U.S. A stormwater permit issued under NPDES is authorization by EPA to discharge stormwater under certain specified conditions.

Non-Exposure Certification (NEC) – A permit exemption for certain outfalls or pollutant constituents, granted to facilities that can demonstrate no discharge or absence of particular constituents through monitoring.

Notice of Intent (NOI) – A formal notice to EPA that, under the NPDES General Permit, a stormwater discharge will take place. The NOI provides information on the permittee, location of discharge, and the type of discharge. It also certifies that the permittee will comply with certain specified conditions as outlined in the General Permit.

Notice of Termination (NOT) – A formal notice to EPA that a specific site permitted under the NPDES Program is no longer discharging stormwater.

Permeable / Pervious / Porous Surface – A material or layer that permits fluid to pass through the material and allows stormwater to infiltrate where it falls.

Phytoremediation – A biological process by which various plants remove, stabilize, and uptake pollutants and contaminants from soil and water.

Qualified Person – A person knowledgeable in the principles and practices of stormwater controls, pollution prevention, practice of erosion and sediment controls, and possesses the education and ability to assess conditions at an industrial facility or construction site that could impact stormwater quality, and the education and ability to assess the effectiveness of stormwater controls (BMPs) selected and installed to meet the requirements of the applicable NPDES Permit. For NMDOT, the Standard Specifications of Highway and Bridge Construction, Section 603, Temporary Erosion and Sediment Control, requires a qualified person to conduct SWPPP inspections on NMDOT construction projects. Other New Mexico agencies may have similar requirements.

Retention Facility – A pond or stormwater facility that holds runoff in a reservoir without release except by means of evaporation, infiltration, or emergency bypass.

Semi-Arid Area – Areas with an average annual rainfall of 10 to 20 inches.

Stormwater Pollution Prevention Plan (SWPPP) – A plan consisting of site maps, construction/contractor activities that could cause pollutants in stormwater, and a description of measures or practices to control those pollutants. SWPPP documents are required by both the CGP and the MSGP.

Temporary Erosion and Sediment Control Plan (TESCP) – The formal compilation of required erosion- and sediment-control activities prepared for a specific construction site and project. TESCP is an NMDOT term.

Treatment Train – A stormwater treatment train is the combination of multiple, sequential stormwater best management practices (BMPs) that collectively deliver better overall results compared to use of a single BMP for reducing pollutants reaching the downstream receiving waters.

Urbanized Area (UA) – A U.S. Census Bureau term, a UA is a continuously built-up area with a population of 50,000 or more. It comprises one or more places and the adjacent densely settled surrounding area of other places and nonplace territory.

INTRODUCTION – PURPOSE OF THIS MANUAL

This *Stormwater Management Guidelines for Construction, MS4, and Industrial Activities* is to be used as a guidance document to assist with understanding National Pollutant Discharge System (NPDES) General Permit requirements for stormwater runoff from construction projects, municipal separate storm sewer system (MS4) areas, and industrial activities.

The NPDES Stormwater Permit Program is a federal program developed under Section 402 of the Clean Water Act (CWA). New Mexico currently does not have primacy for its NPDES program; the U.S. Environmental Protection Agency (EPA), Region 6 regulates New Mexico's NPDES programs. Users are encouraged to check the EPA Region 6 website for updated permits and forms. Users with complex sites, issues, or questions should consult with the local or state regulatory agencies or an expert in NPDES requirements.

This NPDES Manual was created to:

- Assist NPDES regulated entities in understanding the importance of stormwater management related to protecting surface water quality;
- Assist NPDES regulated entities in understanding the permitting, notification, compliance, and reporting processes for the General Permit for Discharges from Construction Activities (referred to as the Construction General Permit, or CGP) and the Multi-Sector General Permit (MSGP) for Stormwater Discharges Associated with Industrial Activity;
- Assist Municipal Separate Storm Sewer Systems (MS4s), along with entities working within MS4s, with understanding their programmatic requirements, some of which are associated with the NPDES permitting requirements for the CGP and the MSGP; and
- Provide the basics of planning and design for stormwater management including a focus on incorporating Green Stormwater Infrastructure (GSI) and Low Impact Development (LID) Best Management Practices (BMPs). This Manual is meant to highlight that GSI/LID BMPs are an encouraged approach for projects in New Mexico.
    - These BMP conceptual guidelines are intended to assist NMDOT and other agencies across the state in increasing the resilience of New Mexico's built infrastructure and reducing the negative impact of stormwater runoff on the environment; and Provide the basic information regarding the development of Stormwater Pollution Prevention Plans (SWPPPs), as well as the application of BMPs for construction and industrial facilities.
    - This Manual describes many BMP options in detail within Appendix A. The BMPs in this update offer general methodologies and conceptual layouts in order to provide designers with some leeway in terms of their applicability to specific project sites. The suggested BMPs provided in this Manual should be used as a guide and, along with good engineering judgment and design, will produce a better product for NMDOT, other agencies, and the public.

APPENDIX A – BEST MANAGEMENT PRACTICES (BMPs)

APPENDIX A

Table of Contents

APPENDIX A

Introduction

The Best Management Practices (BMPs) summarized on the following pages are intended to provide NMDOT personnel, consultants, and contractors with a range of options for reducing or eliminating air and water pollution resulting from transportation-related construction activities in New Mexico. From fugitive dust to accidental discharges of fuels or lubricants, construction activities and post-construction uses can be major sources of pollution that, if left untreated, eventually end up in rivers, lakes, or groundwater. Appendix A includes a broad sampling of proven techniques collected from local, regional, and national sources that can be used in various combinations to help meet National Pollutant Discharge Elimination System (NPDES) requirements for developing a Stormwater Pollution Prevention Plan (SWPPP) in the short term, as well as offering longer term solutions to meet MS4 pollution control requirements.

Since the introduction of the NPDES program under the Clean Water Act of 1972, an entire industry has sprung up to try to simplify the process of addressing its requirements. Over time, those mitigation measures have become increasingly standardized, using largely off-the-shelf products. Unfortunately, many of those products - such as silt fence - are not biodegradable, so if they are not removed upon completion of a project (as is often the case) they become eyesores at best, and potential sources of pollution themselves. At the same time, the design of traditional ("gray") drainage infrastructure has perpetuated the approach of collecting and moving stormwater away from roadways and the built environment as quickly as possible. Those conventional collection systems often discharge untreated, pollutant-laden, storm runoff directly into local drainageways and water bodies.

In contrast, the BMPs illustrated here include a variety of green stormwater infrastructure (GSI) solutions that treat stormwater as a resource that can increase environmental sustainability while achieving regulatory compliance. A GSI/Low Impact Development (LID) approach more closely mimics nature by capturing water further up the stormwater chain, slowing and spreading it so that it can be used by plants, filtered and cleaned, and encouraged to infiltrate into the ground before it makes its way into waterways and aquifers. Additional derivative benefits from this approach can include reduced localized flooding; increases in vegetation and tree canopies, which in turn help reduce the heat island effect and provide improved wildlife and migratory bird habitat; and improving the overall visual character of communities.

As presented in this appendix, the BMPs are fairly general in nature, and should be supported by sound engineering judgement. Designers should ensure that proposed BMPs will not conflict with other design features – such as through potential inundation of nearby underground utility boxes or structural subgrades. Nonetheless, while the BMPs include both traditional engineering solutions along with newer GSI/LID techniques, designers are encouraged to consider a GSI/LID approach first, and revert to more traditional practices only as a last resort.

It should also be noted that a different kind of management and maintenance regime will accompany some of these newer BMPs. Just as runoff is captured higher up in the watershed in a more decentralized manner, maintenance will also need to be conducted in a more dispersed manner and on a smaller scale, at those points of capture. Both designers and user agencies should be cognizant of those differing requirements and associated costs, which may include both equipment and training.

APPENDIX A

Best Management Practices (BMPs)

OVERVIEW

Appendix A includes 46 Best Management Practices (BMPs) which are divided into three overall categories:

A1: CONSTRUCTION PLANNING, MANAGEMENT AND CLEAN UP

BMPs included in the Construction Planning, Management and Clean Up category are related to site and natural features protection, management, and good housekeeping. These BMPs typically occur in all construction phases of a project. Several of these BMPs are also applicable to stormwater management for industrial facilities.

A2: EROSION AND SEDIMENT CONTROL

The Erosion and Sediment Control category includes BMPs addressing protection from erosion and sedimentation. These BMPs are typically included during site preparation and construction and can serve as both short and long term protection from erosion. The included BMPs are suitable for both rural and urban conditions.

A3: LOW IMPACT DEVELOPMENT AND POLLUTION CONTROL

The Low Impact Development and Pollution Control category features BMPs ranging from low-scale intervention to elaborate techniques. Several BMPs in this category are considered part of Green Stormwater Infrastructure (GSI) principles. Several listed BMPs are specifically developed to fit urban conditions.

The BMP Matrix (page 4) includes a complete listing of all BMP's in this Manual. The matrix is designed to function as a dashboard - a selection tool that facilitates quick BMP comparisons for application (urban or rural), general cost, maintenance level, and where it is typically applied in the construction process. There are additional Function Overview tables at the beginning of each category A1-A3 that provide information on typical BMP application and targeted constituents designed to address.

Each BMP sheet includes the following information:

» *Description - describes the BMP .*
» *Primary Use - lists where and why to use the BMP.*
» *Application - describes how to use the BMP and what are the main design consideration.*
» *Limitations - list any major limitations.*
» *Maintenance Requirements - outline main steps needed to maintain the BMP.*

The descriptive information is followed by graphics in a plan view, section view, and/or isometric view, where applicable. The shown graphics are schematic in nature and not intended to be construction drawings. Actual installations should be designed by qualified personnel. NMDOT Standard Drawings are referenced where applicable.

EXAMPLES OF COMBINED BMP APPLICATIONS

Following the individual BMP sheets, four examples are provided that show how some of these BMPs can be used effectively in various combinations. The combined applications in this Manual focus on BMP applications within typical roadway projects.

BMP MATRIX

CATEGORY		#	BEST MANAGEMENT PRACTICE	PAGE	APPLICATION	COST *	MAINTENANCE **	CONSTRUCTION PHASE	TESCP *** SYMBOL
					Urban/Rural	\$ \$\$ \$\$\$	⛏ ⛏⛏ ⛏⛏⛏	**1.** *Preconstruction & Planning* **2.** *Mobilization & Site Preparation* **3.** *Construction* **4.** *Site Cleanup & Restoration*	
A1	CONSTRUCTION PLANNING, MANAGEMENT AND CLEANUP	*A1-1*	*Dust Control*	*7*	*U/R*	\$ \$	⛏⛏⛏	1, 2 and 3	DU
		A1-2	*Tree Protection*	*9*	*U/R*	\$	⛏	1, 2 and 3	TPr
		A1-3	*Natural Features Protection and Restoration*	*11*	*U/R*	\$	⛏	1, 2, 3 and 4	NFP
		A1-4	*Grassland Seedbanks Protection*	*13*	*R*	\$	⛏	1, 2, 3 and 4	GSP
		A1-5	*Stockpile Management*	*15*	*U/R*	\$	⛏⛏	1, 2 and 3	SM
		A1-6	*Sanitary Facility Management*	*17*	*U/R*	\$	⛏⛏	1, 2 and 3	SF
		A1-7	*Equipment Maintenance*	*18*	*U/R*	\$ \$	⛏⛏	1, 2, 3 and 4	EM
		A1-8	*Chemical and Materials Storage Protection*	*19*	*U/R*	\$ \$	⛏⛏	1, 2, 3 and 4	CMP
		A1-9	*Spill Prevention Plan*	*21*	*U/R*	\$ \$	⛏⛏	1, 2, 3 and 4	SPP
		A1-10	*Concrete Waste Management*	*23*	*U/R*	\$	⛏⛏	1, 2, 3 and 4	CWM
		A1-11	*Solid Waste Management*	*25*	*U/R*	\$	⛏	1, 2, 3 and 4	SWM
		A1-12	*Hazardous Waste Management*	*27*	*U/R*	\$ \$	⛏⛏	1, 2, 3 and 4	HWM
		A1-13	*Stabilized Construction Entrance/ Exit*	*29*	*U/R*	\$ \$	⛏	1, 2 and 3	SCEE
A2	EROSION AND SEDIMENT CONTROL	*A2-1*	*Seeding*	*33*	*U/R*	\$	⛏	4	SEED
		A2-2	*Mulching*	*35*	*U/R*	\$	⛏	4	Mu
		A2-3	*Surface Roughening*	*37*	*R*	\$	⛏	4	SR
		A2-4	*Land Imprinting*	*39*	*R*	\$ \$	⛏	4	LI
		A2-5	*Keylining*	*41*	*R*	\$	⛏⛏	4	KL
		A2-6	*Drop Inlet Protection*	*43*	*U/R*	\$	⛏⛏	1, 2 and 3	DIP
		A2-7	*Culvert Protection*	*45*	*U/R*	\$	⛏	2, 3 and 4	CP
		A2-8	*Mulch Socks*	*48*	*U/R*	\$	⛏	2, 3 and 4	MS/CMS
		A2-9	*Slope Drain*	*50*	*R*	\$ \$	⛏⛏⛏	2 and 3	SD
		A2-10	*Sediment Trap*	*52*	*R*	\$ \$	⛏⛏	2 and 3	ST
		A2-11	*Sediment Basin*	*56*	*R*	\$ \$	⛏⛏	4	SB
		A2-12	*Pond Outfall Structure*	*59*	*U/R*	\$ \$	⛏⛏	4	POS
A3	LOW IMPACT DEVELOPMENT AND POLLUTION CONTROL	*A3-1*	*Diversion Channel*	*64*	*U/R*	\$ \$	⛏⛏	4	DC
		A3-2	*Contour Swale*	*67*	*R*	\$	⛏	4	CS
		A3-3	*Rock Check Dam*	*70*	*R*	\$	⛏	4	RCD
		A3-4	*Media Luna*	*73*	*R*	\$	⛏	4	ML
		A3-5	*Flow Line Extender*	*76*	*U/R*	\$ \$	⛏	4	FLE
		A3-6	*Buffer / Filter Strip*	*78*	*U/R*	\$	⛏	4	Bu
		A3-7	*Waffle Slope*	*80*	*U/R*	\$ \$	⛏⛏	4	WS
		A3-8	*Live Wattle*	*82*	*R*	\$	⛏⛏	4	LW
		A3-9	*Detention Basin*	*84*	*U/R*	\$ \$	⛏⛏	4	DB
		A3-10	*Bio(Retention) Swale*	*86*	*U/R*	\$ \$	⛏⛏	4	BRS
		A3-11	*Stormwater Harvesting Basin*	*90*	*U/R*	\$ \$	⛏	4	SHB
		A3-12	*Infiltration Trench*	*93*	*U/R*	\$ \$	⛏⛏	4	TR
		A3-13	*Dry Well*	*96*	*U/R*	\$ \$	⛏	4	DW
		A3-14	*Below Grade Storage*	*99*	*U*	\$ \$ \$	⛏⛏⛏	4	BGS
		A3-15	*Permeable/Alternative Pavement*	*101*	*U*	\$ \$	⛏⛏	4	PP
		A3-16	*Green Parking*	*103*	*U*	\$ \$	⛏⛏	4	GP
		A3-17	*Curb Treatment*	*105*	*U*	\$	⛏	4	CT
		A3-18	*Depressed Median*	*110*	*U/R*	\$	⛏	4	DM
		A3-19	*Urban Tree Planting*	*114*	*U*	\$	⛏	4	UTP
		A3-20	*Trash Capture Devices*	*119*	*U*	\$	⛏⛏⛏	4	TCD
		A3-21	*Mechanical Devices / Separators*	*121*	*U/R*	\$ \$ \$	⛏⛏⛏	4	MD

* Dollar symbol (\$) gives a relative cost range to implement BMP. **\$** = low. **\$ \$** = medium. **\$ \$ \$** = high.
** Maintenance symbol (⛏) describes estimated frequency of required maintenance actions. ⛏ = annual maintenance action required. ⛏⛏ = monthly/weekly maintenance action required⛏⛏⛏ = regularly occurring maintenance action required.
*** TESCP = Temporary Erosion and Sediment Control Plan.

APPENDIX A1

Construction Planning, Management and Cleanup

BEST MANAGEMENT PRACTICES

CATEGORY A1 **FUNCTION OVERVIEW**

		Application	Infiltration	Perimeter Control	Slope Protection	Sediment Trapping	Channel Protection	Temporary Stabilization	Permanent Stabilization	Waste Management	Good Housekeeping	Targeted Constituents	Sediments	Nutrients	Toxic Materials	Oil and Grease	Floatable Materials	Construction Wastes
A1-1	Dust Control			✓		✓		✓					✓					
A1-2	Tree Protection				✓			✓	✓									
A1-3	Natural Features Protection and Restoration					✓	✓		✓				✓			✓		
A1-4	Grassland Seedbank Protection				✓	✓			✓				✓					
A1-5	Stockpile Management									✓	✓		✓					✓
A1-6	Sanitary Facility Management									✓	✓							
A1-7	Equipment Maintenance									✓	✓				✓	✓		
A1-8	Chemical and Materials Storage Protection									✓	✓			✓	✓	✓		✓
A1-9	Spill Prevention Plan									✓	✓				✓	✓		
A1-10	Concrete Waste Management									✓	✓							✓
A1-11	Solid Waste Management									✓	✓							✓
A1-12	Hazardous Waste Management									✓	✓				✓			
A1-13	Stabilized Construction Entrance/Exit			✓				✓					✓					

A1-1 DUST CONTROL

Image credit: Sites Southwest

DESCRIPTION

Dust control measures reduce a construction site's potential for producing airborne fugitive dust that can lead to air and water pollution. Sediments that are transported from construction sites by wind and construction vehicles that have left the site, are often re-dispersed to the air by subsequent vehicular traffic and winds. Likewise, these sediments may be transported by the next rainfall to streams and into public storm sewer systems. Implementation of control measures to minimize the generation of fugitive dust from disturbed landscapes and construction sites will also limit the quantity of sediments in stormwater.

PRIMARY USE

Dust control is used to limit and control nuisance fugitive dust from disturbed landscapes and construction sites. Project types and conditions that benefit from execution of a dust control strategy include, but are not limited to, the following:

» *Grading operations (land clearing and earthmoving).*
» *Drilling and blasting.*
» *Batch drop operations (loader operation).*
» *Exposed, cleared, and unstabilized areas.*
» *Vehicle traffic on unpaved surfaces.*
» *Sediment tracking on paved surfaces.*
» *Blasting and wrecking ball operations.*
» *Soil and debris storage piles.*

SEE ALSO

A1-4 *Grassland Seedbank Protection*

A1-5 *Stockpile Management*

A2-1 *Seeding*

A2-2 *Mulching*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

DU

A1-1 DUST CONTROL CONTINUED

APPLICATION

Dust control measures vary widely and should be selected alone or in combination for the specific project type, conditions, and resource availability. Dust control measures include, but are not limited to, the following:

» *Provide covers for trucks transporting materials that contribute dust.*
» *Pave, apply gravel, vegetate or chemically stabilize large disturbed areas.*
» *Immediately water disturbed areas.*
» *Regularly water and dampen unstabilized areas.*

Additionally, if the contractor is responsible for complying with the requirements of the air pollution control permit, the following is typically required:

» *Provide dust control plans for construction or land-clearing projects.*
» *Conduct enforcement activities with priority given to citizen complaints.*
» *Conduct documentation of maintenance.*

LIMITATIONS

Some dust control measures may be of limited use due to lack of resources at the site, construction sequencing, and the need to repeatedly re-implement measures during the course of construction. Limitations may include:

» *Access to water.*
» *Availability of equipment.*
» *Drought.*
» *Frequent disturbance during construction.*

MAINTENANCE REQUIREMENTS

» *Inspect stabilized soils for disturbance on a regular basis.*
» *Wet soil and soils treated with stabilization agents.*
» *Regrade and reapply soil stabilizing agents.*

A1-2 TREE PROTECTION

Image credit: Sites Southwest

DESCRIPTION

Tree protection measures preserve existing trees that provide valuable ecosystem services, including stormwater pollution protection. Trees stabilize the soil and help prevent erosion, decrease stormwater runoff, moderate temperatures, provide buffers and screens, filter pollutants from the air, supply oxygen, provide wildlife habitat, provide visual relief, beauty and scale along highway corridors and in urban areas, and increase property values.

PRIMARY USE

Tree protection measures are taken where existing trees and plants are legally protected, or considered to have significant value to the community, the environment, or the project. Tree and plant protection efforts begin during project planning and continue through design and construction.

APPLICATION

Specific tasks for the application of tree protection during planning and design include:

» *Analyze existing conditions and regulations.*
» *Establish protected areas.*
» *Review plans during design to ensure that protected trees and plants are not negatively impacted by grading, drainage, and the addition of physical site improvements.*
» *Mark trees to be protected at a height visible to equipment operators. Marking on trees shall not be permanent or damaging to trees.*
» *Protect trees and roots with fencing. Best practice for tree protection is to erect a fence 6'-0" outside of the tree drip line. Fences may be placed at the tree drip line if site and construction constraints are severe.*

SEE ALSO

A1-3 *Natural Features Protection and Restoration*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

TPr

A1-2 TREE PROTECTION CONTINUED

APPLICATION *CONTINUED*

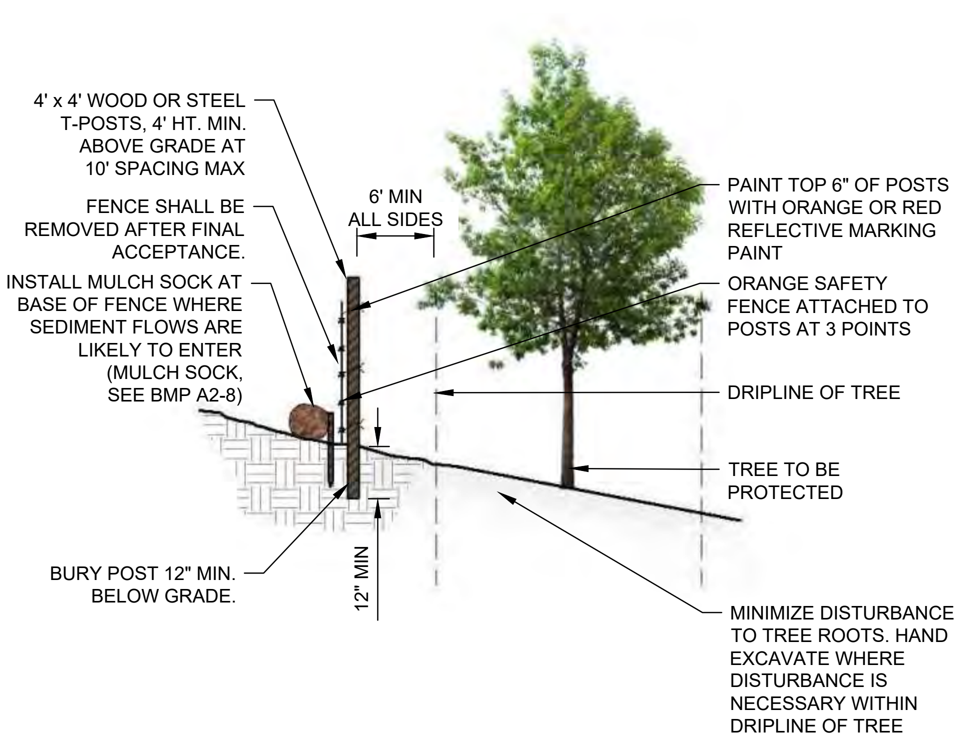
- *Locate limits of grading and clearing outside the tree drip line.*
- *Trench as far away from trees as possible. Consider tunneling or hand-trenching as an option.*
- *Restore/repair impacted trees with appropriate measures as identified by a forester, certified arborist or a tree specialist.*

LIMITATIONS

- *Project site area limitations for the design program and required construction area.*
- *Topography and challenges preserving grade in protection areas.*
- *Drainage requirements impacting protection areas.*
- *Compaction required adjacent to protection areas.*

MAINTENANCE REQUIREMENTS

- *Prune and fertilize as needed.*
- *Inspect for pests and apply pesticides, if necessary.*
- *Remove leaves and seeds seasonally.*
- *Remove weeds in tree protection areas.*
- *Water trees in tree protection areas.*
- *Remove litter and sediment.*



Typical tree protection detail - SECTION VIEW.

A1-3 NATURAL FEATURES PROTECTION AND RESTORATION

Image credit: Sites Southwest

DESCRIPTION

Natural feature protection measures preserve existing environments that provide valuable ecosystem services, including stormwater pollution protection. Wetlands, grasslands and shrub cover stabilize the soil and help prevent erosion, decrease stormwater runoff, moderate temperatures, provide buffers and screens, filter pollutants from the air, supply oxygen, provide wildlife habitat, provide visual relief, beauty and scale along highway corridors and in urban areas, and increase property values.

PRIMARY USE

Protecting and restoring natural features controls wind and rain erosion, and filters water borne sediment, thereby reducing stormwater effects on local stormwater systems and drainage ways.

APPLICATION

Natural feature protection and restoration strategies are applied during planning and design. There are several necessary steps:

» *Identify resources that will be disturbed due to construction or development activity.*
» *Identify resources to be protected.*
» *Develop measures to ensure protected resources maintain existing conditions and functions.*
» *Restore damaged natural features to their original condition and function.*

SEE ALSO

A1-2 *Tree Protection*
A1-4 *Grassland Seedbank Protection*

NMDOT TESCP (TEMPORARY EROSION AND SEDIMENT CONTROL PLAN) SYMBOL

NFP

A1-3 NATURAL FEATURES PROTECTION AND RESTORATION CONTINUED

APPLICATION *CONTINUED*

There are several planning and design strategies to consider:

» *Cluster development.*
» *Use new urbanist design principles such as reducing road widths or providing alleys and alternative transportation networks.*
» *Set aside dedicated open space.*

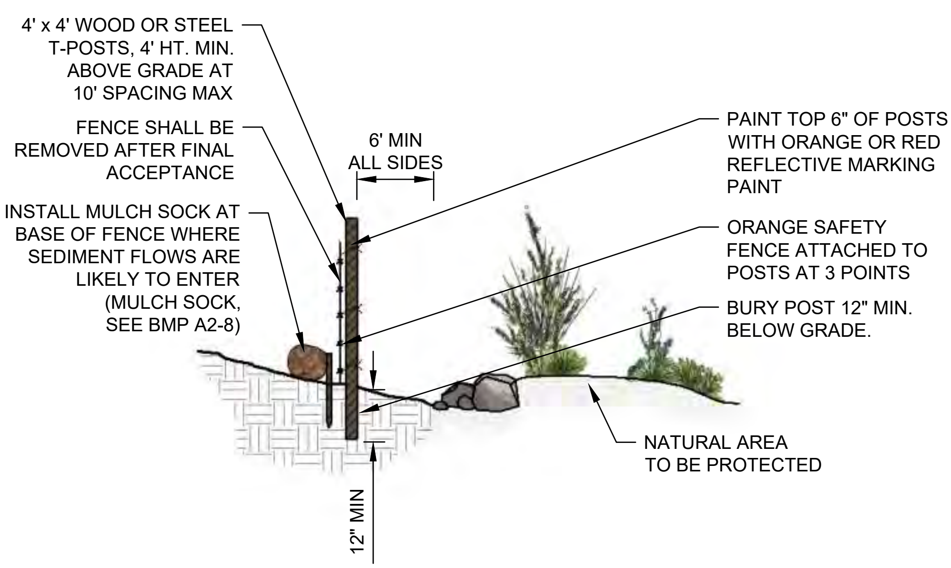
LIMITATIONS

General limitations to natural feature protection and restoration can be related to both real and perceived costs and benefits - where the costs of protection outweigh the benefits. Specific limitations may include:

» *Local zoning codes might restrict the use of clustering, and other techniques for natural area preservation. Developers should work with local regulatory agencies to determine whether they can obtain waivers to protect natural features.*
» *Restoration of degraded natural features requires specialized design and construction skills, and can be costly and time consuming.*

MAINTENANCE REQUIREMENTS

» *Maintain identified areas in a natural state in perpetuity.*



Typical protection detail - SECTION VIEW.

A1-4 GRASSLAND SEEDBANK PROTECTION

Image credit: Sites Southwest

DESCRIPTION

Protection of grassland seedbanks is the identification and preservation of undisturbed mature grasslands and their associated seeds, seed-rich soils, and root systems that build soil, sequester carbon, and preserve soil moisture. Once damaged, grassland seedbanks are difficult and costly to return to their natural condition.

PRIMARY USE

Grassland seedbanks exist wherever there is significant grassland vegetation or places where grasslands were once present but have been diminished due to conditions such as surface disturbance, compaction, drought and overgrazing. Grassland seedbanks can exist in close proximity to roadways such as in medians, gore areas and along roadsides, as well as in open spaces and lands adjacent to roadways that may have been impacted by wind erosion and grazing. Protecting grasslands and their seed-rich soils maximizes the ability for a disturbed site to recover. The faster the recovery of a disturbed site the quicker grasslands can:

» *Decrease erosion.*
» *Stabilize soil.*
» *Sequester carbon.*
» *Maximize dust control measures.*

APPLICATION

Strategies for grassland seedbank protection include:

» *Stockpile existing topsoil in mounds not exceeding 6 feet in height for reapplication after construction.*

SEE ALSO

A1-1 *Dust Control*

A1-3 *Natural Features Protection and Restoration*

NMDOT STANDARD SPECIFICATION

603 Temporary Erosion and Sediment Control

NMDOT TESCP (TEMPORARY EROSION AND SEDIMENT CONTROL PLAN) SYMBOL

GSP

A1-4 GRASSLAND SEEDBANK PROTECTION CONTINUED

APPLICATION *CONTINUED*

- *Cover stockpiled soil with filter fabric .*
- *Limit heavy machinery on sub soils during construction.*
- *Reapply stockpiled topsoil after tilling/roughening subsoil.*
- *Conduct reseeding operations as determined by construction work.*

LIMITATIONS

- *Project site area may be limited to accommodate the design program, required construction area, and protection areas.*
- *Stockpiling soils with existing seedbanks may be limited by laydown yard and construction staging area constraints.*

MAINTENANCE REQUIREMENTS

- *Water and moisten stockpile of seedbank topsoil.*
- *Mow native grass stands that were protected during construction in the fall and let stubble, seeds and stems remain.*
- *Weed site for a recommended maintenance period of one year.*
- *Follow Stormwater Pollution Prevention Plan (SWPPP) requirements where applicable.*

A1-5 STOCKPILE MANAGEMENT

Image credit: State of Hawaii Department of Transportation, Highways Division, Oahu District - www.stormwaterhawaii.com

DESCRIPTION

Stockpile management methods and practices reduce erosion and stormwater pollution from stockpiled materials.

PRIMARY USE

Stockpile management occurs on sites where material stocks such as concrete, soil, asphalt, chemicals, petroleum products, and bulk delivered materials such as soil amendments are temporarily located prior to use or removal from the site. Stockpile management is a best management practice for stormwater protection for new construction, renovations and existing properties including industrial facilities.

Stockpile management strategies occur in the following areas:

» *Construction sites with laydown yards, delivery spaces and heavy machinery parking.*
» *Construction sites with earth-moving operations.*
» *Maintenance yards or industrial facilities with stockpiled soil, concrete, aggregate, chemicals, and asphalt materials.*

APPLICATION

Strategies for stockpile management include:

» *Place materials on pallets and cover materials.*
» *Label and remove contaminated soil stockpiles.*
» *Protect soil stockpiles with temporary soil stabilization measures.*
» *Cover and protect cold mix materials or treated wood with an erosion control barrier.*

SEE ALSO

A1-1 *Dust Control*

A2-8 *Mulch Socks*

NMDOT STANDARD SPECIFICATION

603 Temporary Erosion and Sediment Control

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

SM

A1-5 STOCKPILE MANAGEMENT CONTINUED

APPLICATION *CONTINUED*

» *Fence stockpile areas to limit wind-blown debris and applying perimeter erosion barriers.*
» *Limit temporarily stockpiled materials such as topsoil, compost and wood mulch to use within 48 hours after delivery.*
» *Cover, secure and protect long-term stockpiled materials (longer than 48 hours) from wind and water erosion.*
» *Install temporary erosion control measures such as mulch socks or staked hay bales around stockpiles.*

LIMITATIONS

» *Site constraints may complicate strict adherence to measures.*
» *Stockpile protection measures such as plastic tarps can increase runoff volumes.*
» *Stockpiles shall not be located in areas of concentrated stormwater flows and shall be a minimum of 50 feet away from all drainage inlets.*

MAINTENANCE REQUIREMENTS

» *Inspect erosion control measures surrounding the stockpile areas according to the Stormwater Pollution Prevention Plan (SWPPP).*
» *Inspect stockpile areas and protection measures weekly and after storm events.*

A1-6 SANITARY FACILITY MANAGEMENT

Image credit: iStock/ Merrimon

DESCRIPTION

Portable sanitary facilities store sanitary waste to eliminate onsite disposal and minimize nuisances. Sanitary waste can harm public health and safety and adversely affect the environment. Nuisance complaints regarding poor sanitary facility management can adversely affect the project schedule, project cost, and public perception of NMDOT and private contractors.

PRIMARY USE

Sanitary facilities prevent onsite disposal of sanitary wastes, and minimize illicit discharges and nuisance odors.

APPLICATION

Sanitary facilities are required for all work sites or construction areas.

LIMITATIONS

» *Sanitary facilities shall be located a minimum of 50 feet away from receiving waters and drop inlets.*

MAINTENANCE REQUIREMENTS

» *Schedule regular waste removal.*
» *Maintain facilities in good working order.*
» *Restock supplies regularly.*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

SF

A1-7 EQUIPMENT MAINTENANCE

Image credit: iStock/Paul Vasarhelyi

DESCRIPTION

Establishing an equipment maintenance program of procedures reduces contamination of onsite soils, and discharge into local stormwater and drainage systems.

PRIMARY USE

Non-sediment storm water pollution can occur on large construction sites or industrial facilities where heavy equipment, truck storage, and maintenance yards are located, and in locations with on-site refueling operations. Improper maintenance and disposal of equipment fluids, parts and tires can adversely affect the environment and public health. Proper execution of procedures including equipment handling and maintenance can prevent this pollution.

APPLICATION

Strategies for equipment maintenance include:

» *Create an equipment maintenance program that includes designated locations for maintenance activities.*
» *Train personnel to properly operate and maintain equipment.*
» *Train refueling contractors in the correct equipment operation to limit spills.*

LIMITATIONS

» *Remote locations may complicate equipment operations, repair and maintenance, and prolong construction schedules.*

MAINTENANCE REQUIREMENTS

» *Store new and used fluids, tires, and equipment parts properly.*
» *Dispose of fluids, tires, and equipment parts properly.*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

EM

A1-8 CHEMICAL AND MATERIALS STORAGE PROTECTION

Image credit: iStock/ Vladimir Liverts

DESCRIPTION

Chemical and toxic materials protection is the prevention and minimization of hazardous materials affecting the environment. Chemicals and toxic materials can be hazardous to public health and safety and adversely affect the environment.

PRIMARY USE

Wind and rain can move and wash pollutants from improperly stored chemical materials into local drainage systems or waterways. Construction sites or industrial facilities that store chemical or toxic materials for any length of time shall properly cover and store chemicals, materials, and waste containers so that they are protected from rainwater and have appropriate leak containment.

APPLICATION

Strategies for chemical and materials storage protection includes:

» *Seal and label all containers.*
» *Protect storage areas with a solid roof structure or storage container.*
» *Protect outdoor stored materials with a concrete pad, palettes, aggregate base or tarp.*
» *Place a berm or create an impervious basin around storage area.*

SEE ALSO

A1-9 *Spill Prevention Plan*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

CMP

A1-8 CHEMICAL AND MATERIALS STORAGE PROTECTION CONTINUED

APPLICATION *CONTINUED*

Specific strategies for salt storage need to be applied to prevent the migration of salt into groundwater. Strategies include, but are not limited to:

- *Pave the area directly outside the salt storage building.*
- *Regularly sweep up salt outside salt storage.*
- *Install perimeter controls outside salt storage areas.*

LIMITATIONS

- *Chemical and materials storage areas shall not be located within the drip line of trees, in protected grasslands or natural areas to be preserved.*
- *Chemical and materials storage areas shall be located a minimum of 50 feet away from low-lying areas, drainage ways, receiving waters, and drop inlets.*

MAINTENANCE REQUIREMENTS

- *Inspect storage protection areas weekly and after storm events.*
- *Keep record of stored potential contaminants.*
- *Remove concrete pad, solid covering and protective measures at construction closure.*

A1-9 SPILL PREVENTION PLAN

Image credit: iStock/Shelly Still

DESCRIPTION

A spill prevention plan is an emergency plan to contain spills of dangerous, hazardous, or toxic wastes in order to mitigate environmental damage, safeguard the public and provide prompt notice to proper authorities. Hazardous chemicals include but are not limited to fertilizers, paints, oils, grease, pesticides, fuels, and construction or industrial facility chemicals.

PRIMARY USE

Spill prevention plans are applicable to all construction sites and specified in the Stormwater Pollution Prevention Plan (SWPPP). Sites closest to watercourses, canals, and reservoirs are at highest risk of contaminating surface waters with an uncontained spill.

APPLICATION

The spill prevention plan is created prior to construction and includes measures to limit the scope of spills and minimize the impact on the environment and public health. Typical spill prevention plan strategies include:

» *Designate a Pollution Prevention and Spill Response Coordinator (refer to Section I.B.2.h of the Manual).*
» *Select a designated area for storage.*
» *Seal and label all containers.*
» *Surround storage areas by a berm with an impermeable liner. Construct berms to provide a storage volume of no less than 1.5 times the total volume of the stored material.*
» *Establish cleanup procedures and have cleanup materials readily available.*

NMDOT STANDARD SPECIFICATION

603 Temporary Erosion and Sediment Control

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

SPP

A1-9 SPILL PREVENTION PLAN CONTINUED

APPLICATION *CONTINUED*

- *Post cleanup procedures near where dangerous, hazardous or toxic materials are stored or used.*
- *Dispose of contaminated material in accordance with state or local requirements.*

Other strategies for specific situations include:

- *Small or incidental spills (<5 gallons): contain and clean the spill using facility personnel if they are able to do so without risking safety and injury.*
- *Large or reportable spills (> 5 gallons): clean the spill using emergency responders and/or clean up contractors. For releases of hazardous substances, the federal government has established Superfund Reportable Quantities (RQs).*
- *Releases of Hazardous Substances: if a hazardous substance is released to the environment in an amount that equals or exceeds its RQs, the release must be reported to federal authorities, unless certain reporting exemptions for hazardous substances releases also apply. Information on RQs can be found on the EPA website (https://www.epa.gov/epcra/cercla-and-epcra-continuous-release-reporting). In the event of a spill of a hazardous substance, notify the National Response Center (NRC) at (800) 424-8802, the New Mexico Environment Department (NMED) at (505) 827-9329, and the local fire department.*

LIMITATIONS

- *No major limitations.*

MAINTENANCE REQUIREMENTS

- *Inspect hazardous material storage areas frequently and after storm events.*
- *Maintain storage areas in a clean and orderly fashion.*
- *Maintain records of stored hazardous materials.*

A1-10 CONCRETE WASTE MANAGEMENT

Image credit: SoCal Sandbags

DESCRIPTION

Concrete waste management reduces or prevents the discharge of pollutants to stormwater by implementing management measures.

PRIMARY USE

Concrete waste products can negatively affect the pH of water, harm aquatic life, and contribute to total suspended solids in stormwater. Concrete waste management strategies keep the discharge of concrete waste materials from affecting local stormwater and drainage systems during concrete construction operations.

Concrete construction operations that have the potential for contaminating receiving waters include, but are not limited to:

- *Pouring and finishing concrete slabs on grade and concrete paving.*
- *Pouring vertical cast in place concrete (header curbs, concrete curbs and gutters, retaining walls, concrete footings).*
- *Drilling, cutting, polishing, and curing concrete.*
- *Washing concrete dust, and exposed aggregate concrete.*
- *Spilling concrete.*
- *Dampening freshly made concrete.*
- *Creating and applying concrete slurry coat.*
- *Building masonry structures.*
- *Finishing surfaces with stucco.*
- *Washing equipment.*

SEE ALSO

A1-9 *Spill Prevention Plan*

A1-11 *Solid Waste Management*

A1-12 *Hazardous Waste Management*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

CWM

A1-10 CONCRETE WASTE MANAGEMENT CONTINUED

APPLICATION

Concrete waste management strategies include:

» *Avoid mixing excess amounts of fresh concrete or cement onsite.*
» *Perform washout of concrete trucks offsite or in designated areas on site at least 50 feet from storm drains, open ditches or bodies of water.*
» *Block drop inlets and direct concrete wastewater into temporary pits where the concrete can set, be broken up, and then disposed of properly.*
» *Collect and return sweepings to aggregate base stockpile or dispose of properly.*
» *Train employees and subcontractors in proper concrete waste management.*

LIMITATIONS

» *Offsite washout of concrete wastes may not always be possible.*

MAINTENANCE REQUIREMENTS

» *Ensure subcontractors properly manage concrete wastes.*
» *Dispose of hardened concrete on a regular basis.*
» *Regularly inspect drop inlet protection measures.*

A1-11 SOLID WASTE MANAGEMENT

Image credit: Public Domain

DESCRIPTION

Solid waste management prevents or reduces the discharge of pollutants into stormwater and drainage systems from solid and/or construction wastes. Solid waste can harm public safety, adversely affect the environment, and harm the public perception of NMDOT and private contractors.

PRIMARY USE

Solid waste management is applicable to construction sites and industrial facilities with any of the following construction debris:

- *Solid waste generated from trees and shrubs removed during land clearing, demolition of existing structures (rubble), and building construction.*
- *Packaging materials including wood, paper, and plastic.*
- *Scrap or surplus building materials including scrap metals, rubber, plastic, glass pieces, and masonry products .*
- *Domestic wastes including food containers such as beverage cans, coffee cups, paper bags, plastic wrappers, and cigarettes.*

APPLICATION

The following strategies help keep a clean site and reduce stormwater pollution:

- *Identify designated waste collection areas onsite.*
- *Inform trash-hauling contractors that you will accept only watertight dumpsters for onsite use.*
- *Locate containers in a covered area and/or in a secondary containment.*
- *Provide an adequate number of containers with lids to keep rain out and to prevent loss of waste during windy conditions.*

SEE ALSO

A1-9 *Spill Prevention Plan*

A1-10 *Concrete Waste Management*

A1-12 *Hazardous Waste Management*

NMDOT TESCP (TEMPORARY EROSION AND SEDIMENT CONTROL PLAN) SYMBOL

SWM

A1-11 SOLID WASTE MANAGEMENT CONTINUED

APPLICATION *CONTINUED*

- *Plan for additional containers and more frequent pickup during the demolition phase of construction.*
- *Regularly and promptly remove solid waste from erosion and sediment control devices.*
- *Salvage or recycle useful material.*
- *Clean dumpsters offsite.*
- *Collect waste regularly and clean up spills immediately.*
- *Train employees and subcontractors in proper solid waste management.*

LIMITATIONS

- *No major limitations.*

MAINTENANCE REQUIREMENTS

- *Collect site trash daily.*
- *Inspect waste area regularly.*
- *Arrange for regular waste collection.*
- *Inspect dumpsters for leaks and repair or replace dumpsters that are not watertight.*

A1-12 HAZARDOUS WASTE MANAGEMENT

Image credit: Pexels/Waldemar Brandt

DESCRIPTION
Hazardous waste management prevents or reduces the discharge of pollutants to stormwater from hazardous waste through proper material use, waste disposal, and training of employees and subcontractors.

PRIMARY USE
Hazardous waste planning and management is applicable to all construction sites, maintenance sites, and industrial facilities where hazardous materials are present.

APPLICATION
Chemicals can become hazardous materials that become hazardous waste upon disposal. These wastes may include:

» *Paints and solvents.*
» *Petroleum products such as oils, fuels, and grease.*
» *Herbicides and pesticides.*
» *Acids for cleaning masonry.*
» *Concrete-curing compounds.*

In addition, sites with existing structures may contain hazardous materials that become hazardous waste during demolition. These wastes must be disposed of in accordance with federal, state, and local regulations. These wastes include:

» *Sandblasting grit mixed with lead-, cadmium-, or chromium-based paints.*
» *Asbestos.*
» *Polychlorinated biphenyls (PCBs), particularly in older transformers.*

SEE ALSO

A1-9 *Spill Prevention Plan*

A1-10 *Concrete Waste Management*

A1-11 *Solid Waste Management*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

HWM

A1-12 HAZARDOUS WASTE MANAGEMENT CONTINUED

APPLICATION *CONTINUED*

The following strategies will help reduce stormwater pollution from hazardous wastes:

Material Use

- *Use all of the product before disposing of the container.*
- *Do not remove the original product label containing important safety and disposal information.*
- *Apply herbicides and pesticides correctly in the amounts recommended by the manufacturer and only apply the materials in the recommended temperature, wind, and humidity climate conditions.*
- *Clean brushes and containers in a clean out area.*
- *Rinse water-based paints to the sanitary sewer.*
- *Dispose of excess oil-based paints and sludge as hazardous waste and filter and reuse thinners and solvents.*

Waste Recycling/Disposal

- *Identify designated hazardous waste collection areas onsite.*
- *Store hazardous materials and waste in covered containers protected from vandalism or in a secondary containment.*
- *Dispose of waste separately - mixed waste can cause chemical reactions, make recycling impossible, and complicate disposal.*
- *Recycle any useful material such as used oil or water-based paint.*
- *Make sure that toxic liquid wastes (used oils, solvents, paints) and chemicals (acids, pesticides, additives, curing compounds) are not disposed of in dumpsters designated for construction debris.*
- *Arrange for regular waste collection before containers overflow.*
- *Collect, remove and dispose of hazardous waste (e.g. excess oil-based paint and sludges) at authorized disposal areas.*

LIMITATIONS

- *A licensed hazardous waste hauler must dispose of hazardous waste that cannot be reused or recycled.*

MAINTENANCE REQUIREMENTS

- *Inspect the hazardous waste area and receptacles regularly.*
- *Collect hazardous waste regularly.*
- *Train personnel about proper hazardous material use, storage, and disposal.*
- *Keep record of stored potential contaminants.*

A1-13 STABILIZED CONSTRUCTION ENTRANCE/EXIT

A1
A2
A3

Image credit: Sites Southwest

DESCRIPTION

A stabilized construction entrance/exit consists of a pad of crushed stone, recycled concrete, or other rock-like material on top of a geotextile filter, which is used to facilitate the wash-down and removal of sediment and other debris from construction equipment prior to exiting the site.

PRIMARY USE

Stabilized construction entrances/exits are used to reduce offsite sediment tracking from trucks and construction equipment, and for sites where considerable truck traffic occurs each day. They also reduce the need to clean adjacent pavement as often, and help route site traffic through a single point. Stabilized construction entrances and exits are recommended for all construction sites, and may be required for Construction General Permit compliance.

APPLICATION

Strategies for successful and effective stabilized construction entrances/exits include but are not limited to:

» *Location selection able to accommodate construction traffic.*
» *Appropriate selection of locally available material.*

LIMITATIONS

» *Selection of the construction entrance/exit location is critical. To be effective, it must be used exclusively.*
» *Stabilized access points can be expensive and must be installed in combination with one or more other sediment control techniques. It may be more cost effective, however, than labor-intensive street cleaning.*

NMDOT STANDARD DRAWING

603-01-7/7 Offsite Tracking Prevention

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

SCEE

A1-13 STABILIZED CONSTRUCTION ENTRANCE/EXIT CONTINUED

LIMITATIONS *CONTINUED*

- *Site constraints may limit the recommended 50 feet entrance/exit drive length.*

MAINTENANCE REQUIREMENTS

- *Inspect the stabilized construction entrance after major storm events to ascertain sediment and pollution are being effectively captured on site. When sediment or debris has substantially clogged the void area between the rocks, the aggregate mat must be washed down or replaced.*
- *Re-grade and top dress stone periodically to retain the effectiveness of the entrance/exit.*

APPENDIX A2

Erosion and Sediment Control

BEST MANAGEMENT PRACTICES

GENERAL NOTE

Silt fence is not included as a BMP in this Manual because NMDOT does not allow silt fence in their Final Stabilization Temporary Erosion and Sediment Control Plan (TESCP). For NMDOT projects, the contractor could choose to use silt fence for Construction Phase TESCP. If silt fence is used, then the contractor is responsible for proper installation and maintenance, and removal before the end of the NMDOT project. Use of silt fence may be allowed by other agencies in New Mexico and proper usage, installation, and maintenance can be found in other references, such as the City of Albuquerque Construction Site Manual or EPA's Stormwater BMP Silt Fences Fact Sheet.

CATEGORY A2 **FUNCTION OVERVIEW**

		Application	Infiltration	Perimeter Control	Slope Protection	Sediment Trapping	Channel Protection	Temporary Stabilization	Permanent Stabilization	Waste Management	Good Housekeeping	**Targeted Constituents**	Sediments	Nutrients	Toxic Materials	Oil and Grease	Floatable Materials	Construction Wastes
A2-1	Seeding				✓	✓	✓	✓	✓				✓					
A2-2	Mulching				✓	✓		✓					✓	✓				
A2-3	Surface Roughening				✓	✓		✓					✓					
A2-4	Land Imprinting		✓			✓		✓	✓				✓					
A2-5	Keylining				✓	✓			✓				✓					
A2-6	Drop Inlet Protection					✓							✓				✓	
A2-7	Culvert Protection						✓	✓					✓					
A2-8	Mulch Socks				✓	✓	✓	✓					✓					
A2-9	Slope Drain				✓								✓				✓	
A2-10	Sediment Trap					✓							✓					
A2-11	Sediment Basin		✓			✓		✓	✓				✓				✓	
A2-12	Pond Outfall Structure					✓	✓	✓	✓				✓	✓			✓	

A2-1 SEEDING

Image credit: iStock/FCerez

DESCRIPTION

Temporary and permanent seeding operations are used to establish vegetative cover on disturbed areas. Vegetation effectively reduces erosion on stockpiles, berms, mild to medium slopes, and in swales and along roadways. Even the use of narrow vegetative strips can help control sedimentation when used as a perimeter control for utility and site development construction.

Temporary seeding operations use locally appropriate, rapidly growing annual vegetation, annual grasses, small grains, and/or legumes. Short-term vegetation reduces erosion and subsequent sedimentation of disturbed areas that will not be permanently stabilized within an acceptable period of time. Temporary seeding also reduces mud and dust from construction activities on bare, unprotected soil surfaces.

Permanent seeding operations use locally appropriate perennial grasses, forbs, and shrubs to permanently stabilize sites to reduce erosion and sedimentation on disturbed areas.

PRIMARY USE

Temporary seeding is used on disturbed areas that will not be permanently stabilized or that will not have work performed upon them for a period of 21 days or more. These sites include denuded areas, soil stockpiles, dikes, berms, temporary embankments, excavation areas, slopes, and other disturbed and exposed areas that need temporary stabilization. NMDOT typically does not utilize temporary seeding.

Permanent seeding is used to stabilize disturbed areas and the grasses and other vegetation that establish protect the soil and provide some sediment filtration for overland runoff. Subjected to acceptable

SEE ALSO

A2-2 *Mulching*

A2-4 *Land Imprinting*

NMDOT STANDARD SPECIFICATION

632 Revegetation

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

SEED

A2-1 SEEDING CONTINUED

PRIMARY USE *CONTINUED*

runoff velocities, seeding is an effective method of permanent stormwater management that can also serve as habitat and a visual amenity.

APPLICATION

Permanent vegetation techniques can and should apply to every construction project, with few exceptions. Seeding operations should be planned for when conditions are most favorable for germination and growth and on areas that are impacted by construction or maintenance disturbance. Strategies for successful seeding installations include the following:

Surface Preparation

- *Complete interim or final grading prior to seeding, minimizing steep slopes.*
- *Install necessary erosion structures such as dikes, swales, diversions, etc. prior to seeding.*
- *Groove or furrow slopes steeper than 3:1 on the contour line before seeding.*
- *Provide 4-6 inches of topsoil over rock, gravel, or otherwise unsuitable soils.*
- *Ensure seedbed is well pulverized, loose, and uniform.*

Seed Selection, Fertilization and Irrigation

- *Use only high quality, U.S. Department of Agriculture (USDA)-certified seed.*
- *Use an appropriate species or species mix adapted to local climate, soil conditions, and season. Consult with the local Natural Resources Conservation Service (NRCS) office or local County Extension Service as necessary for selection of proper species and application techniques.*
- *Follow NRCS or Extension Service recommendations on seeding rates.*
- *Apply fertilizer according to the manufacturer's recommendation with proper spreading equipment. Typical application rate for 10-10-10 grade fertilizer is 700-1000 lb/acre. Do not overapply fertilizer.*
- *Do not mix seed and fertilizer more than 30 minutes before application, if using hydroseeding.*
- *Evenly apply seed using cyclone seeder, seed drill, cultipacker or hydroseeder.*
- *Provide adequate water to aid in establishment of vegetation. Consider establishing a temporary irrigation system if possible as it contributes to more successful germination.*
- *Use appropriate mulching techniques where necessary.*

LIMITATIONS

- *Temporary seeding may not be an effective practice in arid and semi-arid regions where the climate prevents fast plant establishment. In those areas, or when seasonal planting restrictions prohibit seeding, temporary mulching may be a better short-term solution.*

MAINTENANCE REQUIREMENTS

- *Inspect seeded areas for germination.*
- *Reseed areas not germinating with additional seed as soon as possible.*
- *Mow permanently seeded areas once a year leaving seeds and straw for soil protection.*

A2-2 MULCHING

Image credit: Sites Southwest

DESCRIPTION

Mulching is an erosion control technique where a variety of organic or inorganic materials, soil stabilizers, netting, or mats are applied alone or in combination over exposed soil. Organic mulches consist of hay, straw, hydro-mulch (wood or paper-based), wood chips, and engineered wood fiber. Inorganic mulch consists of crushed stone aggregates.

PRIMARY USE

Although not utilized in NMDOT projects as a stand alone erosion control measure, mulching is used to prevent erosion by installing or applying a temporary or permanent material over soil to absorb the force of rain droplets, slow surface velocity, trap sediment, and protect surface areas around structures. Mulching is used in areas where permanent runoff velocity control and sediment trapping will be required. When used in combination with seeding operations, mulching is an effective technique for permanently stabilizing disturbed soils.

APPLICATION

Strategies for successful mulching include:

Mulching Operations for Organic Mulches

» *Select hay from native grasses free of noxious weed seeds (certified weed-free hay or straw may be required in designated areas of the state).*
» *Select straw consisting of clean cereal shafts.*
» *Spread hay and straw mulch at a rate of 1.5 to 2 tons per acre.*
» *Install mulch that is 10 inches or more in length, for a minimum of 65% of mulch by weight.*

SEE ALSO

A2-1 *Seeding*

NMDOT STANDARD SPECIFICATION

632 Revegetation

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

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A2-2 MULCHING CONTINUED

APPLICATION *CONTINUED*

- *Apply organic mulches to depth required by drawings and specifications. The mulch should be uniformly applied so that no more than 10% of the soil surface is exposed.*
- *Anchor hay and straw mulch to the soil surface using tackifiers, blankets, or nets, or with a mulch-crimping machine. Mechanical anchoring, or crimping, is preferred and recommended for slopes flatter than 2:1. Blankets or nets on slopes steeper than 2:1 should be anchored to the soil.*
- *Use tackifiers (for anchoring) that consist of a free-flowing non-corrosive powder. This material shall not contain any mineral filler, recycled cellulose fiber, clays, or other substances that may inhibit germination or growth of plants.*
- *Apply tackifiers (for anchoring) in a slurry with water and wood fiber (100 lbs of powder and 150 lbs of fiber per 700 gallons of water). Application rate of powder should be between 80 and 200 lbs per acre.*

Mulching Operations for Inorganic Mulches

- *Apply inorganic mulches to depth required by drawings and specifications.*

LIMITATIONS

- *Use of organic mulches is not recommended in low-lying areas or areas with stormwater flows.*
- *Organic mulches can increase the germination of weeds and maintenance.*

MAINTENANCE REQUIREMENTS

- *Replenish mulch in eroded areas.*

A2-3 SURFACE ROUGHENING

Image credit: 4AG

A1
A2
A3

DESCRIPTION

Surface roughening provides a rough soil surface with a series of horizontal ridges and depressions, running perpendicular to the slope, creating micro-environments for seeding and water infiltration. Slopes can be roughened by furrows or by stair cutting. Furrows are small depressions on slopes usually formed with by tilling operations. Stair cutting is a more aggressive steep slope roughening treatment that cuts steps into soil.

PRIMARY USE

Surface roughening is used to slow surface flow, increase material deposition, and trap water which encourages plant growth. Surface roughening is used on steep slopes prior to or in conjunction with seeding or mulching; and on slopes where seeding and mulching cannot be accomplished due to seasonal conditions or lack of water.

APPLICATION

Strategies for successful surface roughening include:

» *Operate the machinery to leave horizontal depressions in the soil.*
» *Make as few passes as possible to minimize compaction.*
» *Seed and mulch roughened areas the same day.*

LIMITATIONS

» *No major limitations.*

SEE ALSO

A2-4 *Land Imprinting*

NMDOT STANDARD DRAWING

603-01-6/7 Surface Roughening

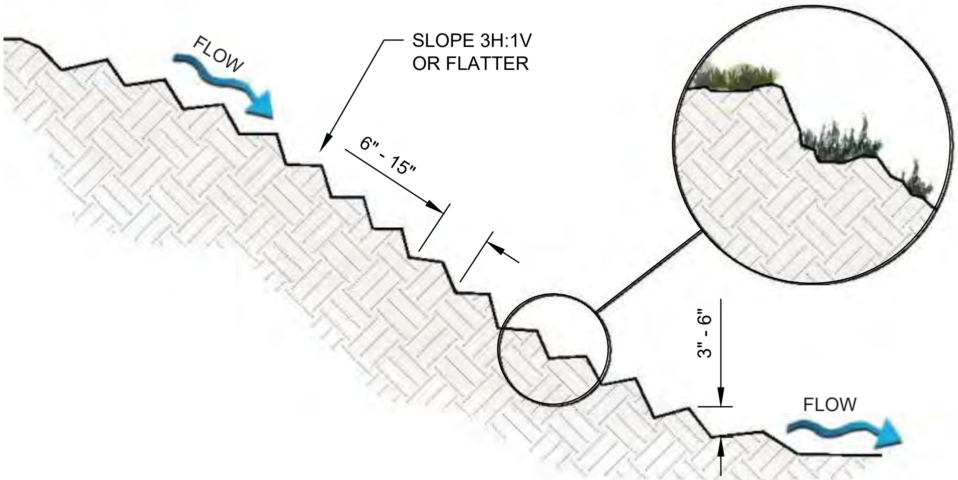
NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

SR

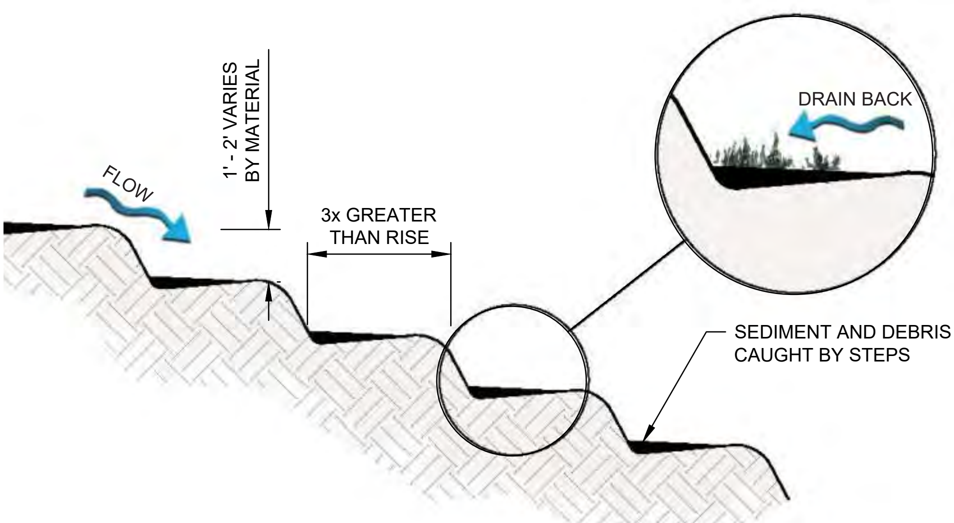
A2-3 SURFACE ROUGHENING CONTINUED

MAINTENANCE REQUIREMENTS

» *Use fencing where necessary to limit vehicles and equipment access onto roughened areas.*



Surface roughening - SECTION VIEW of furrows.



Surface roughening - SECTION VIEW of stair cut slope.

A2-4 LAND IMPRINTING

Image credit: Sites Southwest

DESCRIPTION

Land imprinting is an erosion control practice used in conjunction with final grading, seeding, and revegetation. Land imprinting involves increasing the relief of a bare soil surface with mechanical equipment that creates a pattern of small pocket depressions.

PRIMARY USE

Land imprinting reduces runoff velocity, increases infiltration, reduces erosion, traps sediment, and prepares the soil for seeding by giving seed an opportunity to take hold and grow in pocket depressions. These small depressions provide protection from wind erosion and help create micro-areas of moisture accumulation.

Land imprinting is appropriate for all slopes, can be used on slopes steeper than 2:1, and can be used on piles of excavated soil and in areas with highly erodible soils.

APPLICATION

Strategies for successful land imprinting include:

» *Use this practice in conjunction with seeding, planting, and mulching to stabilize an area.*
» *Use a combination of land imprinting and seeding for steep slopes.*

SEE ALSO

A2-1 *Seeding*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

LI

A2-4 **LAND IMPRINTING** CONTINUED

LIMITATIONS

» *Not appropriate for rocky slopes, shallow soils or very fine sands.*
» *Effective only for gentle or shallow depth rains.*
» *Track machinery can excessively compact the soil.*
» *Machinery availability and operator expertise might be regionally limited.*

MAINTENANCE REQUIREMENTS

» *Inspect land imprinted areas monthly and after major storm events.*
» *Imprint surface again if imprinting is washed away in a heavy storm.*
» *Reseed areas that are imprinted during regular maintenance.*

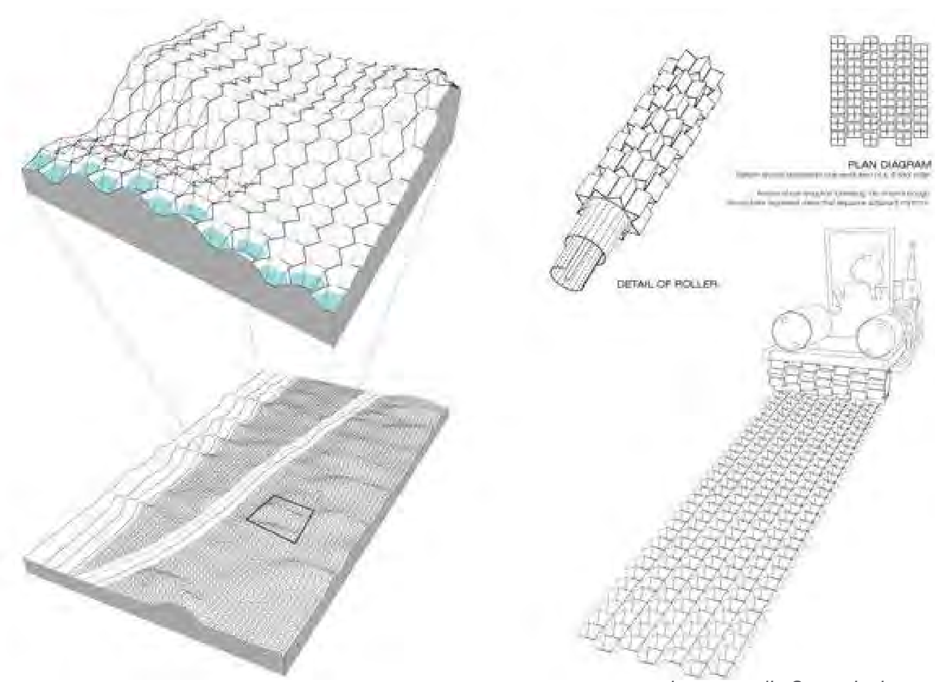


Image credit: Scenario Journal

Land imprinting isometric details.

Image credit: Offgridquest

Example of imprinting roller.

A2-5 KEYLINING

Image credit: Gordon Tooley

DESCRIPTION

Keylining is a land management practice designed to modify landscape water flow patterns, lengthen water routes, and increase water resource benefits. Although keylining can be achieved with range of techniques, this BMP focuses on keylining as a deep tillage subsoil treatment.

PRIMARY USE

Keylining is a large-scale land management practice often affiliated with agriculture and range land management designed to extend the flow paths of water in drought prone areas for revegetation and improved plant growth. The keyline plow penetrates the soil without mixing or inverting the soil. Ripping the soil along the contour lines, the plow creates micro ditches and berms that harvest and divert water. The plowed "keylines" lengthen water flow paths to distribute water from wet to dry areas across the broader landscape.

APPLICATION

Strategies for successful keylining include:

» *Apply this technique only on gently sloping lands (no more than 3%) with sheet flow characteristics.*
» *Consider keylining in areas subject to wind erosion to more equally distribute water over larger land areas and create more consistent grass cover.*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

KL

A2-5 **KEYLINING** CONTINUED

LIMITATIONS

- *Not suitable for steep topography.*
- *Not suitable for highly erodible soils (keylines might decrease soil moisture).*
- *Not suitable for highly organic or saturated soils (keylines close quickly under these conditions).*
- *Not suitable in areas with shallow soils and exposed bedrock.*

MAINTENANCE REQUIREMENTS

- *Keyline annually to retain water distribution characteristics until site has met vegetation coverage goals.*

Image credit: Gordon Tooley

Keyline plow with roller.

Image credit: Gordon Tooley

Keyline equipment behind a tractor.

A2-6 DROP INLET PROTECTION

Image credit: NMDOT

DESCRIPTION

A variety of drop inlet protection methods are used to intercept sediments at median drop inlets (MDI) and curb drop inlets (CDI) through the use of stone, filter fabric, mulch socks, or other materials.

PRIMARY USE

Drop inlet protection is normally used in combination with other BMPs and as a second defense in site sedimentation control at drop inlets.

APPLICATION

Inlet protection techniques for various conditions include:

» *Installation of mulch socks as a filter barrier on small-sized projects with shallow slopes.*
» *Installation of masonry block and gravel for situations where flows exceed 0.5 cfs.*
» *Use of wire mesh and gravel where vehicular traffic crosses inlet.*

LIMITATIONS

» *Drop inlet protection is only viable at low-point inlets. Inlets that are on a slope cannot be effectively protected because stormwater will bypass the inlet and continue downstream, causing an overload condition at inlets beyond.*
» *Regular maintenance of porosity is key to effectiveness in order to avoid ponding and possible flooding.*

SEE ALSO

A2-8 *Mulch Socks*

NMDOT STANDARD DRAWING

603-01-4/7 Drop Inlet Protection

NMDOT TESCP (TEMPORARY EROSION AND SEDIMENT CONTROL PLAN) SYMBOL

DIP

A2-6 DROP INLET PROTECTION CONTINUED

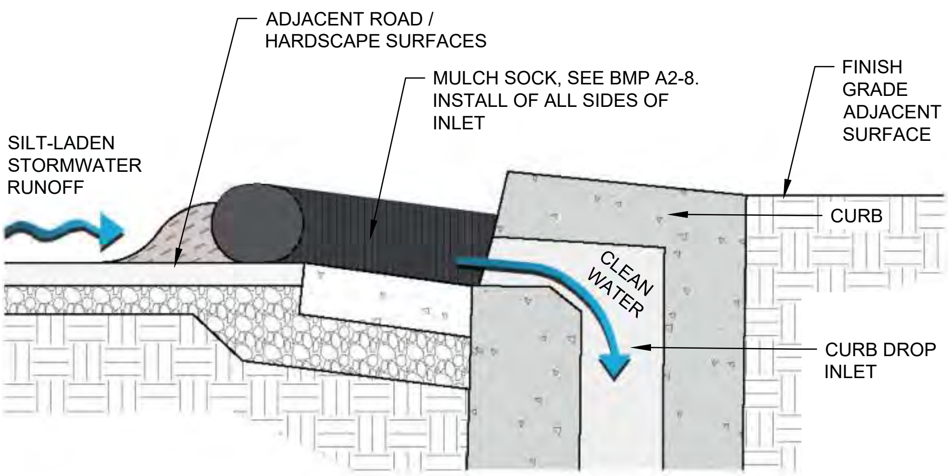
MAINTENANCE REQUIREMENTS

» *Inspect on a weekly basis and after major storm events.*
» *Clean debris from protection or, if necessary, replace protection measures.*
» *Remove sediment regularly.*
» *Clean and replace clogged stone protection measures.*

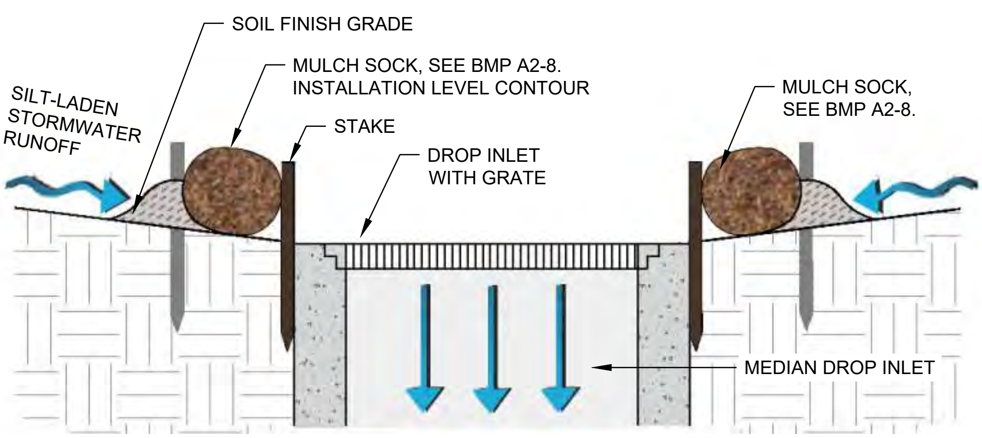
Image credit: NMDOT

Image credit: Sites Southwest

Drop inlet protection with mulch socks staked in place in rural application or median (LEFT) and at a curb in urban application (RIGHT).



Curb drop inlet protection with mulch sock at a curb - SECTION VIEW.



Median drop inlet protection with mulch sock - SECTION VIEW.

A2-7 CULVERT PROTECTION

Image credit: Sites Southwest

DESCRIPTION

Culverts are essential elements of floodplain design used at different scales for stormwater control. Culvert protection is the use of structures and materials including rip rap, geotextiles, wire and mulch socks to direct flow into culverts and mitigate concentrated stormwater velocities at the outlet.

PRIMARY USE

Culvert protection reduces the velocity and energy of stormwater flow going into or out of a culvert. This helps to reduce erosion of the receiving downstream reach, prevent undercutting, and protect public safety and infrastructure. Culvert protection is often easier to install and less expensive than concrete aprons or energy dissipators. Culvert protection may also serve to trap sediment.

APPLICATION

Temporary culvert protection can be achieved by mulch socks, while permanent protection may require the use of riprap, wire, and geotextile. Strategies for successful culvert protection include:

» *Use of grouted or wire-tied rock riprap, which can minimize maintenance requirements.*

LIMITATIONS

» *Culvert protection may need continual maintenance because major storms often wash away the stone and leave the area susceptible to erosion.*

MAINTENANCE REQUIREMENTS

» *Inspect monthly and after major storm events.*
» *Replace rock as needed.*

SEE ALSO

A2-8 *Mulch Socks*

NMDOT STANDARD DRAWING

602-02-1/1 Erosion Control at Culvert Outlets
603-01-4/7 Culvert Protection

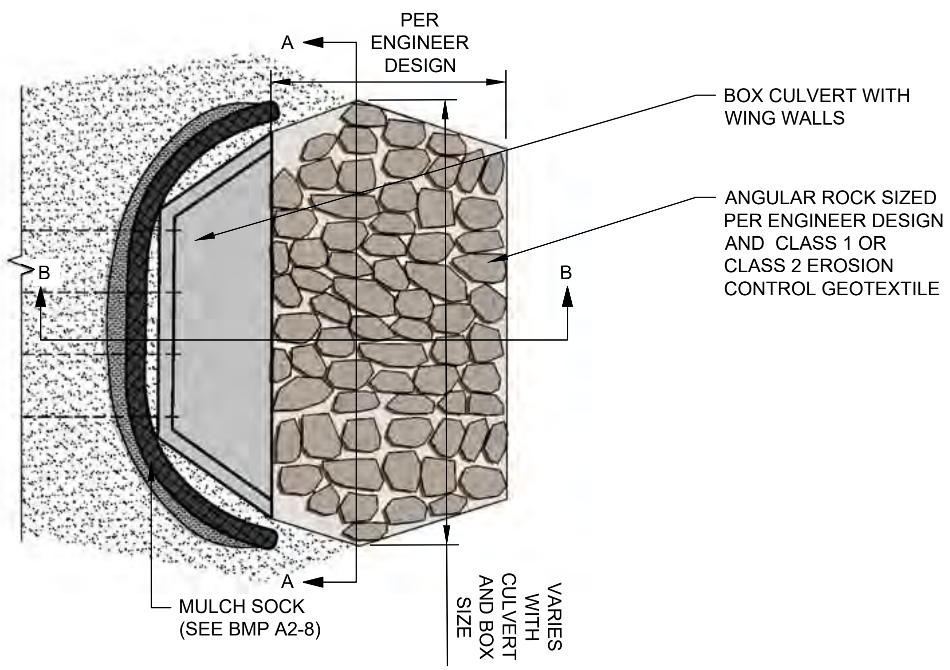
NMDOT STANDARD SPECIFICATION

602 Slope and Erosion Protection Structures

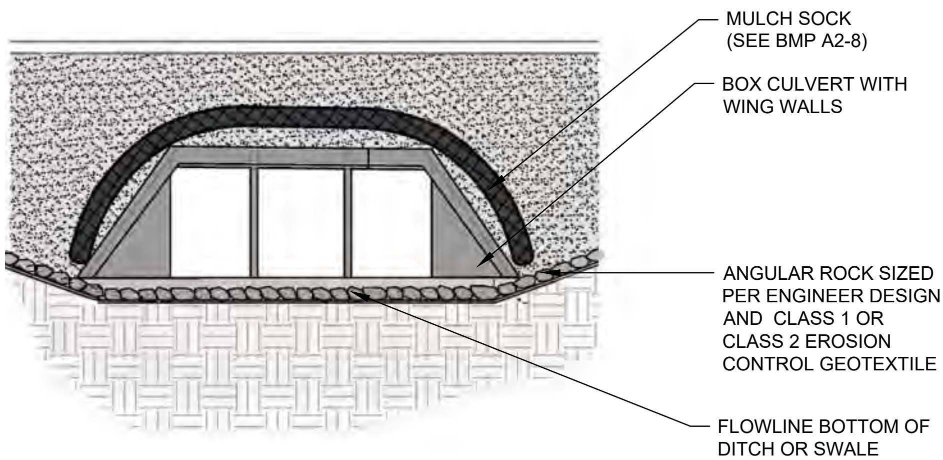
NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

CP

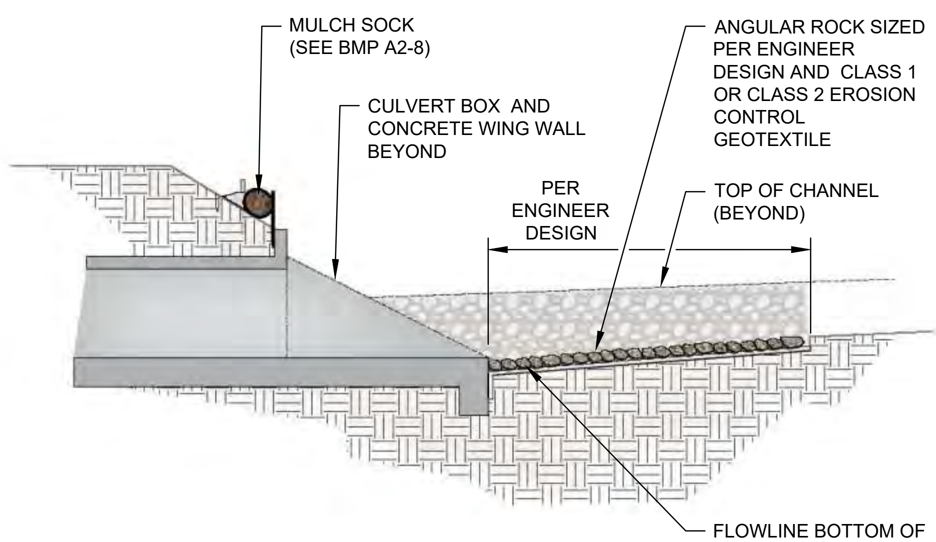
A2-7 CULVERT PROTECTION CONTINUED



Box culvert protection - PLAN VIEW.

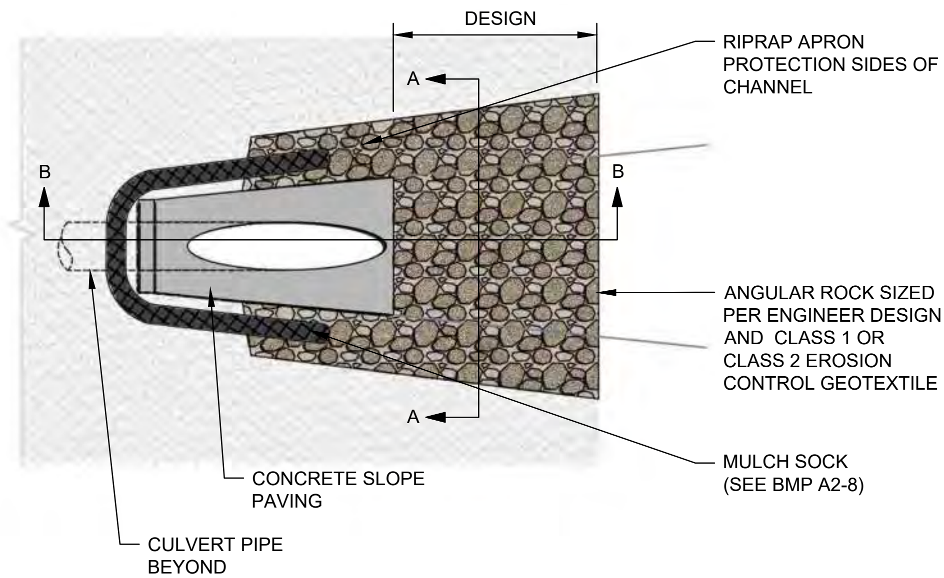


Box culvert protection - SECTION A-A.

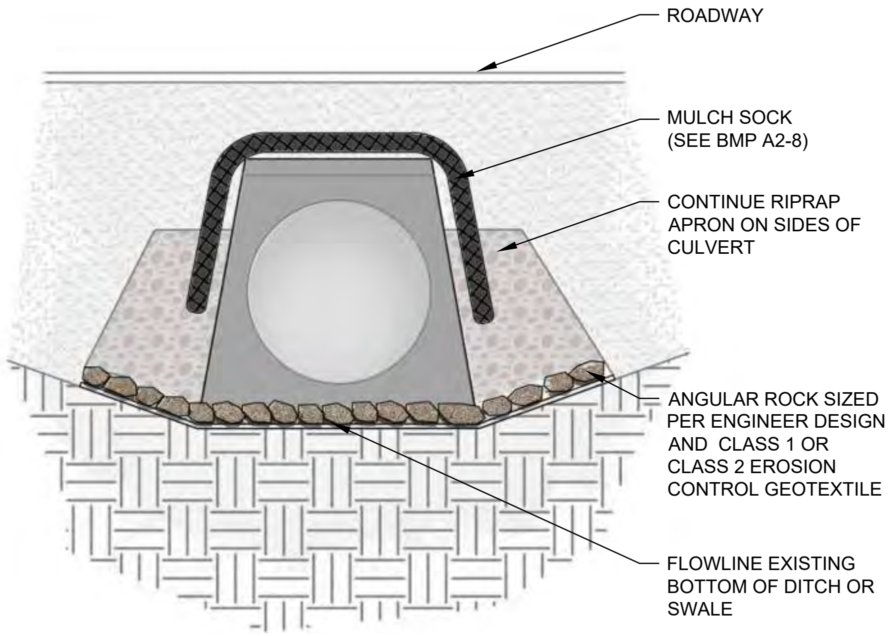


Box culvert protection - SECTION B-B.

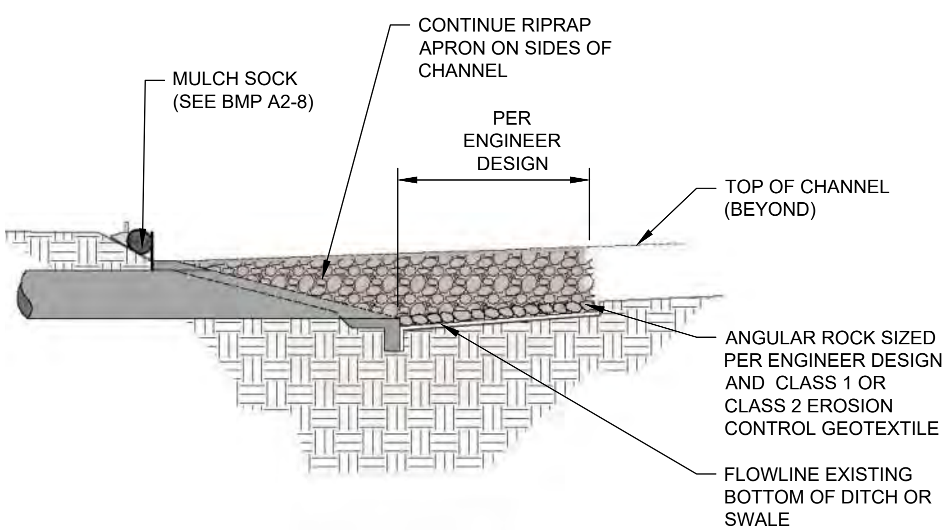
A2-7 CULVERT PROTECTION CONTINUED



Sloped culvert protection - PLAN VIEW.



Sloped culvert protection - SECTION A-A.



Sloped culvert protection - SECTION B-B.

A2-8 MULCH SOCKS

Image credit: NMDOT

DESCRIPTION

Mulch socks are erosion and sediment control materials made typically of high density polyethylene (HDPE) or biodegradable plastic filament mesh tubes filled with compost or other organic media.

PRIMARY USE

Mulch socks are primarily used to filter and slow stormwater. Uses include:

» *Filter sediment and silts from sheet stormwater flowing from disturbed sites.*
» *Protect inlets from sediment.*
» *Create temporary ponding areas behind socks to facilitate the deposition of suspended solids.*
» *Slow stormwater runoff and reduce peak flows.*
» *Filter heavy metals, pollutants and oil from stormwater when socks are filled with adsorbent media.*
» *Provide temporary protection at drop inlets or culverts.*
» *Create check dams or sediment traps at concrete washout areas.*
» *Provide perimeter control, runoff diversion, and slope interruption.*
» *Reinforce stream banks and aid in the protection and establishment of stabilizing watercourse vegetation.*

APPLICATION

Strategies for successful use of mulch socks include:

» *Lay the sock upon the surface and stake the tube every 10 feet.*
» *Lay the tube along contours, vegetated channels, and outside of the toes of slopes.*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

MS
CMS

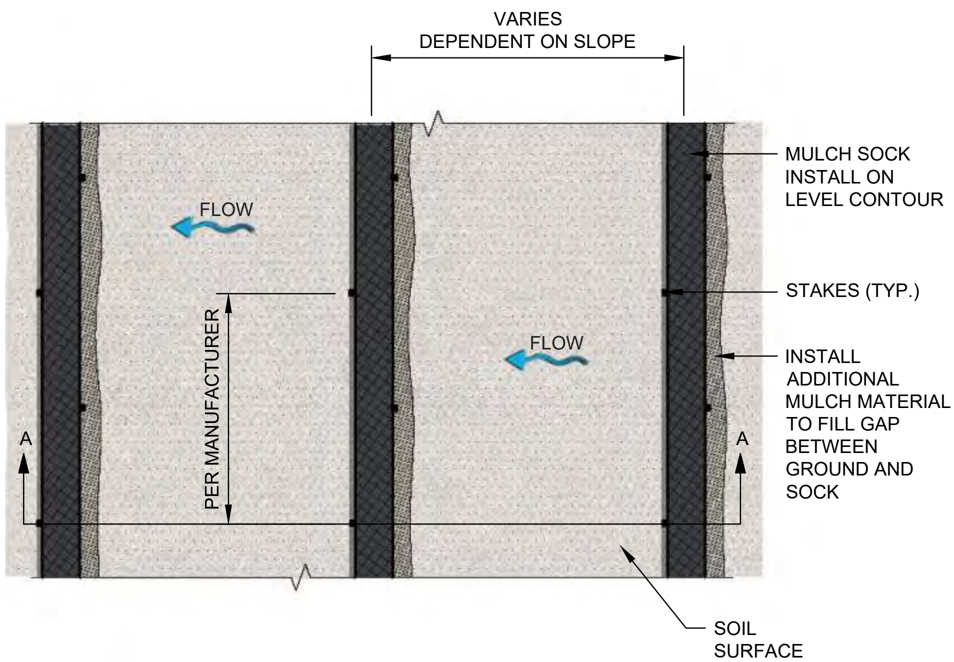
A2-8 MULCH SOCKS CONTINUED

LIMITATIONS

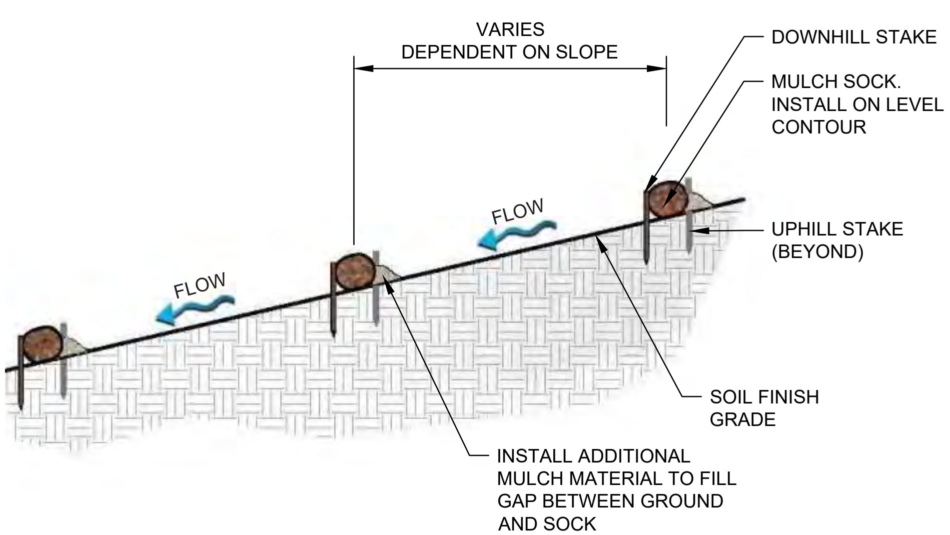
» *Mulch socks do not provide long-term solutions for stormwater storage.*
» *Mulch socks have limited usefulness in concentrated flow conditions.*
» *On NMDOT projects composted mulch socks (CMS) are used exclusively; wood chip mulch socks are not allowed.*

MAINTENANCE REQUIREMENTS

» *Inspect mulch socks periodically, especially after major storm events.*
» *Remove sediments from behind socks after accumulation is 1/3 sock height.*
» *Restake and overlap socks that are displaced due to storm events or construction disturbance.*



Mulch sock - PLAN VIEW.



Mulch sock - SECTION A-A.

A2-9 SLOPE DRAIN

Image credit: Google Street View

DESCRIPTION

A slope drain is a temporary pipeline that conveys flow from diversion channels, dikes, or other areas with concentrated flows down an unstabilized slope. The drain is anchored on the upstream end with a form of headwall and diversion dike to limit erosion and secure the pipe.

PRIMARY USE

Slope drains are used on long, unstabilized, steep slopes subject to erosion from overland flow. Slope drains are useful on sites with large berms or grade changes.

APPLICATION

Strategies for successful slope drain use include:

- *Grade upstream area to ensure flow is directed into the slope drain.*
- *Install a riprap apron or other energy dissipater at the outlet to reduce velocity and spread the flow.*
- *Direct flow from slope drain to a sediment trap or basin.*

LIMITATIONS

- *Drains must be located away from construction areas, since the drain can easily be damaged by construction traffic.*
- *Securing the pipe to the slope can be difficult and require significant maintenance during the life of the system.*

NMDOT STANDARD DRAWING

603-01-6/7 Slope Drain

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

SD

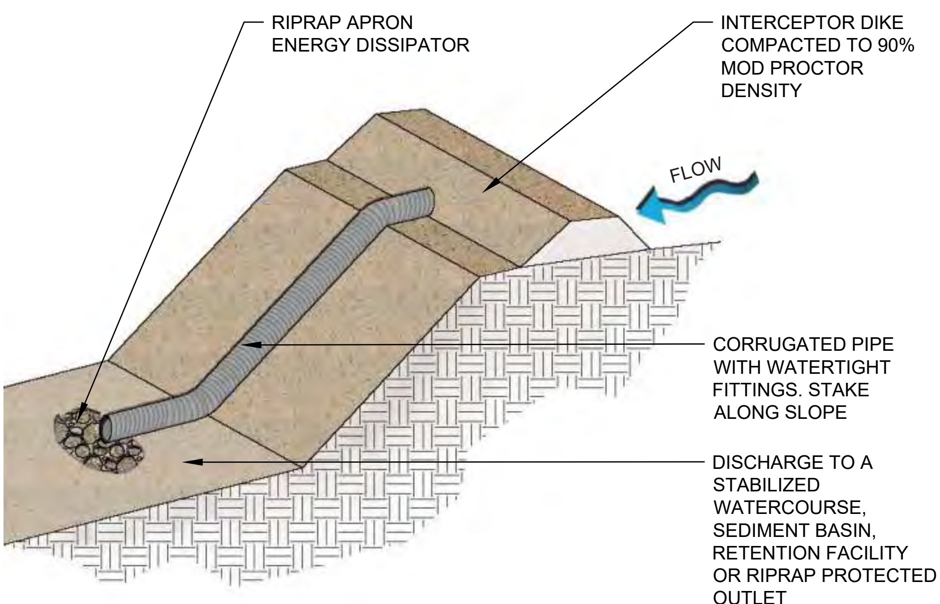
A2-9 SLOPE DRAIN CONTINUED

LIMITATIONS *CONTINUED*

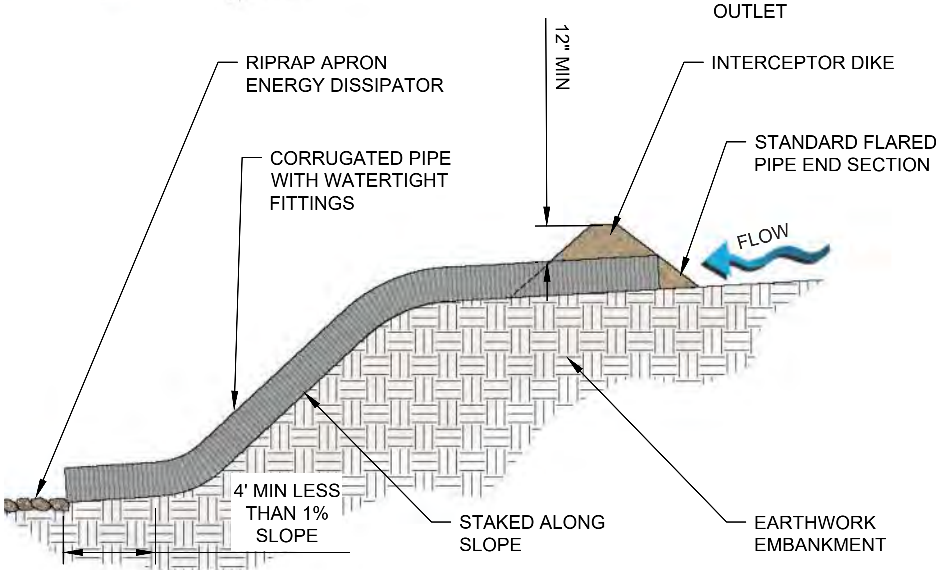
- *In situations where slope drains convey sediment-laden runoff, pipes can become clogged during major storm events, causing water to overtop the diversion dike and thereby creating a serious erosion condition.*
- *Grading is normally required upstream of the pipe slope drain in order to direct flow into the system. This can cause additional cost and maintenance.*
- *A pipe slope drain reduces erosion but does not prevent it or reduce the amount of sediment in the runoff. Additional measures should be used in conjunction with the pipe slope drain to treat the flow.*

MAINTENANCE REQUIREMENTS

- *Inspect slope drain after (>0.5 inch) storm events to locate and repair any damage to joints or clogging of the pipe.*
- *Reinforce the dike with sandbags or install a concrete collar where the diversion channel has deteriorated from around the entrance of the pipe.*
- *Regrade and reconstruct drain if erosion occurs by stabilizing the area with erosion control mats, crushed stone, concrete, or other acceptable method.*



Typical slope drain detail - ISOMETRIC VIEW.



Typical slope drain detail - SECTION VIEW.

A2-10 SEDIMENT TRAP

Image credit: Coleman Engineering

DESCRIPTION

A sediment trap is a small temporary ponding area where water is slowed, and sediment can settle. There are two types of sediment traps: bermed traps and excavated traps.

PRIMARY USE

Sediment traps are used to collect and store sediment from small sites, and cleaned or graded areas during construction. Sediment traps are used where the disturbed site area is less than 5 acres, and is located at points of discharge from the disturbed area. Sediment traps are temporary measures maintained until permanent measures are installed.

APPLICATION

Sediment trap design strategies include:

» *Create a rectangular and shallow trap with a length-to-width ratio of 2:1 or greater.*
» *Construct an outlet structure that consists of a stone section in the embankment formed by a combination coarse aggregate/riprap to provide for filtering/detention capability.*
» *Locate the outlet crest at least 1 foot below the top of the embankment.*
» *Place geotextile fabric at the stone-soil interface to act as a separator.*

SEE ALSO

A2-11 *Sediment Basin*

NMDOT STANDARD DRAWING

603-01-5/7 Sediment Trap

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

ST

A2-10 SEDIMENT TRAP CONTINUED

LIMITATIONS

» *The amount of land required may limit sediment trap use.*

» *Sediment traps can cause minor flooding upstream of a dam, impacting construction operations.*

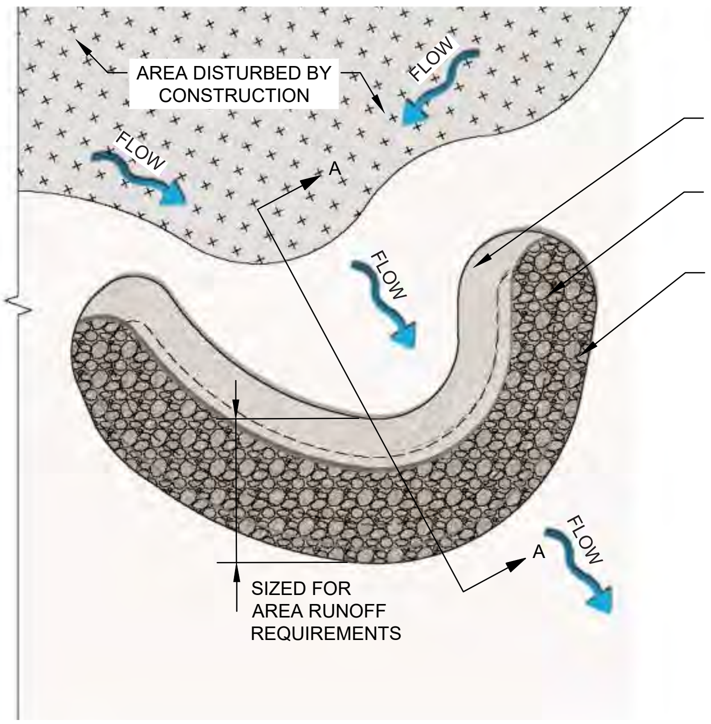
» *Sediment traps are a temporary measure during construction and should not be used for more than 18 months due to reduced efficiency.*

MAINTENANCE REQUIREMENTS

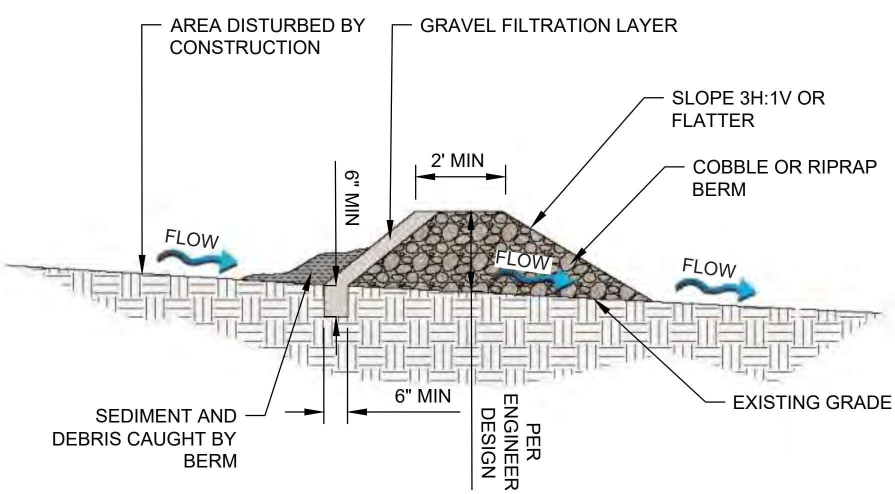
» *Remove sediment and re-grade to its original dimensions when the capacity of the impoundment has been reduced to one-half of its original storage capacity. Stockpile sediment or redistribute in areas that are protected from erosion.*

» *Inspect trap after major storm events to check for clogging of the void spaces between stones. If the aggregate appears to be silted in such that efficiency is diminished, the stone should be replaced.*

A2-10 SEDIMENT TRAP CONTINUED

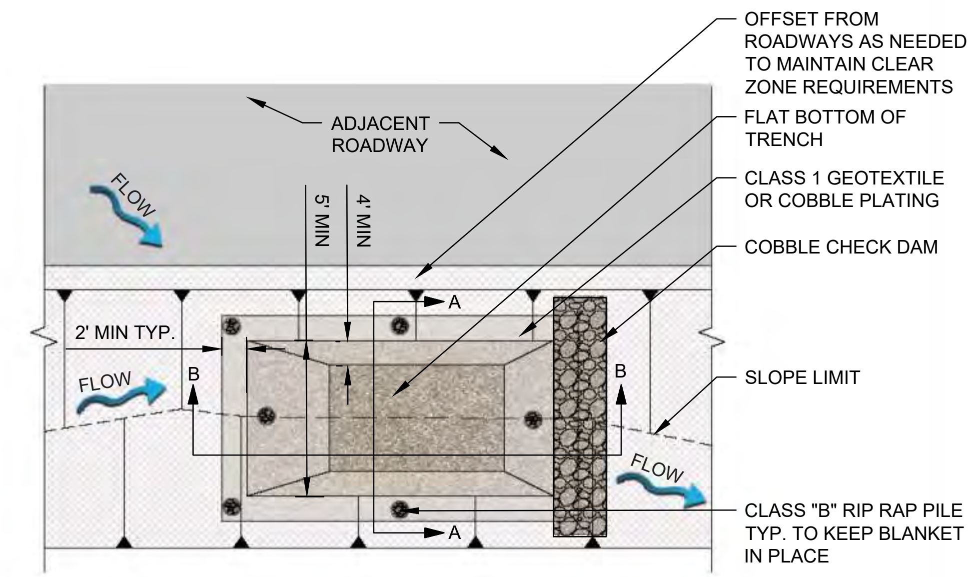


Bermed sediment trap - PLAN VIEW.

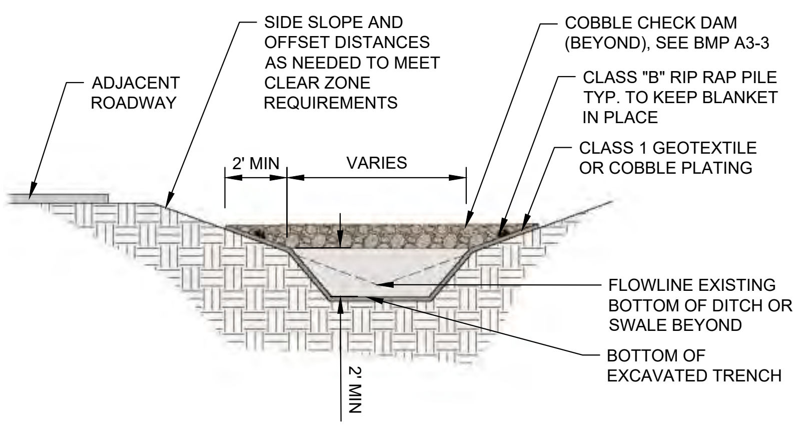


Bermed sediment trap - SECTION A-A.

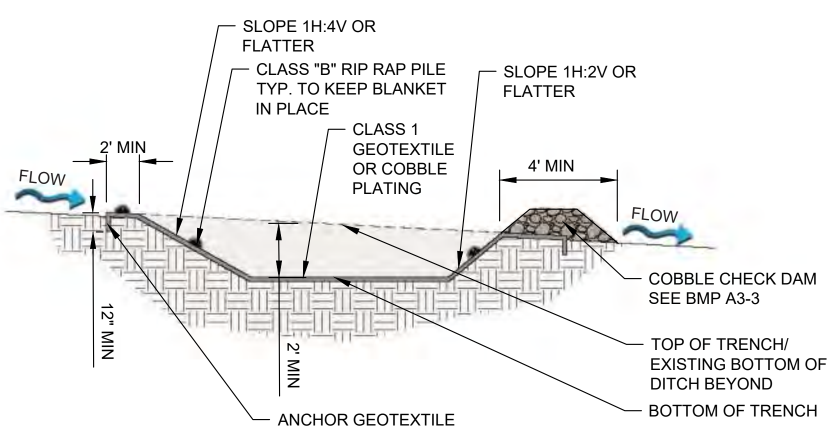
A2-10 **SEDIMENT TRAP** CONTINUED



Excavated sediment trap - PLAN VIEW.



Excavated sediment trap - SECTION A-A.



Excavated sediment trap - SECTION B-B.

A2-11 SEDIMENT BASIN

Image credit: Integra Engineering & Science Services/ Julie Coco

DESCRIPTION

A sediment basin is a pond area with a controlled outlet in which suspended sediment is allowed to settle. A sediment basin is a highly effective treatment device for removing sediments and other pollutants from stormwater for the design storm event.

PRIMARY USE

Sediment basins are used as permanent erosion and sediment control facilities to provide stormwater treatment and control outflow, minimizing flood problems downstream. Sediment basins should be used where there is adequate open space to direct most of the site drainage into the basin.

APPLICATION

Strategies for successful sediment basin design include:

» *Design sediment basins for two-year storm (or higher) runoff volumes.*
» *Create an outlet structure that consists of a stone section in the embankment formed by a combination of coarse aggregate and riprap to provide for filtering/detention capability.*
» *Locate the outlet crest at least 1 foot below the top of the embankment.*
» *Use a geotextile at the stone-soil interface to act as a separator.*
» *Provide an emergency overflow spillway for rainstorms that exceed the capacity of the sediment basin.*

SEE ALSO

A2-10 *Sediment Trap*

A3-9 *Detention Basin*

NMDOT STANDARD DRAWING

603-01-5/7 Sediment Basin

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

SB

A2-11 SEDIMENT BASIN CONTINUED

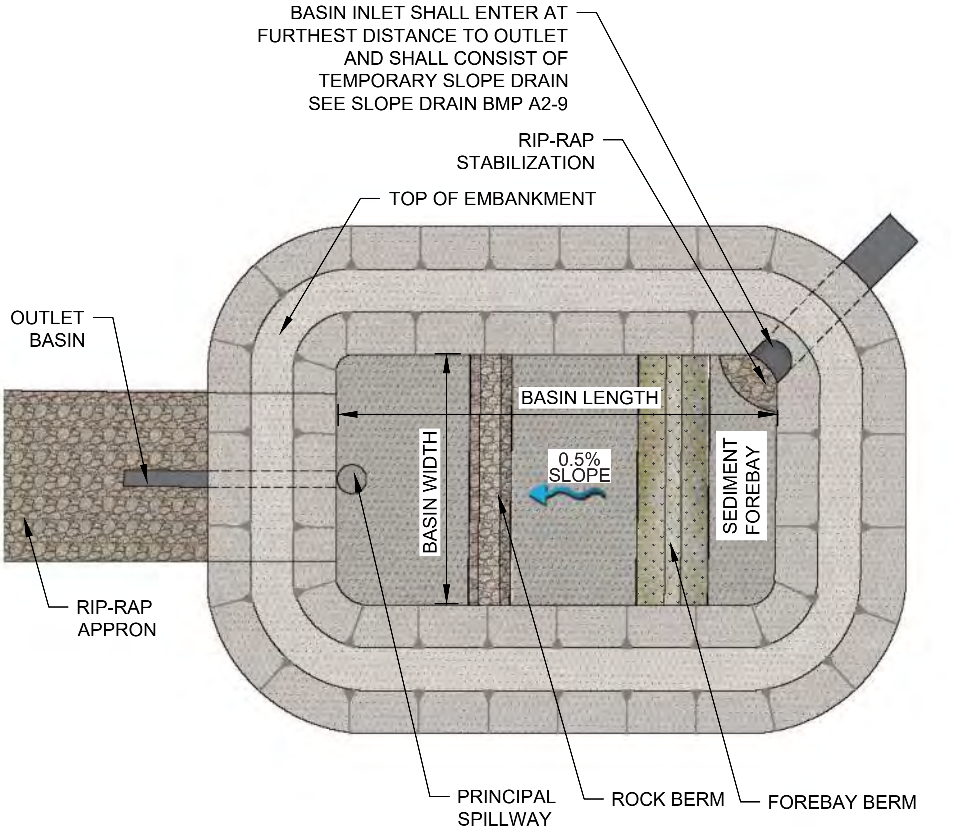
LIMITATIONS

- *Sediment basins can be rather large, depending on site conditions.*
- *Sediment basins require comprehensive planning for construction phasing prior to implementation.*
- *Storm events that exceed the design storm event can cause damage to the spillway structure of the basin and cause unexpected flooding around and downstream of the basin.*

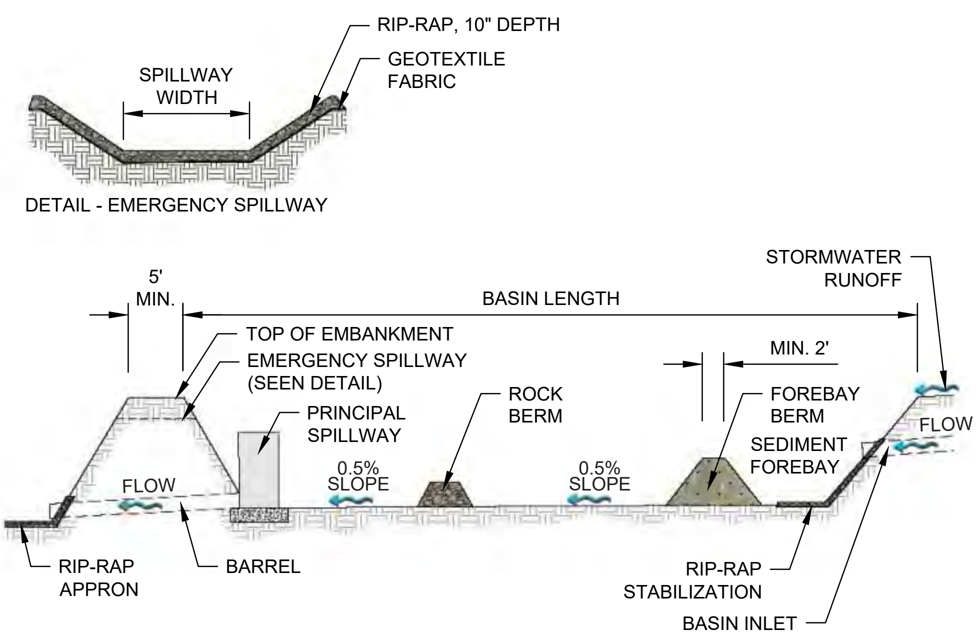
MAINTENANCE REQUIREMENTS

- *Remove sediment and re-grade basin to its original dimensions when the capacity of the impoundment has been reduced significantly from its original storage capacity. The removed sediment shall be stockpiled or redistributed in areas that are protected from erosion.*
- *Inspect basin outlet structure and emergency spillway (if present) after major storm events to inspect for damage and to ensure that obstructions are not diminishing the effectiveness of the structures.*

A2-11 **SEDIMENT BASIN** CONTINUED



Sediment basin - PLAN VIEW.



Sediment basin - SECTION VIEW.

A2-12 POND OUTFALL STRUCTURE

Image credit: Sites Southwest

DESCRIPTION

Pond outfall structures are constructed mechanical devices or cobble weirs that regulate the release of stormwater and facilitate the capture of sediment and floatables. Pond outfall structures are most often found in association with detention ponds, water harvesting basins, depressed medians, infiltration trenches, and bio(retention) swales.

PRIMARY USE

Pond outfall structures are used to decrease/regulate peak flows and stormwater volumes. Typically placed at the discharge point of a stormwater detention facility, pond outfall structures allow for ponding within multiple green stormwater infrastructure BMPs and provide an outlet for larger storm events that exceed the capacity of the BMP.

APPLICATION

Strategies for the design of successful outfall structures include:

» *Installation of a downstream discharge or outfall conveyance, such as a storm sewer system, storm basin or arroyo.*
» *Installation of a raised inlet with a sump or baffle to allow trash, debris, and sediment to drop out of the stormwater.*

LIMITATIONS

» *Maintenance equipment such as a vactor truck is required and may limit the structures' feasibility in areas where this equipment is not available.*

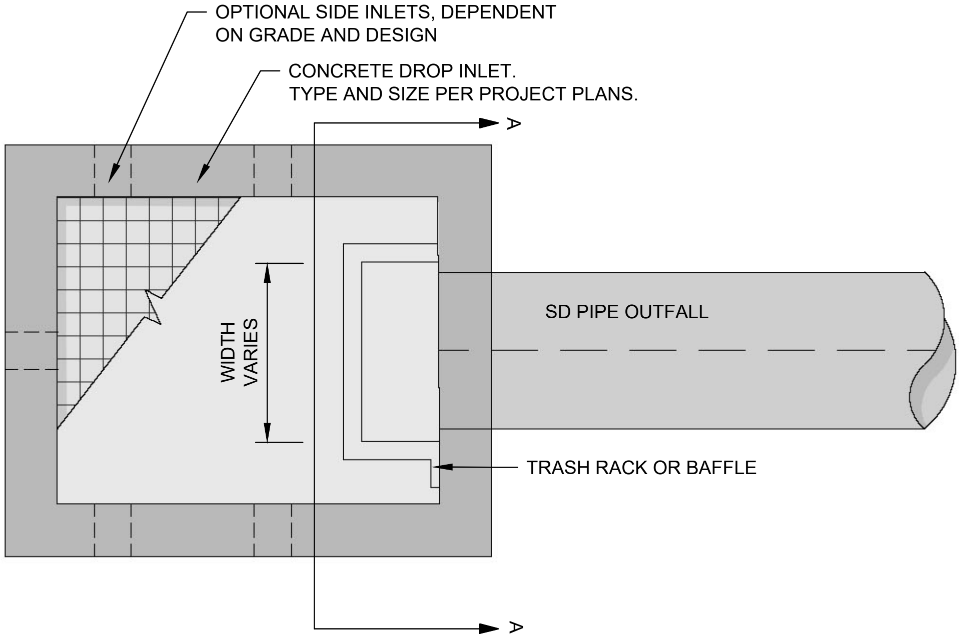
NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

POS

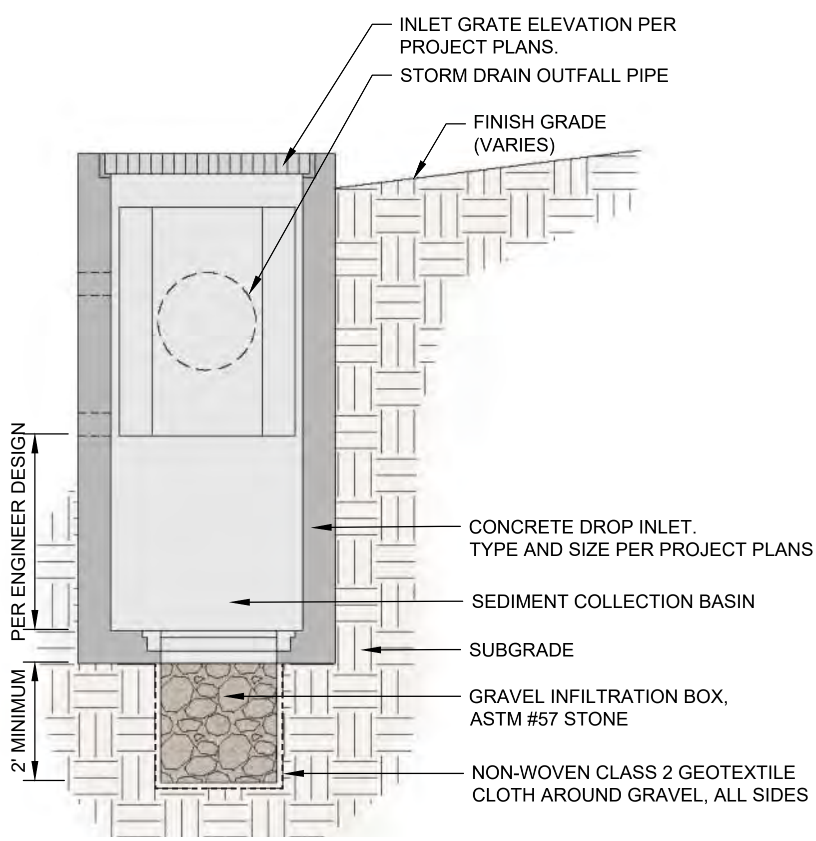
A2-12 POND OUTFALL STRUCTURE CONTINUED

MAINTENANCE REQUIREMENTS

- *Inspect semi-annually and after major storm events.*
- *Remove debris, trash, and accumulated sediment from the inlet grate and structure sump. A vactor truck may be needed for structure sump maintenance.*
- *Prune or remove encroaching vegetation to maintain a minimum of 2 feet clear from the structure.*

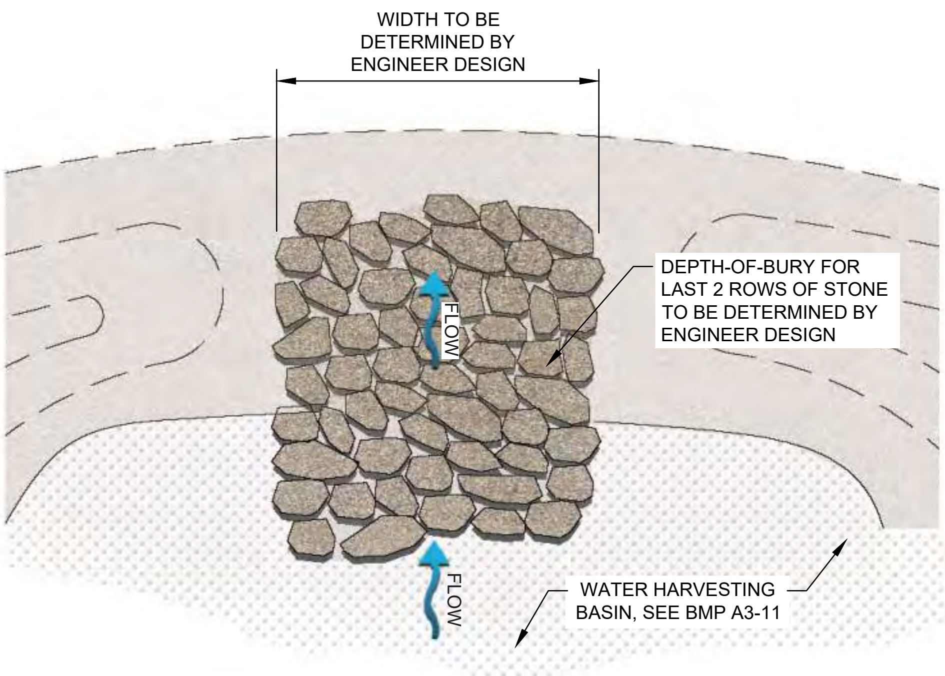


Mechanical outfall protection structure - PLAN VIEW.

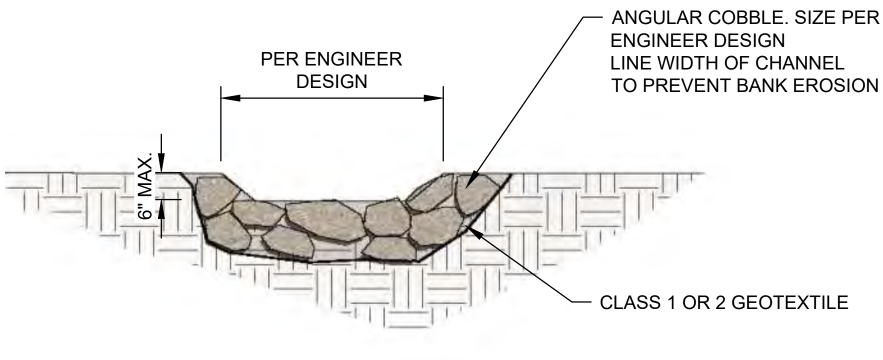


Mechanical outfall protection structure - SECTION A-A.

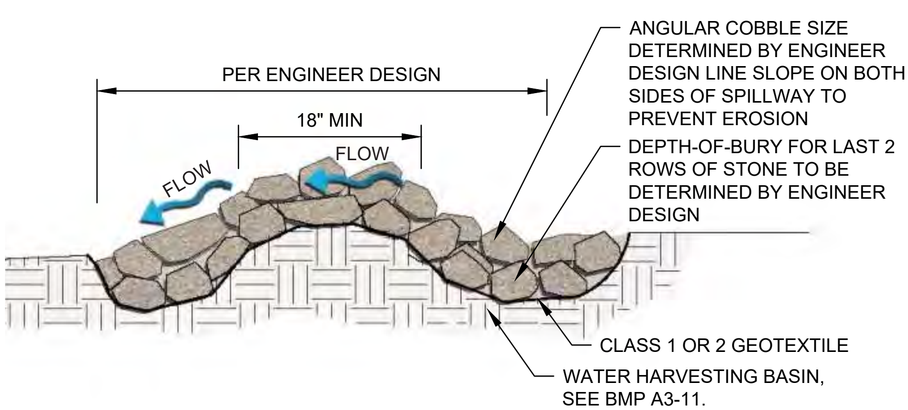
A2-12 POND OUTFALL STRUCTURE CONTINUED



Cobble weir outfall protection - PLAN VIEW.



Cobble weir outfall protection - SECTION VIEW.



Cobble weir outfall protection - PROFILE VIEW.

APPENDIX A3

Low Impact Development and Pollution Control

BEST MANAGEMENT PRACTICES

CATEGORY A3 **FUNCTION OVERVIEW**

		Application	Infiltration	Perimeter Control	Slope Protection	Sediment Trapping	Channel Protection	Temporary Stabilization	Permanent Stabilization	Waste Management	Good Housekeeping	Targeted Constituents	Sediments	Nutrients	Toxic Materials	Oil and Grease	Floatable Materials	Construction Wastes
A3-1	Diversion Channel			✓	✓								✓				✓	
A3-2	Contour Swale				✓	✓	✓		✓				✓					
A3-3	Rock Check Dam					✓	✓	✓	✓				✓					
A3-4	Media Luna				✓	✓	✓		✓				✓					
A3-5	Flow Line Extender		✓		✓	✓			✓				✓					
A3-6	Buffer/Filter Strip		✓			✓			✓				✓	✓		✓		
A3-7	Waffle Slope				✓	✓			✓				✓					
A3-8	Live Wattle					✓		✓	✓				✓			✓		
A3-9	Detention Basin					✓		✓	✓				✓			✓	✓	
A3-10	Bio(retention) Swale		✓	✓		✓	✓		✓				✓	✓		✓	✓	
A3-11	Stormwater Harvesting Basin		✓			✓			✓				✓			✓	✓	
A3-12	Infiltration Trench		✓			✓							✓			✓	✓	
A3-13	Dry Well		✓			✓							✓			✓	✓	
A3-14	Below Grade Storage		✓			✓		✓	✓				✓	✓		✓		
A3-15	Permeable/Alternative Pavement		✓			✓		✓	✓				✓	✓		✓		
A3-16	Green Parking		✓			✓		✓	✓				✓	✓		✓		
A3-17	Curb Treatments		✓			✓							✓			✓		
A3-18	Depressed Median		✓			✓							✓			✓	✓	
A3-19	Urban Tree Planting					✓							✓					
A3-20	Trash Capture Devices									✓	✓			✓	✓	✓	✓	
A3-21	Mechanical Devices / Separators					✓			✓				✓	✓		✓	✓	✓

A3-1 DIVERSION CHANNEL

Image credit: iStock/Olga Ihnatsyeva

DESCRIPTION

Diversion channels are constructed conveyances that concentrate and route stormwater flow away from construction areas or toward desired locations. They can be constructed as either dikes (berms) or swales.

PRIMARY USE

Diversion channels are typically used to collect and direct flow around disturbed areas into a controlled outlet. Diversion channels are useful when significant offsite flow could disturb a site; when flow needs to be directed away from staging, storage, or fueling areas; or where routing is required for treatment.

APPLICATION

Berms and diversions should be constructed of compacted soil or coarse aggregate. Strategies for successful diversion channel design include:

Earth Dike (Berm)

- » *Provide immediate stabilization of compacted earth dikes upon placement to avoid contributing to site erosion and sedimentation.*
- » *Design berms with a minimum height of 18 inches, side slopes of 2:1 or flatter, and a minimum base width of 6 feet.*
- » *Design berms to include uninterrupted positive grade to a stabilized outlet.*

Diversion Channel (Swale)

- » *Quickly stabilize interceptor swales upon excavation to avoid contributing to site erosion and sedimentation.*
- » *Excavate and shape diversion channels to line, grade, and cross section as indicated in the plans and as required to meet the criteria specified.*

SEE ALSO

A3-2 *Contour Swale*

NMDOT STANDARD DRAWING

603-01-5/7 Earth Dike (Berm)
603-01-7/7 Diversion Dike

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

DC

A3-1 DIVERSION CHANNEL CONTINUED

LIMITATIONS

Earth Dike (Berm)

» *The dikes can be a hindrance to construction equipment moving on the site. Carefully plan placement prior to installation.*

Diversion Channel (Swale)

» *Swales may be unsuitable to site conditions (too flat or steep).*
» *Temporary swales might have limited flow capacity.*

MAINTENANCE REQUIREMENTS

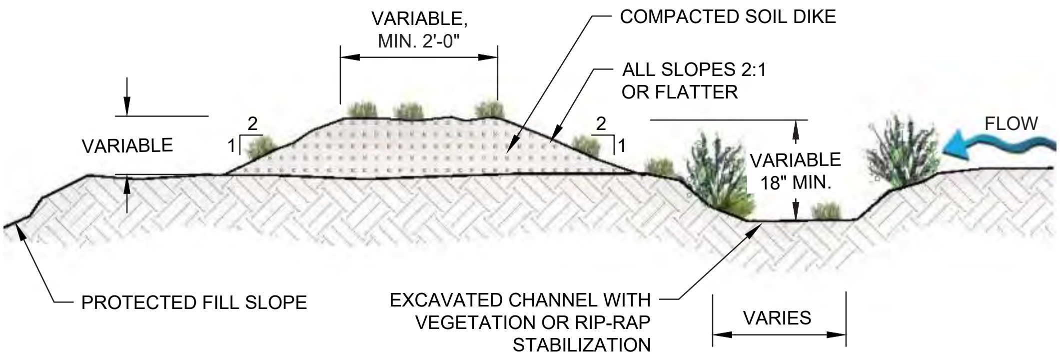
Earth Dike (Berm)

» *Inspect weekly and after (>0.5 inch) storm events during construction to determine if silt is building up behind the dike, or if erosion is occurring on the face of the dike.*
» *Remove silt in a timely manner.*
» *Stabilize slopes through mulch or seeding (or flatten the slope) if erosion is occurring on the face of the dike.*

Diversion Channel (Swale)

» *Inspect weekly and after (>0.5 inch) storm events during construction to locate and repair any damage to the channel.*
» *Clear debris or other obstructions so as not to diminish flow capacity.*
» *Repair damage from storms or normal construction activities, such as tire ruts or disturbance of swale stabilization.*

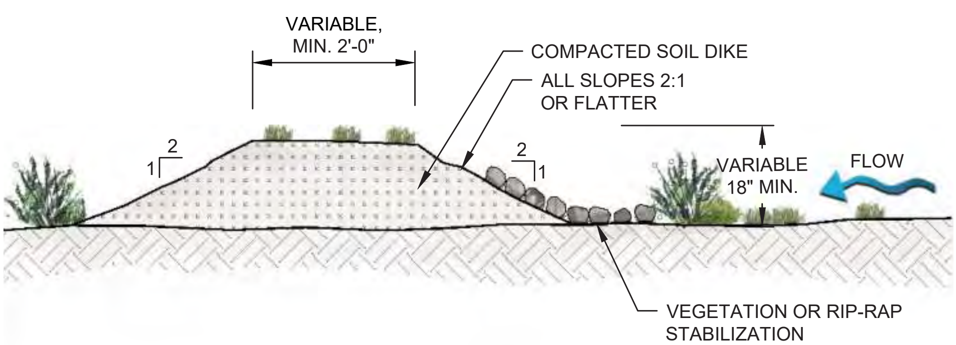
A3-1 DIVERSION CHANNEL CONTINUED



NOTES:

1. THE CHANNEL BEHIND THE DIKE SHALL HAVE POSITIVE GRADE TO A STABILIZED OUTLET.
2. THE DIKE SHALL BE ADEQUATELY COMPACTED TO PREVENT FAILURE.

Earth dike and excavated swale combination - SECTION VIEW.



NOTES:

1. THE CHANNEL BEHIND THE DIKE SHALL HAVE POSITIVE GRADE TO A STABILIZED OUTLET.
2. THE DIKE SHALL BE ADEQUATELY COMPACTED TO PREVENT FAILURE.

Earth dike without excavated swale - SECTION VIEW.

A3-2 CONTOUR SWALE

Image credit: The Rain Catcher

DESCRIPTION
A contour swale is a linear depression with an associated berm that is constructed on sloping sites at a consistent elevation, and that captures and infiltrates water.

PRIMARY USE
The primary use of a contour swale is to stabilize slopes, decrease erosion, and provide additional water for stabilizing plantings on the slope. Contour swales are suitable for cut and fill graded areas. They can also be used on existing hillside cuts experiencing erosion.

APPLICATION
Contour swale design strategies include:

» *Construct an overflow weir at either end of the swale to allow water to run into a secondary contour swale or into another BMP.*
» *Seed contour swales with native grass and shrub seeds.*
» *Construct swales somewhat level to prevent overtopping.*

LIMITATIONS
» *Unsuitable for cuts in exposed bedrock or loose, unconsolidated sedimentary slopes.*
» *Unsuitable for controlling concentrated flows.*

SEE ALSO

A3-1 *Diversion Channel*

A3-3 *Rock Check Dam*

NMDOT STANDARD DRAWING

603-01-7/7 Diversion Dike

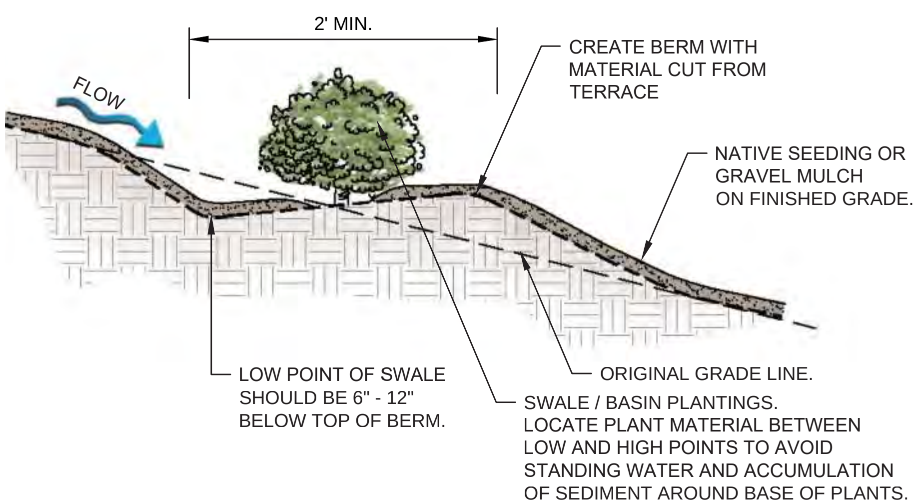
NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

CS

A3-2 **CONTOUR SWALE** CONTINUED

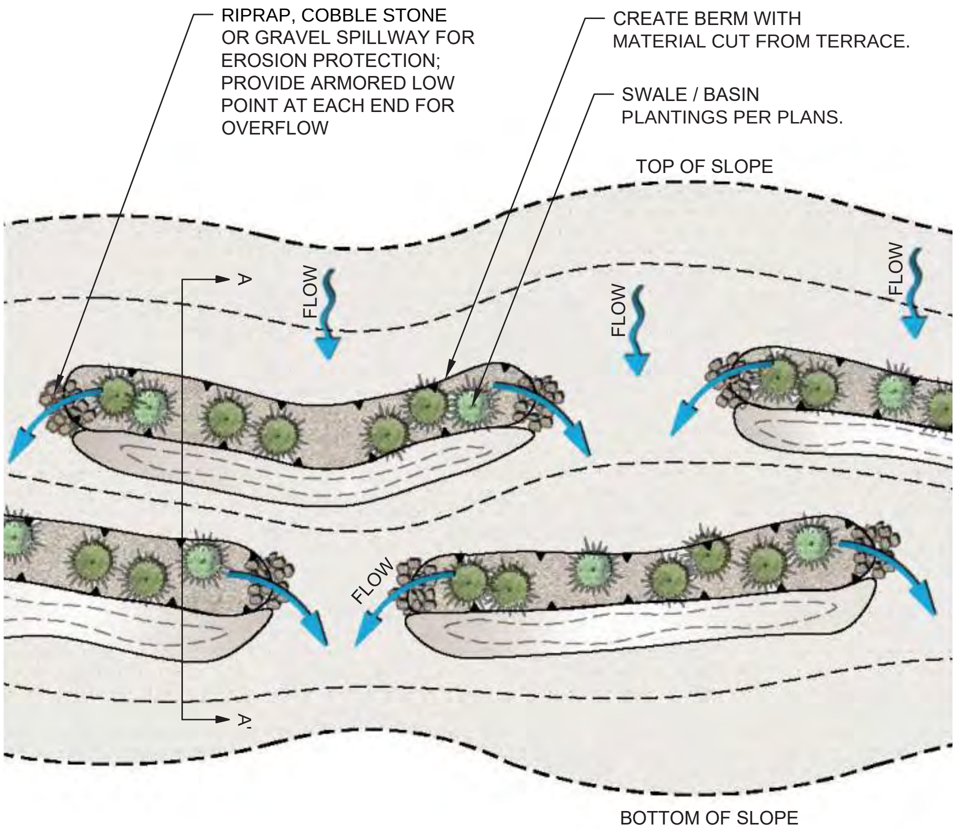
MAINTENANCE REQUIREMENTS

» *Inspect semi-annually and after major storm events.*
» *Regrade to correct erosion, rilling and gullying.*
» *Reseed portions of the swale that have not stabilized.*
» *Remove invasive plants and weeds as necessary.*

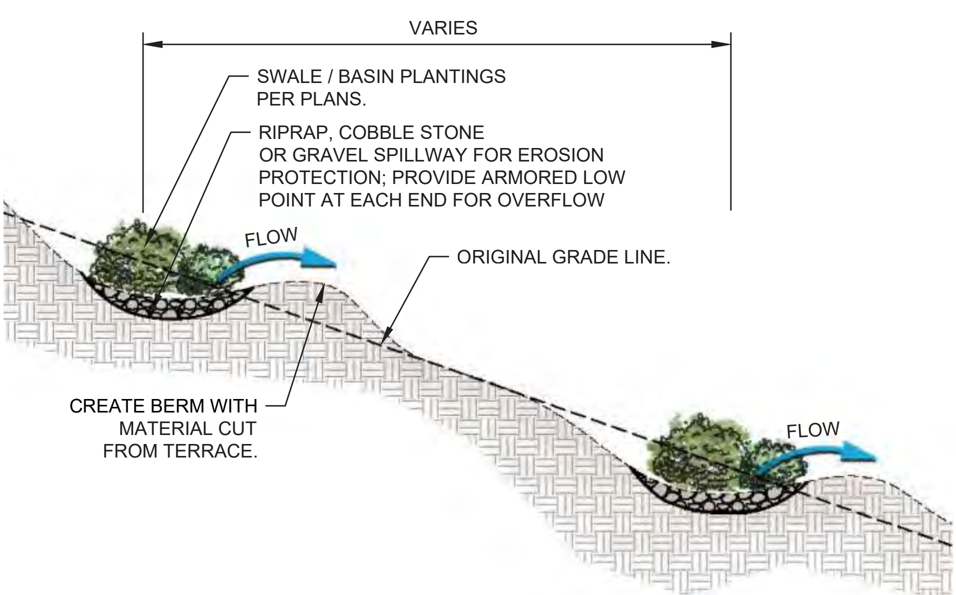


Typical swale construction - SECTION VIEW.

A3-2 **CONTOUR SWALE** CONTINUED



Offset contour swales combination- PLAN VIEW.



Combination of two contour swales - SECTION A-A.

A3-3 ROCK CHECK DAM

Image credit: Sites Southwest

DESCRIPTION
Check dams are small dams constructed across a swale or drainage ditch to reduce erosion. Check dams can be constructed as boulder check dams or as riprap/angular cobble stone dams and can be both temporary or permanent features.

PRIMARY USE
By slowing the stormwater flow velocity, check dams are used for sediment capture and velocity reduction in small channels, roadside ditches, and temporary swales (i.e. open channels that drain ten acres or less).

APPLICATION
Strategies for successful rock check dam design and construction are illustrated on the following pages.

LIMITATIONS
- *Not suitable for impermeable soils that prohibit infiltration and may contribute to flooding.*
- *Extensive maintenance or replacement of the dams may be required at heavy flow and high-velocity areas.*

MAINTENANCE REQUIREMENTS
- *Inspect annually.*
- *Remove accumulated sediment buildup.*

NMDOT STANDARD DRAWING

603-01-2/7 Stone Dam

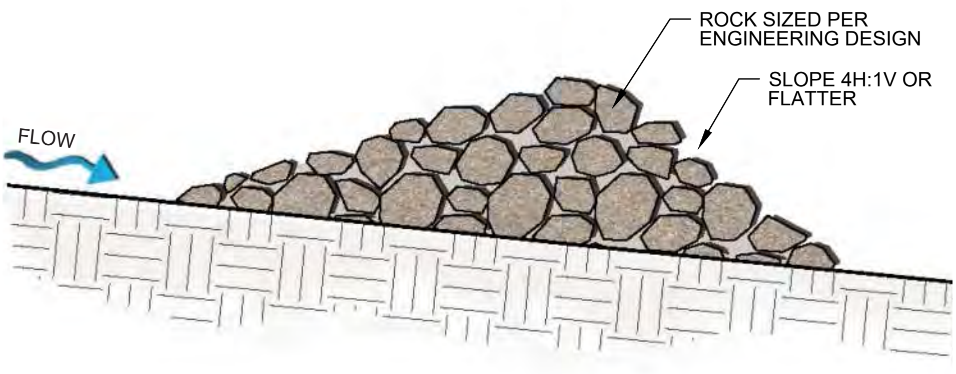
NMDOT STANDARD SPECIFICATION

602 Slope and Erosion Protection Structures

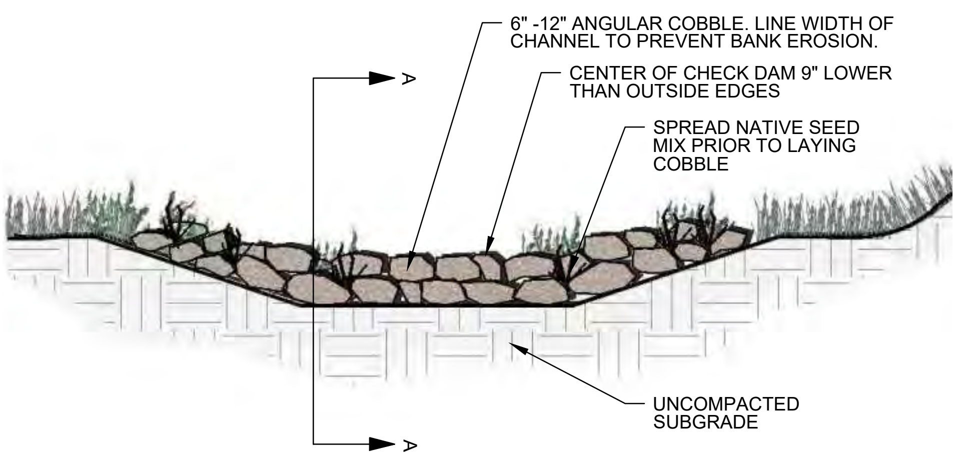
NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

RCD

A3-3 ROCK CHECK DAM CONTINUED

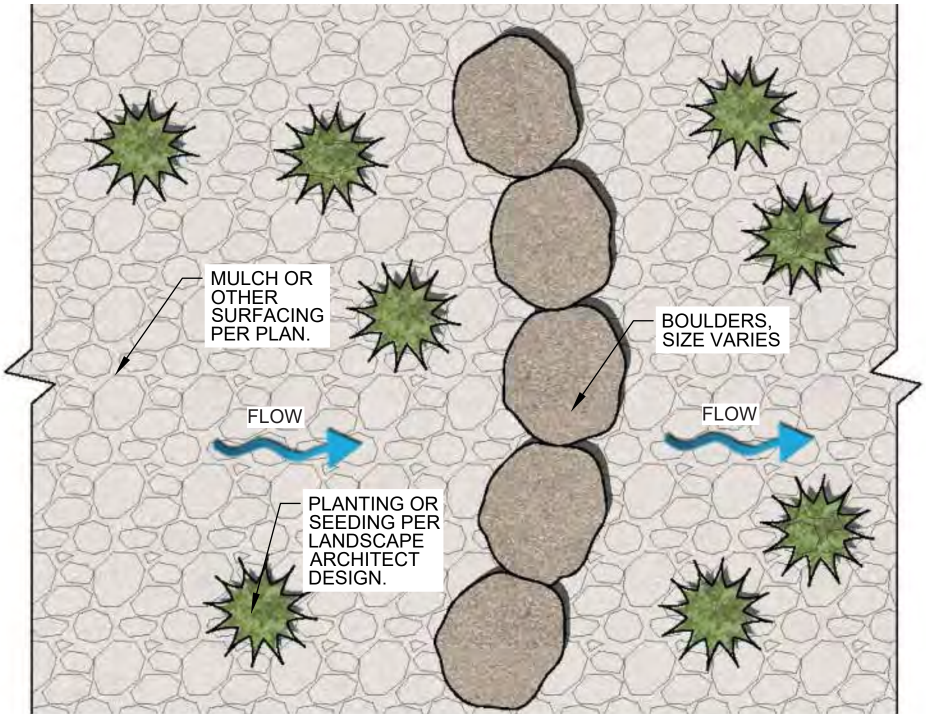


Cobble stone check dam - SECTION A-A - PROFILE VIEW.

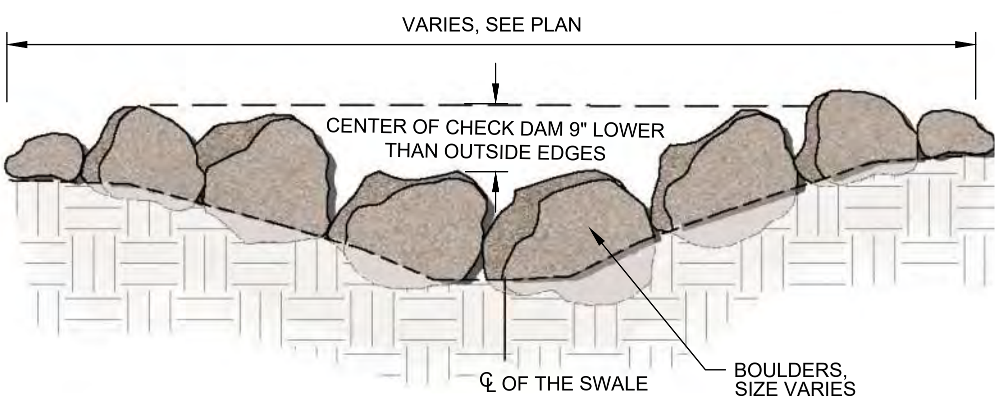


Cobble stone check dam - SECTION VIEW.

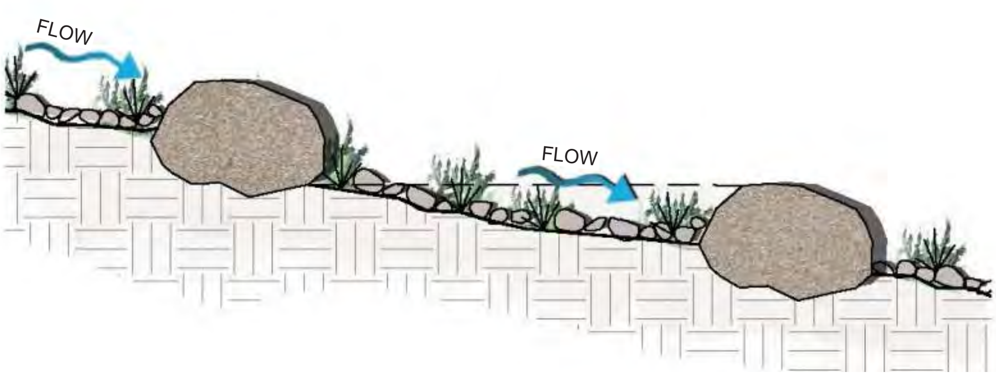
A3-3 ROCK CHECK DAM CONTINUED



Single-row boulder check dam - PLAN VIEW.



Single-row boulder check dam - SECTION VIEW.



Single-row boulder check dam combination - PROFILE VIEW.

A3-4 MEDIA LUNA

Image credit: The Rain Catcher

DESCRIPTION

A media luna (halfmoon) is a water dissipation structure used at the top and/or bottom of a slope, gully or channel. The structure is typically made of stone and formed in the shape of an arc. Media lunas located at the head of rills and gullies create a stable transition from sheet flow to channel flow and media lunas located at the depositional areas (or flat areas at the end of channel flow) disperse erosive channel flow to reestablish sheet flows.

PRIMARY USE

Media lunas are used to stabilize rills and gullies entering a channel or swale condition. Specific locations for media lunas include tops and bottoms of hillside gullies, channels, and swales. They can be used either as dispersals (flow spreaders) of concentrated flows or as concentrators by concentrating flow into channels.

APPLICATION

Design strategies for successful use of media lunas include:

» *Hand build media lunas with the largest fractured face of stone set into roughened soil.*
» *Set stones are as tight as possible to force water to disperse between them.*
» *Install native seed mixes under the stones.*

LIMITATIONS

» *The size of stone available, and the slope and site conditions will determine the stormwater capacity/capabilities of each media luna.*
» *Media lunas are best used with a series of stabilization measures such as seeding, surface roughening and rock check dams.*

SEE ALSO

A3-5 *Flow Line Extender*

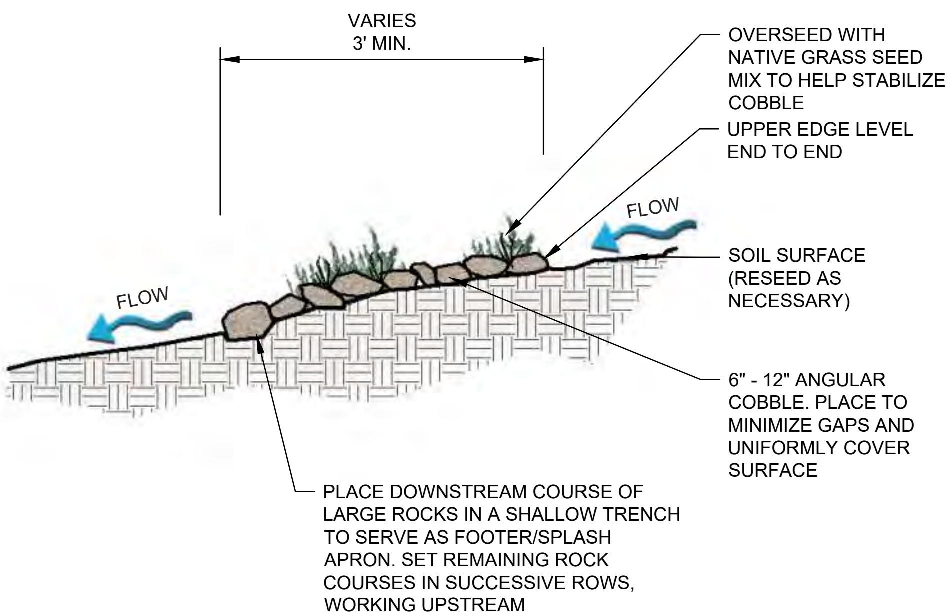
NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

ML

A3-4 MEDIA LUNA CONTINUED

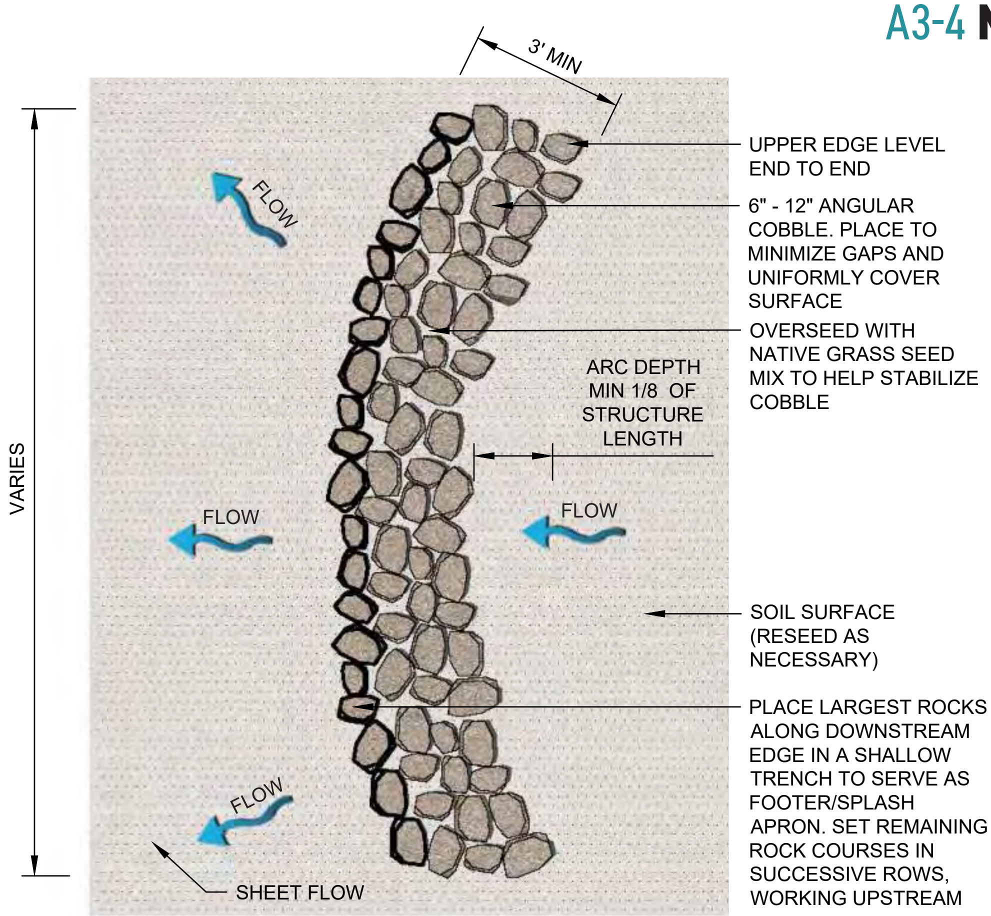
MAINTENANCE REQUIREMENTS

» *Inspect annually.*
» *Build another media luna above the first after sedimentation behind the media luna builds up.*

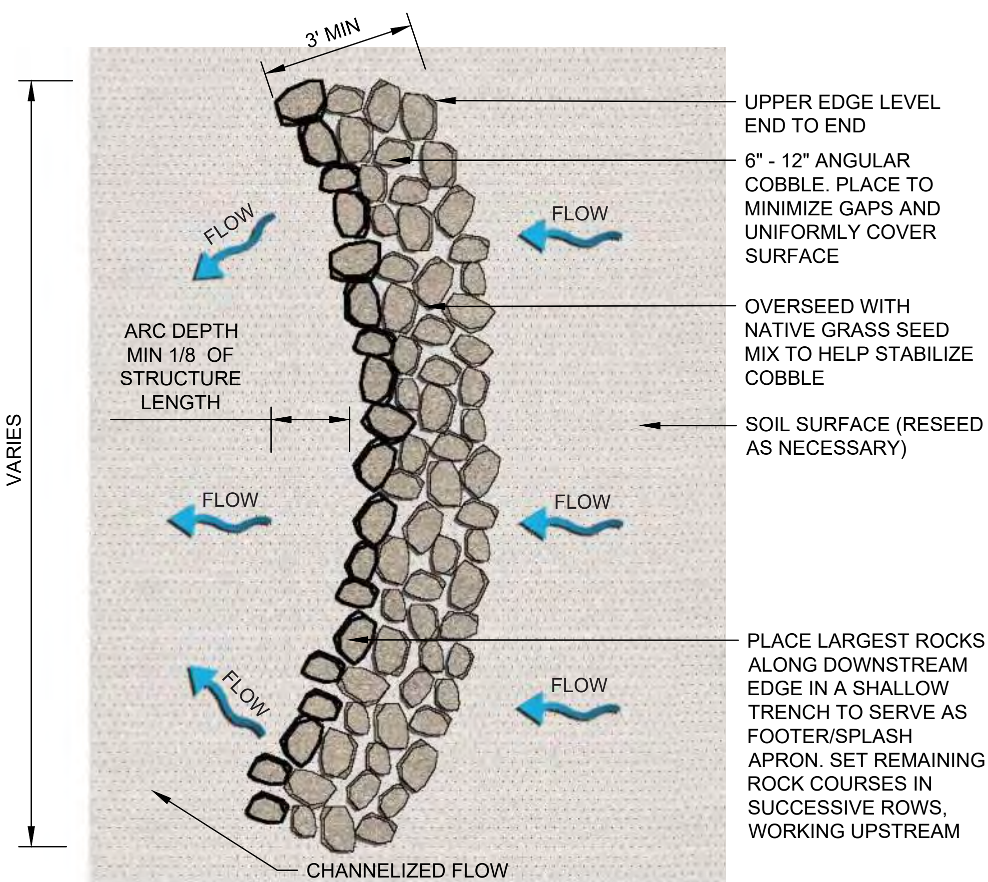


Media luna - PROFILE VIEW.

A3-4 MEDIA LUNA CONTINUED



Media luna as flow spreader - PLAN VIEW.



Media luna as flow concentrator - PLAN VIEW.

A3-5 FLOW LINE EXTENDER

DESCRIPTION

Flowline extenders are a series of linear structures placed across a stormwater flowline, causing the flowline to meander, thereby extending the length of its route. By making the length of the flow line longer, stormwater has more time to infiltrate, filter pollutants, and drop sediment.

PRIMARY USE

Use flow line extenders to slow peak flows, create wetland habitat, increase infiltration, and treat stormwater. Flow line extenders can be used in many different settings including:

» *Drainage channels and conveyance structures with sufficient right of way.*
» *Relatively wide, shallow sloped channels*
» *Parks and highly visible public spaces to showcase stormwater and educate the public about hydrology, green infrastructure, and wetlands.*
» *Wetlands, ponds or lake entrances and exits.*
» *Arroyos or channels in need of incised restoration.*

APPLICATION

Design strategies for successful flow line extenders include:

» *Armor or stabilize slopes of side channels to address scour and minimize erosion potential.*

LIMITATIONS

» *Unsuitable for highly erodible and/or collapsible soils.*

SEE ALSO

A3-4 *Media Luna*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

FLE

A3-5 FLOW LINE EXTENDER CONTINUED

MAINTENANCE REQUIREMENTS

» *Inspect after major storm events for scour, erosion and performance.*
» *Maintain planting as needed including pruning, weeding, mowing, fertilization, replacement, and pest control.*
» *Remove invasive plant material.*
» *Remove sediment.*

A3-6 BUFFER/FILTER STRIP

Image credit: RM Oberdorfer

A1
A2
A3

DESCRIPTION
Buffer/filter strips are transition spaces from paved surfaces to landscape areas or other BMPs. The strips are usually made up of vegetation and mulch and are positioned perpendicular to surface flows. The strips function by slowing runoff velocities, filtering out sediment and other pollutants, and facilitating stormwater infiltration into underlying soils.

PRIMARY USE
Buffer/filter strips are useful for initial erosion protection at the edge of hardened surfaces. Buffer/filter strips are well suited for treating runoff from roads and highways, roof downspouts, small parking lots, and pervious surfaces. They are also ideal components of the "outer zone" of a stream buffer.

APPLICATION
Design strategies for successfully using buffer/filter strips include:

» *Design the paving/filter strip interface so that runoff is flowing into the filter strip as sheet flow, not concentrated flow.*

LIMITATIONS
» *The buffer/filter strips have limited pollutant removal capability when used as standalone feature.*
» *Buffer/filter strips can require a large amount of space, typically equal to the impervious area they treat, which may limit their use.*
» *Buffer/filter strips are not suitable for steep slopes.*
» *Improper grading that creates concentrated flow can render the strips ineffective in terms of pollutant removal.*

SEE ALSO

A3-12 *Infiltration Trench*

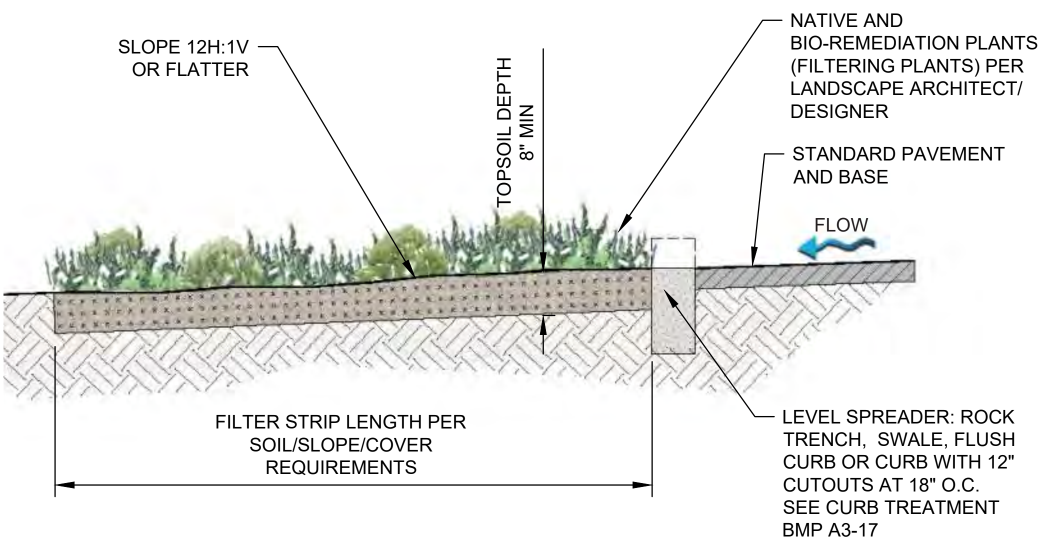
NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

Bu

A3-6 BUFFER/FILTER STRIP CONTINUED

MAINTENANCE REQUIREMENTS

- *Inspect annually.*
- *Remove accumulated sediment.*
- *Reseed/replant areas if needed to ensure continuous vegetative cover.*
- *Remove/grade encroaching vegetation adjacent to paving every five years.*



Filter strip - SECTION VIEW.

Filter strip - ISOMETRIC VIEW.

A3-7 WAFFLE SLOPE

Image credit: Sites Southwest

DESCRIPTION

Similar to Native American waffle gardens, a waffle slope creates a pattern of small ponds (or waffles) that create micro-watersheds that help sustain planting and revegetation. Stabilizing steep slopes with cobblestone and vegetation, the treatment greatly reduces erosion, allows for water infiltration, and slows stormwater.

PRIMARY USE

Waffle slopes are used where the erosive forces of upstream stormwater need to be controlled and where the stormwater can be harvested. Waffle slopes are effective in decreasing extreme soil erosion. The waffle slope soil stabilizing approach can be used for cut or fill slopes flatter than 2:1 but typically are used for steeper slopes on roadsides, interchanges, and other areas as an alternative to geoweb-type synthetics, where steep grading is necessary due to tight roadside grading conditions.

APPLICATION

Design strategies for waffle slopes include:

» *Use of site-quarried cobblestone and rock - set aside and reused on the slope.*
» *Use buried straw bales around trees planted in waffles to help with absorptions and slow release of stormwater.*
» *Establish standard waffle dimensions- typically 3 feet by 6 feet. Dimensions can be adjusted and vary depending on slope steepness and the length of the area to be treated.*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

WS

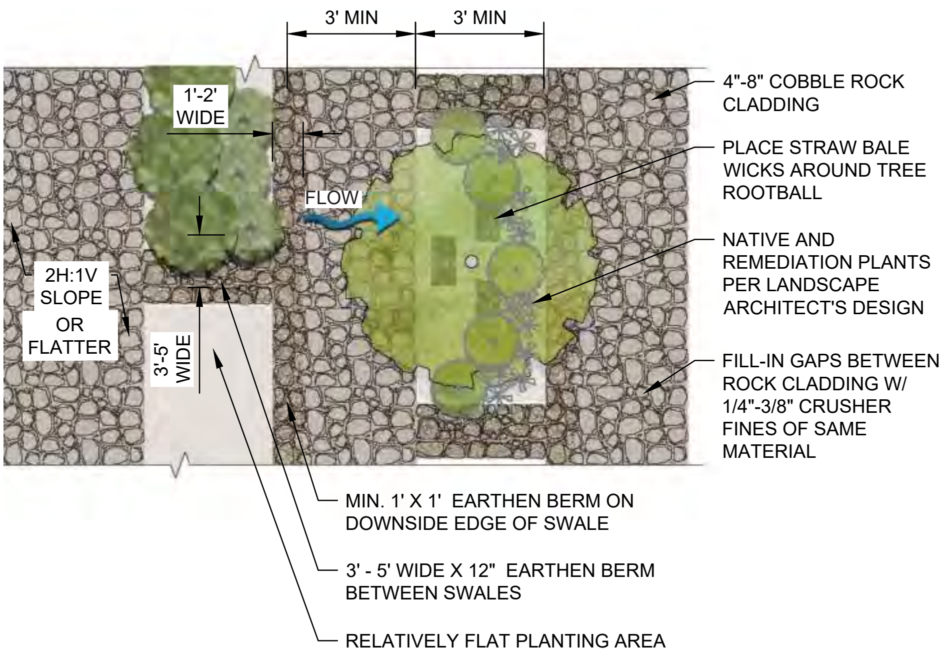
A3-7 WAFFLE SLOPE CONTINUED

LIMITATIONS

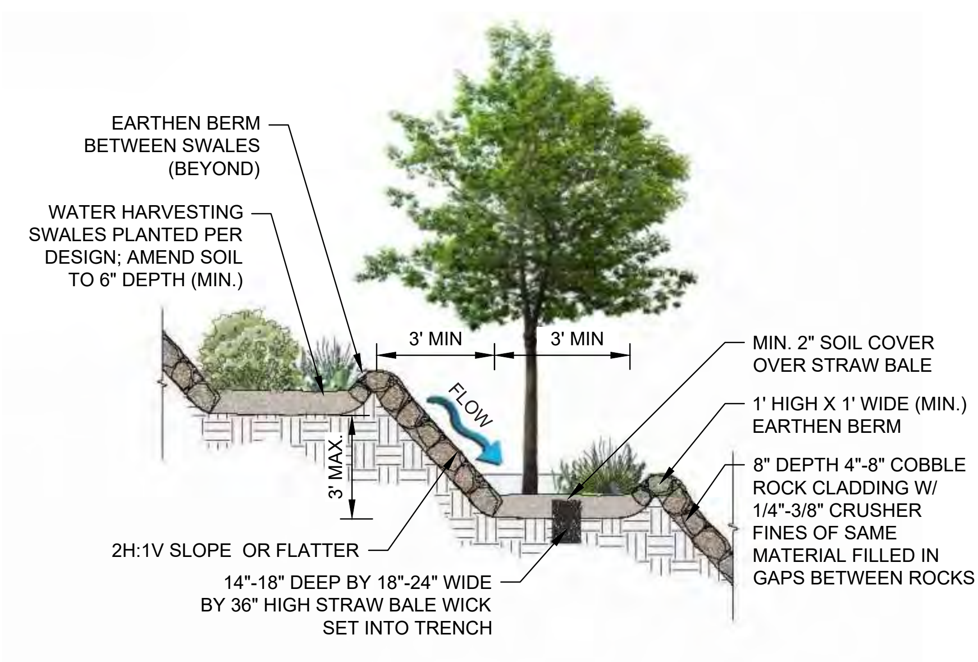
- *Difficult to build purely by mechanized earthmoving equipment - some handwork is necessary.*
- *Not suitable for areas in which bedrock or loose sedimentary rock layers are exposed by grading operations.*

MAINTENANCE REQUIREMENTS

- *Remove trash and weeds regularly.*
- *Prune and replace dead plant material as necessary.*
- *Inspect after storm events (100-year storm events or greater if designed correctly).*
- *Repair after storm events.*



Waffle slope protection - PLAN VIEW.



Waffle slope protection - SECTION VIEW.

A3-8 LIVE WATTLE

Image credit: Kathy Peterson

DESCRIPTION

A live wattle is typically a blend of carefully harvested live, onsite materials utilized to stabilize embankments, remove pollutants, and reduce erosion through filtration.

PRIMARY USE

Live wattles are used as a linear control BMP to promote vegetative growth. Wattles are used to slow, filter, and spread overland flows and can be installed on slopes with careful design and construction.

Live wattles are suitable for use in the following situations:

» *Shallow slopes.*
» *Site perimeters.*
» *Check dams in unlined ditches.*
» *Stream, ditch, and acequia embankments.*
» *Downslope of exposed soil areas.*
» *Around temporary stockpiles.*

APPLICATION

Strategies for the successful use of live wattles include:

» *Use live wattles only in low flow locations.*
» *Harvest live stakes in a dormant condition (fall or early spring) and bundle stakes in 6-8 inches diameter bundles.*
» *Trench along contour to a depth of 6-8 inches as determined by the wattle diameter and stake wattle to subsoil with either a live or dead stake.*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

LW

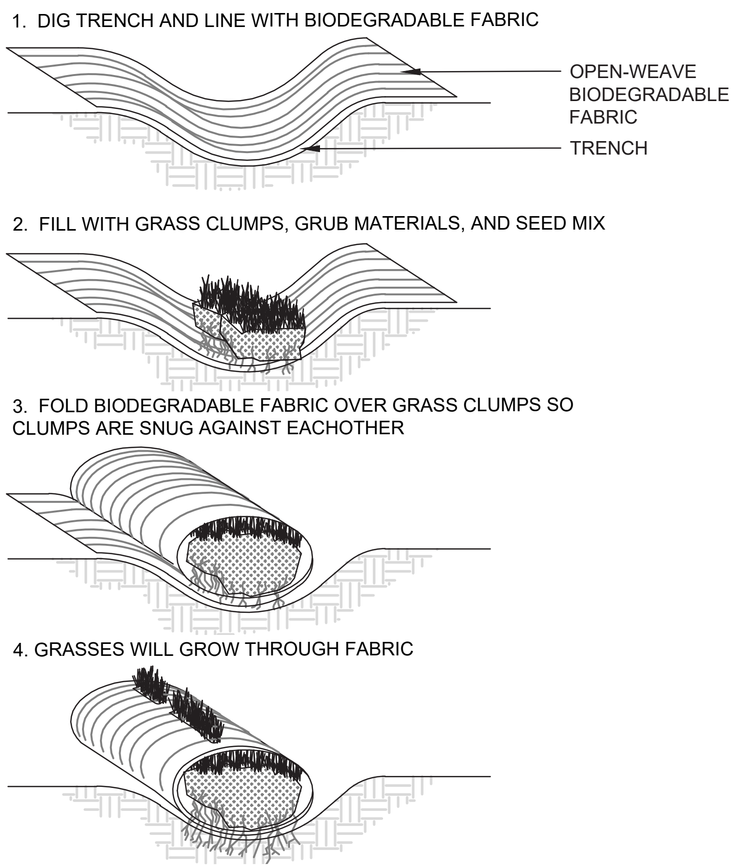
A3-8 LIVE WATTLE CONTINUED

LIMITATIONS

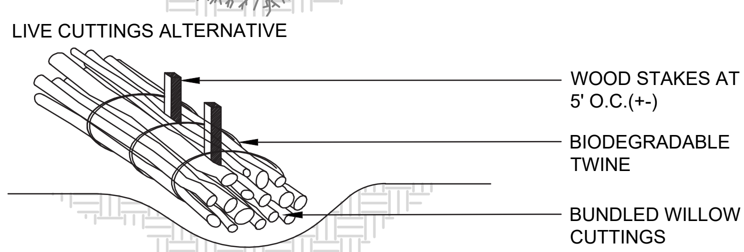
» *Can be disturbed or moved by high flows.*
» *Need to be used with perennial flows.*
» *Use may be limited by lack of available live vegetation in some regions.*

MAINTENANCE REQUIREMENTS

» *Inspect wattles bi-weekly.*
» *Reconstruct wattles if undermined or eroded.*



Installation sequence for fabric-wrapped live wattle.



Wood stakes alternative to live cuttings.

A3-9 DETENTION BASIN

Image credit: Sites Southwest

DESCRIPTION
A detention basin is an excavated basin with a restrictive outlet sized to slowly release collected stormwater runoff.

PRIMARY USE
Detention basins improve stormwater runoff quality by holding sediment laden runoff in an inactive state, allowing sediment and associated pollutants to settle out prior to discharge. Detention basins limit peak flow rate and velocities, provide a sedimentation area, and reduce downstream erosion. The basins are suitable for large scale projects where drainage can be channelized or otherwise conveyed into the basin.

APPLICATION
Detention basins can be utilized as a sediment control measure during construction phase and then modified to a permanent post-construction BMP. Strategies for successful detention basin design and construction are illustrated on the following pages.

LIMITATIONS
» *Not effective at removing liquid and dissolved pollutants.*
» *Requires appropriate topography for drainage consideration.*
» *Design must account for downstream and failure considerations.*
» *May become public welfare concern through vector concerns.*

MAINTENANCE REQUIREMENTS
» *Inspect bi-weekly and after major storm events.*

SEE ALSO

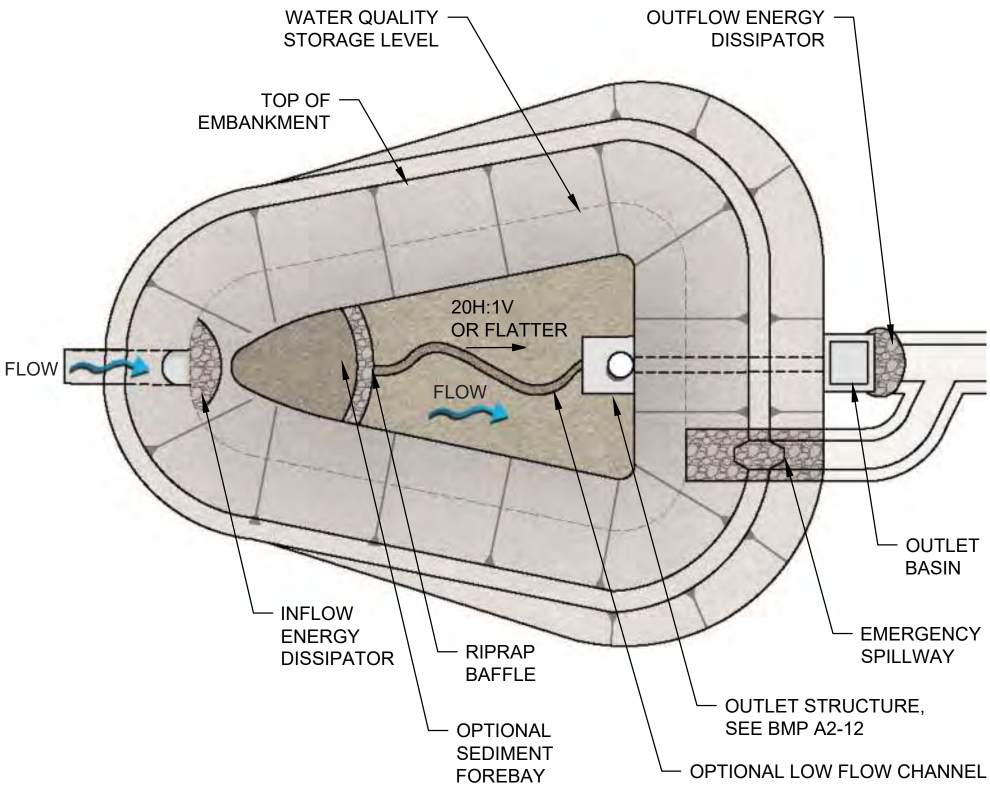
A2-11 *Sediment Basin*

A2-12 *Pond Outfall Structure*

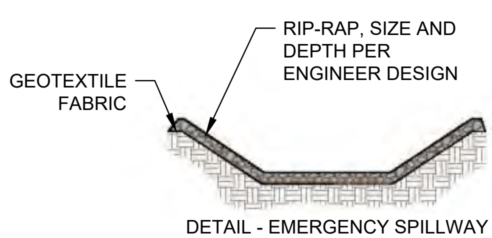
NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

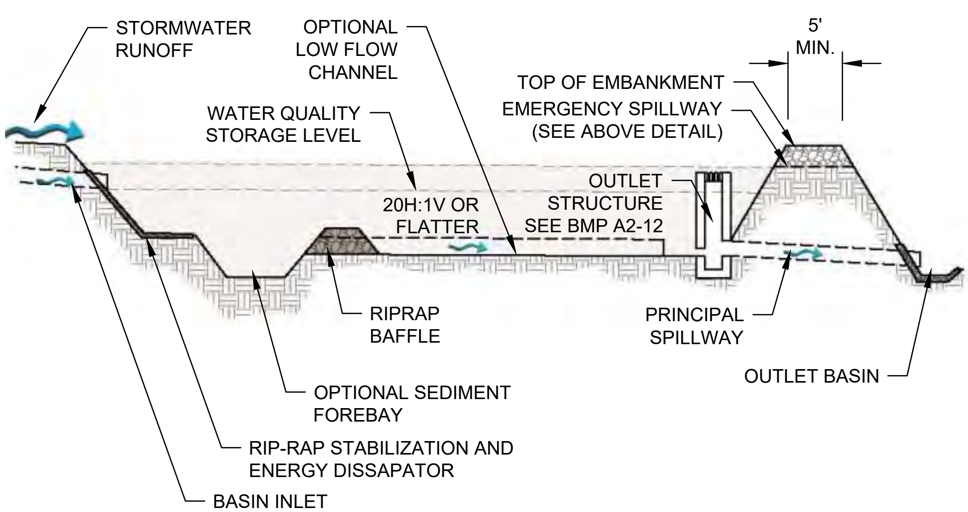
DB

A3-9 DETENTION BASIN CONTINUED



Detention basin - PLAN VIEW.





Detention basin - SECTION VIEW.

A3-10 BIO(RETENTION) SWALE

Image credit: University of California, Santa Barbara: Cheadle Center for Biodiversity & Ecological Restoration

DESCRIPTION

Bio(retention) swales are stormwater management features used to slow and treat runoff through vegetation and increasing infiltration.

PRIMARY USE

Bio(retention) swales are often used to treat runoff from large impervious areas, such as parking lots or roadways. Bio(retention) swales are also useful in open spaces, gore areas, and medians and can be flexibly designed in many configurations in urban conditions. The swales are lined with mulch and plant materials which aid in removing silt and solids from runoff. Bioretention features utilize engineered soil with small amounts of organic matter and aggregates to store, infiltrate, and treat stormwater. The "bio" in bioretention refers to plant material and phytoremediation processes that can remove, transfer, stabilize, and destroy contaminants found in stormwater. Additional water quality treatment can be achieved with specific soil additives such as zeolite that remove pollutants and heavy metals.

Bio(retention) swales are used to:

» *Reduce velocity and peak storm flows.*
» *Filter stormwater of sediment and pollutants.*
» *Extend stormwater detention and storage.*
» *Adsorb some pollutants and heavy metals.*
» *Provide supplemental water for plantings.*
» *Convey excess stormwater.*
» *Improve street side and parking lot aesthetics.*

SEE ALSO

A3-3 *Rock Check Dam*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

BRS

A3-10 BIO(RETENTION) SWALE CONTINUED

APPLICATION

Strategies for successful bio (retention) swale design include:

- *Use a hard edge like a flush curb or raised concrete curbs with curb cuts where drainage occurs along the interface of paving and the swale.*
- *Identify and use a suitable soil blend - typically 85% sand, 8-12% fines and under 2-5% plant-derived organic material with a recommended minimum infiltration rate of 6 inches per hour.*
- *Provide a 10 foot setback from structural foundations.*
- *Limit the grades of slopes draining to the bio(retention) swale to 15% or less. Side slopes should be 3H:1V or flatter and the longitudinal slope of the swale shall be determined by the storm event flow velocity.*
- *Construct a rock-armored forebay for trash/sediment removal and velocity reduction at concentrated inflow locations.*
- *Add check dams within the swale to pond water for increased infiltration.*

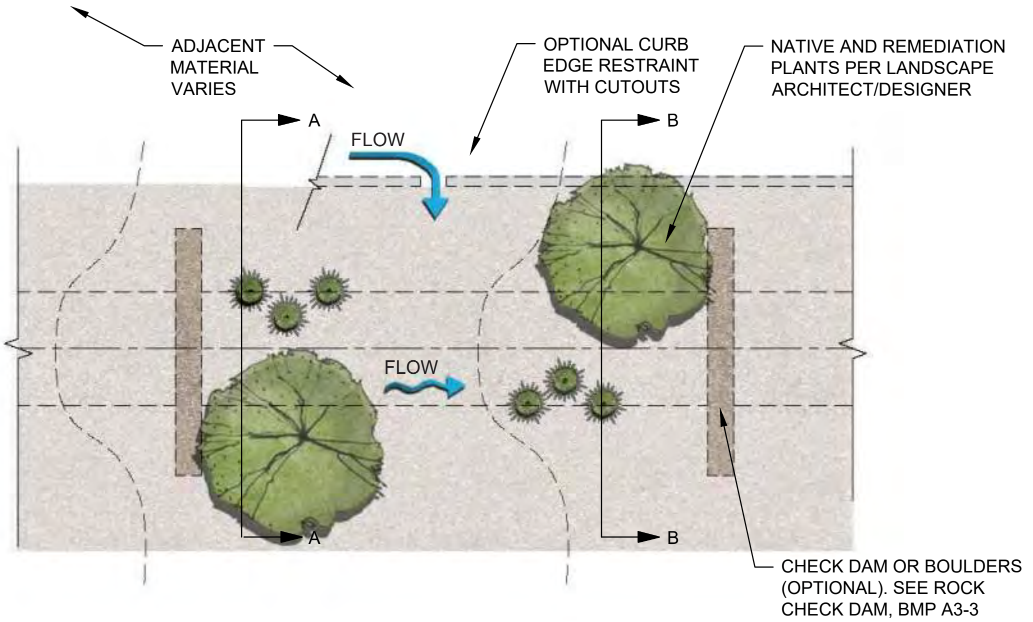
LIMITATIONS

- *Site investigation is important for successful implementation.*
- *Infiltration of ponded water in the bio(retention) swales is dependent on the porosity of subsurface soils. Impermeable subsoil layers may require an underdrain. Underdrains shall be connected to other BMP features, stormwater sewers or drainage facilities.*
- *Governing codes, standards and regulations may not allow stormwater harvesting on top of utilities.*
- *Supplemental irrigation is recommended to establish and maintain vegetative health in arid southwest regions.*
- *Not suitable for steep slopes with high velocity flows. Maximum flow velocity should not exceed 3 feet per second.*
- *Not suitable at locations with high water tables that will reduce infiltration below acceptable rates.*
- *Not suitable for installation where contaminated soil is a concern.*

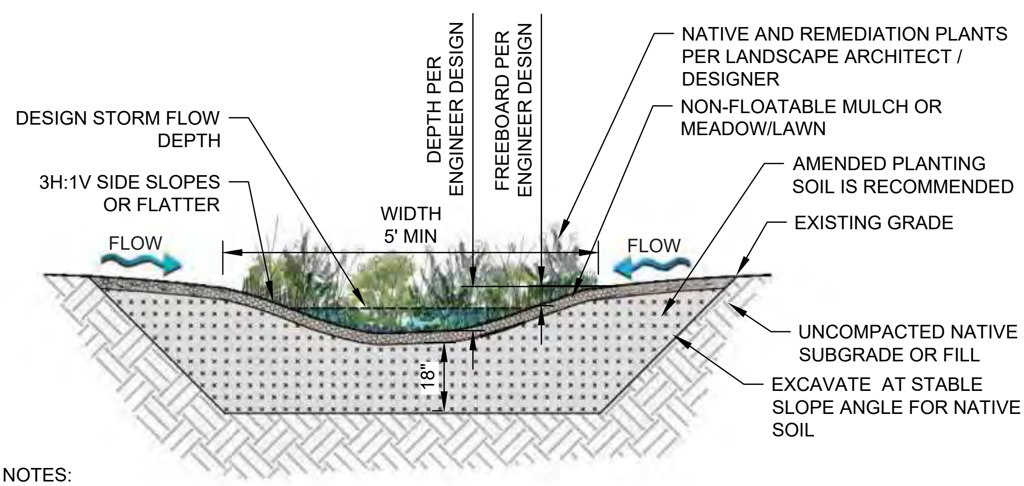
MAINTENANCE REQUIREMENTS

- *Inspect swales after major storm events during and post-construction.*
- *Inspect and maintain swales semi-annually for excessive sediment and debris build-up, significant mulch relocation due to water velocity, damaged vegetation and berm damage.*
- *Remove and replace dead vegetation.*
- *Restore surface soils by scarifying surface to improve percolation.*
- *Maintain planting as needed including pruning, weeding, mowing, fertilization, replacement, and pest control.*
- *Remove trash regularly.*

A3-10 BIO(RETENTION) SWALE CONTINUED



Bio(retention) swale - PLAN VIEW.



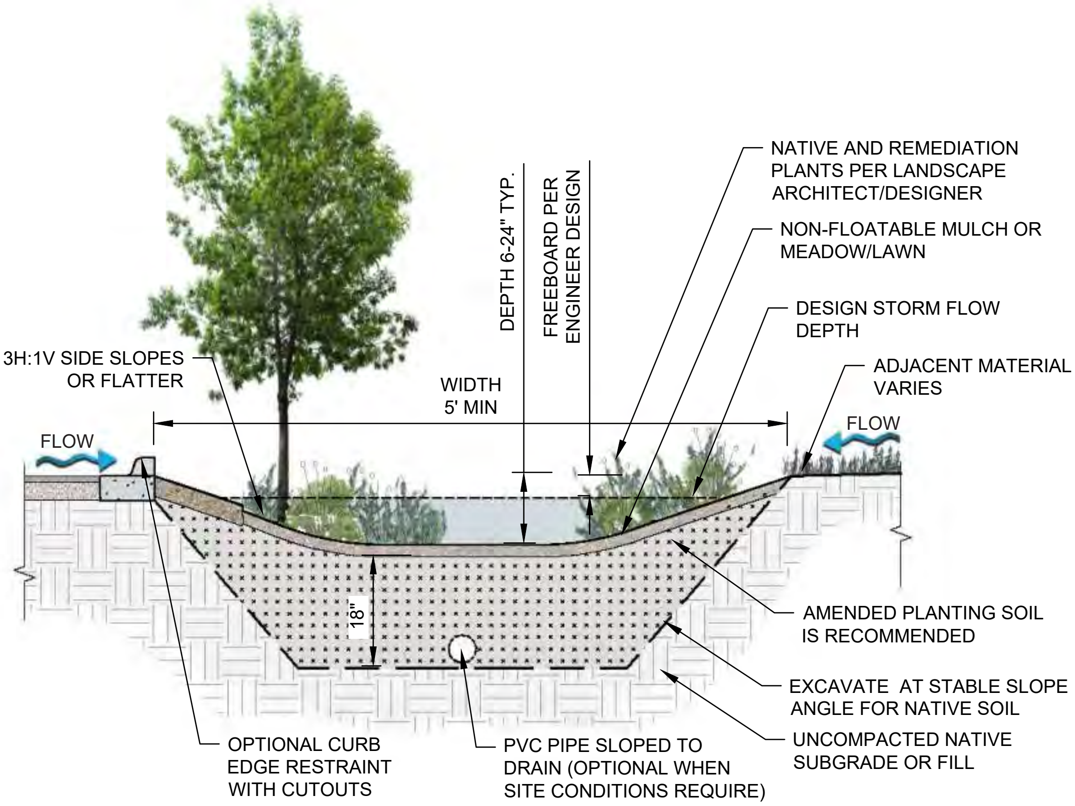
NOTES:

1. CHECK DAMS AND/OR BOULDERS MAY BE ADDED TO DECREASE FLOW VELOCITY, ENCOURAGE INFILTRATION AND MINIMIZE EROSION.
2. TREES AND SHRUBS SHOULD BE LOCATED AT THE EDGES OF THE SWALE TO MINIMIZE DURATION OF EXPOSURE TO SATURATED SOIL CONDITIONS.

Bio(retention) swale without hard edging - SECTION A-A.

Typical bio(retention) swale without hard edging - ISOMETRIC VIEW.

A3-10 BIO(RETENTION) SWALE CONTINUED



Bio(retention) swale with hard edging - SECTION B-B.

Typical bio(retention) swale with hard edging - ISOMETRIC VIEW.

A3-11 STORMWATER HARVESTING BASIN

Image credit: Tess Houle

DESCRIPTION

Stormwater harvesting basins are shallow stormwater areas without engineered soil that are typically designed to collect and infiltrate stormwater runoff to support native vegetation.

PRIMARY USE

Stormwater harvesting basins are an effective and relatively inexpensive practice for reducing stormwater volumes, controlling release rates of stormwater, and displaying green infrastructure practices. Benefits of stormwater harvesting basins include:

- » *Regulate stormwater discharge rates and volumes by enhancing infiltration.*
- » *Improve water quality.*
- » *Provide supplemental irrigation for plantings.*
- » *Improve aesthetics: well designed and vegetated water harvesting basins are often well received by the public for their aesthetic qualities.*

Stormwater harvesting basins are typically less than 12 inches in depth, and frequently located high in the watershed as opposed to detention basins which are usually found further downstream. They are useful in many different contexts including streets and roadways with adequate rights-of-ways, open space, commercial/institutional sites, pedestrian corridors, parks, medians, and gore areas.

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

SHB

A3-11 STORMWATER HARVESTING BASIN CONTINUED

APPLICATION

Strategies for successful stormwater harvesting basin design include:

» *Design an upstream inlet bypass mechanism for flood events.*
» *Consider sediment traps at the inlet(s) to decrease sediment load.*
» *Follow AASHTO roadway clear zone requirements if the stormwater harvesting basin is next to a travel lane.*
» *Design an overflow directing flows to a watercourse or other green infrastructure feature for major storm events.*
» *Provide interpretative signage at the basin to provide an opportunity to educate the public about stormwater.*
» *Design basins to be compliant with local and state provisions to infiltrate stormwater in specified amounts of time.*
» *Design side slopes no steeper than 3H:1V and line slopes with rock lining or other erosion control measures as necessary.*
» *Consider climate conditions and periodic saturated soil conditions when selecting and placing plant materials at stormwater harvesting basins.*
» *Include supplemental irrigation to establish plant materials and maintain plant health in arid conditions. Under certain conditions, the irrigation systems may be removed/disconnected after plant establishment.*
» *Design plant and mulch installation without filter fabric at stormwater harvesting basins.*
» *Protect soils from compaction during construction.*

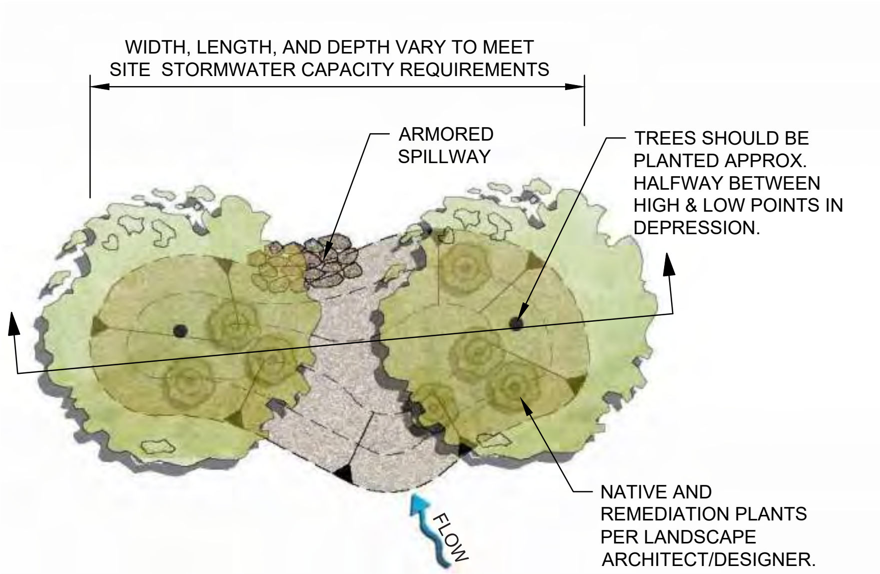
LIMITATIONS

» *Supplemental irrigation is recommended to establish and maintain plant health in arid conditions.*
» *Not suitable in poorly drained soils, caliche, bedrock or near sensitive infrastructure.*
» *Not suitable for installation where contaminated soil is a concern.*
» *Prolonged surface water storage can be a vector concern and can harm plants.*
» *Governing codes, standards and regulations may not allow stormwater harvesting on top of utilities.*

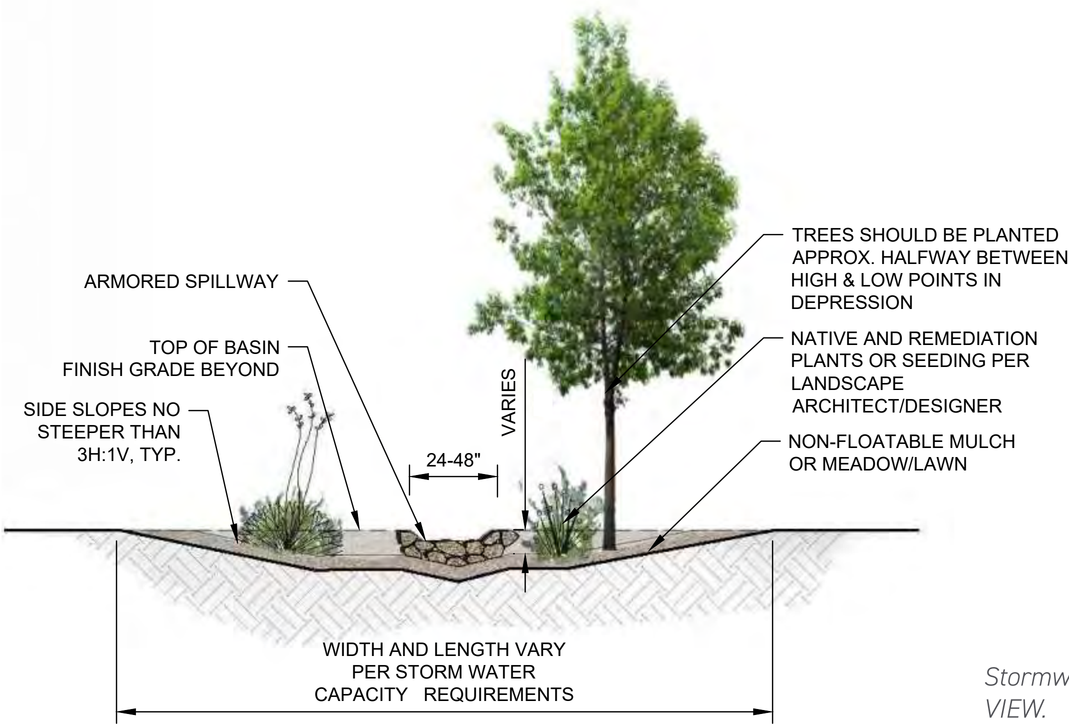
MAINTENANCE REQUIREMENTS

» *Inspect basins after major storm events.*
» *Inspect and maintain basins semi-annually for excessive sediment and debris build-up, significant mulch relocation due to water velocity, prolonged surface water storage, damaged vegetation and side slope damage.*
» *Remove invasive/advantageous plant material.*
» *Remove sediment, debris, and floatables.*
» *Maintain planting as needed including pruning, weeding, mowing, fertilization, replacement, and pest control.*
» *Stabilize and repair minor erosion.*
» *Regrade pond bottom if significant sedimentation occurs.*

A3-11 STORMWATER HARVESTING BASIN CONTINUED



Stormwater harvesting basin - PLAN VIEW.



Stormwater harvesting basin - SECTION VIEW.

A3-12 INFILTRATION TRENCH

Image credit: Blue-Green Building

DESCRIPTION

An infiltration trench is a filter fabric-wrapped, coarse aggregate-filled trench that collects runoff from adjacent impervious surfaces and infiltrates stormwater into subsoils.

PRIMARY USE

Infiltration trenches are passive underground storage basins - temporarily storing and then infiltrating stormwater below grade between gravels. Infiltration trenches are used in and along roadways and medians where space is limited. Infiltration trenches may be used in concentrated flow areas. They are particularly useful where site conditions are prone to slow drainage such as flat areas, and locations where there are no connections to traditional underground storm drain systems.

Infiltration trenches provide valuable benefits:

» *Reduce stormwater runoff volumes and velocity.*
» *Improve water quality.*
» *Provide supplemental irrigation water for plantings, when combined with vegetation.*

SEE ALSO

A3-6 *Buffer/Filter Strip*

A3-13 *Dry Well*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

TR

A3-12 INFILTRATION TRENCH CONTINUED

APPLICATION

Strategies for designing successful infiltration trenches include:

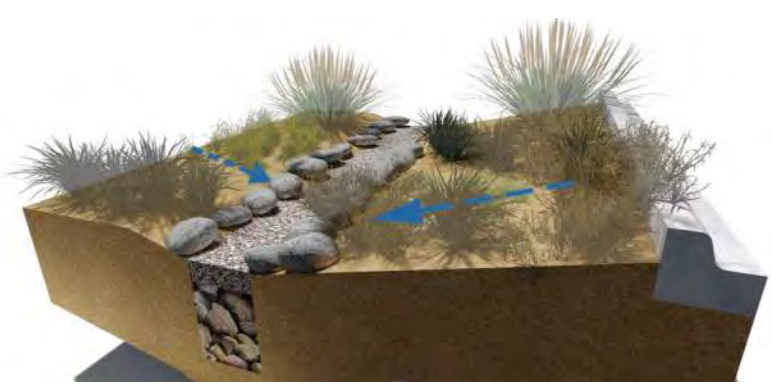
» *Include upstream pretreatment of stormwater (e.g. filter strips) to prevent clogging.*
» *Install a sand filter or oil/grit separator or mechanical settling tank if design directs stormwater into a drop inlet prior to discharge into the infiltration trench.*
» *Specify stone aggregate trench infill and require that it is uniformly graded, washed and contains 40% void capacity such as AASHTO No.3 aggregate.*
» *Protect subsoils from compaction during construction.*
» *Install a perforated pipe underdrain system where warranted to convey stormwater and/or act as an overflow.*

LIMITATIONS

» *Not suitable for vegetation growth within the trench, however a vegetated filter strip adjacent to the trench is recommended to filter sediment from paved surfaces. Vegetation shall not interfere with the trench drainage characteristics.*
» *Not suitable in locations with high water tables.*
» *Not suitable for steeper grades presenting velocity and flow control challenges.*
» *Not suitable for soils with an infiltration rate less than 0.5 in./hr.*
» *If perforated pipe is used, confer with NMED regarding applicability of UIC Class V well permitting requirements.*
» *Governing codes, standards and regulations may not allow stormwater harvesting on top of utilities.*

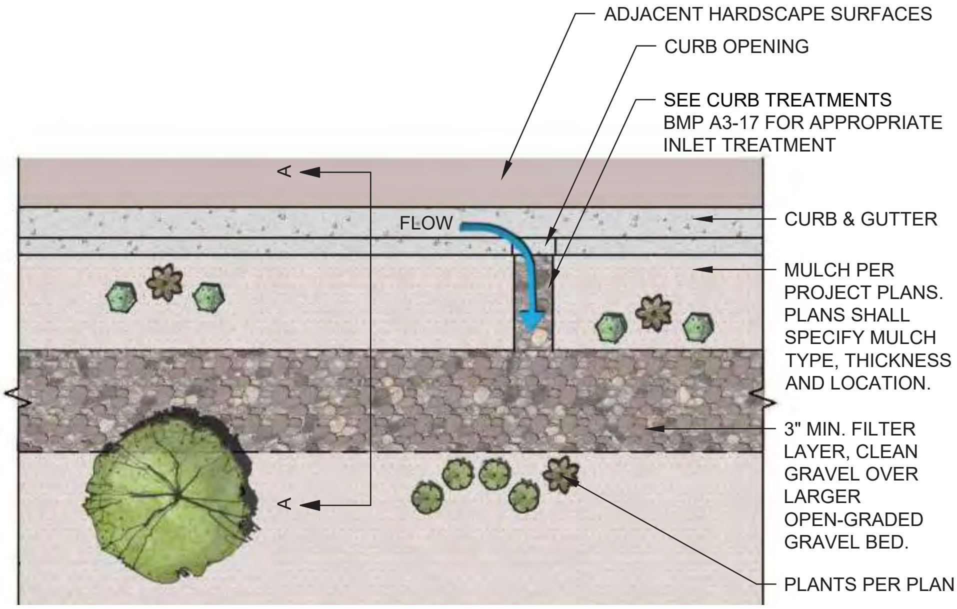
MAINTENANCE REQUIREMENTS

» *Inspect annually and after major storm events (maintenance is required if water stands longer than 24 hours).*
» *Clean or replace sediment build-up in the top gravel layer. Resurfacing, patching or sealing of adjacent asphalt paving will contribute to emulsified asphalt particulate runoff and reduce infiltration capacity of top layer gravels.*
» *Remove and replace gravel and filter fabric if infiltration rates decrease substantially.*
» *Clean perforated pipe conveyance system if utilized in design.*
» *Inspect and maintain encroaching vegetation.*

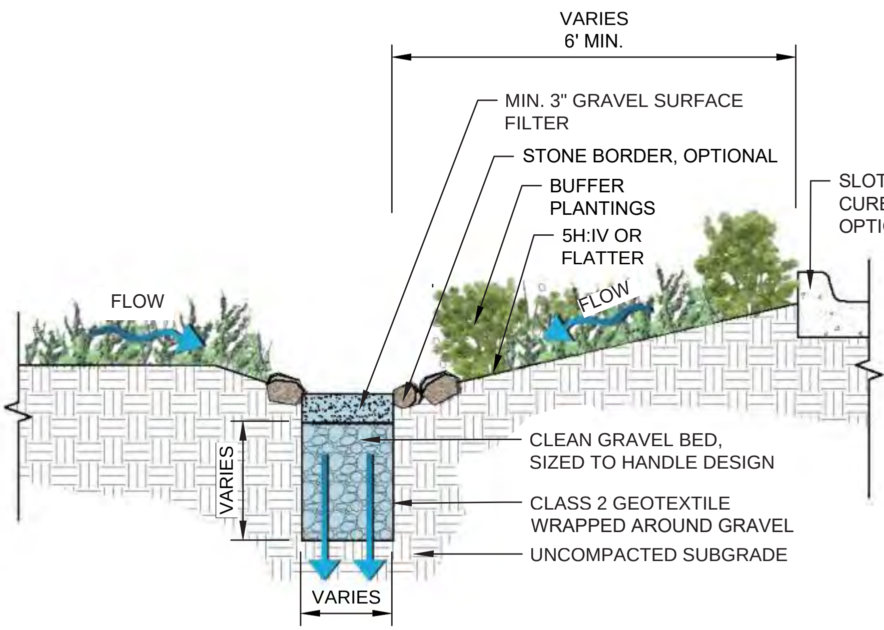


Infiltration trench - ISOMETRIC VIEW.

A3-12 INFILTRATION TRENCH CONTINUED



Infiltration trench - PLAN VIEW.



Infiltration trench - SECTION A-A.

A3-13 DRY WELL

Image credit: Eco Plumber

DESCRIPTION

A dry well is an excavation (often an augured hole) filled with gravel and used to hold stormwater. A dry well works in a similar manner to an infiltration trench, but is a vertical, deeply excavated hole - often only a few feet in diameter. Because of their vertical form and relatively small footprint, drywells are useful stormwater management tools for confined urban areas and in conditions where much of the surface soil condition has low or no permeability.

PRIMARY USE

Dry wells are used to collect, retain, and infiltrate stormwater in confined site situations such as parking lot islands and roadways. Dry wells are suitable for deep infiltration when soil conditions such as clay, caliche or tuft limit percolation rates.

APPLICATION

A dry well is traditionally created by excavating a deep hole, lining the hole with geotextile fabric and filling the hole with aggregate. The fabric is used to prevent fine soil particles from filling the voids in the aggregate. There are also manufactured pre-cast concrete dry wells that can be used independently or as part of a larger stormwater management system to collect, retain, and discharge stormwater without the use of gravel.

Strategies for successful design and installation of drywells include:

» *Specify stone aggregate and require that it is uniformly graded, washed and contains 40% void capacity such as AASHTO No.3 aggregate.*
» *Evaluate the need for an overflow connection to a downstream system due to anticipated capacity requirements and design accordingly.*

SEE ALSO

A3-12 *Infiltration Trench*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

DW

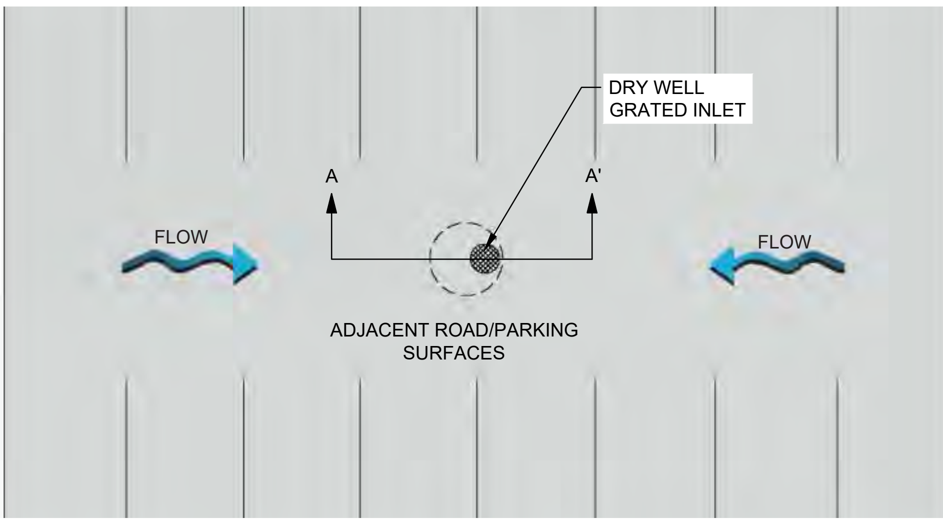
A3-13 DRY WELL CONTINUED

LIMITATIONS

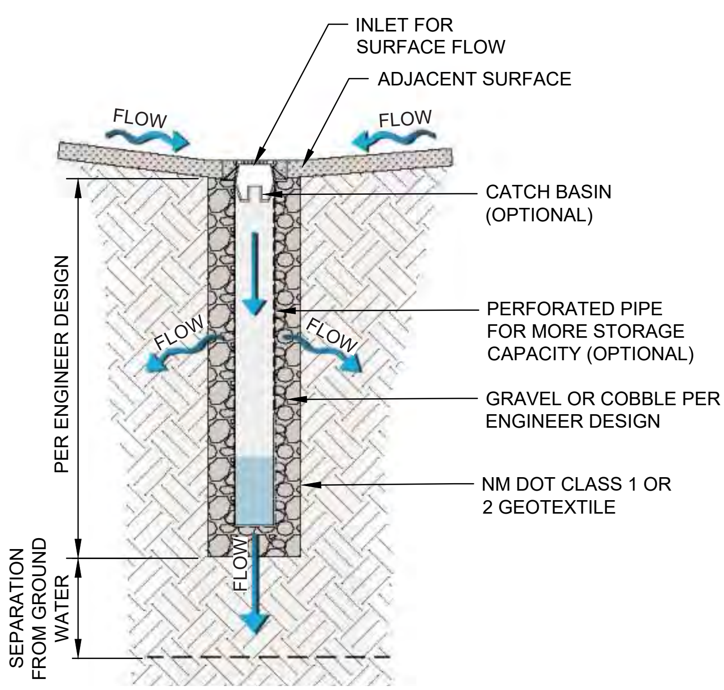
» *NMED UIC Class V well permitting requirements: a dry well may need to be permitted as a Class V well by the New Mexico Environment Department. Confer with NMED during BMP selection and design.*
» *Bedrock or formational materials may limit infiltration.*
» *Stormwater reuse is limited.*
» *Stormwater pre-treatment is recommended to limit sediment and debris from entering dry well.*
» *Unsuitable for contaminated sites and sites with high groundwater.*

MAINTENANCE REQUIREMENTS

» *Inspect annually and after major storm events.*

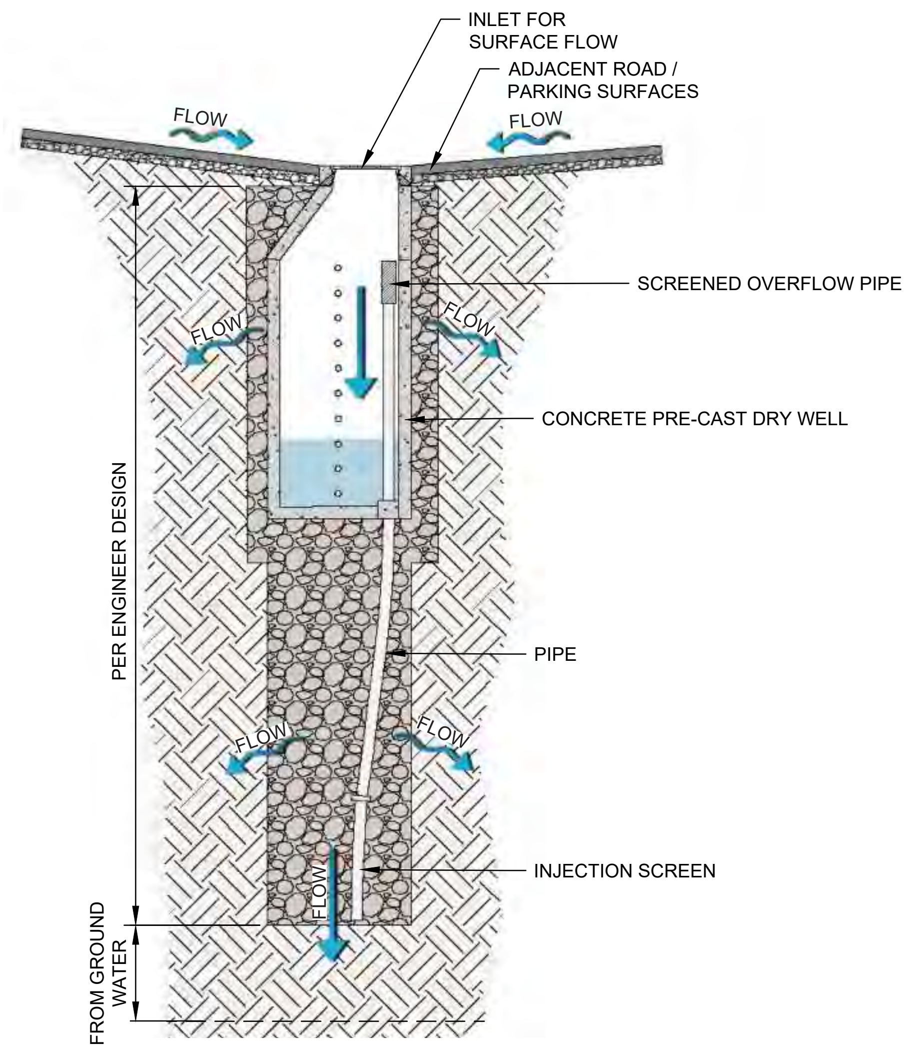


Example of dry well in parking area - PLAN VIEW.



Example of perforated pipe dry well in parking area - SECTION A-A.

A3-13 **DRY WELL** CONTINUED



Example of concrete dry well in parking area - SECTION A-A.

A3-14 BELOW GRADE STORAGE

Image credit: Wikipedia

DESCRIPTION

Below grade storage is the capture and temporary storage of stormwater collected from surrounding impervious surfaces. Stormwater is stored subsurface in individual or interconnected manufactured units or systems.

PRIMARY USE

Below grade storage is a useful, but relatively expensive practice for reducing peak water flows in specific circumstances:

» *Confined or constrained site conditions where surface stormwater storage is not possible, limited or not the highest and best use of the land.*
» *Zero discharge sites such as some industrial facilities where stormwater must be held on site and/or contained in a specific area.*

Below grade storage is typically used under surface parking lots, in industrial areas, and in other urban locations with low sediment loads, and a lack of available surface area. Water from below grade storage systems can be released into the larger stormwater management system, used for automated irrigation, or allowed to infiltrate into the ground if conditions allow. Below grade systems are good options for high density urban areas, are durable, long lasting, and can be constructed rapidly using prefabricated modular systems.

APPLICATION

Strategies for successful design of below grade storage includes:

» *Design an upstream pre-treatment system to collect sediment and debris prior to entering the storage system.*
» *Design sufficient personnel access points for easy maintenance.*

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(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
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A3-14 BELOW GRADE STORAGE CONTINUED

APPLICATION *CONTINUED*

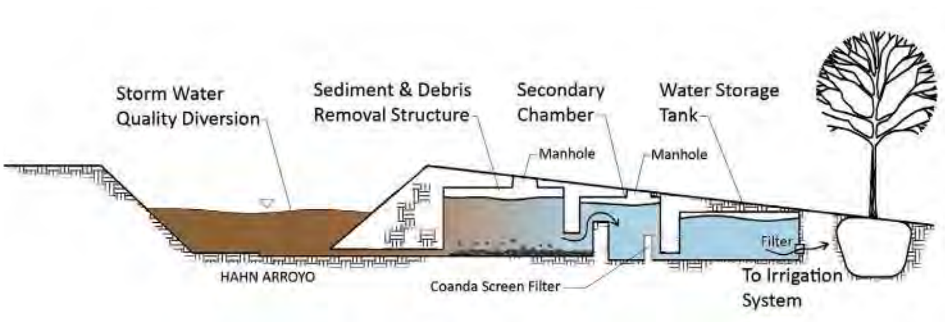
» *Include an emergency overflow system to convey excess flows to an appropriate location.*
» *Install rip rap at the outflow.*
» *Require use of experienced engineers, suppliers, and installers.*

LIMITATIONS

» *Does not substantially improve water quality.*
» *Difficult to inspect and maintain.*
» *Relatively expensive BMP.*
» *Standing water may create mosquito habitat.*
» *NMED UIC Class V well permitting requirements: below grade storage may need to be permitted as a Class V well by the New Mexico Environment Department. Confer with NMED during BMP selection and design.*

MAINTENANCE REQUIREMENTS

» *Inspect monthly and after major storm events.*
» *Remove accumulated sediment using vacuum truck if sediment impacts system function.*



Example of below grade storage - SECTION VIEW.

Image credit: Tierra West and Sites Southwest

Below grade storage cleanout access during and after construction.

A3-15 PERMEABLE/ALTERNATIVE PAVEMENT

Image credit: Sites Southwest

DESCRIPTION

Permeable pavement refers to any one of several types of pavements and surface hardening that allows infiltration of stormwater below the pavement surface.

PRIMARY USE

Permeable paving materials provide an alternative to standard impermeable/impervious pavements in both vehicular and pedestrian areas. Permeable paving is suitable in urban settings with pedestrian traffic or lower volume vehicular traffic. Permeable pavings can be utilized to improve flood control, reduce nuisance drainage, and improve adjacent vegetation by infiltrating stormwater to root systems.

APPLICATION

Strategies for successful design and use of permeable paving include:

» *Select the most appropriate permeable pavement type for the use and location.*
» *Design subgrade per local conditions and manufacturer's recommendations.*
» *Design landscape areas in and adjacent to paving.*
» *Evaluate the need for an underdrain system and design accordingly.*
» *Require use of experienced engineers, suppliers, and installers.*

LIMITATIONS

» *Not appropriate where offsite flows with high sediment loading are entering the paved area as clogging might occur.*
» *Permeable pavement might require a hard edge (e.g. flush concrete curb).*

SEE ALSO

A3-16 *Green Parking*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

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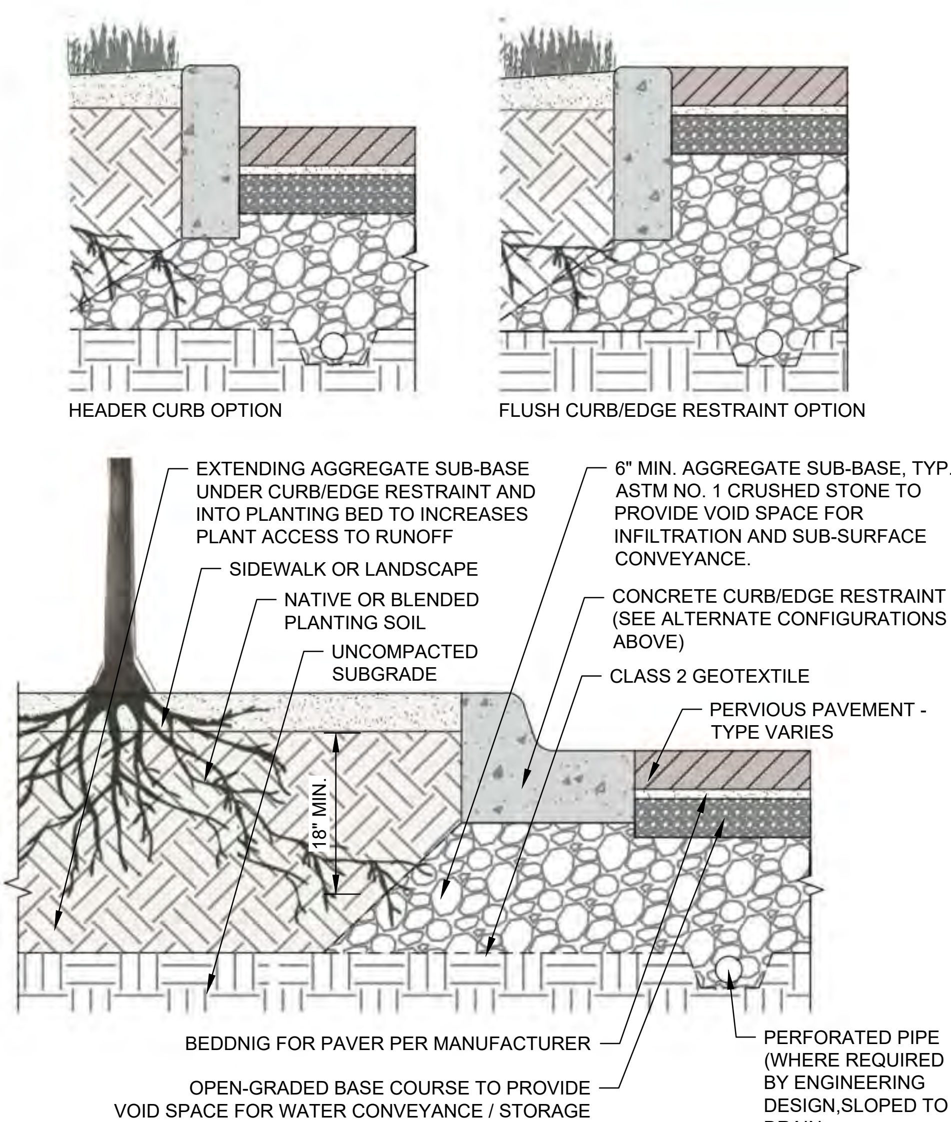
A3-15 PERMEABLE/ALTERNATIVE PAVEMENT CONTINUED

MAINTENANCE REQUIREMENTS

» *Inspect monthly and after major storm events.*
» *Vacuum pavement if inspections observe clogging or perviousness of paving is diminished. Vacuum only if recommended by manufacturer.*

Image credit: Sites Southwest

Example of permeable parallel parking with header curb and flush curb at edges.



Various curb options for permeable pavement systems.

A3-16 GREEN PARKING

Image credit: Environmental Consulting and Technology/ Jason Cooper

DESCRIPTION
Green parking refers to a broad spectrum of design techniques that when used in combination result in new types of functional parking areas that are more pervious, have lower amounts of runoff and higher levels of infiltration.

PRIMARY USE
Green parking techniques can be applied to new parking lot construction and parking lot renovations. From a stormwater perspective green parking techniques, such as permeable paving and bioretention swales, can dramatically reduce impervious cover and the amount of stormwater runoff. Additionally, increased stormwater infiltration can improve the growth and viability of parking lot trees, increase shade, reduce the urban heat island effect, and create a more hospitable environment for users.

APPLICATION

Strategies and techniques for creating successful green parking lots include:

» *Utilize permeable pavement to the extent it works for the project: throughout the parking lot, just in parking spaces or only in overflow parking areas.*
» *Set maximums for the number of parking spaces created.*
» *Minimize the dimensions of parking lot spaces.*
» *Direct runoff to landscape areas to supplement irrigation for plants.*
» *Encourage shared parking.*
» *Provide economic incentives for parking structures.*

SEE ALSO

A3-12 *Infiltration Trench*

A3-15 *Permeable/ Alternative Pavement*

A3-17 *Curb Treatment*

A3-18 *Depressed Median*

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(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
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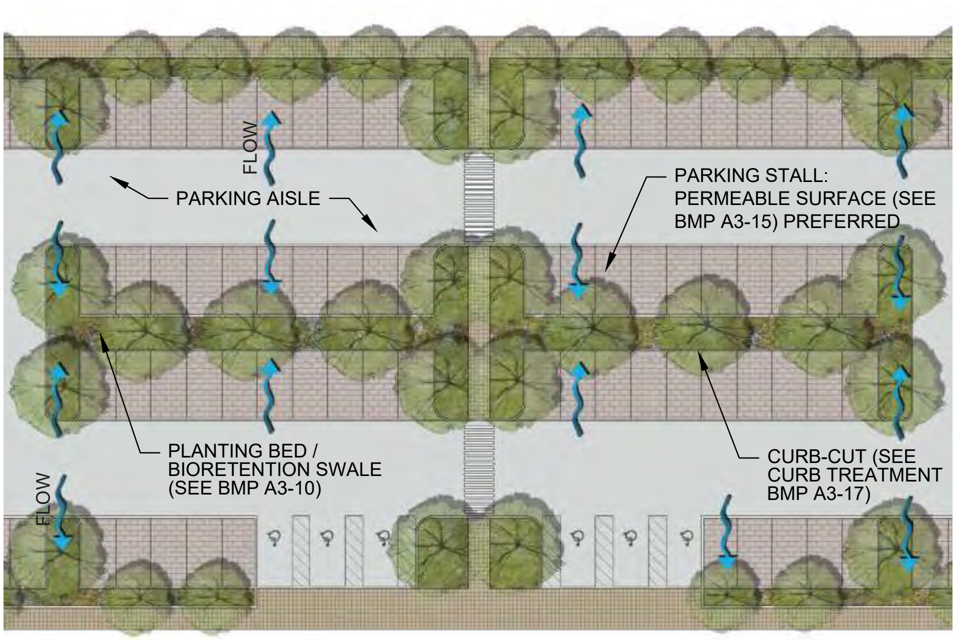
A3-16 GREEN PARKING CONTINUED

LIMITATIONS

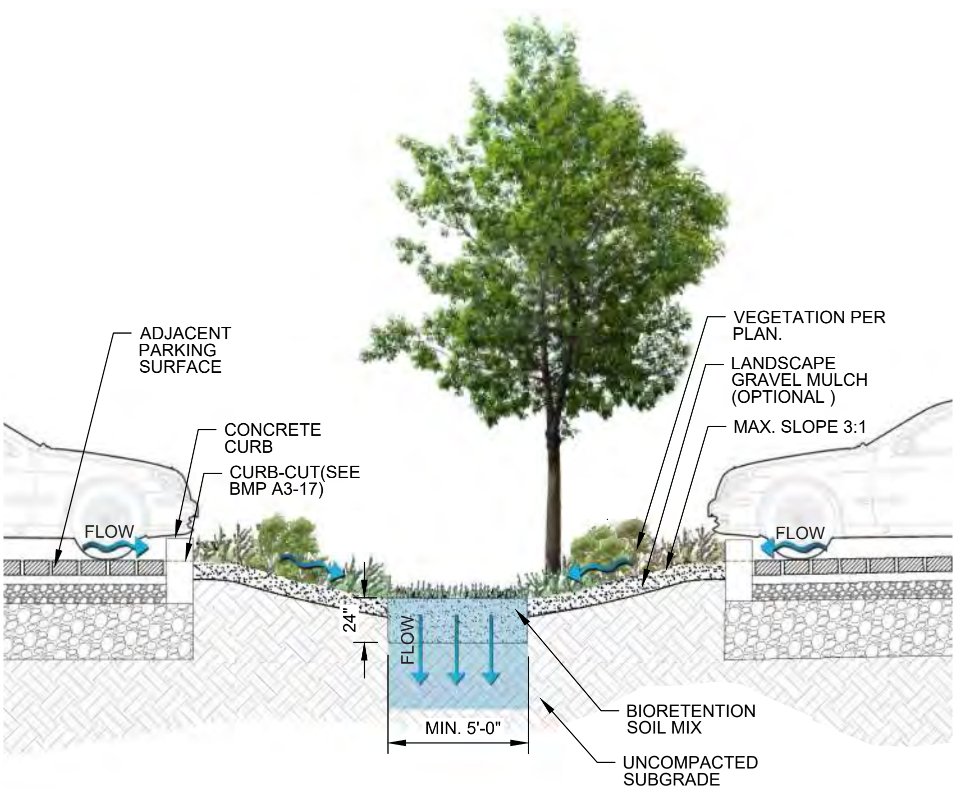
» *Applicability, cost, and maintenance.*

MAINTENANCE REQUIREMENTS

» *Sweep permeable areas. Vacuum if recommended by product manufacturer.*
» *Collect debris and trash regularly.*



Green parking example layout - PLAN VIEW.



Green parking example layout with infiltration trench - SECTION VIEW.

A3-17 CURB TREATMENT

Image credit: Sites Southwest

DESCRIPTION

Curb treatments are roadway design features that interrupt the typical concentration of stormwater flows at the flow lines of concrete curbs and gutters and redirect some stormwater runoff into curbside green stormwater infrastructure interventions.

PRIMARY USE

Curb treatments can be used in both renovations and new construction to convey stormwater from an impervious surface to a green stormwater infrastructure features. Curb treatments are suitable along roadways, in medians, at parking islands, and parking lots. Curb treatments can be designed to reduce peak flows by redirecting stormwater off of the street and into landscape areas where water can infiltrate. The stormwater can be used to supplement irrigation to curbside plantings which helps reduce the urban heat island effect, and provides beauty and habitat.

There are three primary types of curb treatments:

Curb cuts

Curb cuts (or curb penetrations) are strategically located openings in the curb that serve as inlets and outlets to and from streets, a connection to a storm drain, or a connection to other green stormwater infrastructure interventions. Curb cuts on either side of a chicane (bump out) act as inlets and outlets for stormwater conveyance.

SEE ALSO

A3-3 *Rock Check Dam*

A3-10 *Bio(Retention) Swale*

A3-18 *Depressed Median*

NMDOT STANDARD DRAWING

609-01-1/1 Sidewalk Curb and Gutter

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
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A3-17 CURB TREATMENT CONTINUED

PRIMARY USE *CONTINUED*

Flush Curbs

Flush curbs are sometimes referred to as estate curbs and consist of curbs that are flush with adjacent pavement. The flush surface, as opposed to typical gutters, helps to decrease the concentration of stormwater flows by allowing water to sheet flow into permeable areas such as gravel shoulders, landscaped areas and basins, and vegetated filter strips.

Chicanes

Chicanes are stormwater curb extensions or bump outs that add curves to an otherwise straight roadway. The bump out space is capable of infiltrating stormwater and accommodating streetscape planting. Chicanes also serve as traffic calming devices and have been used on many New Mexico mainstreets.

APPLICATIONS

Strategies for designing curb treatments include:

» *Protect inlets from scour with angular riprap or stone, sediment traps or sediment cleanout forebays.*
» *Consider use of short fences or other barriers to prevent pedestrians stepping into a recessed area.*
» *Limit potential effects of soil saturation adjacent to roadway paving and infrastructure.*
» *Consider use of permeable gutter pans: a curb treatment option that is less common but potentially beneficial for use independently or in combination with the other curb treatments.*
» *Design planting to reflect water availability. Plant selections and density shall be dependent on local climate and conditions and use or absence of supplemental irrigation.*
» *Design planting so that it does not block sight lines.*
» *Reference the AASHTO Roadside Design Guide for safety requirements and design guideance when placing and designing curb openings adjacent to travel ways.*

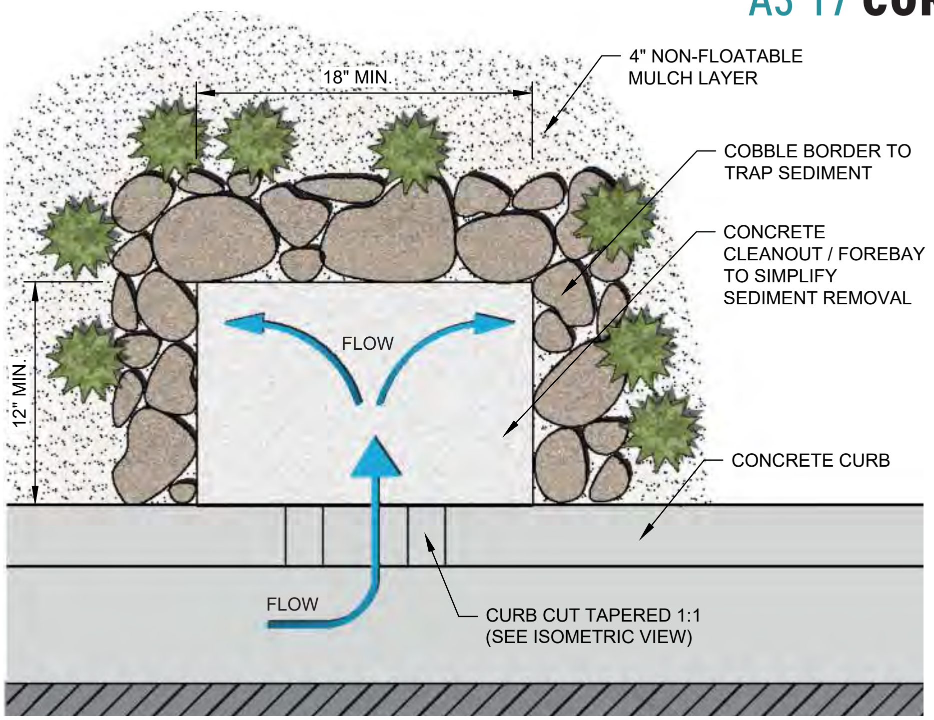
LIMITATIONS

» *Curb cuts can become blocked/clogged with floating debris, leaves and sediment.*
» *Governing codes, standards and regulations may not allow stormwater harvesting on top of utilities.*

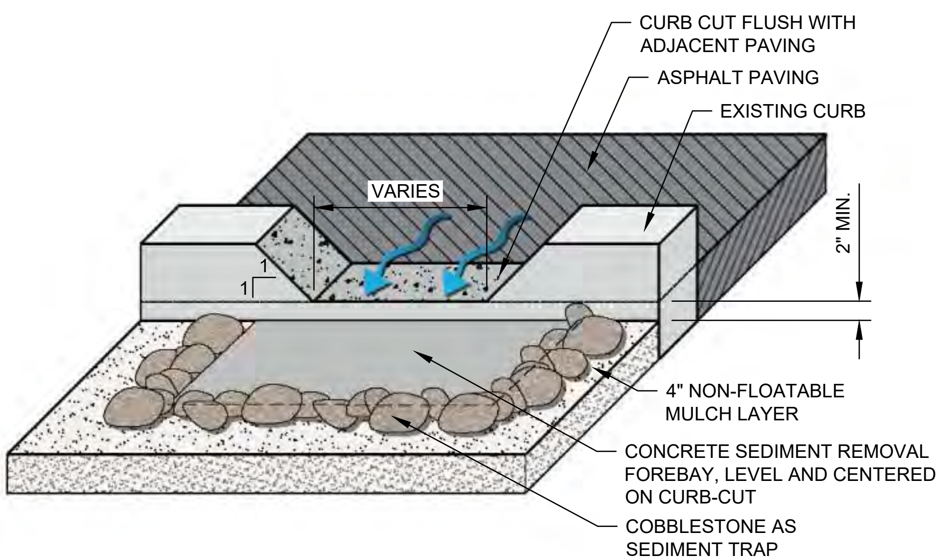
MAINTENANCE REQUIREMENTS

» *Maintain openings at curb cuts free of debris, sediment and trash.*
» *Inspect semi-annually post construction.*
» *Inspect after major storm events.*

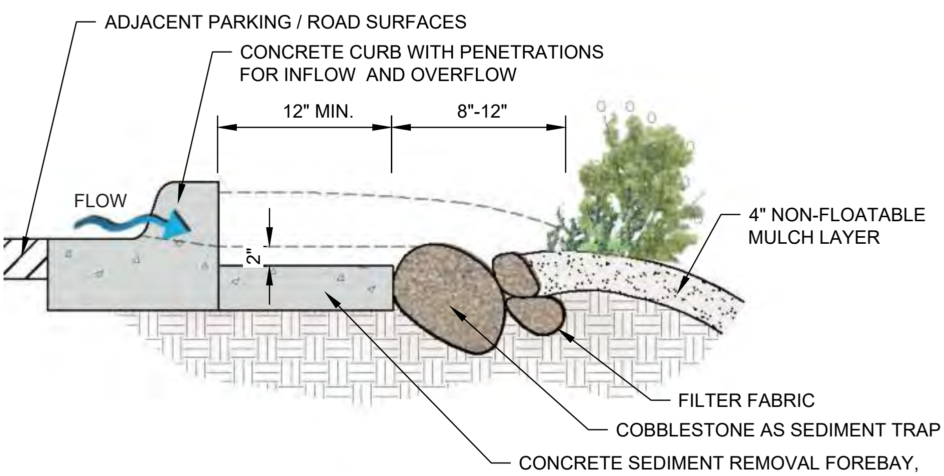
A3-17 CURB TREATMENT CONTINUED



Concrete curb cut - PLAN VIEW.

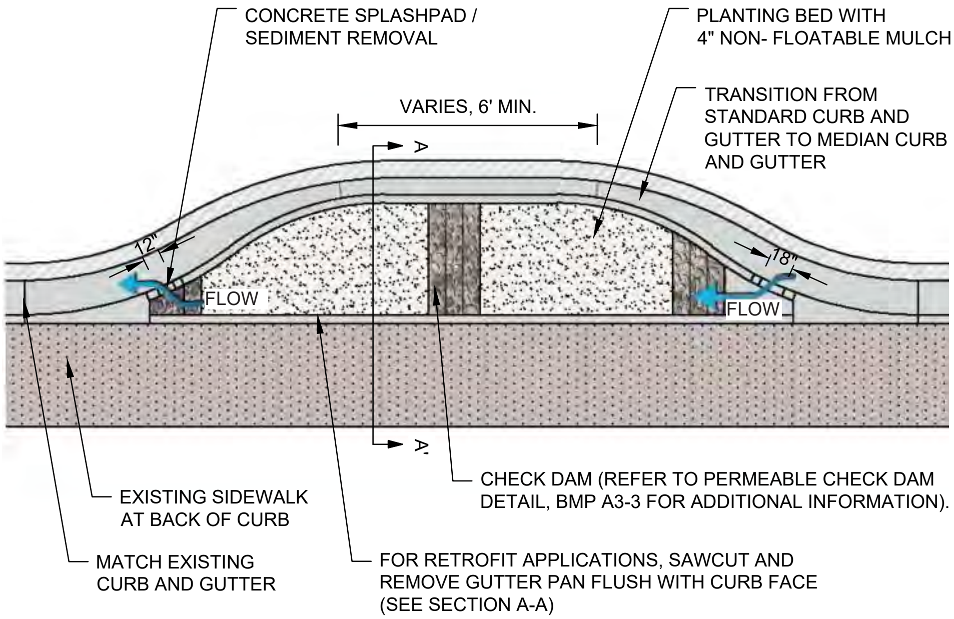


Concrete curb cut - ISOMETRIC VIEW.

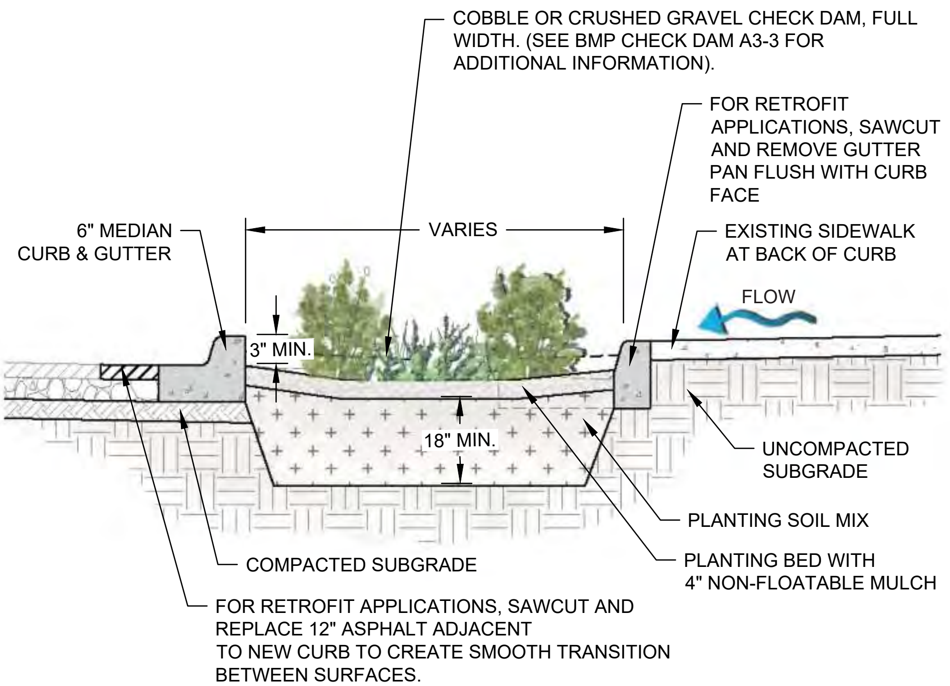


Sediment cleanout forebay at concrete curb cut - SECTION VIEW.

A3-17 **CURB TREATMENT** CONTINUED

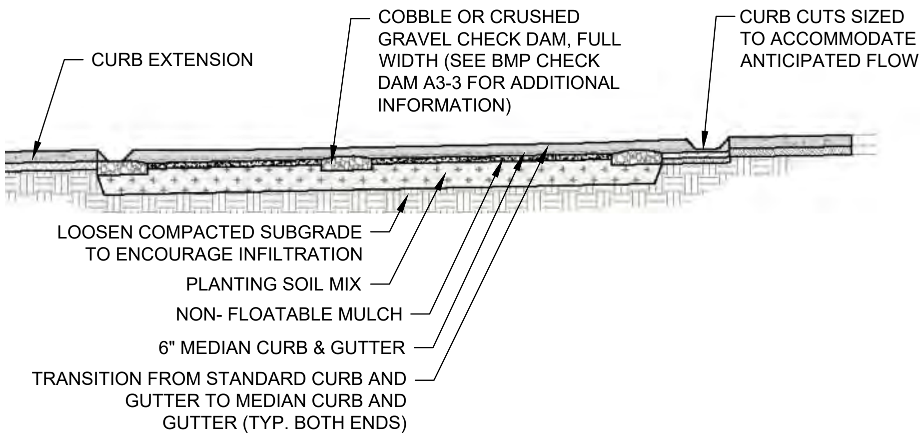


Chicane (stormwater curb extension retrofit) - PLAN VIEW.

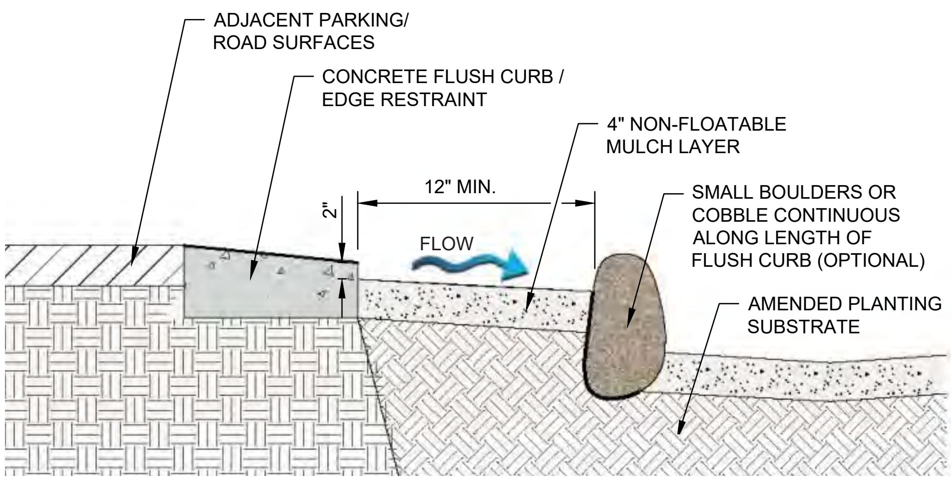


Chicane (stormwater curb extension retrofit) - SECTION A-A.

A3-17 CURB TREATMENT CONTINUED



Chicane (stormwater curb extension retrofit) - PROFILE VIEW.



Flush curb - SECTION VIEW.

A3-18 DEPRESSED MEDIAN

Image credit: Sites Southwest

DESCRIPTION

Depressed medians are shallow stormwater harvesting depressions typically designed to collect and infiltrate stormwater runoff to support vegetation. Depressed medians can be designed with flush curbs or with standard raised curbs and curb openings as an efficient and inexpensive median retrofit to decrease stormwater runoff volume.

PRIMARY USE

» *Decrease stormwater velocity, runoff volumes, and peak flows.*
» *Improve stormwater quality.*
» *Provide supplemental water to median planting.*
» *Support median street trees which reduce urban heat island effect, calm traffic, and provide beauty and habitat.*

APPLICATION

Strategies for designing depressed medians include:

» *Grade depressed medians with standard curbs to only collect rainwater that falls on the median.*
» *Where grading and roadway crown allows, retrofit curbs by adding curb cuts to serve as inlets and outlets for stormwater conveyance between adjacent paving and the median.*
» *Protect curb cuts inlets with angular riprap or stone.*
» *Consider use of flush curb installations in both roadways and parking lot medians.*

SEE ALSO

A3-10 *Bio(Retention) Swale*
A3-17 *Curb Treatment*
A3-19 *Urban Tree Planting*

NMDOT TESCP (TEMPORARY EROSION AND SEDIMENT CONTROL PLAN) SYMBOL

DM

A3-18 DEPRESSED MEDIAN CONTINUED

APPLICATION *CONTINUED*

Strategies for successful planting depressed medians include:

- » *Create a planting design that is suited for the site's water availability. Plant selections and density shall be dependent on local climate and conditions, including an absence of supplemental irrigation.*
- » *Choose and place plants to reflect potential periodic wet soil conditions and/or standing water in slow infiltrating soils.*
- » *Limit potential effects of soil saturation adjacent to roadway paving and infrastructure.*
- » *Create a planting design that will not encroach upon vehicle sight lines.*

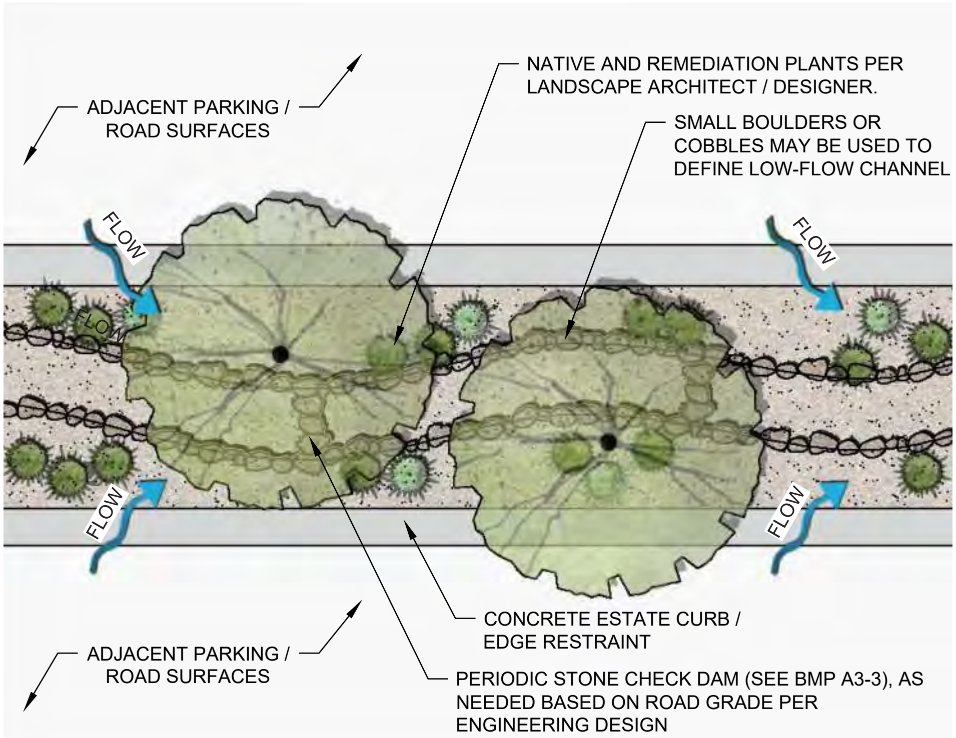
LIMITATIONS

- » *Supplemental irrigation is recommended to establish and maintain vegetative health in arid conditions.*
- » *Depressed medians are not well-suited for use in poorly-drained soils including soils with caliche and shallow bedrock.*
- » *Special planting considerations include proximity to infrastructure and AASHTO Roadside Design Guide safety zones.*
- » *Governing codes, standards and regulations may not allow stormwater harvesting on top of utilities.*
- » *Ponding depths vary depending on the width of the median.*
- » *Governing codes, standards and regulations may not allow stormwater harvesting on top of utilities.*

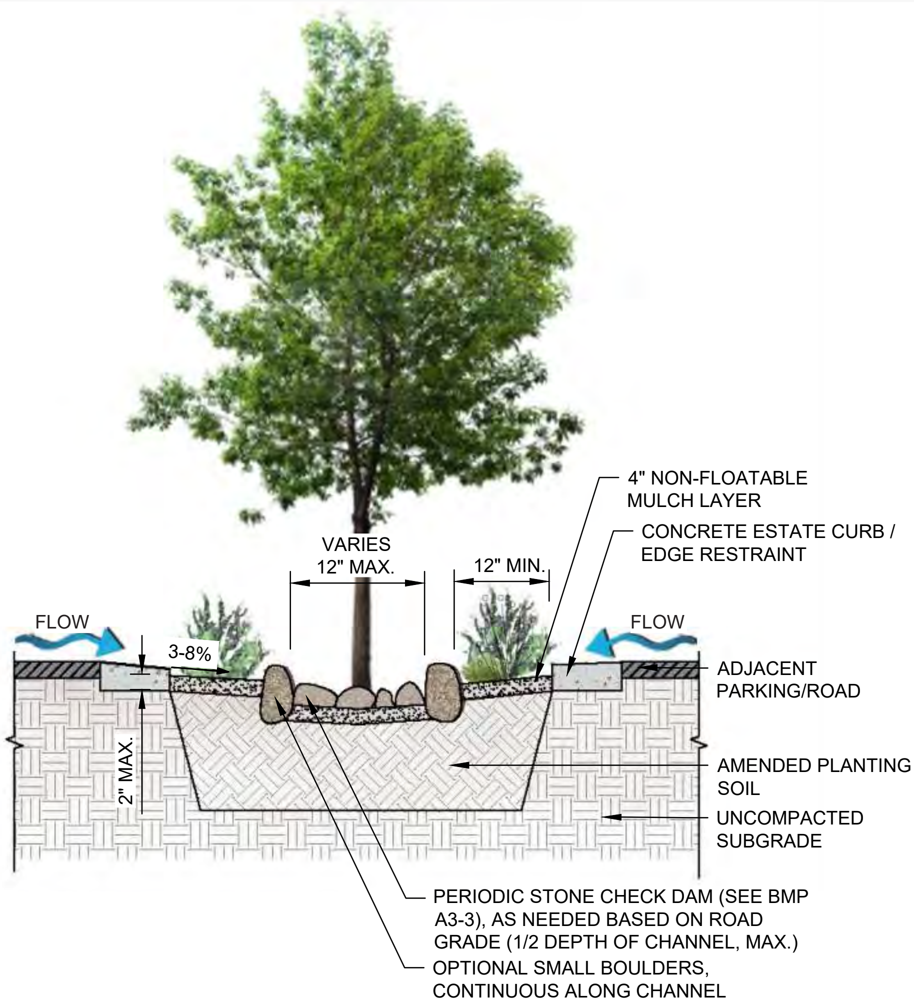
MAINTENANCE REQUIREMENTS

- » *Inspect quarterly post construction.*
- » *Remove debris, litter, and sediment.*
- » *Maintain planting as needed including pruning, weeding, mowing, fertilization, replacement, and pest control.*
- » *Repair irrigation system, if installed, and make seasonal watering adjustments where applicable.*
- » *Repair and regrade surface where it has been disturbed.*
- » *Redistribute and replace mulches as needed.*

A3-18 DEPRESSED MEDIAN CONTINUED

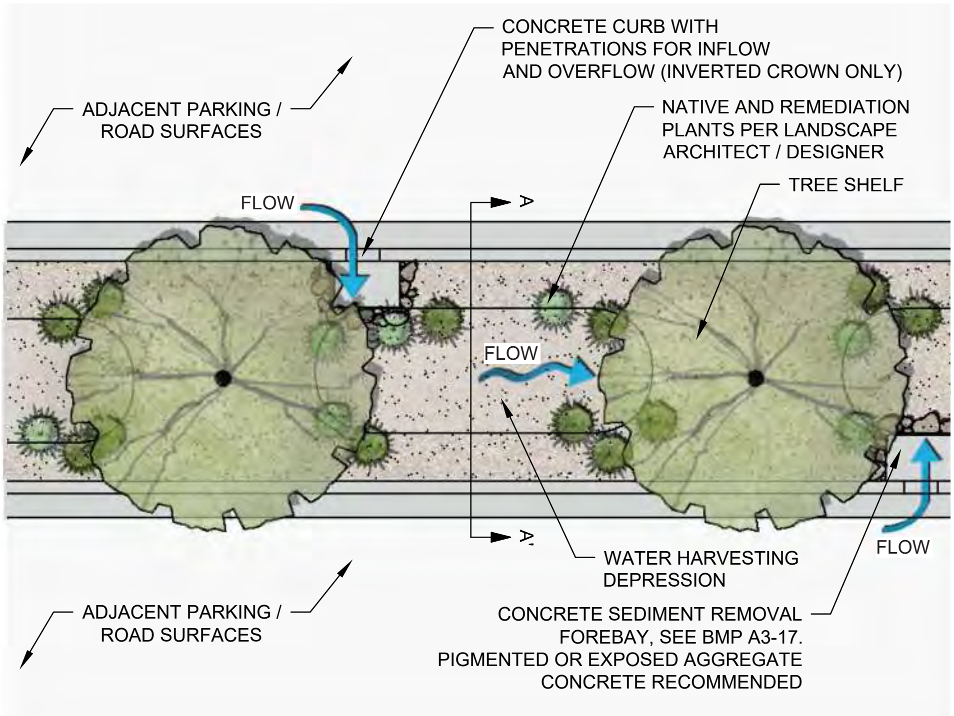


Depressed median with flush curbs - PLAN VIEW.

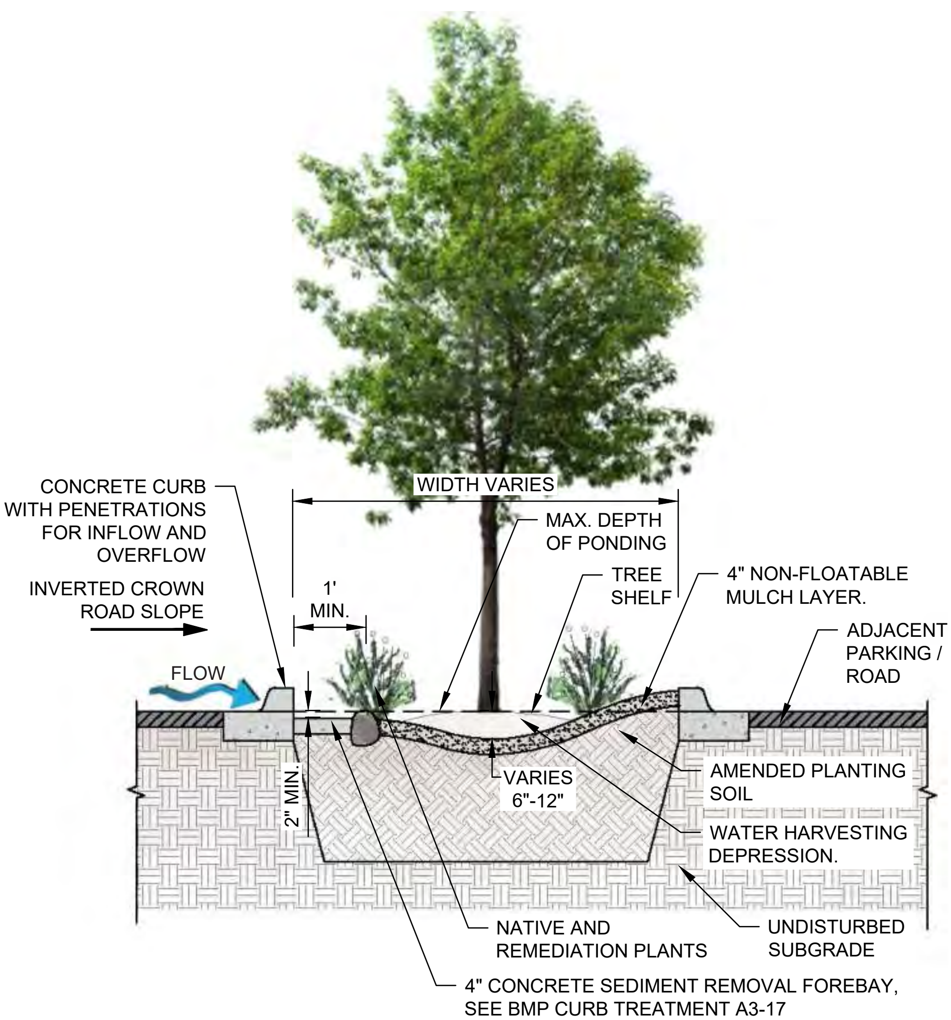


Depressed median with flush curbs - SECTION VIEW.

A3-18 DEPRESSED MEDIAN CONTINUED



Depressed median with raised curbs - PLAN VIEW.



Depressed median with raised curbs - SECTION A-A.

A3-19 URBAN TREE PLANTING

Image credit: Sites Southwest

DESCRIPTION

Urban tree planting emphasizes the use of trees to reduce erosion, improve air quality, and reduce the urban heat island effect. Technical methodologies for urban tree planting include suspended pavement with structural soils, large scale tree trenches, streetside stormwater planters, and traditional inground and raised planter installations.

PRIMARY USE

Tree planting is suitable along the sides and in the medians of highways, streets and transit corridors; in gore areas, detention ponds and drainage conveyances; and within parks, open spaces and trail corridors. Urban trees provide multiple environmental benefits:

» *Reduce the urban heat island effect through evapotranspiration and shading of paving and roofs.*
» *Improve air quality by filtering ozone, dust, pollutants, carbon dioxide, and sulfur dioxide while providing oxygen.*
» *Temper and dissipate raindrops thus reducing soil erosion and sedimentation.*
» *Stabilize soils with extensive root systems.*

Urban trees also provide societal benefits:

» *Calm traffic.*
» *Create a physical buffers between streets and sidewalks or trails.*
» *Improve the economic value of commercial and residential properties.*
» *Reduce building heating and cooling costs.*
» *Provide habitat and help connect people to the natural environment.*

SEE ALSO

A3-17 *Curb Treatment*
A3-18 *Depressed Median*

NMDOT STANDARD DRAWING

664 Landscape Planting

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

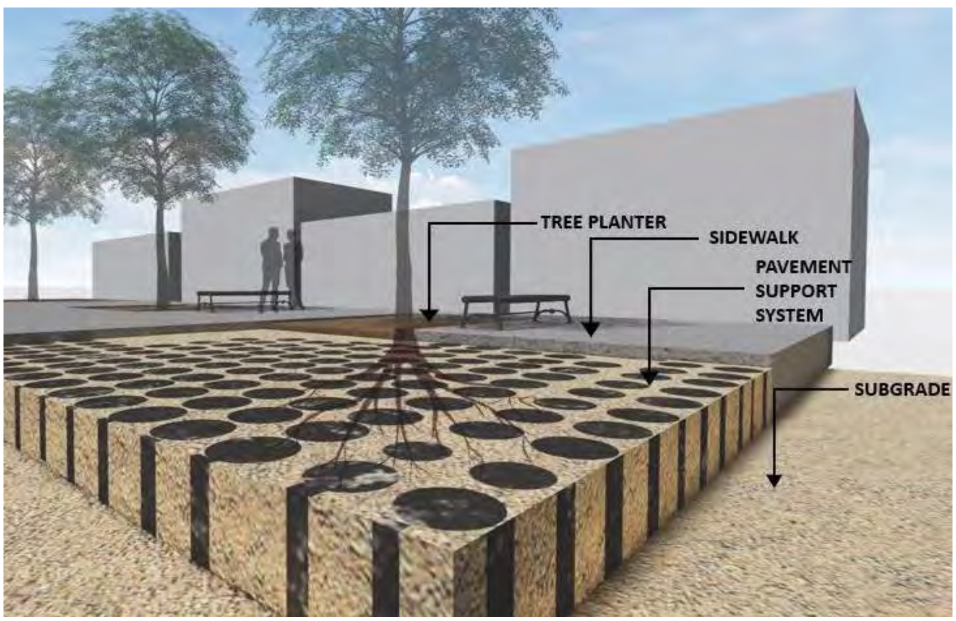
UTP

A3-19 **URBAN TREE PLANTING** CONTINUED

In addition to traditional urban tree planting in the ground or raised planters, there are three ancillary BMPs that fall under urban tree planting:

Suspended Pavement/Structural Soils

Suspended pavements are systems designed to create void space under the pavement for water retention/infiltration and adequate volume for tree root growth. Structural soils are a blend of crushed stone and planting soils that rely on the interlocking nature of the stone to support pavement, while uncompacted planting soil fills the void spaces. Both systems offer greatly improved soil porosity for water retention, oxygen transfer, and resulting root growth where space is limited in urban areas.



Tree planting in suspended pavement - ISOMETRIC VIEW.

Tree Trench/Pit:

Tree trenches or tree pits are curbside vaults, typically constructed from concrete. The vaults accept stormwater from curb cuts or drain pipes, filter stormwater through a variety of media to remove sediment and pollutants, and provide adequate root space for curbside tree planting.

Streetside Stormwater Planter:

Streetside stormwater planters are constructed features immediately behind the curb that accept stormwater from curb cuts or flush curbs. These planters filter stormwater through a variety of media to remove sediment and pollutants and provide soil and space to accommodate curbside trees and shrubs. "First flush" runoff can be absorbed into these planting beds, helping reduce pollutant levels and overall runoff volumes. Streetside stormwater planters can be installed in bulb-outs in retrofit applications.

A3-19 URBAN TREE PLANTING CONTINUED

APPLICATIONS

Planning and design strategies for successful urban tree planting include:

- *Consider local climate, soil conditions and water availability when selecting the best trees for site conditions. Consult local sources for a list of trees suitable to the area.*
- *Consider use of short fences, barriers or curbs at recessed areas that are not grated or flush with adjacent paving.*
- *Design permanent, well-constructed irrigation systems in association with urban tree planting.*
- *Ensure that suspended pavements provide adequate soil volume for mature street trees.*
- *Consider designing permeable pavements adjacent to tree plantings to provide additional water and soil porosity.*
- *Avoid and/or eliminate soil compaction under and adjacent to tree canopies.*

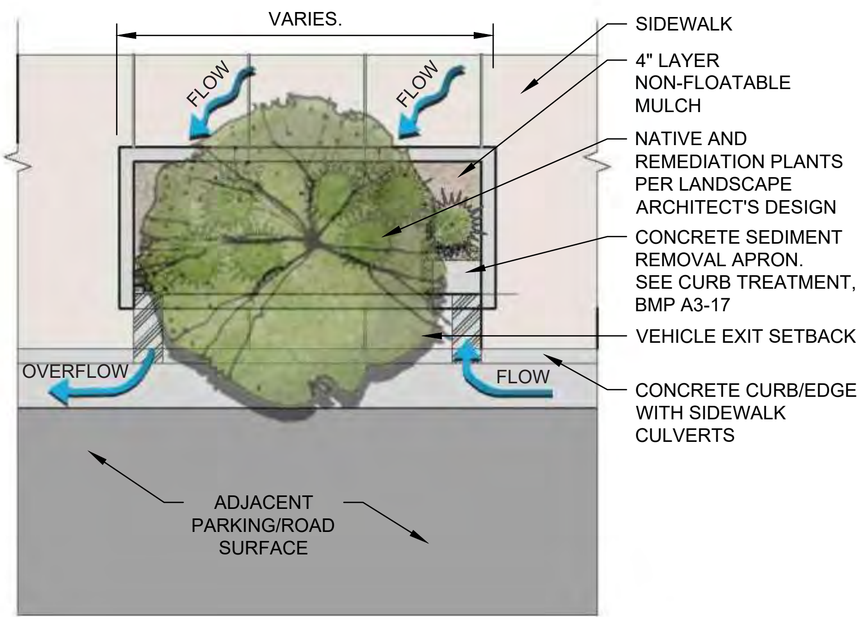
LIMITATIONS

- *Water availability for irrigation.*
- *Trees must be selected and planted in urban locations to minimize effects on paving and infrastructure. Poorly located and selected trees can lift pavement, effect water/sewer lines, and grow into overhead and underground utilities.*
- *Surface roots can pose tripping hazards in the landscape.*

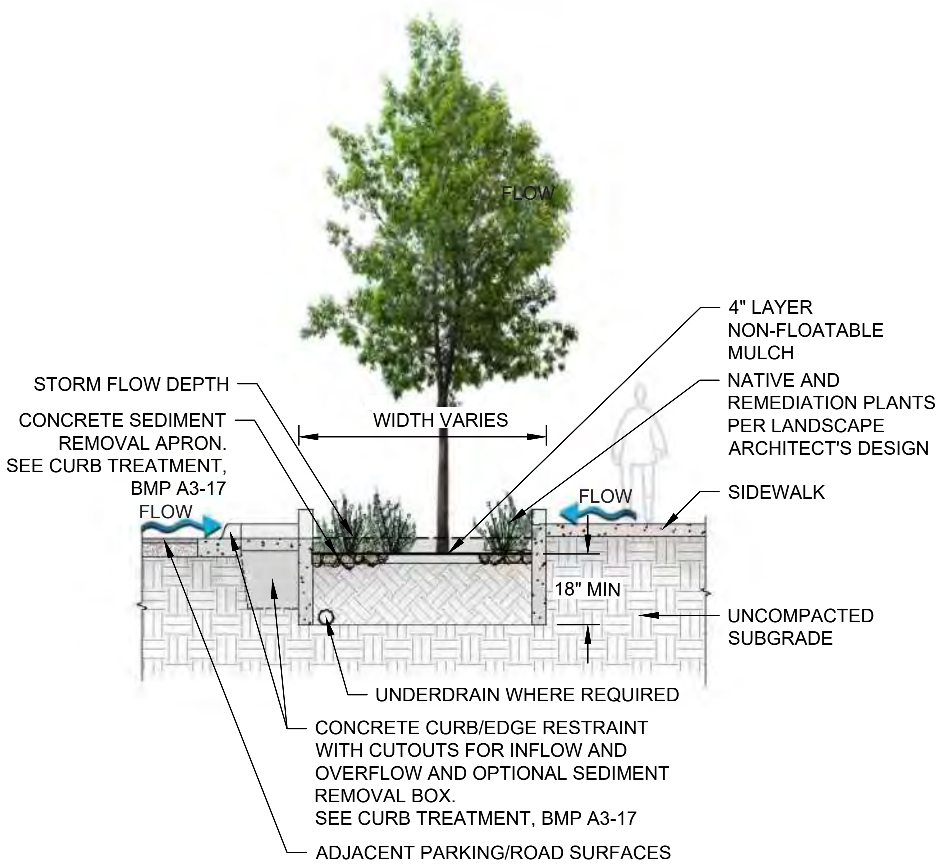
MAINTENANCE REQUIREMENTS

- *Inspect trees quarterly for pests, dead and dying limbs, and general health.*
- *Train, prune, and fertilize trees annually.*
- *Inspect irrigation system quarterly. Repair broken components and adjust watering requirements seasonally.*
- *Rake and collect debris including leaves, twigs, branches, nuts, flowers, and berries seasonally.*
- *Replenish mulch around trees bi-annually.*

A3-19 URBAN TREE PLANTING CONTINUED

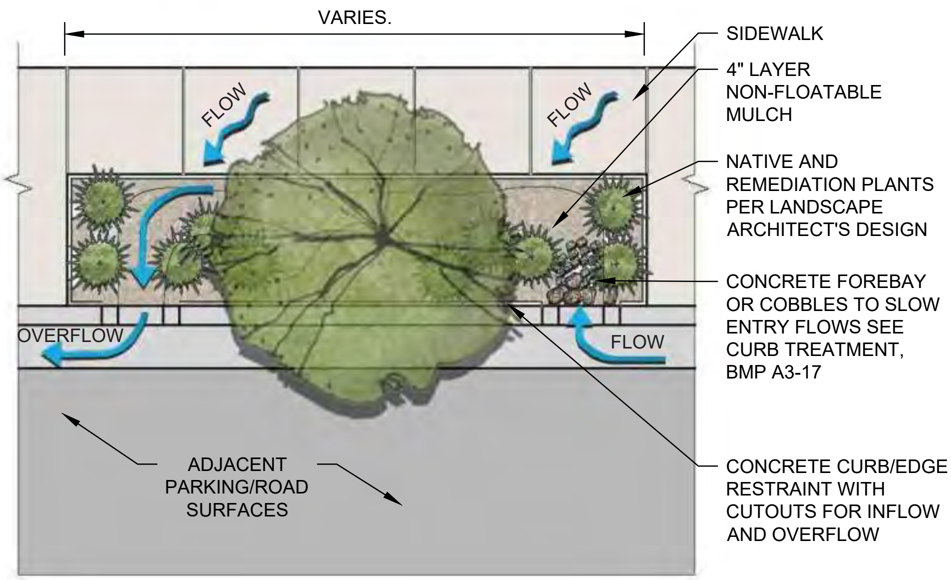


Tree planting in infiltration tree trench/ pit set back from curb - PLAN VIEW.

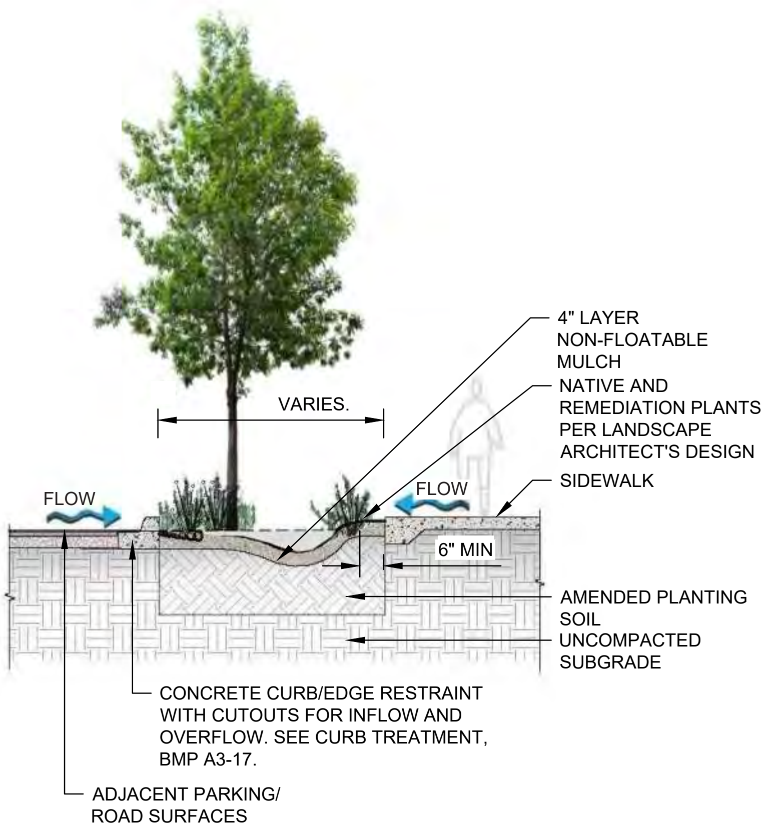


Tree planting in infiltration tree trench/ pit set back from curb - SECTION VIEW.

A3-19 **URBAN TREE PLANTING** CONTINUED



Tree planting in streetside stormwater planter with curb cuts - PLAN VIEW.



Tree planting in streetside stormwater planter with curb cuts - SECTION VIEW.

A3-20 TRASH CAPTURE DEVICES

Image credit: Sites Southwest

DESCRIPTION

Trash capture devices capture floatables and sediment before stormwater enters a subsurface conveyance system or green stormwater infrastructure BMP. Devices capturing debris and pollutants include trash racks, baffle walls, and screening systems that catch coarse sediments and floatables as water flows through the devices.

PRIMARY USE

Trash capture devices are used as a preliminary treatment of stormwater to remove gross solids, sediment and (in some cases) pollutants. Their use minimizes maintenance in downstream stormwater infrastructure/facilities or green infrastructure BMP's in a treatment train. Trash capture devices are used at inlets to traditional storm sewers, detention ponds, filtration and infiltration green infrastructure features. Certain devices are also suitable for use inside open channels and at the outlets of stormwater pipes. Trash capture devices are typically used in urban locations known to accumulate floatables. They can be integrated as retrofits into existing stormwater systems as well as designed as part of new construction.

APPLICATION

Strategies for the planning and design of trash capture devices include:

» *Consider one time capital costs and ongoing maintenance and operations costs when selecting the device.*
» *Evaluate operation and maintenance capabilities and requirements when selecting the device/technology.*
» *Select the right device for the site's primary pollutants and hydrology.*

SEE ALSO

A3-21 *Mechanical Devices/ Separators*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

TCD

A3-20 TRASH CAPTURE DEVICES CONTINUED

LIMITATIONS

- *Ongoing maintenance is needed to remove accumulated debris and trash.*
- *Some devices have a high capital cost, but if used in areas with heavy trash loads, they can be an effective and efficient management practice.*
- *Clearance may be required near device for service vehicle access.*

MAINTENANCE REQUIREMENTS

- *Remove sediment and debris regularly.*
- *Inspect and maintain devices in good operational condition.*
- *Remove and replace filtration media depending upon the media type, stormwater quality, and manufacturer's maintenance instructions.*

A3-21 MECHANICAL DEVICES/SEPARATORS

Image credit: Hydro International

DESCRIPTION

Mechanical devices/separators are inline and underground devices that remove pollutants from stormwater runoff. These devices include gravity separators, filters, and hydrodynamic devices.

PRIMARY USE

Mechanical devices and separators are generally utilized to remove floatables and particulate contaminants including sediment, oil, grease, litter, and debris. They can provide specific area treatment for a wide variety of contaminants and include devices such as metal and fabric catch basin inserts, media filtration (zeolite, perlite and activated carbon filters), chambered separator units, and hydrodynamic separators. Mechanical devices and separators are suitable for urban settings with high levels of sediment and debris. Appropriate locations for mechanical devices and separators may include parking lots, commercial developments, detention facilities, and locations where sheet flows are initially channelized.

APPLICATION

Strategies for the planning and design of mechanical devices/separators include:

» *Evaluate and explore existing conditions and compare to mechanical device requirements.*
» *Consider one time capital costs and ongoing maintenance and operations costs when selecting the device.*
» *Evaluate operation and maintenance capabilities and requirements when selecting the device/technology.*
» *Select the right device for the site's primary pollutants and hydrology.*

SEE ALSO

A3-20 *Trash Capture Devices*

NMDOT TESCP
(TEMPORARY EROSION AND SEDIMENT CONTROL PLAN)
SYMBOL

MD

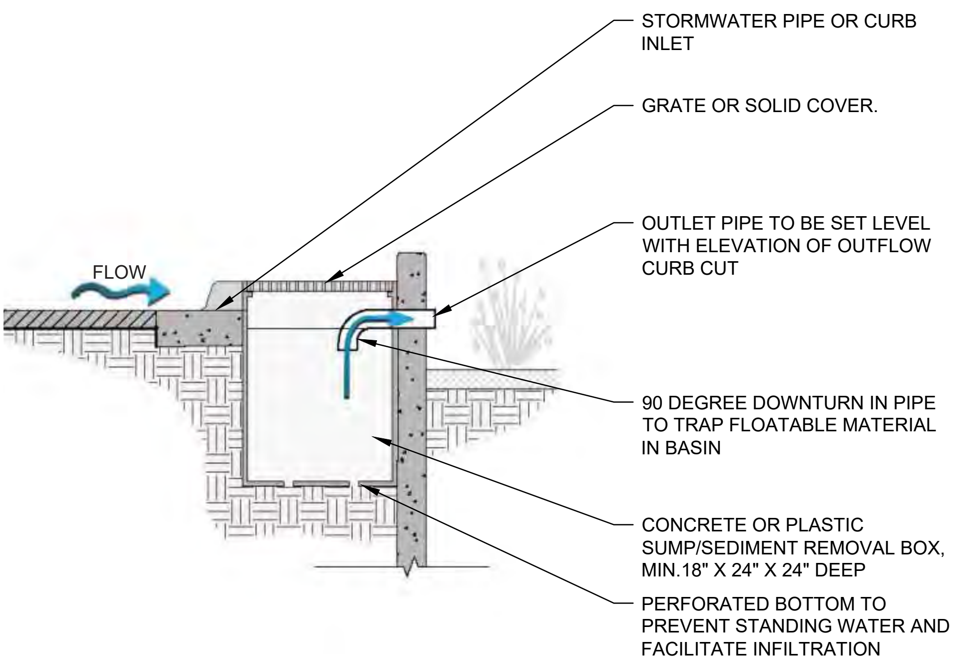
A3-21 MECHANICAL DEVICES/SEPARATORS CONTINUED

LIMITATIONS

- *Higher solids loading can render some devices ineffective.*
- *Ongoing maintenance to remove accumulated debris and trash.*
- *Some devices have a high capital cost, but if used in areas with heavy trash loads, they can be an effective and efficient management practice.*
- *Clearance may be required near device for service vehicle access.*
- *Specialized equipment like vactor trucks may be needed for maintenance.*

MAINTENANCE REQUIREMENTS

- *Remove sediment and debris regularly.*
- *Inspect and maintain devices in good operational condition.*
- *Follow manufacturers maintenance processes and schedules.*
- *Remove and replace filtration media depending upon the media type, stormwater quality, and manufacturer's maintenance instructions.*



Simple mechanical separator to treat street stormwater runoff - SECTION VIEW.

APPENDIX A

Examples of Combined BMP Applications

OVERVIEW

The Best Management Practices outlined on the preceding pages are most effective when used in various combinations, and tailored to a given site. Following are four examples of combined BMPs applied to specific types of project sites. Each illustration shows a typical roadway design or construction scenario with a sampling of BMPs that could be applied to that situation.

URBAN INTERSECTION

BMPs shown in this example include applications that are more appropriate to developed urban areas. Most urban roadways are crowned at the center, so water harvesting can be accomplished at the edges, through permeable parking surfaces and curb cuts that direct water to tree planters. Even though runoff is not directed toward the medians in this case, depressed medians still collect and hold any water that falls on them, rather than shedding it onto the road surface. The lower right portion of the illustration shows additional BMPs that can be applied to private property by landowners in cooperation with the guidance provided by this document.

ROUNDABOUT

As traffic roundabouts become more common, they will need to be addressed with greater frequency. Grading is typically more challenging with a roundabout than a more traditional intersection, given the need to provide smooth transitions between and among the various connecting legs. Low-Impact Design BMPs can help offset some of those challenges. A stormwater basin in the center of the roundabout can collect and store a great deal of runoff, while allowing the surrounding roadways to be superelevated in the direction of travel, sloping in toward the circle, rather than away from it. Likewise, given the greater peripheral space between the road and ROW, numerous options can be utilized to capture offsite flows before they enter the roadway.

RURAL ROADWAY

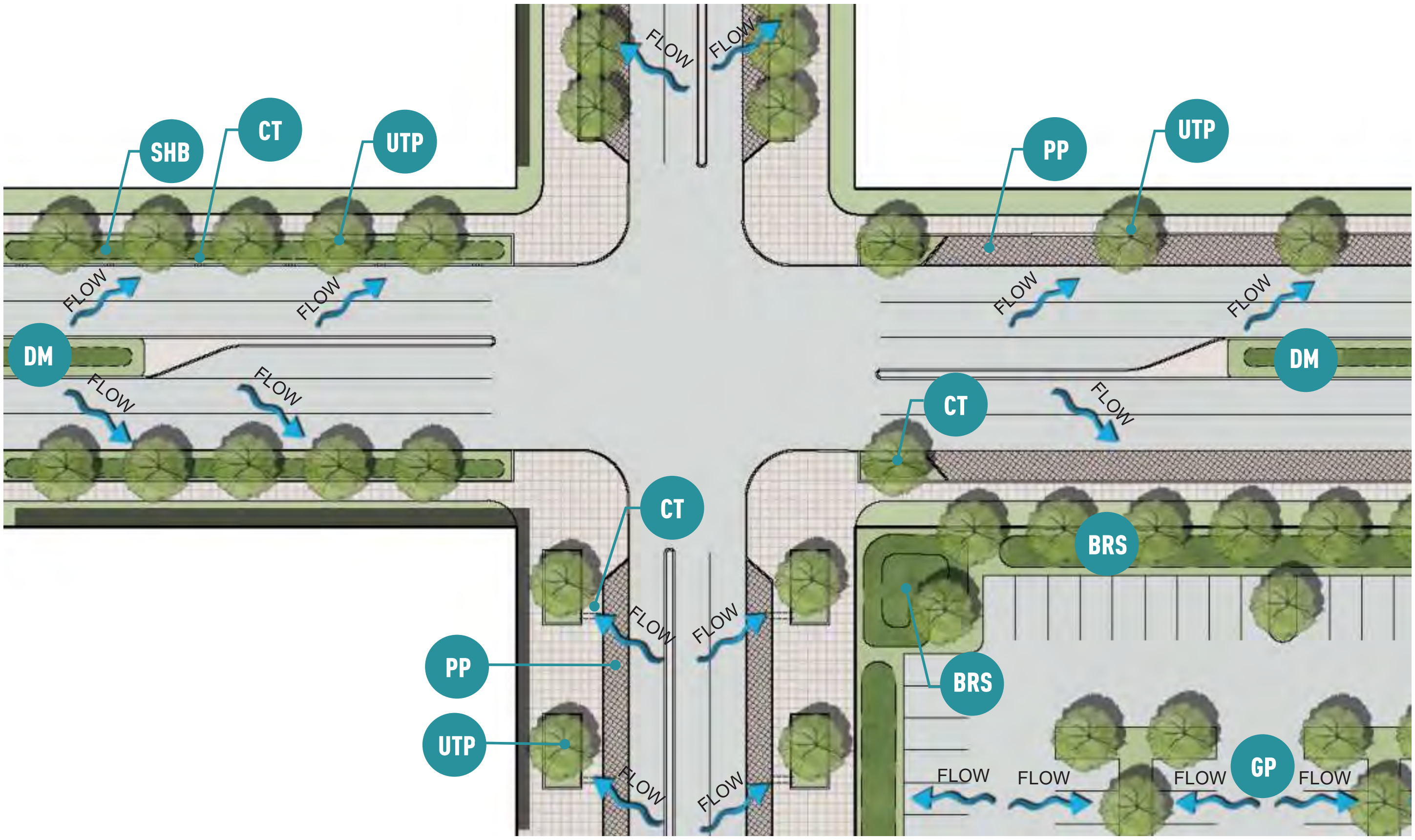
Typical of the long stretches of road between urban areas in New Mexico, rural roads may offer fewer opportunities for widespread use of LID/GSI BMPs, but certain applications will still be useful. Buffer strips along roadways help slow and filter runoff before it enters roadside ditches, and culvert protection will be required at drainage crossings. Revegetation seeding and associated mulching are requirements for NPDES permitting. Rural roadways – particularly interstates – sometimes also offer opportunities for depressed center medians, either as divided roadways or with introduced medians at intersection approaches, which can be converted to bio-retention swales which both beautify the roadway and reduce untreated runoff.

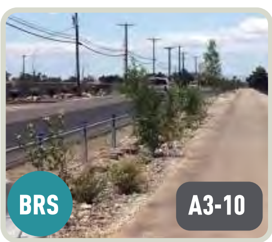
HIGHWAY INTERCHANGE

Freeway interchanges provide many opportunities for combining BMPs into an interconnected system. This illustration shows both construction-phase BMPs and permanent applications. During construction, administrative/housekeeping BMPs will need to be utilized in construction yards and staging areas, while temporary erosion control measures are applied along the ROW to minimize silt-laden runoff and fugitive dust. Once construction is complete, permanent BMPs help the drainage system function as a healthy ecosystem. Stormwater harvesting basins collect runoff for infiltration and plant use before discharging excess flows into bio-retention swales or infiltration trenches.

These are but a few of the possible combinations that can and should be used when designing a project and developing a related SWPPP. As noted previously, in all instances thoughtful engineering design should guide the final configuration.

COMBINED BMP APPLICATION **URBAN INTERSECTION**

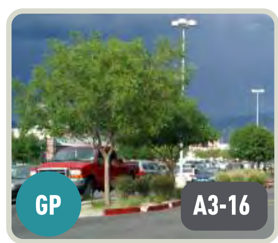




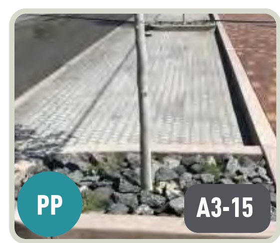
BIO(RETENTION) SWALE

CURB TREATMENT

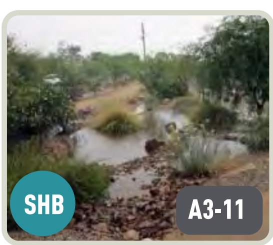
DEPRESSED MEDIAN



GREEN PARKING



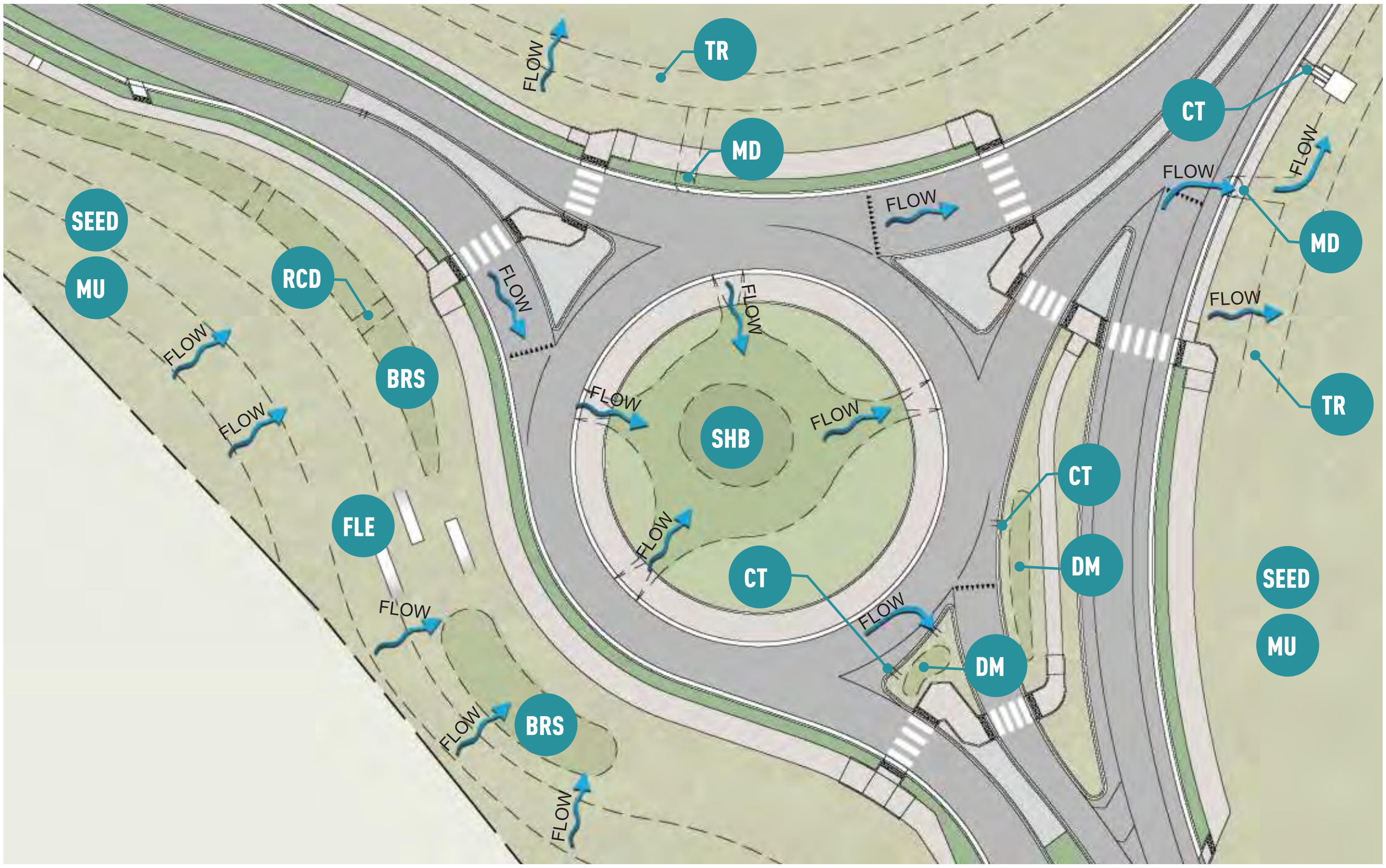
PERMEABLE/ALTERNATIVE PAVEMENT

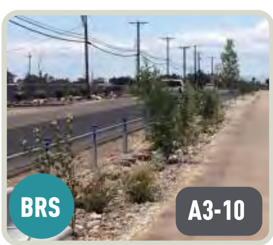


STORMWATER HARVESTING BASIN

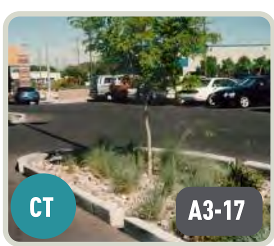
URBAN TREE PLANTING

COMBINED BMP APPLICATION **ROUNDABOUT**





BIO(RETENTION) SWALE

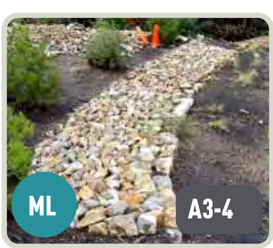


CURB TREATMENT

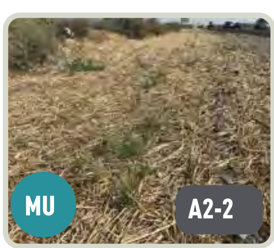
DEPRESSED MEDIAN

FLOW LINE EXTENDER

MECHANICAL DEVICES

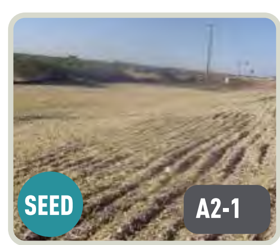


MEDIA LUNA

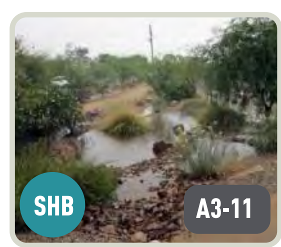


MULCHING

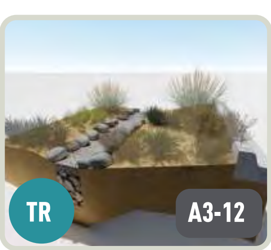
ROCK CHECK DAM



SEEDING

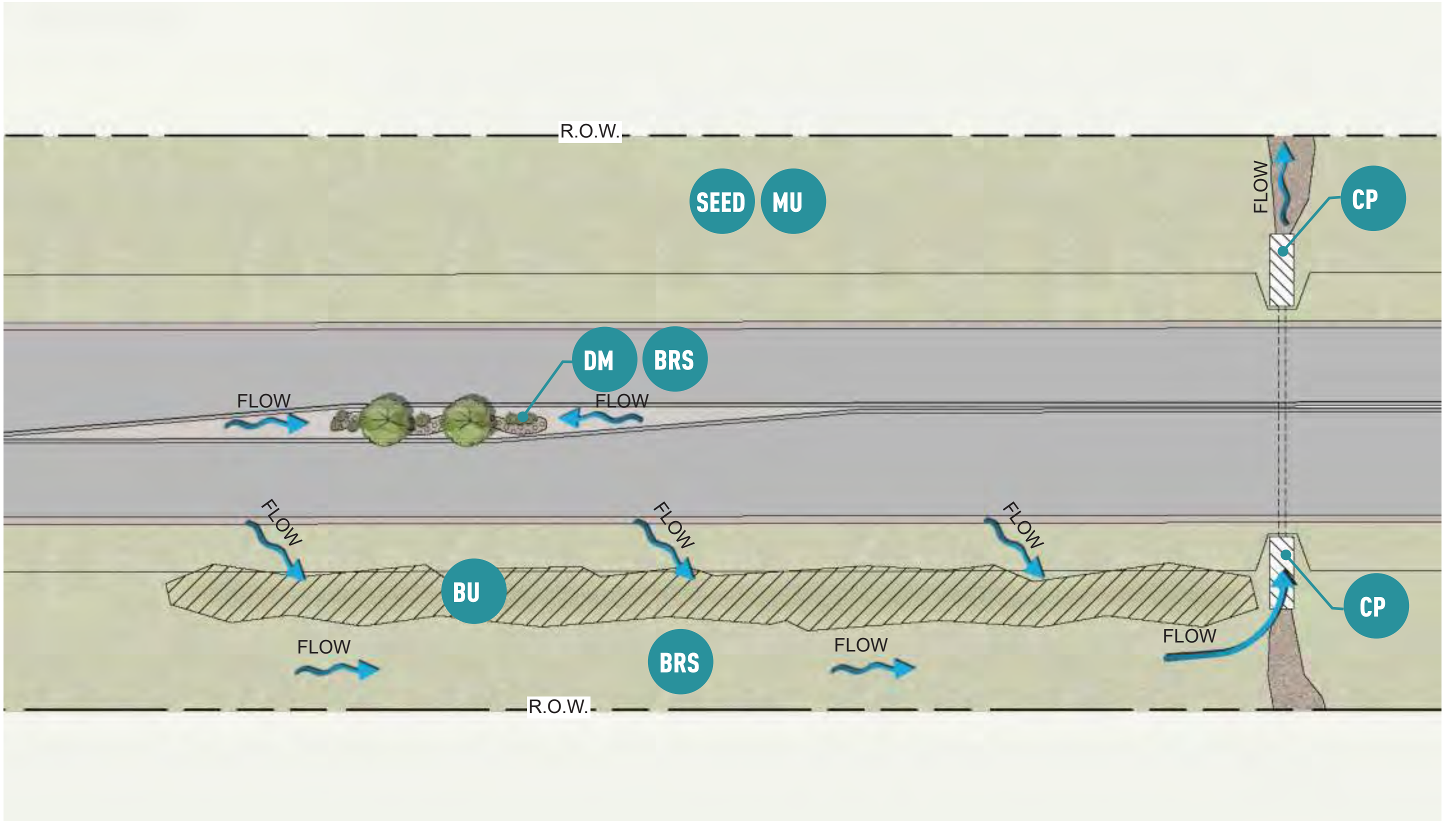


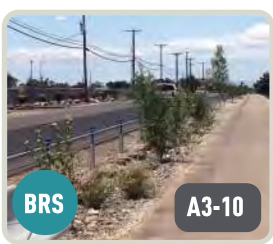
STORMWATER HARVESTING BASIN



INFILTRATION TRENCH

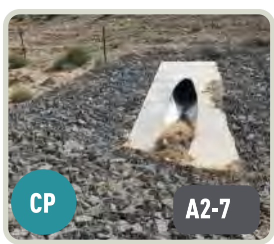
COMBINED BMP APPLICATION **RURAL ROADWAY**





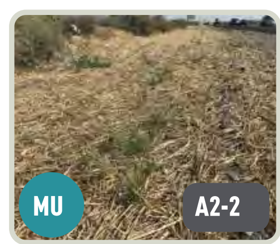
BIO(RETENTION) SWALE

BUFFER/FILTER STRIP



CULVERT PROTECTION

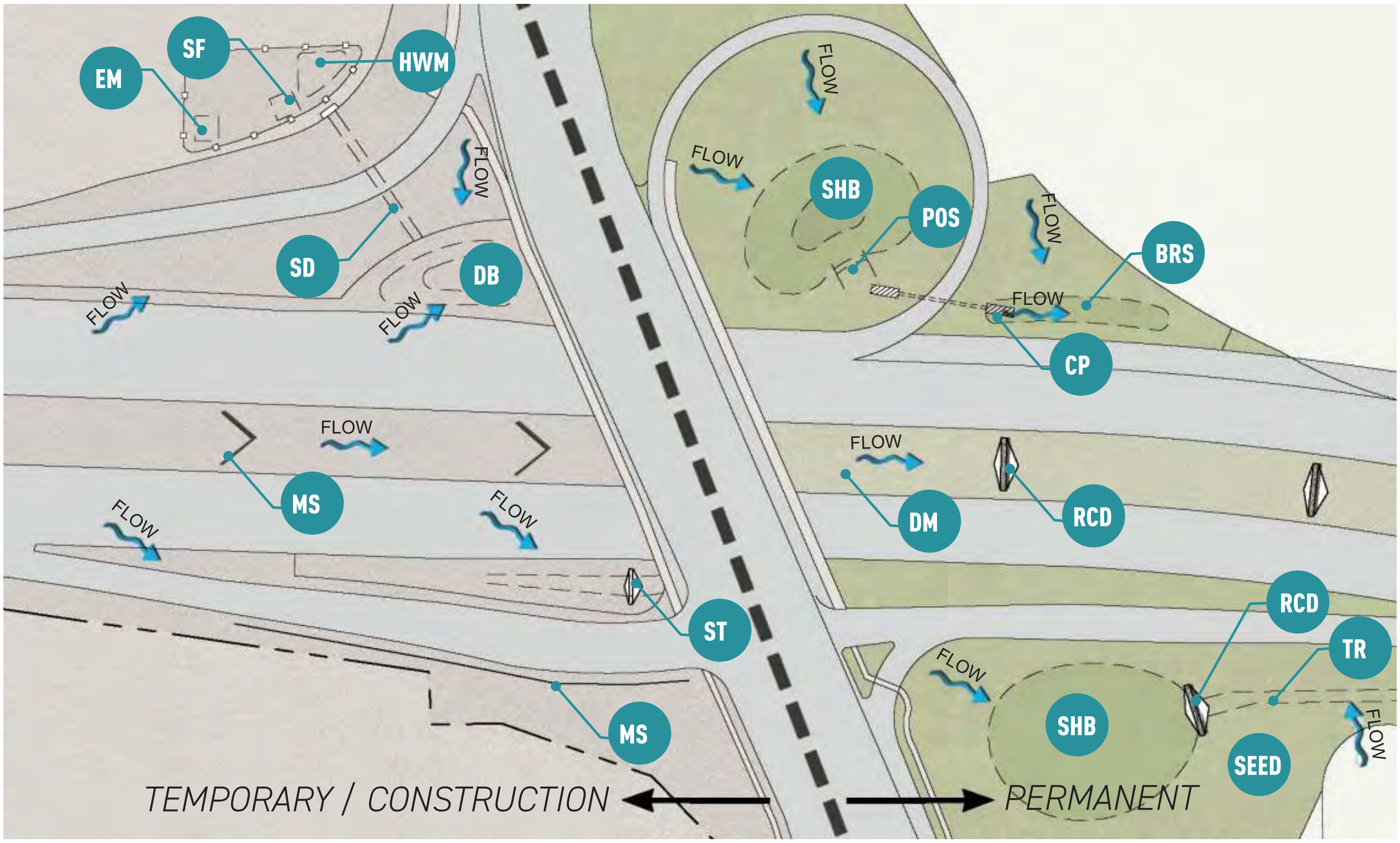
DEPRESSED MEDIAN

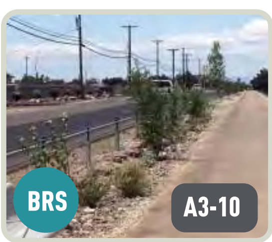


MULCHING

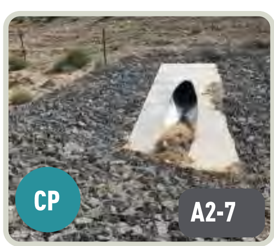
SEEDING

COMBINED BMP APPLICATION **HIGHWAY INTERCHANGE**

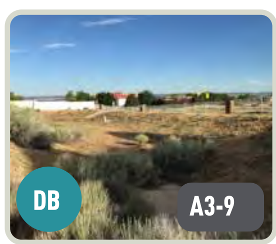




BIO(RETENTION) SWALE

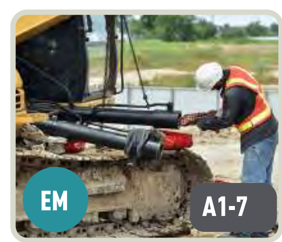


CULVERT PROTECTION

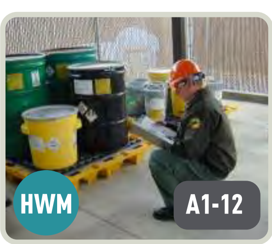


DETENTION BASIN

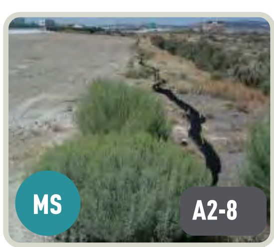
DEPRESSED MEDIAN



EQUIPMENT MAINTENANCE



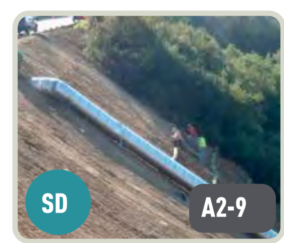
HAZARDOUS WASTE MANAGEMENT



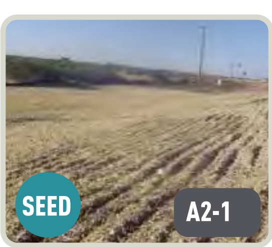
MULCH SOCKS

POND OUTFALL STRUCTURE

ROCK CHECK DAM



SLOPE DRAIN



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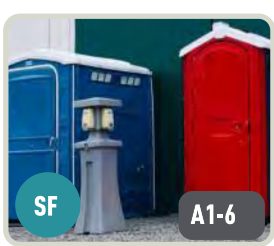
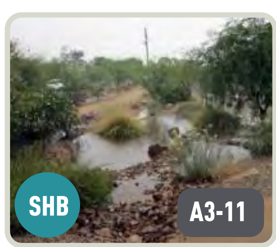
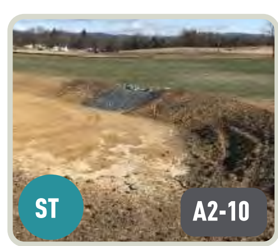


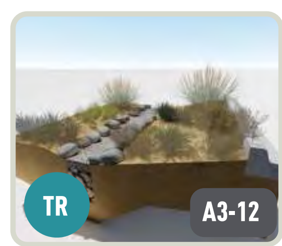
SANITARY FACILITY MANAGEMENT



STORMWATER HARVESTING BASIN



SEDIMENT TRAP



INFILTRATION TRENCH

ATTACHMENT C

GREEN INFRASTRUCTURE FOR DESERT COMMUNITIES

GREEN INFRASTRUCTURE

FOR DESERT COMMUNITIES

Green Infrastructure for Desert Communities

Version 2.0

Revised January 2017

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English and Spanish version are available online at https://watershedmg.org/learn/resource-library

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Table of Contents

1. What is green infrastructure?

Green infrastructure (GI) refers to constructed features that use living, natural systems to provide environmental services, such as capturing, cleaning, and infiltrating stormwater; creating wildlife habitat; shading and cooling streets and buildings; and calming traffic.

Green infrastructure is a strategy that a growing number of communities are using to manage stormwater more sustainably, while using that water to grow vegetation that provides myriad benefits.

GI strategies for arid and semi-arid desert communities need to be different than GI strategies developed in temperate areas of North America. The Southwestern U.S. and Mexico face long periods of drought interspersed with intense rainfall that can make implementing GI challenging.

This manual provides guidelines and best practices for retrofitting neighborhood streets, open spaces, right-of-ways, and parking lots with green infrastructure.

This guide draws on Watershed Management Group's experience working with landowners, neighborhoods, and local governments to install GI in the Southwestern U.S. and Mexico. Design specifics are given only for conceptual understanding, and will always require adaptation to local site conditions and government regulations.

University of Arizona retrofitted their parking lot landscape buffer with a swale to capture runoff.

Newly planted chicanes harvest stormwater moving along the gutter. Right: This stormwater basin is constructed with repurposed urbanite in La Paz, Mexico.

2. About green infrastructure

2.1 The problem

As communities develop, natural vegetation is removed and soil is covered with asphalt, concrete, and buildings. These impervious surfaces do not allow water to infiltrate into the ground. Desert cities are no exception, where automobile-centered infrastructure has created sprawling suburban areas with wide streets and inefficient layouts that maximize impervious surfaces (also known as "hardscape"). When rainfall runs off these surfaces, it can cause a variety of problems:

- Flooding of buildings, streets, and waterways
- Increased erosion in streams and washes/arroyos
- High volume and velocity of runoff
- Delivery of pollutants like automobile oil, herbicides, and pet waste into waterways

Impervious surfaces also contribute to other issues in urban areas:

- Streets and parking lots are rarely or minimally shaded by vegetation, making temperatures hotter and neighborhoods less livable.
- Pavement and buildings retain and radiate heat, causing an "urban heat island effect," the phenomenon of developed areas becoming warmer than surrounding rural areas (which in turn causes increased energy consumption and air pollution).
- Hardscapes can also increase local drought conditions between rainfalls by preventing rainfall from infiltrating into the soil.

Grey infrastructure

Most cities have dealt with increased runoff from hardscape by building "grey infrastructure," such as concrete channels, pipes, and barren detention basins.

Pros of grey infrastructure

- Reduces local flooding by sending water out of the system as quickly as possible
- Manages enhanced urban runoff

Cons of grey infrastructure

- Exacerbates flooding downstream
- Degrades and destroys wildlife habitat and recreation areas in washes and streams
- Does not address water quality issues
- Serves only one function at high cost
- Requires maintenance indefinitely
- Increases urban heat island effect
- Prevents infiltration and creates dangerous, high-velocity runoff

Examples of grey infrastructure: Concrete channels, which have replaced natural washes, send stormwater quickly downstream.

2.2 An integrated solution

Green infrastructure

Green infrastructure offers an integrated solution to stormwater management, meaning it solves many problems and provides many benefits at the same time. GI methods utilize stormwater as a resource by dispersing it throughout a site rather than moving it off-site as quickly as possible, as grey infrastructure does.

Pros of green infrastructure [1]

- Reduces stormwater pollutants and localized flooding [2]
- Conserves water by reducing or eliminating municipal water needs for streetside landscapes and parks, where native plant landscapes are passively irrigated by stormwater instead of municipal water
- Supports riparian vegetation and wildlife, while replenishing local groundwater aquifers when utilized in shallow groundwater areas
- Enhances traffic calming and pedestrian/bike safety features
- Grows an urban forest, which in turn:
    - shades and cools neighborhood streets
    - provides wildlife habitat
    - beautifies neighborhoods
    - increases property values

Cons of green infrastructure

- May not always be able to provide largescale flood control
- Requires space to incorporate in street designs and may conflict with utilities

Implementation of GI on this corner in a Tucson neighborhood captures runoff that previously flooded the street while creating a community asset.

[1] Sikdar, K., Shipek, C., Jones, C. (2015), Solving Flooding Challenges with Green Stormwater Infrastructure. https://watershedmg.org/document/solving-flooding-challenges-green-stormwater-infrastructure-airport-wash-area

[2] Tempe Area Drainage Master Study: LID Application Review and FLOD-2D Modeling. Flood Control District of Maricopa County, 2016.

2.3 Principles of green infrastructure

Though not an exhaustive list, this section outlines a few of the most important principles that should be followed when using green infrastructure practices[3]:

(A) Protect and restore natural areas

Natural areas—like forests, grasslands, and undisturbed riparian areas—provide the functions that GI emulates. These areas offer services including air and water filtration, as well as wildlife habitat.

When a natural feature like a wetland is removed, it is costly and difficult to rebuild the original feature's complex web of ecological interactions, and thus replace the services it provides. For this reason it is always preferable to preserve and protect natural areas, not only in places that are being newly developed, but also in the pockets of nature that still exist throughout our cities and towns.

In most communities, the undeveloped areas that remain are degraded from their original state. Working with nature to restore these areas' ecological functions and services is an essential green infrastructure practice.

(B) Serve multiple functions with GI

GI marks a new way of thinking about how we meet our goals as communities. Instead of creating infrastructure that only serves one purpose (like the concrete channel in Section 2.1), the best GI practices will serve multiple functions, like calming traffic, improving pedestrian and bicycle pathways, cooling and beautifying streets, reducing and cleaning stormwater runoff, and creating wildlife habitat. For desert communities, GI is an essential way to conserve water through irrigating public landscapes with passive water harvesting. Such integrated design creates GI practices that are more cost-effective and beneficial for communities.

(C) Include the community

GI approaches require a multidisciplinary and inclusive planning and design process. Including local residents, neighborhoods, businesses, and institutions like schools and churches is essential to creating projects that are successful and supported over the long term. Through methods like volunteer workshops and tree plantings, GI construction can be a community-led process that is educational, fun, and builds community connections. Many of the sites shown in this manual were installed by volunteers in public workshops.

[3] Green Infrastructure Principles [Internet]. Washington, DC: National Association of Regional Councils; 2006; Available from http://narc.org/environment/green-infrastructure-and-landcare/green-infrastructure-principles/

3. Planning for community scale green infrastructure

Green infrastructure works great at individual sites, such as homes, parks, and businesses. Green infrastructure can be scaled-up to the neighborhood and community level to holistically address flooding, urban heat island, and community livability. At the neighborhood scale, you can use GI to create green spaces that connect people with neighborhood assets and achieve community goals, like creating safer routes to schools.

Start with the watershed

If you are planning GI improvements in a neighborhood, the first place to start is with defining the watershed—identify how water collects and flows across individual parcels, drains along the streets, and combines with drainages, arroyos, creeks, and rivers. Once you have the watershed(s) defined, map the following:

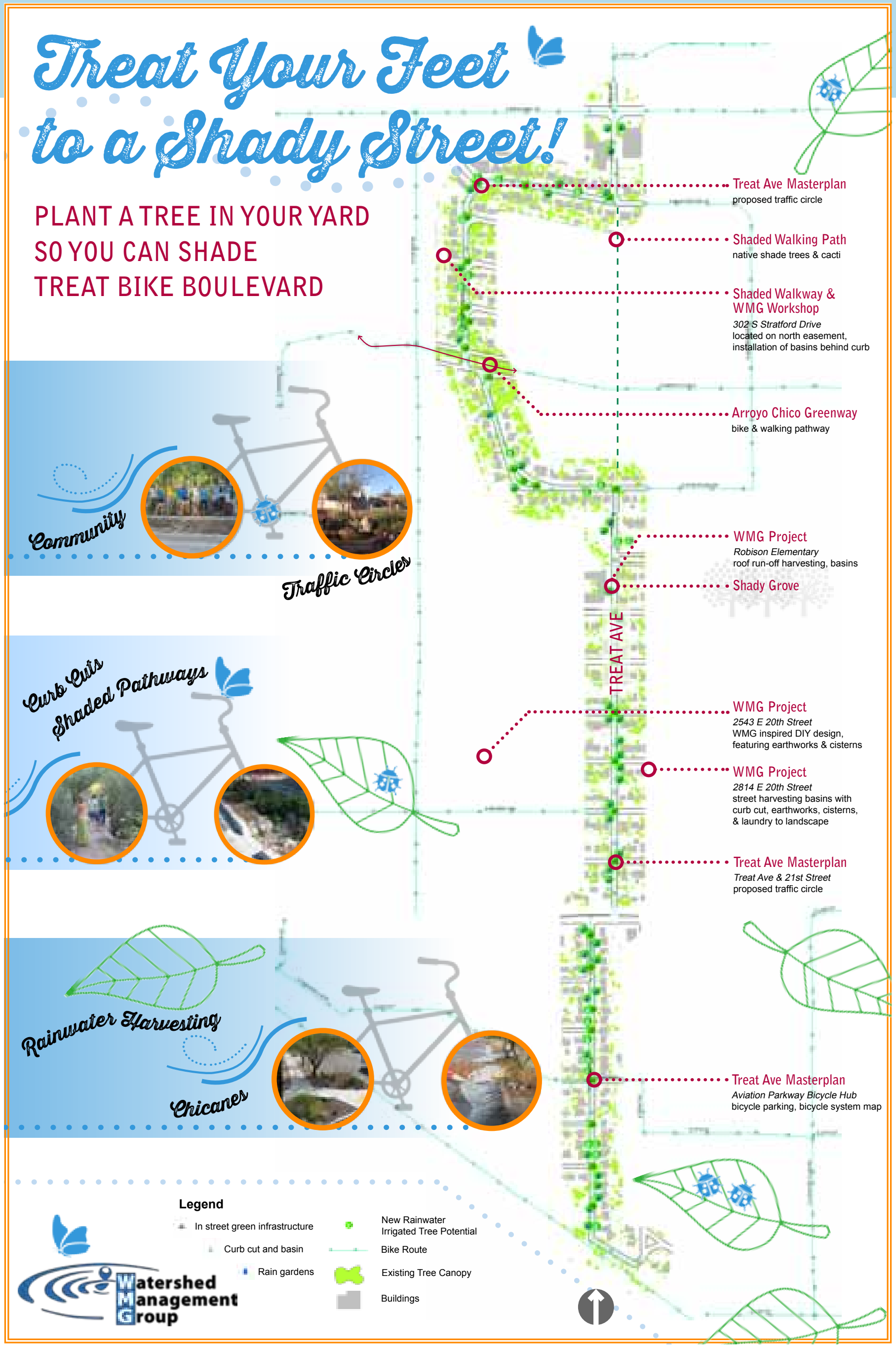
- Areas with chronic flooding, ponding, or soil erosion
- Areas ideal for groundwater recharge, like those near washes or in shallow groundwater areas
- Popular routes for pedestrians and cyclists and gathering spaces for adults and children
- Available landscape areas where GI can be installed, including:
    - wide right-of-ways (greater than 10 feet)
    - open space, relic floodplain
    - vacant lots
    - parks, churches, and schools
    - excess, unused hardscapes, and parking lots

Get creative with your GI. An overwide neighborhood intersection converted into a pocket park is complete with benches and shade trees.

Once you look at these areas on a map, you will be able to better prioritize where GI is most needed and where there are opportunities to install GI. The sweet spot is where these two areas intersect. We suggest concentrating GI to have a greater impact, instead of spreading it out across the watershed. For example, group GI features along one particular street that connects GI with nearby parks and businesses.

Vacant lots can be a blank slate for GI. Large broad basins and meandering pathways create a great place for people and wildlife habitat.

A green infrastructure traffic circle thrives with native plants, directs cyclists with signage, and calms neighborhood traffic on overwide streets.



A 2014 bike boulevard GI planning and outreach exercise helped community stakeholders identify and visualize opportunities to promote shade trees.

3.1 Finding green space opportunities

Most urban areas are in dire need of more green space, and green infrastructure provides an opportunity to create new green spaces or enhance open spaces without increasing irrigation needs in desert communities. Green infrastructure can create linear parks along streets, be incorporated into empty lots and abandoned landscapes to create pockets of new native vegetation, and enhance floodplains and arroyos. In fact, there may be more opportunities for green infrastructure in these forgotten landscape areas where there may be more space and fewer underground utilities than along streets. These GI sites can be incorporated into a larger-scale GI planning to reduce peak floods and enhance landscapes near creeks and arroyos.

Before: Palo Verde Pocket Park is a barren lot, October 2014.

One year of growth, October 2015.

After: Palo Verde Pocket Park is transformed with broad basins, meandering pathways, and a mix of native trees and shrubs, October 2016.

A newly retrofitted landscape space along a neighborhood park accepts stormwater to irrigate native plants and conserves water by reducing irrigated turf.

Identify under-utilized parcels owned by local jurisdictions where you can put stormwater to beneficial use establishing and supporting native vegetation. In Tucson, the Palo Verde Pocket Park was created in partnership with the local water utility. This parcel with a water supply well was an eyesore for the neighborhood and contributed significant runoff and sediment to the streets in heavy monsoon rains. Now basins throughout the property slow and infiltrate the flow, creating a community amenity that provides shade and wildlife habitat while significantly reducing downstream sediment and flood flows.

In existing parks, utilize opportunities to reduce irrigation needs and increase native vegetation with GI by harvesting stormwater runoff. Existing parks often have large open spaces below the grade of adjacent streets and parking lots. By directing stormwater to these areas and creating new basins to slow the flow, additional shaded areas and wildlife habitat can be created to enhance park amenities and gathering spaces. If turf is desired, large shallow basins (3 – 6″ deep x 10′ wide) can be utilized to achieve maximum benefit from stormwater while also maintaining equipment access. Park turf areas and underlying soils can be compacted from heavy use and large equipment. Ensure maintenance practices eliminate or minimize heavy equipment use in basin infiltration areas to reduce soil compaction and promote infiltration of water.

Washes and arroyos are important natural corridors in the urban environment. Upstream of arroyos, GI can improve conditions in washes by capturing and treating stormwater higher in the watershed. Revegetating, restoring, and enhancing wash channels and adjacent floodplains can provide significant stormwater quality and flood mitigation benefits while also enhancing riparian habitat. Review *Let the Water Do the Work* by Zeedyk and Clothier and the *Erosion Control Field Guide* by Sponholtz and Anderson for design details and site specific considerations for natural channels [4, 5].

[4] Sponholtz, C. and Anderson, A.C. 2013. Erosion Control Field Guide. Quivira Coalition.

[5] Zeedyk, B. and Clothier, V. 2014. Let the Water Do the Work: Induced Meandering, an Evolving Method for Restoring Incised Channels. 2nd Edition, Chelsea Green Publishing

3.2 Reducing flooding

According to a 2015 study conducted by Watershed Management Group, site-scale green infrastructure, when incorporated throughout a watershed, can make a significant difference in flood mitigation. To understand the potential for green infrastructure to address major flooding challenges, WMG focused on the Airport Wash area of southern Tucson[6]. This low-lying area experiences severe floods several times a year. These destructive events make the streets impassable and cause significant property damage throughout the community.

Working with Pima County Regional Flood Control District, WMG identified water-harvesting opportunities for streets, homes, businesses, schools, and churches within the Airport Wash area. Two scenarios were developed—one with 10% of private and public properties adopting green infrastructure features, and another with 25%—and both were evaluated for flood reduction and cost-benefit effectiveness.

The results were impressive. Both models showed that water harvesting can significantly reduce the flood impacts of even large rainstorms. As an example, under the 25% adoption scenario, peak flow conditions were diminished by 24% during a 100-year, three-hour rain event in a 930 acre watershed with 54% impervious cover. This sizeable effect affirms the power of simple water-harvesting features like front yard rain gardens and streetside stormwater harvesting to provide substantial benefits in watershed-scale flood mitigation.

The Flood Control District of Maricopa County has also developed a method to hydrologically model (using FLO-2D) GI across large watersheds[7]. This study also found that front yard water-harvesting GI can have a significant impact on localized flooding. Modeling of a neighborhood where 10% of residents install these features showed a 20% reduction in peak flow for a 100-year storm event. If 50% of residents retrofit their front yards with GI, this figure rises to a 62% reduction in peak flow.

[6] Sikdar, K., Shipek, C., Jones, C. (2015), Solving Flooding Challenges with Green Stormwater Infrastructure. https://watershedmg.org/document/solving-flooding-challenges-green-stormwater-infrastructure-airport-wash-area

[7] Tempe Area Drainage Master Study: LID Application Review and FLOD-2D Modeling. Flood Control District of Maricopa County, 2016.

3.3 Return on investment

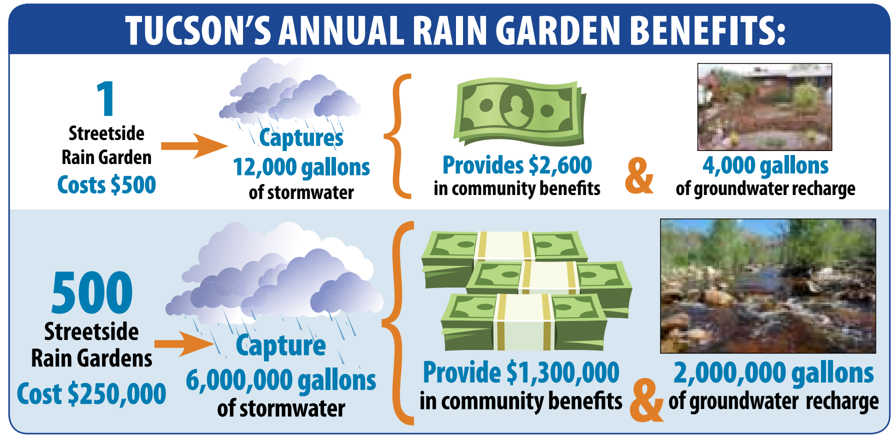
Rain gardens add economic value to community

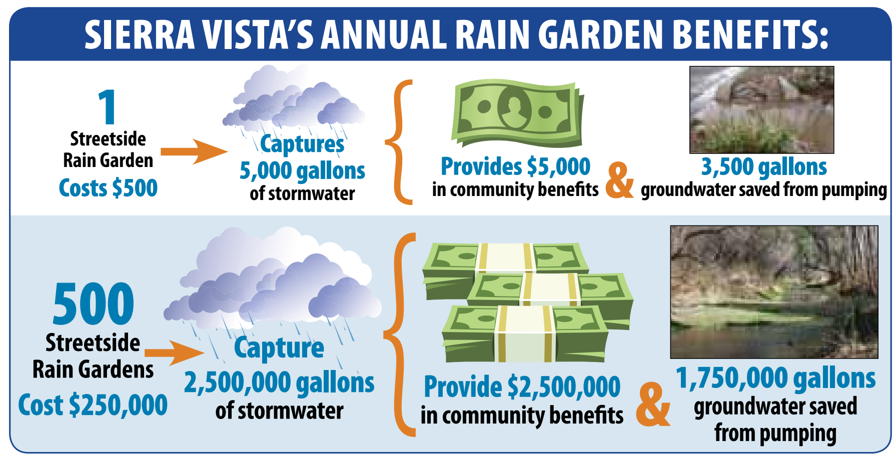
In addition to flood reduction, rain gardens provide a variety of other benefits. They create lush, shady green spaces that raise property values, lower energy costs for cooling, reduce street maintenance needs, calm traffic, and improve air quality and walkability. As thirsty sponges that soak up storm flows, rain gardens also save on irrigation costs and municipal water use, while helping filter stormwater pollution that ends up in our creeks and washes. Adding up these benefits, WMG's study found that water harvesting offers a strong return on investment, delivering $3 - $6 in community value for every dollar spent. This results in a payback period of less than eight years. For new development, the payback period is much shorter, as returns are higher with less investment.

WMG ran a cost benefit analysis for rain gardens in Tucson[8] and Sierra Vista[9] to compare the impacts these features are having in two Arizona desert communities. The impact of a rain garden depends on many factors, including soil type, climate, rainfall patterns, and plant palette. Our calculations are based on a 40 square foot rain garden with 1 to 2 native trees, organic mulch, native shrubs, and bunch grasses—totaling an average cost of $500.

Soil type plays a large role in a rain garden's performance. In Tucson, most soils can infiltrate water quickly, which supports deeper basins. This also allows for higher rates of groundwater recharge, as more water seeps through the soil to the aquifer before being used by rain garden plants. This is especially important in areas of shallow groundwater near washes and rivers as illustrated on the next page.

Although Sierra Vista receives more rainfall than Tucson, the prevalence of high-clay soils with poor infiltration rates limits the amount of stormwater that can be harvested there. Shallower basins must be used to ensure that water does not "pond" in the landscape. Even without much groundwater recharge capacity, rain gardens in Sierra Vista provide a water conservation benefit by reducing demand for supplemental irrigation. This, in turn, reduces the need to pump more groundwater—which keeps more water flowing in the San Pedro River.





[8] Sikdar, K., Shipek, C., Jones, C. (2015), Solving Flooding Challenges with Green Stormwater Infrastructure. https://watershedmg.org/document/solving-flooding-challenges-green-stormwater-infrastructure-airport-wash-area

[9] Shipek, C., Sikdar, K., Jones, C. (2015), A Stormwater Action Plan for Sierra Vista. https://watershedmg.org/document/stormwater-action-plan-sierra-vista

3.4 Conserving and enhancing water resources

When flooding occurs, stormwater typically evaporates without providing a direct benefit to landscapes or groundwater supplies. GI practices turn this "nuisance" water into a resource to irrigate plants and infiltrate more water deep into the soil. Water is conserved through reducing the need for irrigation, and groundwater supplies are enhanced through increased recharge of the aquifer. Increasing groundwater recharge in areas of shallow groundwater near streams and rivers in especially critical. Shallow groundwater areas quickly respond to enhanced recharge, and rising groundwater levels can contribute to enhanced flow in the stream channel (see next page).

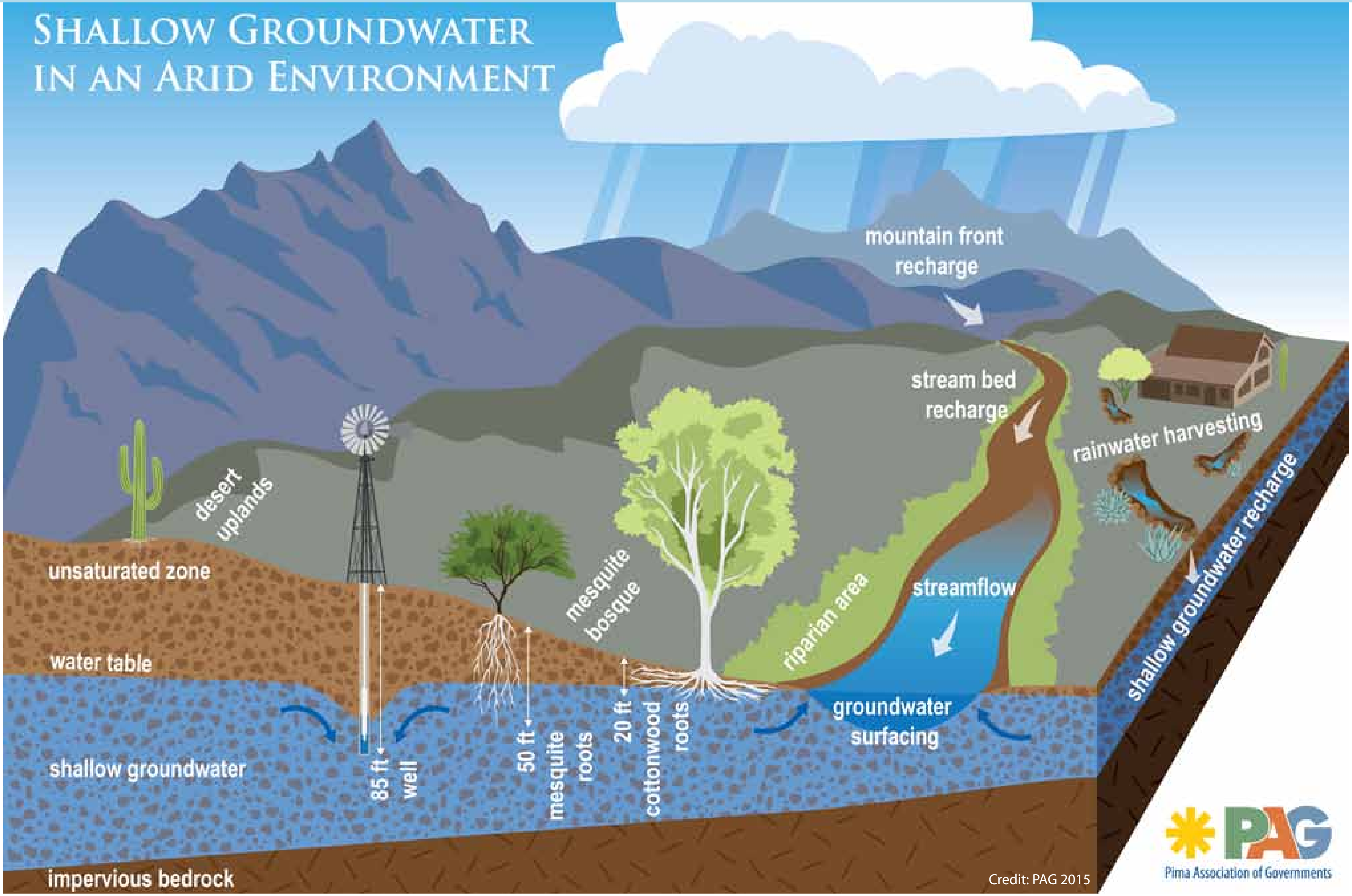
At Watershed Management Group's Living Lab and Learning Center in Tucson, Arizona, there are several stormwater basins that provide a powerful example of water conservation. The basins collect enough stormwater to provide all the irrigation needs of the native vegetation and collect additional water for potential groundwater recharge. Check out the table to the right to see one example of a stormwater basin's water budget.

A small basin accepts and infiltrates more street stormwater runoff than is needed to irrigate these native plants as highlighted in the adjacent table.

STORMWATER BASIN ANNUAL WATER BUDGET

Basin volume		Supply*		Plant Demand:		Balance:
840 GALLONS	{	16,800 GALLONS average total stormwater harvested annually	–	8,000 GALLONS used by native mesquites and understory plants in basin	=	8,800 GALLONS available for deep infiltration that has the potential to recharge groundwater

*See pg 27 to see how to calculate water budgets



Shallow groundwater is water found within 50 feet of the land surface—vital for supporting the native mesquite bosques, willow galleries, ash and hackberry trees, and bunch grasses associated with desert riparian habitats. Green infrastructure can help sustain these rare and important riparian areas by increasing local infiltration through sinking more stormwater into the ground. Learn more on PAG's Water Resources web page, http://www.pagregion.com/tabid/911/default.aspx

3.5 Reducing water pollutants

Non-point source pollution

Non-point source (NPS) pollution comes from dispersed sources like auto oil, pet waste, herbicides, and sediment.

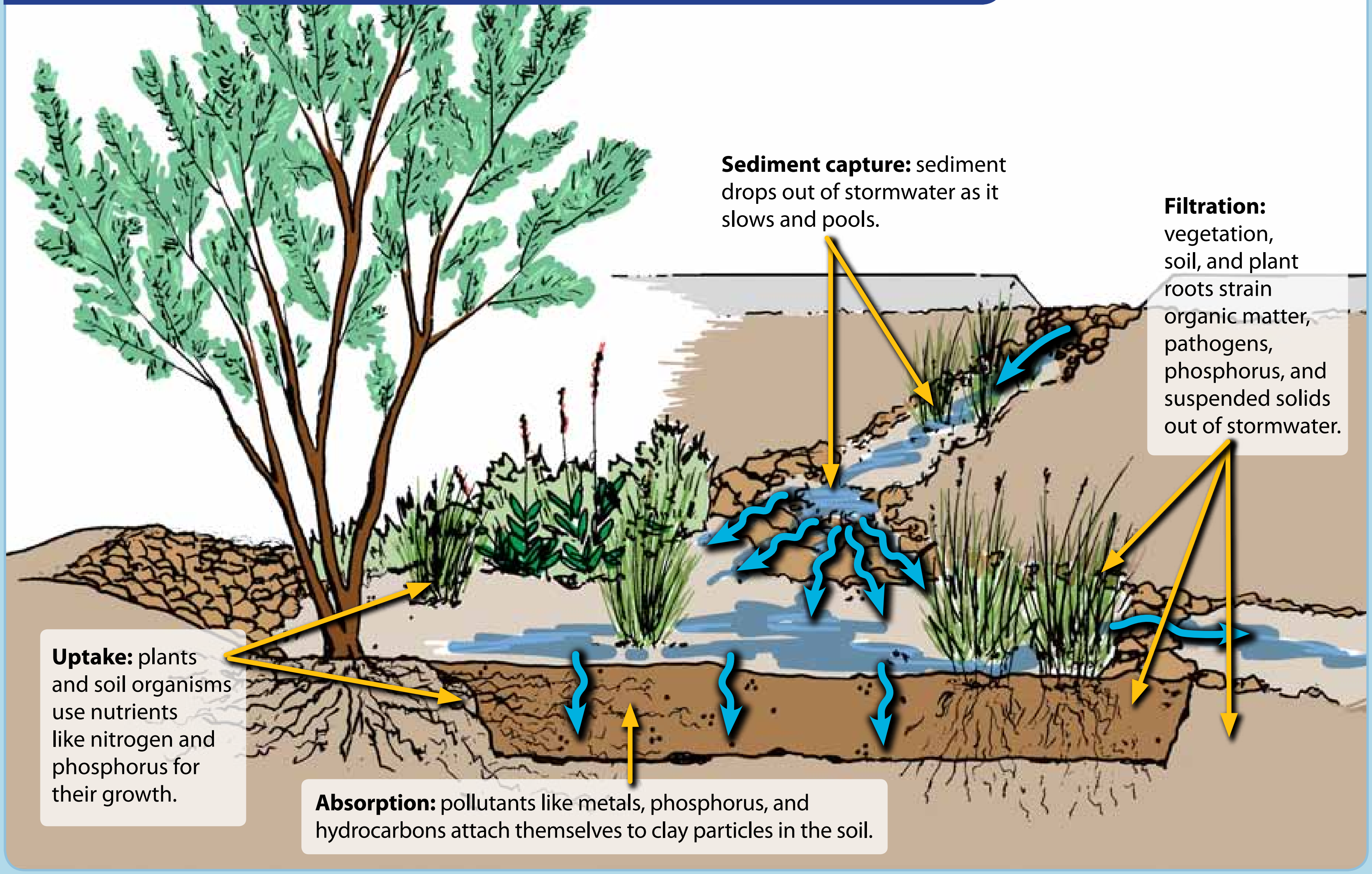
When collected and concentrated by rainfall, these pollutants can lead to serious problems for wildlife and human health alike. Other NPS pollutants common in developed areas include residue from brake pads, tires, vehicle exhaust, fertilizers, and detergents. Whatever we put on the land ends up in the water. Without changing people's behavior (like dumping trash or misusing herbicides) and the nature of the products we use (particularly automobiles, which contribute oil, heavy metals, etc. to stormwater), GI cannot solve all the problems of urban non-point source pollution.

Bioretention

GI addresses the issue of NPS through bioretention, the use of vegetation and soils to clean stormwater runoff as seen on the next page. GI can reduce pollutant accumulation in our washes and water courses, where wildlife diversity and abundance numbers are higher. Washes also have greater hydrologic connectivity to deep aquifers, thus GI can reduce the potential to pollute groundwater sources. When stormwater flows into an earthen basin lined with plants and mulch, pollutants in the water are filtered out or broken down by these processes.

Soil, mulch and plants filter pollutants from stormwater. Some potential pollutants, like hydrocarbons, are taken up by plant roots as nutrients.

RAIN GARDENS REDUCE STORMWATER POLLUTANTS



Microbial action: bacteria in the soil and plant roots break down pollutants like nitrogen and hydrocarbons, including some petroleum products[10]. Organic mulch can also increase the presence of beneficial microorganisms in soil.

[10] Environmental Protection Agency, Office of Water (US) [EPA]. (1999, September). Storm Water Technology Fact Sheet: Bioretention. Washington, DC: EPA; 1999 Sep. 8 p. Retrieved from: http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=200044BE.txt. Accessed 2016 December 1.

4.1 Vegetation

4.1.1 Function

Vegetation is an essential element of all green infrastructure practices; in other words, green infrastructure will not function without vegetation. There are many benefits of vegetation in green infrastructure[11] :

- Filters stormwater pollutants
- Reduces local temperatures by shading hardscape and providing cooling evapotranspiration, which in turn saves energy
- Extends the life of asphalt through shading
- Provides habitat for wildlife
- Builds organic matter in soil
- Increases permeability of soil through penetration of roots[12]
- Takes up atmospheric carbon dioxide and cleans the air
- Beautifies neighborhoods
- Adds value to homes
- Slows traffic along neighborhood streets
- Increases human well-being

Native plants are the best choice for use in GI practices, as they:

- Are uniquely adapted to grow in local soil and climate conditions, including low and variable precipitation in the Southwest, and generally do not require supplemental irrigation once established.
- Provide the best habitat for native wildlife.
- Help create a unique sense of place and connection with the surrounding environment.

In Tucson, for instance, South American mesquite species are sometimes chosen as landscape trees over the native velvet mesquite (prosopis velutina) for their ability to grow faster and create denser shade canopies. While these are valuable assets, South American mesquite trees have the following problems that natives do not:

- Produce shallow roots that can damage nearby hardscape
- Tend to outgrow their root systems and become vulnerable to uprooting in storms
- Produce flowers that do not attract native bees and birds as well as native plants do
- Hybridize with native mesquites in the wild

It is often difficult to find non-native plants that provide environmental services better than natives over the long term. Refer to your locally approved plant list when working in the right-of-way.

[11] Benefits of trees in urban areas [Internet]. Broomfield, CO: Colorado Tree Coalition; 2010; Available from: http://www.coloradotrees.org/benefits.htm

[12] Bartens J, Day S, Harris J, Dove J, Wynn T. Can urban tree roots improve infiltration through compacted subsoils for stormwater management? J Environ Qual 2008. 37: 2048-2057.

4.1.2 Site selection

Though each GI practice has its own vegetation guidelines, follow these guidelines for plants in all applications:

- Where possible, choose sites where adequate runoff can be collected to offset or eliminate the need for long-term irrigation of vegetation (see Section 4.1.4).
- Choose sites in which vegetation will provide maximum desired benefit, such as shading hardscape and parking areas, calming traffic, or creating community gathering spaces.
- Plan for the mature size of plants when selecting and designing GI sites. Planting too densely based on the size of young plants can create overgrown landscapes, result in stunted plants that compete for resources, and cause plants to encroach on adjacent areas (e.g. streets, sidewalks, power lines) requiring frequent pruning.

This native mesquite tree thrives in a swale that collects stormwater runoff from the street, providing shade for pedestrians.

4.1.3 Design guidelines: plant selection & placement

These two pages provide information on the environmental benefits, aesthetics, and appropriate placement of different types of plants used in GI sites. A key consideration for siting plants is where they are placed relative to standing water. During storms, water will pool in bioretention areas for periods up to several hours (see Section 4.3 for guidelines to ensure infiltration in proper time periods). The trunks and stems of many desert plants will rot when standing in water or where wet mulch lays against their trunks or stems for extended periods. Using plants, like native bunch grasses, at or near basin bottoms is critical to ensure infiltration of stormwater. Many native grasses are tolerant of standing pools of water for up to 12 – 24 hours.

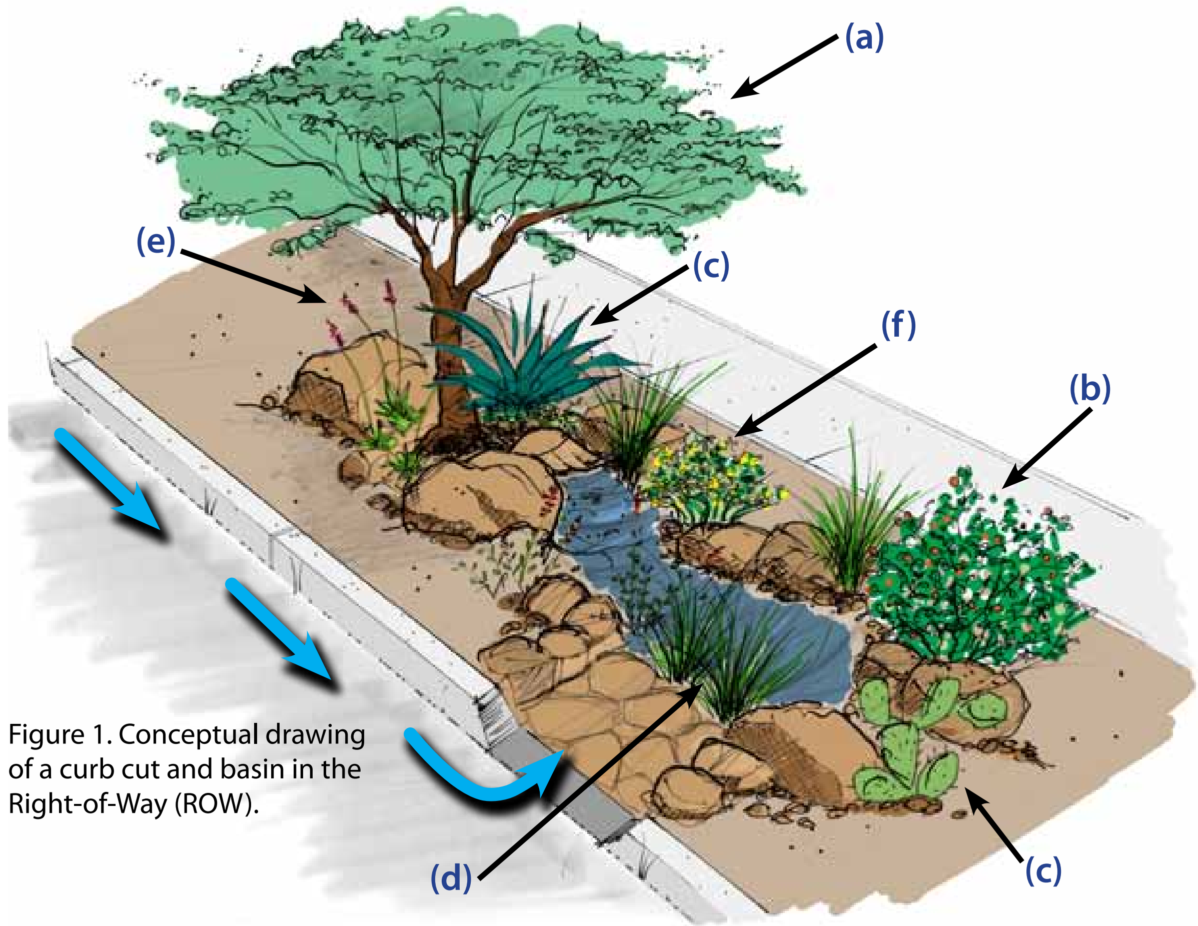


Figure 1. Conceptual drawing of a curb cut and basin in the Right-of-Way (ROW).

Trees (a)

Environmental services
See Section 4.1.1 for a comprehensive list.

Aesthetics
Trees are unmatched in their ability to create inviting, attractive landscapes.

Placement
Plant trees adjacent to bioretention areas, or on raised terraces (above level of standing water) within bioretention basins. Trees' extensive root systems allow them to reach water supplies well beyond the spread of their canopy.

Determine spacing of trees based on available water and mature canopies. For example, calculate the water demand of your tree and the amount of surface area needed to produce that amount of water. From there you can determine how many trees you can plant per basin or curb cut (see Section 4.1.4 to learn how to create a water budget).

Other considerations
Trees are not native to parts of the Chihuahuan, Great Basin, and Mojave deserts. In these areas, non-native trees, or trees native to higher elevations, may have to be used and may have higher water needs.

Shrubs (b)

Environmental services
Shrubs provide excellent habitat—flowers, fruits, seeds and cover—for native birds, insects, reptiles, and mammals.

Shrubs reduce erosion by protecting the soil surface.

Aesthetics
Shrubs create an often missing "mid-story"—an important aesthetic element in landscapes between tall trees and smaller plants.

Placement
Plant shrubs on the slope of a basin or swale or on a raised terrace just above the level of standing water, where they are low enough that their roots can easily reach moisture in the soil but not so low that they will be inundated for extended periods.

Cacti, agaves, yuccas (c)

Environmental services
Blossoms and fruits of cacti and succulents are important food sources for a variety of birds, bats, and other mammals.

These plants do little to filter stormwater or build soil, thus should not be the only type of plants used in GI sites.

Aesthetics
Cacti and succulents provide unique, sculptural landscape elements that help define a sense of place.

Taller succulents like ocotillos and Joshua trees can provide vertical elements in landscapes, while using much less water than trees.

Placement
Plant cacti and succulents above the level of inundation in bioretention basins.

Cacti and succulents use very little water, so they can be used in areas that do not receive extra runoff from hardscape.

Grasses (d)

Environmental services
Grasses provide dense networks of stems and roots that effectively filter stormwater pollutants, reduce erosion, and increase infiltration of stormwater into the soil.

Aesthetics
Native bunch grasses can provide stunning landscape elements.

Placement
Plant grasses at the bottom of bioretention areas. They typically survive both inundation and extended drought quite well and provide the best benefits in cleaning stormwater.

Other considerations
Many environments in the Southwest have primarily bunch grasses and do not have native turf-forming grasses, which are a common element of GI practices in other regions.

Wildflowers (e)

Environmental services
Flowers provide important food sources for pollinators like hummingbirds, bees, and butterflies.

Aesthetics
Wildflowers are usually the first plants to reach maturity in new GI sites and can provide welcome color during the initial establishment period for trees and shrubs.

Seeded annuals can create a rush of seasonal color in the first rainy season after planting, but will quickly turn to dry stalks when hot/dry conditions return. Plan for maintenance accordingly.

Placement
Wildflowers' tolerance of inundation varies. Seek local knowledge and experiment.

Groundcovers (f)

Environmental services
Some perennial wildflowers and shrubs can be used as groundcovers to help protect soil and hold down organic mulch.

Aesthetics
Groundcover helps to create a sense of lushness even in arid environments.

Placement
Groundcovers' tolerance of inundation varies. Seek local knowledge and experiment.

4.1.4 Water management

One of the myths about green infrastructure in the desert is that the plants will always require long-term irrigation. In many cases, the need for long-term irrigation can be eliminated or significantly reduced by 1) using native plants that are adapted to local rainfall patterns and 2) placing vegetation in areas where it will receive supplemental rainfall runoff from adjacent rooftops, streets, and parking lots.

To create a vegetated GI site that does not require long-term irrigation, create and follow a water budget for the site using one of two methods:

1. For sites where the contributing area of runoff is known (such as a portion of a parking lot discharging runoff to a bioretention basin), use local monthly or annual rainfall averages to calculate how much runoff will flow into the bioretention area over a given time period. Design a planting plan based on the estimated available water. These calculations are expertly detailed and freely available on the website of Brad Lancaster, author of Rainwater Harvesting for Drylands and Beyond[13] .

2. For bioretention features supported by street runoff such as chicanes, medians, traffic circles, or curb cut-fed basins, use the method shown in the box at right.

A velvet mesquite tree is planted on a terrace above the level of stormwater inundation at this GI site. Planting on a terrace ensures the tree's base is not inundated in water, but the roots can access the moisture.

[13] Lancaster B. Rainwater Harvesting for Drylands and Beyond Vol. 1, 2nd Edition. Tucson, AZ: Rainsource Press; 2014. 281p. (Water harvesting calculations can be found at: http://www.harvestingrainwater.com/rainwater-harvesting-inforesources/water-harvesting-calculations/)

Creating water budgets for bioretention areas in the street or right-of-way, with example for Tucson

Calculating water budgets for GI features capturing runoff from streets is an inexact process. This method assumes that, given the large amounts of runoff generated by streets, an in-street bioretention area like a chicane (see Section 6.4), or a basin capturing street runoff in the right-of-way via curb cuts (see Section 5.3), will fill to capacity with water in rainfall events of a certain size. This method is conservative in that it assumes that a bioretention area will fill only one time during all rain events (i.e. that zero infiltration is occurring). Though infiltration is actually required for a GI site to function (see next page), this conservative method is recommended to take into account such factors as climate variability. Observe local conditions to determine if this method is appropriate for your site and modify as needed.

1. Determine the water holding capacity of the bioretention area. *Example: A basin in the right-of-way with 3:1 sloping sides is designed to be 20′ long and 6′ wide at the full water line, with 8″ of stormwater holding depth. Volume = depth x ([L1 x W1] + [L2 x W2]) / 2); Volume = .66ft x ([20 ft x 6ft] + [16ft x 2ft]) /2 = 50.2 ft3; 1 ft3 = 7.48 gallons; 50.2ft3 x 7.48 gal/ft3 =* ***375.5 gallons of stormwater capacity***

2. Determine the number of average annual rainfall events in your region. This information may be available locally or through the National Climatic Data Center (www.ncdc.noaa.gov) or Western Regional Climate Center. *Example: Tucson receives an average of* ***30 days of recorded rainfall per year.***

3. Subtract the number of events with rainfall depths less than one-tenth of an inch, as these events will generally not generate runoff[14] . *Example: about 40% of recorded annual rainfall events in Tucson are less than .1 inch =* ***20 events in an average year with more than .1 inch of rainfall***

4. Multiply the remaining total number of average rainfall events over .1 inch times the stormwater capacity of the bioretention area to calculate an estimate of available annual runoff to that feature. *Example: 20 events x 375.5 gallons =* ***7,510 gallons of available annual stormwater runoff***

Design a planting plan appropriate to the estimated annual runoff available to the site (refer to local cooperative extension offices, water departments or landscape manuals for information on local plant water requirements). *Example: this bioretention feature could support two native velvet mesquite (Prosopis velutina) trees with 20′ diameter canopies (each requiring approx. 2,940 gallons annually) along with several native shrubs, grasses, wildflowers and cacti*[15] .

[14] Environmental Protection Agency, Office of Water (US) [EPA]. (2009, December). Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act. Washington, DC: EPA; 2009 Dec. 61 p. https://www.epa.gov/greeningepa/technical-guidance-implementing-stormwater-runoff-requirements-federal-projects. Accessed 2016 December 1.

[15] Lancaster, op. cit. pp. 136-141. Also available at: http://www.harvestingrainwater.com/wp-content/uploads/Appendix4PlantLists.pdf

4.1.4 Water management (continued)

- Irrigate plants for a 2- 3 year establishment period after planting; reduce irrigation as much as possible thereafter.
- After establishment period, plants may need occasional irrigation during periods of extended drought.
- Provide hand-watering for establishment instead of drip irrigation where possible. This method conserves resources, can save on costs, saves water, and ensures better plant care[16] .
- In areas where long-term drip irrigation is deemed necessary, set irrigation timers to mimic natural rainfall patterns by providing deep, infrequent irrigation (this can reduce maintenance needs by controlling plant growth).
- Irrigate at dawn or dusk to minimize evaporation rates.

Sonoran desert wildflowers pop with color in this streetside swale.

Plant Establishment Tips: Establish your native plants with this general watering guide to make sure your plants survive and grow healthy.

1st Year: Baby them now for stronger plants later.
- Water deeply right after you plant, and every 1 – 2 days for the first two weeks.
- Water two times a week during the hot season.
- Water one time a week during the cool season.

2nd Year: Start to wean your plants off additional irrigation.
- Water one time a week during the hot season.
- Water 1 – 2 times a month during the cool season.

3rd Year and beyond
- Water during dry summer months or during times of drought.

**If you receive rainfall, then you can skip your extra watering cycle! Remember plants native to your bioregion can thrive off natural rain cycles. By harvesting rainwater and stormwater, you are actually increasing the amount of water a plant will receive in a rain event and storing extra moisture in the soil. Once plants are established this is all they should need.

[16] Wittwer, Gary. (City of Tucson Department of Transportation, Landscape Architect). Conversation with: Kieran Sikdar. 2016 May.

4.1.5 Setbacks

- Required setbacks from the City of Tucson are given as an example of the kinds of considerations required for vegetation. Consult the local transportation department for regulations in your area.
- Follow appropriate setbacks from under- and above-ground utilities as determined by local guidelines.
- In areas where transportation visibility is required (usually within any in-street practices and in the ROW at intersections), plant only shrubs lower than 30" and canopy trees that are clear of leaves and branches up to 6' at maturity.
- Trees should generally be located 3 feet back from sidewalks and the street.
- Trees with canopies extending over sidewalks must be pruned to 8' high.
- Trees with canopies extending into traffic lanes must be pruned to 14' high.

4.1.6 Maintenance

- Use mulch and establish good perennial ground cover to reduce weed growth.
- Prune shrubs and trees to maintain access to pathways and visibility requirements.
- Cut up prunings and drop in the basin to replenish mulch as needed.
- If possible, allow trees to grow for 2 – 3 years with no pruning to build strong trunks.
- Replace plants lost to mortality.

4.2 Surface mulch

Mulch refers to any substance used to cover and protect soil.

- Organic mulch is made from dry, shredded plant pieces.
- Rock mulch is made from gravel, stone, urbanite, or broken brick.

4.2.1 Function

One of the primary functions of mulch in green infrastructure is to reduce evaporation of moisture from the soil. This function is crucial in desert areas, where potential evaporation (100″ in Tucson) far exceeds rainfall (12″ in Tucson). See the table below for additional benefits provided by mulch.

In this just-installed chicane, 4″-8″ rip-rap is used in the channel where stormwater will flow rapidly, and 1″ gravel covers upslope areas.

Function, costs & benefits of organic and rock/gravel mulch

	Organic mulch	Rock/gravel
Controls weeds	yes	somewhat
Retains soil moisture	yes	somewhat
Regulates soil temperature	yes	no
Builds soil organic matter	yes	no
Reduces erosion	yes	yes
Stays in place in areas of high water flow	no	yes
Provides wildlife habitat	yes	somewhat
Leaf litter that falls must be cleaned up	no	sometimes
Renewable, low embodied-energy resource	yes	no
Promotes beneficial soil microbes	yes	no
Cost	low/free*	higher

* Tree-trimming companies will often provide chipped mulch for free.

4.2.2 Site selection & design

Based on its many beneficial characteristics, use of organic mulch is preferred when possible. The main advantage of rock mulch is that it does not move in areas of high pedestrian traffic and significant stormwater flow.

Taking these factors into account, the general rule of thumb for choosing mulch is:

- Use organic mulch in areas where water pools/eddies/is deposited, such as in a basin attached to a curb cut.
- Use rock mulch in areas where water is being transported or where flooding is a concern, such as in a swale or in-street practices.

Other considerations in using mulch include:

- A 4″ layer of organic mulch is required to effectively reduce weed growth.
- Keep mulch away from trunks of trees or shrubs to prevent rot.
- Do not use decomposed granite or unwashed gravel in or near infiltration areas; small particles can fill pore spaces in the soil and prevent infiltration of water.
- Use tightly placed larger rock (4″ – 8″ or larger) to reduce erosion in sites where serious flooding is an issue.

4.2.3 Maintenance

- Replenish organic mulch every 1 – 3 years to maintain a depth of 3″ – 4″.
- Tree and plant trimmings can be chopped and left in place to replenish the organic mulch layer.

A 4″ layer of organic mulch dramatically reduces weeds in a neighborhood park. Use organic mulch where stormwater has low velocity.

4.3 Soil health

Healthy desert soils infiltrate more water and help filter pollutants.

Understanding soil is critical to designing and building green infrastructure projects. Soil structure and ability to infiltrate water below the soil surface dictate basin size, shape, and depth. Urban desert soils are often compacted and degraded, making infiltration difficult. Often construction of green infrastructure neglects the importance of soil health and results in compacted basin bottoms filled with rock, void of vegetation, and with no means to easily manage sediment or prevent soil surface sealing. By creating the conditions for soil life and native vegetation to thrive, soils will improve naturally to ensure green infrastructure performance, and soil health will improve over time, maximizing water quality improvements and native vegetation growth.

Warning, this is bad design! This chicane was installed without plants, taking the "green" out of the infrastructure. Without plants, the soil surface may seal and cause ponding. Plant roots create spaces for water to infiltrate and are needed for the soil food web to work. Invasive plants may also take hold which will be difficult to manage. The large rip rap in the basin will make any maintenance very tedious – including removal of weeds or sediment.

4 basic steps to promote healthy soils:

1. Build organic mulch: Apply a 2 – 4" layer of organic mulch and incorporate native bunch grasses to improve infiltration (see Section 4.1.3). Let leaf litter accumulate in basin bottoms and between riprap. If needed, add compost soil amendments to enhance poorly draining soils at the time of GI installation. Leave mulched vegetation trimmings in basin bottoms to support long-term infiltration rates.

2. Reduce compaction and eliminate soil disturbances: Avoid heavy equipment in basin bottoms and break up existing compaction and/or restrictive soil layers to at least twice the ponding depth. Once installed, avoid ongoing soil disturbing activities which destroy or severely set back soil restoration (e.g. tilling, scraping, raking, spraying herbicides, pesticides, etc).

3. Create root mass: Select and mix plants with shallow, deep, and far reaching root structures. Native bunch grasses have dense and deeply penetrating roots which are helpful for improving infiltration and de-compacting soil. Native trees add organic material through root mass underground which also promotes movement of air and water through dense soil layers.

4. Encourage structural planting: Native trees provide a protective canopy which creates a beneficial micro-climate for understory plants and can send roots deep. Understory plants help to further de-compact soil through dense roots, increasing soil organic content, and prevent soil surfaces from sealing due to accumulation of fine sediments, oils, and grease.

Dealing with difficult soils

All GI sites should be designed to infiltrate their maximum stormwater capacity within 24 hours to avoid mosquito breeding. Conduct a percolation test (a simple test to assess how quickly water is absorbed into soil) to determine infiltration rates.

- In areas with clay soils, hardpan, or caliche (an impenetrable layer of calcium carbonate often found in desert soils), consider removing or boring holes, and/or improving soil with compost. A digging bar, jack hammer, or pick can be used to create drainage holes through the caliche into the underlying soil. In some cases, soil may have to be replaced with engineered soil mixes to allow adequate infiltration.

- Avoid compaction of soils during construction. Till or rip soil surface after construction to reduce compaction.

- Make your basins wider and/or add compost or loamy soil to decrease the depth of your basin.

- Soil improvements such as compost, minerals, etc. do little to enhance the growth of most drought-adapted native plants[17] . However, mixing soil with compost may be a useful tool for improving soil infiltration and moisture retention.

- In areas where the water table is high and/or infiltration is low, underdrains may need to be incorporated into bioretention features—these are not covered in this manual.

- See the Appendix for an example basin cross section that includes best practices for soil health.

[17] Cromell C, Miller J, Bradley LK. 2003. Earth–Friendly Desert Gardening. Phoenix, AZ: Arizona Master Gardener Press; 2003. 136p. (p. 71).

What is the right-of-way?

Rights-of-way (ROWs) are pieces of land reserved for transportation, utilities, and other public uses. Neighborhood streets are located within municipally-owned transportation ROWs that usually include the street itself and strips of land on either side where sidewalks, utilities, and street trees are located. For the purposes of this guide, the term rights-of-way refers only to the strip of land between the street and private properties.

Why work in the ROW?

One inch of rain falling on one block of typical city street (40′ x 300′) generates some 6,700 gallons of stormwater runoff. This runoff can become a problem for communities in the form of downstream flooding and nonpoint source pollution, or it can become a resource providing moisture for neighborhood vegetation if captured close to the source.

By using the techniques on the following pages, ROW landscape areas can be turned into rain gardens that infiltrate stormwater from neighborhood streets while growing beautiful trees and shrubs that shade streets and sidewalks[18]. ROWs are legally and logistically easier to work in than the street itself, making them good locations for volunteer-led neighborhood tree planting efforts and green infrastructure projects.

5.1 Site selection, design and workflow

Working in the ROW can be something that is undertaken by a city, a neighborhood group, or an individual homeowner. Though a single curb cut and basin in front of a home may have only a small impact on local stormwater issues, it can provide great benefit as a demonstration of green infrastructure principles and practices that others can clearly see. If a practice is installed as part of an educational workshop or neighborhood volunteer effort, the educational value is magnified as well. The ROW practices featured in the following pages were all installed via volunteer workshops led by WMG.

When working in the ROW, follow these steps:

1. *Identify owners of adjacent properties and obtain necessary permissions.* The ROW is publicly owned, but adjacent landowners are often held responsible for maintenance of landscape features and vegetation in the ROW in front of their home or business. Landowners may also be held liable for accidents that occur in the ROW. Know your municipality's policies, and get written permission from adjacent landowners.

   The best sites for working in the ROW are often those where the landowner is actively interested: they will tend to be better stewards of the site (watering, weeding, and trash pickup) than absentee landlords or disinterested neighbors.

[18] For additional details on individual practices and construction best practices see Pima County and City of Tucson's Low Impact Development and Green Infrastructure Guidance Manual, March 2015.

A Tucson neighborhood ROW captures street runoff to feed a cooling canopy of native trees and shrubs.

Volunteers install bioretention basins in the right-of-way at a workshop in Tucson led by Watershed Management Group.

5. Streetside green infrastructure practices

This 400 sq ft rain garden has the potential to harvest 4,500 gallons of stormwater each time it rains. The project was installed by WMG in partnership with the City of Mesa, in front of the Mesa Urban Gardens.

2. *Identify who will maintain the site and how it will be maintained.* This step is often overlooked, but it is crucial to the success of any GI site (see Section 8).

3. *Visit the site to assess water flows.* Visiting a site during rain events will provide invaluable information for evaluating appropriate sites for GI:

    - How much runoff flows through the site in different size storms?
    - Does stormwater flow along the gutter or in the middle of the street? If the latter, street runoff will not be available to ROW plantings.
    - Does stormwater overtop the curb in large storms? If so, plan for erosion control behind the curb.

4. *Locate utilities.* The ROW is often used as a corridor for water, gas, and other underground utility lines. Locate lines early in the process, as excavation and/or planting is restricted around them. In Tucson, for instance, mechanical excavation is not allowed within 2 – 4 feet of a buried utility line. Use a utility locating service (free in most areas) to mark lines on the site, and determine required setbacks for planting and excavation. Be creative in working around utility lines—sometimes careful hand-excavation close to lines can make a site a viable candidate for GI. When planting trees, be aware of how tree growth may interfere with overhead lines.

    Note: Many ROW GI projects are made impossible by the presence of underground utilities. Some forward-thinking cities, recognizing that the ROW is an excellent place for planting street trees, require utilities to locate in the street. "Trenchless" approaches are now available that allow utilities to maintain their lines without digging up the asphalt.

5. *Create a water budget for the site.* See Section 4.1.4.

6. *Create a design*. Use the information on individual practices (Sections 5 – 7).

7. *Submit the design for permits.* A municipal permit is often required to work in the ROW. Contact your local jurisdiction to find out about the permit process.

8. *Conduct pre-excavation if necessary.* Desert soils can be incredibly hard, particularly if they have been compacted by years of pedestrian or vehicle traffic. Using machinery for rough excavation of the site will often be necessary. Plan for where excavated soil will go. Using excavated soil locally (such as in raised pathways on-site) can reduce hauling costs.

9. *Cut curbs.* If cutting the curb is a part of the project, it should be done after rough excavation and before final installation to facilitate appropriate placement of erosion-control rockwork (see Section 5.2).

10. *Conduct final earth shaping, rockwork, planting, and mulching*. This can be a great step to involve neighborhood volunteers. The ROW features shown in this manual were primarily installed through volunteer workshops.

11. *Visit the site to assess function and maintenance needs and collect information for future sites.* Make changes as necessary. GI sites require ongoing stewardship to preserve their function.

Note: for an excellent step-by-step description of installing a ROW GI site, review Brad Lancaster's book, Rainwater Harvesting for Drylands and Beyond, Vol 2, page 198.

5.2 Curb inlets

Curb inlets, cuts, or cores are openings created in the curb to allow stormwater from the street or other adjacent impervious surface (e.g. parking lot) to flow into a depressed infiltration and planting area. This page focuses on the curb cuts themselves; the practices in Section 5.3 – 5.5 give details on how to create the adjacent bioretention areas.

5.2.1 Function

- Curb inlets are useful for retrofitting existing neighborhoods with green infrastructure practices without major reconstruction.
- Cutting or coring curbs is significantly cheaper than working to collect stormwater via in-street practices.
- 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.

5.2.2 Site selection

- Crowned streets are appropriate for using curb cuts, because they are highest at the middle of the street and carry stormwater along the curb.
- Observe the site during a rainfall event to determine if and how much stormwater actually flows along the curb where a cut is planned. Even on a crowned street, one side may be higher than the other, or flows may be altered by upstream factors. Also, small divots or cracks in the pavement may direct runoff away from the curb in smaller rainfall events.
- Avoid streets with slopes greater than 5% or in areas where the curb is routinely submerged.
- A permit and/or licensed contractor may be required for curb cuts along the ROW. Check with your municipality's transportation department for permit information as well as required setbacks and location guidelines. (In the City of Tucson, for instance, curb cuts must be 5' away from driveway aprons and 20' back from intersections).
- Minimum width of the earthen area between curb and sidewalk/path must be 6' in areas with on-street parking and 5' without parking.

5.2.3 Design and construction

Curb Cuts:

- Typically, in Tucson curb cuts are 18" – 24" wide, with 45° sloped sides. Variations based on curb type or in other communities have also been successful (see adjacent photos).
- The bottom of a curb cut should slope away from the street and slightly toward basin area.
- A rip-rap apron (sediment trap) should be built where the water flow crosses the cut curb into the ROW area. The apron will prevent soil erosion and undercutting of the road surface. Rock sized 4" – 8" can be laid in a single well-fitted course around the entrance. The top of the rock surface should be laid 1 – 2" below the level of the bottom of the curb cut to ensure positive water flow into the basin.

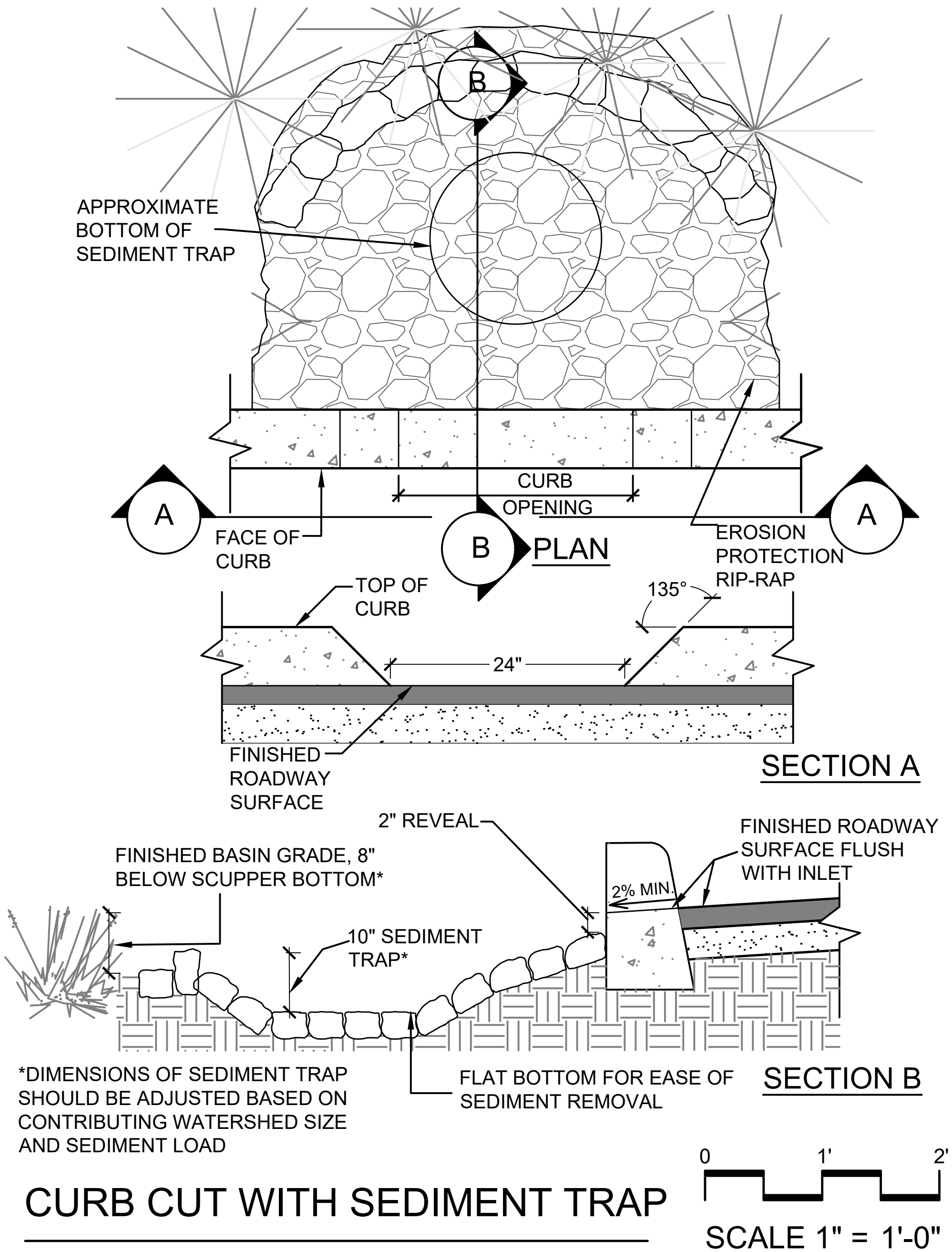


Figure 2. Example curb cut inlet detail.

Curb cuts can still work on wedge curbs.

Simple, angled curb cut enhances capture of stormwater moving along the gutter.

Curb Cores:

- Curb core inlets are typically 3" – 4" diameter with the opening at street level through a vertical curb. The larger diameter is preferred when possible to prevent clogging of the inlet. Since cores are more prone to blockage by debris, they should be used as a last resort, and only in cases where a raised curb exists, the beveled sides of a curb cut present safety concerns, and the curb is a minimum of 6" above street grade. Variations of the curb core can be used to convey water under sidewalks or pathways to basins (see adjacent photos).
- Slope of core should convey water away from the street and towards basin area.
- A rip-rap apron (sediment trap) should be built where the water flow crosses the cored curb into the ROW area. The apron will prevent soil erosion and undercutting of the road surface. Rock sized 4" – 8" can be laid in a single well-fitted course around the entrance. The top of the rock surface should be laid 1 – 2" below the level of the bottom of the curb cut to ensure positive water flow into the basin.

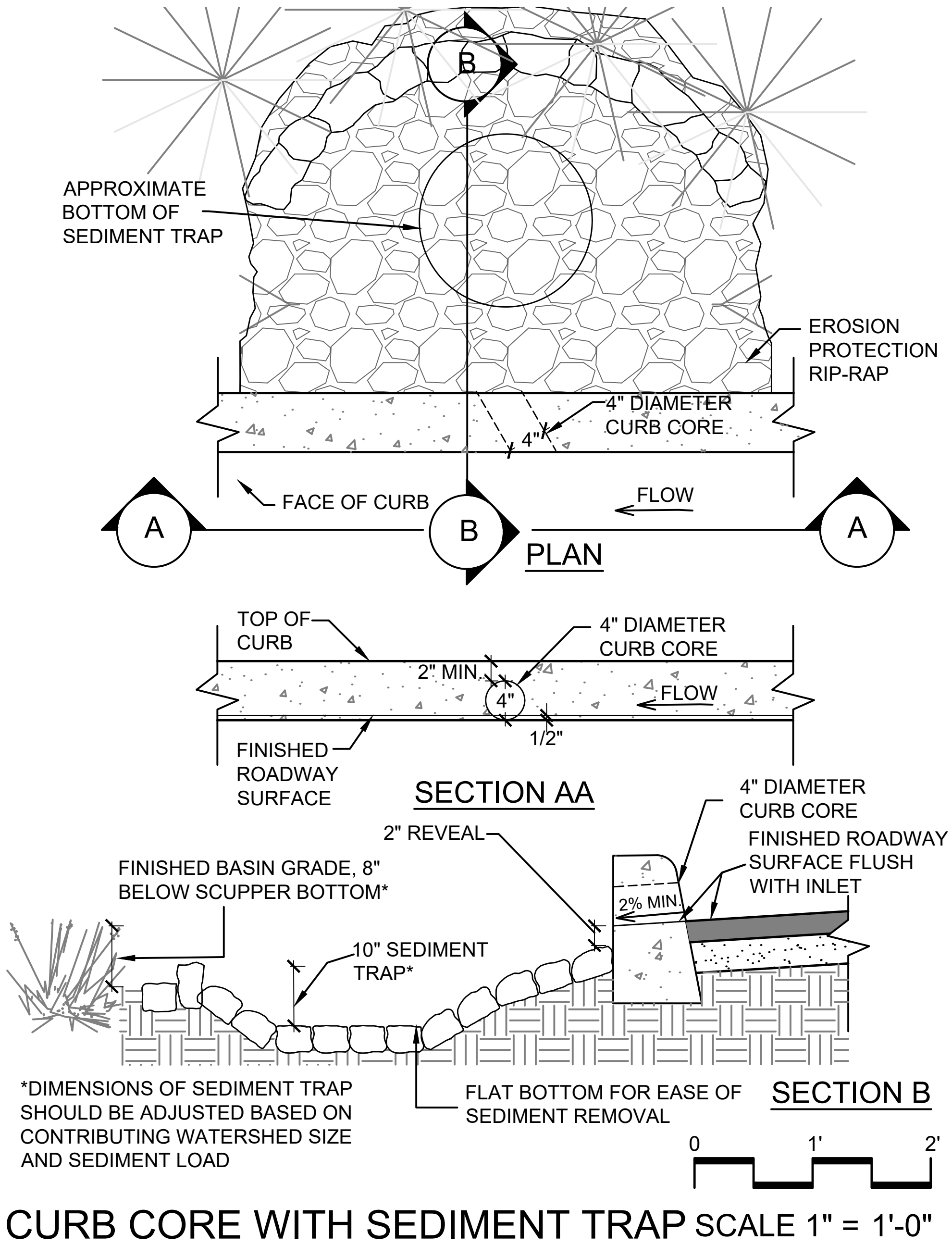


Figure 3. Example curb inlet core detail.


Drilling a 4″ core at a slight downward angle to enhance water flow into basin.


The core inlet is fitted with a plastic pipe sleeve to move water under the pathway into the basin.

Sidewalk Scuppers:

- A scupper is an opening with a cover plate that allows runoff to enter a streetside bioretention basin while maintaining pedestrian access and safety.
- Scuppers are preferred in high-use pedestrian zones and/or when water needs to be conveyed through a non-landscaped area (e.g. under a sidewalk).
- Scuppers are preferred over curb cores, as cores are more prone to blockages and require periodic maintenance to ensure function. (see adjacent photo)

5.2.4 Maintenance

- Regularly clear curb inlets of any debris that may prevent the free flow of stormwater into basins (1 – 2 times per year).
- Check rip-rap aprons for signs of erosion and repair/reinforce as needed (annually).

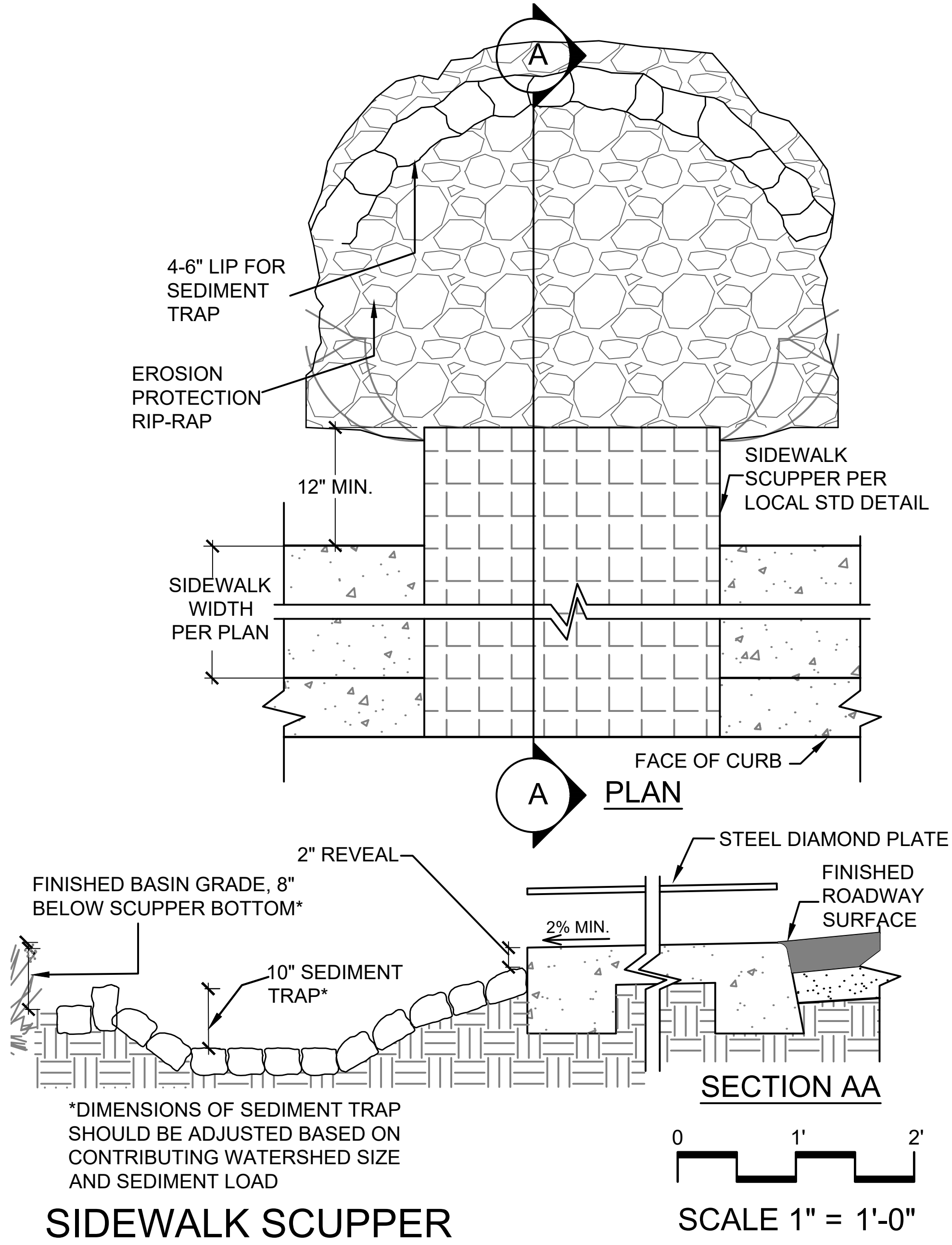


Figure 4. Example sidewalk scupper detail.

Variations of sidewalk scuppers allowing stormwater to flow under sidewalk.

5.3 Curb cut and basin

To collect and infiltrate stormwater from curb cuts into the right-of-way, bioretention basins must be excavated in the ROW to a depth below street level. If the ROW landscape width is 9′ or wider then basins with shallow slopes that are not lined with rock can be created. If the ROW landscape width is narrower, then rocks or other reinforcement materials should be used to prevent erosion along steeper sloped basin edges.

5.3.1 Function

Advantages

- This practice can be used to collect stormwater from relatively narrow or wide ROWs.
- Basins create a delineated area for mulch and planting.
- Organic mulch can be used where only a single curb cut allows water in or out and street flooding does not occur over the top of the curb.

Disadvantages

- Basins may inhibit walkability in high-use pedestrian zones.
- Basins are often constrained due to presence of underground utilities.
- Along streets with steep slopes, basins should be sized appropriately to ensure stormwater does not spill out of the lower lip of the basin. Zuni bowls can be utilized on extremely steep slopes to control the grade while reducing the velocity of water[19].

5.3.2 Site selection

- Follow site selection guidelines for curb cuts (Section 5.1) and vegetation (Section 4.1).
- Minimum width of the earthen area between curb and sidewalk/path must be 6′ in areas with on-street parking and 5′ without parking.
- Avoid streets with longitudinal slopes greater than 5%.
- Maintain setbacks from above- and below-ground utilities as required.

5.3.3 Design and construction

- Excavate bottom of basin 10″ – 12″ below the surface of the street and backfill with 2″ – 4″ of mulch. (Note: In Tucson, basins must not allow standing water deeper than 8″. Excavating deeper and backfilling with mulch allows greater stormwater capacity. The top of mulch must be 2″ below the curb cut inlet.)
- In areas where the slopes of the basin will exceed 3:1 or 33%, the edges of the basin must be lined with rock to prevent erosion.
- If pedestrian access to cross the ROW is needed, size basins no longer than 20′ in length, with 5′ level pathways between basins.
- Make level area at bottom of basin as large as possible to maximize stormwater infiltration.
- In areas with on-street parking, preserve an 18″ "step-out zone" of flat soil or gravel next to the curb (sloped 1% toward basin) to allow passengers to step in and out of vehicles.

[19] Erosion Control Field Guide, pages 6-7, Sponholtz and Anderson, Quivira Coalition.

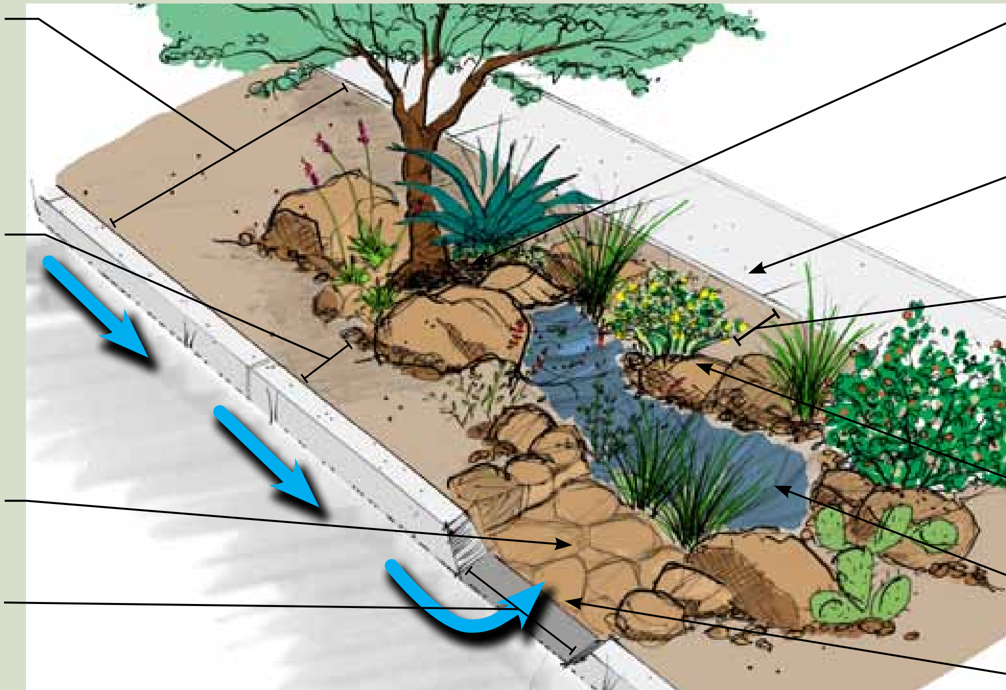


Figure 5. Conceptual drawing of a curb cut and rock-lined basin in the ROW.

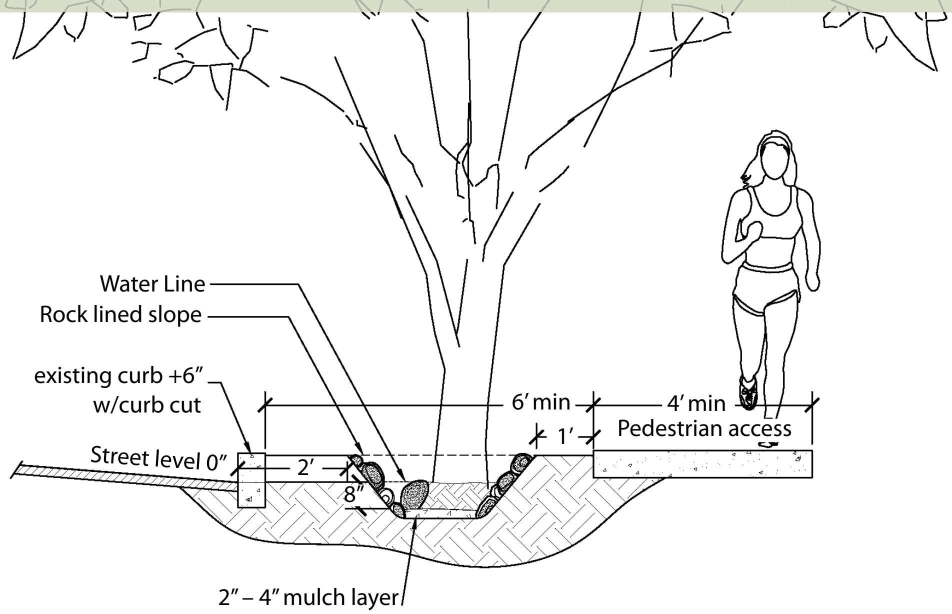


Figure 6. Section A. Typical cross-section of a basin with rock-lined edges, showing typical setbacks for a site on a residential street with on-street parking. For plan view, see Appendix.

- Preserve a 1′-wide area (sloped 1% toward basin) next to pedestrian pathways or sidewalks to ensure basin slope is not right next the pathway.
- If sidewalks are not present, preserve a minimum 4′ flat pedestrian pathway within the ROW (sloped 1% toward basin).
- The curb cut should be both the inlet and the overflow outlet of the basin. To achieve this, the bottom of the curb cut should be at least 4″ below any other point along the edge of the basin rim. This step is imperative to ensure that overflow exits back onto the street and not onto adjacent properties. The more a site is sloped, the shorter the basin must be to maintain these levels.
- Create planting terraces along the basin to support native trees and shrubs. Be sure planting shelves do not block flow of stormwater along the basin length.

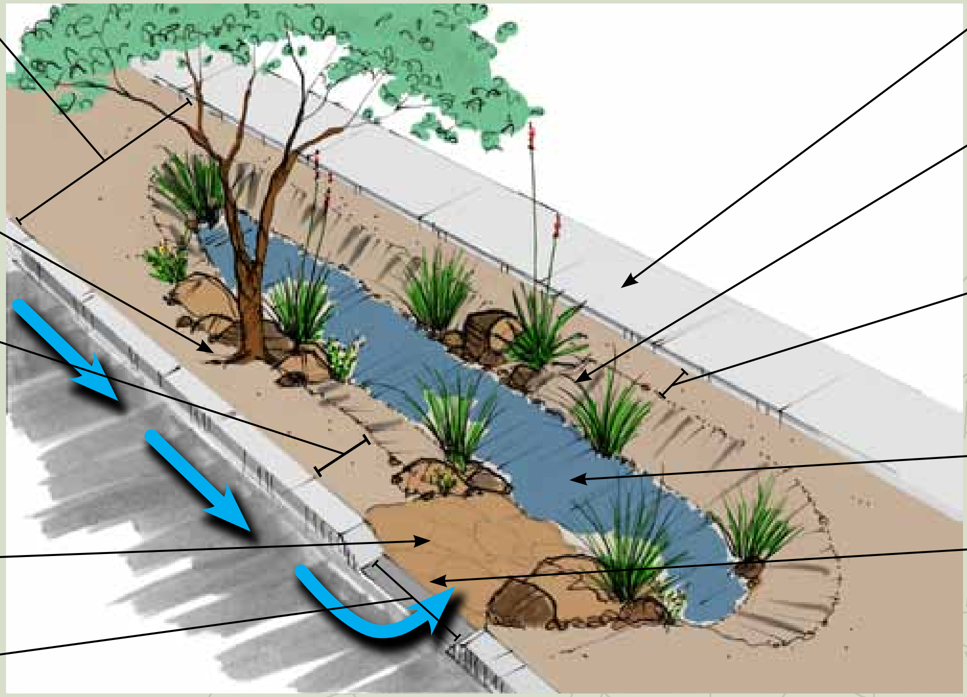
To preserve visibility, do not plant trees or shrubs that will encroach into travel lanes. A tree canopy may extend over parking areas at a minimum height of 8′ – 9′ and over travel lanes at 14′ (refer to local codes).

5.3.4 Materials

- For steeply sloped basins use 8″ – 20″ rip-rap to line the perimeter.
- Use 4″ – 8″ rip-rap as an apron below curb cuts to reduce erosion. Make use of urbanite (repurposed concrete) in place of rip-rap if available.
- Use organic mulch in basin wherever possible. If street experiences severe flooding then rock mulch may be necessary.

5.3.5 Adapting the practice to your site

- In ROW areas without on-street parking, reduce "step-out zone" to a minimum of 6″.
- If utilities cross the ROW perpendicularly, use these areas as raised pathways for pedestrians to cross the ROW between basins.
- In areas where the ROW is not wide enough for this practice, consider smaller basins without curb cuts to capture runoff from adjacent sidewalk/path and properties (see Section 5.5).
- Turn an upstream driveway cut into an opportunity to harvest water flowing along the curb and gutter and direct it to the basin. This saves from having to cut a new inlet.
- A basin can be constructed along a ROW without a formed curb. Along these streets an 8′ clear setback is often required before the start of the vegetated basin. Cut a gradual slope along the street or a gentle swale laid with gravel to direct flow to the basin.
- In high pedestrian traffic areas or where minimal landscape space is available then heavy metal grates can be placed over the inlet and basin to provide a stable walking surface that irrigates the vegetation.



Note: this illustration shows an intentionally under-vegetated basin to show slope contours.

Figure 7. Conceptual drawing of a curb cut and basin with shallow slopes in the ROW.

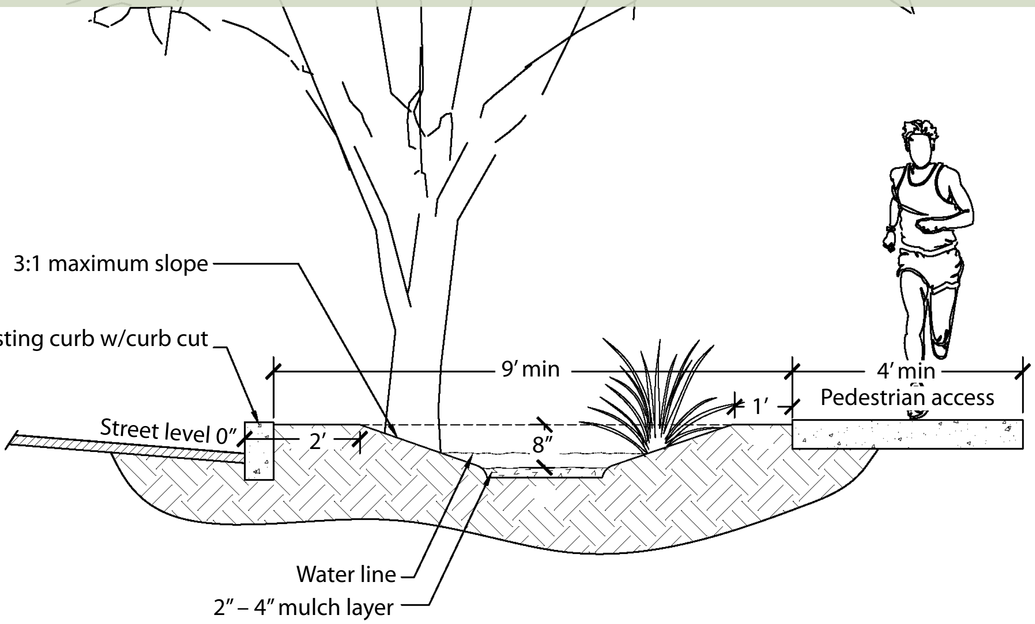


Figure 8. Section B. Typical cross-section of a basin with sloping sides, showing typical setbacks for a site on a residential street with on-street parking. For plan view, see Appendix.

5.4 Sediment traps

Sediment removal poses a considerable challenge in the maintenance of GI sites. In the arid Southwest, high proportions of bare soil are common, yielding faster rates of erosion and sedimentation. This requires that GI sites in areas of high flow be armored with rock or gravel, which in turn makes sediment removal more problematic. Sediment traps help to address this issue.

5.4.1 Function

Sediment traps capture and collect sediment at the entrance to bioretention areas, facilitating periodic sediment removal and extending the functional life of these features.

5.4.2 Site selection

- Use sediment traps in areas where high sediment loads are observed in stormwater.
- Traps can be used at the inflow of any GI feature. These diagrams show an example for use with a curb cut and rock-lined basin.

5.4.3 Design and construction

- Excavate an 8″ depression, 1′ from the inside of the curb cut, approximately 2′ x 2′.
- Create a 4″ – 6″ rock lip separating this area from the rest of the basin.
- Plant native bunch grasses immediately adjacent to the rock lip on the basin side to further assist in slowing the flow and filtering stormwater pollutants.

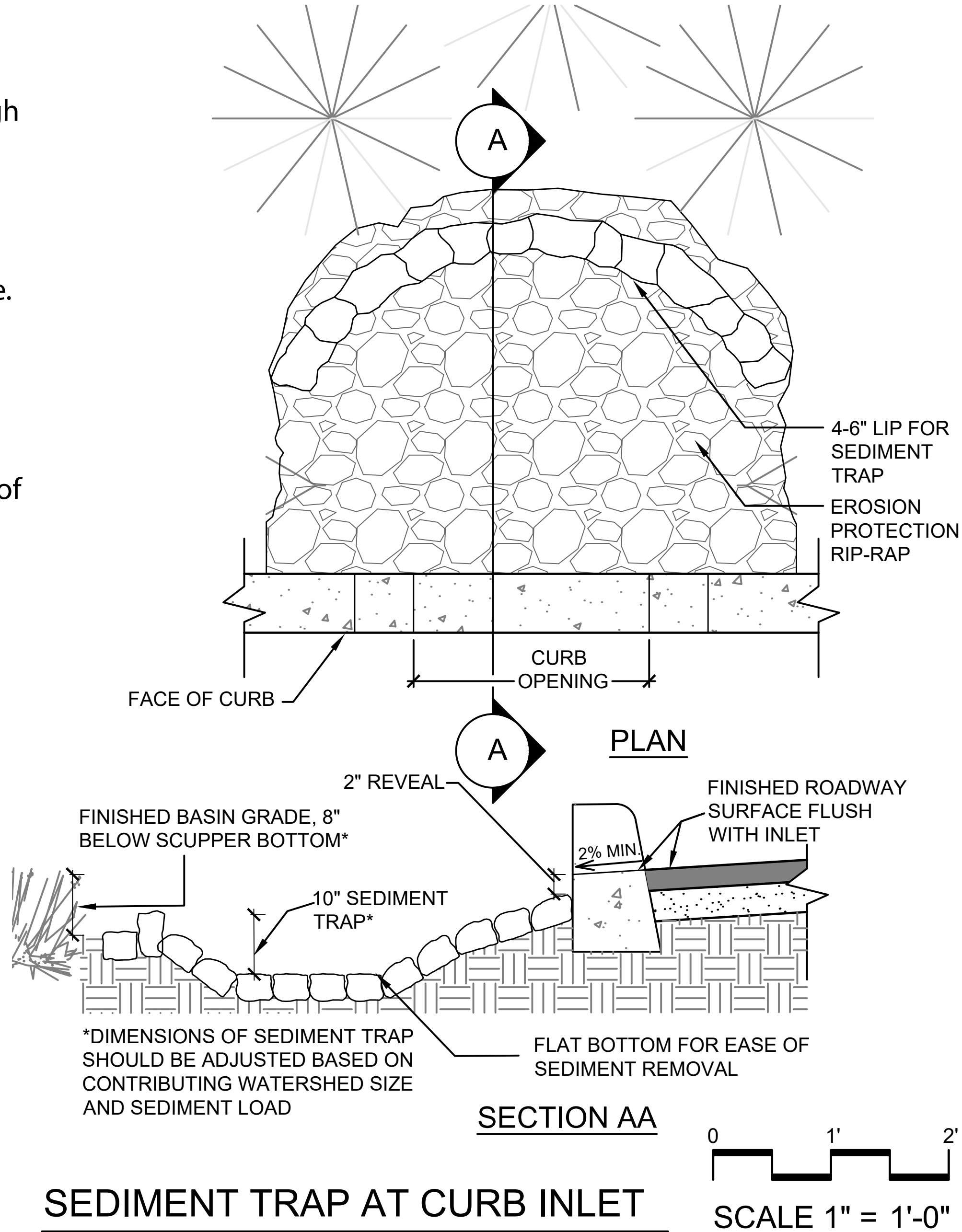


Figure 9. Example detail for a sediment trap.

5.4.4 Materials

- Line curb cut apron, bottom of sediment trap, and slope of berm with a single well-placed, well-anchored course of 4″ – 8″ rip-rap or urbanite (repurposed concrete).
- Tie 4″ – 8″ rock (above) into rip-rap edges of larger basin (see plan view for detail).

5.4.5 Adapting the practice to your site

- This concept will work for many GI applications beyond the one shown. The key concept is to create a place where water will pool momentarily to allow coarse sediments to drop out of stormwater before it spills over into the main bioretention feature.
- Always ensure that the top of the retention lip is a minimum of 4″ below the bottom of the stormwater inlet (or flush curb).

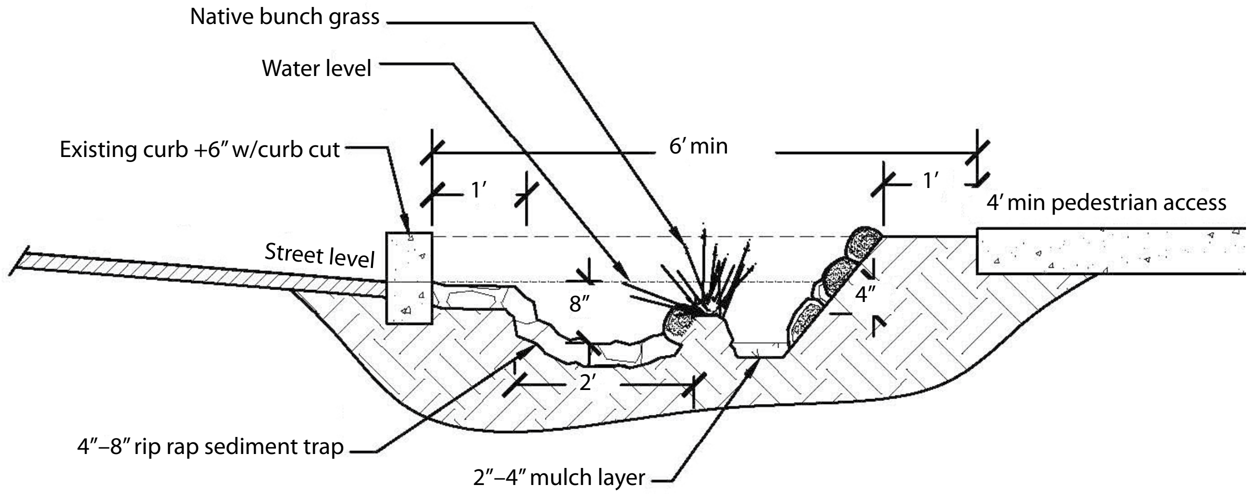


Figure 10. Section A1. Typical cross sectin of sediment trap for curb cut with rock-lined basin.

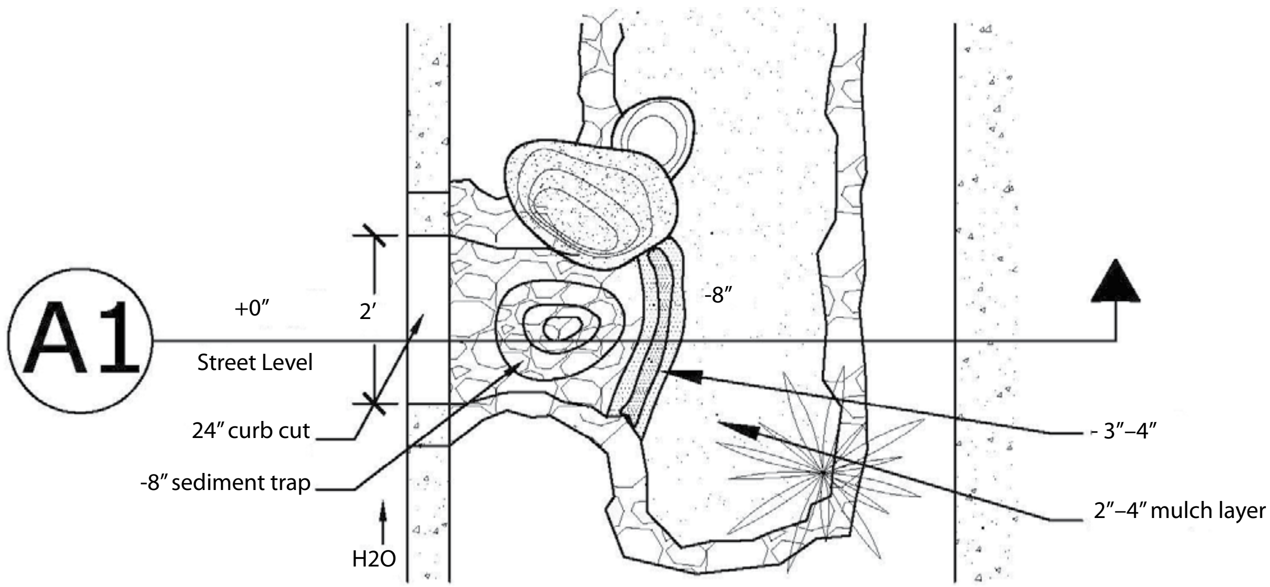


Figure 11. Plan view of sediment trap for curb cut with rock-lined basin.

5.5 Other applications

5.5.1 Swale with curb cuts

A swale is a bioretention feature with gently sloping sides that is long and linear in shape. Swales may capture and infiltrate stormwater in place (when level-bottomed), or transport water downhill to a drain or other detention feature. In the example below, a long swale was created to capture stormwater from the street via a series of curb cuts.

This design can have an identical cross-section to the shallow-sloped basins in Section 5.3.3; the difference is that the swale is one long continuous feature rather than being broken up into individual basins. This practice would not work in areas where more frequent pedestrian crossing of the ROW is required, or on steeper slopes where erosion might be caused by the through-flow of water in and out of curb cuts.

5.5.2 Basin or swale without curb cuts

In areas where the ROW is too small to create a basin with curb cuts or where stormwater does not flow along the gutter, swales and basins may still be created to capture runoff from sidewalks and adjacent properties.

- If only collecting runoff from an adjacent sidewalk (versus from a street or parking lot), this method will generally provide less passive stormwater irrigation to plants.
- Downspouts from adjacent buildings can be directed into basins in the ROW. These must be sized appropriately to capture and infiltrate the calculated rooftop runoff.
- Since no curb cut is present to serve as the overflow for bioretention features, ensure that overflow is directed to the street and not onto adjacent properties.

This long, shallow swale in the right of way has multiple curb cuts along its length.

At this site in Tucson, a 3″ deep swale was created in the ROW to collect runoff from the sidewalk and adjacent property.

This series of basins collects stormwater from the adjacent sidewalk and businesses (without curb cut).

The problem: Overwide streets

Too many southwestern streets are

- Too wide
- Barren of vegetation
- Hot and unfriendly to bicyclists and pedestrians, as well as adjacent homes and businesses

They generate stormwater runoff that

- Carries non-point source pollution to waterways
- Floods the street, creating traffic hazards
- Erodes soil downstream of paved areas
- Increases maintenance costs

A solution: Narrowing with green infrastructure

In-street GI features:

- Chicanes or bump outs
- Medians
- Traffic circles

These features reduce the street width, accept stormwater, and create planting areas, which

- Calm traffic
- Reduce flooding, sedimentation, and erosion
- Capture, clean, and infiltrate stormwater
- Grow vegetation that shades streets and sidewalks, cooling neighborhoods and creating more desirable places for biking and walking

6.1 Why work in the street?

The following points outline the advantages and disadvantages of using in-street green infrastructure practices versus working only in the rights-of-way with curb cuts and basins.

Advantages

- Possible in areas with limited ROW options
- Can capture more stormwater
- More effective traffic calming
- Dramatically affects streetscape and neighborhood aesthetics

Disadvantages

- More expensive
- More disruptive (can displace parking, more construction, etc.)
- May not be possible in areas where stormwater conveyance is needed

Median with curb cut

Chicane with no curb cut

Typical Southwestern street

Traffic circle with curb flush with street level

6.2 Site selection, design, and workflow

Preserving street width

To preserve access for emergency vehicles, the Uniform Fire Code requires that each lane of traffic must be at least 10′ wide, however some municipalities may require greater width. (In the City of Tucson, for instance, traffic lanes on residential streets must be 11′ wide.) An 8′ width is also required for each lane of parallel parking along the curb. For example, a street with two lanes of traffic and parallel parking on one side could be a minimum of 28′. Any width over 28′ could potentially be incorporated into a feature like a chicane, median, or street width reduction. Consider reducing on-street parking to make installing these practices possible.

Stormwater conveyance

Many southwestern streets are designed to convey stormwater. For example, in Tucson many "washes," or designated waterways, are actually streets that flow with large amounts of stormwater in powerful desert storms. Essentially the street functions as the "river bottom" and the curbs act as the "river banks." In these situations, adding a raised median or a curb extension to the street can reduce the street's stormwater capacity and increase the risk of flooding adjacent properties. GI practices designed for southwestern streets will need to take this unique challenge into account. In general, the solution is found by creating in-street GI features that have flush curbs and bioretention areas depressed below the level of the street (see following pages).

Bicycles and pedestrians

The in-street GI practices described in this manual are all designed to calm traffic. Chicanes, medians, and traffic circles all narrow the roadway forcing drivers to slow down. While they can create obstacles for bicyclists, slower overall traffic speeds mean that serious injury accidents involving bicyclists and pedestrians are less likely to happen[20]. In addition, chicanes and medians at intersections can reduce pedestrian crossing time (by reducing the distance between the curbs) and increase visibility for both drivers and pedestrians (by keeping parked cars farther away from intersections). These properties of in-street GI features make them a great option for those neighborhoods seeking to make streets safer and more livable and reduce cut-through traffic.

Workflow

Because they are on public streets, these GI features generally require a high level of government involvement in the design and installation process. Workflow of in-street projects will likely be determined by local official protocols. However, local knowledge about stormwater flows, dangerous intersections, neighborhood goals, etc. are invaluable to the planning and design process—and sadly, often overlooked. This manual is intended as a bridge to provide neighborhood residents with relevant information to contribute to planning processes and to offer officials a neighborhood perspective on green infrastructure.

[20] Bikesafe Bicycle Countermeasure Selection System [Internet]. Washington, DC: Department of Transportation, Federal Highway Administration (US). Available from: http://www.pedbikesafe.org/bikesafe/

General Design Details

- Excavate the feature to a final depth of 8 – 12" (e.g. if laying 4" – 8" rock, excavate 4" – 8" deeper to enable at least a final depth of 8").
- For chicanes and street reductions, where possible, extend vegetated and depressed bioretention areas into the adjacent ROW. This may be achieved by laying ROW slopes back (see plan view in Appendix) or pouring a new curb deeper into the ROW (see Figure 9 next page).
- Maximize the area of level bottom of the feature by using steep side slopes (up to 50%) armored with rock.
- Use flush header curbs 18" deep to protect the adjacent asphalt surface.
- Create raised planting areas for trees and shrubs that do not tolerate inundation. The raised planting areas can additionally function to slow stormwater flow through the bioretention area.
- To preserve visibility, do not plant trees or shrubs that will encroach into travel lanes. A tree canopy may extend over a travel lane at a minimum height of 14' (refer to local codes).
- Use a modified sediment trap (Section 5.4) at the flow entrance of the feature to facilitate maintenance.

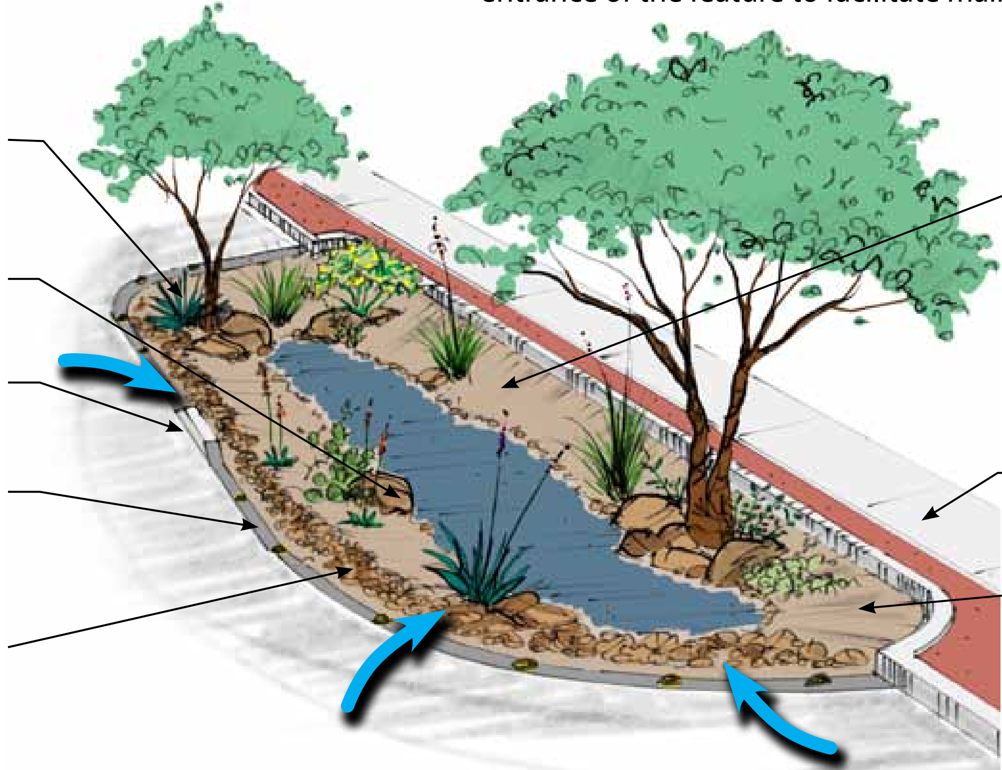


Figure 12. Conceptual drawing of a chicane with bioretention area for a neighborhood street.

6.3 Materials

- In areas of higher flow (concentrated flow with depths >1″ – 2″), line soil surface with 4″ – 8″ rock (or urbanite) to prevent scouring of soil. Areas that experience lesser flows can use coarse gravel or a mix of 1″ – 3″ rock.
- Place several larger boulders within the feature to increase visibility and prevent vehicle entry.
- Place 6″ ceramic disks along the top of header curb to discourage entry by automobiles. These may be reflective.
- Place flashing solar lights on the asphalt to warn oncoming traffic of obstruction.

6.4 Chicanes and street width reductions

For many over-wide neighborhood streets, it may be appropriate to narrow the width of the street. Narrowing of a street can occur in shorter sections using chicanes (also called "bump outs" or "curb extensions") or along the entire length of the street using street width reductions. These features are created by removing pavement and increasing the bioretention area along street edges.

Narrowing the street width significantly reduces impervious area, increases safety by calming traffic speeds, collects and infiltrates stormwater, and increases vegetation and tree canopy cover. It may also provide new space for pedestrian paths and sitting areas. Size these features as large as possible to increase stormwater mitigation and traffic calming effects. Generally, the encroachment width into the street is 8′ and the length can be from 18 – 20 feet, or the entire length of the street in the absence of driveways.

When designed with a flush curb and depressed bioretention area, these street narrowing features collect and infiltrate stormwater that flows along curbs.

Why a chicane or street width reduction?

- These features function best to collect stormwater on crowned streets, because they are highest at the middle of the street and carry stormwater along the curb.
- Chicanes can be used effectively both mid-street and on the corners at intersections. Consider incorporating chicanes with pedestrian crossings to shorten crossing distance and restrict parking near intersections.
- Most chicanes require a minimum of 8′ of available (surplus) street width. See Section 6.2 for details on preserving appropriate street width.
- Take on-street parking needs into consideration. Chicanes may displace existing on-street parking.
- On steeper sloped roads (> 2%), berms or check dams may be needed to slow stormwater flowing through the bioretention features.

The concrete curb to the left of the blue arrow is flush with the street.

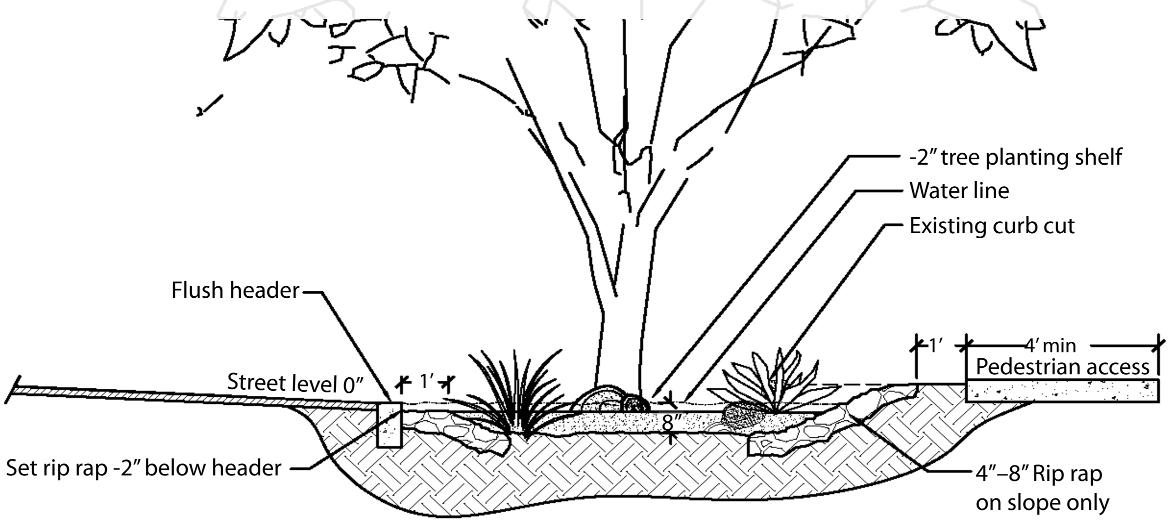


Figure 13. Section F. Typical cross-section of a chicane with flush curb and depressed bioretention area. For plan view, see Appendix.

Adapting chicanes or street width reductions to your site

- If these features are designed for concave streets (with the lowest point in the middle of the street), use a uniformly raised curb and a depressed planting area to capture and infiltrate stormwater that falls on the basin area and the adjacent ROW.
- In areas with higher sediment flows, consider using sediment traps (see Section 5.4) to improve maintenance. If you are designing a series of chicanes along a single flow path with an upstream sediment source then design the first chicane to be your primary sediment trap.
- For streets where maintaining maximum stormwater conveyance is not an issue, features with raised curbs (and a flush stormwater inlet) can also be used (see photo below). If the design can be modified to function similar to a curb cut and basin, organic mulch should be used.
- In lengthy street width reductions, parking spaces can be incorporated by cutting them in (by retaining existing asphalt) to the bioretention area at intervals along the street.
- Incorporate creative methods such as seating areas, pathways, or public art to enhance the community value and utility of larger street width reduction projects.

6.5 Medians

Medians are features that divide the street in the center. Medians slow traffic by reducing the effective street width, and can increase safety by keeping traffic lanes separate. When designed with a flush curb and depressed bioretention area, medians can collect and infiltrate stormwater that flows along the street and use that water to grow vegetation that shades the street and slows traffic. The bioretention area promotes vegetation, reduces stormwater volumes, and filters non-point source pollutants from stormwater.

Why select a median?

- Medians function best to collect stormwater on concave, or inverted crown, streets, because they are lowest in the middle and carry stormwater along the middle of the street.
- Medians can be an excellent way to slow traffic entering a neighborhood from higher-speed regional streets, and/or to prevent cars from making unsafe or unwanted turns mid-street. They can also serve as refuge islands for pedestrians and bicyclists crossing wide roads, especially when paired with crossing traffic signals.

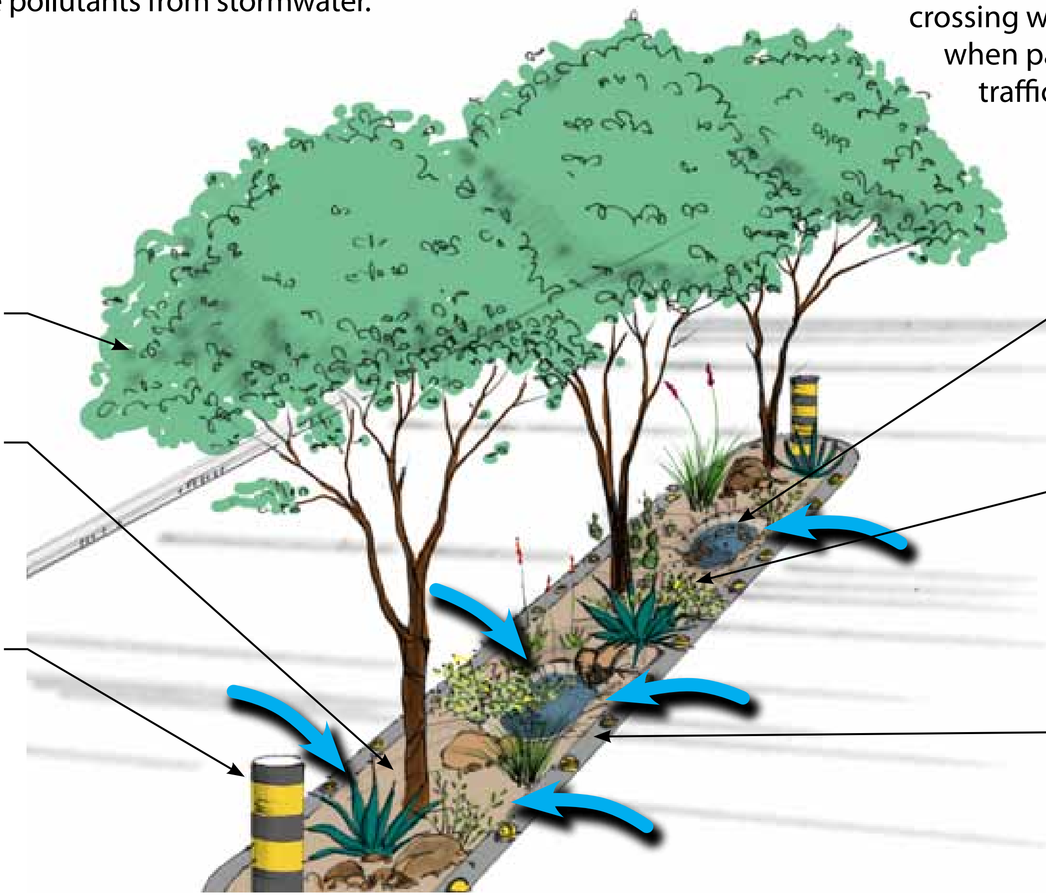


Figure 14. Conceptual drawing of a median with depressed bioretention area for a neighborhood street.

- Medians require a minimum 5′ of surplus street width. See Section 6.2 for details on preserving appropriate street width.
- Consider reducing on-street parking to make installing medians possible.
- Bioretention medians may not be appropriate for steeply sloped streets; consult local transportation departments.

Adapting medians to your site

- Place bollards (posts with reflective markings) at both ends of the median to warn oncoming traffic of obstruction.
- Consider striping pavement surface in approach to median to increase visibility of feature (see plan view in Appendix).
- If medians are designed for crowned streets (with the highest point in the middle of the street), use a uniformly raised curb and a depressed planting area, no higher than street level, to capture and infiltrate stormwater that falls on the median itself.

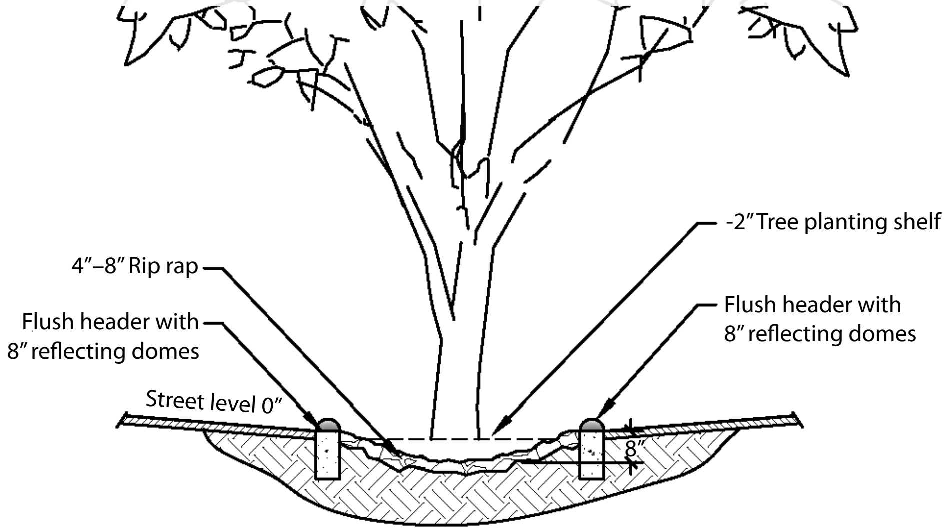


Figure 15. Section E. Typical cross-section of a median with flush curbs and depressed bioretention area. For plan view, see Appendix.

6.6 Traffic circles

Traffic circles are used in intersections to slow traffic. They are an excellent way to reduce impervious area in a neighborhood and can be designed with a flush curb and depressed bioretention area to collect and infiltrate stormwater. The bioretention area within the traffic circle will promote vegetation, reduce stormwater volumes, and filter non-point source pollutants.

Size traffic circles to be as large as possible within allowable constraints to increase stormwater mitigation and traffic calming effects. Check with your local emergency and waste hauling services about turning radius needs of larger vehicles for your intersection.

Why select a traffic circle?

- Traffic circles function best to collect stormwater at intersections where water flows through the intersection along a centerline. This usually occurs where the streets are concave (lowest in the middle).
- Traffic circles constrict the intersection and turning radius. To preserve access for emergency vehicles, codes typically require that the minimum distance from the traffic circle header to the nearest corner of the intersection be 20′ (check local municipal guidelines).

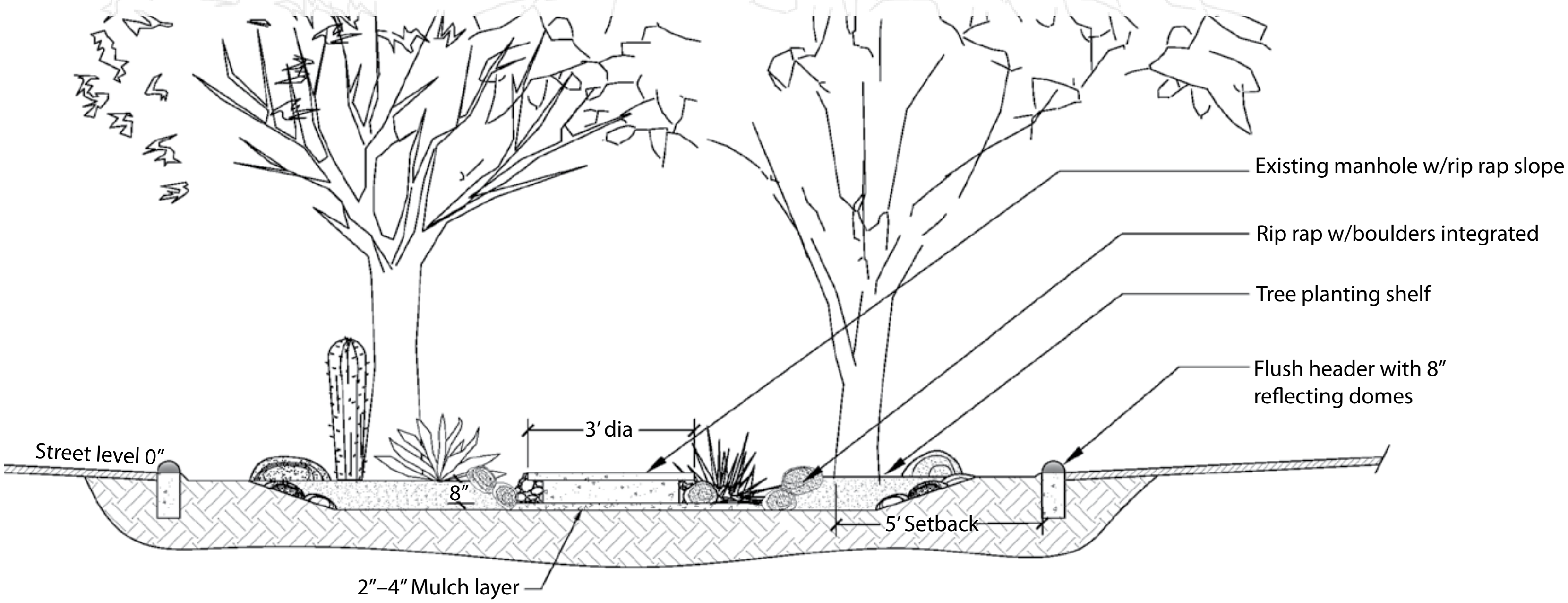


Figure 16. Section C. Typical cross-section of a traffic circle with flush curbs and depressed bioretention area. For plan view, see Appendix.

Adapting traffic circles to your site

- If traffic circles are used in crowned intersections (highest in middle), use a uniformly raised curb and a depressed planting area to capture and infiltrate stormwater that falls on the traffic circle itself (see adjacent photo).
- A traffic circle is designed to slow but not stop the flow of traffic. If you are adding a traffic circle at an intersection with stop signs you may want to check with your transportation authority about removing the stop signs and replacing with yield signs in tandem with your traffic circle.

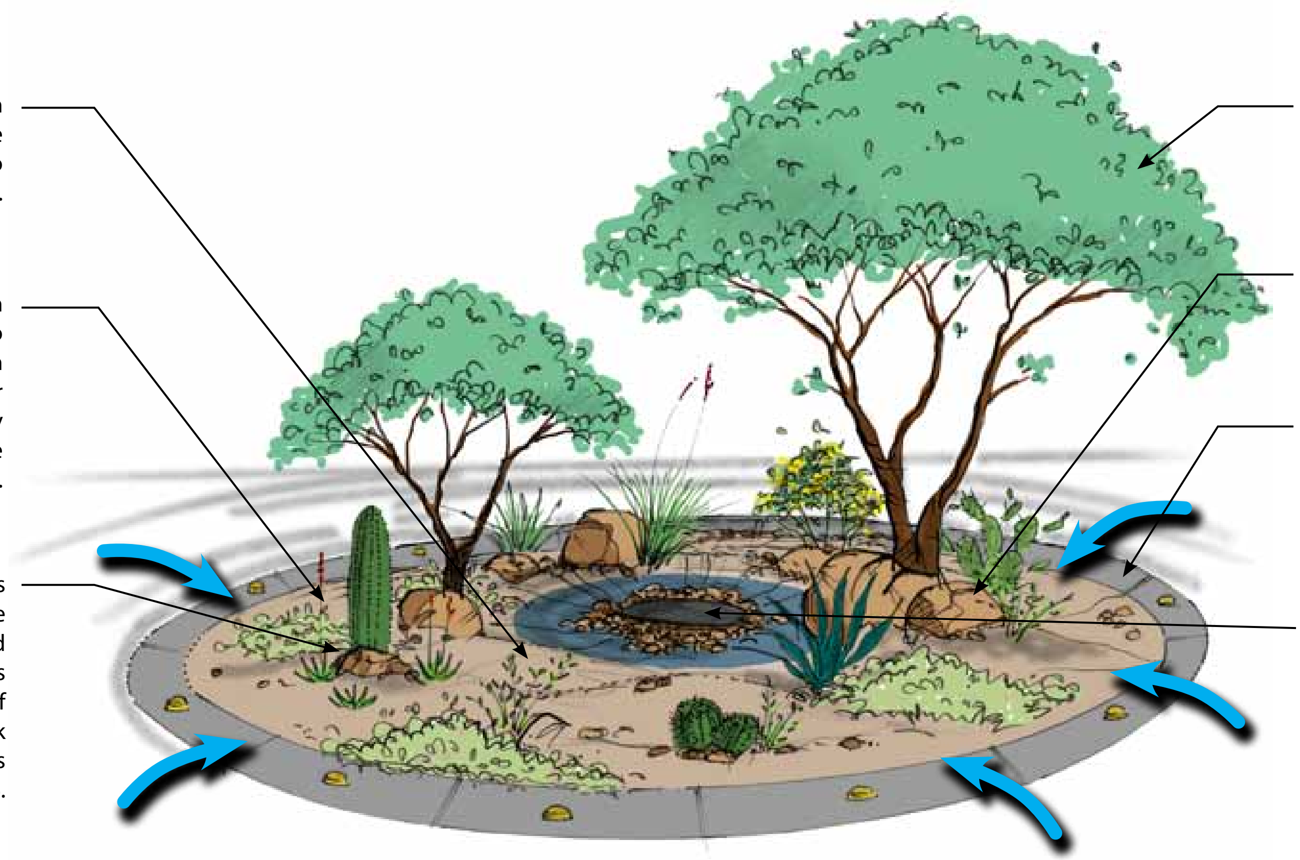


Figure 17. Conceptual drawing of a traffic circle with depressed bioretention area for a neighborhood street.

7. Parking lot practices

The problem: Too much asphalt

Whether at a church or a "big box" store, parking lots are a major element of many neighborhoods. Their presence, though often necessary, has several consequences for the local environment and neighborhood character.

One 8.5′ x 20′ asphalt parking space generates about 100 gallons of runoff in a 1″ storm. This runoff accumulates quickly, and in many neighborhoods, this stormwater is sent out into the street or directly into arroyos and washes. To deal with this issue, many municipalities now require parking lots to be outfitted with detention/ retention basins that capture stormwater runoff.

These "grey infrastructure" detention basins often have serious drawbacks:

- Taking up otherwise buildable land
- Creating vacant, often unusable areas without landscaping that can become an eyesore
- Failing to address water quality issues
- Requiring fencing or walls
- Serving only a single function

A Solution: Green infrastructure for parking lots

GI parking lot practices take the function of the detention basin and spread stormwater management throughout the site, creating multiple bioretention areas that collect stormwater close to its source. As GI does on neighborhood streets, these practices integrate stormwater management with landscape improvements to provide many benefits:

- Increasing the amount of buildable land, or land available for green spaces
- Creating more attractive parking landscapes that appeal to both users/customers and neighborhood residents
- Cooling local temperatures
- Cleaning and infiltrating stormwater
- Reducing landscape irrigation needs
- Reducing maintenance needs

Why work in and around parking lots?

Urban heat island

Parking lots create great expanses of asphalt or concrete that contribute significantly to warming of towns and cities. Municipalities commonly have minimum landscape requirements for parking lots that begin to mitigate this issue by shading hardscape. The City of Tucson, for instance, has stringent regulations that require one tree to be planted for every four parking spaces in new parking lots, and that at least 50% of the lot be shaded by mature tree canopy.

Neighborhood character and livability

Neighborhoods are often in favor of large parking lots as they help keep parking from businesses off of residential streets. However, large expanses of asphalt can create hot, barren areas that detract from neighborhood aesthetics.

7.1 Site selection, design and workflow

Retrofitting vs. new construction

Cities like Tucson are doing much through codes and ordinances to improve new parking lots through proactive stormwater, landscape, and/or green infrastructure requirements like those mentioned above. Several excellent references provide information on incorporating GI practices into new parking lot construction[21].

However, most of the hundreds of square miles of existing southwestern parking lots do not incorporate these best practices. At these sites, GI practices can become part of resurfacing, reconstruction, and revitalization projects. This section provides examples of ways to retrofit existing parking lots with GI approaches to improve neighborhood environments.

7.2 Replace asphalt with bioretention

Existing parking lots often have inefficient layouts with wasted space. Even in those that do not, a few parking spaces can often be converted to bioretention areas. Replacing asphalt with bioretention has the double effect of reducing impervious area while creating spaces to collect and infiltrate runoff.

[21] Phillips AE, editor. City of Tucson Water Harvesting Guidance Manual. Tucson, AZ: City of Tucson; 2005. 35p.

This parking lot retrofit was designed to reduce flooding. Tucson Association of Realtors also installed a large cistern to provide landscape irrigation.

Follow these best practices:

- To protect the asphalt surface, reinforce cut asphalt edges with flush concrete header, 6" wide x 12" – 18" deep.
- In areas where there is a risk of motorists driving into bioretention areas, use concrete curb stops at the pavement margin or landscape boulders within the basin to prevent vehicle entry, or use a raised curb with curb cuts to allow stormwater flow while deterring vehicles.
- Plan for where overflow will exit bioretention features and, where possible, route to the next downstream basin.

7.3 Create bioretention in ROW/ landscape buffer areas

Where space allows, bioretention basins or swales can be incorporated into existing landscape areas within or adjacent to parking lots. Methods will vary widely depending on the type and amount of space available:

- Use curb cuts, flush curbs, and/or natural spillover points to collect stormwater in bioretention features.
- Speed bumps can be used as a retrofit tool to direct stormwater from existing parking lots.
- Infiltration chambers can be used under parking lots or adjacent landscape areas to create additional water collection capacity while maintaining pedestrian access.

First-hand observation is essential when designing retrofit features. It is cheaper than surveying and will help you notice small topographical details that can dramatically affect stormwater flow. For example, at the site shown in the photo progression at right, observing the site in a storm revealed a small bump in the pavement that sends runoff from both an alley and parking lot into an earthen ROW area.

This progression of photos shows a ROW that collects runoff from a UA parking lot (far right of photos).

December 2008: Runoff from the lot and adjacent alley wash over bare dirt and the sidewalk into the street.

April 2009: newly-dug basins capture storm runoff to feed young plants.

August 2010: Native grasses, shrubs and trees thrive just 18 months after installation.

At this Tucson City Council Ward office, asphalt was removed from an unused portion of the parking lot. Runoff from the lot (foreground) and the adjacent building fills the unfinished basins in a summer storm.

One year later, stormwater-fed native vegetation has grown to shade the parking lot and entrance. Note that basin slopes are lined with rock to reduce erosion.

At this University of Arizona parking lot, an unused space happened to coincide with the lot's natural low point. The asphalt was removed and a biorention basin installed. Note concrete header and curb stops. The basin's interior was terraced and shaped to distribute stormwater evenly. Overflow exits the back left corner and flows to the street.

Before: At this University of Arizona (UA) parking lot, small curb cuts allowed stormwater to flow past existing trees onto the pedestrian area in the ROW, and then on to the street.

After: A long, thin swale was installed and additional trees and shrubs planted to capture and use runoff from the lot.

7.4 Alternative parking lot materials: pervious pavement

Pervious pavement allows for percolation of stormwater through subsurface aggregate and offers an alternative to conventional concrete and asphalt paving. It is particularly useful when space is limited and stormwater goals cannot be met in available landscape areas. There are many different types of pervious pavement[22] :

- Stabilized aggregate: a mixture of compacted stone aggregate and a binder
- Porous asphalt: standard asphalt pavement in which the fines have been screened and removed, creating void spaces that make it highly permeable to water
- Porous concrete: single size, screened aggregate consists of a special mix design with void spaces that make it highly permeable
- Structural grid systems: 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
- Permeable pavers: pre-cast concrete pavers designed to be set on a compacted base and highly permeable setting bed with joints filled with sand or fine gravel

The use of pervious pavement is encouraged for sites such as parking lots, driveways, pedestrian plazas, and rights-of-way. Pervious pavement must be designed to support the maximum anticipated traffic load but should not be used in high-traffic areas. Stormwater that drains through the pervious surface is infiltrated into underlying soils and excess runoff should be directed to landscape areas. Pair pervious pavement with basins and swales to increase infiltration capacity and make the most of infiltrated water to grow native trees and shrubs.

The complexity of pervious pavement design will highly depend on soils. If the soil has poor percolation, engineered soils and drainage pipes may be required. Regular maintenance is essential to maintain runoff infiltration capacity. Specialized equipment is required to remove accumulated materials that clog porous surfaces with vacuuming or pressure washing.

Participants in a professional green infrastructure training learn how to install a permeable parking surface. A recycled plastic base retains a gravel surface that promotes infiltration.

[22] Low Impact Development Toolkit. City of Mesa. April 2015.

8. Appropriate care of GI features

Green infrastructure needs regular care to function properly and enhance delivery of environmental services over time. Appropriate care of GI features will also ensure the maximum return on investment. Maintenance tasks usually include:

- Watering new plants during establishment period
- Identifying and removing noxious or invasive weeds
- Clearing inlets of debris and vegetation
- Pruning trees and shrubs for safety, visibility, plant health, and aesthetics
- Removing sediment and trash
- Replacing dead plants
- Adding organic mulch
- Repairing erosion
- Repairing human-caused damage

Without adequate planning for maintenance from the outset of a project, GI features may lose their capacity to function properly and become perceived as eyesores or hazards by the community. Maintenance responsibility, necessary funding, and plans for enforcement of maintenance requirements must be accounted for at the beginning of project planning.

8.1 Green infrastructure care fact sheet

Monthly:

- Remove invasive plants and weeds, particularly buffel grass and bermuda grass which, left unchecked, can render green infrastructure ineffective.

- Clean up any trash that may have blown or floated into your basins.

Hand tools are the best way to remove weeds. You can be selective about what weeds you pull, and there is no noise or chemical pollution!

Mulch may float when basins fill with water. Plants and rock features can help keep mulch in place, but if your mulch is consistently washed away in rain storms, use larger rocks as mulch.

Bermuda grass, *Cynodon dactylon* (Note: Tricky to remove. You will need to be diligent to remove Bermuda grass manually. Dig out full root system—up to 1.5 ft deep.)

Buffle grass, *Cenchrus ciliaris* (Note: This plant is a fire hazard. Make sure you carefully identify buffel grass. Don't make the mistake of removing native bunch grasses, which look similar to buffel grass, and are often used in rain gardens. Learn more at buffelgrass.org.)

Seasonal (before and during rainy seasons):

- Observe basin during rain events to evaluate function and make necessary adjustments.
- Inspect inlets and outlets for blockage.
- Remove sediment from basin inlets and sediment traps.
- Inspect berms, basin slopes, and spillways for signs of erosion. Reinforce or armor earthworks as necessary to mitigate erosion.
- Add plant trimmings and other yard waste to basin bottoms to replenish mulch with on-site materials. Exception: undesirable weeds that have set seed should be disposed of off-site!
- Check basins and swales after rainfall for excessive ponding. Incorporate organic mulch, deep-rooted plantings, or deep infiltration trenches if needed.
- Prune trees and plants to ensure plants do not obstruct pathways or required traffic visibility at intersections.

If you hire a landscape crew for routine maintenance, they can reduce their number of visits and tasks. Here's what you can tell them:

- No raking, please!
- Keep pruning to a minimum—only prune trees and shrubs if they interfere with human pathways.
- Weed less by using more organic mulch.
- Don't spray chemical herbicides—hand pull weeds when they pop up during rainfall seasons.

8.2 Design for maintenance

To facilitate long-term care, take the following into consideration when designing GI practices:

- **Remove perennial weeds during site preparation.** For instance, throughout Arizona, Bermuda grass is a persistent, deep-rooted non-native turf grass that aggressively invades disturbed soil. If established within a landscape, it is virtually impossible to remove without disturbing other plant roots or affecting desirable plants through overspray of herbicides. If the grass is removed through deep excavation during the preparation phase of a project, later maintenance needs can be significantly reduced.

- **Use native, drought-adapted plants and climate-appropriate watering schedules.** Desert plants are adapted to prolonged periods of drought interspersed with intermittent rainfall. If constant irrigation is applied, plants can grow too quickly, developing weak growth and requiring constant pruning. If a regionally-appropriate schedule of deep, infrequent watering is maintained (see Section 4.1.4), many plants will require less pruning through the year. Trees will develop deeper root systems that will help them withstand high winds.

- **Prune native trees and shrubs to natural growth forms.** Prune only to promote the health of the tree, keep branches clear of walkways, and shape the canopy for better shade. Wait at least one year, and up to two years, before you prune trees after planting. Trees become stressed when they are transplanted, and they need ample time to adjust to the new soil, moisture, and light conditions. By not pruning, you allow the tree to develop a more natural shape and strengthen as it grows. Plants will be healthier and stronger if they are allowed to keep their natural shape. When laying out the plants in your feature, plan for the mature size of shrubs and trees. This will ensure plants don't need to be constantly pruned to prevent crowding.

Plan your landscape to let the water flow through your yard and soak into the soil.

Let your plants grow and prune minimally. You'll be pleased with the results—healthier plants, unique shapes, and better wildlife habitat.

Desert plants have characteristic shapes and growth forms that are part of what make our regions unique. Most arid-adapted trees, for instance, naturally grow multiple trunks. When pruned into "lollipop" trees of a single stem and high canopy they require much more pruning, and are more likely to blow over in the wind. Shrubs pruned into fine sculptures obviously require more maintenance.

- **Use organic mulch wherever possible.** Since it can be easily removed and replaced, organic mulch better facilitates sediment removal than gravel or rock mulch. Leaf drop and chipped tree trimmings can be used to replenish mulch instead of being constantly picked up and hauled away (which is often required for gravel surfaces).

- **Use sediment traps (see Section 5.4).** If sediment traps are not used at GI sites armored with rock or gravel, sediment removal will be labor-intensive. This may be achieved by total removal of rock and sediment, and subsequent grading and replacement of rock.

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10. Glossary

Note: These definitions were developed for the purposes of this manual, and are not necessarily intended to be generalized for other uses.

apron: a reinforced area at the inlet to a bioretention feature to prevent erosion from stormwater; usually made of set-in rock

basin: an earthen depression designed to collect and infiltrate stormwater

bioretention: the use of vegetation and soils to clean stormwater runoff

green infrastructure: constructed features that use natural processes to provide environmental services such as capturing, cleaning, and infiltrating stormwater; creating wildlife habitat; shading and cooling streets and buildings; and calming traffic

hardscape/impervious area: surface that does not allow water to infiltrate into the ground (e.g. asphalt, concrete)

infiltration/percolation: absorption of water into the soil

native plants: a plant that is indigenous or naturalized to a region over a given period of time

non-point source pollution: pollution often carried by/in stormwater that comes from dispersed sources—auto oil, pet waste, herbicides, and sediment

rights-of-way (ROW): the area along a street between the curb and property lines

runoff/stormwater: rainfall that has hit the ground and begun to run off

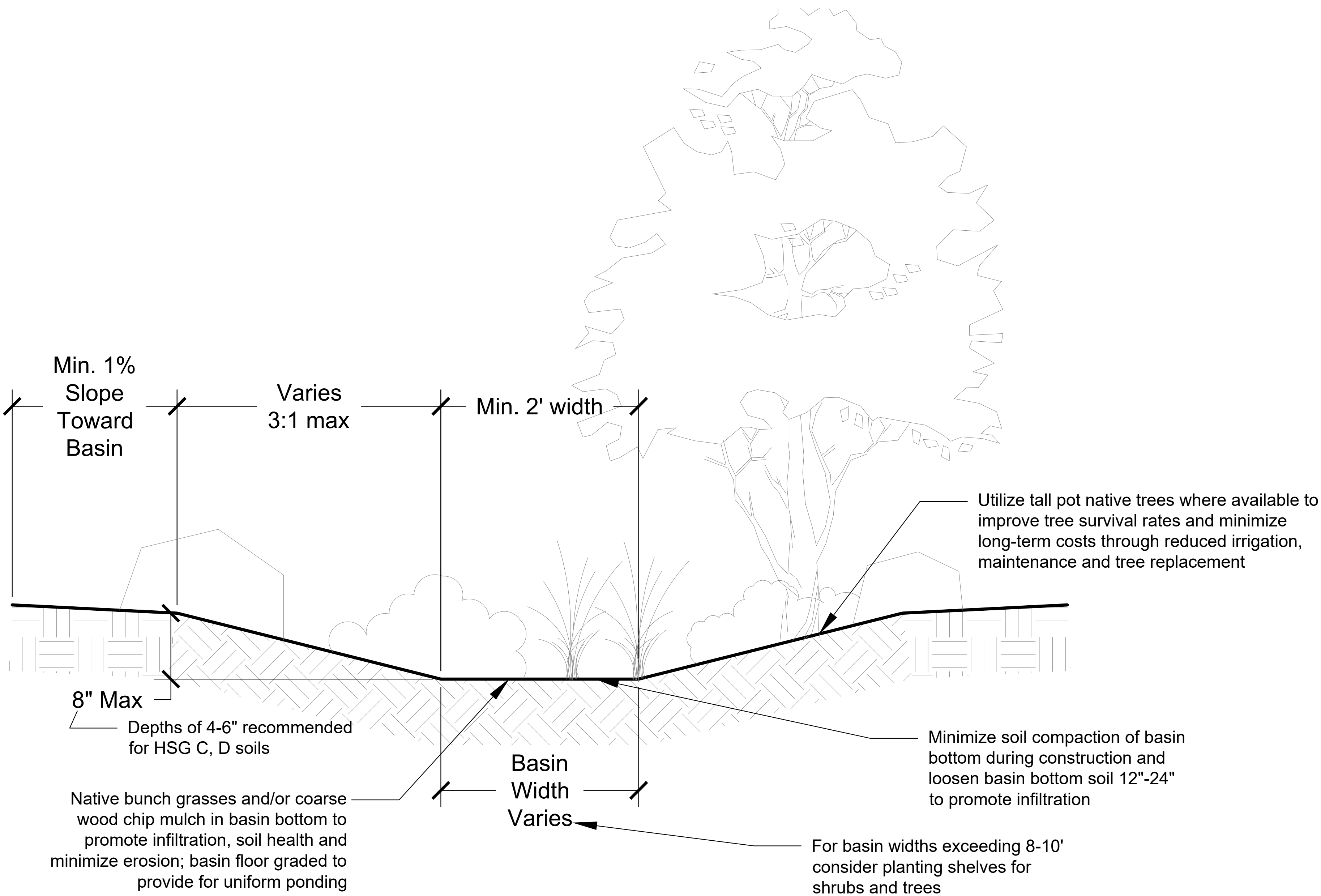
swale: an elongated, shallow depression designed to infiltrate and transport stormwater

urban heat island effect: the phenomenon of urban areas being warmer than surrounding rural/undeveloped areas due to the higher proportion of heat-trapping surfaces

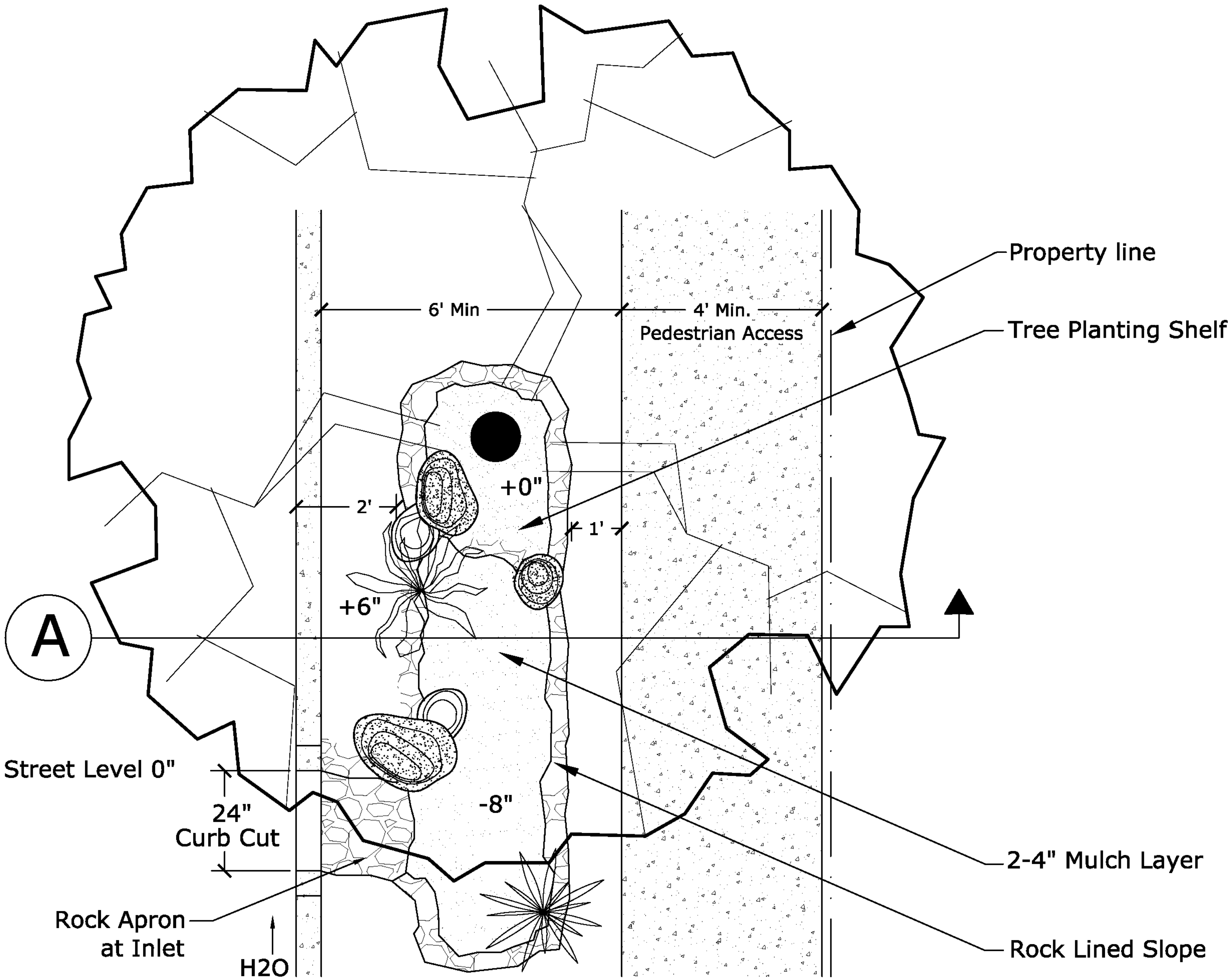
traffic calming: the practice of slowing traffic through residential areas using roadway constrictions, vegetation, or other features

11. Appendix

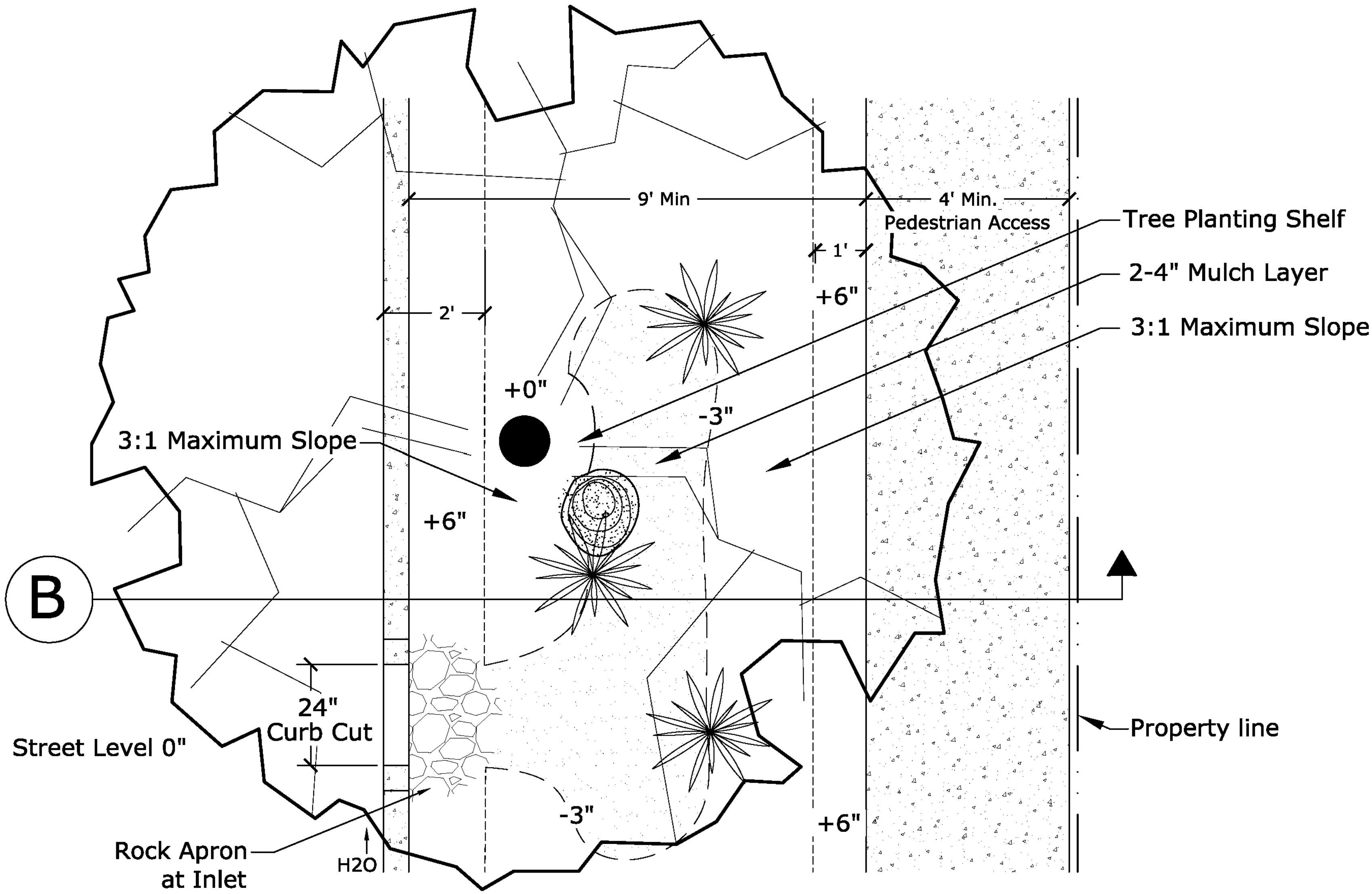
11. Appendix: rainwater harvesting basin/swale



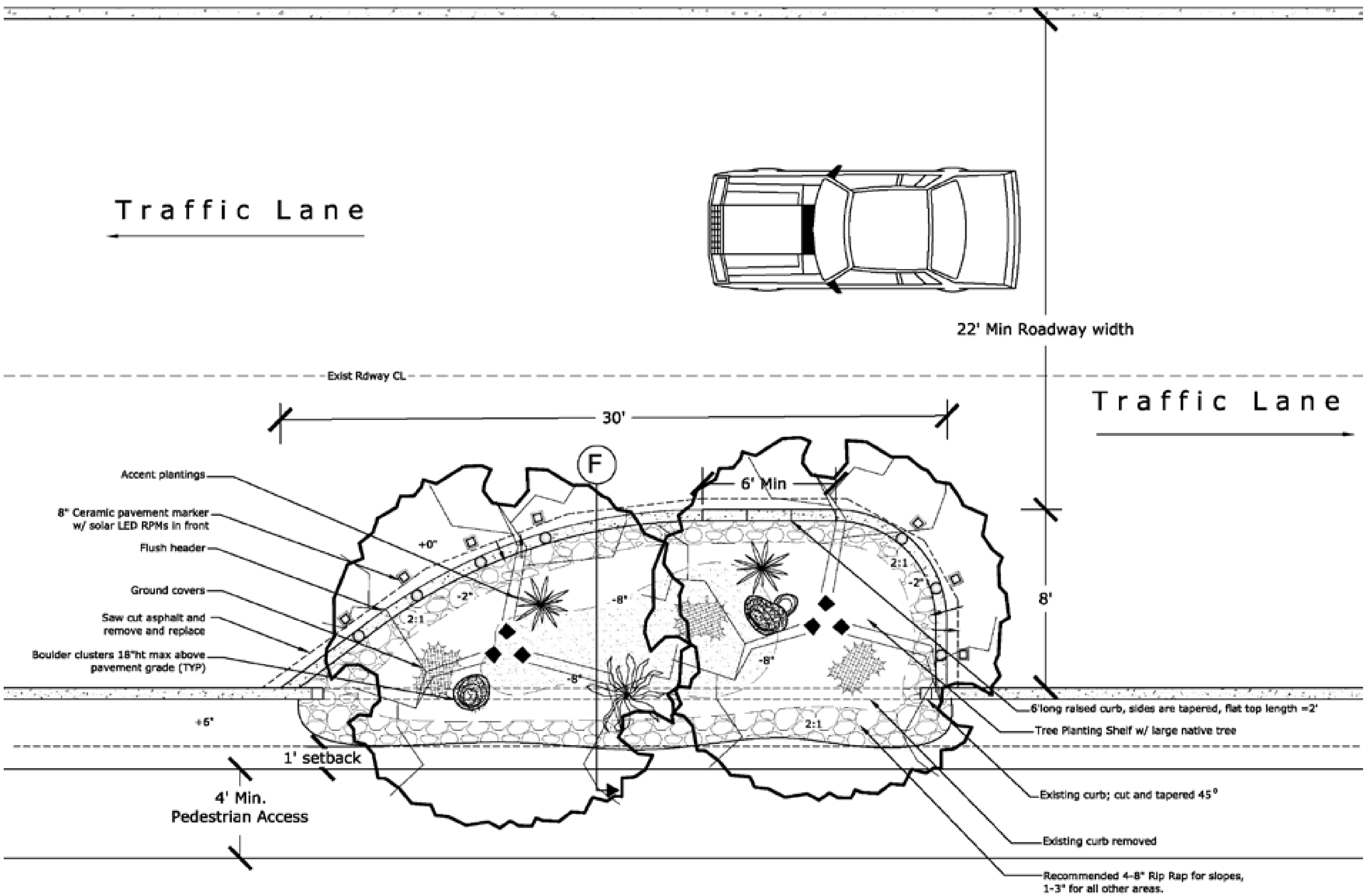
11. Appendix: curb cut & basin, rock-lined, plan view



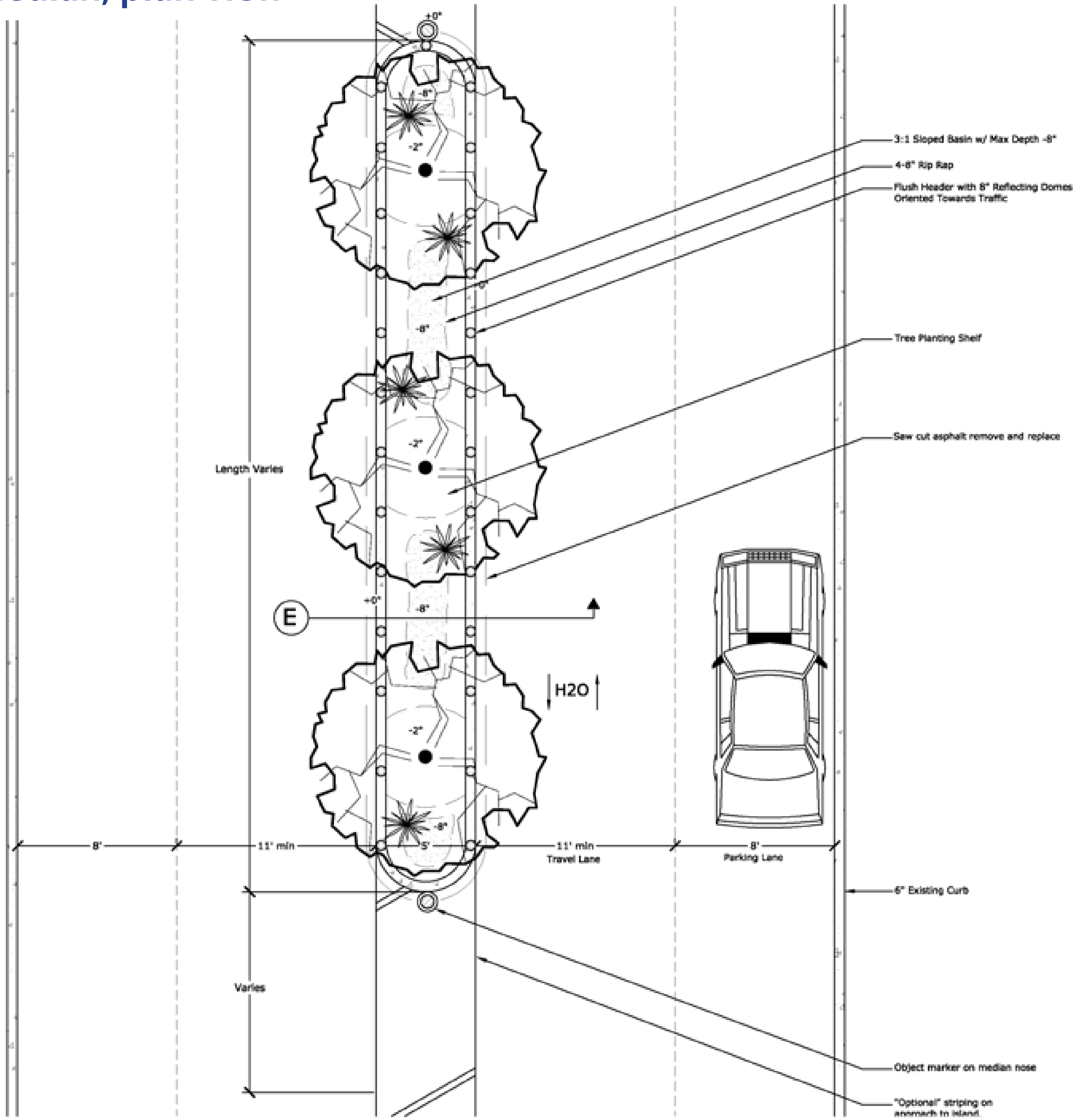
11. Appendix: curb cut & basin, shallow slope, plan view



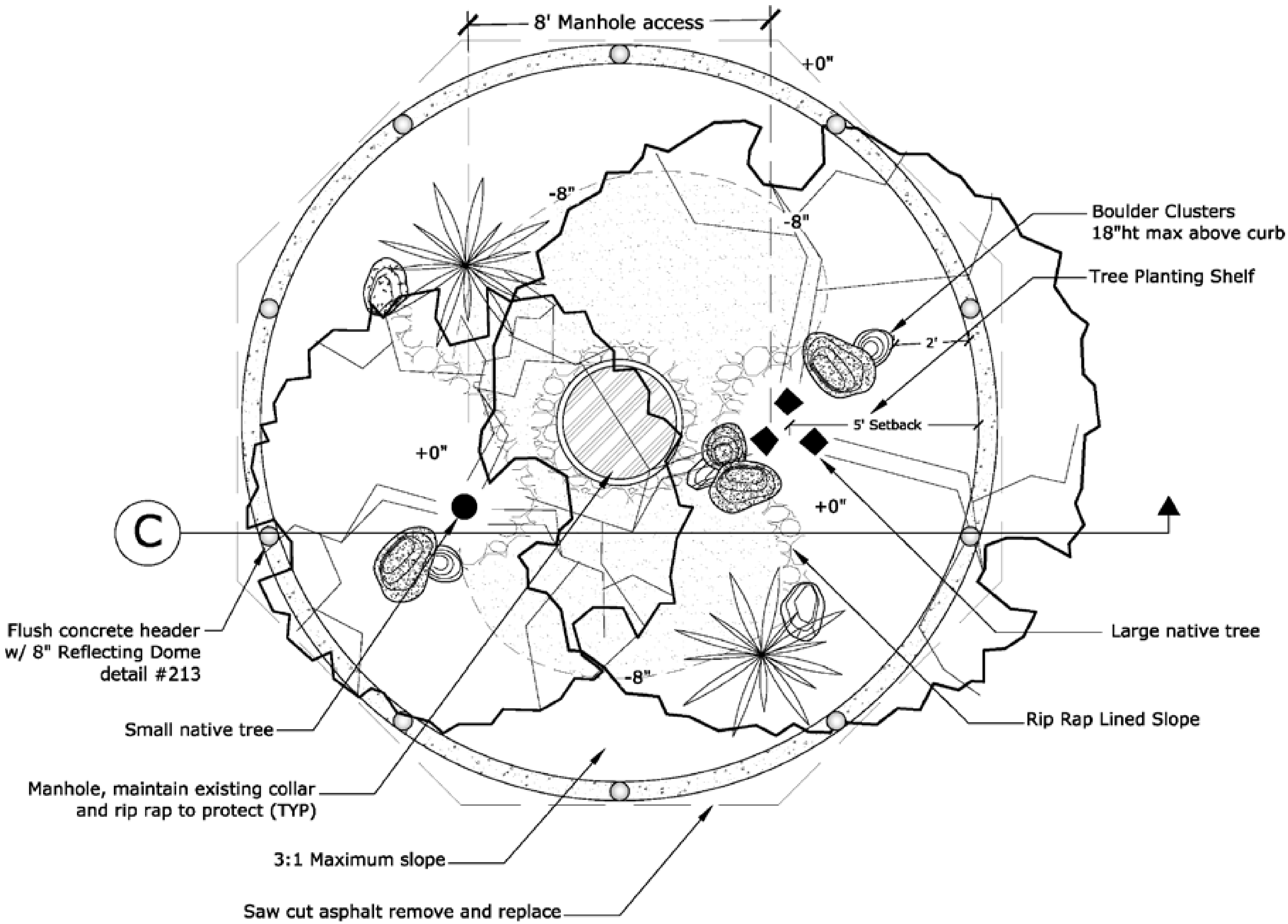
11. Appendix: chicane, plan view



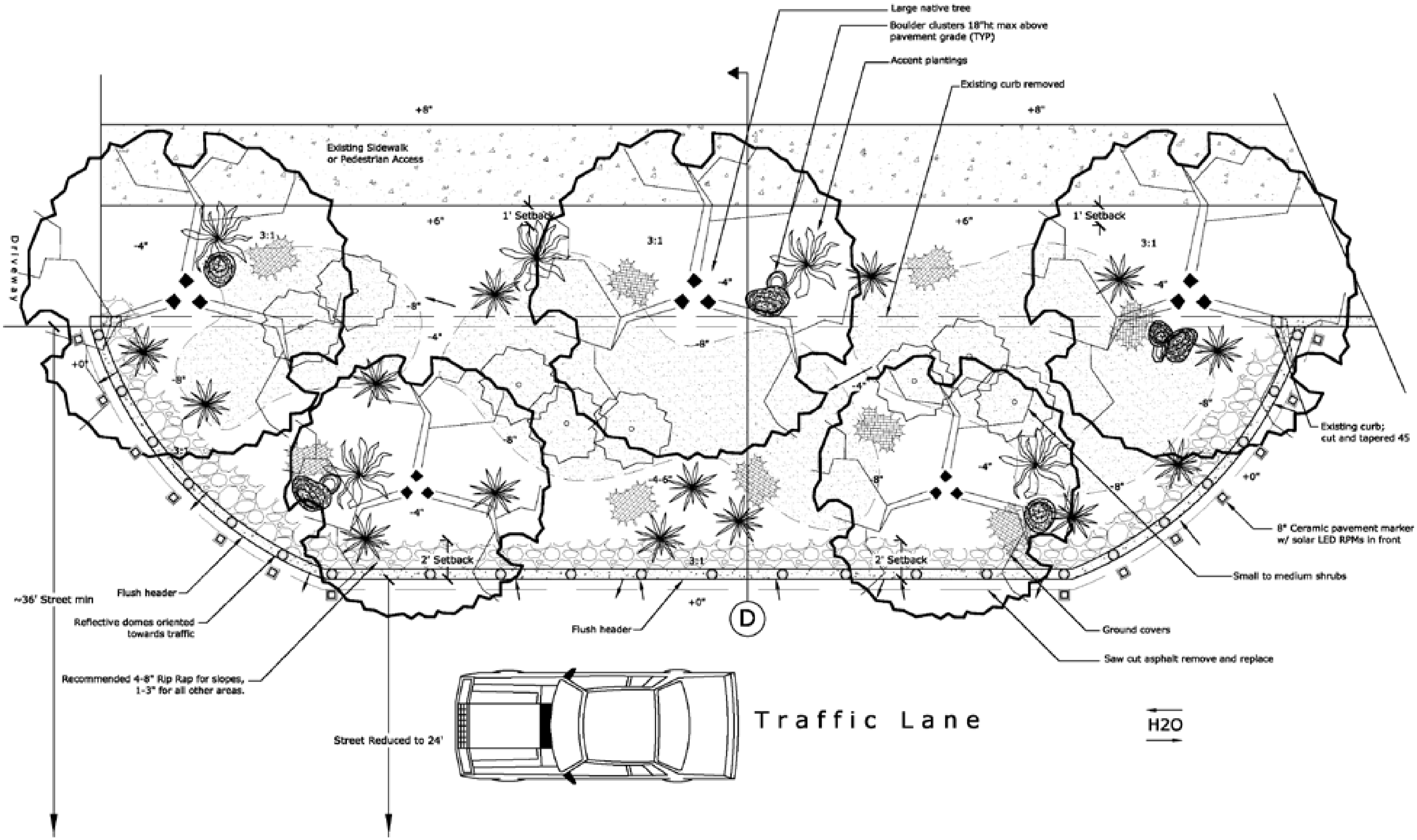
11. Appendix: median, plan view



11. Appendix: traffic circle, plan view



11. Appendix: street width reduction, plan view



12. About Watershed Management Group

Watershed Management Group (WMG) is a 501(c)3 non-profit organization whose mission is to develop and implement community-based solutions to ensure the long-term prosperity of people and health of the environment. We provide people with the knowledge, skills, and resources for sustainable livelihoods. WMG's programs include:

Green Living Co-op

WMG's popular Co-op helps people transform their yards with rainwater and greywater harvesting, native and edible gardens, soil building, and passive solar. Projects are installed through fun, barn-raising workshops led by experienced WMG project managers.

Green Infrastructure and Watershed Planning

We provide consulting, design, demonstration site, and capacity building services to both public and private partners in the Southwestern U.S. and Mexico.

Living Lab and Learning Center

The Living Lab and Learning Center is a community educational hub for regenerative desert living in the heart of Tucson. Visitors of all ages are invited to explore sustainability practices in action through our interactive exhibits, classes, and events. The center features water harvesting, native habitat, food forests, composting toilets, passive solar, monitoring systems, and is a campus entirely supported by rainwater.

Schoolyard Water Education

WMG provides customized programs for K-12 Students, focusing on water conservation and wildlife habitat through water harvesting and native gardening activities on school campuses.

Advocacy and Public Policy

WMG staff provide leadership on advisory boards, coalitions, and stakeholder groups to develop policy that restores our rivers and promotes green infrastructure in our cities. WMG is a founding member and fiscal sponsor of the Community Water Coalition, a group that provides leadership and guidance toward water policy that sustains healthy ecosystems and quality of life in Southern Arizona.

50 Year Program: Restoring Tucson's Free Flowing Rivers

WMG is leading a long-term initiative to restore Tucson's heritage of year-round, flowing rivers through community education, on-the-ground restoration, and policy actions. The first campaign in this program is to restore regular flow to Sabino and Tanque Verde Creeks.

Consultation and Design Services:

WMG staff provide clients with expert advice on water conservation and water harvesting, edible landscapes, landscape restoration, and green infrastructure features. Staff create conceptual landscape plans for clients including a written report with recommendations of active and passive water harvesting features and a water budget summary with rain and greywater supply and plant water use calculations.

Green Workforce Development:

WMG conducts job training for a variety of professionals and youth in water harvesting, green infrastructure, stream restoration, eco-sanitation, and more.

International Programs:

WMG works with partners in Mexico to offer training and create demonstration projects in watershed restoration, green infrastructure, and eco-sanitation.

For more information visit: www.watershedmg.org

Watershed Management Group

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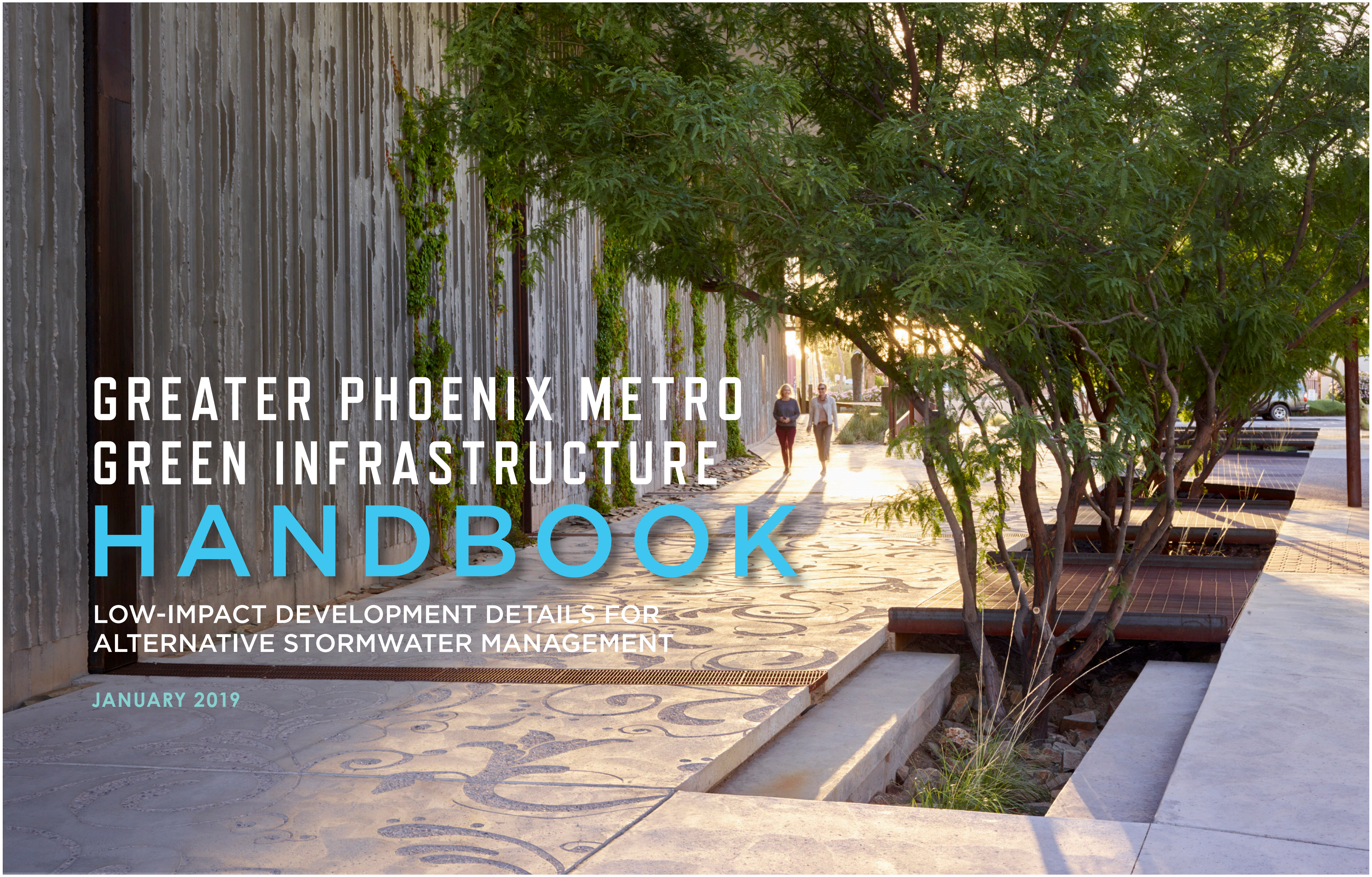
ATTACHMENT D

GREATER PHOENIX METRO GREEN INFRASTRUCTURE HANDBOOK



GREATER PHOENIX METRO GREEN INFRASTRUCTURE HANDBOOK

LOW-IMPACT DEVELOPMENT DETAILS FOR ALTERNATIVE STORMWATER MANAGEMENT

JANUARY 2019

Prepared for CITY OF SCOTTSDALE in Collaboration with ASU Sustainable Cities Network Arizona State University and Member Communities

Greater Phoenix Metro Green Infrastructure

HANDBOOK

Low-Impact Development Details for Alternative Stormwater Management

Prepared for

City of Scottsdale

ASU Sustainable Cities Network
Arizona State University

With funding from

ADEQ
Arizona Department of Environmental Quality

WIFA

By the team of

Dibble Engineering

LOGAN SIMPSON

Cover Image Credit: Marion Brenner
Scottsdale Museum of the West
Landscape Architecture by Colwell Shelor

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City of Gilbert

City of Peoria

ACRONYM LIST

AASHTO American Association of State Highway and Transportation Officials

AMA Active Management Area

ASTM American Society for Testing and Materials

ASCE American Society of Civil Engineers

ADA Americans with Disabilities Act

ADEQ Arizona Department of Environmental Quality

ASU Arizona State University

BMP Best Management Practice

BSM Biorentention Soil Media

CPI Concrete Pavement Institute

ESAL Equivalent Single Axle Load

°F Fahrenheit

FCDMC Flood Control District of Maricopa County

FPS Feet Per Second

GI Green Infrastructure

ICPI Interlocking Concrete Pavement Institute

LID Low Impact Development

MAG Maricopa Association of Governments *(Uniform Standard Specifications and Details for Public Works Construction, 2018 Revision to the 2015 Edition)*

MPH Miles Per Hour

NRMCA National Ready Mix Concrete Association

PSI Pounds Per Square Inch

PPM Parts Per Million

SCN Sustainable Cities Network

TSDS Technical Standard Details and Specifications

UofA University of Arizona

WIFA Water Infrastructure Finance Authority

Location: *ASU Polytechnic Campus*
Credit: *FCDMC*

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SECTION 1 - INTRODUCTION

PURPOSE OF THE HANDBOOK

The purpose of this Handbook is to provide members of the design, planning, and development communities in Maricopa County, Arizona with guidance and specific techniques for low impact development (LID) that can be implemented on their projects. The Handbook is intended to address non-point source pollutant load reductions, conformance with first-flush requirements, and stormwater peak flow and volume reductions for water quality and flood hazard mitigation benefits within the Salt and Gila rivers, specifically, and the Middle Gila Watershed in general. Equally important in the Sonoran Desert is the opportunity to ameliorate water supply/demand concerns by increasing rainfall infiltration, recharging groundwater, and harvesting stormwater to offset potable water used for outdoor purposes.

The goal of this Handbook is to advance the implementation of LID and green infrastructure (GI) by developing selected LID technical standard details and specifications (TSDS). These TSDS are expected to be used primarily on public projects associated with road and street improvements, although the concepts and techniques are equally applicable to private projects. Ultimately, it is anticipated these TSDS, or improved versions of these TSDS, will be incorporated into the design and development standards of communities across Maricopa County.

LID TSDS have several identifiable environmental benefits. Utilizing LID practices can reduce the amount of runoff and stormwater conveyed through the existing conveyance systems of Phoenix-area communities, which will directly translate to reductions in the amount of pollutants that are discharged into the Middle Gila Watershed. Pollutants can be filtered naturally by increasing runoff infiltration into soils through LID installations. Additionally, implementation of LID practices can result in the beneficial use of stormwater as a supplemental source of landscape irrigation.

Location: *Scottsdale's Museum of the West*
Credit: *Marion Brenner*

Community and secondary benefits include overall water conservation, urban heat reduction, improvements in population health, and the aesthetic benefits of additional green spaces.

BACKGROUND

When introduced by Maryland's Prince George's County in 1999, LID was a radically different approach to stormwater management. It was developed to address issues related to new residential, commercial, and industrial development through reimagined environmental design and implementation practices. As originally conceived, the LID approach combined a hydrologically effective and integrated design that incorporated site-scale pollution prevention measures to compensate for land development impacts on hydrology and water quality. LID was intended to recreate natural (pre-construction) hydrologic patterns by utilizing landscaping and collection techniques that store, absorb, infiltrate, evaporate, and detain runoff throughout a site to keep as much rainwater as possible onsite near the location where it landed. This differed significantly from the prevailing approach at that time, in which stormwater was shed from a site as efficiently as possible through structural methods.

The objectives of the LID approach are accomplished by:

- Minimizing stormwater impacts to the extent practicable. Techniques include reducing imperviousness, conserving natural resources and ecosystems, maintaining natural drainage courses, reducing the use of pipes and structural collection systems, and minimizing clearing and grading.
- Providing dispersed runoff storage measures throughout a site using a variety of detention, retention, and runoff practices.
- Maintaining predevelopment times of concentration by strategically routing flows to maintain travel times and to control the discharge.
- Implementing an effective public education program to encourage property owners to use pollution prevention measures and to maintain LID management practices on their sites.

Since its introduction, LID has gained wide acceptance nationally and has been extensively practiced in the eastern and northwestern portions of the United States. It is integral to land planning and development criteria in that part of the country because of the higher rainfall, greater potential for pollution via runoff, and the obvious need for a higher level of stormwater management. In Arizona, the City of Tucson and Pima County have championed and implemented LID and/or water harvesting for many years. In the Phoenix Metropolitan Area and other areas of Arizona, receptivity to and interest in LID has been minimal until the last few years. There is newfound interest in LID practices in central Arizona for a variety of reasons. These include greater visibility of the concept through outreach efforts by a variety of organizations and entities, rising infrastructure and water costs, and higher public consciousness about the scarcity of water in the Southwest. There is also a recognition by local design and planning professions and community leaders that LID is a sustainable approach that can be adapted for use in the Sonoran Desert through thoughtful consideration.

Some of the original techniques conceived by Prince George's County are not applicable because of our Sonoran Desert setting. The basic concepts of working with natural patterns, reducing impervious surfaces, capturing stormwater and pollutants, reliance on vegetation to absorb stormwater, dispersed on-site capture locations to keep rainwater near where it falls on the ground, minimizing pipes, etc. are all valid and implementable in central Arizona.

Location: *Gateway Community College*
Credit: *Leigh Padgitt*

HYDROLOGIC DESIGN ANALYSIS

The rainfall characteristics of the Desert Southwest are very different from many other climates based on research conducted by the University of Arizona (U of A) as published in Pima County's 2015 Low Impact Development and Green Infrastructure Guidance Manual (Reference 1). High-intensity, short-duration thunderstorms occur frequently during the monsoon—typically occurring in July through September; dissipating tropical storms may travel over the area during some years during the fall; and lower-intensity, frontal storms often occur during winter months. A frontal storm develops at the boundary or front of two different masses of air and depends less on the season of the year as compared to the monsoon storms.

In general, Arizona's rainfall seasons are often separated by prolonged periods of dry conditions with low humidity.

Data from more than 4,700 rainfall events in Pima County were recorded by the U of A between 1895 and 2000. An average of 45 rainfall events per year occurred during this period. Of those, approximately 40 percent produce 0.1 inch or less of precipitation, and approximately 85 percent of all events had less than 0.5 inch. Because the 85 percent rainfall event (< 0.5 inch) has been identified by the American Society of Civil Engineers (ASCE 1998) as the most appropriate event for capturing rainfall for stormwater mitigation, Maricopa County has chosen this 0.5-inch event as a minimum threshold for first-flush retention (Reference 2). The first-flush rainfall was selected because this is the amount of rainfall that collects the highest amounts of pollutants.

The results indicate that very small events, such as those of less than 0.1 inch, contribute very little to runoff from a site, because most of the precipitation is eliminated by the initial abstraction or infiltrated into the dry soils. Rainfall events with depths between 0.3 and 0.5 inches are frequent enough and large enough to produce the majority of the average annual runoff volume from a site.

The analysis of annual peak daily rainfall from the U of A data shows that rainfall depths greater than 1.5 inches are fairly infrequent. Since these large events cause floods, designing systems to mitigate the impacts will be beneficial to the surrounding lands and/or development (however, just meeting this criteria may not satisfy the regulatory [i.e., 100-year] flood-event requirements). Nonetheless, analysis of the U of A rainfall data indicates that stormwater systems and individual features should be designed to accommodate rainfall events between 0.5 and 1.5 inches. Because the TSDS identified in this Handbook are also intended to be used in locations with possibly limited rights of way (ROWs), the rainfall volume considered throughout this document is 0.5 inches. It is recognized that the TSDS can be sized to accommodate larger rainfall volumes; a maximum value of 1.25 inches is recommended for the maximum design storm depth if larger facilities are planned.

HYDROLOGIC DESIGN REQUIREMENTS

Rainfall information from 319 Flood Control District of Maricopa County (FCDMC) rain gauges was collected and analyzed for this Handbook. Many of these gauges have been in service since 1982. The analysis revealed that 90 to 95 percent of all storms were below 1.5 inches depending on the rainfall gauge location, which is an ideal rainfall amount for designing the maximum storage capability of LID systems in Maricopa County. Rainfall events less than the first flush rainfall, which is typically the first 0.5 inches of rainfall, occurred on 82 percent of all the storms recorded at all gauge locations. The first flush rainfall is the design criteria used in this Handbook. The rainfall analysis has been included in Appendix A.

Location: *ASU Taylor Mall*
Credit: *Leigh Padgitt*

Location: *Scottsdale's Museum of the West*
Credit: *Colwell Shelor*

OVERVIEW OF THE SELECTION PROCESS FOR THE TOP 10 TECHNICAL STANDARD DETAILS AND SPECIFICATIONS

Arizona State University's (ASU's) Sustainable Cities Network (SCN) has been critical to the development of this LID Handbook. Since 2009, SCN has consistently convened Phoenix-area communities on important, local sustainability topics, including green infrastructure (GI) and urban forestry. As the first university-city sustainability network of its kind in the US, SCN engages with Arizona cities, towns, tribal communities, counties, government agencies, and other public and private partners to further local and regional sustainability, and engage communities with ASU students, faculty, and innovative research. Through SCN's GI Workgroup, municipalities and interested stakeholders actively discuss challenges and opportunities for expanding how GI techniques like LID can be more widely used throughout the Phoenix area. With SCN's guidance; through the hard work of the core members of SCN's Specs & Standards Subgroup (including the cities of Scottsdale and Phoenix and FCDMC); and with the efforts of municipal review teams, the idea of a LID handbook geared toward the area's unique environment took shape.

To help make the Handbook a reality, the City of Scottsdale acquired grant funding to develop the Greater Phoenix Metro Green Infrastructure Handbook from the Arizona Department of Environmental Quality (ADEQ) 604(b) grant program, as well as monies from the Water Infrastructure Finance Authority (WIFA) Technical Assistance Fund. The City of Scottsdale also contributed funding and project and grant management.

The purpose of this project is the development of 10 LID TSDS. A data-collection effort was completed that produced several alternatives that were presented to a stakeholder group made up of eight Phoenix Metropolitan Area municipal representatives. These alternatives were ranked by the stakeholder groups. The results were tabulated and then reviewed by a core team, including representatives from the City of Scottsdale, City of Phoenix, FCDMC, and SCN.

GENERAL NOTES OF CONSIDERATION FOR ALL LID DETAILS

The TSDS presented in this Handbook are the initial generation of standards and have been prepared to be modified (as necessary) in the future based on user feedback about materials, construction, and/or performance based on conventional monitoring of the installations.

An analysis of local soils and percolation rates will be required to determine if subgrade soils will percolate as necessary and if structured soils, over-excavation, and/or specifically designed backfill are required.

An evaluation of underground utilities should be carried out prior to design.

Additional engineering or the use of provided calculations may be needed to appropriately size detention facility flow velocities, and in some cases, structural bearing capacities.

If there are subsurface infiltration restrictions like poorly draining soils, caliche, bedrock, soil contamination, or moisture-sensitive adjacent structures as identified during geotechnical investigations, the TSDS shown in this Handbook may not be recommended without augmentation.

These conditions may require the TSDS be modified to include features such as impermeable membranes to prevent undesirable underground migration. Another option is to create an enclosed detention system, or to incorporate an underdrain collector connected to an appropriate downstream drainage facility, LID element, and/or underground stormwater collection system. Each designer will need to determine, if any, the types of additional features that are necessary to ensure the proper function of the GI elements and to protect potentially affected resources.

To avoid the potential risk of off-site properties and resources, LID elements should be located at least:

- 10 feet offset from buildings and building foundations
- 10 feet from property lines
- 150 feet from water supply wells
- 50 feet from septic systems

Note: *The above dimensions are considered minimums; the actual dimensions shall be determined through geotechnical studies and engineering evaluations.*

The details may require modifications for adequate sediment and erosion control.

The provision of an appropriate maintenance plan for each detail type and unique site features will be required. The maintenance plan may differ from current practices and vary from detail to detail.

Proper percolation or underground storage infiltration must be designed for vector control.

For several of the LID elements, landscaping is integral to function and aesthetics. Incorporating landscaping slows the stormwater, which increases water infiltration and absorption. Landscaping can decrease the reliance on potable water for irrigating the plants, depending on the landscape design and the volume and pattern of stormwater collection.

Where feasible, it is preferred that the TSDS surface treatments consist of landscaping, seeding, organic materials (e.g., wood mulch) or other natural, moisture-retaining products. Similar materials can also be incorporated into the bioretention soil media (BSM) of the TSDS to aid in holding moisture conveyed to the LID element.

Location: *Manzanita Park*
Credit: *Leigh Padgitt*

MARICOPA ASSOCIATION OF GOVERNMENTS

MAG is a Council of Governments that serves as a regional planning agency for in the Phoenix Metropolitan Area. MAG is made up of 27 cities and towns, three Native American communities, Maricopa County, and portions of Pinal County. MAG was founded in part to ensure maximum efficiency and economy in governmental operations. MAG's Public Works Program was established to standardize infrastructure construction throughout the region by coordinating the building codes and construction specifications and details used by member agencies. These TSDS were developed to be used in association with MAG 's Uniform Standard Specifications and Details for Public Works Construction (Standards) to ensure that construction is cost-effective and meets safety and quality standards. Under this program, MAG makes its Standards available online and through purchase. These materials are used by MAG members, as well as the private construction industry within MAG communities, as the base construction standards for building a wide variety of infrastructure-related improvements. The MAG Standards have some unique aspects that are useful to understand when reviewing the TSDS included in this Handbook.

The Standards include a definition of the terms used, the materials to be used, steps to be taken, and performance requirements to be met by the finished construction. The construction details in the Standards are a series of technical drawings showing a graphical representation of the feature(s) to be built, with tables, charts, notes, and references back to the specifications. The specifications and details are broken into sections of related construction work in a numbered sequence with periodic gaps to allow for the incorporation of new standards.

While intended to be standards for municipalities in the MAG region, the specifications and details can be changed by the agencies on a project-by-project or city-wide basis to reflect local preferences and practices; for improved functionality (e.g., greater capacity); funding constraints; site conditions (e.g., expansive soils); and/or for other reasons. Typically, the project-based changes to the Standards occur as "add," "delete," "replace with," and "modify to" the MAG specifications and details as described and shown in the project-specific drawings and specifications. City-wide modifications to the MAG Standards are published by those agencies as supplements to the MAG Standards and are made available to the design and construction industry by those communities.

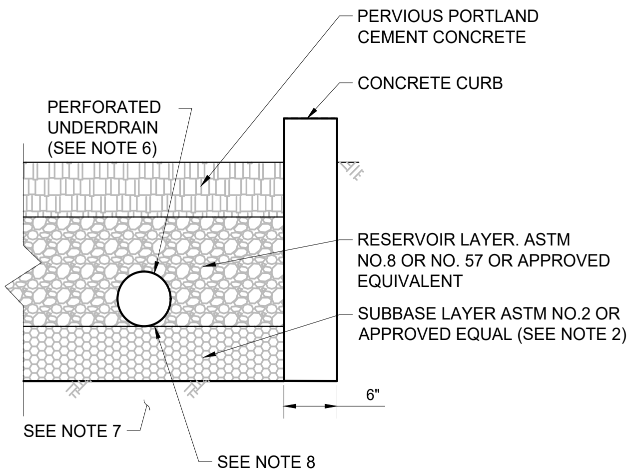
A unique aspect of the MAG specifications is that construction work is generally defined and specified primarily by activity rather than a completed item of work. For example, building a road is specified in several specification sections. Excavating or grading the roadbed is addressed in Section 205. Placing the subbase material is in Section 310. Placing the asphalt is in Section 321. All landscape-related work is specified in Section 430.

The MAG format also allows for specifying complete items of work (such as for installation of a street light pole), similar to how some of the TSDS specifications are proposed in this Handbook. In the design and construction industry, these are known as "bid item" specifications. This approach allows for placing all of the requirements for the work related to installing a street light pole, for instance, in a single location. When using a bid-item specification approach, it is customary to refer to existing MAG specification sections or details, rather than repeating them entirely within the bid-item specification. When you read "refer to MAG Section 203 for subgrade preparation requirements," it should be understood by the reader that Section 203 currently exists in the Standards, and it contains requirements that are applicable to the item of work being described.

The user would need the TSDS descriptions and the referenced MAG Standards to fully understand the requirements for the item being specified. Because the current Standards do not include all of the TSDS in this Handbook, new section numbers have been created to incorporate them in accordance with the MAG numeric and activity structure. If "MAG" does not precede the specification, that indicates that it is a special provision developed for this Handbook and is not found in the MAG standards.

Digital versions of the TSDS in this Handbook can be found at https://sustainability.asu.edu/sustainable-cities/resources/lid-handbook/.

SECTION 2 - LID DETAILS AND SPECIFICATIONS



PERVIOUS CONCRETE

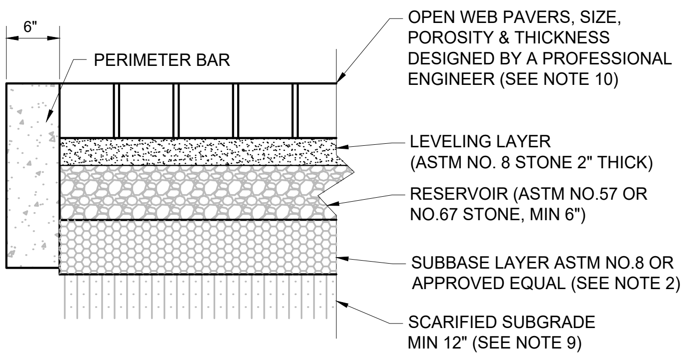
NOTES:

1. AGGREGATE LAYERS SHALL MEET PROPOSED SPECIAL PROVISION 303.
2. GEOSYNTHETIC TO BE USED TO PROTECT PIPES FROM CLOGGING. SEE MAG SPECIFICATION 796.
3. DEPTH OF RESERVOIR LAYER AS SHOWN ON DESIGN PLANS SHOULD BE SIZED TO DRAIN WITHIN 72 HOURS.
4. TOP OF PAVEMENT SHOULD BE DESIGNED TO ACHIEVE 1% MAXIMUM SLOPE IN ANY DIRECTION.
5. WHEN FILTER LAYER IS OMITTED, PROVIDE GEOSYNTHETIC CLASS-A MATERIAL BENEATH RESERVOIR LAYER.
6. UNDERDRAIN REQUIRED FOR LOW PERCOLATING SOILS (SEE SPECIFICATION 622).
7. UNCOMPACTED SUBGRADE FOR AREAS DESIGNED FOR INFILTRATION FEATURES ONLY.
8. GEOSYNTHETIC MATERIAL (SEE SPECIFICATION 796)
9. COMPACTION REQUIREMENTS IF ANY WILL BE DESIGNED BY GEOTECHNICAL ENGINEER.
10. SOLID PAVERS CAN BE USED (OPTIONAL).
11. MINIMUM COVER OVER THE UNDERDRAIN PER MANUFACTURER RECOMMENDATION.

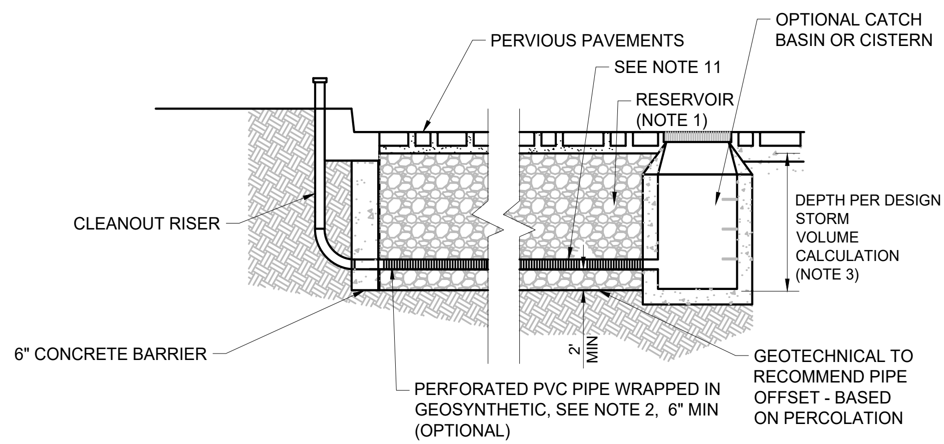
PERVIOUS CONCRETE PAVEMENT

MINIMUM PAVEMENT THICKNESS

PAVEMENT ITEM	CLASS A	CLASS B
PERVIOUS PORTLAND CEMENT CONCRETE	6"	8"
RESERVOIR LAYER	6", SEE NOTE 3	12", SEE NOTE 3
SUBBASE LAYER	4"	4"



PERVIOUS CONCRETE PAVERS



PERMEABLE PAVEMENT
WITH UNDERGROUND RESERVOIR
AND UNDERDRAIN (OPTIONAL)

DETAIL NO.	STANDARD DETAIL		REVISED	DETAIL NO.
LID-01	ENGLISH	PERMEABLE PAVEMENT	01-29-2019	LID-01

1. PERMEABLE PAVEMENTS

Permeable pavements (LID-01) are a highly versatile LID element because they can effectively reduce pollutants and can be integrated into site plans with various configurations and drainage elements. Permeable pavement allows streets, parking lots, sidewalks, and other impervious covers to utilize the infiltration capacity of underlying soils while maintaining the structural and functional features of the materials they replace, if retrofitted into an existing hardscape situation.

Permeable pavement has small voids or aggregate-filled joints that allow water to drain through to an aggregate reservoir. Stormwater stored in the reservoir layer can then infiltrate underlying soils or drain at a controlled rate through underdrains to other downstream stormwater control systems. Permeable pavement systems can be designed to operate as underground detention if the native soils do not have sufficient infiltration capacity, or if infiltration is precluded by aquifer protection, contaminated soils, or adjacent structures.

Permeable pavement can be developed using modular paving systems (e.g., permeable interlocking concrete pavers, concrete grid pavers, or plastic grid systems) or poured-in-place solutions (e.g., pervious concrete). Some pervious concrete systems can also be precast. In many cases, especially where space is limited, permeable pavement is a cost-effective solution relative to other practices because it can double as both transportation infrastructure and as GI.

The components of a permeable pavement system, in general, should include a permeable paving surface and a reservoir material, such as a base layer of crushed aggregate. Liners, geotextiles, and underdrains can also be used with this LID feature.

1.1 APPLICABILITY AND ADVANTAGES

Permeable pavements are suitable for low- to moderate-vehicular use areas, such as parking lots, overflow parking areas, sidewalks, and access roads. Permeable pavements are currently not suitable for higher speed traffic (>30 mph) or areas designed for high structural loads. Table 1 shows the typical permeable pavement applications, which was developed in the Puget Sound LID Manual (Reference 3).

Table 1: Application of Permeable Pavers

Application	Residential Walk/Patio	Residential Driveway	Commercial Pedestrian Plaza	Emergency Access Lane or Overflow Parking	Parking Lot or Travel Lanes	Residential Street or Collector (<30 mph)	High Speed Highway (>30 mph)
Permeable Pavers	Yes	Yes	Yes	Yes	Yes	Yes	No
Pervious Concrete	Yes	Yes	Yes	Yes	Yes	Yes	No
Porous Asphalt	Yes	Yes	No	Yes	No	No	No
Grid Pavements	Yes	Yes	Yes	Yes	No	No	No

This LID element is **not recommended** in areas where higher pollutant loading is expected. Examples of high pollutant load areas are fueling stations, vehicle storage areas, or industrial process facilities. If this element is scheduled for installation at these types of facilities, appropriate pretreatment, such as an oil-water separator or a filtering device, must be provided, or the areas should be diverted from the permeable pavement. Infiltration barriers may also be required in these types of locations.

Permeable pavements advantages include:

- Reducing stormwater runoff rate and volume.
- Reducing loads of some pollutants in surface runoff by reducing the volume of stormwater leaving a site.
- Reducing stormwater infrastructure footprint and promoting multibenefit uses by capturing stormwater in parking/driving areas, which reduces project costs as compared to singular uses.
- Increasing groundwater recharge.
- Compatibility with retrofit projects.
- Many material choices and design options.
- The ability to utilize them in recharge zones, karst, expansive clays, and contaminated soil conditions, if properly designed.

1.2 DESIGN CONSIDERATIONS

Permeable pavements must be designed to achieve two aims:

- Support traffic loads.
- Manage surface water effectively (i.e. provide sufficient storage).

Other considerations that should be accounted for during the design of permeable pavements include:

- As with any pavement, Americans with Disabilities Act (ADA) requirements must be followed.
- To prevent clogging, decomposed granite should not be used with this facility or located adjacent to this facility.
- Specific structural design considerations may be needed to prevent rutting.
- Site-specific geotechnical information is needed.
- Soil conditions do not typically constrain the use of permeable pavement, although they do determine whether an underdrain is needed (also see discussion regarding underdrains). Infiltration may be promoted in these designs, however, by incorporating an infiltration sump (i.e., a layer of stone below the invert of the underdrain). When designing a permeable pavement practice, designers must verify soil permeability by using the locally-approved on-site soil investigation methods.

1.3 HYDROLOGIC FUNCTION

Permeable pavement systems are designed to reduce surface runoff by allowing stormwater to infiltrate the pavement surface. While the specific design can vary, most permeable pavements have a similar structure consisting of a surface course layer and an underlying stone aggregate reservoir layer. Modular underground storage units, chambers, and pipes can also be integrated for additional subsurface storage. Where soils permit, permeable pavement allows captured runoff to fully or partially infiltrate into underlying soils.

Volume reduction (stormwater capture) primarily depends on the drainage configuration and subsoil infiltration capacities. Systems installed without underdrains in highly permeable soils can achieve practically 100 percent volume reduction efficiency (Reference 4). Systems installed in restrictive clay soils can still give significant volume reduction (Reference 5 and 6). The volume reduction can be further enhanced by treating the subgrade with scarification, ripping, or trenching as discussed in Impacts of Construction Activity on Bioretention Performance (Reference 7, Appendix B.5.2). Additional volume reduction can be done by incorporating an internal water storage layer by upturning underdrain inverts to create a sump (Reference 8). Peak flow can be also effectively attenuated by permeable pavement systems by reducing overall runoff volumes, promoting infiltration, and increasing the lag time to peak discharge (Reference 9).

If permeable pavement is used in a parking lot or another setting that involves vehicles, the pavement surface must be able to support the maximum anticipated traffic load. The structural design process will vary according to the type of pavement selected. The manufacturer's specific recommendations should be followed. The thickness of the permeable pavement and reservoir layer must be sized to support structural loads and to temporarily store the design storm volume. On most new development and redevelopment sites, the structural support requirements will dictate the depth of the underlying stone reservoir.

The structural design of permeable pavements involves considering four main site elements:

- Total traffic
- In-situ soil strength
- Environmental constraints
- Bedding and reservoir layer design

The resulting structural requirements can include the thickness of the pavement, filter, and reservoir layer. Designers should note that if the underlying soils have a low California Bearing Ratio (CBR) (less than 4 percent).

Designers should determine structural design requirements by consulting transportation design guidance sources, such as the following:

- American Association of State and Highway Transportation Officials (AASHTO) Guide for Design of Pavement Structures (Reference 10).
- AASHTO Supplement to the Guide for Design of Pavement Structures (Reference 11).

Designers should also review guidelines specific to the municipality where the permeable pavement is being designed.

1.4 STRUCTURAL DESIGN REQUIREMENTS

Some of the different kinds of permeable pavements and associated reservoir materials are described below.

1.4.1. PERMEABLE PAVERS

Permeable pavers interlock in such a way that 5 to 15 percent of the surface remains open to allow water to pass. The pavers themselves may not be pervious. Pavers should be laid per manufacturer guidance, but a herringbone pattern is typically the best structural design for rectangular permeable pavers. Permeable pavers are a flexible pavement system, which means a structural analysis must be performed to ensure that the underlying aggregate layer provides sufficient structural support for the anticipated vehicular loads.

Permeable pavers must be built on relatively flat surfaces with slopes not exceeding 5 percent. Designers may consider using a terraced design for permeable pavement in areas with steeper slopes. In all cases, designs must ensure that the slope of the pavement does not lead to ponding on the lower elevations of the pavement surface.

1.4.2. PERVIOUS CONCRETE

Because it is designed without the fine particles used in most concrete aggregate, pervious concrete is a surface that allows water to infiltrate, resulting in a gap-graded mixture with highly connected pore space. Pervious concrete is a rigid pavement system, which means that structural analysis should ensure that the thickness of the slab can support the anticipated surface loads.

Structural and reservoir base layer aggregate that forms the base layer should be uniformly graded to have connected pore spaces, such as ASTM No. 8 or 57 aggregate, and should be washed free of all fine particles. The reservoir layer should generally have a minimum thickness of 6 inches. The subbase layer should generally have a minimum thickness of 4 inches, but should be determined based on structural loading. If the total thickness of the reservoir layer exceeds 4 inches, a subbase layer of washed ASTM No. 2 aggregate is recommended below the 4-inch ASTM No. 57 or 67 aggregate base layer. Exceptions apply to pedestrian applications, where a 6-inch base layer of ASTM No. 57 or 67 aggregates is generally acceptable.

Reservoir and subbase layers should be sufficiently compacted to provide structural support and to prevent differential settling. The leveling and method of compaction will vary depending on the chosen pavement type. To maximize infiltration, care should be taken not to compact the soil subgrade.

Reservoir and subbase layer designs should always conform to local design standards and should address site-specific conditions.

For unlined designs, the bottom slope of a permeable pavement installation should be as flat as possible (i.e., zero percent longitudinal and lateral slopes are preferred, and 5 percent is the maximum) to enable even distribution and infiltration of stormwater.

Permeable/pervious pavement storage volume for infiltration design is calculated using the following equation:

$$S_v = A_p \left[\left(d_p * n_r \right) + \left(\frac{t * t_f}{2} \right) \right]$$

where:

- S_v = storage volume [ft³]
- A_p = permeable pavement surface area [ft²]
- d_p = depth of the reservoir layer (or depth of the infiltration sump for enhanced designs with underdrains) [ft]
- n_r = effective porosity for the reservoir layer [0.15 - 0.4]
- i = field-verified infiltration rate for the subgrade soils [ft/day]. If an impermeable liner is used in the design then i = 0.
- t_f = time to fill the reservoir layer [day] (assume 2 hours or 0.083 days)

*Note: For enhanced designs that use an infiltration sump, d_p is only the depth of the infiltration sump.

Permeable pavement storage volume for standard design (no infiltration) is calculated using the following equation:

$$S_v = A_p * d_p * d_p$$

1.5 UNDERDRAINS

Permeable pavement systems without an underdrain are appropriate for soils with a minimum corrected in-situ infiltration rate of 0.3 inches/hour.

Based on the suitability of native soils, the land use of the site, and other considerations (such as whether infiltration is prudent), there are three primary designs for underdrain systems suitable for pervious pavements.

The elevation difference needed for permeable pavement to function properly is generally nominal, although 2 – 4 feet of head pressure from the pavement surface to the underdrain outlet is typically necessary. This pressure may vary based on several design factors, such as required storage depth and underdrain location.

1.6 CONSTRUCTION CONSIDERATIONS

Notes on construction plans should specify that tracked vehicles (versus wheeled vehicles) be used whenever practicable to minimize compaction of subsoils. Construction specifications should also include notes requiring the testing of subgrade infiltration rates before installing aggregate (for infiltrating systems). This step ensures that captured water will draw down in the required duration. If subgrade infiltration rates are drastically lower than design values, the subgrade should be treated by scarifying, ripping, or trenching according to the recommendations for the bioretention system. The area that will be scarified should be roped off to avoid inadvertent traversing. If infiltration rates remain lower than required, the profile depth must be changed to provide additional storage or the drainage configuration must be altered to regulate the drawdown.

Careful inspection of several construction steps can prevent costly errors. Construction of permeable pavement systems should be performed only by a contractor with experience in permeable pavement installation and who is certified by the Interlocking Concrete Pavement Institute (ICPI) or the National Ready Mix Concrete Association (NRMCA) . Lists of certified contactors are at http://www.icpi.org or http://www.nrmca.org.

1.7 MAINTENANCE

Maintenance of permeable pavement systems is critical to the overall and continued success of the system. This LID feature requires special inspection by experienced personnel. Specific maintenance activities are listed in Table 2, which was developed in the San Antonio LID Manual (Reference 12). Key maintenance procedures consist of the following:

- Adjacent areas that drain to the permeable pavement area should be permanently stabilized and maintained to limit the sediment load to the system.
- Vacuum sweeping should be typically performed a minimum of twice a year. Adjust the frequency according to the intensity of use and deposition rate on the permeable pavement surface.
- Any weeds that grow in the permeable pavement should be immediately sprayed with herbicide or an alternative, environmentally-friendly aqueous solution that can eliminate them (an alternative solution is preferred; the National Green Infrastructure Certification Program does not support pesticides). Weeds should not be pulled, because doing so can damage the pavement, level, and /or reservoir larger media. The presence of weeds indicates accumulated sediment, which must also be removed. Spray and then pull weeds from pervious concrete to avoid damage.

1.8 COMPATIBILITY WITH OTHER LID PRACTICES

Permeable pavements are typically the upstream LID facilities in a system, but they can be designed adjacent to curb openings. They can also outfall into LID features such as a vegetated/rock swale or a stormwater harvesting basin.

1.9 SPECIFICATIONS

SECTION 303 – AGGREGATES FOR PERMEABLE PAVEMENTS

303.1 DESCRIPTION

This item shall consist of constructing base courses for permeable pavements to the specified depths on a prepared foundation conforming to the lines, grades, and cross sections shown in the contract documents. Base courses may include leveling layer, base layer, subbase layer, open-graded subbase layer, and associated, optional or required liner materials, included in the contract documents. May also include appurtenances such as underdrains.

Table 2: Operation and Maintenance Tasks for Permeable Pavements

Tasks	Frequency	Indicator Maintenance is Needed	Maintenance Notes
Catchment inspection	Weekly or biweekly during routine property maintenance.	Sediment accumulation on adjacent impervious surfaces or in voids/joints of permeable pavement.	Stabilize any exposed soil and remove any accumulated sediment. Adjacent pervious areas might need to be graded to drain away from the pavement.
Miscellaneous upkeep	Weekly or biweekly during routine property maintenance.	Trash, leaves, weeds, or other debris accumulated on permeable pavement surface.	Immediately remove debris to prevent migration into pavement voids. Identify source of debris and remedy problem to avoid future deposition.
Preventative vacuum/ regenerative air street sweeping	Twice a year in higher sediment areas.	N/A.	Sweep with a vacuum power or regenerative air street sweeper at least twice per year to maintain infiltration rates.
Replace fill materials	As needed.	For paver systems, whenever void space between joints becomes apparent or after vacuum sweeping.	Replace bedding fill material to keep fill level with the paver surface.
Restorative vacuum/ regenerative air street sweeping	As needed.	Surface infiltration test indicates poor performance or water is ponding on pavement surface during rainfall, or if weeds grow.	Sweep with a vacuum power or regenerative air street sweeper to restore infiltration rates.

303.2 MATERIALS

Coarse aggregate shall be of the types designated in the contract documents, and shall consist of clean, tough, durable fragments of crushed stone, or crushed gravel, conforming to the gradations in Table 3 and shall also meet the following:

A. Be double-washed, sufficient to remove dust and other coatings.
B. Be free from clay balls, organic matter, and other deleterious substances.
C. Minimum 75 percent by mass (weight) of the material coarser than the No. 4 sieve with at least 2 fractured faces, and 90 percent shall have one or more fractured faces as determined by ASTM D5821.
D. Have not more than 5 percent of flat or elongated pieces (>5:1) as specified in ASTM D4791.
E. Material shall have a CBR of at least thirty (30) as determined by laboratory test on a 4-day soaked sample in accordance with ASTM D1883.
F. The sub-base and base aggregate should be hard, durable, crushed stone with a Los Angeles (LA) Abrasion of < 40 (per A-STM C131 and C535).

Minimum sub-base thickness depends on vehicle loads, soil type, and stormwater storage requirements. Typical sub-base depths range from 6 to 24 inches. The ICPI recommends base/ sub-base thicknesses for pavements up to a lifetime of 1 million 18,000-lb equivalent single axle loads (ESALs). For example, at lifetime ESALs of 500,000 with a CBR of 5 percent, the sub-base (ASTM No. 2 stone) should be 18 inches and the base (ASTM No. 57 stone) thickness should be 4 inches. Increased aggregate sub-base thicknesses can be applied for increased stormwater volume storage. See ICPI guidelines for details on base thickness and design.

The levelling layer is an open-graded stone, typically ASTM No. 8 stone, between the wearing surface and the reservoir layer, for providing separation and preventing migration between the layers due to differences in material and void sizes underneath.

Saturated hydraulic conductivity of the gravel shall be not less than 10 inches per hour according to ASTM D5856-95 (2000) when compacted to a minimum of 95 percent Standard Proctor, ASTM 698.

The reservoir layer is an open graded stone (recommended ASTM No. 2, No. 3, or No. 57 stone or approved equal) under the choker layer, for meeting the retention volume requirement (to the maximum extent practicable, where applicable). The depth of the stone shall be determined based on the required storage volume for the site and pavement design requirement.

Gradation for base courses shall be as presented in Table 3.

Impermeable waterproof membranes should be used in permeable pavement systems as follows:

G. Facilities within 10 feet of a structure shall be lined on the side adjacent to the structure.
H. At the interface between pervious pavement and traditional pavement.
I. In areas where infiltration is not permitted, such as areas prone to contaminated runoff and for utility protection.
J. Facilities designed for water re-use or harvesting.
K. Where the installation is located on expansive soils, as recommended by the Geotechnical Engineer.

Table 3: Base Course Gradation

Pavement Reservoir Layer	Choker Layer for Permeable Pavements	Filter Layer	Storage/Drainage Layer
ASTM No. 2 or No. 3 Stone	AASHTO No. 57 Stone	AASHTO No. 8 Stone	AASHTO No. 57 Stone

At locations where the native soil design infiltration rate is insufficient to drain the underground runoff within 36 hours, an underdrain connected to a downstream drainage facility should be installed. The underdrain should be installed in accordance with Specification 622.

Geosynthetics meeting the requirements of MAG Specification 796 shall be placed on the sides of open-graded stone, to prevent migration of adjacent fine material into the permeable pavement stone.

303.3 GENERAL

Careful attention to the subgrade preparation during construction is required to balance the structural support requirements of the material and the infiltration rates. Relative uniformity of the subgrade conditions is necessary to prevent differential settling or other stresses to the system for all permeable pavements. The subgrade shall not be compacted for installations where contract documents specify a minimum infiltration rate for the subgrade.

Upon completion of subgrade work, the Engineer shall be notified and shall inspect the subgrade before the contractor continues installation. The Engineer shall have the option to perform infiltration testing on the subgrade to verify minimum infiltration rates, at the contractor's expense where specified on the contract documents.

Any accumulation of debris or sediment which takes place after approval of subgrade shall be removed prior to installation continuing at no extra cost.

The contractor shall be allowed to perform subgrade compaction and can utilize geotextile fabric or impermeable liners as specified in the contract documents for permeable pavements where no infiltration rate is specified for the subgrade.

Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding, this material shall be removed with light equipment and underlying soils scarified to a minimum additional depth of 6 inches with a rake and a tracked vehicle used in combination, or equivalent. Construction equipment shall not be allowed on the subgrade, except as noted above.

Trucks meeting the same cleanliness requirements of the double-washed materials shall be used during hauling. Trucks shall be inspected and cleaned prior to each use. Do not install aggregate base course when rainfall or other weather conditions will detrimentally affect the quality of the work.

Final grading should be completed by machinery operating on a preliminary subgrade that is at least 12 inches higher than the grade to distribute equipment load. The final excavation is achieved as the machinery is pulling back and traveling on preliminary grade as final grade is excavated.

Do not dump the aggregate base course in piles, but evenly spread it and place the aggregate on the prepared subgrade in layers of uniform thickness without segregation. Where the base course is constructed in more than one layer, clean previously constructed layers of loose and foreign matter prior to placing subsequent layers.

Avoid subgrade preparation during rainfall or immediately after a rainfall event when the subgrade is wet. If machinery must access the final grade, limit the access to a specific travel way that can be tilled before application of the base aggregate or place heavy steel plates on subgrade and limit traffic to the protective cover.

Moisten and roll each lift of aggregate with a 10-ton roller, keeping equipment movement over exposed subgrade to a minimum. Roll each lift between 4 and 6 passes. If a required depth of aggregate in a lift exceeds 10 inches, the aggregate layer shall be rolled in 10-inch lifts.

Make adjustments in placing procedures or equipment to obtain true grades, to minimize segregation and degradation, to reduce or increase water content, and to insure a satisfactory aggregate base course.

Geosynthetics along edges – Geotextile fabric or impermeable liners, or both, shall be used along the edges or sides of aggregate base course materials for permeable pavement as specified in the contract documents. Following placement of an aggregate base course, and at the conclusion of each day's work, the geotextile or impermeable liner, or both, shall be folded back and secured to protect from sediment washout along all bed edges. At least a 2-foot strip shall be used to protect stone from adjacent bare soil. This edge strip shall remain in place until all bare soils contiguous to beds are stabilized and fully vegetated or until the wearing surface for the permeable pavement has been placed.

Unfinished Edges of Base Course – In fill conditions, place earth or other approved materials along any unfinished edges of the base course in such quantity that it will compact to the thickness of the aggregate base course being constructed. In each operation, allow at least a 2-foot width of the shoulder along all unfinished edges to be compacted with vibratory plates and compacted simultaneously with the rolling and compacting of each layer of aggregate.

Protection work will be performed by the contractor at their expense. As construction is completed, maintain and protect the aggregate base course, except where a portion of the succeeding course is under construction thereon. Maintenance includes drainage, rolling, shaping, and watering, as necessary, to maintain the course in proper condition. Correct deficiencies in thickness, composition, and construction that develop during the maintenance, to conform to the requirements specified herein. Maintain sufficient moisture by light sprinkling with water at the surface to prevent dusty conditions.

Runoff onto an aggregate base course shall be minimized until the site is fully stabilized. Diversion ditches or other approved types of erosion and sediment control measures shall be placed at the toe of slopes that are adjacent to permeable pavement areas, to prevent sediment from washing into areas of aggregate base course at all times during and after construction. Any sediment accumulation into the aggregate base course shall be removed immediately by cleaning or replacement of the aggregate by the contractor at no cost to the owner.

303.4 TESTING

All materials shall be inspected, tested and accepted by the Engineer before incorporation in the work. Any work in which untested or unaccepted materials are used will be performed at the contractor's risk and may be considered as unacceptable and unauthorized work.

The contractor shall furnish material samples for inspection or testing. These samples may be required prior to or during the use of the material or at any time prior to acceptance of the work. Unless otherwise designated, materials shall be sampled and tested in accordance with the requirements of the standards that are current on the date of advertisement for bids.

Prior to production and delivery of aggregates, take at least 1 initial sample in accordance with ASTM D75. Collect each sample by taking 3 incremental samples at random locations from source material to make a composite sample. Samples of untreated aggregates or soils shall be taken from the road at the lay down machine prior to compaction.

Repeat sampling procedure when source of material is changed or when deficiencies or variations from specified grading of materials are found in testing.

Testing should be located and done at an adequate frequency to produce a soil profile characterization that fully represents the infiltration capacity of permeable pavement area.

Pilot infiltration tests are appropriate methods for estimating field infiltration rates. Infiltration tests should be conducted at the subgrade surface and followed by excavation into the soil profile below the subgrade surface where stormwater will infiltrate. Infiltration tests conducted at the subgrade surface provide valuable information for permeable pavement design.

Infiltration tests should be done once the subgrade preparation is complete to verify design infiltration rates were not significantly affected by compaction. Testing pits are not acceptable at this stage in order to maintain the structural integrity of the subgrade. Double ring infiltration tests are recommended for accuracy (ASTM C1701).

303.5 ACCEPTANCE

Testing responsibilities will be performed by the contractors at their expense. Materials approval testing may be performed by the Engineer. Failure to detect defective work or materials early will not prevent rejection if a defect is discovered nor shall it obligate the owner for final acceptance at any time. Submit all test reports to the Engineer.

A. ***Gradation*** – Test each sample of aggregate base course material for gradation in accordance with ASTM C 136 and with the sampling described in Section 303.4.

B. ***Thickness*** – Measure each 100 square yards of each layer of aggregate base course placement. Make depth measurements by test holes, at least 3 inches in diameter, through the base course. Where base course deficiency is more than 0.5 inch, correct by scarifying, adding mixture of proper gradation, re-blading, and re-compacting. Where the measured thickness is more than 0.5-inch thicker than indicated, consider it as the indicated thickness plus 0.5 inch for determining the average. The average thickness is the average of the depth measurements for the entire area and shall not under-run the thickness indicated in the contract documents without written approval from the Engineer.

303.6 PAYMENT

The unit of measure for aggregates for permeable pavements will be:

- Cubic yard for the levelling layer, reservoir layer, subbase layer, and the filter layer.
- Geotextile will be measured by the square foot.

The actual number of cubic yards measured complete in place will be paid for the contract unit price per cubic yard, for which payment will include all labor, materials, tools, equipment and incidentals necessary to complete the work as specified herein. Payment will also include all subgrade preparation and testing necessary to achieve the required placement.

MAG SECTION 323 – PLACEMENT OF PERVIOUS CONCRETE

323.1 DESCRIPTION

Pervious concrete describes a near-zero-slump, open-graded material with sufficient continuous voids to allow water to pass from the surface to underlying layers. It does not look or behave like typical concrete. The finished surface is not tight and uniform but is open and varied to allow permeability. Minor surface irregularities, minimal amounts of surface raveling, and color variations are normal. Pervious concrete is usually part of a water management system used to reduce runoff rates and volumes from on-grade surfaces such as patios, walkways, driveways, fire lanes, and parking spaces. The work covered by this specification is intended for light traffic areas and consists of furnishing all materials, labor, and equipment for the placement of pervious concrete.

323.2 MATERIALS

Materials utilized in pervious concrete shall conform to the requirements of the MAG Specification Section 723.

323.3 GENERAL

The pervious concrete contractor shall be experienced in the installation of pervious concrete and shall employ no less than 1 NRMCA-certified pervious concrete craftsman who must be on site overseeing each placement crew during all pervious concrete placements or employ no less than 3 NRMCA-certified pervious concrete installers on each pervious concrete placement crew during all pervious concrete placements. The minimum number of certified individuals (1 craftsman or 3 installers) is to be present at each pervious concrete placement, and a certified individual is to oversee the placement crew and the construction procedures.

Field test(s) of pervious concrete shall be performed by an individual certified as both an NRMCA-certified pervious concrete technician or equivalent, and American Concrete Institute concrete field technician grade 1 or equivalent as approved by the Engineer.

323.4 CONSTRUCTION OF TEST SECTION(S)

If required by the Engineer or contract documents, the contractor shall construct a test section(s) using the same equipment and placement crew as proposed to be used for the remainder of the pervious concrete work. Test sections may be placed non-contiguously. Test section(s) shall be a minimum of 275 square feet and shall include a construction joint and a control joint. Test section(s) must be at the required project thickness to demonstrate that in-place void contents, unit weights, and infiltration rates can be met and to demonstrate effective jointing that does not compromise the cured concrete integrity. Test section(s) may be placed at any of the final pervious concrete placement locations and may be incorporated into the work if approved by the Engineer.

323.4.1 Test Panel Infiltration:

Test panels shall be tested for infiltration in accordance with ASTM C1701.

323.4.2 Test Panel Acceptance:

Satisfactory test panels will be determined by:

A. Infiltration rate of at least 100 inches per hour.
B. Compacted thickness within 0.25 inches of the specified thickness.
C. Void content ± 3 percent of the design void content.
D. Unit weight ± 5 pounds per cubic foot of the design unit weight.

If test panels meet the requirements of 323.4.2, they can be left in place and included in the completed work. If test panels do not meet those requirements, they shall be removed and disposed of in an approved manner and replaced with an acceptable test panel at the contractor's expense.

323.4.3 Sample fresh pervious concrete in accordance with ASTM C172. The size of the sample shall be at least 1 ft^3. The temperature of the pervious concrete shall be tested in accordance with ASTM C1064 and shall be 95 degrees or less unless a higher temperature is approved by the Engineer. Complete at least one density test on a sample of freshly mixed pervious concrete in accordance with ASTM C1688. The acceptable fresh density shall be within ± 5 lbs/ft^3 of the approved mix design density.

323.4.4 Remove cores not less than 7 days after placement in accordance with ASTM C42 Obtaining and Testing Drilled Cores and Sawed Beams of Concrete. Test thickness in accordance with ASTM C174 and test saturated density in accordance with ASTM C140, paragraphs 8.3 and 9.3.

Tolerance for thickness, and density, reported as the average of three cores of each test panel, shall be as follows:

A. The average compacted thickness shall not be greater than 0.25 inch less than the specified thickness, with no single core exceeding 1 inch less than the specified thickness; nor shall the average compacted thickness be 1.5 inches more than the specified thickness.

B. The acceptable hardened density shall be within ± 5 lbs/ft^3 of the approved mix design density.

323.5 PERVIOUS CONCRETE BASE PREPARATION

A. ***Subgrade Preparation*** – Shall be in accordance with proposed Specification 303.
B. ***Base Materials*** – Shall be in accordance with proposed Specification 303.

323.6 PLACEMENT

323.6.1 Spreading and Finishing:

A. Moisten the base materials or subgrade immediately prior to concrete placement. Deposit concrete directly from the transporting equipment onto the base materials or subgrade, as appropriate.
B. Pervious concrete shall be constructed a minimum of 6 inches in depth, unless otherwise specified in the plans or special provisions. When hot weather is anticipated, recommended practices in ACI 305, Specification for Hot Weather Concreting, can provide good Reference information to help the contractor prepare and submit detailed procedures for the production, transportation, placement, protection, and curing of pervious concrete for approval by the Engineer. Evaporation retarders shall be available during placement and applied as needed in accordance with the manufacturer's recommendations to protect the pervious concrete from rapid evaporation (see MAG 323.7).
C. Each truckload shall be visually inspected for moisture consistency prior to concrete discharge. Water addition shall not be permitted at the point of discharge to obtain the required mixture consistency and truckloads lacking the required moisture consistency shall be rejected as determined by the inspector.
D. Discharge shall be a continuous operation and shall be completed as quickly as possible.

Concrete shall be deposited as close to its final position as practical and such that discharged concrete is incorporated into previously placed and plastic concrete. If consolidation occurs during concrete discharge, placement shall be halted, the mixture shall be addressed, and the consolidated portion removed and replaced immediately.

E. Pervious concrete shall be uniformly deposited over the entire formed area. The concrete will be spread using a come-along, short-handle square ended shovel or rake, or similar equipment.

323.6.2 Compaction of Pervious Concrete

Rolling compaction shall be achieved using a motorized or hydraulically actuated, rotating, weighted tube screed that spans the width of the section placed and exerts a minimum vertical pressure of 10 pounds per square inch (psi) on the concrete. A steel pipe roller meeting the same criteria may be used as an alternative.

Plate compaction may be necessary in small areas. A standard soil plate compactor with a base area of at least two square feet that exerts a minimum pressure of 10 psi on the concrete through a 0.75-inch minimum plywood cover shall be used in these cases. Cross-rolling shall be performed using a roller specifically designed to smooth and compact pervious concrete. Lawn rollers are not allowed. Foot-traffic shall not be allowed on fresh concrete.

Placement operations shall not result in the voids becoming sealed in order to maintain an adequate continuous voids structure for water passage through the pervious concrete. Surface depressions shall be corrected immediately after compaction by placing fresh pervious concrete in the depressions and compacting using a hand tamper or roller compactor. The final surface shall not deviate more than 0.375-inch from a 10-foot straightedge laid on the surface.

323.6.3 Joints

Contraction joints shall be installed at locations and spacing shown in the contract documents at one-quarter the depth of the thickness or a maximum of 1.5 inches for roadway and alley pavements, and at 0.5 inch for sidewalks and trails.

Unless otherwise approved, contraction joints shall be constructed by one of the following methods:

A. ***Rolled Joints*** – Shall be formed in plastic concrete using a steel pipe roller to which a beveled fin with the required diameter to achieve the joint depth has been attached around the circumference of the roller. Rolled joints are formed immediately after roller consolidation. Sidewalks and trails shall have rolled joints.

B. ***Sawed Joints*** – Shall be constructed as soon as the pervious pavement can be sawed without raveling the sawed edge and before initial cracking occurs, using a wet saw or an early-entry saw. Sawed joints shall typically be constructed between 24 – 48 hours after concrete placement, depending on site conditions. Only the area occupied by the concrete saw shall be uncovered and exposed with all other curing materials remaining in place. Any dust or slurry generated during sawing shall be immediately removed during the sawing operation. Immediately after sawing each joint, the exposed area shall be fogged with water and re-covered in accordance with MAG Section 323.7.

Construction joints shall be installed at locations and spacing shown in the contract documents and whenever concrete placement is suspended for a sufficient length of time that concrete may begin to harden.

Expansion joints shall be installed when pervious concrete will abut existing concrete slabs or other structures such as walls, footings, columns, catch basins, stairs, light poles, and other points of restraint.

Use isolation joints only where pavement abuts fixed objects, such as buildings, foundations, and manholes. Extend isolation joints through the full depth of the pavement. Fill the entire isolation joint with expansion joint material that complies with MAG Specification 729.

323.6.4 Curing

The contractor shall submit a curing plan to the Engineer for review and approval. The curing must begin within minutes unless longer working time is approved by the Engineer. The surface and edges shall be securely covered with polyethylene sheeting/film having a minimum thickness of 30 mil. The cover shall be checked daily to verify that it has not been displaced or damaged, and that condensation is evident underneath the sheeting. Damaged sheeting shall be repaired immediately. Displaced sheeting shall be replaced immediately. When there is no observable condensation, 1.5 gallons of water per square yard shall be applied to the surface of the pervious concrete. Curing methods shall remain in place for a minimum of 7 days or as directed by the Engineer. Pavement sections shall not be opened to light vehicular traffic until the concrete has cured for at least 14 days (28 days for heavy traffic), and until approved by the Engineer for opening to traffic.

A fog shall be sprayed above the surface, before covering, when required due to hot weather conditions. Equipment must include fog nozzles that atomize water using air pressure to create a fog blanket over the slab.

323.8 QUALITY CONTROL FIELD TESTING

Complete at least one density test on a sample of freshly mixed pervious concrete for every 50 cubic yards or each day of concrete placement, whichever is less, in accordance with ASTM C1688. Sample fresh pervious concrete in accordance with ASTM C172. The size of the core shall be 6 inches in diameter. The temperature of the pervious concrete shall be tested in accordance with ASTM C1064 and shall be 95 degrees or less unless a higher temperature is approved by the Engineer. Discharge of the previous concrete shall be completed in accordance with MAG Specification 725.9 (A)(4).

Remove three cores from each lot of 5,000 square feet or each day's production, whichever is less, in accordance with ASTM C42 not less than 7 days after placement of the pervious concrete. Select three locations in accordance with ASTM D3665. Upon approval of the Engineer, small test sections may be cast for sample extraction along with each placement to avoid removing cores from in-place work. Measure the cores for thickness in accordance with ASTM C174.

The cores shall be measured for void content and unit weight determined using the methods described in Section 323.4.2 of this specification. Satisfactory test panels will be determined by:

A. Compacted thickness ±0.25 inches of the specified thickness.
B. Void content ± 3 percent of the design void content.
C. Unit weight ± 5 pounds per cubic foot of the design unit weight.

If pervious concrete fails to meet the above requirements, the Engineer shall make a determination of acceptance, or rejection. The infiltration of the pavement surface shall be tested in accordance with ASTM C1701. All applied water shall infiltrate directly without puddle formation or surface runoff, and the testing shall be observed by the Engineer. A minimum infiltration rate of 100 inches per hour shall be achieved. The test results should be submitted to the Engineer and the core holes should be filled with standard concrete.

323.9 TOLERANCES

Mechanically sweep or vacuum pavement with clean equipment or flush with water before testing for compliance with tolerances.

Tolerance for hardened thickness, and density, reported as the average of three cores of each test panel shall be as follows:

A. Average hardened thickness from a lot shall not be more than 0.5 inch less than the specified thickness, with no single core exceeding 1 inch less than the specified thickness; nor shall the average hardened thickness be 1.5 inches more than the specified thickness.
B. Average hardened density from a lot shall be within ± 5 lbs/ft^3 of the average hardened density of the test section(s) from Section 323.4.
C. Unless otherwise specified in the Specifications, pervious concrete shall have a minimum infiltration rate of 100 inches per hour when tested in accordance with ASTM C1701.

323.10 Acceptance

Pervious concrete does not look or behave like typical concrete. The finished surface shall be open and varied to permit permeability. Minor surface irregularities and moderate amounts of surface raveling and color variations are normal and acceptable. Pervious concrete shall have no visible excess cement paste, tears, or gouges. Roller constructed joints shall have smooth, rounded, and uniformly compacted edges. Saw-cut joints shall not contain cement paste or dust nor exhibit evidence of spalling.

Acceptance will be based on conformance to the specifications. When a lot is outside one of more of the tolerances in MAG Section 323.9, the lot shall be subject to rejection, removal, and replacement at the contractor's expense, unless accepted by the Engineer.

323.11 PAYMENT

Payment for pervious concrete shall be made at the contract unit price per square foot for each thickness shown on the plans.

SECTION 344 – PLACEMENT OF PERMEABLE INTERLOCKING CONCRETE PAVERS

344.1 DESCRIPTION

This work shall consist of constructing permeable unit pavers on a prepared subgrade in accordance with these specifications and in conformity with the lines, grades, thicknesses, and typical sections shown in the contract documents or as directed by the Engineer.

The permeable unit pavers shall consist of a combination of unit pavers and aggregate for the joints and bedding layer, to form an integrated, structural wearing surface when compacted.

Permeable interlocking concrete pavers are designed with various shapes and thicknesses from high-density concrete to allow infiltration through a built-in pattern of openings or joints filled with aggregate. Pavers are typically 3.125 inches thick for vehicular applications and pedestrian areas may use 2.375-inch thick units.

Properly installed and maintained, high-density pavers have high load bearing strength and are capable of carrying heavy vehicle weight at design speeds below 30 miles per hour.

344.2 MATERIALS

344.2.1 Permeable paver materials shall be approved in accordance with MAG Specification 106 requirements, and as described below:

A. All unit pavers shall meet surface requirements of the latest ADA requirements and accessibility guidelines.

B. Unit pavers shall be of the type, style, color, and other details as described in the contract documents and in accordance with all manufacturer's recommendations for the selected unit paver system.

1. **Shapes:** rectangular, L-shaped, hexagonal, square as specified in design plans.
2. **Thickness:** 3.125 inches for vehicular use, 2.375 inches for pedestrian use.
3. **Colors:** are specified in the design plans.
4. **Concrete Unit Pavers:** The material and fabrication for the unit pavers shall meet or exceed the requirements of ASTM C936 Solid Concrete Interlocking Paving S-34 Units and must allow a minimum infiltration rate of 10 inches/hour through the pavement upon installation.
   a.) Portland cement: ASTM C150, Type 1.
   b.) Aggregate: Normal weight ASTM C33.
   c.) Pigments: ASTM C979 and as specified in the Contract Documents.
   d.) Other constituents: Previously established by test or experience as suitable for use in concrete, in compliance with applicable ASTM standards or as otherwise approved by the Engineer.
   e.) Paver physical properties:
      1.) Provide only sound units free of defects that would allow proper placing of units to achieve the specified pavement strength and performance.
      2.) Compressive strength: ASTM C140, when delivered to the project site, average compressive strength of not less than 8,000 psi, with no individual unit less than 7,200 psi.
      3.) Absorption: ASTM C140, average absorption not greater than 5 percent, with no individual unit greater than 7 percent.
      4.) Abrasion resistance: ASTM C418, maximum volume loss of 0.915 cubic inches / 7.75 square inch average thickness loss of no more than 0.118 inch (3 mm) due to abrasion testing.
      5.) Dimension tolerances: Length +/- 0.0625inch, height +/- 0.125 inch.
5. **Other Material:** Clay, brick, or other alternate materials shall be utilized as called for in the contract documents and shall meet physical properties described above in B.4., unless otherwise specified in contract documents.
6. **Bedding or Joints:** AASHTO No. 8 aggregate or similar, as directed by the contract documents and in accordance with Specification 303.

344.2.2 Base Course Materials:

Subgrade

- Open graded subbase: No. 2 stone.
- Open graded base: No. 57 stone.
- Levelling course: No. 8 stone.
- Soils should be analyzed by a qualified professional for infiltration rates and load bearing, given anticipated soil moisture conditions.
- The ICPI recommends a minimum CBR of 4 percent (96-hour soak per ASTM D 1883 or AASHTO T193) to qualify for use under vehicular traffic applications.
- Refer to proposed Specification 303, common components and design criteria for permeable pavement systems guidelines and construction techniques to reduce compaction are included in proposed Specification 303.

344.3 GENERAL

Contractor shall submit drawings and documentation as required in this specification and obtain written acceptance of submittals before using the materials or methods requiring approval.

A. ***Contractor Qualifications*** – As part of the bid submission, the contractor will:
   1. Submit written evidence of an installer who will be on-site at all times during the unit permeable interlocking paver installation, with a current certificate from the ICPI Installer Certification Program and a record of completion from the Permeable Interlocking Concrete Paver (PICP) Specialist course, or
   2. Submit written evidence that the contractor will obtain the service of a consultant who has the required certifications and who will be on site at all times during the permeable unit paver installation, acting as the installer for the project.

B. ***Testing Agency*** – Within 7 days after notice to proceed, the contractor shall submit the name and location of a third-party quality assurance (QA) testing agency with experience in testing permeable unit pavements, who will oversee and document production and assembly. Use of testing services will not relieve contractor of the responsibility to furnish materials and construction in full compliance with the contract documents.

344.4 TEST SECTIONS

Testing Panels – At least 15 days before construction of the permeable unit paver installation, and following the Engineer's acceptance of the qualifications described above, the contractor shall provide a minimum of 1 test panel for acceptance. Place, joint and cure the test panel, to be a minimum of 275 square feet in size or as specified in the contract documents, at the required project thickness to demonstrate to the Engineer's satisfaction that the unit pavers and design flow rates are acceptable, and that a satisfactory pavement can be installed at the site location.

344.5 PERMEABLE INTERLOCKING PAVEMENT BASE PREPARATION

A. ***Subgrade Preparation*** – Shall be in accordance with proposed Specification 303.

B. ***Base Materials*** – Shall be in accordance with proposed Specification 303.

PLACEMENT

Pre-Placement Meeting – A mandatory pre-installation meeting will take place at least 1 week prior to installation of the permeable unit pavers and shall include at a minimum, the Engineer, inspector, general contractor, permeable unit paver installer, and field testing agency.

Install base materials in accordance with proposed Specification 303. Moisten, spread and screed aggregate bedding material and fill any voids left by screed rails. Do not roll or compact the bedding material prior to placing the permeable unit pavers.

Lay the permeable unit pavers in the type, style, pattern, dimensions, and locations with joint widths as recommended by the manufacturer and shown on the contract documents. Maintain consistent and uniform patterns for the entire pavement area.

Fill gaps at the edges of the paved area with cut units. Cut the permeable unit pavers subject to vehicular traffic shall be no smaller than 0.67 of a whole unit and shall have no sharp edges. Patterns shall be maintained to the extent possible in placing cut units to fill gaps in the pattern. Stagger blocks to avoid running bond or other straight joints or seams in the pattern.

Fill the openings and joints with washed ASTM No. 8 aggregate. Some permeable unit paver joint widths may be too narrow to accept most No. 8 stone. In such case, use joint material that will fill joints such as washed ASTM No. 8 or No. 9 stone. Sweep excess aggregate from the surface.

Compact and seat the permeable unit pavers into the bedding material using a low amplitude, 75 – 90 Hz plate compactor capable of at least 5,000 lbf centrifugal compaction force. This will require at least 2 passes with the plate compactor over the entire surface.

Apply additional ASTM No. 8, No. 9 or No. 89 aggregate to the openings and joints as needed filling them in completely, then remove excess aggregate by sweeping, and make at least 2more passes with the plate compactor over the entire surface.

All permeable unit pavers within 6 feet of the laying face must be fully compacted at the completion of each day's work.

344.6 QUALITY CONTROL FIELD TESTING

Testing responsibilities will be performed by the contractor's testing agency or the manufacturer at the contractor's expense, as described below. Materials approval testing will be performed by the Engineer. Failure to detect defective work or materials early will not prevent rejection if a defect is discovered nor shall it obligate the owner for final acceptance at any time.

A. ***Roughness Test*** – Test finished permeable unit paver system with a 10-foot straightedge, applied parallel with and at right angles to the center line of the paved area. Correct deviations in the surface in excess of 0.5 inch by removing the unit pavers as necessary and then loosening, adding or removing material, re-shaping, watering, and recompacting. The smoothness requirements specified herein apply only to the top lift of each layer, when base course is constructed in more than one lift.

B. ***Infiltration Test*** – The full permeability of the pavement surface shall be tested prior to final acceptance by application of clean water at least 5 gallons per minute, using a hose or other distribution device. Water used for the test shall be clean, free of suspended solids and deleterious liquids. All applied water shall infiltrate directly without large puddle formation or surface runoff, and the testing shall be observed by the Engineer. A minimum flow rate of 100 inches per hour is required.

PROTECTION

A. As construction is completed, maintain and protect the permeable unit pavers. Correct deficiencies in thickness, composition, construction, and smoothness, which develop during the maintenance, to conform to the requirements specified herein.

B. Finishing along the edges of the permeable unit pavers for protection during construction shall be until the site is fully stabilized, at which time excess filter fabric and impermeable liners can be cut back to the pavement edges.

C. In addition, runoff onto the permeable unit pavers shall be minimized until the site is fully stabilized as described in the contract documents. Diversion ditches or other approved types of erosion and sediment control measures shall be placed at the toe of slopes that are adjacent to permeable unit pavers, to prevent sediment from washing into pavement areas at all times during and after construction. Any sediment accumulation onto the permeable pavement shall be removed immediately by cleaning or replacement of the aggregate by the contractor at no cost to the owner.

344.8 MEASURE AND PAYMENT

The unit of measure for permeable unit pavers will be in square yards for the type(s) specified in the contract documents. The actual number of square yards complete in place will be paid for at the contract unit price per square yard, which payment includes unit pavers, bedding material, and joint filler, complete and in place. Payment will include costs for furnishing all materials, labor, tools, equipment, and incidentals to complete the work.

SECTION 622 – UNDERDRAIN FOR LID FACILITIES

622.1 DESCRIPTION

This work shall consist of furnishing and placing the items specified to construct perforated PVC pipe for underdrains, cleanouts, observation wells, field connections to existing stormdrains as shown in the drawings and in accordance with MAG Standards, where applicable. Except as herein stated, the requirements specified in MAG Specification 505 are applicable to this specification.

622.2 MATERIALS

All materials shall meet the following requirements:

A. ***PVC (perforated or non-perforated as specified in the contract drawings)*** – Shall be schedule 40 for underdrains and pipe risers and shall conform to Section 745 of the MAG Specifications. PVC shall meet ASTM D 2729 and ASTM D 3034 specifications.

B. ***Screw Cap*** – Shall be threaded PVC with 2 inch square lug.

C. ***Fittings*** – Fittings shall be PVC and used as indicated on the design drawings.

D. ***Cleanout*** – The cleanout cover assembly in pavement shall be cast iron and have an adjustable housing with a cast iron cover as indicated in the design drawings.

E. ***Observation Well*** – 2 inch well test plug using EnviroTech, ErgoGrip, or approved equal with tethering eyelet.

F. ***Field Connections*** – All materials shall meet the requirements set forth in the MAG Specifications 324, 505, 601, or modified in the special provisions.

622.3 GENERAL

622.3.1 General installation

The contractor shall make the requisite excavations for constructing the underdrain, appertaining structures, and connections and make provisions to maintain and protect fences, trees, underground installations, and other structures. Contractor shall be responsible for the repair of all damage that may result from his operations.

The contractor shall, after giving due notice to parties affected thereby, provide plank crossings, barricades or other means of maintaining and protecting travel on streets or roads in which trenches are excavated and shall maintain these in good and safe condition until construction is completed and shall then remove such temporary expedients and restore such ways to their proper condition.

Perforated pipes shall be placed with perforations down. Pipe shall be placed with the bell end up grade. Pipe sections shall be joined with appropriate couplings. The ends of underdrain pipe shall be plugged on the upstream side as directed by the Engineer.

622.4 TESTING

When construction is complete, the contractor shall test all completed underdrain systems for continuous, unimpeded flow.

Suggested test methods for each pipe run are as follows:

- At the highpoint or upstream end of underdrain pipe, open cleanout and insert hose from water source.
- Turn on water.
- Acceptance of pipe run consists of free flow of water through drain outlet into the existing storm sewer structure.
- Any sections of the underdrain that are clogged or crushed shall be repaired at the contractor's expense.

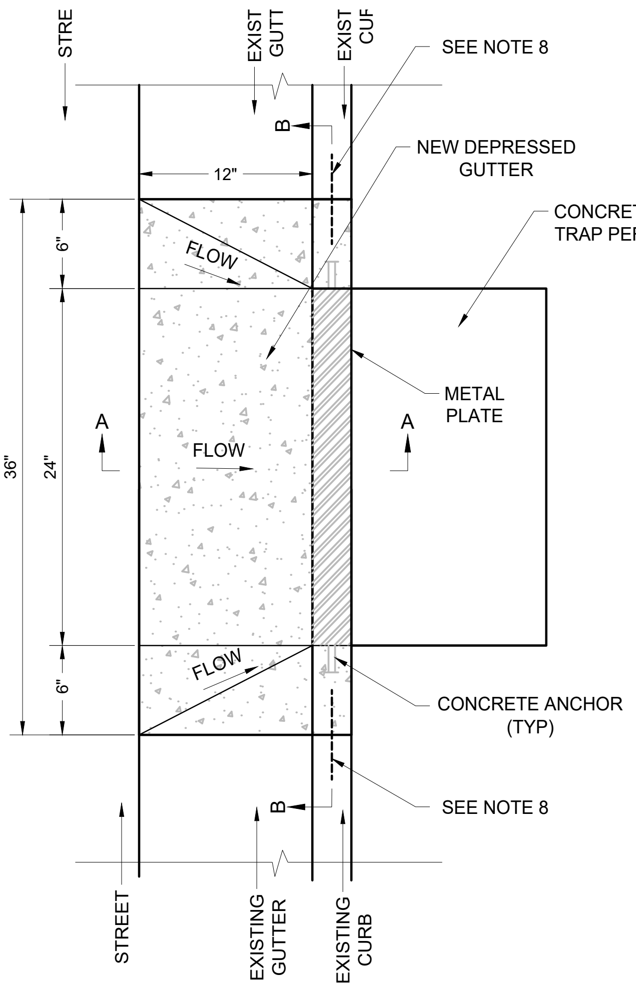
622.5 MEASURE AND PAYMENT

622.5.1 Underdrain Pipe

Payment for underdrain pipe will include all costs for furnishing all materials, labor, tools, equipment and incidentals (including pipe risers, caps, and fittings) to complete the work. The unit of measurement will be linear feet.

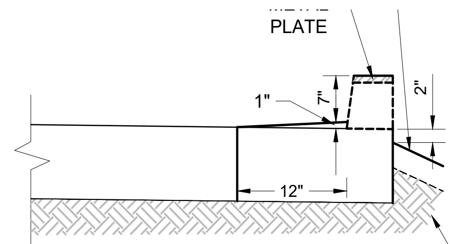
622.5.2 Field Connection

The unit of measure for underdrain cleanout and observation well will be per each. payment for underdrain cleanout or underdrain observation well will be made at the contract unit price per each, which will include excavation, shoring, backfill, compaction, installation of cleanout including wye and jointing, pipe riser, gaskets, frame and cover or screw cap, concrete encasement, and all labor, materials, tools, equipment and incidentals needed to complete work specified.



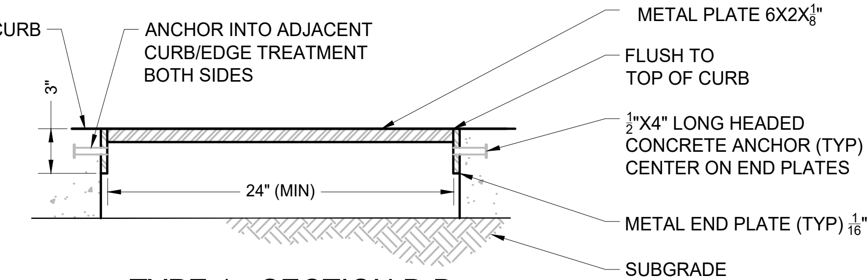
CURB OPENING - TYPE 1

RETROFIT OPENING WITH VERTICAL CUT

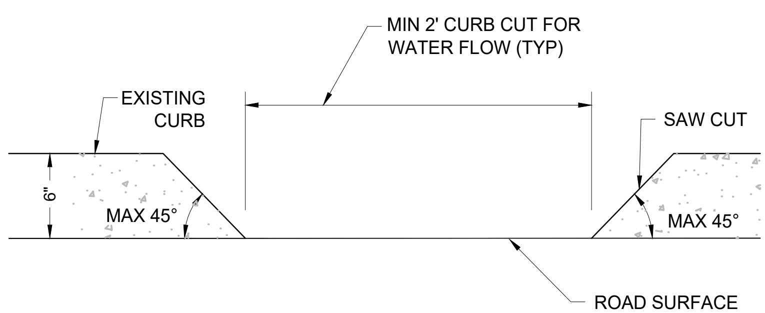


TYPE 1 - SECTION A-A

REQUIREMENTS OF ASTM A-108.
2. METAL PLATE 6X2X1/8 CHANNEL SHALL MEET THE REQUIREMENTS OF ASTM A-500 GRADE B.
3. END PLATES SHALL MEET THE REQUIREMENTS OF ASTM A-36.
4. ENTIRE ASSEMBLY SHALL BE HOT DIP GALVANIZED IN ACCORDANCE WITH ASTM A-123.
5. DESIGN VERTICAL WHEEL LOAD IS 8.5 KIPS.
6. SEE SPECIFICATION 341 FOR MATERIAL AND CONSTRUCTION INFORMATION.
7. REFER TO AASHTO ROADWAY DESIGN GUIDE FOR CLEAR ZONE REQUIREMENTS FOR SPEED DESIGNS.
8. DRILL & EPOXY #4x6"REBAR



TYPE 1 - SECTION B-B



CURB OPENING - TYPE 2

ANGLED CURB CUT

NOTES:

1. DO NOT CUT DEEPER THAN ROAD SURFACE ELEVATION.
2. ALL CURB OPENINGS SHALL BE MADE BY SAW CUT METHOD.
3. GRIND EXPOSED METAL AND SEAL TO PROTECT FROM CORROSION.

DETAIL NO.	STANDARD DETAIL		REVISED	DETAIL NO.
.ID-02	ENGLISH	CURB OPENINGS	01-29-2019	LID-02

2. CURB OPENINGS

Curb openings (LID-02 and LID-03) convey runoff into and out of LID features, such as swales or bioretention areas. This LID treatment can be retrofitted into an existing roadway, or can be built as part of new construction and can be used in almost any situation.

2.1 APPLICABILITY AND ADVANTAGES:

The clear openings are typically 2 feet wide. Curb openings are regularly used to convey flows from parking lots and streets into stormwater capture areas and LID facilities. They are the most common LID practice. For safety purposes, roadway design speeds, clear zone offsets, and the type of curb opening must be considered during the curb opening selection process.

- Metal grate curb openings can be designed to meet ADA standards while accommodating water flows and pedestrian traffic.
- Curb openings are useful in areas where the runoff source is not separated from a LID feature by a pedestrian path.
- Curb openings are relatively easy to maintain.

2.2 DESIGN CONSIDERATIONS

- By themselves, curb openings are not a LID treatment.
- The curb openings should be at least 24 inches wide to prevent clogging.
- When the curb cut is angled, it should have chamfered sides at 45 degrees, which is the maximum angle that can be achieved with typical concrete saws.
- The floor of the curb opening should slope toward the stormwater or LID element.
- A minimum 2-inch grade drop should be provided between the floor of the curb opening and the finished grade of stormwater element to allow positive drainage.
- The curb opening must be sized allow the design flow to pass without causing ponding in the adjacent roadway travel lane.
- The back slope of curb opening inlet should be armored to prevent erosion if a sediment trap is not also installed.

2.3 CONSTRUCTION CONSIDERATIONS

Curb cuts can be built as new construction or retrofitted into an existing roadways and ROWs. Either way, curb cuts require review and approval during the design and construction phases. Traffic control will typically be required during construction on public streets in accordance with the municipal requirements. The contractor may elect to remove an entire curb section and replace with a poured curb opening in lieu of using the curb-cut method.

2.4 MAINTENANCE

Curb openings should be inspected after storms of 0.5 inches or greater to make sure that they are not clogged with debris or sediments. While inspecting the curb openings, observations should also be made about the potential debris or sediment buildup in the collection element. View routinely for damage from vehicle strikes and schedule repairs as necessary.

2.5 COMPATIBILITY WITH OTHER LID PRACTICES

Curb openings can be implemented as an accessory to many LID and non-LID facilities. They can be used with vegetated/rock swales; stormwater harvesting systems; sediment traps; and bioretention systems to capture roadside stormwater.

2.6 SPECIFICATIONS

SECTION 341 – CURB OPENINGS

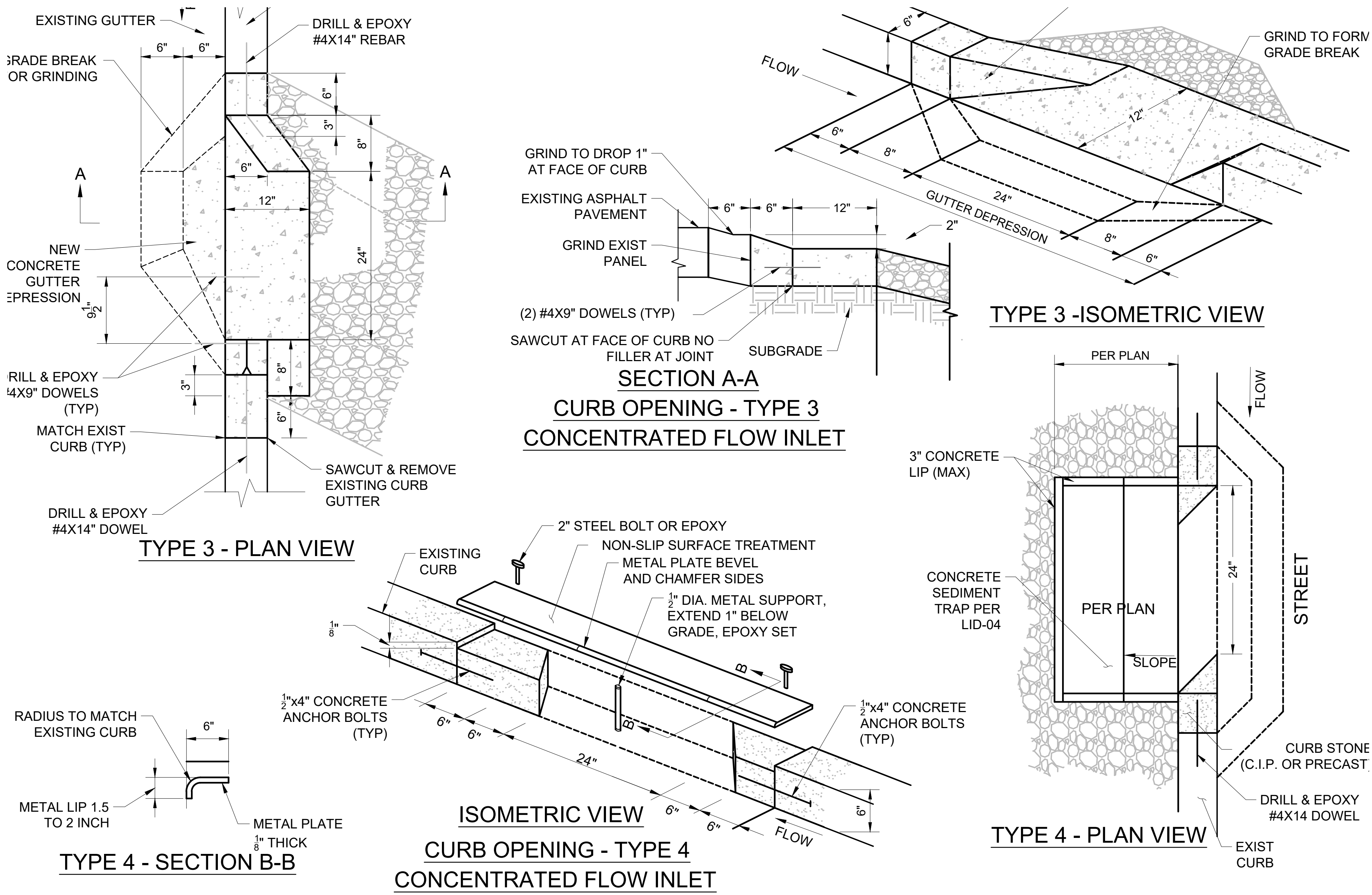
341.1 DESCRIPTION

Curb openings accept roadway and impervious surface stormwater runoff to flow into and release from associated other types of LID features such as vegetated swales, rainwater harvesting basins or bioretention areas. Curb openings can be retrofitted onto an existing roadway or they can be constructed as part of the original construction.

Except as herein stated, the requirements indicated in MAG Specifications 201, 215, 340, 401, and 505 are applicable to this specification for curb openings.

341.2 MATERIALS

All aprons and curb openings shall be completed in concrete. Aprons will follow MAG Specification 505. Curb openings should include a rock pad, riprap or protected inlet on side slope, and a concrete sediment trap on the downstream side.



DETAIL NO.			REVISED	DETAIL NO.
ID-03	STANDARD DETAIL ENGLISH	CURB OPENINGS	01-29-2019	LID-03

341.3 GENERAL

The minimum curb cut of 24 inches is recommended. The curb shall not be cut lower than 0.25 inch below the gutter. The flow entrance should drop a minimum 2 inches from the curb line. The curb cut will be done by the saw-cut method and have maximum chamfered sides at 45 degrees, but the curb cut may be vertical.

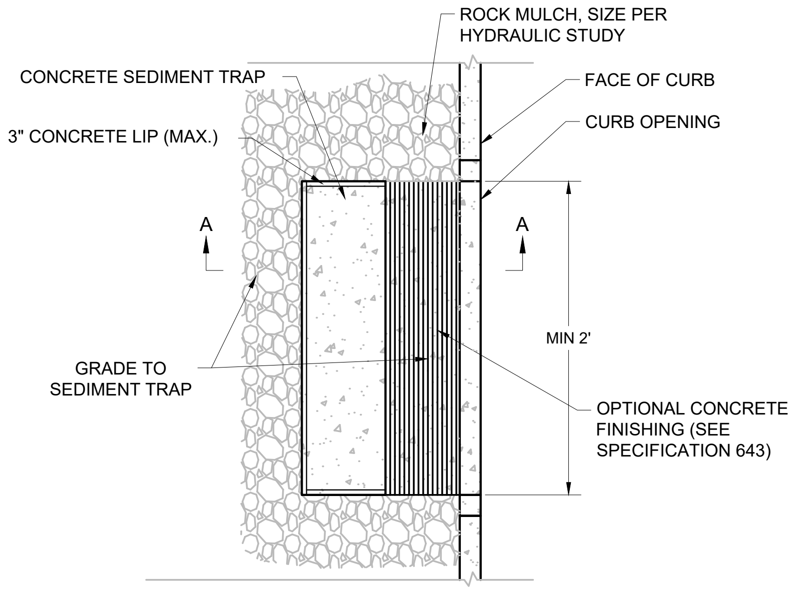
No curb may be lowered, or driveway constructed, which may be in any way dangerous or hazardous to pedestrian or vehicular traffic. Any curb opening on roadways with design speeds over 30 miles per hour (mph) will require a metal plate constructed on top of the entire curb opening. The plate shall meet current ADA standards; please refer to the ADA Design Guide.

All damage that occurs during the construction process shall be repaired in accordance with the MAG Specification 340. The additional costs will be incurred at the contractor's expense. All repairs must be completed within 24 hours.

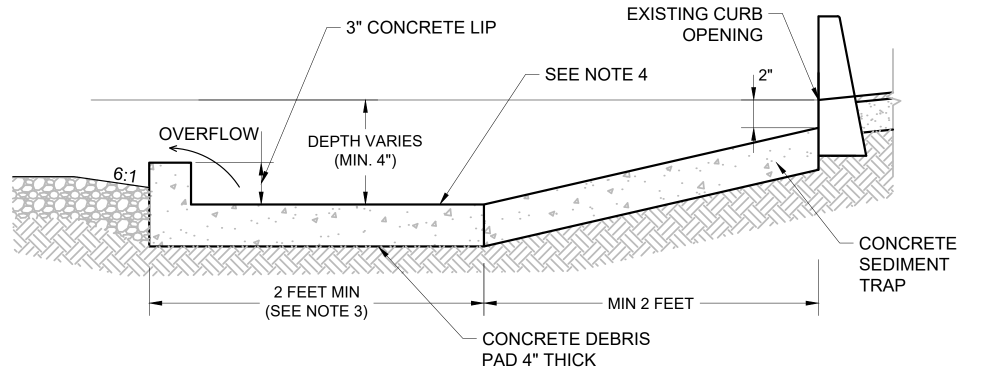
The contractor is responsible for the quality of the curb opening and any related work therein and shall guarantee this work against failure for a period of 3 years. This guarantee does not cover damage resulting from accident, disaster, misuse, abuse, or modification of the curb opening. The contractor is responsible for traffic control per MAG Specification 401.

341.4 PAYMENT

Payment will be made for the applicable items at the contract unit prices bid in the proposal, and shall constitute full payment for furnishing all material, equipment, tools, labor and incidentals necessary to complete the work and for carrying out the maintenance provisions.



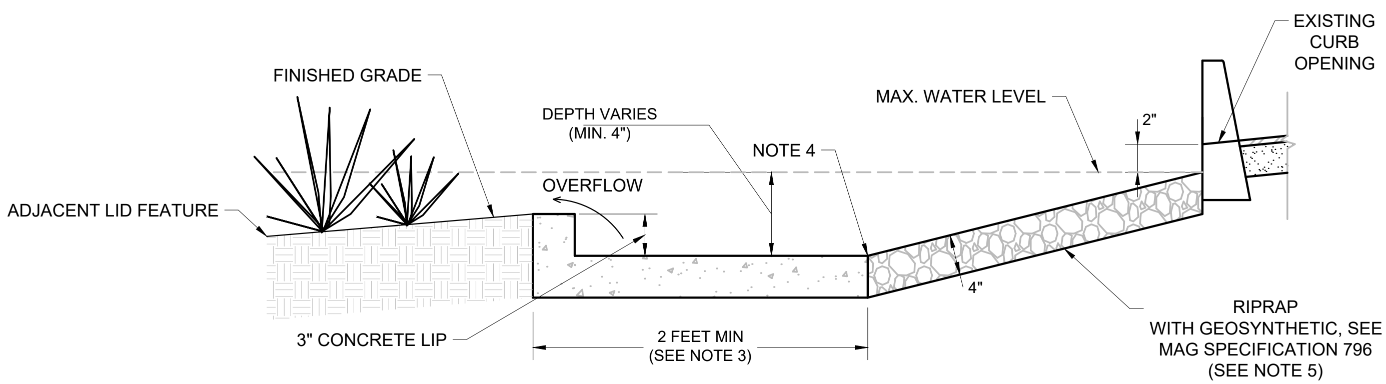
SEDIMENT TRAP PLAN VIEW



SECTION A-A

NOTES:

1. DIMENSIONS OF SEDIMENT TRAP SHOULD BE ADJUSTED BASED ON CONTRIBUTING WATERSHED SIZE AND SEDIMENT LOAD.
2. SEDIMENT TRAP CAN BE PRECAST OR CAST IN PLACE CONCRETE.
3. DEBRIS PAD SHOULD BE DESIGNED TO CONTAIN HYDRAULIC JUMP (IF POSSIBLE).
4. EXPANSION/CONTRACTION JOINT
5. RIPRAP SIZE BASED ON DESIGN REPORT.



SEDIMENT TRAP WITH RIPRAP SPILLWAY

DETAIL NO.	STANDARD DETAIL		REVISED	DETAIL NO.
LID-04	ENGLISH	SEDIMENT TRAPS	01-29-2019	LID-04

3. SEDIMENT TRAPS

Sediment traps (LID-04) should be installed at curb openings and/or inlets that receive concentrated stormwater flows. A sediment trap provides a collection point for sediment and other debris before runoff enters a stormwater capture or LID facility. Sediment traps facilitate individual component and system maintenance.

3.1 APPLICABILITY AND ADVANTAGES

Sediment traps are applicable to areas with concentrated runoff flowing into a stormwater capture or LID facility. Traps are generally used as an accessory to another LID element or storage basin.

Sediment traps:

- Reduce sedimentation of adjacent basins and LID features.
- Reduce erosion and disperse energy.
- Reduce maintenance efforts because the concrete debris pad facilitates easy removal of sediment and debris.
- Improve the overall LID system function and life cycle/longevity.

3.2 DESIGN CONSIDERATIONS

- The debris pad of the sediment trap should be as flat as possible to aid in the removal of debris. A 3-inch concrete lip should be constructed on three sides to reduce maintenance and encourage sediment deposition.
- The flow path length-to-width ratio should be 3 to 1 or less because a higher flow path length to width ratio increases fine sediment removal.
- The sediment trap flow path and debris pad can be built as a single unit from poured concrete or from precast units.
- A riprap bottom is not recommended because they are difficult to clean. Riprap or appropriately sized rock should be used to armor the sediment trap side slopes.
- The optimal sediment trap design would be long enough so that the hydraulic jump occurs within the feature, the length of the hydraulic jump and tailwater depth can be calculated using the equations in FCDMC Hydraulics Manual (Reference 13) given below:

$$F_{R1} = \frac{V_1}{(gY_1)^{\frac{1}{2}}}$$

$$Y_2 = \frac{1}{2} Y_1 \left[\sqrt{1 + 8F_{R1}^{2}} - 1 \right]$$

$$L_j \approx 6Y_2$$

Where:

- F_{R1} = Froude's number upstream of hydraulic jump
- V_1 = initial upstream velocity (ft/sec)
- Y_1 = initial upstream flow depth (ft)
- Y_2 = tailwater depth downstream from Y_1 (ft)
- g = acceleration of gravity (32.2 ft/sec^2)
- L_j = length of hydraulic jump (ft/ft)

- Sediment traps can have adjacent landscaping or can have grasses within the concentrated flow portion of the facility.

3.3 CONSTRUCTION CONSIDERATIONS

Flows should be diverted around the sediment trap to protect it from inundation during construction. Excavated material should be stored such that it cannot be washed back into the sediment trap or downstream, if a storm occurs during construction.

3.4 MAINTENANCE

Sedimentation or debris should be removed at least every 6 months and after storms of 0.5 inches or greater. The debris pad to should be completely clean after maintenance is finished.

3.5 COMPATIBILITY WITH OTHER LID PRACTICES

Sediment traps must be utilized as an accessory with another LID facility or conveyance structure. They typically are designed in conjunction with curb openings and vegetated/rock bioswales.

3.6 SPECIFICATIONS

SECTION 643 – SEDIMENT TRAPS FOR LID FACILITIES

643.1 DESCRIPTION

This work shall consist of supplying and constructing a sediment trap outlet in catch basins with additional sump depth as shown on the plans, profiles and details and as specified herein. This work shall be done in accordance with MAG Specifications 201, 215, 220, 425, and 430, except as herein provided.

643.2 MATERIALS

Materials for sediment trap shall are specified in MAG Specification 505, 703, 705, and 725.

643.3 GENERAL

The sediment trap shall be constructed with a minimum 8-inch depth sump, measured from the curb opening the concrete floor. The sediment trap shall be constructed in accordance with the diameter and details shown on the project plan and details. A 3-inch concrete lip will be placed around the splash pad to support maintenance activities. Optional concrete finishing is achieved by roughening concrete surface with hard broom or rake and seeding the wet concrete surface with 0.25-inch decomposed granite.

The sediment trap outlet and all associated connection hardware necessary to complete the sediment trap outlet within the structure shall be completed as shown on the detail sheets of the plans and/or as directed by the Engineer.

643.4 PAYMENT

The unit of measure for the sediment trap will be per each and the payment will be made at the contract unit price per each specified, which will include excavation, shoring, backfill, compaction, rip-rap installation, and all labor, materials, tools, equipment and incidentals needed to complete work specified. Refer to MAG Specification 206, 215, and 220 for those items that are included in the sediment trap construction.

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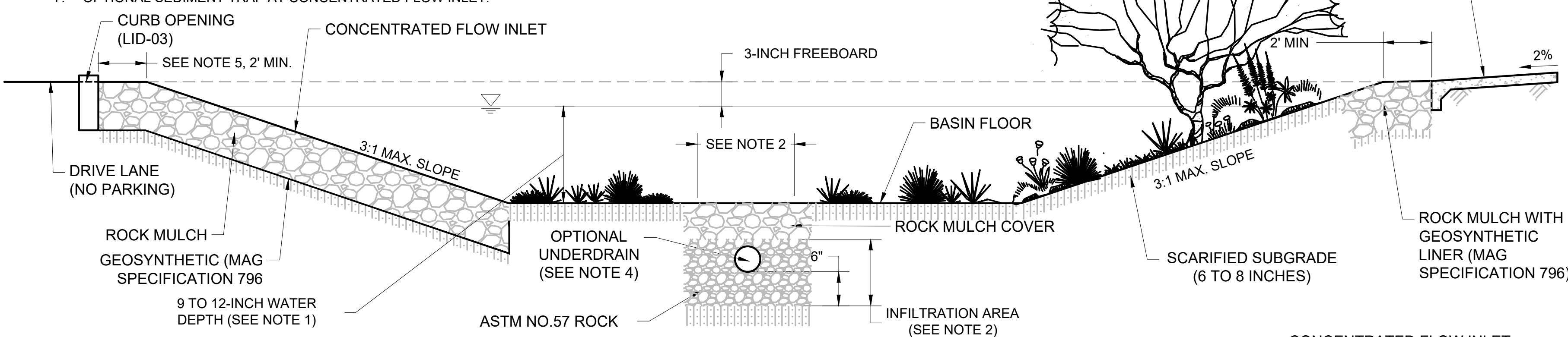
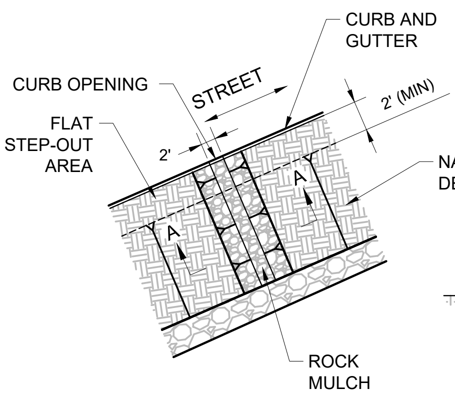
GENERAL NOTES (BASIN):

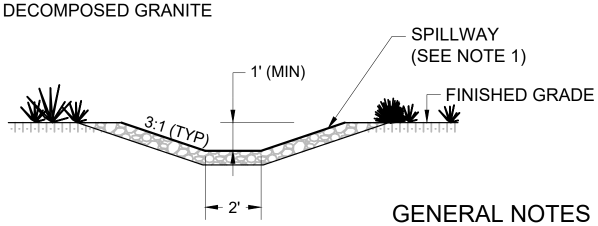
1. SURFACE WATER MUST DRAIN WITHIN 36 HOURS.
2. INFILTRATION AREA DEPTH AND WIDTH DETERMINED BY PERCOLATING WITHIN 72 HOURS. WIDTH MUST EXCEED DEPTH.
3. DEDICATED OUTFLOW MAY BE REQUIRED FOR THIS FEATURE.
4. FOR OPTIONAL PERFORATED UNDERDRAIN (SEE SPECIFICATION 622)
5. REFER TO AASHTO ROADWAY DESIGN BOOK FOR CLEAR ZONE REQUIREMENTS.
6. NO PLANTINGS IN THE CONCENTRATED FLOW INLET.
7. OPTIONAL SEDIMENT TRAP AT CONCENTRATED FLOW INLET.



STORMWATER HARVESTING BASIN SECTION
WITH CUT THROUGH CONCENTRATED FLOW INLET



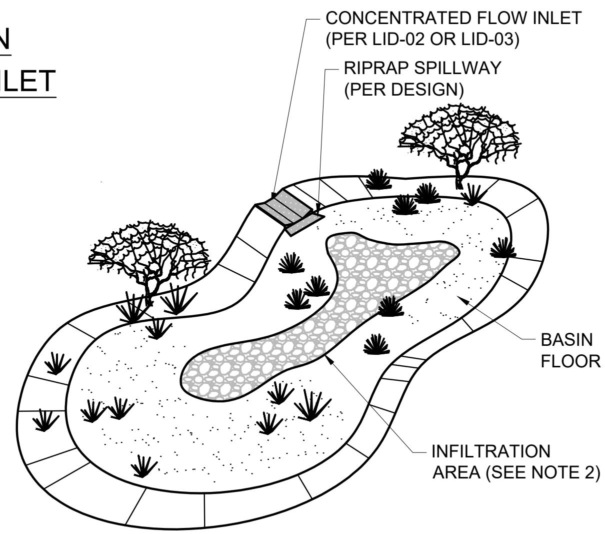
PLAN



SECTION A-A

GENERAL NOTES (INLET):

1. SPILLWAY CAN BE 4" THICK CONCRETE TRAPEZOID SCUPPER 6" DEEP OR ROCK SPILLWAY BASED ON DESIGN.



ISOMETRIC VIEW

RIPRAP SPILLWAY (PLAN & SECTION)

DETAIL NO.	STANDARD DETAIL		REVISED	DETAIL NO.
LID-05	ENGLISH	STORMWATER HARVESTING BASINS	01-29-2019	LID-05

4. STORMWATER HARVESTING BASINS

Stormwater harvesting basins (LID-05), also known as rain gardens, are shallow vegetated earthen depressions that collect stormwater and cleanse it prior to the water percolating into the subsurface. These differ from typical retention basins in that they provide subsurface storage within the constructed facility. An infiltration trench is designed in the center of the storage area so that surface water is infiltrated within 36 hours.

Generally, harvesting basins are utilized in onsite planning for stormwater detention. They can be constructed at any size and for various developments, including residential, commercial, or industrial land uses. Harvesting basins should be built adjacent to impervious areas like parking lots and recreational areas such as sport courts. When there is adequate ROW, basins may also be incorporated as roadway enhancements. Harvesting basins are typically landscaped.

4.1 APPLICABILITY AND ADVANTAGES

- Harvesting basins may accomplish a portion of the onsite detention requirements, if designed and maintained with that intent.
- Harvesting basins should be built immediately adjacent to localized runoff sources/impervious areas (e.g. parking areas, driveways, and rooftops) in lieu of constructing a large, centralized on-site basin.
- Harvesting basins can be retrofitted into sites with or without existing drainage features, are compatible features when adjacent to parking and roadways, easily fit within natural areas, and can be used to achieve drainage volume credit in some municipalities, if designed and approved to meet those requirements.
- Harvesting basins are relatively simple to build, relatively easy to maintain, and scalable in size.
- Harvesting basins can be multifunctional, providing wildlife habitat and creating a "softer" aesthetic for streets and roads by incorporating additional landscaping and vegetation.
- Harvesting basins enhance stormwater infiltration, potentially improving water quality.
- Harvesting basins can reduce the reliance on potable water sources for landscaping irrigation for other portions of the project area, depending on the landscape design and the volume and pattern of stormwater collection.
- Harvesting basins create planting conditions that encourage enhanced vegetation growth that yields cooling properties for adjacent land areas and the Phoenix Metropolitan Area heat island phenomenon.

4.2 DESIGN CONSIDERATIONS

- There may be a need to design the basin with an underdrain or overflow drain option if the soils have low infiltration rates or if the anticipated capture volume exceeds the holding capacity of the basin and the infiltration trench. Please refer to the LID Storage and Infiltration tables located in Appendix B to determine the design volume and percolation rates of underground systems. The overflow outlet should be located at the downstream end of a drainage basin. Subterranean outlets associated with the underdrain must be connect to an appropriate downstream drainage facility, LID element, and/or underground stormwater collection system.
- The first flush rainfall (0.5 inch) can be used to determine the design stormwater volume in accordance with the local standards. The allowable surface storage of a harvesting basin should be 9 – 12 inches with a recommended freeboard of 3 inches. Stormwater harvesting basins should drain surface ponding in less than 36 hours in accordance with the local standards for vector control purposes. The underground runoff volume should percolate within 72 hours so the feature remains effective during the monsoon.
- Stormwater harvesting basins may accept distributed flow along some or all perimeter sides from areas like parking lots or landscape areas. If the basin slope can be designed to be flatter than 3 to 1, the basin sides accepting the distributed flow may be of vegetated earthen construction. Slopes steeper than 3 to 1 should be rock-lined based on the engineering analysis.
- When the stormwater harvesting basin is located next to a travel lane, the Engineer must refer to the AASHTO Roadway Design Book for clear zone requirements (Reference 14).
- The underground work will likely require a special inspection during construction.
- For steep slopes and inlets where flow is concentrated, scuppers or riprap spillways should be designed to prevent erosion.
- Harvesting basins should be located as close to the runoff sources as possible and be distributed throughout the site instead of relying on one large basin to capture the flows.

To facilitate revegetation, soil fertility testing should be conducted on exposed soils to determine what nutrients/amendments may be needed to foster vegetation growth. Imported soils are not encouraged.

- Because of their association with new or existing development, basin sides are typically landscaped to improve the aesthetics of the element, to match an existing landscape character, and/or to reduce potential erosion on the side slopes. The landscaping treatment can range from a native, drought-tolerant palette to a more ornamental landscaping approach commensurate with urban development. Soil building materials such as organic mulch, biota, and fertilizers may be incorporated into the planting area to improve vegetative success; the need for these can be identified through soil fertility testing and by specifically defining the landscaping objectives and performance expectations.
- Plant selections should consider the location of the plants within the basin and their potential frequency of inundation or for damage. In general, installed plantings (not native seeding) will require some degree of supplemental watering to get the plants established. Watering is typically accomplished through an underground irrigation system whose volume may be reduced over time and/or abandoned once the plants have been established, depending on the success of the landscape installation and the volume and pattern of stormwater collection.

4.3 CONSTRUCTION CONSIDERATIONS

Filter fabric should not be used in stormwater harvesting basins. Compaction should be avoided during construction. The construction area should be fenced off with construction fencing or silt fencing to prevent compaction of soils by construction equipment or traffic during construction of surrounding improvements. At a minimum, the bottom grade and side slopes should have the top 6 – 8 inches scarified. A percolation test should be completed before the construction of the underground storage area to determine if the site soils will perform as anticipated and/or if an underdrain is necessary. Vegetation should be selected to thrive within the anticipated hydrological regime and infiltration rates of the harvesting basins to minimize long-term maintenance commitments.

4.4 MAINTENANCE

After every storm greater than 0.5 inches, or semiannually at a minimum, the harvesting basins should be checked for erosion, sediment, debris, litter, and clogging. If there is standing water, the perforated underdrain should be checked for clogs and cleaned as necessary. Section 3 identifies the maintenance practices for the landscape element of this LID treatment. If an altered water flow pattern, erosion, or plant die-off is observed, these should be corrected in kind, at a minimum, and/or evaluated for further corrective measures.

4.5 COMPATIBILITY WITH OTHER LID PRACTICES

Stormwater harvesting basins are harmonious with and can seamlessly incorporate other LID techniques such as curb openings, bioretention systems, and sediment traps. If it is determined that a harvesting basin's functional operation will be insufficient, this LID element must be used in combination with other LID techniques.

4.6 SPECIFICATIONS

SECTION 641 – STORMWATER HARVESTING BASIN

641.1 DESCRIPTION

Work under this item includes the installation of a stormwater harvesting basin and associated appurtenances. Except as herein stated, the requirements specified for MAG Specifications 201, 215, 220, 425, 430, and 796 are applicable to this specification.

641.2 MATERIALS

See MAG Specifications 201, 215, 220, 425, 430, and 796.

641.3 GENERAL

641.3.1 Temporary Erosion Control

Install all temporary erosion control measures prior to site disturbance. Install storm drain inlet protection to prevent clogging of the storm drains and increases in sediment loads to downstream stormwater facilities or waterbodies.

Inspect erosion control measures at least once a week and after each rainfall event. Make any required repairs immediately.

Erosion control devices shall be maintained until the site is stabilized, as determined by the Engineer.

If sediment is introduced into the basin during or immediately following excavation, the sediment will need to be removed from the basin or underdrain prior to initiating the next step in the construction process.

641.3.2 Excavation, Backfilling, and Grading

Refer to MAG Specification Section 215 – Earthwork for Open Channels, except as follows:

If an underdrain is required per the construction documents excavate the underdrain to the specified depth (elevation) and follow proposed Special Provision 622. All subgrade material below the specified elevation shall be left undisturbed, unless otherwise directed by the Engineer. Material excavated from the basin shall be disposed of on-site at locations (temporary stockpile areas) designated by the Engineer.

641.3.3 Construction Sequence Scheduling

An implementation schedule should be included as part of the erosion control plan to identify the order of operations for construction activities. This is particularly important when constructing stormwater best management practices (BMPs) that are designed to infiltrate stormwater runoff.

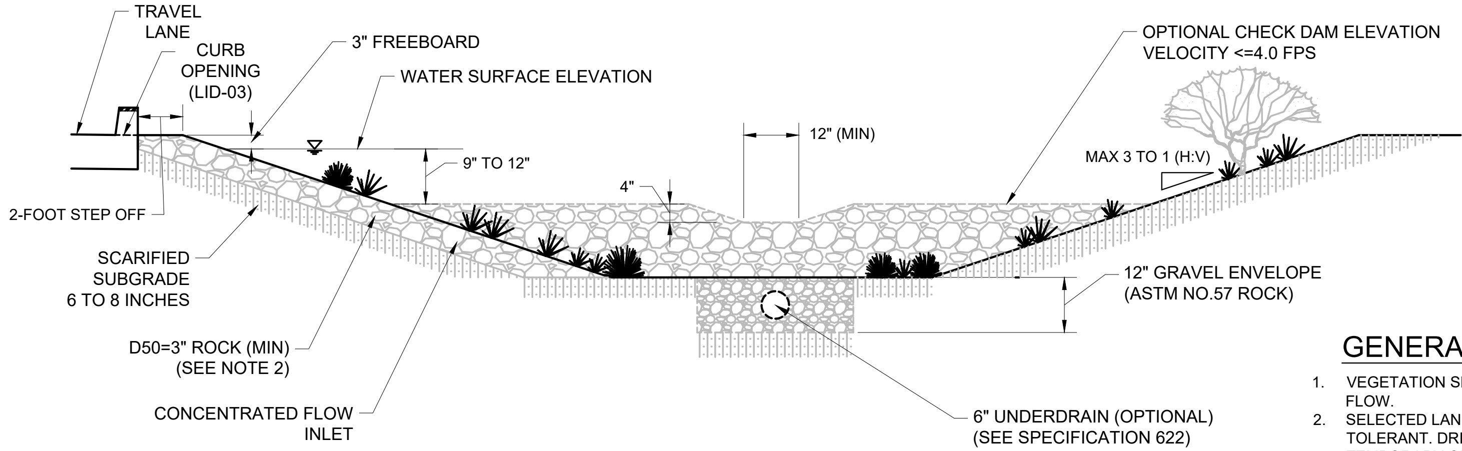
There are many construction activities which may contribute to the failure of a stormwater BMP if they are not planned for accordingly. The following items should be considered in developing an implementation schedule for a project:

A. Perform continuous inspection of temporary construction access to ensure that it is providing adequate erosion and sedimentation control for the construction site.
B. Install erosion protection along the perimeter of the site to prevent sediment from leaving the site during the construction process. Protection should be installed at a uniform elevation and constructed so that flow cannot bypass the ends.
C. All down-gradient perimeter sediment-control BMPs (e.g. temporary outlet controls) must be in place before any up-gradient land-disturbing activity begins.
D. Rough grade the site leaving the basin area undisturbed until the contributing drainage area has been completed and the site is stabilized.
E. Construct the road/site improvements in a manner that minimizes adverse impacts to the location and function of the stormwater BMPs. For example, ensure that construction access or equipment staging areas do not conflict with the final location of the basin.
F. Perform all other site improvements in a manner that minimizes adverse impacts to the location and function of the stormwater BMPs.
G. Final grade the site. Grading of the basin shall be accomplished using low-impact earth-moving equipment to prevent compaction of the underlying soils. Wide-tracked vehicles such as backhoes, small dozers and sjid-steers are recommended. Excavating equipment should operate from the side of the basin to the extent feasible. If excavation leads to substantial compaction of the subgrade, the first several feet shall be removed and replaced with a blend of topsoil and sand to promote infiltration and plant growth.
H. Stabilize the site by implementing the landscaping plan.
I. Install any required erosion control berms, ditch checks, and other semi-permanent and permanent erosion control measures.
J. Remove the temporary erosion and sediment controls after the basin is stabilized per the Engineer's approval. It is important for the basin to be stabilized before receiving stormwater flow.

641.4 MEASUREMENT AND PAYMENT

The unit of measure for the stormwater harvesting basin will be cubic yards. The payment will be in accordance with the following MAG Specification Sections, including all labor, materials, tools, equipment and incidentals needed to complete work specified.

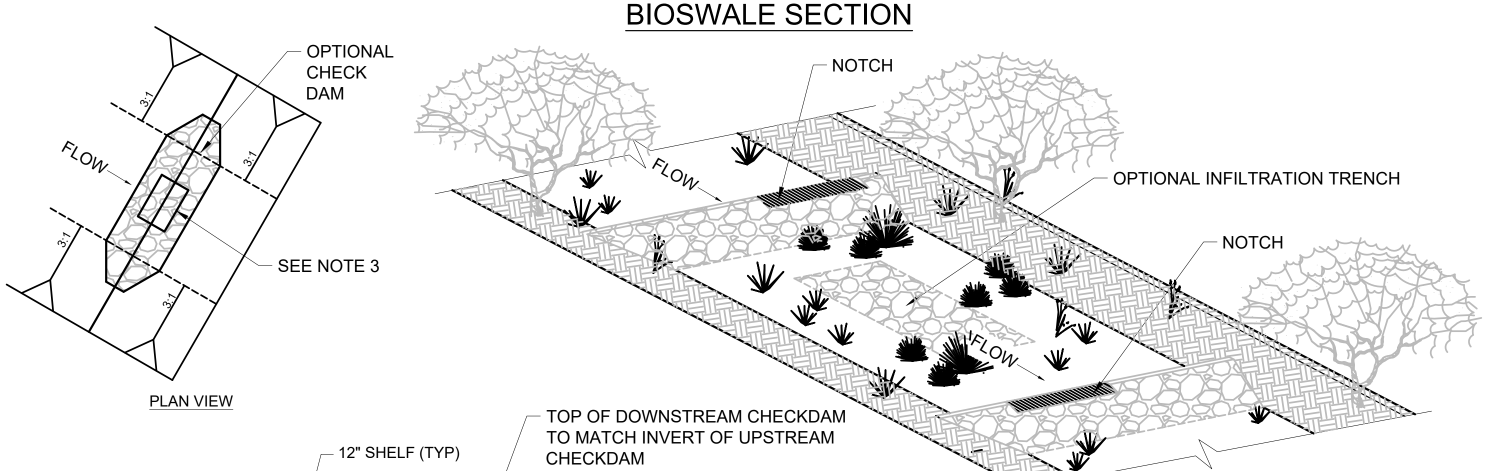
Section 201 – Clearing and Grubbing
Section 215 – Earthwork for Open Channels
Section 220 – Riprap Construction
Section 430 – Landscaping and Planting
Section 796 – Geosynthetics

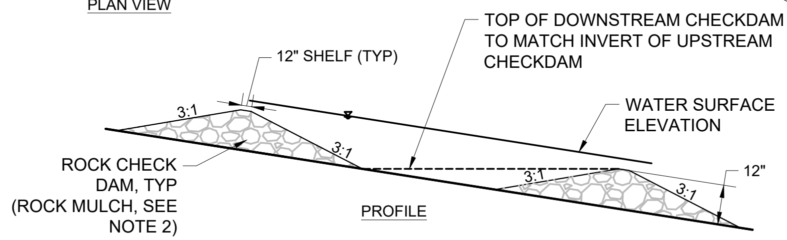


GENERAL NOTES (BIOSWALE):

1. VEGETATION SHOULD BE OFFSET FROM CONCENTRATED FLOW.
2. SELECTED LANDSCAPE PLANTS SHOULD BE DROUGHT TOLERANT. DRIP IRRIGATION WILL BE PROVIDED BY A TEMPORARY OR PERMANENT IRRIGATION SYSTEM.

BIOSWALE SECTION





OPTIONAL ROCK CHECK DAM

GENERAL NOTES (CHECK DAM):

1. OPTIONAL CHECK DAM IS MEANT TO DISPERSE DURING HIGHER FLOWS, SEE SECTION 640.3.3 OF SPECIFICATIONS.
2. D50 SIZE DETERMINED BY THE DESIGN REPORT.
3. NOTCHES SHALL BE OFFSET FROM ONE ANOTHER.
4. DEDICATED OUTFLOW REQUIRED FOR THIS FEATURE.
5. OPTIONAL ROCK CHECK DAM TO BE LOCATED TO REDUCE VELOCITIES PER DESIGN REPORT.
6. RIPRAP AND ROCK MULCH REQUIRED WHEN VELOCITIES EXCEED TABLE 6.2 OF THE FLOOD CONTROL DISTRICT OF MARICOPA COUNTY HYDRAULICS MANUAL.

DETAIL NO.	STANDARD DETAIL		REVISED	DETAIL NO.
LID-06	ENGLISH	VEGETATED OR ROCK BIOSWALES	01-29-2019	LID-06

5. VEGETATED OR ROCK BIOSWALES

Vegetated/rock swales (LID-06) are open, shallow channels that may have trees, grasses, and other low-lying vegetation covering the swale bottom and side slopes, with pervious surface plating materials such as decomposed granite, larger rock, and/or mulch. Vegetated or rock bioswales are designed to slow the flow of runoff to downstream discharge points through various optional methods such as a meandering layout, roughened surfaces, plants, and check dams. Vegetated bioswales should encourage and accommodate additional landscaping within the feature.

When landscaped, vegetated swales may provide additional pollutant removal through infiltration and vegetation uptake. Bioswales can provide water harvesting opportunities, depending on the site conditions and their hydraulic requirements. When properly designed, swales may allow percolation of cleansed storm water into the ground.

Depending on the location, the preferred vegetation may be limited to grasses and forbs and/or arid-adapted species that are drought-tolerant and don't require irrigation after establishment. Other locations may consider a different plant palette that is also drought tolerant but that requires limited irrigation. In all cases, care must be taken when selecting plant materials used in the bottom of bioswales; these plants must also be able to accommodate occasional inundation, as they may be in water until infiltration has occurred.

5.1 APPLICABILITY AND ADVANTAGES

Rock bioswales are usually placed inline within a storm drain system and are intended to slow down and infiltrate runoff. Specifically, swales:

- Slow the water which minimizes and decreases runoff, reduces erosion, and allows filtration (cleansing) of stormwater.
- Provide a method of water harvesting that promotes plant growth, thereby reducing the reliance on potable water for landscape irrigation; they also capture pollutants in stormwater.
- Produce planting conditions that encourage enhanced vegetation growth, providing cooling for adjacent land areas and helping to reduce the Phoenix Metropolitan Area heat island phenomenon. The aesthetics of the swales are enhanced when landscaped.
- Are relatively simple to build, cost-effective, and relatively easy to maintain.
- Can become tiered/stepped features for detaining stormwater where longitudinal grades are steep.

5.2 DESIGN CONSIDERATIONS

- Prevention of erosion of in-situ soils should be paramount during the design. Rock, vegetation, and/or organic mulches can be used to stabilize the surface.
- Subterranean outlets associated with the underdrain must connect to an appropriate downstream drainage facility, LID element, and/or underground stormwater collection system.
- By building obstruction structures perpendicular to the flows (i.e., check dams and weirs), flow velocities are reduced and infiltration is improved.
- Side slopes of bioswales should not be steeper than 3 to 1 for safety, erosion, and maintenance purposes. If located adjacent to sidewalks or parking lots, a 2-foot level shelf must be created along those elements as a recovery area. Swale bottom widths should be less than 8 feet if meandering is desired.
- The bioswale can be designed as a trapezoid. The flow depth and limiting velocity should be recommended as part of the design report. If the velocity is less than 1 foot per second (fps), scour and sediment transport of fine materials will be reduced. The longitudinal slope can be reduced by either increasing the longitudinal length or by meandering the flow path.
- May require rock covering, more robust soil cover, or soil amendments to counter the erosion potential for areas with steeper slopes.
- Sediment traps (LID –04) should be used where concentrated runoff enters the bioswale to dissipate flow velocities and to uniformly distribute flows across the channel. Flow spreaders may also be incorporated into the improvements.
- Energy dissipation should be designed at the toes of each vertical drop if energy dissipators, check dams, or similar structures are used.

- The maximum flow velocity from the first flush storm event (0.5 inches) should be less than 2 fps so that vegetation is not damaged and sediments can be deposited. The Manning's "n" coefficient should be increased to achieve reduction in velocities. The equation below by Phillips and Ingersoll (1998) can be used to estimate Manning's "n" coefficient for channels with a median bedding material diameter (d_{50}) that ranges from 0.28 to 0.36 feet (Reference 15):

$$n = \frac{0.0926R^{1/6}}{1.46+2.23\log\left(\frac{R}{d_{50}}\right)}$$

where

d_{50} = Intermediate diameter of bed material (feet) that equals or exceeds that of 50 percent of the particles (i.e. median grain size).

R = Hydraulic radius (ft)

- The residence time in a swale should be typically 10 minutes to optimize pretreatment and sediment removal. The swale length can be calculated as below (See Reference 5):

$$L = 600V_{wq}$$

L = swale length (ft)

V_{wq} = design flow velocity (ft/sec)

- When landscaped, the design objective is typically to improve the aesthetics of the swale and/or to match the existing landscape character of the surrounding lands. The landscaping treatment can range from a native, drought-tolerant palette to a more ornamental landscaping approach commensurate with the surrounding character. Soil building materials such as organic mulch, biota, and fertilizers may be incorporated into the planting area to improve vegetative success; the need for these can be identified through soil fertility testing and by specifically defining the landscaping performance expectations. Plant selections need to consider the location of the plants within the bioswale and their potential frequency for inundation, damage, or flow blockage. In general, installed plantings (not native seeding) require supplemental watering to get the plants established. Watering is typically accomplished through an underground irrigation system whose volume may be reduced over time and/or abandoned once the plants have been established, depending on the success of the landscape installation and the volume and pattern of stormwater collection.

5.3 CONSTRUCTION CONSIDERATIONS

The areas upgradient of a bioswale must be stabilized prior to the construction of the bioswale. If the upslope area has not been stabilized, temporary or permanent erosion and sediment control measures must be installed. Equipment passes should be avoided in the bottom of the swale to prevent compaction. If the subgrade soil is compacted, it should be scarified to a depth of 6 – 8 inches to loosen the soil particles. After rough grading, the bioswale should be fine-graded to avoid nonconformities. Angular rock can be placed following fine grading to provide a roughened surface to slow flow velocities and to protect the subgrade. Placing rock and seeding will improve overall aesthetics and support revegetation.

5.4 MAINTENANCE

After every storm greater than 0.5 inches or annually at a minimum, swales should be checked for erosion, sediment, debris, litter, and clogging. If the sediment level inhibits vegetation or reduces capacity, the sediment should be removed. A sediment trap (LID-04) could be added at the flow concentration inlet to reduce maintenance and increase long-term performance. Section 3 identifies the maintenance practices for the landscape element of this LID treatment. If an altered water flow pattern, erosion, or plant die-off is observed, these should be corrected in kind, at a minimum, and/or evaluated for further corrective measures.

5.5 COMPATIBILITY WITH OTHER LID PRACTICES

Vegetated/rock bioswales often are designed in conjunction with curb openings or permeable pavements. Overflow structures are required when the system is connected to a downstream drainage facility or bioretention element. The bioswales should be connected to a proper discharge facility if designed for smaller storm events.

5.6 SPECIFICATIONS

SECTION 640 – VEGETATED OR ROCK BIOSWALES

640.1 DESCRIPTION

Work under this item includes the installation of vegetated and/or rock bioswales and associated appurtenances. Except as herein stated, the requirements specified for MAG Specifications 201, 215, 220, 425, 430, and 796 are applicable to this specification.

640.2 MATERIALS

See MAG Specifications 201, 215, 220, 425, 430, and 796.

640.3 CONSTRUCTION METHODS

640.3.1 Temporary Erosion Control

Install all temporary erosion control measures prior to site disturbance.

Install storm drain inlet protection to prevent clogging of the storm drains and increases in sediment loads to downstream stormwater facilities or waterbodies.

Inspect erosion control measures at least once a week and after each rainfall event. Make any required repairs immediately.

Erosion control devices shall be maintained until the site is stabilized, as determined by the Engineer.

If sediment is introduced into the swale during or immediately following excavation, the sediment will need to be removed from the vegetated bioswale or underdrain prior to initiating the next step in the construction process.

640.3.2 Swale Excavation, Backfilling, and Grading

Refer to MAG Specification Section 215 – Earthwork for Open Channels, except as follows:

If the vegetated bioswale is used for runoff conveyance during construction, initial grading of the swale shall be performed in conjunction with rough grading of the site. Once construction in the contributing drainage area has been completed and the site is stabilized, re-grade and restore the bioswale to ensure functionality.

If an alternative temporary sediment basin facility is being provided before discharge to the bioswale, grading and construction of the vegetated bioswale should not be connected until the contributing drainage area has been completed and stabilized.

If an underdrain is required per the construction documents excavate the underdrain to the specified depth (elevation) and follow Specification 622. Typical details would be required when connected to a downstream drainage facility. All subgrade material below the specified elevation shall be left undisturbed, unless otherwise directed by the Engineer.

Materials should be graded and contoured onsite when possible or excavated from the vegetated swale shall be disposed of on-site at locations (temporary stockpile areas) designated by the Engineer.

The perforated pipe (underdrain) shall be laid directly on the gravel bed. Grade and alignment shall not vary from the prescribed grade by more than 0.1 foot at any point. The joints between sections of pipe shall be connected in a fashion acceptable to Engineer. Once the pipe is in place, it shall be covered immediately with open-graded stone material as specified in the construction documents. The material shall be of uniform depth on either side of the pipe. Special inlets and special devices at the outlet end of the pipe shall be constructed as shown in the plans.

640.3.3 Check Dams

Refer to Specification 644 for check dam construction. Maximum spacing between check dams should be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam. The maximum height of the dam should not exceed 2 feet.

640.3.4 Construction Sequence Scheduling

An implementation schedule should be included as part of the erosion control plan to identify the order of operations for construction activities. This is particularly important when constructing stormwater BMPs that are designed to infiltrate stormwater runoff. There are many construction activities which may contribute to the failure of a stormwater BMP if they are not planned for accordingly. The following items should be considered in developing an implementation schedule for a project:

A. Perform continuous inspection of temporary construction access to ensure that it is providing adequate erosion and sedimentation control for the construction site.
B. Install erosion protection along the perimeter of the site to prevent sediment from leaving the site during the construction process. Protection should be installed at a uniform elevation and constructed so that flow cannot bypass the ends.
C. All down-gradient perimeter sediment-control BMPs (e.g. temporary outlet controls) must be in place before any up-gradient land-disturbing activity begins.
D. Rough grade the site leaving the vegetated bioswale area undisturbed until the contributing drainage area has been completed and the site is stabilized.

E. Construct the road/site improvements in a manner that minimizes adverse impacts to the location and function of the stormwater BMPs. For example, ensure that construction access or equipment staging areas do not conflict with the final location of the vegetated swale.
F. Perform all other site improvements in a manner that minimizes adverse impacts to the location and function of the stormwater BMPs.
G. Install any required erosion control blanket, ditch checks, and other semi-permanent and permanent erosion control measures.
H. Stabilize the site by implementing the landscaping plan.
I. Remove the temporary erosion and sediment controls after the swale is stabilized per the Engineer's approval. It is important for the bioswale to be stabilized before receiving stormwater flow.

640.4 MEASUREMENT AND PAYMENT

The unit of measure for vegetated or rock bioswales will be linear feet. The payment will be in accordance with the following MAG Specification Sections, including all labor, materials, tools, equipment and incidentals needed to complete work specified.

Section 201 – Clearing and Grubbing
Section 215 – Earthwork for Open Channels
Section 220 – Riprap Construction
Section 430 – Landscaping and Planting
Section 796 – Geosynthetics

SECTION 644 - CHECK DAMS FOR LOW IMPACT DEVELOPMENT FACILITIES

644.1 DESCRIPTION

Work under this item includes the installation of check dams to slow and hold water flow in LID facilities. Except as herein stated, the requirements specified for MAG Specifications 201, 211, 215, 220, and 301 are applicable to this specification.

644.2 MATERIALS

The stone shall meet the requirements set forth in the design plans or modified in the special provisions.

644.3 GENERAL

644.3.1 Construction Requirements:

Stone Check Dam: Construct the check dam with washed angular rock with D50 of 3 inches minimum (or approved equal) with side slopes of 3 to 1. Modification to this layout need to be approved by the Design Engineer. Place the stone so that it completely covers the width of the area and sides per the detail on the drawings. Form the overflow notch so that top of the outlet crest is approximately 4 inches lower than the outer edges.

Maximum spacing between check dams should be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam. The maximum height of the dam should not exceed 2 feet. Mechanical placement required to achieve complete coverage of swale and to ensure that center of dam is lower than edges.

644.4 MEASURE AND PAYMENT

The unit of measure and payment for stone check dam will be made per cubic yard and include installation, setting, and leveling of stone and all labor, materials, tools, equipment and incidentals needed to complete the work specified.

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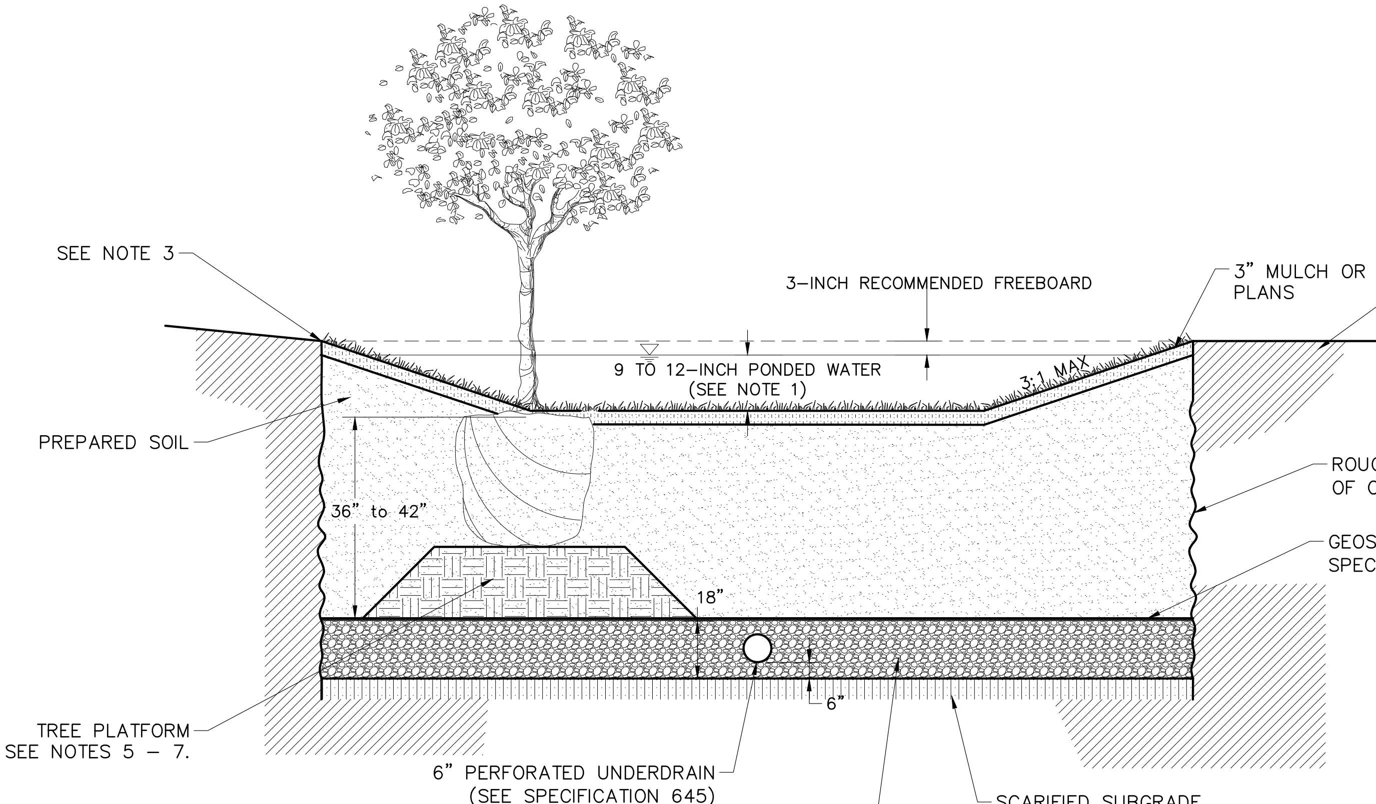

NOTES:

1. SURFACE PONDED WATER MUST PERCOLATE WITHIN 36-HOURS.
2. MINIMUM DEPTH OF 36 TO 42 INCHES TO ACCOMMODATE 48-INCH BOX TREE PLANTING.
3. SEE SPECIFICATION 645 FOR BUILDING SETBACK DISTANCES.
4. INTENDED TO CAPTURE SUBWATERSHED, DEDICATED OUTLET STILL REQUIRED.
5. TREE PLATFORM SHALL CONSIST OF COMPACTED ON-SITE SOIL. PLATFORM SHALL BE 1.5X THE WIDTH OF THE ROOTBALL AND INCLUDE 45-DEGREE SIDE SLOPES (MAX.).
6. INSTALL FILTER FABRIC BETWEEN TREE PLATFORM AND NO.57 STONE/ROCK MULCH.
7. TREE PLATFORMS TO BE PLACED TREE LOCATIONS. REFER TO LANDSCAPE PLAN.

DETAIL NO.	STANDARD DETAIL		REVISED	DETAIL NO.
LID-07	STANDARD DETAIL ENGLISH	BIORETENTION SYSTEMS	01-29-2019	LID-07

6. BIORETENTION SYSTEMS

Bioretention is a treatment process that removes pollutants from stormwater through an engineered soil media. Bioretention systems (LID-07) may either allow percolation into the subsoil or may have an underdrain that directs infiltrated stormwater to a downstream drainage system. These differ from stormwater harvesting basins and rain gardens because they are generally deeper and their main purpose is to capture pollutants and to provide a medium to infiltrate stormwater. Like stormwater harvesting basins, bioretention systems can be constructed within roadway ROWs or areas of limited ROW.

6.1 APPLICABILITY AND ADVANTAGES

Bioretention systems are applicable to residential, commercial, and industrial sites and along roadways where stormwater volume reduction by infiltration or improved water quality is desired. Bioretention may be particularly well-suited to urban locations with highly impervious sites where space is limited, because they can provide higher infiltration rates.

- This facility is an active water purification system, thereby improving water quality.
- The increased open space of a bioretention area can be multifunctional, providing wildlife habitat and creating a "softer" aesthetic for streets and roads by incorporating additional landscaping and vegetation.
- Bioretention creates planting conditions that encourage enhanced vegetation growth that can help cool adjacent land areas and reduce the Phoenix Metropolitan Area heat island phenomenon.
- Bioretention can reduce the reliance on potable water sources for landscaping irrigation for other portions of the project area, depending on the landscape design and the volume and pattern of stormwater collection.
- Bioretention provides a drainage option from traditional drainage approaches, particularly for space-constrained, highly urbanized environments.
- Bioretention reduces vector concerns due to limiting ponding.

6.2 DESIGN CONSIDERATIONS

- Bioretention systems are relatively simple to build and relatively easy to maintain.
- If the side slopes where the inflow will occur are steeper than 3 to 1, they should be rock-lined.
- Bioretention areas should have a sediment trap at the inlet to collect the concentrated flow to prevent clogging, thereby prolonging the effective lifespan of the facility.
- If underdrains are used, they should be a minimum of 6 inches in diameter so that they can be cleaned without being damaged. A vertical clean-out pipe is an optional item. PVC and HDPE pipes used as underdrains should conform to ASTM D3034 and AASTHO 252M, respectively.
- The underdrain should be placed parallel to the bottom of the bioretention collector and backfilled and bedded with 6 inches of washed ASTM No. 57 or approved equal aggregate drain rock, which should encase at least 1 foot around the sides and top of the underdrain.
- Subterranean outlets associated with the underdrain must connect to an appropriate downstream drainage facility, LID element, and/or underground stormwater collection system.
- The BSM should be minimum of 36 – 42 inches, depending on the design to accommodate a 48-inch box tree planting. The recommended depth for a bioretention system in a desert environment to remove pollutants was developed in the Pima County Low Impact Development and Green Infrastructure Guidance Manual (Reference 1) and is shown in Table 4.
- The runoff volume can be calculated from first flush design storm (0.5 inch) based on the drainage area. The recommended ponding depth for a bioretention system should be 9 – 12 inches, with 3 inches of freeboard from an overflow structure to the berm or the lowest adjacent finished grade surrounding the system. The system should drain ponded water within 36 hours to prevent any vector-control issues. The underground runoff should drain within 72 hours so that the facility remains effective during the monsoon. An overflow structure or dedicated outlet should be included with the design so that larger storms have an outfall.
- The bioretention system should be sized using the first flush design storm (0.5 inch) volume V_{design}, with the limiting infiltration rate k (inches/hour); depth of soil medium d (feet); the porosity of the soil medium n; the allowable ponding depth p (feet); and whether the bioretention system has an underdrain. The minimum required area for the bioretention system with an underdrain can be calculated using this equation from the Pima County LID Manual (See Reference 1):

$$A = \frac{V_{design}}{(d_s + n_s) + (d_g + n_g) + p + d_{in}}$$

Table 4. Recommended Depth of Bioretention Media to Target Pollutant of Concern

Pollutant of Concern	Removal Zone	Recommended Depth (feet)
Sediment	Surface, top to 2 to 8 inches	1.5
Total Nitrogen	At depth in saturated layer (>2 feet)	3
Total Phosphorus	Top 1 to 2 feet	2
Pathogens	Top 1 to 2 feet	2
Metals	Top 1 to 2 feet	2
Oil and grease	Surface	2
Temperature	At depth	4

where

V_{design} = design stormwater volume (cubic feet)

K = effective infiltration rate (inches/hour)

d_s = depth of the soil medium (feet)

n_s = porosity of the soil medium (dimensionless)

d_g = depth of the rock, stone or gravel layer (feet)

n_g = porosity of the rock, stone, or gravel layer (dimensionless)

p = allowable ponding depth (feet)

d_{in} = depth of infiltration calculated as

$$d_{in} = k\left(\frac{p + d_g}{d_g}\right) \cdot (3hrs) \cdot (1ft/12in)$$

where

k = effective infiltration rate of the subsoil (inches/hour)

$3\ hrs$ = assumed storm duration and approximate time of runoff

- Bioretention systems are typically landscaped. The design objective is typically to improve the aesthetics of the bioretention area and/or to install plant materials that will thrive in BSM and within the inundation characteristics of the element. Soil-building materials such as organic mulch, biota, and fertilizers may be incorporated into the prepared soil to improve vegetative success; the need for these can be identified through soil fertility testing and by specifically defining the landscaping objectives and performance expectations. In the Sonoran Desert, the landscaping treatment will usually be limited to a select list of plants (Refer to Section 3). Irrespective of these plants' ability to thrive in an artificial environment, they will require some degree of supplemental watering to get the plants established and periodically during dry periods to maintain their viability.
- Watering is typically accomplished through an underground irrigation system whose volume may be reduced over time and/or abandoned once the plants have been established, depending on the success of the landscape installation and the volume and pattern of stormwater collection.

6.3 CONSTRUCTION CONSIDERATIONS

- The construction area should be fenced off with construction fencing or silt fencing to prevent compaction of soils by construction equipment or traffic during construction of surrounding improvements.
- At a minimum, the subgrade soils should have the top 6 – 8 inches scarified. A percolation test should be completed before the construction of the underground storage area to determine if the site soils will perform as anticipated and/or if an underdrain is necessary.
- After excavation of existing soils, inspections should be performed to ensure that the bioretention system meets the design specifications. Filter fabric should not be placed over the scarified subgrade. If an underdrain pipe is used, it should be surrounded by ASTM No. 57 (or approved equal) washed gravel.
- Rock must be washed and free of fine particles before being placed in the bioretention system.
- Once the prepared soil has been placed, limit compaction of the prepared soil to the specified requirements.

6.4 MAINTENANCE

This LID feature should be inspected quarterly and after storms of 0.5 inches or greater. Any significant sediment accumulation or debris should be cleared. The cleanout risers should be opened and visually inspected during routine maintenance. Any ponded water should be documented. Section 3 identifies the maintenance practices for the landscape element of this LID treatment. If an altered water flow pattern, erosion, or plant die-off is observed, these should be corrected in kind, at a minimum, and/or evaluated for further corrective measures.

6.5 COMPATIBILITY WITH OTHER LID PRACTICES

A sediment trap and curb opening are often designed in conjunction with this element. When an underdrain system is necessary, an appropriate outlet must be found.

6.6 SPECIFICATIONS

SECTION 645 - BIORETENTION SYSTEM

645.1 DESCRIPTION

Work under this item includes the construction of a bioretention system and associated appurtenances. Except as herein stated, the requirements specified for MAG Specifications 201, 206, 215, 220, 425, and 796 are applicable to this specification.

A bioretention system may include tree, shrub and groundcover plantings, see Section 3. Possible areas for bioretention include tree space, parking lanes, bump-outs for traffic calming, intersection triangles, open areas, and areas adjacent to sidewalk.

645.2 MATERIALS

See MAG Specifications 201, 215, 220, 425, 430, and 796.

A reservoir layer of 4 – 6 inches of open graded ASTM No. 57 stone shall be placed beneath the bioretention layer and geotextile shall be placed between the stone and the BSM.

645.3 GENERAL

Bioretention systems prepared soil should be a minimum of 36 – 42 inches to accommodate the planting of 48-inch box trees.

Edge conditions around bioretention facilities adjacent to pedestrian areas may be sloped to 3 to 1 maximum. Bioretention with a sloped side must provide a (8 percent maximum slope) 2-foot minimum width buffer of different material to meet flush with adjacent sidewalk. Bioretention with a depth greater than 3 feet must provide a (8 percent maximum slope) 24-inch minimum width buffer.

Access is required to all bioretention areas for maintenance. For facilities off the road, an access road may be needed. For facilities on high speed roads, ensure safe access via a shoulder or designated area. Within the bioretention area, the overflow structure must be accessible to maintenance crews.

645.3.1 Temporary Erosion Control

Install all temporary erosion control measures prior to site disturbance. Inspect erosion control measures at least once a week and after each rainfall event. Make any required repairs immediately. Erosion control devices shall be maintained until the site is stabilized, as determined by the Engineer.

645.3.2 Construction Sequence Scheduling

An implementation schedule should be included as part of the erosion control plan to identify the order of operations for construction activities. This is particularly important when constructing features designed to infiltrate stormwater runoff. There are many construction activities which may contribute to the failure of a stormwater BMP if they are not planned for accordingly. The following items should be considered in developing an implementation schedule for a project:

A. Perform continuous inspection of temporary construction access to ensure that it is providing adequate erosion and sedimentation control for the construction site.
B. Install erosion protection along the perimeter of the site to prevent sediment from leaving the site during the construction process. Protection should be installed at a uniform elevation and constructed so that flow cannot bypass the ends.
C. All down-gradient perimeter sediment-control BMPs (e.g. temporary outlet controls) must be in place before any up-gradient land-disturbing activity begins.
D. Install underground utilities (water, sanitary sewer, electric, telephone, etc.) taking the location and function of stormwater BMPs into consideration.
E. Rough grade the site leaving the basin area undisturbed until the contributing drainage area has been completed and the site is stabilized.
F. Perform all other site improvements in a manner that minimizes adverse impacts to the location and function of the stormwater BMPs.
G. Final grade the site. Grading of the basin shall be accomplished using low-impact earth-moving equipment to prevent compaction of

the underlying soils. Wide-tracked vehicles such as backhoes, small dozers and skid-steers are recommended. Excavating equipment should operate from the side of the basin to the extent feasible.

H. At a minimum, the subgrade shall be scarified, ripped, or tilled to a depth of 6 – 8 inches with equipment having tines spaced no greater than 8 – 12 inches apart. A minimum of two percolation tests should be completed for every 40,00 square feet of the excavated area before placing the rock to determine if the site soils will perform as designed. Alterations to the work, such as additional modifications to the subgrade soils or the installation of an underdrain shall be measured and paid for in accordance with Section 104 of the Standard Specifications.

I. Stabilize the site by implementing the landscaping plan.

J. Install any required erosion control blanket, ditch checks, and other semi-permanent and permanent erosion control measures.

K. Remove the temporary erosion and sediment controls after the basin is stabilized per the Engineer's approval. It is important for the basin to be stabilized before receiving stormwater flow.

645.4 MEASUREMENT AND PAYMENT

The unit of measure for a bioretention system will be cubic yards. The payment will be in accordance with the following MAG Specification Sections, including all labor, materials, tools, and equipment needed to complete work specified.

Section 201 – Clearing and Grubbing
Section 215 – Earthwork for Open Channels
Section 220 – Riprap Construction
Section 430 – Landscaping and Planting
Section 796 – Geosynthetics

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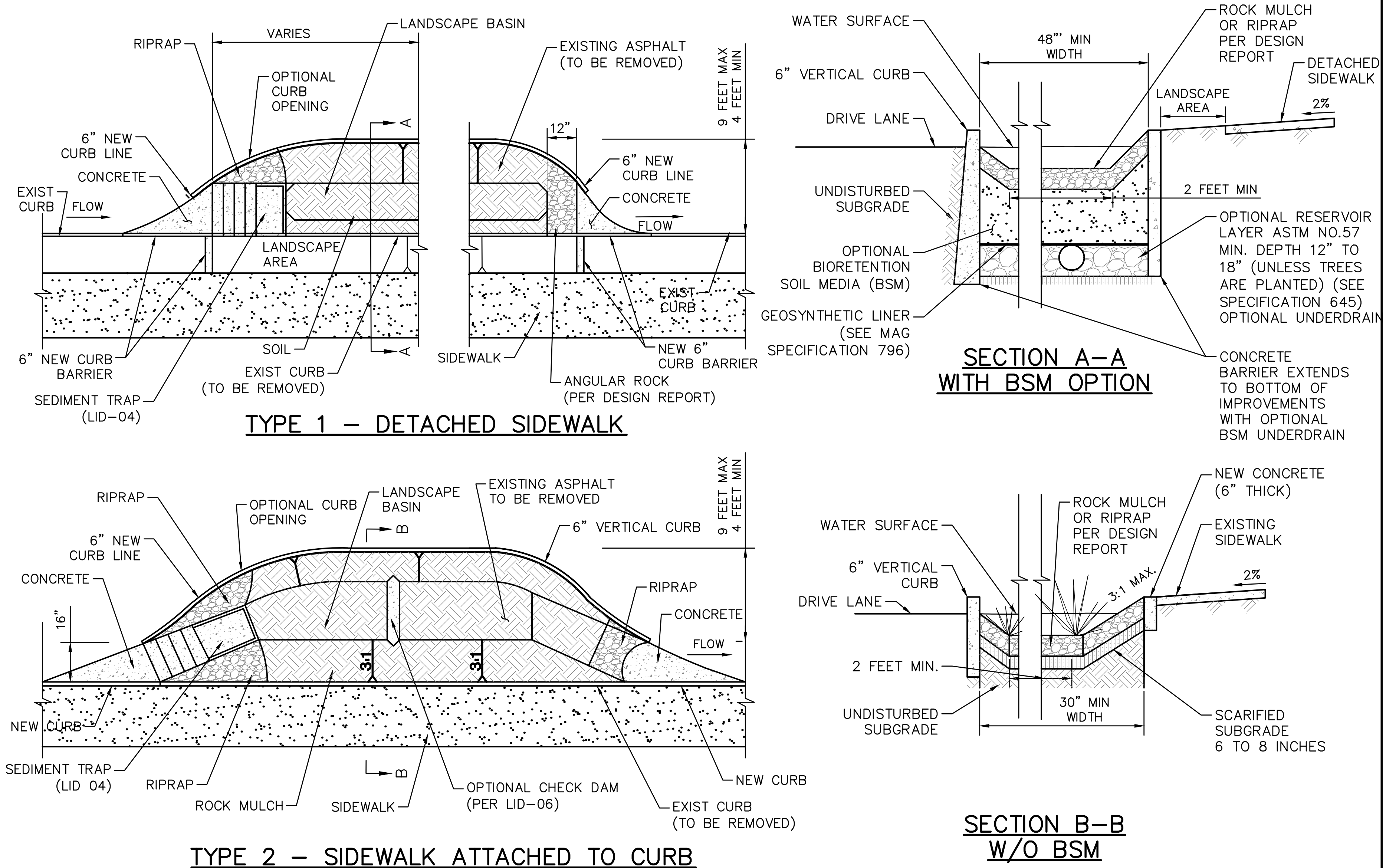


DETAIL NO.			REVISED	DETAIL NO.
LID-08	**STANDARD DETAIL ENGLISH**	**CURB EXTENSIONS**	01–29–2019	**LID-08**

7. CURB EXTENSIONS

Curb extensions (LID-8) are generally placed in locations where a new curb is built out into a travel or parking lane to create an opportunity for the bioretention of street runoff and a space for trees. Curb extensions (also known as chicanes) may have sloped or vertical sides. In most cases, curb extensions will be designed as online (flow-through) elements. Curb extensions are typically landscaped.

7.1 APPLICABILITY AND ADVANTAGES

This LID element can be used along low-speed roadways, driveways, and parking lots.

- This LID element can also function well in urban streetscapes as a traffic-calming measure.
- Curb extensions are easy to retrofit into an existing area.
- The increased open space of the curb extension can create a "softer" aesthetic for streets and roads by incorporating additional landscaping and vegetation.
- The curb extension landscaping creates planting conditions that encourage enhanced vegetation growth that helps cool adjacent land areas and reduce the Phoenix Metropolitan Area heat island phenomenon.
- Curb extensions provide additional stormwater storage capacity as compared to conventional landscape planters.

7.2 DESIGN CONSIDERATIONS

- Minimum soil depth should be 12 – 18 inches to facilitate storage capacity and to be beneficial for vegetation. If trees are required, the landscape architect should recommend the minimum depth.
- The opening must be designed to collect the roadway flow width for the first flush design storm (0.5 inch) without causing ponding.
- Minimum planter width should be 30 inches, but any geometric shape can be built. The minimum width is dictated by the width of a small excavator or backhoe.
- Curb extensions should be designed carefully not to be in conflict with dry utilities.
- Curb extensions are typically designed with curb outlets allowing flow back onto the roadway so they act as a flow-through system.
- If used, underdrains must be connected to a downstream conveyance facility or additional LID element with a positive outlet for extra drainage.
- Curb extensions are typically landscaped. The design objective is typically to improve the aesthetics of the streetscape, to provide shade and landscaping for comfort, and/or to install plant materials that will thrive in the BSM and within the inundation characteristics of the element. Soil-building materials such as organic mulch, biota, and fertilizers may be incorporated into the BSM to improve vegetative success; the need for these can be identified through soil fertility testing and by specifically defining the landscaping objectives and performance expectations. In the Sonoran Desert, the landscaping treatment will usually be limited to a select list of plants (refer to Section 3). Irrespective of these plants' ability to thrive in an artificial environment, they will require some degree of supplemental watering to get the plants established and periodically during dry periods to maintain their viability. Watering is typically accomplished through an underground irrigation system whose volume may be reduced over time and/or abandoned once the plants have been established, depending on the success of the landscape installation and the volume and pattern of stormwater collection.

7.3 CONSTRUCTION CONSIDERATIONS

The asphalt, concrete curb, and subgrade removal are construction considerations and they should adhere to the MAG Specification (Reference 16). The construction areas should be fenced off with a construction fence or silt fence to prevent soil compaction from equipment during construction of surrounding improvements. After excavation of existing soils, inspections and a percolation test should be completed before the construction of the underground storage area to determine if the site soils will meet the design criteria and/or if an underdrain is necessary. At a minimum, the bottom of the curb extension planter should have the top 6 – 8 inches scarified. Shoring may be required to reduce the potential of the adjacent soils from sloughing into the construction area.

If an underdrain pipe is used, it should be surrounded by ASTM No. 57 (or approved equal) washed gravel and geotextile fabric. Gravel must be washed and free of fine particles before being placed in the bioretention planter. Once the gravel drainage layer and prepared soil have been placed, limit compaction of the prepared soil to the specified requirements. The structural properties of the soil must be considered during excavation.

7.4 MAINTENANCE

This LID element should be inspected quarterly and after storms of 0.5 inch or greater. These inspections are needed because damage is not apparent during dry weather. Any significant sediment accumulation or debris should be cleared. Any ponded water should be documented. Section 3 identifies the maintenance practices for the landscape element of this LID treatment. If an altered water flow pattern, erosion, or plant die-off is observed, these should be corrected in kind, at a minimum, and/or evaluated for further corrective measures.

7.5 COMPATIBILITY WITH OTHER LID PRACTICES

Curb extensions are compatible with curb openings, sediment traps, permeable pavements, and overflow structures.

7.6 SPECIFICATIONS

SECTION 647 – CURB EXTENSION

647.1 DESCRIPTION

Work under this item includes the construction of a curb extension and associated appurtenances. Except as herein stated, the requirements specified for MAG Specifications 201, 205, 206, 215, 220, 320, 350, 401, 425, 430, and 796 are applicable to this specification.

A curb extension is typically a small-scale bioretention cell located along rural streets between and replaces the roadway and roadway curb. These facilities may include tree, shrub, and groundcover plantings.

647.2 MATERIALS

See MAG Specifications 201, 215, 220, 425, 430, and 796.

A reservoir layer of 12 – 18 inches of open graded ASTM No. 57 stone shall be placed beneath the prepared soil. Geotextile shall be placed on the sides of the stone.

647.3 GENERAL

Curb extension systems are designed to have an upstream and downstream curb opening that allows runoff to flow through a passive filtration system.

When placing and designing curb extension facilities adjacent to travel ways, check the AASHTO Roadway Design Guidebook for approach distances, curb height, and curb radius dimensions. This feature is constructed adjacent to travel lanes and should follow MAG Specification 401 for traffic control.

Access is required to all bioretention areas for maintenance. For facilities on high-speed roads, ensure a safe access route for maintenance personnel.

647.3.1 Temporary Erosion Control

An access road may be needed. Install temporary erosion control measures prior to site disturbance. Inspect erosion control measures once a week and after each rainfall event. Make any required repairs immediately. Erosion control devices shall be maintained until the site is stabilized, as determined by the Engineer.

647.3.2 Construction Sequence Scheduling

An implementation schedule should be included as part of the erosion control plan to identify the order of operations for construction activities. This is particularly important when constructing features designed to infiltrate stormwater runoff. There are many construction activities which may contribute to the failure of a stormwater BMP if they are not planned for accordingly.

The following items should be considered in developing an implementation schedule for a project:

A. Perform continuous inspection of temporary construction access to ensure that it is providing adequate erosion and sedimentation control for the construction site.

B. Install erosion protection along the perimeter of the site to prevent sediment from leaving the site during the construction process. Protection should be installed at a uniform elevation and constructed so that flow cannot bypass the ends.

C. Install underground utilities (water, sanitary sewer, electric, telephone, etc.) taking the location and function of stormwater BMPs into consideration.

D. Perform all other site improvements in a manner that minimizes adverse impacts to the location and function of the stormwater BMPs.

E. Final grade the site. Grading of the curb extension shall be accomplished using low-impact earth-moving equipment to prevent compaction of the underlying soils. Wide-tracked vehicles such as backhoes, small dozers, and skid-steers are recommended. Excavating equipment should operate from the side of the basin to the extent feasible.

F. At a minimum, the subgrade shall be scarified, ripped, or tilled to a depth of 6 – 8 inches with equipment having tines spaced no greater than 8 – 12 inches apart. A minimum of one percolation test should be completed for each curb extension planting area unless the Engineer approves fewer tests based on the facility size and adjacent planters. Alterations to the work, such as additional modifications to the subgrade soils or the installation of an underdrain shall be measured and paid for in accordance with Section 104 of the Standard Specifications.

G. Stabilize the site by implementing the landscaping plan.

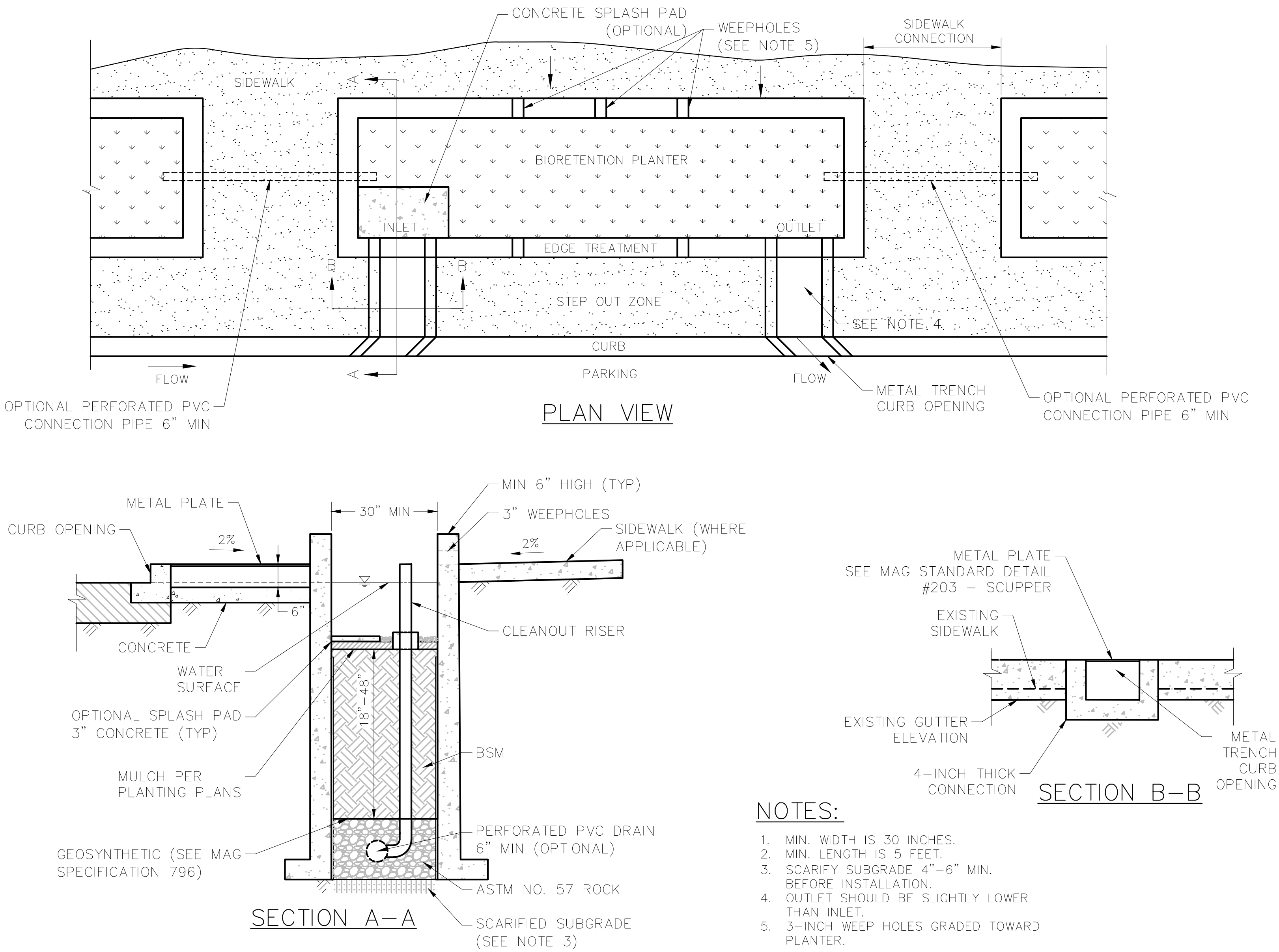
H. Install any required erosion control blanket, ditch checks, and other semi-permanent and permanent erosion control measures.

I. Remove the temporary erosion and sediment controls after the basin is stabilized per the Engineer's approval. It is important for the basin to be stabilized before receiving stormwater flow.

647.4 MEASUREMENT AND PAYMENT

The unit of measure for a curb extension will be cubic feet. The payment will be in accordance with the following MAG Specification Sections, including all labor, materials, tools, equipment and incidentals needed to complete work specified.

Section 201 – Clearing and Grubbing
Section 215 – Earthwork for Open Channels
Section 220 – Riprap Construction
Section 430 – Landscaping and Planting
Section 796 – Geosynthetics



NOTES:

1. MIN. WIDTH IS 30 INCHES.
2. MIN. LENGTH IS 5 FEET.
3. SCARIFY SUBGRADE 4"-6" MIN. BEFORE INSTALLATION.
4. OUTLET SHOULD BE SLIGHTLY LOWER THAN INLET.
5. 3-INCH WEEP HOLES GRADED TOWARD PLANTER.

DETAIL NO.	STANDARD DETAIL		REVISED	DETAIL NO.
LID-09	ENGLISH	BIORETENTION PLANTERS	01-29-2019	LID-09

8. BIORETENTION PLANTERS

Bioretention planters (LID-09) are typically a small-scale bioretention cell, often located in hardscape areas between the curb and sidewalk. These elements may include tree, shrub, and groundcover plantings. This LID feature may be designed at depths that require railings or curbs for pedestrian safety.

8.1 APPLICABILITY AND ADVANTAGES

This LID application can be used where there is available ROW and an offset from travel lanes. Curb openings can be designed in conjunction with this LID feature.

- Bioretention planters function well in urban streetscape designs.
- Bioretention planters provide additional stormwater storage capacity as compared to conventional landscape planters.
- Bioretention planters work in urban settings with MAG Concrete Scupper 206, 1 – 3.
- Bioretention planters create planting conditions that encourage enhanced vegetation growth that helps cool adjacent land areas and reduce the Phoenix Metropolitan Area heat island phenomenon.

8.2 DESIGN CONSIDERATIONS

- Minimum soil depth should be 18 inches to facilitate storage capacity and to provide a benefit for vegetation. Trees and deep-rooted vegetation would require 36- to 42-inch minimum soil depth as determined by a landscape architect.
- The minimum planter width should be 30 inches so they are easy to construct with a small excavator or backhoe, but any geometric shape can be built.
- Curbed openings and piped entrances, such as roof downspouts, should include rock, splash blocks, or other erosion controls at the ground line of the bioretention planter to dissipate energy and disperse flows.
- The basin areas should be sized to capture and treat the first flush design storm (0.5 inch) and drain surface water in less than 36 hours. The subsurface would need to infiltrate the runoff within 72 hours. The time for the selected ponding depth to filter through the media can be calculated using an equation from the Los Angeles LID Manual (Reference 17):

$$t_p = \frac{d}{\left(\frac{f_{design}}{12}\right)}$$

where:

t_p = required detention time for surface ponding (max 36 hours) (hr)

d = ponding depth (maximum 3 feet) (ft)

f_{design} = design infiltration rate (in/hr)

- If t_p exceeds 36 hours, reduce surface ponding depth (*d*). In nearly all cases, t_p should not approach 36 hours unless f_{design} is low (< 0.3 inches per hour).
- The area of bioretention planter can be calculated using the following equation, the volume required is determined by the first flush design storm:

$$A = \frac{V_B}{d}$$

Where:

A = bottom surface area of bioretention planter area (ft^2)

V_B = bioretention planter design volume (ft^3) and

d = ponding depth (maximum 1 foot) (ft).

- The underdrain shall have a mainline diameter of 6 inches using slotted PVC SDR 26 or PVC C9000. Slotted PVC allows for pressure water cleaning and root cutting, if necessary. The slotted pipe should have 2 – 4 rows of slots cut perpendicular to the axis of the pipe or at right angles to the pitch of corrugations. Slots should be 0.04- to 0.1-inch wide and 1 – 1.25 inches long. Slots should be longitudinally spaced such that the pipe has a minimum of a 1 square inch opening per linear foot and should face downward.
- The underdrain pipe should be wrapped in geotextile.
- Underdrains should be sloped at a minimum of 0.5 percent for positive drainage. The underdrain must flow freely to an acceptable discharge point.
- The underdrain should be elevated from the bottom of the stormwater planter by 6 inches. The gravel envelope should be ASTM No. 57 (or approved equal) washed gravel. The top and sides of the underdrain pipe should be covered with gravel to a minimum depth of 6 inches.

- Geotextile fabric should be used to separate the prepared soil and the gravel envelope.

Bioretention planters are typically landscaped. The design objective is typically to improve the aesthetics of the planter, to provide shade and landscaping for comfort, and/or to install plant materials that will thrive in the prepared soil and within the inundation characteristics of the element. Soil-building materials such as organic mulch, biota, and fertilizers may be incorporated into the prepared soil to improve vegetative success; the need for these can be identified through soil fertility testing and by specifically defining the landscaping objectives and performance expectations. In the Sonoran Desert, the landscaping treatment will usually be limited to a select list of plants (Refer to Section 3). Irrespective of these plants' ability to thrive in an artificial environment, they will require some degree of supplemental watering to get the plants established and periodically during dry periods to maintain their viability. Watering is typically accomplished through an underground irrigation system whose volume may be reduced over time and/or abandoned once the plants have been established, depending on the success of the landscape installation and the volume and pattern of stormwater collection.

8.3 CONSTRUCTION CONSIDERATIONS

Construction areas should be fenced off with a construction fence or silt fence to prevent soil compaction from equipment during construction of surrounding improvements. After excavation of existing soils, inspections and a percolation test should be completed before the construction of the underground storage area to determine if the site soils will meet the design criteria and/or if an underdrain is necessary. At a minimum, the bottom of the bioretention planter should have the top 6 – 8 inches scarified. Shoring may be required to reduce the potential of the adjacent soils from sloughing into the construction area.

If an underdrain pipe is used, it should be surrounded by ASTM No. 57 (or approved equal) washed gravel and geotextile fabric. Gravel must be washed and free of fine particles before being placed in the bioretention planter. Once the gravel drainage layer and prepared soil have been placed, limit compaction of the prepared soil to the specified requirements.

8.4 MAINTENANCE

This LID element should be inspected quarterly and after storms of 0.5 inches or greater. Any significant sediment accumulation or debris should be cleared. The cleanout risers should be opened and visually inspected during the routine maintenance. Any ponded water should be documented. Section 3 identifies the maintenance practices for the landscape element of this LID treatment. If an altered water flow pattern, erosion, or plant die-off is observed, these should be corrected in kind, at a minimum, and/or evaluated for further corrective measures.

8.5 COMPATIBILITY WITH OTHER LID PRACTICES

Bioretention planters can be integrated with curb openings.

8.6 SPECIFICATIONS

SECTION 646 – BIORETENTION PLANTER

646.1 DESCRIPTION

Work under this item includes the construction of a bioretention planter and associated appurtenances. Except as herein stated, the requirements specified for MAG Specifications 201, 206, 215, 220, 425, 430, and 796 are applicable to this specification.

A bioretention planter is typically a small-scale bioretention cell, often located between the curb and sidewalk. These facilities may include tree, shrub and groundcover plantings, see Specification 430. Streetscape bioretention planters will usually have vertical sides but may have sloped sides if sufficient space is available.

646.2 MATERIALS

See MAG Specifications 201, 215, 220, 425, 430, and 796.

A geotextile layer shall be placed beneath the bioretention soil to prevent the soil from migrating into the underlying stone. A reservoir layer of 18 inches of open graded ASTM No. 57 stone shall be placed beneath the geotextile layer, with perforated pipes embedded in the ASTM No. 57 stone. Geotextile shall be placed on the sides of the stone.

Underdrains are to be constructed following Specification 622. Connect underdrains to catch basins, manholes, or direct connect to storm drain pipe, with applicable permitting. Connection to catch basin is generally the most cost-effective option.

646.3 GENERAL

Overflow devices are recommended where the lowest adjacent top of curb or sidewalk is equal to or lower than the inflow point elevation. Typical overflow devices include outflow curb openings to gutter, and overflow structures.

Bioretention facility edges that are adjacent to pedestrian areas may be sloped or with a vertical drop. Railings are required around bioretention with a vertical drop adjacent to sidewalks in high-volume pedestrian areas and follow MAG Specification 415. The top of railing shall be 42 inches above the sidewalk, with vertical and/or horizontal member spacing that meets ADA detection requirements for visually impaired pedestrians. Bioretention with a vertical drop adjacent to sidewalks in low-volume pedestrian areas must be surrounded by a curb of minimum 6 inches high and 6 inches wide. Bioretention with a vertical drop must have a minimum 6-inch high curb or 42-inch railing between the parking step out zone and the drop. Bioretention with a sloped side must provide a flat (8 percent maximum slope) 6-inch minimum width buffer of different material to meet flush with adjacent sidewalk. Bioretention with a depth greater than 3 feet must provide a flat (8 percent maximum slope) 24-inch minimum width buffer.

Bioretention facilities with sloped sides with a total depth of more than 5 feet shall require a fence of 42-inch height enclosing the entire facility. Facilities with a greater than 30-inch vertical drop require a 42-inch railing meeting MAG Specification 415.

Access is required to access all bioretention areas for maintenance. Provide a safe, practical access route for maintenance crews.

646.3.1 Temporary Erosion Control

Install all temporary erosion control measures prior to site disturbance. Install storm drain inlet protection to prevent clogging of the storm drains and increases in sediment loads to downstream stormwater facilities or waterbodies. Inspect erosion control measures at least once a week and after each rainfall event. Make any required repairs immediately.

Erosion control devices shall be maintained until the site is stabilized, as determined by the Engineer.

646.3.2 Construction Sequence Scheduling

An implementation schedule should be included as part of the erosion control plan to identify the order of operations for construction activities. This is particularly important when constructing stormwater GI Infrastructure that is designed to infiltrate stormwater runoff. There are many construction activities which may contribute to the failure of a stormwater BMP if they are not planned for accordingly. The following items should be considered in developing an implementation schedule for a project:

A. Perform continuous inspection of temporary construction access to ensure that it is providing adequate erosion and sedimentation control for the construction site.

B. Install erosion protection along the perimeter of the site to prevent sediment from leaving the site during the construction process. Protection should be installed at a uniform elevation and constructed so that flow cannot bypass the ends.

C. All down-gradient perimeter sediment-control BMPs (e.g. temporary outlet controls) must be in place before any up-gradient land-disturbing activity begins.

D. Install underground utilities (water, sanitary sewer, electric, telephone, etc.) taking the location and function of stormwater BMPs into consideration.

E. Rough-grade the site leaving the basin area undisturbed until the contributing drainage area has been completed and the site is stabilized.

F. Perform all other site improvements in a manner that minimizes adverse impacts to the location and function of the stormwater BMPs.

G. Final grade the site. Grading of the basin shall be accomplished using low-impact earth-moving equipment to prevent compaction of the underlying soils. Wide-tracked vehicles such as backhoes, small dozers, and skid-steers are recommended.

H. At a minimum, the subgrade shall be scarified, ripped, or tilled to a depth of 6 – 8 inches with equipment having tines spaced no greater than 8 – 12 inches apart. A minimum of one percolation test should be completed for each bioretention planter unless the Engineer approves fewer tests based on the bioretention size and adjacent planters. Alterations to the work, such as additional modifications to the subgrade soils or the installation of an underdrain shall be measured and paid for in accordance with Section 104 of the Standard Specifications.

I. Stabilize the site by implementing the landscaping plan.

J. Install any required erosion control blanket, ditch checks, and other semi-permanent and permanent erosion control measures.

K. Remove the temporary erosion and sediment controls after the planter is stabilized per the Engineer's approval. It is important for the planter to be stabilized before receiving stormwater flow.

646.4 MEASUREMENT AND PAYMENT

The unit of measure for the bioretention planter will be per each and the payment will be made at the contract unit price per each specified. The payment will be in accordance with the following MAG Specification Sections, including all labor, materials, tools, equipment and incidentals needed to complete work specified.

Section 201 – Clearing and Grubbing
Section 215 – Earthwork for Open Channels
Section 220 – Riprap Construction
Section 430 – Landscaping and Planting
Section 796 – Geosynthetics

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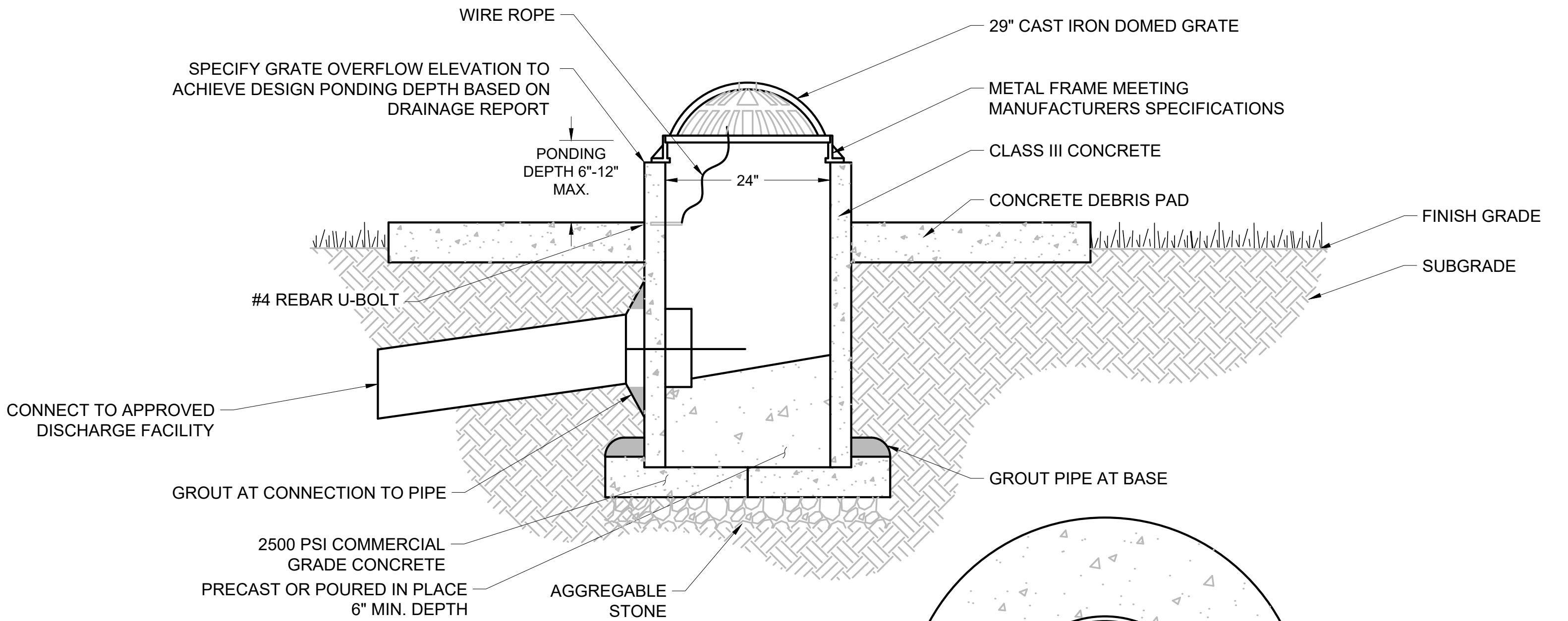
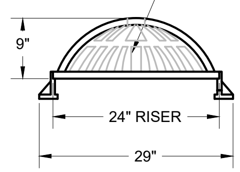
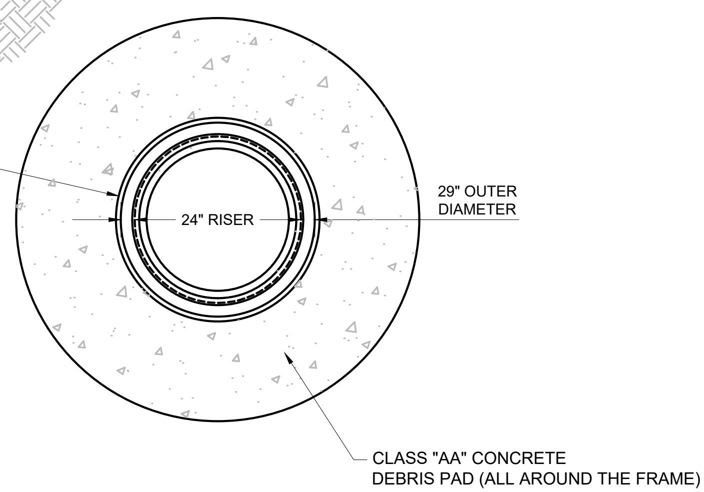




DOMED GRATE



NOTES:

1. PROVIDE GRATE OVERFLOW ELEVATION ON PLAN.
2. DO NOT ADJUST OVERFLOW GRATE ELEVATION, CONSTRUCT AS SHOWN ON PLANS.
3. GRATE OVERFLOW ELEVATION SHALL BE 3-INCHES BELOW ADJACENT SIDEWALK OR CURB.
4. LOCATE ON DOWNSTREAM END OF FACILITY.
5. VEGETATION PLACED 2-FEET AWAY FROM DEBRIS PAD.

REVERSIBLE MANHOLE FRAME

DETAIL NO.	STANDARD DETAIL		REVISED	DETAIL NO.
LID-10	ENGLISH	DOMED OVERFLOW STRUCTURES	01-29-2019	LID-10

9. DOMED OVERFLOW STRUCTURES

Overflow structures (LID-10) allow for ponding within multiple stormwater capture facilities and provide an outlet for larger storm events that exceed the capacity of each facility. Overflow structures drain into a downstream collection system, such as a storm drain, basin, channel, or natural wash.

9.1 APPLICABILITY AND ADVANTAGES

- Overflow structures are applicable to most commercial, industrial, and high-density residential developments that have a drainage collection system downstream. They are used in conjunction with other LID facilities or storage basins or are discharged to an appropriate receiving facility.
- A domed overflow structure has fewer maintenance issues compared to a flat grate placed in the bottom of a basin, because the ponded water allows sediments to drop out before entering the outlet opening. Similarly, debris must build up before it can enter the outlet.
- The debris pad surrounding the overflow structure provides easy removal of debris and sediment.

9.2 DESIGN CONSIDERATIONS

- Overflow structures must connect to a downstream collection system, such as a storm drain, basin, channel, or natural wash.
- The overflow structure must be designed to allow the overflow to drain without overtopping the overflow elevation. The grate overflow elevation should be at least 3 inches below adjacent sidewalk or top of curb.
- There should be a landscape buffer around the overflow structure so that vegetation does not interfere with element's ability to drain. There should be a 2-foot barrier from the debris pad to any vegetation.
- The inlet structure capacity can be designed with the orifice equation 3.14 presented in the FCDMC Hydraulic Manual (Reference 13) for the first flush (0.5 inches) design storm. The area of opening would need to be calculated accounting for the domed grate, the orifice equation is:

$$Qi = C_0 hL(2gd_0)^{0.5}$$

Where

- Q_i = discharge (ft³/s)
- C_0 = orifice coefficient (0.67)
- g = gravity (32.2 ft²/s)
- d_0 = effective depth at the center of the curb opening orifice (ft)
- h = Curb opening catch basin height, curb opening orifice, or orifice throat (ft)
- L = length of curb opening (ft)

9.3 CONSTRUCTION CONSIDERATIONS

The grouting at the connection points should be carefully checked to ensure they are totally covered. The overflow structure should be located at the downstream end of a drainage facility. Connect riser to storm drain using the appropriate reducer fittings, tees, and/or elbows.

9.4 MAINTENANCE

Overflow structures should be inspected after storms of 1.25 inches or greater to make sure that they are not clogged with debris or sediments. Inspection should happen at least annually to remove any debris and prevent clogging of the inlet structure. Encroaching vegetation should be pruned or removed to maintain the landscape buffer.

9.5 COMPATIBILITY WITH OTHER LID PRACTICES

Overflow structures work well with other LID elements that involve surface water or ponding, such as vegetated or rock bioswales and stormwater harvesting basins, because they provide a specific outlet and mitigate the possibility the element will overtop.

9.6 SPECIFICATIONS

SECTION 642 – DOMED OVERFLOW STRUCTURE

642.1 DESCRIPTION

This work shall consist of furnishing and placing domed overflow risers in LID facilities as shown in the contract documents, or as directed by the Engineer. Except as herein stated, the requirements specified for MAG Specifications 324 and 505 are applicable to this specification.

642.2 MATERIALS

- Concrete Pipe Riser: PCC Pipe per MAG Specification 505.
- Concrete for Riser - Catch Basin – Concrete Debris Pad: PCC 2500 PSI per MAG Specification 505.
- Domed/Beehive Grate: 29-inch diameter domed grate using cast or ductile iron.

642.3 GENERAL

642.3.1 General Installation

Provide domed risers for LID facilities placed on aggregate stone as indicated in the design plans.

Top of riser shall be set as specified in the design plans for ponding depth and a minimum 3 inches below adjacent sidewalk or top of curb, as designed. Connect riser to underdrain piping using the appropriate glues, primers, fittings, tees, and/or elbows.

Landscaping should not interfere with their ability to drain. There should be a 2-foot barrier from the debris pad to any vegetation. They must be located at the downstream end of the feature.

642.3.2 Measure and Payment

The unit of measure for domed overflow risers will be per each. Payment for domed overflow risers will be made at the contract unit price per each for the diameter specified, which will include excavation, shoring, backfill, compaction, installation of pipe riser and stone base including connections, gaskets, domed/beehive grate, and all labor, materials, tools, equipment and incidentals needed to complete work specified.

SECTION 3 - LANDSCAPING DETAILS AND SPECIFICATIONS

The role of vegetation is obvious and inherent to the origination and success of LID treatments. While engineering analyses establish the stormwater management needs, the selection of appropriate LID treatments requires an integrated, iterative process between drainage and landscape designers based on on-site ecological resources, design requirements, and budgetary considerations. In Maricopa County, native vegetation is generally sparse, providing limited stormwater management functions. As a result, purposely installed landscaping is needed to produce an effective vegetative cover for LID treatments. To ensure viable landscaping, a number of factors must be considered. This section of the Handbook elaborates on those factors and offers guidance and recommendations on the design, implementation, and maintenance of LID landscaping.

GEOLOGIC SETTING

The Greater Phoenix Metropolitan Area is located within Arizona's Basin and Range Geological Province, which is characterized by numerous mountain ranges that rise abruptly from broad, plain-like valleys or basins (Reference 18). The mountains can range from 300 feet to several thousand feet above sea level. The mountain masses can extend for up to 60 miles in length and 15 miles in width. Over time and through mass wasting and granular disintegration, these protruding bedrock features have produced the basin fill material (soil) that is found in the intermountain basin areas around Phoenix and other parts of the State of Arizona. Basin-area soils are made up of varying combinations and depths of gravels, sands, silts, clays, gypsum, salt, and other minerals found in the parent materials. Older basin fills exhibit profile development (layering) which is most notably exemplified in Arizona near the ground surface by caliche layers.

SOILS

“Soil” is the ubiquitous term used to describe the (non-rock) mineral materials that make up the earth's terrestrial crust. Ecologically, soil is important as the growing medium for the plants that cover and cool the earth's land areas. Soils and soil forming, as identified above, vary due to the effect of past and current actions such as mountain forming, mass wasting, volcanism, glaciation, and more subtle hydrologic, geochemical, and biological processes. Soils may be fine-grained or may consist of rocky, boulder-strewn matrices. Regardless of their texture or depth, soils overlay much deeper hard rock.

Soils have four main constituents: minerals, organic materials, air, and water. According to Hendricks, mineral matter makes up approximately 50 percent of Arizona soils, with air and water each comprising 25 percent, although McLane has indicated that in her soils testing laboratory, 15 percent water is more common (Reference 18; Reference 19). Organic matter comprises less than 5 percent in Arizona soils, with 1 percent being common (Reference 18; Reference 19).

Soils are typically referred to by their textures; the distinguishing characteristic is generally associated with the volume of sand, silt, or clay that the soils contain. These differences between soil types are determined by the size of their particles, with sand having the largest particles and clay having the smallest. Soils with roughly equal proportions of these separates are considered "loamy." A preferred soil for landscaping purposes is a loamy sand or sandy loam texture, which happens to be the primary soil makeup in Arizona and specifically in Maricopa County. Loamy sand and sandy loam are classified as coarse-textured soils; they contain a highly functional composition of mineral matter, air, and water that can be utilized by plants while also having a high level of hydraulic conductivity (permeability). Per McLane, Maricopa County soils typically percolate at a rate of 0.25 – 0.75 inches per hour and can possibly reach up to 2 inches per hour, depending on the location and site conditions (Reference 19).

When planning for LID techniques, other soil characteristics should be considered. High mineral counts affect the performance of site soils by limiting or prohibiting plant growth or causing plant death. Soils with high sodium (salt) content are not uncommon in Greater Phoenix; flushing agriculture crop areas with water is commonly required to keep salts from rising up in the soil layers and contacting the plant roots. Properly designed and maintained irrigation systems usually flush most salts from ornamental planting's root zones. Soil salinity, which is naturally caused by a combination of several select minerals (sodium, potassium, calcium, magnesium, and chlorine) can also severely inhibit plant growth. Arizona soils are generally alkaline with a pH between 7 and 8.5; native plants are adapted to these conditions and the restrictions that alkaline soils create for nutrient uptake. However, many non-native plants struggle as the pH level rises.

It is not uncommon to find clay, caliche, or other hardpan soil layers at relatively shallow depths in Greater Phoenix. These conditions require perforating the impermeable layer or installing an underground drainage system so that supplemental irrigation or stormwater entering the planting area can be drained away, thereby reducing the risk of having plants sitting in saturated soil.

Because of the low organic content of Arizona soils, it is tempting to try to improve those conditions by introducing a higher amount of organic material into the growing medium. Organics, such as wood mulch; biosolids (manure); and hulls, however, should be carefully considered, since they have the potential of releasing concentrated minerals that can become toxic to plant life once the decomposition has occurred. This is because stubborn constituents will remain in the soil matrix until they are absorbed, flushed away, or converted over time through chemical reactions. For example, natural bark mulch, if not nitrogen-stabilized, will release nitrogen as it decomposes. Since the rate of decomposition is not controlled in the growing medium, nitrogen will be released at rates that may "burn" surrounding plants. Composted organics provide a level of protection from this occurrence. While there are concerns about the use of chemical fertilizers, they are more predictable than organic material when used to provide plantings with nutrients and micronutrients. Additionally, soils that are overloaded with organics could be subject to collapse over time.

Each of the above dynamics must be evaluated when considering whether to employ LID at a site. There are means for overcoming these conditions as long as the designer (and site manager) recognize the importance of making informed choices based on a detailed assessment of the site's soils, future maintenance needs, and ongoing monitoring.

PLANT PALETTE

Native plants have learned to survive in the harsh climate and soil conditions of the Sonoran Desert, and they define the landscape character of the southwestern United States (Reference 20). Native plants provide a variety of benefits beyond their appearance, including erosion protection, food sources, wildlife habitat, and human comfort (shade). However, landscape installations in the Greater Phoenix Metropolitan Area are not limited to native plants. Since the 1960s, horticulturalists and commercial nursery growers have been introducing arid-adapted plants from around the world into the Phoenix area. These introductions have significantly added to the landscape industry's plant palette, while also greatly enhancing the aesthetics and enjoyment of Arizona's outdoor places and living spaces.

Not all native and introduced species on the Greater Phoenix palette are permitted for use in public ROWs. In the early 1980s, the Arizona Department of Water Resources established planning areas correlated to Arizona's groundwater basins to provide regional perspectives on water supply and demand and management of statewide water resource issues. These Active Management Areas (AMAs) include most of the state's largest urbanized areas and provide a regulatory framework for addressing water resource issues. The Phoenix AMA compiled the Low Water Use Drought Tolerant Plant List, which identifies the specific plant species permitted for use within public ROWs (for roads, streets, etc.). These plants have been evaluated by landscape and horticultural professionals and have been deemed compliant with the water-conserving objectives of the AMA. Landscape development on private land is not bound by the AMA restrictions or the Low Water Use List. As a result, a greater variety of plant species and LID techniques are available for use by these parties. The Arizona Municipal Water Users Association (www.amwua.org) and the Maricopa County Air Quality Department (www. cleanairmakemore.com) have published lists of viable plants in the Greater Phoenix Area using different selection criteria; these plants may be considered for use on LID installations when not on public ROWs. Some low water use plants are found on multiple lists.

Plants on the Low Water Use List have been chosen for their water conservation characteristics. It is understood that the low water use plants, much like all native and introduced species, can thrive under somewhat higher levels of periodic water contact. However, it is not known how much additional water and what watering intervals will, if at all, create detrimental conditions for these plants. You will note later in this document that plants have been identified based on their perceived ability to thrive above or below the anticipated inundation elevations (referred to as plants in groups A and B). Close monitoring of how native desert plants adapt to GI conditions will be important to determining the future success of LID installations in the Greater Phoenix Metropolitan Area and throughout Arizona.

Except for native plants like cacti and succulents that can survive on rainwater after a 1 – 2 year establishment period, newly installed "xeriscape" landscaping (a combination of native and arid-adapted plants) are typically irrigated through a permanent underground system to maintain the plantings' health and viability. It is not uncommon with a native plant installation to use water trucks, temporary above-ground systems, or a lower-cost underground system (poly pipe), making it feasible to either abandon the system in place after a few years or to use it only during times of extended drought. Regardless of which watering method is used, maintenance personnel routinely monitor the water being delivered to their landscaping.

For the near term, it is hoped that an even greater level of monitoring and documentation will occur after the GI treatments identified in this Handbook are installed, so that knowledge of the irrigation performance and related considerations can be better understood.

MAINTENANCE

One of the most recurring concerns expressed by local maintenance staff about implementing GI/LID has been the effect that such a paradigm shift would have on maintenance activities and costs. An additionally noted concern relates to the long-term viability of LID treatments. The GI treatments proposed in this Handbook cannot resolve all concerns or potential impacts that may result from their implementation, since there are numerous factors that contribute to maintenance costs. However, we have incorporated features into the LID details to ease the effort needed to maintain the installations. For example, sediment traps have a smooth bottom to allow easy scooping of the captured materials; this design will help maintenance personnel to efficiently do their jobs.

Regardless of the efficiency built into the details as noted above, a routine activity that impacts maintenance costs is the extent of trimming and pruning that might result from enhancing the growing conditions of GI plantings. A key method for offsetting this long-term effort is to select plants carefully, to be mindful of their size at maturity, and their position relative to the inundation zones. Increased diligence on plant selection and adopting this strategy will avoid issues such as placing plants in improper locations or installing plants that will overgrow their available space, thereby increasing the need for pruning.

Allowing the installed plants to grow into their natural shape will reduce maintenance costs related to pruning. Additionally, because they have been placed in locations where stormwater is collected and because LID treatments have been enhanced to capture and percolate stormwater, they will generate volunteer vegetation growth, primarily in basin bottoms, if not otherwise precluded. Volunteers are generally acceptable unless they interfere with the overall performance of the GI facility. While the resultant naturalized landscape appearance may be less "manicured" than current practices, it should gain overall acceptance as the benefits of GI become known to the public and maintenance managers.

As GI is more widely implemented in the Greater Phoenix Area, the body of knowledge about the optimum maintenance practices necessary to keep these treatments operating effectively for many years will be developed.

Key questions about maintenance include which are the high performing plants or plant groups; which plants are most maintenance-intensive or subject to disease and pest damage; whether LID plantings require less supplemental water; how often LID facilities need to be maintained; what type of maintenance is most effective (i.e., pruning, debris removal, soil refurbishment, etc.); how long before the treatments become "clogged"; and how the cost of LID facility maintenance compares to standard maintenance practices. Further, in the future, monitoring how and to what extent LID/GI contributes to broader social benefits such as improving air quality and encouraging environmental awareness will be important for gauging the full benefits of this approach.

RECOMMENDATIONS AND GUIDELINES

DESIGN CONSIDERATIONS

This section contains design and maintenance recommendations plus guidance on the suitability of specific plants for side slopes and bottoms of water harvesting basins, bioretention systems, bioretention planters, and curb extensions—based on their tolerance for different (higher or lower) levels of inundation. These guidelines are offered for initial consideration and should be evaluated for applicability at each development site by a qualified landscape architect or horticultural specialist. In general, seeding will be associated with larger-scale facilities in more rural settings and will depend on the performance objectives of the facility.

LANDSCAPING DETAILS AND SPECIFICATIONS

RECOMMENDATIONS

- Where space is available, trees and shrubs should comprise the majority of the plantings because of their longevity and ability to affect surrounding ground temperatures.
- Create landscape groupings with appropriate plant densities, to avoid over-competition for available moisture.
- Plan for the mature size of plants to avoid vegetation from overhanging streets and sidewalks or growing into overhead power lines.
- Grasses, low-growing groundcovers, and organic mulches are the preferred surface materials for LID facilities. The site location, context, and facility purpose will determine whether volunteer vegetation is appropriate.
- Vegetation should be monitored monthly.
- Plantings should be allowed to grow naturally, with little or no pruning, other than the removal of dead or damaged limbs and branches or to address pest control. Plants that bend under flow conditions should be considered for channel and pass-through situations. Vegetation that impairs sight visibility or presents a hazard to pedestrians should be pruned or removed. Shearing should not be a standard practice (particularly shearing of plants into geometric shapes).
- Dead, damaged, and invasive vegetation should be cleared and replaced with like kind or desirable plant species.
- Leaves, flowers, and seed pods (natural litter) that accumulates under the grasses and beneath the plants should be allowed to remain, to provide an organic mulch layer for moisture retention and to improve the soil medium.
- Leaf raking and vegetative debris removal should be undertaken only when it is evident that not doing so would reduce the effectiveness of the LID treatment.
- Weed control is most important during the first several years of establishment, and thereafter should be done on an as-needed basis. The use of herbicides is discouraged; hand-weeding of volunteer, invasive plants such as fountain grass, African sumac, and Mexican palo verde is preferred.
- Plants should be irrigated only as much as necessary to maintain health; overwatering encourages excessive growth.
- The irrigation system should be checked monthly and more frequently during hotter months to ensure proper functioning.
- Non-organic litter and other debris that accumulates as a result of runoff should be removed as needed.
- Sustainable landscape maintenance practices are encouraged.

Native Seeding

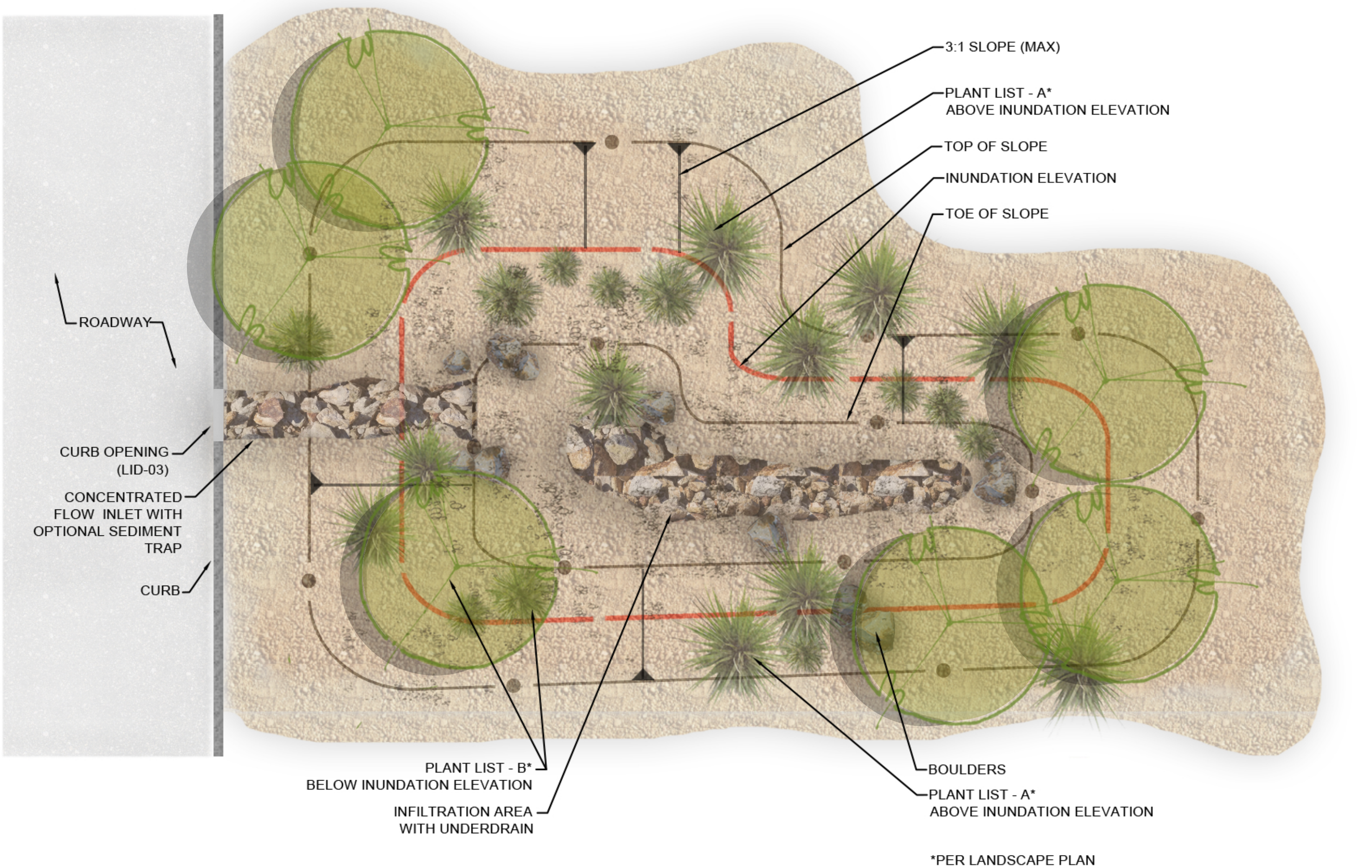
Native seeding should be considered on a case-by-case basis, depending on GI/LID objectives.

GUIDELINES

The following pages provide planting guidelines for GI projects in the Greater Phoenix Metropolitan Area.

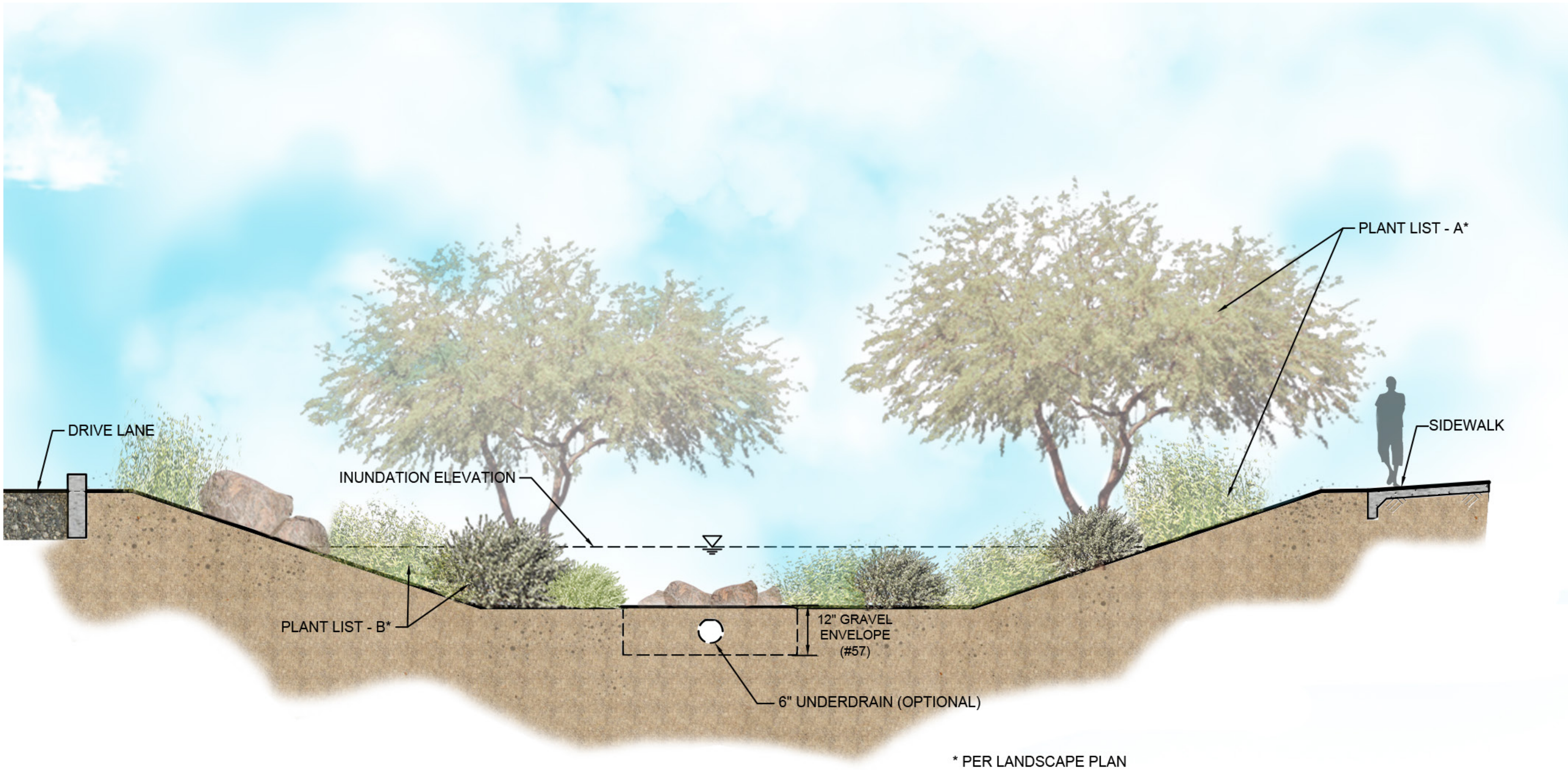
SPECIFICATIONS

Important considerations for GI landscape specifications follow the Guidelines.



LID 5 STORMWATER HARVESTING BASIN - PLAN

N.T.S.



LID 5 STORMWATER HARVESTING BASIN - SECTION

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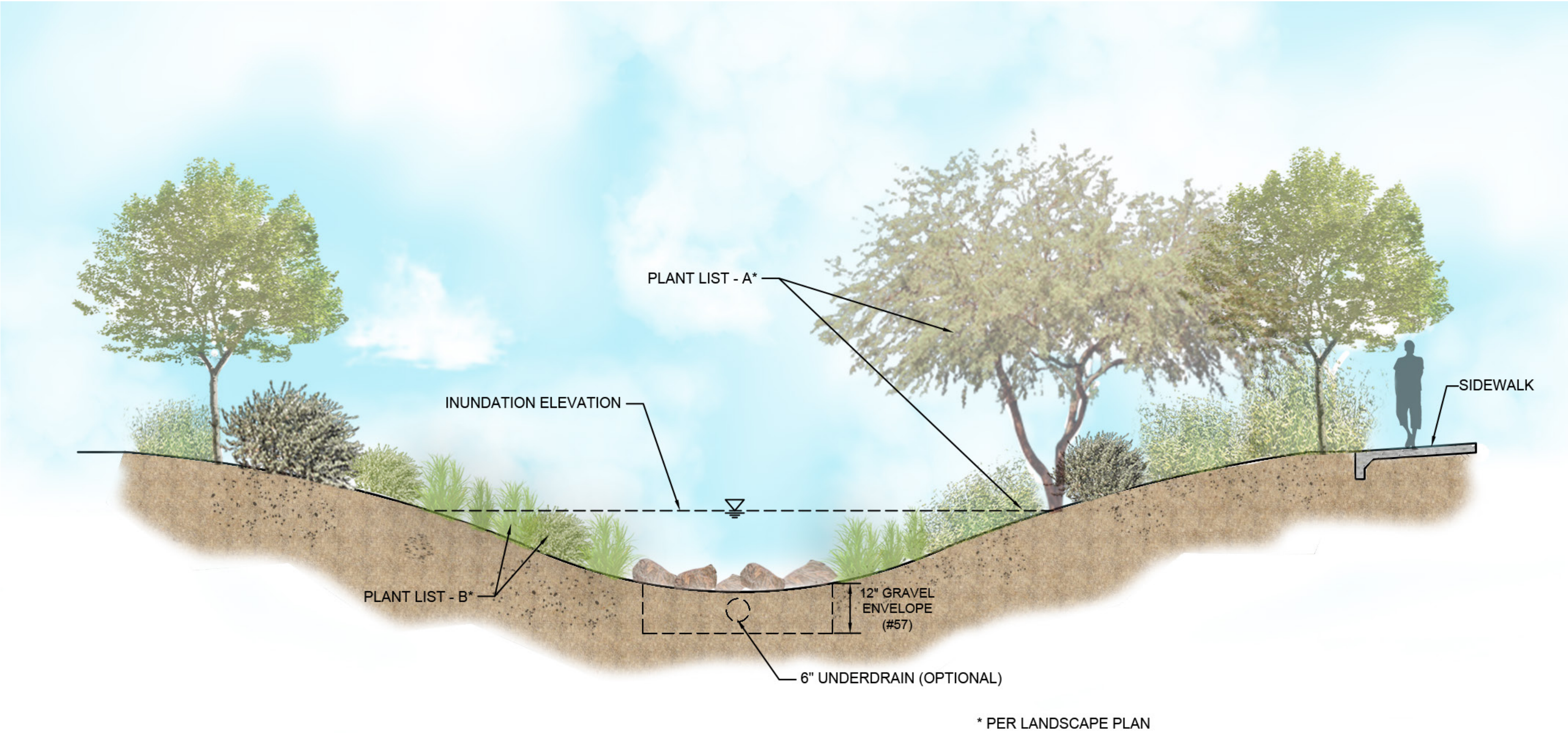
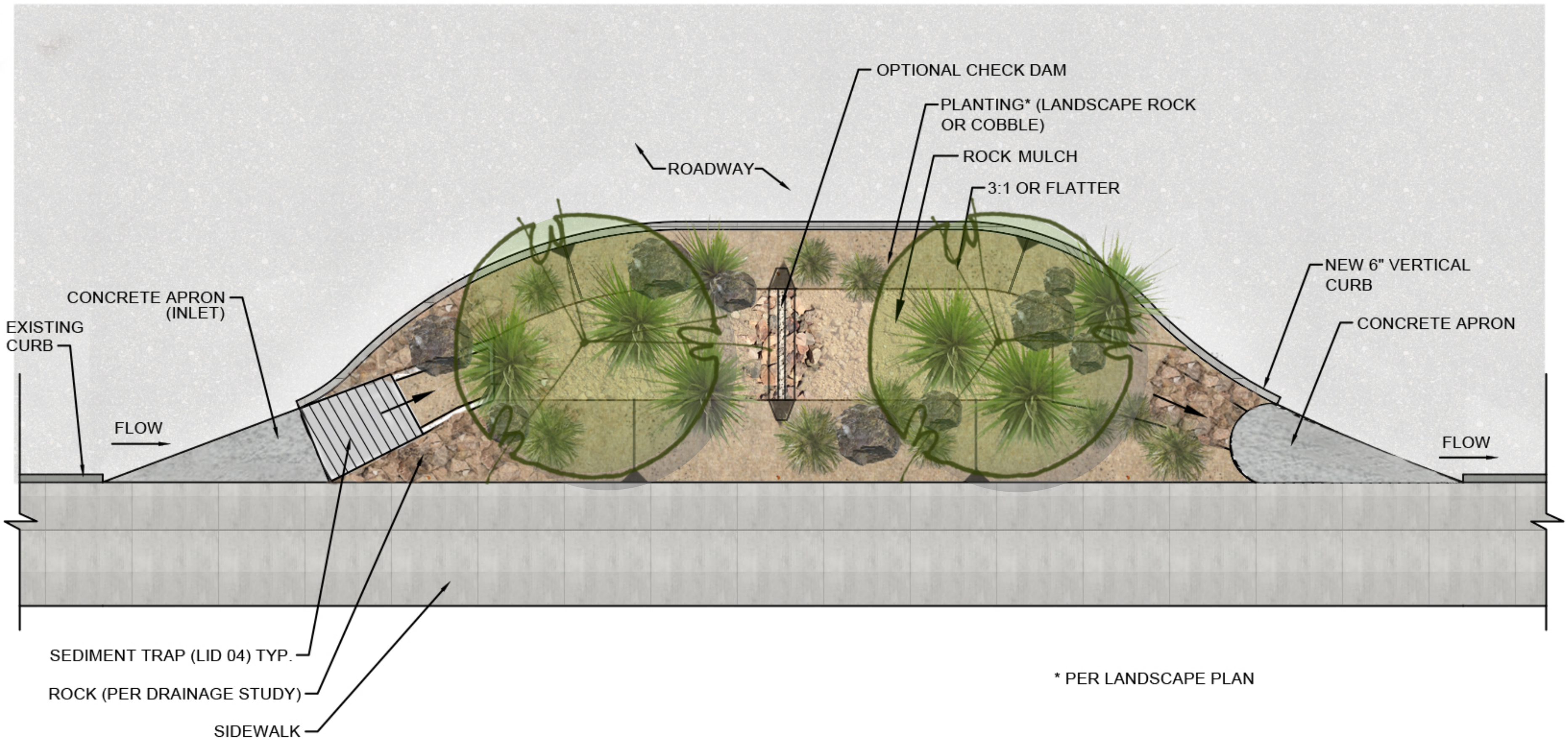


LID 6 BIOSWALE
N.T.S.



LID 8 | CURB EXTENSION

N.T.S.

PLANT LIST A

(ABOVE THE INUNDATION ELEVATION)

* Indicates plants native to Maricopa County

Botanical Name	Common Name
TREES	
Acacia aneura	Mulga
Caesalpinia cacalaco	Cascalote
*Chilopsis linearis	Desert-willow
*Olneya tesota	Ironwood
*Parkinsonia florida	Blue Palo Verde
*Prosopis pubescens	Screwbean Mesquite
*Prosopis velutina	Velvet Mesquite
Vachellia (Acacia) farnesiana	Sweet Acacia
SHRUBS	
*Ambrosia deltoidea	Triangleleaf Bursage
Caesalpinia mexicana	Mexican Bird of Paradise
Caesalpinia pulcherrima	Red Bird of Paradise
Calliandra californica	Baja Red Fairy Duster
*Calliandra eriophylla	Fairy Duster
Cordia parvifolia	Littleleaf Cordia
*Encelia farinosa	Brittlebush
*Larrea tridentata	Creosote Bush
Leucophyllum frutescens	Texas Ranger
Leucophyllum laevigatum	Chihuahuan Sage
Ruellia peninsularis	Desert Ruellia
*Senegalia (Acacia) greggii	Catclaw Acacia
Senna artemisioides	Feathery Senna
*Simmondsia chinensis	Jojoba
*Vachellia (Acacia) constricta	Whitethorn Acacia
*Viguiera parishii (deltoidea)	Goldeneye

Please see Appendix C for additional plant lists.

PLANT LIST B

(BELOW THE INUNDATION ELEVATION)

* Indicates plants native to Maricopa County

Botanical Name	Common Name
TREES	
Brahea armata	Mexican Blue Fan Palm
Phoenix dactylifera	Date Palm
Washingtonia filifera	California Fan Palm
Prosopis velutina	Velvet Mesquite
Prosopis pubescens	Screwbean Mesquite
Parkinsonia florida	Blue Palo Verde
Eucalyptus spathulata	Swamp Mallee
Prosopis hybrid	South American Hybrid Mesquite
Eucalyptus microtheca	Coolibah Tree
SHRUBS	
*Ambrosia ambrosioides	Giant Bursage
*Atriplex canescens	Fourwing Saltbush
*Atriplex lentiformis	Quail Bush
*Baccharis sarothroides	Desert Broom (male, non-seeding plants only)
*Celtis ehrenbergia (pallida)	Desert Hackberry
*Hymenoclea monogyra	Burrobrush
*Justicia californica	Chuparosa
*Lycium andersonii	Anderson Thornbush
Maytenus phyllanthoides	Mangle Dulce
Ruellia brittoniana	Purple Ruellia
*Senna covesii	Desert Senna
*Sphaeralcea ambigua	Globemallow
Tecoma stans	Yellow Bells
*Zizyphus obtusifolia	Graythorn
GRASSES	
*Aristida purpurea	Purple Threeawn
Muhlenbergia capillaris	Pink Muhly
*Muhlenbergia rigens	Deer Grass
*Pleuraphis (Hilaria) rigida	Big Galleta

SECTION 215 EARTHWORK FOR OPEN CHANNELS

Excavation and placement of BSM for GI/LID projects shall conform to Section 215 of the MAG Uniform Standard Specifications, 2018 Revision to the 2015 Edition, and as specified herein.

215.1 DESCRIPTION:

Add the following:

Sections 430, 440, and 795 of the Standard Specifications and these special provisions contain requirements that apply to this Section.

215.3 EXCAVATION:

Add the following:

Delineate the limits of the GI installation. Upon approval of delineation, stakes, temporary construction fencing, or similar materials shall be placed as directed by Engineer to maintain limits of work.

If the BSM installation location has been used as the site for an erosion and sediment control measure, remove all remnants of prior use of the location, including all collected sediment and debris.

Excavation and grading shall be accomplished using low-impact earth-moving equipment to prevent compaction of the underlying soils. Wide-tracked vehicles such as backhoes, small dozers, and skid-steers are recommended. Excavating equipment should operate from the side of the basin to the extent feasible. Excavation methods should consider the excavation and installation of underdrains, if included in the contract documents.

If excavation leads to substantial compaction of the subgrade, the compacted area shall be removed and replaced with acceptable soil material to a depth approved by the Engineer.

Do not excavate, place BSM, or amend the installation during wet or saturated weather conditions. Excavations shall result in subgrade surfaces that are friable, firm, but not compacted and shall be in accordance with the lines and grades indicated in the contract documents. Roughen subgrade surfaces to remove smears, glazing, compacted areas, and equipment marks.

After subgrades are established for each stormwater harvesting basin, bioretention system, curb extension, or bioretention planter, a minimum of two percolation tests should be completed for each 40,000 square feet of excavation area. A minimum of one percolation test shall be completed for each, regardless of the size of the excavation area. For rock or vegetated bioswales, one percolation test shall be completed for each 750 linear feet of swale.

To conduct the percolation test, the test hole shall be 12 inches by 12 inches square or 15 inches in diameter by at least 12 – 18 inches deep. Do not alter the structure of the soil during the excavation. Scarify or loosen smeared soil surfaces within the test hole; remove loosened materials from the bottom of the hole.

The percolation test(s) shall be conducted in accordance with AAC R18-9-A310(F). The percolation test(s) shall be conducted during a daylight work shift so it can be observed by the Engineer. Percolation test results shall be reported in minutes per inch of water surface drop within the test hole. Alterations to the work, such as modifications to the subgrade soils, installation of drainage chimneys, or the construction of an underdrain will be determined by the Engineer based on the findings of the percolation test(s). Alterations to the work will be measured and paid for in accordance with the requirements of MAG Section 104.

Where indicated in the contract documents, scarify, rip, or till the subgrade to a depth of 6 – 8 inches by hand or with equipment with tines spaced no greater than 8 – 12 inches apart. Scarification shall occur subsequent to percolation tests once soils are dry and prior to placement of BSM or rip rap/rock and landscaping for bioswales and basins.

215.4 FILL AND BACKFILL:

Add the following:

BSM Production:

BSM may be produced from excavated or imported soil materials, including soil excavated from work areas outside the boundaries of the GI installation, provided it meets the requirements of these special provision and the imported material and material source is approved by the Engineer. At the contractor's option, BSM may be manufactured in bulk from the excavated/imported materials. The contractor shall accept complete responsibility for the planning and management of the BSM collection, storing, stockpiling, ensuring that the BSM remains as a homogenous mixture while stored and until installed, and the accuracy of the quantities necessary to provide and install all BSM work as indicated in the contract documents. The collection and mixing of the material in bulk shall not commence until direction is provided by the Engineer.

To be acceptable for use, excavated or imported soil material must be fertile, friable, and free from nut grass, refuse, construction debris, roots, substantial sand or dense clay pockets, clods, noxious weed seeds, fertilizers, chemicals, or other deleterious materials toxic to plant growth and viability. Soil shall meet the gradation requirements for topsoil in MAG Subsection 795.2, except that the #200 shall not exceed 30 – 40 percent passing. If imported soil is used, material may not be brought to the site until material has been approved by the Engineer. Soil shall also meet or be modified to meet the following requirements:

Calcium	2500 – 7000 parts per million (ppm)
Magnesium	150 – 400 ppm
Sodium	<300 ppm
Potassium	120 – 800 ppm
Manganese	<50 ppm
Zinc	<30 ppm
Copper	<10 ppm
Nitrate-n	28 – 35 ppm
Phosphate-p	22 – 28 ppm
Boron	0.5 – 2.0 ppm
Sulfur	20 – 200 ppm
Ec	<0.3 dS/m

As soon as possible after the area to be excavated or the import material source is accessible, contract with a licensed soils lab to take a minimum of 1 soil sample (0 – 1 foot depth) of the existing in-situ soil and 2 soil samples (0 – 1 foot depth) for each import source location. Agricultural fertility analyses showing ppm of the collected samples shall include the criteria above, at a minimum, and all characteristics necessary to make fertility recommendations for landscape installations. Also include levels of salinity, pH, sodium, and free lime. Provide recommendations for soil amendments to correct any nutrient deficiencies, eliminate conditions detrimental to plant growth and/or to improve the soil fertility. Testing shall be conducted no more than 60 days prior to use on the project. Batch-specific testing will be required for all installations. Provide the fertility test results and recommendations to the Engineer for review.

BSM Mixing:

BSM shall be a mixture of soil, sand, compost, amendments, and fertilizers that supports plant growth while absorbing moisture and attenuating pollutants. The composition of the mixture shall be (by volume):

Excavated or Imported Soil:	75%
Sand:	15%
Fine Compost:	10%
Gypsum:	5 pounds per cubic yard of BSM
Sulfur:	1 pound per cubic yard of BSM
Fertilizer:	As indicated in the contract documents
Ec:	<0.3 dS/m

BSM mixing shall be as approved in the procedures manual described in Section 430 of these special provisions. Mixing is not allowed within the BSM placement pits or excavation area.

Upon completion of the BSM mixing, a 1 cubic foot sample of BSM product shall be provided to the Engineer.

As part of this work, the following analysis shall also be completed and provided to the Engineer:

1. Grain size analysis of the soil material shall be performed in accordance with ASTM D422, Standard Test Method for Particle Size.
2. Compost testing shall be performed in accordance with ASTM F 1647, Standard Test Methods for Organic Matter Content of Athletic Field Rootzone Mixes or Testing Methods for the Examination of Compost and Composting (TMECC) 05.07A, Loss-on-Ignition Organic Matter Method, and as required to demonstrate compliance with Subsection 795.3 of these special provisions.
3. Constant head permeability testing of the BSM in accordance with ASTM D2434, Standard Test Method for Permeability of Granular Soils (Constant Head) shall be conducted on a minimum of 2 samples with a 6-inch mold and vacuum saturation.
4. Hydraulic conductivity rate of the BSM should not be less than 3 inches per hour when tested with a double ring infiltrometer in accordance with ASTM D 3385, Standard Test Method for Infiltration Rate of Soils in Field Using Double Ring Infiltrometer, a single ring infiltrometer, a modified Philip-Dunne infiltrometer, or other approved methods.

Provide information about the laboratory(ies) conducting the testing, including name, address, contact person, phone number and email, and qualifications and certifications for ASTM/US Department of Agriculture testing.

Ship or delivery BSM materials with Certificate of Inspection required by governing authorities. Before delivery, Certificates of Compliance shall be submitted, certifying that materials meet or exceed the requirements specified, including physical property, and performance. Prior to shipment, provide certified copies of the reports for the Engineer's approval. Certification shall indicate the supplier's name, address, telephone number, date of purchase, name and technical description of item purchased, and quantity of each item purchased. Material samples shall be forwarded in a single package to the Engineer within 2 weeks after award of the bid. Certified copies of the documentation shall be provided for the following materials:

1. PVC pipe for the cleanout riser
2. Geosynthetic fabric

If, in the opinion of the Engineer after review of any or all testing, a change is warranted to the BSM components, component ratios, soil amendments, or other fertilizers, the Engineer may request a proposal for making alterations to the work. Changes to soil amendments from those shown in the contract documents may be covered by anadjustment in contract price for the affected items as approved by the Engineer.

BSM Placement:

BSM shall be placed uniformly in the designated areas to the depths and grades indicated in the contract documents. The contractor shall place BSM in 6 – 8 inch lifts. The initial lift shall be placed in a manner that reduces stratification and air pockets at the interface with the scarified subgrade.

After each layer has been placed, the BSM shall be foot compacted by contractor personnel and water settled so that the fluff and air pockets are substantially reduced. Add additional material as necessary to achieve the finished grade.

Avoid over-compacting and over-watering in the placement and spreading operation. Over-compacted areas shall be loosened or scarified as directed by the Engineer.

Prior to planting, vehicles, foot traffic, and construction equipment shall not be allowed to drive on, move over, or disturb the BSM once placed and water settled.

If indicated in the contract documents, a cleanout riser shall be installed. The riser shall be wrapped with a geosynthetic. The riser and geosynthetic shall be as described in Section 795 of these special provisions. Maintain placement of the fabric during the BSM filling operation so that the full height of the riser is protected by fabric after the filling operation is complete.

The contractor shall properly dispose of excess BSM.

215.8 PAYMENT:

Add the following:

Alterations to the work will be measured and paid for in accordance with the requirements of MAG Section 104.

Traffic control, if required for the project, shall be in accordance with the Phoenix Barricade Manual upon approval by the Engineer and is considered as incidental to the contracted items. No separate measurement and payment will be made for this work.

SECTION 430 LANDSCAPING AND PLANTING

Landscaping for GI/LID projects shall conform to Section 430 of the MAG Uniform Standard Specifications, 2018 Revision to the 2015 Edition, and as specified herein.

430.1 DESCRIPTION:

Add the following:

As indicated in the contract documents, landscaping shall be installed in stormwater harvesting basins, rock or vegetated bioswales, bioretention systems, curb extensions, and bioretention planters. Native seeding may also be installed in stormwater harvesting basins and rock or vegetated bioswales as indicated in the contract documents.

Sections 215, 440, and 795 of the Standard Specifications and these special provisions contain requirements that apply to this Section.

Perform work in accordance with all applicable laws, codes, and regulations required by authorities having jurisdiction over such work and provide for all inspections and permits required by federal, state, and local authorities in furnishing, transporting, and installing materials as indicated and for completing the work identified herein.

Cooperate and coordinate with other contractors and trades working in and adjacent to the work areas.

Comply with MAG and Arizona 811 requirements related to locating underground utilities. Determine location of underground utilities and perform work in a manner that will avoid possible damages. Maintain flags, stakes, or paint markings by others until removal is mutually agreed upon by the affected parties. Hand excavate, as required when working in close proximity to any underground utilities. At no additional cost to the project, repair all damages to located utilities as approved by the Engineer.

430.2 GENERAL:

Add the following:

Furnish all labor, materials, equipment and incidental needs to install the landscape installation to the lines, grades, cross sections, and details indicated in the contract documents.

Existing utilities and improvements not designated for removal shall be protected in place. Any damages will be repaired by the contractor at no additional cost to the project.

Unless otherwise stated, planting, irrigation, native seeding, and other improvements shall be installed in concert with the finish grade construction.

The contractor shall bear final responsibility for proper surface drainage of planted areas. Any discrepancy in the drawings or these special provisions, obstructions on the site, or prior work done by another party, which contractor feels precludes establishing proper drainage, shall be brought to the attention of the Engineer in writing for correction or relief of said responsibility prior to start of operations.

All landscape areas within the project shall be graded so that finished surfaces conform to the typical sections, proposed lines and grades, and surrounding surfaces as indicated in the contract documents. Finished surfaces shall be reasonably smoothed, compacted, and free from irregular surface drainage.

For landscape installations, finished grades shall have a vertical tolerance of ±0.1 foot from the specified grade and cross section.

Weed control shall be completed by hand or mechanical means.

Applicable publications listed below form a part of this specification to the extent referenced:

- American Association of Nurserymen, Inc. (AAN): American Standard for Nursery Stock (ASNS), 1986 Edition.
- American Joint Committee on Horticultural Nomenclature (AJCHN): Standardized Plant Names (SPN), Second Edition, 1942.
- Arizona Nursery Association Growers Committee (ANA): Recommended Tree Specifications, latest edition.

Ship materials with certificate of inspection required by governing authorities. Before delivery, certificates of compliance shall be submitted, certifying that materials meet the requirements specified.

Unless otherwise specified, the contractor shall perform all testing, or provide test results to the Engineer from accredited laboratories. The contractor shall pay the cost for all testing in addition to all removal and replacement of materials not meeting these special provisions.

The Engineer reserves the right to take and analyze samples of materials for conformity to these special provisions at any time. Contractor shall furnish samples upon request. Rejected materials shall be immediately removed from the site at the contractor's expense.

Procedures Manual: Within 14 days of award of the bid, submit a procedures manual identifying the methods/procedures proposed by the contractor to complete the landscape installation work. The manual shall specifically identify the proposed sources of materials and component mixture ratios to produce the BSM material testing methods for the individual BSM components, and the overall mixture, equipment, and methods for mixing and placing the BSM, BSM settling/compaction procedures, details and methods proposed for planting the plants, including excavating the plant pits, backfilling techniques, watering, staking, bracing, fertilizing, and maintenance of the installation during the maintenance and warranty period. The manual shall also include descriptions of modifications and protection of the installation for seasonal climatic conditions/events such as monsoon storms or frost. The manual shall also identify any anticipated temporary, on-site plant storage areas, if used, and their proposed watering system, plus recommendations for herbivore protection, if indicated in the contract documents.

The manual will be reviewed by the Engineer who reserves the right to request further information on the methods proposed by the contractor.

Upon written acceptance and agreement by the Engineer, the procedures manual shall be modified as agreed-upon and included as part of these Special Provisions and shall govern the requirements of those portions of the work therein. Resubmit the procedures manual with agreed-upon modifications.

430.4 DECOMPOSED GRANITE AREA:

Add the following:

Landscape areas to receive decomposed granite or an organic mulch shall be graded according to the contract documents prior to the placement of any rock material. The ground shall be reasonably smooth and rocks larger than 1 inch in diameter within the top 1 inch of the ground surface, shall be removed and disposed of off-site.

Decomposed granite shall be evenly distributed on the designated areas to a depth as indicated in the contract documents. If a depth is not indicated the minimum depth shall be 2 inches. Pre-emergents shall not be used unless specifically called out in the contract documents.

After placing and grading the decomposed granite, the contractor shall water-settle the decomposed granite with a light spray to remove fine materials from the surface. Do not roll the decomposed granite.

At the locations specified in the contract documents, an organic mulch may be placed as the surface plating material. Organic mulch shall be evenly distributed on the designated areas to a depth as indicated in the contract documents. If a depth is not indicated the minimum depth shall be 3 inches.

430.5 TREE, SHRUB AND GROUND COVER PLANTING:

Add the following for BSM installations:

Setting and Backfilling for Trees and Shrubs: Excavate plant pit in sufficient size to install the root ball. When set, place BSM around root ball. Water thoroughly to remove air pockets after backfill is complete. Add BSM as required to achieve finished grade. Repeat watering as necessary to settle BSM.

In the event ambient air temperature is greater than 110° F, the contractor shall pre-wet all plant pits prior to installing trees, shrubs, or groundcovers. Do not install plant material until all water has fully percolated out of the plant pit into the surrounding BSM, do not allow plant pit sides or bottom to excessively dry out prior to planting operations.

Stake all trees per the contract documents. Avoid "rigid" restraint of tree and allow for some trunk movement.

430.5.1 Substitutions:

Add the following:

If the specified planting materials are not obtainable prior to the installation, submit proof of non-availability from three sources within 14 days of award of the bid along with recommendations for at least 2 – 3 suitable plant substitutions.

430.5.2 Plant Inspection Prior to Delivery to the Project Site:

Add the following:

The contractor will pay for the Engineer's travel to nurseries located outside of the Phoenix Metropolitan Area.

430.5.7 Clean Up:

Insert the following subsection:

Any material placed or deposited in non-designated areas shall be immediately removed at the contractor's expense. Non-designated areas may include, but are not limited to, do not disturb areas; structures; walls; fences; pavement; roads; trails/paths; signs; trees; plants; site furnishings; and equipment.

430.8 PLANT GUARANTEE AND MAINTENANCE:

Add the following:

Warranty all plant material for a period of 1 year after final acceptance of landscape installation against defects, including death and unsatisfactory growth, except for defects resulting from neglect by the Engineer, vandalism, abuse or damage by others, or unusual phenomena or incidents which are beyond the contractor's control. Remove and replace plant material found to be dead or in unhealthy condition at any time during warranty period or as directed by the Engineer. Replace plant material that is in doubtful condition at the end of the warranty period, unless, in opinion of Engineer, it is advisable to delay replacement.

Only one replacement (per tree, shrub, or cacti) will be required during the warranty period, except for loss or replacements due to failure to comply with specified requirements.

Replacements made during the warranty period shall be completed within 7 days of written notice from the Engineer. The Engineer shall approve replacement material prior to planting.

Unless otherwise authorized, the Contractor shall maintain all landscape areas during the plant establishment period on a continuous basis as they are completed during the course of work and until final acceptance by the Engineer. Maintenance shall include keeping the landscape areas free of debris, control of undesirable weeds and vegetation or infestations that would jeopardize the growth of planted materials, fertilization as needed, cultivating the planting areas, and providing additional BSM to meet the finished grades indicated in the contract documents. Make replacements within 7 days of notification from the Engineer. Remove dead, damaged, or vandalized plants within 7 days of notification.

Replacements shall be of the same kind and size as originally specified and shall be installed as indicated in the contract documents. Replacements of vandalized plants and/or other installed items shall be measured and paid for in accordance with the requirements of MAG Section 104.

After planting, landscape areas shall be maintained as plants shall be inspected at least once a week and appropriate maintenance performed. Pruning is to include removal of any growth conflicting with vehicular or pedestrian movement and sight lines.

Pruning: Pruning shall be done so that an aesthetic framework of branches is left, which preserves the size and best features of the affected plant so that the plant will fill in for a balanced appearance. Pruning shall not damage the collar of the branch being removed. Current standards for arboriculture, such as ANSI A300 Pruning Standards, shall be used.

Trimmings for each plant shall be removed from the site and properly disposed of by the contractor on the same day as the trimming activity.

The contractor shall maintain the irrigation system and make any necessary repairs to assure a complete and operational system as originally designed and constructed. Repairs shall be made within 48 hours of detection.

If the landscape areas are improperly maintained, if appreciable plant replacement is required (for whatever reason excluding vandalism), if corrective work is required for the proper operation of the irrigation system, or if other corrective work is necessary, the plant guarantee and maintenance period shall be extended at the sole discretion of the Engineer; the contractor shall continue to maintain the entire site at no increased cost until final acceptance by the Engineer.

430.9 PLANT ESTABLISHMENT PERIOD:

Add the following:

The plant establishment period for the installed plants and irrigation system shall be 90 days, although a longer period may be indicated in the contract documents, and is exclusive of the allotted contract period.

Landscaping Installation Acceptance Inspection: A pre-plant establishment period inspection will be performed upon substantial completion of all planting and irrigation work. The contractor shall notify Engineer within 5 days of inspection to arrange schedule. The Engineer, contractor and such others as the Engineer shall direct, shall be present at the inspection. The Engineer shall issue the effective beginning date for the 90-day plant establishment period for all or portions of the landscaping. Work requiring corrective action in the judgment of the Engineer shall be performed within 5 days after the inspection. Corrective work and materials replacement shall be in accordance with the contract documents and shall be made at no cost to the project. When inspected work does not comply with requirements, replace rejected work and continue specified maintenance until re-inspected by Engineer and found to be acceptable. Remove rejected plants and materials promptly from the project area.

Final Plant Establishment Inspection: At the end of the 90-day plant establishment period, a final inspection will be performed to accept the landscape installation. At the time of final establishment inspection, all planting areas under this contract shall be free of weeds and neatly cultivated. All plants shall be alive and healthy, without signs of stress. Landscape areas shall be free of rills, rivulets, or erosion. An inspection of planting activities will be made by the Engineer in the presence of the contractor to substantiate that the completed work is in compliance with the requirements of the project. If, after the inspection, the Engineer is of the opinion that all work has been performed as per the contract documents and that all plant materials are in satisfactory growing condition, a written notice of final acceptance of the landscape installation and commencement of the 1-year warranty period will be issued.

Work requiring corrective action or replacement in the judgment of the Engineer shall be performed within 7 days after the final inspection. Corrective work and materials replacement shall be in accordance with the contract documents, and shall be made by the contractor at no additional cost to the project.

430.10 MEASUREMENT AND PAYMENT:

Add the following:

Alterations to the work will be measured and paid for in accordance with the requirements of MAG Section 104.

No separate measurement or payment will be made for the preparation and necessary modifications to the procedures manual as described herein. The work is considered incidental to the contracted items.

Traffic control, if required for the project, shall be in accordance with the Phoenix Barricade Manual upon approval by the Engineer and is considered as incidental to the contracted items. No separate measurement and payment will be made for this work.

SECTION 440 SPRINKLER IRRIGATION SYSTEM INSTALLATION

Irrigation installations for GI/LID projects shall conform to Section 440 of the MAG Uniform Standard Specifications, 2018 Revision to the 2015 Edition, and as specified herein.

440.1 DESCRIPTION:

Add the following:

Sections 215, 430, and 795 of the Standard Specifications and these special provisions contain requirements that apply to this Section.

As indicated in the contract documents, an automatic, underground irrigation system shall be installed in stormwater harvesting basins, vegetated bioswales, bioretention systems, curb extensions, and bioretention planters.

Irrigation systems shall be designed to allow for each type of LID treatment (stormwater harvesting basin, vegetated bioswale, bioretention systems, curb extensions, and bioretention planters) to be zoned independently from other LID treatments and from non-LID landscape improvements. For all treatments, trees and shrubs shall be valved separately.

SECTION 795 LANDSCAPE MATERIALS

795.4 ORGANIC SOIL CONDITIONERS:

Delete this subsection in its entirety and substitute with the following:

Compost shall be used as the organic soil conditioner. Compost shall consist of composted organic vegetative materials. Prior to being furnished on the project, compost mulch samples shall be tested for the specified microbiological and nutrient conditions, including maturity and stability, by a testing laboratory approved for testing of organic materials. Written test results shall be submitted to the Engineer for review and approval.

Compost material shall be dark brown in color with the parent material composted and no longer visible. The structure shall be a mixture of fine- and medium-size particles and humus crumbs. The maximum particle size shall be within the capacity of the contractor's equipment for application to the constructed slopes. The odor shall be that of rich humus with no ammonia or anaerobic odors.

Compost shall also meet these requirements:

Table 5. Compost

Cation Exchange Capacity (CEC)	Greater than 60 meq/100 g
Carbon: Nitrogen Ratio	Less than 20:1
pH (of extract)	6 - 8.5
Organic Matter Content	Greater than 25%
Total Nitrogen (not added)	Greater than 1%
Humic Acid	Greater than 5%
Maturity Index	Greater than 50% on Maturity Index at a 10:1 ratio
Stability	Less than 100 mb 02/Kg compost dry solids - hour

795.8 MISCELLANEOUS MATERIALS:

Add the following items:

795.8.4 Decomposed Granite:

Decomposed granite used as a surface treatment shall be washed and screened (no fines) or as specified in the contract documents. Submit material certificates from material producer and contractor, certifying that the granite meets these requirements. Submit 5-pound samples of decomposed granite in colors and sizes specified in the contract documents. Verify in writing to Engineer that there is sufficient supply from single source to supply entire project.

795.8.5 Bioretention Soil Media:

Shall comply with the requirements of Section 215 of these special provisions.

795.8.6 Sand:

Shall meet the requirements of 701.3 Fine Aggregate (Sand) except that the size and gradation shall be as specified for natural sand in ASTM C144.

795.8.7 Perforated Cleanout Riser:

Riser shall be 3-hole PVC of the size indicated in the contract documents and comply with ASTM D2329 for non-pressurized pipe condition.

795.8.8 Geosynthetic Fabric:

Shall be a woven fabric complying with Class A of Table 796-2 of the MAG Standards.

Contact herbicides and pesticides used must comply with all applicable state and Federal laws and be registered with the U.S. Environmental Protection Agency. Contact herbicides shall be quick acting and permit planting within 7 – 10 days of their use. Herbicides, insecticides and fungicides shall be applied as needed and in accordance with the manufacturer's recommendations.

GLOSSARY

Abstraction: The maximum amount of rainfall absorbed without producing runoff

Best Management Practices (BMP): Methods or techniques found to be the most effective and practical means in minimizing pollution while making the optimum use of the feature.

California bearing ratio (CBR): CBR is a penetration test for evaluation of the mechanical strength of natural ground, subgrades and base courses beneath new construction

Cubic feet per second (cfs): The volume of water flowing past a given point

Design storm: Recurrence interval storm over an identified time frame

Detention: Runoff Storage Area that detains water before it is released into a downstream conveyance facility

Head pressure: The internal energy of a fluid due to the pressure exerted on the boundary .

Heat island phenomenon: A phenomenon that occurs in developed areas where the replacement of natural land cover with paving, buildings, roads, and parking lots results in an increase in outdoor temperatures

Hydraulic radius (area / wetted perimeter) (R): Hydraulic parameter that is the area divided by the wetted perimeter.

Hydrologic soil type: Draining characteristics of the soil

Infiltration: Infiltration is the process by which water on the ground surface enters the soil. Infiltration rate in soil science is a measure of the rate at which soil is able to absorb rainfall

Median diameter of the soil (d50): Particle Size Distribution D50 is also known as median diameter or medium value of particle size distribution, it is the value of the particle diameter at 50% in the cumulative distribution.

Right-of-way (ROW): The right of way may be a specific grant of land or an "easement," which is a right to pass across another's land

"Softer" streets: Streets that have more vegetation, landscaping, and lower speeds

Standard proctor density (SPR): The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density

Time of concentration: The time required for a drop of water to travel from the most hydrologically remote point in the subcatchment to the point of collection.

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21. ***Low Impact Toolkit***, Cities of Mesa and Glendale, Arizona, 2015.
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23. ***Soil Science & Management***, 4th Edition, Edward J. Plaster, Thomson/Delmar Learning, 2003.

APPENDIX A: RAIN GAUGE MEASUREMENTS

Station No	Station Name	Data Begins:	Location	Number of Rainfall Events Observed	Number of Rainfall Events less than 0.5 inch	Ratio of rainfall events less than 0.5 inch
9900	Phoenix Dam 2B	6/29/2009	Thunderbird Rd. at 7th St.	205	170	0.83
9800	Dreamy Draw Dam	1/24/1984	1/4 mi. SSW of 24th St. & Dunlap Ave.	870	716	0.82
9300	Paradise Valley Country Club	7/11/1989	1/2 mi. N of Lincoln Dr. & Tatum Blvd.	797	675	0.85
89500	Bullard Wash @ Indian School Road	6/27/2006	Indian School Rd. @ Wigwam Blvd.	268	230	0.86
87800	White Tank FRS # 4	1/9/1986	1/4 mi. NE of Tuthill Rd. & Van Buren St.	633	547	0.86
87500	Camelback Rd. @ Citrus Rd.	5/10/2012	Camelback Road at Citrus Road	118	94	0.80
87300	White Tank FRS # 3	3/12/1986	4 mi. N of I-10 on the Jackrabbit Trail alignment	750	632	0.84
8700	East Fork Cave Creek Basin # 3	9/13/1994	1/2 mi. SW of Union Hills & Cave Creek Rd.	646	540	0.84
87000	Sun City West	3/30/1995	1/4 mi. SE of the Beardsley Rd. & Litchfield Rd. alignments	546	469	0.86
86700	Dysart Rd. @ Bell Rd.	10/25/1992	Dysart Rd. at Bell Rd.	622	523	0.84
86500	McMicken Dam South	2/13/2002	1/2 mi N of the Peoria and 195th Ave. alignments	353	296	0.84
86200	Ford Canyon Wash	2/5/2002	Alignments of Cactus and Tuthill Roads	396	316	0.80
85800	Dysart Drain @ Luke AFB	8/22/1996	1/4 mi. west of Northern Ave. & Litchfield Rd.	509	429	0.84
85500	Colter Channel @ El Mirage Rd.	6/29/1994	1/4 mi. N of Camelback and El Mirage Rd.	542	465	0.86
8500	E. Fork Cave Cr. near 7th Ave.	5/8/1997	1/2 mi. S of 7th Ave. & Greenway Rd.	585	503	0.86
85000	Agua Fria R. @ Buckeye Rd.	10/6/1988	Buckeye Rd. bridge over the Agua Fria River	704	592	0.84
84700	Mobile	12/15/2004	2 mi. SE of Mobile	292	249	0.85
84500	Upper Waterman Wash	6/23/1988	10 mi. WNW of Mobile	666	585	0.88
84200	Estrella Fan	11/15/1992	Alignments of El Mirage & Germann Roads	602	499	0.83
84000	Waterman Wash	5/10/1983	Alignments of Riggs & El Mirage Roads	815	679	0.83
83800	Gila River @ Estrella Parkway	2/28/1989	Estrella Pwky bridge over the Gila River	646	554	0.86
83500	Tuthill Rd. @ Ray Rd.	12/22/1994	1/2 mi. E of Tuthill and Ray Roads	491	429	0.87
83300	Waterman Wash @ Rainbow Valley Rd.	3/18/1999	Rainbow Valley & Queen Creek Roads	417	365	0.88
83000	Iron Dike	6/30/2009	4.5 miles NNE of Sunflower	410	313	0.76
82700	Bartlett Lake	8/31/2000	Bartlett Lake Sheriff Sub-station	579	455	0.79
82500	Horseshoe Lake	9/11/2000	Horseshoe Lake - SW corner near boat ramp	630	498	0.79

Station No	Station Name	Data Begins:	Location	Number of Rainfall Events Observed	Number of Rainfall Events less than 0.5 inch	Ratio of rainfall events less than 0.5 inch
82200	Sycamore Creek - Upper	6/19/2012	8 miles N of Sunflower	312	243	0.78
8200	E. Fork Cave Cr. Basin # 4	1/18/1994	1/4 mi. S of Union Hills Dr. & 32nd St.	594	487	0.82
82000	Sycamore Creek - West Fork	6/19/2012	5 miles NNW of Sunflower	265	200	0.75
81500	Spookhill FRS @ Brown Rd.	6/4/2008	Brown Rd. @ Red Mtn. Loop 202	257	214	0.83
81300	Apache Junction FRS	12/16/1981	1/3 mi. NW of Lost Dutchman & Idaho Rd.	1093	900	0.82
81000	Thunder Mountain	4/1/1982	1/2 mi. W of the alignments of Ellsworth & Indian School Roads	964	808	0.84
80700	Usery Park Weather Station	2/24/1994	1/4 mi. WNW of Crismon & Thomas Roads	680	556	0.82
80200	Usery Mountain Park	6/20/1985	Alignments of McDowell & Crismon Roads	958	782	0.82
79800	Spookhill FRS @ McKellips Rd.	6/19/2008	McKellips Rd. @ Loop 202	265	215	0.81
79500	Signal Butte FRS	11/10/1987	1/4 mi. NE of Signal Butte & Brown Roads	845	709	0.84
79300	Hesperus Wash	3/10/1997	Near Dixie Mine on east side of McDowell Mtns.	670	538	0.80
79000	Hesperus Dam	12/18/1996	1/4 mi. N of Richwood Ave. & Golden Eagle Blvd.	581	473	0.81
78500	Golden Eagle Blvd.	2/12/1997	0.1 mi. E of Morning Dove Dr. & Golden Eagle Blvd.	621	493	0.79
78200	North Heights Dam	10/11/1996	1/4 mi. SW of Sierra Madre Dr. & Golden Eagle Blvd.	598	476	0.80
7800	E. Fork Cave Cr. Basin # 1	3/2/1994	1/4 mi. E of Beardsley Rd. & Cave Creek Rd.	666	549	0.82
77800	Cloudburst Wash	3/13/1997	2 mi. NW of Sun Ridge Golf Course	647	513	0.79
77500	Sun Ridge Canyon Dam	2/4/1997	Near Lago Blvd. & Palisades Blvd.	614	495	0.81
77300	Stone Ridge Dam	12/11/1996	1/4 mi. W of Cholla Dr. and Fountain Hills Blvd.	592	482	0.81
77000	Camp Creek	7/18/2005	4 mi. SE of Seven Springs Campground	495	369	0.75
76700	Fountain Hills Fire Dept.	12/9/1993	Near Palisades Blvd. & Fountain Hills Blvd.	715	584	0.82
76500	Rackensack Canyon	6/28/2007	8 miles NE of Cave Creek	387	292	0.75
76200	Fraesfield Mountain	8/2/1989	1/4 mile N of Dixileta Dr. and 128th St.	1008	786	0.78
76000	McDowell Mountain Road	5/18/2004	In McDowell Mtn. Park, 2 miles N of Fountain Hills	416	345	0.83
75800	McDowell Mountain Park	8/6/1990	4 mi. WSW of Rio Verde	944	751	0.80
75500	Asher Hills	8/2/1990	Off Asher Dr. in McDowell Mtn. Park, 1 mi. west of Rio Verde	865	703	0.81
7500	Grand Ave. @ Peoria Ave.	7/11/1996	Grand Ave. and Peoria Ave.	503	421	0.84

Station No	Station Name	Data Begins:	Location	Number of Rainfall Events Observed	Number of Rainfall Events less than 0.5 inch	Ratio of rainfall events less than 0.5 inch
75000	Granite Reef Diversion	7/21/2005	Bush Hwy. near Granite Reef Dam	359	299	0.83
74700	Spookhill FRS	3/13/1984	1/2 mi. N of McDowell & Bush Hwy.	916	754	0.82
74500	Vekol Wash	3/7/1990	North of I-8 bridge at Vekol Road	849	742	0.87
74200	Picacho Wash	4/11/2012	SR 74 at Cotton Lane alignment	168	139	0.83
73800	Upper Trilby Wash	9/25/2001	2.2 miles north of Castle Hot Springs Road on Trilby Wash	516	399	0.77
73500	Circle City	10/1/1982	US 60/93, 14 mi. SE of Wickenburg	1004	807	0.80
73400	Vistancia Peak	9/1/2015	5.3 mi. SW of Lake Pleasant	64	50	0.78
73300	CAP @ 163rd Ave.	12/10/2002	CAP canal at 163rd Ave.	371	295	0.80
73200	Twin Buttes Wash	10/1/2015	1/4 mi. SE of Vistancia Blvd. & El Mirage Rd	65	55	0.85
73000	Northwest Regional Landfill	4/27/1993	Near 195th Ave. and Deer Valley Road	581	478	0.82
72500	Wittmann	5/13/1992	60/93 at Wittmann, 4 mi. SE of Circle City	700	576	0.82
72200	Douglas Ranch Rd.	7/16/2013	3.5 miles N of Patton Rd. & Hassayampa R.	130	108	0.83
72000	Patton Road	5/13/1992	7 mi. W of Grand Ave. on Patton Rd.	659	530	0.80
71700	McMicken Dam	3/20/1983	1/4 mi SE of Deer Valley Rd. and Cotton Ln.	750	639	0.85
71500	McMicken Dam @ Bell Rd.	9/8/2016	Bell Road at Perryville Rd. alignment	30	24	0.80
71300	McMicken Floodway	5/19/1992	1/2 mile north of Grand Ave. and Deer Valley Rd.	587	492	0.84
71000	Sauceda Wash	2/28/1990	6 mi. SSW of Gila Bend on SR 85	607	527	0.87
70700	Gila River @ 116th Ave.	1/26/1989	1/4 mi. NNW of 115th Ave. & Baseline Rd.	732	616	0.84
70500	South Mountain Fan	6/9/1993	Alignments of Ray Rd. & 35th Ave.	565	481	0.85
70200	Ahwatukee	3/4/1996	1/4 mi. SSW of Warner Rd. & 44th St.	559	471	0.84
7000	Missouri Ave. @ 16th St.	1/17/1991	SW corner of Missouri Ave. & 16th St.	735	598	0.81
70000	Pecos Basin	1/6/2009	1/4 mi. SW of I-10 & Loop 202	234	208	0.89
69000	South Mtn. Park HQ	5/1/1997	Alignments of Elliot Rd. & 7th Ave.	646	568	0.88
68900	Dobbins Rd. @ 19th Ave.	9/15/2016	1/4 mi. NW of 19th Ave. @ Dobbins Rd.	28	24	0.86
68500	South Mountain Park	10/1/1982	Alignments of Elliot Rd. & 24th St.	918	770	0.84
68200	Guadalupe FRS	6/29/1989	1/4 mi. SSW of Baseline Rd. & I-10	843	738	0.88

Station No	Station Name	Data Begins:	Location	Number of Rainfall Events Observed	Number of Rainfall Events less than 0.5 inch	Ratio of rainfall events less than 0.5 inch
6800	Camelback Rd. @ 24th Ave.	10/8/2015	24th Ave. north of Camelback Road	52	44	0.85
67800	Laveen Basin	11/7/2006	Southern & 43rd Avenues	268	235	0.88
67500	ASU South	7/14/1995	1/4 mi. NNE of Broadway Rd. & Mill Ave.	597	502	0.84
67300	Salt River @ Priest Dr.	9/21/1995	Salt River bridge at Priest Dr.	554	476	0.86
6700	Maryland Ave. @ 27th Ave.	12/22/1994	27th Ave. 1/2 mi. N of Bethany Home Rd.	594	505	0.85
67000	Salt River @ 40th St.	3/22/1996	South side of Salt River @ 40th St.	491	432	0.88
66800	Roeser Rd. @ 23rd Ave.	10/1/2015	23rd Ave. @ Roeser Rd.	56	51	0.91
66700	Roeser Rd. @ 2nd St.	2/12/1991	1/2 mi. SSE of Broadway Rd. & Central Ave.	637	544	0.85
66500	Cesar Chavez Park	8/15/1990	1/2 mi. SW of 35th Ave. & Baseline Rd.	679	588	0.87
66200	Skunk Creek near New River	6/28/2001	Skunk Creek at Fig Springs Rd., 3.5 miles east of New River	527	414	0.79
66000	Cline Creek	8/1/1981	4 miles east of New River	1242	982	0.79
65900	Sonoran Wash	10/13/2015	1.75 miles east of Loop 303 @ I-17	67	60	0.90
65800	Skunk Creek at I-17	11/7/1989	I-17 at Jomax Rd.	769	626	0.81
65700	Skunk Creek @ Carefree Hwy.	8/18/2015	Carefree Hwy., 0.7 mi. E of I-17	65	51	0.78
65500	Fig Springs	11/14/2001	3.5 miles east of New River	530	413	0.78
65300	Upper Cline Creek	11/21/2001	8 miles east of New River	545	441	0.81
6500	City of Glendale	7/6/1989	Grand Ave. & 63rd Ave.	717	606	0.85
65000	Adobe Dam	10/25/1982	1/4 mi. South of Deer Valley Road & 43rd Avenue	922	744	0.81
64700	Skunk Tank Wash	3/2/2006	0.2 mi. S of 7th Ave. & Desert Hills Dr.	327	270	0.83
64200	Tat Momolikot Dam	1/29/1998	19 mi. SW of Casa Grande	493	445	0.90
64000	Greene Wash @ SR 84	3/16/1994	10 mi. W of SR 93 & SR 84	572	497	0.87
63800	Santa Cruz River @ SR 84	3/16/1994	3 mi. W of SR 93 on SR 84	594	526	0.89
63500	Saguaro Lake	1/24/2000	MCSO yard, NW corner of the lake	559	444	0.79
63300	Whitlow Ranch Dam	1/8/1998	5 mi. NE of Florence Junction	652	526	0.81
63000	Cooks Mesa	3/21/1984	10 miles east of Black Canyon City	1460	1119	0.77
62700	New River Fire	7/20/2005	5 miles northeast of New River	407	308	0.76

Station No	Station Name	Data Begins:	Location	Number of Rainfall Events Observed	Number of Rainfall Events less than 0.5 inch	Ratio of rainfall events less than 0.5 inch
62500	New River Landfill	4/29/1993	4 mi. ENE of New Waddell Dam	664	542	0.82
62300	Sunup Ranch	6/10/1981	1 mi. SSW of New River	1148	901	0.78
6200	Buckeye Rd. @ 75th Ave.	8/1/1996	1/4 mi. N of Buckeye Rd. & 75th Ave.	487	418	0.86
62000	New River Dam	5/31/1986	1/2 mi. NE of Jomax Rd. and 83rd Ave.	809	660	0.82
61700	New River @ Bell Rd.	4/4/1990	Bell Road at 83rd Ave.	714	598	0.84
61500	New River @ Glendale Ave.	3/21/1990	On Glendale 1/2 mile east of 99th Ave.	690	596	0.86
61200	Reata Pass Dam	8/26/1993	1/2 mi. S of Dynamite Blvd. & 112th St.	777	616	0.79
61000	Rawhide Wash	7/22/1999	1/3 mi. W of Pima Rd. on Dynamite Blvd.	542	427	0.79
60800	Pima Rd. @ Jomax Rd.	5/6/1993	1/8 mi. NW of Pima Rd. & Jomax Rd.	745	600	0.81
60500	Pinnacle Peak Vista	4/21/1998	1/2 mi. SSE of Deer Valley Rd. & Pima Rd.	553	466	0.84
60300	Pima Rd. @ Union Hills Dr.	10/22/1997	1/4 mi. W of Pima Rd. & Union Hills Dr.	582	495	0.85
6000	Maryvale Municipal Golf Course	8/17/1989	1/4 mi. N of Indian School Rd. & 59th Ave.	755	645	0.85
60000	Reata Pass Wash	5/15/2001	1.6 mi. E of Pima Rd. on Pinnacle Peak Rd.	477	395	0.83
59700	Aztec Park	2/9/1998	Near Thunderbird & Frank Lloyd Wright	553	462	0.84
59500	IBW @ Shea Blvd.	6/9/1998	Shea Blvd. @ 52nd St.	505	436	0.86
59200	Berneil Wash	7/30/1998	Doubletree & Invergordon	503	431	0.86
59000	Lake Margherite	11/25/1997	1/4 mi. W of Doubletree & Hayden Roads	575	492	0.86
58800	Lost Dog Wash	7/13/1990	1/2 mi. NNW of Shea Blvd. & 128th St.	797	660	0.83
58600	CAP Reach11 Dike # 2	7/19/2016	0.4 miles NW of Bell Rd. & 64th St.	37	33	0.89
58300	IBW @ Sweetwater Ave.	12/27/1990	1/2 mi. E of 32nd St. & Sweetwater Ave.	702	584	0.83
58000	Tatum Basin Inflow	6/3/1994	Shea Blvd. @ 40th St.	583	485	0.83
57700	Thunderbird Academy	1/1/1982	1/4 mi. ESE of Thunderbird and Scottsdale	1016	863	0.85
57500	Granite Reef Wash	6/26/2007	On McDowell Rd. just E of Granite Reef Rd.	263	227	0.86
56800	IBW Interceptor Channel	9/28/1983	1/4 mi. SW of Pima Rd. & Indian Bend Rd.	909	762	0.84
56500	IBW @ Indian School Rd.	11/26/1997	Indian School Rd. @ Hayden Rd.	500	421	0.84
56300	IBW @ Indian Bend Rd.	3/25/1992	On IBW just S of Indian School Rd.	731	596	0.82

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56000	Osborn Rd. @ 64th St.	10/22/1997	Osborn Rd. @ 64th St.	504	436	0.87
55700	IBW @ McKellips Rd.	7/15/1985	On IBW 1/4 mi. S of McKellips Rd.	828	679	0.82
55500	Upper Martinez Creek	2/26/2002	3.3 mi. NE of Congress	526	412	0.78
55200	Antelope Creek	7/9/2003	6.5 mi. NNW of Wickenburg	451	353	0.78
5500	Salt River @ 67th Ave.	4/23/1998	67th Ave. at Roeser St. N of Salt River	437	379	0.87
55000	Bucks Well	12/11/2002	5.5 mi. NW of Congress	483	377	0.78
54500	Wilhoit	9/24/1981	10 miles SSW of Prescott	1771	1454	0.82
54300	Hassayampa R. @ Wagoner Rd.	12/19/1983	6 mi. ESE of Kirkland Junction	1389	1141	0.82
54000	Minnehaha	6/16/1981	11 miles E of Wagoner	1791	1402	0.78
53700	O'Brien Gulch	9/1/1981	11 miles NE of Wickenburg	1335	1047	0.78
53500	Hassayampa River @ Box Canyon	11/17/1983	6 miles N of Wickenburg	1079	905	0.84
53200	Burton Tank	3/19/2002	3 miles SSW of Congress	496	386	0.78
53000	Casandro Dam	8/15/1996	1.1 mi. W of the US60 / US93 junction	600	479	0.80
52800	Wickenburg Airport	8/3/1994	4.5 mi. W of the US60 / US93 junction	664	529	0.80
52500	Powder House Wash	5/18/1995	1/2 mi. NE of Constellation Rd. & US 60	616	502	0.81
52300	Constellation Road	8/3/1994	1.4 mi. NE of the US60 / US93 junction	682	555	0.81
52000	Casandro Wash	7/12/1994	2 mi. W of the US60 / US93 junction	689	546	0.79
51700	Flying E Wash	7/12/1994	3 mi. W of the US60 / US93 junction	686	546	0.80
51500	Flying E Tank	5/9/1995	6.3 mi. WSW of the US89 / US93 junction	648	518	0.80
51200	Hartman Wash	7/6/1994	6.3 mi. W of the US60 / US93 junction	701	564	0.80
51000	Black Mountain	7/6/1994	9 mi. W of the US60 / US93 junction	690	561	0.81
50800	Sols Wash near Matthie	8/4/1995	2 mile N of Wickenburg Airport	648	535	0.83
50500	Black Hill	6/15/1995	2.3 mi. WSW of the US93 / US89 junction	666	533	0.80
50300	Sols Tank	7/25/1995	6.3 mi. WNW of the US93/US89 junction	703	555	0.79
5000	Thomas Rd. @ 48th St.	1/30/1991	Thomas Rd. @ 48th St.	722	615	0.85
50000	Sols Wash Tributary @ US 93	5/2/1995	3.2 mi. NW of the US 93 / US 89 junction	694	556	0.80

Station No	Station Name	Data Begins:	Location	Number of Rainfall Events Observed	Number of Rainfall Events less than 0.5 inch	Ratio of rainfall events less than 0.5 inch
49700	Congress	6/16/1994	Junction of US 89 and SR 71	761	604	0.79
49500	Martinez Creek	11/23/1994	1 mi. E of the US93/US89 junction	676	560	0.83
49200	Mid-Martinez Creek	4/27/1995	4.5 mi. SE of Congress	732	584	0.80
49000	Stanton	6/16/1994	6.5 mi. E of Congress	871	696	0.80
48800	Buckeye FRS # 3	11/23/1992	1/4 mi. NE of I-10 & Watson Rd.	547	461	0.84
48500	Daggs Wash	11/8/2007	9.5 miles SW of Circle City	254	208	0.82
48300	Sun Valley Park @ Northern Ave.	8/2/2005	Northern Ave. @ Sun Valley Parkway	266	224	0.84
47700	Sols Wash @ SR 71	9/24/1981	1 mi. west of SR 71 & US 93	1178	925	0.79
47500	Box Wash	3/11/2003	9 mile SW of Wickenburg	386	302	0.78
4700	Old Crosscut Canal @ McDowell Rd.	7/27/1994	S of McDowell Rd. @ SR 143	601	518	0.86
47000	Vulture Mine Road	10/14/1981	3 mi. SW of the US60/US93 intersection	1094	893	0.82
46800	Twin Peaks	3/27/2003	6 miles SW of Wickenburg	368	287	0.78
46500	Sunnycove FRS	8/11/1986	1 mi. SW of the US 60/93 junction	865	698	0.81
46300	Belmont Mountains	12/16/2002	4.8 miles SW of the Wickenburg / Aguila Roads intersection	368	297	0.81
46000	Sunset FRS	5/11/1989	3/4 mi. WSW of the US 60/93 intersection	782	636	0.81
45700	Hassayampa River @ US 60	3/14/1994	Old US 60 bridge over Hassayampa R.	702	569	0.81
45200	Morristown	5/13/1992	US 60/93 10 mi. SE of Wickenburg	729	583	0.80
4500	Papago Park	8/15/1990	1/4 mi. N of McDowell Rd. & 52nd St.	738	646	0.88
45000	Jackrabbit Wash	9/14/1982	Intersection of Wickengurg and Aguila Roads	919	763	0.83
44800	Hassayampa Landfill	4/15/1993	2 mi. NW of Hassayampa	484	405	0.84
44500	Buckeye FRS #2	11/11/1992	Alignments of Yuma and Miller Roads	570	478	0.84
44000	Buckeye FRS #1	7/26/1983	Hassayampa R. @ I-10	789	664	0.84
43700	Dead Horse Wash	11/1/2000	Near Aguila Rd., 14 mi. SE of Aguila	419	348	0.83
4300	Phoenix Zoo Dam # 3	4/25/2016	1/2 mile NE of Galvin Pkwy & Van Buren St.	34	30	0.88
43000	Maricopa Mountains	4/21/2005	11 mi. ENE of Gila Bend on SR 238	255	209	0.82
42800	Rainbow Wash	11/6/2000	9 mi. S of Buckeye on SR 85	339	285	0.84

Station No	Station Name	Data Begins:	Location	Number of Rainfall Events Observed	Number of Rainfall Events less than 0.5 inch	Ratio of rainfall events less than 0.5 inch
42500	Gila Bend Landfill	4/7/1993	3 mi. N of US 80 & I-8	494	428	0.87
42300	Magma FRS	10/27/1988	7 mi. NNW of Florence	835	711	0.85
4200	Perry Park	8/22/1990	1/8 mi. S of Thomas Rd. & 32nd St.	773	665	0.86
42000	Gila River @ Olberg	4/12/1995	3 mi. ENE of Sacaton	586	523	0.89
41700	Gila River @ Maricopa Rd.	4/6/1995	Maricopa Rd. & Gila River bridge	524	455	0.87
41500	Gila Bend Mountains	6/1/1988	16 mi. NW of Painted Rock Dam	596	517	0.87
41200	4th of July Wash	3/14/2002	21 mi. W of Old US80 on Agua Caliente Rd.	312	254	0.81
41000	Copper Wash	2/20/2001	15 mi. N of Agua Caliente	304	246	0.81
40500	Bender Wash	1/12/1982	9 mi. E of Gila Bend on I-8	875	755	0.86
40300	Sand Tank Wash	7/21/1983	9 mi. SSE of Gila Bend	831	704	0.85
4000	Thomas Rd. @ 16th St.	1/17/1991	Thomas Rd. @ 16th St.	701	601	0.86
40000	Sand Tank Wash @ I-8	6/28/2001	I-8 bridge south of Gila Bend	316	271	0.86
39700	Salt River Landfill	1/30/1998	1/4 mi. N of Beeline Hwy. at Gilbert Rd.	529	433	0.82
39500	Salt River @ Val Vista Dr.	4/13/2011	1/2 mi. W of Val Vista at the Salt R.	161	134	0.83
39200	Weekes Wash @ Baseline Rd.	5/27/2008	Baseline Rd. @ Royal Palm Ln.	286	240	0.84
39000	Kings Ranch	9/13/1981	7 mi. ESE of Apache Junction	1139	926	0.81
38800	Bulldog Canyon	7/11/2007	2 mi. NW of McDowell & Tomahawk Roads	354	273	0.77
38500	Florence Junction	8/1/1982	4.5 mi. NW of Florence Junction	1137	914	0.80
38300	Wolverine Pass	7/12/2007	1/4 mi. N of McDowell & Tomahawk	330	265	0.80
3800	Grand Ave. @ 27th Ave.	10/11/1996	Near 28th Ave. & Grand Ave.	496	425	0.86
38000	Queen Cr. @ CAP Canal	1/14/1999	Queen Creek at CAP Canal	484	394	0.81
37700	Queen Cr. @ Rittenhouse Rd.	9/14/1993	1/3 mi. SE of Signal Butte & Chandler Heights	629	512	0.81
37500	Powerline Floodway	2/13/2008	Alignments of Ray & Ellsworth Roads	264	229	0.87
37300	Carney Springs	8/16/2016	6.2 miles NE of Peralta Rd. @ US 60	39	32	0.82
37200	Rittenhouse FRS	9/27/1988	Alignments of Goldfield & Germann Roads	819	693	0.85
37100	Peralta Road	8/16/2016	3.4 miles NE of Peralta Rd. @ US 60	42	33	0.79

Station No	Station Name	Data Begins:	Location	Number of Rainfall Events Observed	Number of Rainfall Events less than 0.5 inch	Ratio of rainfall events less than 0.5 inch
37000	Vineyard FRS	11/2/1983	Alignments of Tomahawk & Williams Field	992	827	0.83
36900	US 60 @ Gold Canyon	5/11/2016	US 60 at Superstition Mountain Dr.	43	33	0.77
36500	Apache Trail	4/14/1993	1/3 mi. NE of Broadway & Idaho Roads	712	581	0.82
36300	Sonoqui Wash near Hawes Rd.	4/23/1993	1/2 mi. SW of Ocotillo & Ellsworth Roads	580	481	0.83
36000	Queen Creek Road	5/1/1982	1/4 mi. NE of Queen Creek Rd. & Ellsworth	998	839	0.84
35700	Guadalupe Channel	8/7/1998	1/4 mi. E of Power Rd. and Guadalupe Rd.	510	433	0.85
35200	E. Maricopa Floodway @ Arizona Ave.	5/10/1989	SR 587 bridge 3 miles S of Riggs Rd.	745	640	0.86
3500	Jackson St. @ 7th Ave.	1/29/1991	County Building, 7th Ave. & Jackson St.	642	541	0.84
35000	Elliot Rd. @ Hawes Rd.	6/26/2001	NE corner of Elliot Rd. at Hawes Rd.	412	343	0.83
34800	EMF @ Queen Creek Rd.	1/18/1989	1/3 mi. W of Queen Creek Rd. and Higley	713	622	0.87
34500	Williams Field Road	7/3/2001	1/4 mi. N of Williams Field Rd. & Meridian	446	376	0.84
34300	E. Maricopa Floodway @ Broadway Rd.	8/10/1989	1/2 mi. SSE of Broadway & Higley Roads	741	621	0.84
34000	Falcon Field	10/1/1995	1/4 mi. NE of McKellips & Greenfield Rds.	588	504	0.86
33700	EMF below Powerline Floodway	4/15/2014	1/4 mi. SE of Ray Rd. & Power Rd.	93	82	0.88
33500	McDowell Rd. @ Meridian Rd.	4/23/2006	125 yards E of McDowell & Meridian Rds.	359	293	0.82
33200	McDowell Rd. @ Hawes Rd.	4/13/2006	100 yards W of McDowell & Hawes Roads	333	266	0.80
3300	Durango Complex	6/23/1980	27th Ave. & Durango St.	966	815	0.84
33000	Crossroads Park	12/18/1995	1/2 mi. NW of Ray Rd. & Greenfield Rd.	552	483	0.88
32800	Freestone Basin	12/19/1995	1/2 mi. SSE of Guadalupe & Lindsay Roads	565	495	0.88
32500	Chandler Airport	1/26/2006	1/4 mi. south of Queen Creek & McQueen	297	257	0.87
32300	Mesa Tower	7/19/1989	1/4 mi. NW of McQueen Rd. & Baseline Rd.	763	651	0.85
32000	Chandler Blvd. @ Arizona Ave.	7/25/1996	1/4 mi. W of Chandler Blvd. and Arizona Ave.	563	485	0.86
31700	Carriage Lane Park	3/26/1991	1/2 mi. S of Price & Gudalupe Roads	686	591	0.86
31500	Price Drain @ Loop 202	2/13/2001	Loop 202 at Loop 101	446	375	0.84
31200	Mountain View Park	3/21/1991	1/2 mi. N of University Dr. & Lindsay Rd.	708	589	0.83
31000	Fitch Park	3/27/1991	1/2 mi. N of University Dr. & Center St.	704	585	0.83

Station No	Station Name	Data Begins:	Location	Number of Rainfall Events Observed	Number of Rainfall Events less than 0.5 inch	Ratio of rainfall events less than 0.5 inch
30500	Joshua Tree	3/5/2002	4.5 mi. W of the US93 / SR71 junction	463	357	0.77
30300	Wood Tank	11/20/2002	8 miles NE of Aguila	417	338	0.81
3000	GateWay Community College	12/16/2003	40th St. & Van Buren St.	346	294	0.85
30000	Ritter Dam	11/21/2002	9 miles NE of Aguila	414	326	0.79
29700	Centennial Divide	8/21/2001	7 mi. W of the US60 / US93 junction	454	368	0.81
29500	Smith Peak	5/1/1980	13 mi. NW of Aguila	1186	996	0.84
29400	Alamo Road	11/19/2015	8 miles north of Wenden	54	47	0.87
29200	Centennial Wash	11/19/1981	19 miles W of Wickenburg	1020	855	0.84
29000	Centennial Wash near Aguila	6/5/2001	5 mi. NNE of the US 60/SR 71 junction	446	361	0.81
28800	Gladden	8/27/1982	US 60 at Gladden, 34 mi. W of Wickenburg	922	781	0.85
28500	Outlaw Hill	5/13/2002	S of US 60; 14 mi. E of Aguila	449	356	0.79
28300	Aguila VFD	9/19/2001	1/4 mi. SE of US 60 & Eagle Eye Rd.	417	353	0.85
28000	Narrows Damsite	9/1/1994	5 miles SE of Salome	489	409	0.84
27700	Upper Grass Wash	11/1/2002	7 miles east of Aguila	398	322	0.81
27500	Centennial Wash @ Wenden	9/2/1998	5.5 mi. NE of Salome on US 60 bridge	442	372	0.84
27000	Tiger Wash	9/15/1999	10 mi. N of Eagle Eye Rd. @ Salome Hwy.	424	344	0.81
26800	Tiger Wash Fan	9/21/1994	1 mi. W of Eagle Eye Rd. and 4 mi. N of Salome Highway	503	421	0.84
26500	Four Mile Wash	7/5/2001	Alignments of 371st Ave. & Glendale Ave.	360	302	0.84
26300	Upper Tiger Wash	11/1/1981	11 mi. S of Aguila off Eagle Eye Rd.	972	789	0.81
26000	Harquahala FRS	9/15/1993	10 mi. WNW of Tonopah	445	376	0.84
25700	Centennial Levee	3/7/1984	2 mi. S of I-10 & 4 mi. E of the western County boundary	696	582	0.84
25500	Winters Wash	7/11/2000	1 mi. N of Indian School & 403rd Ave.	385	321	0.83
25200	Saddleback FRS	12/16/1988	7 miles WSW of Tonopah	541	465	0.86
25000	Delaney Wash	12/20/1999	3 miles SSW of Tonopah	377	312	0.83
24700	Centennial Railroad	2/9/1990	8 mi. NW of Old US 80 at the Gila River	649	561	0.86
24500	Webb Mountain	5/22/2002	4 mi. W of Agua Caliente Rd. & Old US 80	335	270	0.81

Station No	Station Name	Data Begins:	Location	Number of Rainfall Events Observed	Number of Rainfall Events less than 0.5 inch	Ratio of rainfall events less than 0.5 inch
24300	Baseline Rd. @ 547th Ave.	5/24/2000	SW corner of Baseline and 547th Ave.	368	308	0.84
24000	Buckeye Rd. @ 547th Ave.	6/13/2000	Buckeye Rd. at 547th Ave.	341	279	0.82
23700	Cruff Wash	5/14/2002	6 mi. W of Agua Caliente Rd. @ Old US 80	332	267	0.80
23500	Eagle Eye Road @ CAP	6/17/2003	1.5 mi. S of Salome Hwy on Eagle Eye Rd.	287	243	0.85
23200	G&F Woolsey Peak	6/25/2003	8 miles SW of Gillespie Dam	309	252	0.82
23000	Sugarloaf Mountain	5/27/2004	16 mi. NW of Tonopah	328	271	0.83
22800	Centennial Trib. @ Dobbins Rd.	10/1/2012	7.5 mi. WSW of Palo Verde NGS	111	99	0.89
22000	New River Mesa	3/3/2009	11 mi. N of Cave Creek	328	256	0.78
21800	Seven Springs Wash	3/12/2002	11 mi. NE of Cave Creek	660	504	0.76
21500	Seven Springs	11/12/1981	15 mi. NNE of Cave Creek	1682	1336	0.79
21000	Carefree Ranch	7/15/1985	2.5 mi. NE of SkyRanch Airport	1108	883	0.80
20700	Cave Creek @ Spur Cross Rd.	6/16/1993	3.5 mi. N of Cave Creek	825	655	0.79
20600	Galloway Wash @ Galloway Rd.	8/16/2016	Galloway Rd. 1/4 mile N of Cave Creek Rd.	43	36	0.84
20200	Cave Creek Landfill	4/23/1993	1/2 mi. E of Carefree Hwy. & 40th St.	672	545	0.81
2000	Mt. Ord	10/28/1982	4 mi. E of Sunflower (and lots higher!)	1893	1574	0.83
20000	Stagecoach Wash	6/13/2001	1/2 mi. S of Cave Creek Rd. & Pima Rd.	526	416	0.79
19500	Cave Buttes Dam	1/25/1984	1/4 mi. N of Happy Valley Rd. & 16th St.	820	717	0.87
19300	Desert Hills Wash	3/2/2006	Joy Ranch Rd. at 16th St.	341	278	0.82
1900	Thompson Peak	7/27/1989	120th St. and Bell Rd. alignments	874	741	0.85
19000	Cave Creek	5/29/2003	1 mi. W of Cave Creek Town Hall	479	382	0.80
18700	Desert Mountain School	7/19/2006	1/4 mi. SE of Cloud Rd. & 7th Ave.	305	252	0.83
18500	Buckeye Rd. @ SR 85	9/20/2000	1/4 mi. E of Buckeye Rd. @ SR 85	346	304	0.88
18200	I-10 @ 355th Ave.	9/7/2001	3 mi. WNW of Hassayampa R. @ I-10	348	291	0.84
1800	White Tank Peak	4/1/1981	13 mi. N of Buckeye	1025	848	0.83
17800	Dewey	11/1/1982	5 mi. E of Dewey off Orme Ranch Rd.	1574	1313	0.83

Station No	Station Name	Data Begins:	Location	Number of Rainfall Events Observed	Number of Rainfall Events less than 0.5 inch	Ratio of rainfall events less than 0.5 inch
17500	I-17 @ SR 169	11/11/1987	West of Interstate 17 at State Route 169 (Cherry Rd.)	1356	1122	0.83
17300	Arizona Hunt Club	4/1/1981	5 mi. NNW of Cordes Junction	1504	1227	0.82
1700	Towers Mountain	5/1/1992	3 miles NW of Crown King	1630	1312	0.80
17000	Horner Mountain Ranch	4/1/1981	11 mi. ENE of Cordes Junction	1586	1303	0.82
16700	Horseshoe Ranch	5/1/1981	10 mi. SE of Cordes Junction	1440	1140	0.79
16500	Sunset Point	7/11/1981	Sunset Point Rest Area on I-17, 10 mi. N of Black Canyon City	1474	1165	0.79
1600	Yarnell Hill	7/13/1981	1 mile E of Yarnell	1547	1206	0.78
16000	Horsethief Basin	11/24/1986	At HB Lookout, 6 mi. SE of Crown King	1747	1430	0.82
15800	Columbia Hill	7/27/1981	5 mi. NNW of Castle Hot Springs	1292	970	0.75
15500	Garfias Mountain Ranch	4/14/1981	6 mi. WSW of Castle Hot Springs	1313	1012	0.77
15300	Lake Pleasant North	4/24/2001	North end of Lake Pleasant	454	364	0.80
1500	Harquahala Mountain	2/10/1994	36 miles WSW of Wickenburg	789	623	0.79
15000	Lake Pleasant	11/13/2008	South end of Lake Pleasant	254	207	0.81
14700	Agua Fria R. @ Grand Ave.	4/27/1994	Grand Ave. bridge at Agua Fria River	576	497	0.86
14500	El Mirage Drain	2/16/2006	½mile S of Pinnacle Peak and El Mirage	279	243	0.87
14200	Deer Valley Airport	1/23/1991	1/2 mi. N of Deer Valley Rd. and 7th Ave.	777	633	0.81
13800	ACDC @ 67th Ave.	6/7/1990	67th Ave. bridge at Arizona Canal	731	605	0.83
13500	Phoenix West Park	11/29/2001	Peoria Ave. at 7th Ave.	390	330	0.85
13300	Phoenix Basin # 7	10/17/1996	1/4 mi. SW of Thunderbird Rd. & 7th St.	530	445	0.84
1300	Mt. Oatman	4/1/1981	8 mi. WSW of Painted Rock Dam	804	674	0.84
12700	Phoenix Dam # 99	7/7/2009	32nd St. & SR 51	198	170	0.86
12500	Greenway @ 32nd Ave.	1/31/1991	1/4 mi. E of Greenway Rd. & 35th Ave.	702	587	0.84
1200	Humboldt Mountain	7/14/1981	13 mi. NE of Cave Creek	1585	1325	0.84
12000	ACDC @ Cave Creek	3/11/1997	Mountain View Rd. near 23rd Ave.	539	467	0.87
11800	Cave Creek @ Cactus Rd.	7/13/1991	1/4 mi. ENE of I-17 & Cactus Rd.	713	606	0.85

Station No	Station Name	Data Begins:	Location	Number of Rainfall Events Observed	Number of Rainfall Events less than 0.5 inch	Ratio of rainfall events less than 0.5 inch
11500	Phoenix Basin # 3	12/18/2001	Cave Creek Rd. @ 16th St.	376	317	0.84
11300	ACDC @ 43rd Ave.	11/14/1990	1/4 mi. NW of Peoria & 43rd Aves.	735	620	0.84
11000	10th St. Wash Basin # 1	10/23/1996	1/4 mi. SW of Peoria Ave. & Cave Creek Rd.	507	436	0.86
10500	ACDC @ 14th St.	2/9/1994	1/2 mi. N of Glendale Ave. & 14th St.	592	493	0.83
1000	Mt. Union	8/16/1982	10 miles SSE of Prescott	2519	2052	0.81
10000	ACDC @ 36th St.	2/24/1994	1/2 mi. N of 36th St. & Camelback Rd.	615	528	0.86

APPENDIX B: RAINFALL TABLES

Underground Storage Volume and Percolation Rates for Green Infrastructure
4-foot wide x 10-foot long storage area.

Width (ft)	Depth of reservoir layer (ft)	Length (ft)	Design Porosity (% Voids)	Infiltration Rate i (in/hr)	Infiltration Rate i (in/min)	cf/hr/sf	cf/hr	hrs	LID Storage Volume for Standard Design (cf)	Note
4	2	10	0.25	0.02	0.00033	0.002	0.07	300.00	20.00	Must be connected to another drainage facility
4	2	10	0.25	0.04	0.00067	0.003	0.13	150.00	20.00	Must be connected to another drainage facility
4	2	10	0.25	0.06	0.00100	0.005	0.20	100.00	20.00	Must be connected to another drainage facility
4	2	10	0.25	0.08	0.00133	0.007	0.27	75.00	20.00	Must be connected to another drainage facility
4	2	10	0.25	0.10	0.00167	0.008	0.33	60.00	20.00	Must be connected to another drainage facility
4	2	10	0.25	0.15	0.00250	0.013	0.50	40.00	20.00	Must be connected to another drainage facility
4	2	10	0.25	0.20	0.00333	0.017	0.67	30.00	20.00	
4	2	10	0.25	0.25	0.00417	0.021	0.83	24.00	20.00	
4	2	10	0.25	0.30	0.00500	0.025	1.00	20.00	20.00	
4	2	10	0.25	0.40	0.00667	0.033	1.33	15.00	20.00	
4	2	10	0.25	0.50	0.00833	0.042	1.67	12.00	20.00	
4	2	10	0.25	0.60	0.01000	0.050	2.00	10.00	20.00	
4	2	10	0.25	0.70	0.01167	0.058	2.33	8.57	20.00	
4	2	10	0.25	0.80	0.01333	0.067	2.67	7.50	20.00	
4	2	10	0.25	1.00	0.01667	0.083	3.33	6.00	20.00	
4	2	10	0.25	1.50	0.02500	0.125	5.00	4.00	20.00	
4	2	10	0.25	2.00	0.03333	0.167	6.67	3.00	20.00	
4	2	10	0.25	2.50	0.04167	0.208	8.33	2.40	20.00	
4	2	10	0.25	3.00	0.05000	0.250	10.00	2.00	20.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure 4-foot wide x 10-foot long storage area.

Width (ft)	Depth of reservoir layer (ft)	Length (ft)	Design Porosity (% Voids)	Infiltration Rate i (in/hr)	Infiltration Rate i (in/min)	cf/hr/sf	cf/hr	hrs	LID Storage Volume for Standard Design (cf)	Note
4	4	10	0.25	0.02	0.00033	0.002	0.07	600.00	40.00	Must be connected to another drainage facility
4	4	10	0.25	0.04	0.00067	0.003	0.13	300.00	40.00	Must be connected to another drainage facility
4	4	10	0.25	0.06	0.00100	0.005	0.20	200.00	40.00	Must be connected to another drainage facility
4	4	10	0.25	0.08	0.00133	0.007	0.27	150.00	40.00	Must be connected to another drainage facility
4	4	10	0.25	0.10	0.00167	0.008	0.33	120.00	40.00	Must be connected to another drainage facility
4	4	10	0.25	0.15	0.00250	0.013	0.50	80.00	40.00	Must be connected to another drainage facility
4	4	10	0.25	0.20	0.00333	0.017	0.67	60.00	40.00	Must be connected to another drainage facility
4	4	10	0.25	0.25	0.00417	0.021	0.83	48.00	40.00	Must be connected to another drainage facility
4	4	10	0.25	0.30	0.00500	0.025	1.00	40.00	40.00	Must be connected to another drainage facility
4	4	10	0.25	0.40	0.00667	0.033	1.33	30.00	40.00	
4	4	10	0.25	0.50	0.00833	0.042	1.67	24.00	40.00	
4	4	10	0.25	0.60	0.01000	0.050	2.00	20.00	40.00	
4	4	10	0.25	0.70	0.01167	0.058	2.33	17.14	40.00	
4	4	10	0.25	0.80	0.01333	0.067	2.67	15.00	40.00	
4	4	10	0.25	1.00	0.01667	0.083	3.33	12.00	40.00	
4	4	10	0.25	1.50	0.02500	0.125	5.00	8.00	40.00	
4	4	10	0.25	2.00	0.03333	0.167	6.67	6.00	40.00	
4	4	10	0.25	2.50	0.04167	0.208	8.33	4.80	40.00	
4	4	10	0.25	3.00	0.05000	0.250	10.00	4.00	40.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure 4-foot wide x 10-foot long storage area.

Width	Depth of reservoir layer	Length	Design Porosity (% Voids)	Infiltration Rate i					LID Storage Volume for Standard Design	Note
(ft)	(ft)	(ft)		(in/hr)	(in/min)	cf/hr/sf	cf/hr	hrs	(cf)	
4	6	10	0.25	0.02	0.00033	0.002	0.07	900.00	60.00	Must be connected to another drainage facility
4	6	10	0.25	0.04	0.00067	0.003	0.13	450.00	60.00	Must be connected to another drainage facility
4	6	10	0.25	0.06	0.00100	0.005	0.20	300.00	60.00	Must be connected to another drainage facility
4	6	10	0.25	0.08	0.00133	0.007	0.27	225.00	60.00	Must be connected to another drainage facility
4	6	10	0.25	0.10	0.00167	0.008	0.33	180.00	60.00	Must be connected to another drainage facility
4	6	10	0.25	0.15	0.00250	0.013	0.50	120.00	60.00	Must be connected to another drainage facility
4	6	10	0.25	0.20	0.00333	0.017	0.67	90.00	60.00	Must be connected to another drainage facility
4	6	10	0.25	0.25	0.00417	0.021	0.83	72.00	60.00	Must be connected to another drainage facility
4	6	10	0.25	0.30	0.00500	0.025	1.00	60.00	60.00	Must be connected to another drainage facility
4	6	10	0.25	0.40	0.00667	0.033	1.33	45.00	60.00	Must be connected to another drainage facility
4	6	10	0.25	0.50	0.00833	0.042	1.67	36.00	60.00	
4	6	10	0.25	0.60	0.01000	0.050	2.00	30.00	60.00	
4	6	10	0.25	0.70	0.01167	0.058	2.33	25.71	60.00	
4	6	10	0.25	0.80	0.01333	0.067	2.67	22.50	60.00	
4	6	10	0.25	1.00	0.01667	0.083	3.33	18.00	60.00	
4	6	10	0.25	1.50	0.02500	0.125	5.00	12.00	60.00	
4	6	10	0.25	2.00	0.03333	0.167	6.67	9.00	60.00	
4	6	10	0.25	2.50	0.04167	0.208	8.33	7.20	60.00	
4	6	10	0.25	3.00	0.05000	0.250	10.00	6.00	60.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure
4-foot wide x 10-foot long storage area.

Width	Depth of reservoir layer	Length	Design Porosity (% Voids)	Infiltration Rate i					LID Storage Volume for Standard Design	Note
(ft)	(ft)	(ft)		(in/hr)	(in/min)	cf/hr/sf	cf/hr	hrs	(cf)	
4	8	10	0.25	0.02	0.00033	0.002	0.07	1200.00	80.00	Must be connected to another drainage facility
4	8	10	0.25	0.04	0.00067	0.003	0.13	600.00	80.00	Must be connected to another drainage facility
4	8	10	0.25	0.06	0.00100	0.005	0.20	400.00	80.00	Must be connected to another drainage facility
4	8	10	0.25	0.08	0.00133	0.007	0.27	300.00	80.00	Must be connected to another drainage facility
4	8	10	0.25	0.10	0.00167	0.008	0.33	240.00	80.00	Must be connected to another drainage facility
4	8	10	0.25	0.15	0.00250	0.013	0.50	160.00	80.00	Must be connected to another drainage facility
4	8	10	0.25	0.20	0.00333	0.017	0.67	120.00	80.00	Must be connected to another drainage facility
4	8	10	0.25	0.25	0.00417	0.021	0.83	96.00	80.00	Must be connected to another drainage facility
4	8	10	0.25	0.30	0.00500	0.025	1.00	80.00	80.00	Must be connected to another drainage facility
4	8	10	0.25	0.40	0.00667	0.033	1.33	60.00	80.00	Must be connected to another drainage facility
4	8	10	0.25	0.50	0.00833	0.042	1.67	48.00	80.00	Must be connected to another drainage facility
4	8	10	0.25	0.60	0.01000	0.050	2.00	40.00	80.00	Must be connected to another drainage facility
4	8	10	0.25	0.70	0.01167	0.058	2.33	34.29	80.00	
4	8	10	0.25	0.80	0.01333	0.067	2.67	30.00	80.00	
4	8	10	0.25	1.00	0.01667	0.083	3.33	24.00	80.00	
4	8	10	0.25	1.50	0.02500	0.125	5.00	16.00	80.00	
4	8	10	0.25	2.00	0.03333	0.167	6.67	12.00	80.00	
4	8	10	0.25	2.50	0.04167	0.208	8.33	9.60	80.00	
4	8	10	0.25	3.00	0.05000	0.250	10.00	8.00	80.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure
5-foot wide x 10-foot long storage area.

Width	Depth of reservoir layer	Length	Design Porosity (% Voids)	Infiltration Rate i					LID Storage Volume for Standard Design	Note
(ft)	(ft)	(ft)		(in/hr)	(in/min)	cf/hr/sf	cf/hr	hrs	(cf)	
5	2	10	0.25	0.02	0.00033	0.002	0.08	300.00	25.00	Must be connected to another drainage facility
5	2	10	0.25	0.04	0.00067	0.003	0.17	150.00	25.00	Must be connected to another drainage facility
5	2	10	0.25	0.06	0.00100	0.005	0.25	100.00	25.00	Must be connected to another drainage facility
5	2	10	0.25	0.08	0.00133	0.007	0.33	75.00	25.00	Must be connected to another drainage facility
5	2	10	0.25	0.10	0.00167	0.008	0.42	60.00	25.00	Must be connected to another drainage facility
5	2	10	0.25	0.15	0.00250	0.013	0.63	40.00	25.00	Must be connected to another drainage facility
5	2	10	0.25	0.20	0.00333	0.017	0.83	30.00	25.00	
5	2	10	0.25	0.25	0.00417	0.021	1.04	24.00	25.00	
5	2	10	0.25	0.30	0.00500	0.025	1.25	20.00	25.00	
5	2	10	0.25	0.40	0.00667	0.033	1.67	15.00	25.00	
5	2	10	0.25	0.50	0.00833	0.042	2.08	12.00	25.00	
5	2	10	0.25	0.60	0.01000	0.050	2.50	10.00	25.00	
5	2	10	0.25	0.70	0.01167	0.058	2.92	8.57	25.00	
5	2	10	0.25	0.80	0.01333	0.067	3.33	7.50	25.00	
5	2	10	0.25	1.00	0.01667	0.083	4.17	6.00	25.00	
5	2	10	0.25	1.50	0.02500	0.125	6.25	4.00	25.00	
5	2	10	0.25	2.00	0.03333	0.167	8.33	3.00	25.00	
5	2	10	0.25	2.50	0.04167	0.208	10.42	2.40	25.00	
4	8	10	0.25	3.00	0.05000	0.250	10.00	8.00	80.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure
5-foot wide x 10-foot long storage area.

Width	Depth of reservoir layer	Length	Design Porosity (% Voids)	Infiltration Rate i					LID Storage Volume for Standard Design	Note
(ft)	(ft)	(ft)		(in/hr)	(in/min)	cf/hr/sf	cf/hr	hrs	(cf)	
5	4	10	0.25	0.02	0.00033	0.002	0.08	600.00	50.00	Must be connected to another drainage facility
5	4	10	0.25	0.04	0.00067	0.003	0.17	300.00	50.00	Must be connected to another drainage facility
5	4	10	0.25	0.06	0.00100	0.005	0.25	200.00	50.00	Must be connected to another drainage facility
5	4	10	0.25	0.08	0.00133	0.007	0.33	150.00	50.00	Must be connected to another drainage facility
5	4	10	0.25	0.10	0.00167	0.008	0.42	120.00	50.00	Must be connected to another drainage facility
5	4	10	0.25	0.15	0.00250	0.013	0.63	80.00	50.00	Must be connected to another drainage facility
5	4	10	0.25	0.20	0.00333	0.017	0.83	60.00	50.00	Must be connected to another drainage facility
5	4	10	0.25	0.25	0.00417	0.021	1.04	48.00	50.00	Must be connected to another drainage facility
5	4	10	0.25	0.30	0.00500	0.025	1.25	40.00	50.00	Must be connected to another drainage facility
5	4	10	0.25	0.40	0.00667	0.033	1.67	30.00	50.00	
5	4	10	0.25	0.50	0.00833	0.042	2.08	24.00	50.00	
5	4	10	0.25	0.60	0.01000	0.050	2.50	20.00	50.00	
5	4	10	0.25	0.70	0.01167	0.058	2.92	17.14	50.00	
5	4	10	0.25	0.80	0.01333	0.067	3.33	15.00	50.00	
5	4	10	0.25	1.00	0.01667	0.083	4.17	12.00	50.00	
5	4	10	0.25	1.50	0.02500	0.125	6.25	8.00	50.00	
5	4	10	0.25	2.00	0.03333	0.167	8.33	6.00	50.00	
5	4	10	0.25	2.50	0.04167	0.208	10.42	4.80	50.00	
5	4	10	0.25	3.00	0.05000	0.250	12.50	4.00	50.00	

nderground Storage Volume and Percolation Rates for Green Infrastructure
5-foot wide x 10-foot long storage area.

Width (ft)	Depth of reservoir layer (ft)	Length (ft)	Design Porosity (% Voids)	Infiltration Rate i (in/hr)	(in/min)	cf/hr/sf	cf/hr	hrs	LID Storage Volume for Standard Design (cf)	Note
5	6	10	0.25	0.02	0.00033	0.002	0.08	900.00	75.00	Must be connected to another drainage facility
5	6	10	0.25	0.04	0.00067	0.003	0.17	450.00	75.00	Must be connected to another drainage facility
5	6	10	0.25	0.06	0.00100	0.005	0.25	300.00	75.00	Must be connected to another drainage facility
5	6	10	0.25	0.08	0.00133	0.007	0.33	225.00	75.00	Must be connected to another drainage facility
5	6	10	0.25	0.10	0.00167	0.008	0.42	180.00	75.00	Must be connected to another drainage facility
5	6	10	0.25	0.15	0.00250	0.013	0.63	120.00	75.00	Must be connected to another drainage facility
5	6	10	0.25	0.20	0.00333	0.017	0.83	90.00	75.00	Must be connected to another drainage facility
5	6	10	0.25	0.25	0.00417	0.021	1.04	72.00	75.00	Must be connected to another drainage facility
5	6	10	0.25	0.30	0.00500	0.025	1.25	60.00	75.00	Must be connected to another drainage facility
5	6	10	0.25	0.40	0.00667	0.033	1.67	45.00	75.00	Must be connected to another drainage facility
5	6	10	0.25	0.50	0.00833	0.042	2.08	36.00	75.00	Must be connected to another drainage facility
5	6	10	0.25	0.60	0.01000	0.050	2.50	30.00	75.00	
5	6	10	0.25	0.70	0.01167	0.058	2.92	25.71	75.00	
5	6	10	0.25	0.80	0.01333	0.067	3.33	22.50	75.00	
5	6	10	0.25	1.00	0.01667	0.083	4.17	18.00	75.00	
5	6	10	0.25	1.50	0.02500	0.125	6.25	12.00	75.00	
5	6	10	0.25	2.00	0.03333	0.167	8.33	9.00	75.00	
5	6	10	0.25	2.50	0.04167	0.208	10.42	7.20	75.00	
5	6	10	0.25	3.00	0.05000	0.250	12.50	6.00	75.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure
5-foot wide x 10-foot long storage area.

Width	Depth of reservoir layer	Length	Design Porosity (% Voids)	Infiltration Rate i					LID Storage Volume for Standard Design	Note
(ft)	(ft)	(ft)		(in/hr)	(in/min)	cf/hr/sf	cf/hr	hrs	(cf)	
5	8	10	0.25	0.02	0.00033	0.002	0.08	1200.00	100.00	Must be connected to another drainage facility
5	8	10	0.25	0.04	0.00067	0.003	0.17	600.00	100.00	Must be connected to another drainage facility
5	8	10	0.25	0.06	0.00100	0.005	0.25	400.00	100.00	Must be connected to another drainage facility
5	8	10	0.25	0.08	0.00133	0.007	0.33	300.00	100.00	Must be connected to another drainage facility
5	8	10	0.25	0.10	0.00167	0.008	0.42	240.00	100.00	Must be connected to another drainage facility
5	8	10	0.25	0.15	0.00250	0.013	0.63	160.00	100.00	Must be connected to another drainage facility
5	8	10	0.25	0.20	0.00333	0.017	0.83	120.00	100.00	Must be connected to another drainage facility
5	8	10	0.25	0.25	0.00417	0.021	1.04	96.00	100.00	Must be connected to another drainage facility
5	8	10	0.25	0.30	0.00500	0.025	1.25	80.00	100.00	Must be connected to another drainage facility
5	8	10	0.25	0.40	0.00667	0.033	1.67	60.00	100.00	Must be connected to another drainage facility
5	8	10	0.25	0.50	0.00833	0.042	2.08	48.00	100.00	Must be connected to another drainage facility
5	8	10	0.25	0.60	0.01000	0.050	2.50	40.00	100.00	Must be connected to another drainage facility
5	8	10	0.25	0.70	0.01167	0.058	2.92	34.29	100.00	
5	8	10	0.25	0.80	0.01333	0.067	3.33	30.00	100.00	
5	8	10	0.25	1.00	0.01667	0.083	4.17	24.00	100.00	
5	8	10	0.25	1.50	0.02500	0.125	6.25	16.00	100.00	
5	8	10	0.25	2.00	0.03333	0.167	8.33	12.00	100.00	
5	8	10	0.25	2.50	0.04167	0.208	10.42	9.60	100.00	
5	8	10	0.25	3.00	0.05000	0.250	12.50	8.00	100.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure
6-foot wide x 10-foot long storage area.

Width	Depth of reservoir layer	Length	Design Porosity (% Voids)	Infiltration Rate i					LID Storage Volume for Standard Design	Note
(ft)	(ft)	(ft)		(in/hr)	(in/min)	cf/hr/sf	cf/hr	hrs	(cf)	
6	2	10	0.25	0.02	0.00033	0.002	0.10	300.00	30.00	Must be connected to another drainage facility
6	2	10	0.25	0.04	0.00067	0.003	0.20	150.00	30.00	Must be connected to another drainage facility
6	2	10	0.25	0.06	0.00100	0.005	0.30	100.00	30.00	Must be connected to another drainage facility
6	2	10	0.25	0.08	0.00133	0.007	0.40	75.00	30.00	Must be connected to another drainage facility
6	2	10	0.25	0.10	0.00167	0.008	0.50	60.00	30.00	
6	2	10	0.25	0.15	0.00250	0.013	0.75	40.00	30.00	
6	2	10	0.25	0.20	0.00333	0.017	1.00	30.00	30.00	
6	2	10	0.25	0.25	0.00417	0.021	1.25	24.00	30.00	
6	2	10	0.25	0.30	0.00500	0.025	1.50	20.00	30.00	
6	2	10	0.25	0.40	0.00667	0.033	2.00	15.00	30.00	
6	2	10	0.25	0.50	0.00833	0.042	2.50	12.00	30.00	
6	2	10	0.25	0.60	0.01000	0.050	3.00	10.00	30.00	
6	2	10	0.25	0.70	0.01167	0.058	3.50	8.57	30.00	
6	2	10	0.25	0.80	0.01333	0.067	4.00	7.50	30.00	
6	2	10	0.25	1.00	0.01667	0.083	5.00	6.00	30.00	
6	2	10	0.25	1.50	0.02500	0.125	7.50	4.00	30.00	
6	2	10	0.25	2.00	0.03333	0.167	10.00	3.00	30.00	
6	2	10	0.25	2.50	0.04167	0.208	12.50	2.40	30.00	
6	2	10	0.25	3.00	0.05000	0.250	15.00	2.00	30.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure
6-foot wide x 10-foot long storage area.

Width	*Depth of reservoir layer*	*Length*	*Design Porosity (% Voids)*	*Infiltration Rate* i					*LID Storage Volume for Standard Design*	*Note*
(ft)	(ft)	(ft)		(in/hr)	(in/min)	cf/hr/sf	cf/hr	hrs	(cf)	
6	4	10	0.25	0.02	0.00033	0.002	0.10	600.00	60.00	Must be connected to another drainage facility
6	4	10	0.25	0.04	0.00067	0.003	0.20	300.00	60.00	Must be connected to another drainage facility
6	4	10	0.25	0.06	0.00100	0.005	0.30	200.00	60.00	Must be connected to another drainage facility
6	4	10	0.25	0.08	0.00133	0.007	0.40	150.00	60.00	Must be connected to another drainage facility
6	4	10	0.25	0.10	0.00167	0.008	0.50	120.00	60.00	Must be connected to another drainage facility
6	4	10	0.25	0.15	0.00250	0.013	0.75	80.00	60.00	Must be connected to another drainage facility
6	4	10	0.25	0.20	0.00333	0.017	1.00	60.00	60.00	
6	4	10	0.25	0.25	0.00417	0.021	1.25	48.00	60.00	Must be connected to another drainage facility
6	4	10	0.25	0.30	0.00500	0.025	1.50	40.00	60.00	Must be connected to another drainage facility
6	4	10	0.25	0.40	0.00667	0.033	2.00	30.00	60.00	
6	4	10	0.25	0.50	0.00833	0.042	2.50	24.00	60.00	
6	4	10	0.25	0.60	0.01000	0.050	3.00	20.00	60.00	
6	4	10	0.25	0.70	0.01167	0.058	3.50	17.14	60.00	
6	4	10	0.25	0.80	0.01333	0.067	4.00	15.00	60.00	
6	4	10	0.25	1.00	0.01667	0.083	5.00	12.00	60.00	
6	4	10	0.25	1.50	0.02500	0.125	7.50	8.00	60.00	
6	4	10	0.25	2.00	0.03333	0.167	10.00	6.00	60.00	
6	4	10	0.25	2.50	0.04167	0.208	12.50	4.80	60.00	
6	4	10	0.25	3.00	0.05000	0.250	15.00	4.00	60.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure 6-foot wide x 10-foot long storage area.

Width	Depth of reservoir layer	Length	Design Porosity (% Voids)	Infiltration Rate i					LID Storage Volume for Standard Design	Note
(ft)	(ft)	(ft)		(in/hr)	(in/min)	cf/hr/sf	cf/hr	hrs	(cf)	
6	6	10	0.25	0.02	0.00033	0.002	0.10	900.00	90.00	Must be connected to another drainage facility
6	6	10	0.25	0.04	0.00067	0.003	0.20	450.00	90.00	Must be connected to another drainage facility
6	6	10	0.25	0.06	0.00100	0.005	0.30	300.00	90.00	Must be connected to another drainage facility
6	6	10	0.25	0.08	0.00133	0.007	0.40	225.00	90.00	Must be connected to another drainage facility
6	6	10	0.25	0.10	0.00167	0.008	0.50	180.00	90.00	Must be connected to another drainage facility
6	6	10	0.25	0.15	0.00250	0.013	0.75	120.00	90.00	Must be connected to another drainage facility
6	6	10	0.25	0.20	0.00333	0.017	1.00	90.00	90.00	Must be connected to another drainage facility
6	6	10	0.25	0.25	0.00417	0.021	1.25	72.00	90.00	Must be connected to another drainage facility
6	6	10	0.25	0.30	0.00500	0.025	1.50	60.00	90.00	Must be connected to another drainage facility
6	6	10	0.25	0.40	0.00667	0.033	2.00	45.00	90.00	Must be connected to another drainage facility
6	6	10	0.25	0.50	0.00833	0.042	2.50	36.00	90.00	
6	6	10	0.25	0.60	0.01000	0.050	3.00	30.00	90.00	
6	6	10	0.25	0.70	0.01167	0.058	3.50	25.71	90.00	
6	6	10	0.25	0.80	0.01333	0.067	4.00	22.50	90.00	
6	6	10	0.25	1.00	0.01667	0.083	5.00	18.00	90.00	
6	6	10	0.25	1.50	0.02500	0.125	7.50	12.00	90.00	
6	6	10	0.25	2.00	0.03333	0.167	10.00	9.00	90.00	
6	6	10	0.25	2.50	0.04167	0.208	12.50	7.20	90.00	
6	6	10	0.25	3.00	0.05000	0.250	15.00	6.00	90.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure 6-foot wide x 10-foot long storage area.

Width (ft)	Depth of reservoir layer (ft)	Length (ft)	Design Porosity (% Voids)	Infiltration Rate i (in/hr)	(in/min)	cf/hr/sf	cf/hr	hrs	LID Storage Volume for Standard Design (cf)	Note
6	8	10	0.25	0.02	0.00033	0.002	0.10	1200.00	120.00	Must be connected to another drainage facility
6	8	10	0.25	0.04	0.00067	0.003	0.20	600.00	120.00	Must be connected to another drainage facility
6	8	10	0.25	0.06	0.00100	0.005	0.30	400.00	120.00	Must be connected to another drainage facility
6	8	10	0.25	0.08	0.00133	0.007	0.40	300.00	120.00	Must be connected to another drainage facility
6	8	10	0.25	0.10	0.00167	0.008	0.50	240.00	120.00	Must be connected to another drainage facility
6	8	10	0.25	0.15	0.00250	0.013	0.75	160.00	120.00	Must be connected to another drainage facility
6	8	10	0.25	0.20	0.00333	0.017	1.00	120.00	120.00	Must be connected to another drainage facility
6	8	10	0.25	0.25	0.00417	0.021	1.25	96.00	120.00	Must be connected to another drainage facility
6	8	10	0.25	0.30	0.00500	0.025	1.50	80.00	120.00	Must be connected to another drainage facility
6	8	10	0.25	0.40	0.00667	0.033	2.00	60.00	120.00	Must be connected to another drainage facility
6	8	10	0.25	0.50	0.00833	0.042	2.50	48.00	120.00	Must be connected to another drainage facility
6	8	10	0.25	0.60	0.01000	0.050	3.00	40.00	120.00	Must be connected to another drainage facility
6	8	10	0.25	0.70	0.01167	0.058	3.50	34.29	120.00	
6	8	10	0.25	0.80	0.01333	0.067	4.00	30.00	120.00	
6	8	10	0.25	1.00	0.01667	0.083	5.00	24.00	120.00	
6	8	10	0.25	1.50	0.02500	0.125	7.50	16.00	120.00	
6	8	10	0.25	2.00	0.03333	0.167	10.00	12.00	120.00	
6	8	10	0.25	2.50	0.04167	0.208	12.50	9.60	120.00	
6	8	10	0.25	3.00	0.05000	0.250	15.00	8.00	120.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure
8-foot wide x 10-foot long storage area.

Width	Depth of reservoir layer	Length	Design Porosity (% Voids)	Infiltration Rate i					LID Storage Volume for Standard Design	Note
(ft)	(ft)	(ft)		(in/hr)	(in/min)	cf/hr/sf	cf/hr	hrs	(cf)	
8	2	10	0.25	0.02	0.00033	0.002	0.13	300.00	40.00	Must be connected to another drainage facility
8	2	10	0.25	0.04	0.00067	0.003	0.27	150.00	40.00	Must be connected to another drainage facility
8	2	10	0.25	0.06	0.00100	0.005	0.40	100.00	40.00	Must be connected to another drainage facility
8	2	10	0.25	0.08	0.00133	0.007	0.53	75.00	40.00	Must be connected to another drainage facility
8	2	10	0.25	0.10	0.00167	0.008	0.67	60.00	40.00	Must be connected to another drainage facility
8	2	10	0.25	0.15	0.00250	0.013	1.00	40.00	40.00	Must be connected to another drainage facility
8	2	10	0.25	0.20	0.00333	0.017	1.33	30.00	40.00	
8	2	10	0.25	0.25	0.00417	0.021	1.67	24.00	40.00	
8	2	10	0.25	0.30	0.00500	0.025	2.00	20.00	40.00	
8	2	10	0.25	0.40	0.00667	0.033	2.67	15.00	40.00	
8	2	10	0.25	0.50	0.00833	0.042	3.33	12.00	40.00	
8	2	10	0.25	0.60	0.01000	0.050	4.00	10.00	40.00	
8	2	10	0.25	0.70	0.01167	0.058	4.67	8.57	40.00	
8	2	10	0.25	0.80	0.01333	0.067	5.33	7.50	40.00	
8	2	10	0.25	1.00	0.01667	0.083	6.67	6.00	40.00	
8	2	10	0.25	1.50	0.02500	0.125	10.00	4.00	40.00	
8	2	10	0.25	2.00	0.03333	0.167	13.33	3.00	40.00	
8	2	10	0.25	2.50	0.04167	0.208	16.67	2.40	40.00	
8	2	10	0.25	3.00	0.05000	0.250	20.00	2.00	40.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure 8-foot wide x 10-foot long storage area.

Width (ft)	Depth of reservoir layer (ft)	Length (ft)	Design Porosity (% Voids)	Infiltration Rate i (in/hr)	Infiltration Rate i (in/min)	cf/hr/sf	cf/hr	hrs	LID Storage Volume for Standard Design (cf)	Note
8	4	10	0.25	0.02	0.00033	0.002	0.13	600.00	80.00	Must be connected to another drainage facility
8	4	10	0.25	0.04	0.00067	0.003	0.27	300.00	80.00	Must be connected to another drainage facility
8	4	10	0.25	0.06	0.00100	0.005	0.40	200.00	80.00	Must be connected to another drainage facility
8	4	10	0.25	0.08	0.00133	0.007	0.53	150.00	80.00	Must be connected to another drainage facility
8	4	10	0.25	0.10	0.00167	0.008	0.67	120.00	80.00	Must be connected to another drainage facility
8	4	10	0.25	0.15	0.00250	0.013	1.00	80.00	80.00	Must be connected to another drainage facility
8	4	10	0.25	0.20	0.00333	0.017	1.33	60.00	80.00	Must be connected to another drainage facility
8	4	10	0.25	0.25	0.00417	0.021	1.67	48.00	80.00	Must be connected to another drainage facility
8	4	10	0.25	0.30	0.00500	0.025	2.00	40.00	80.00	Must be connected to another drainage facility
8	4	10	0.25	0.40	0.00667	0.033	2.67	30.00	80.00	
8	4	10	0.25	0.50	0.00833	0.042	3.33	24.00	80.00	
8	4	10	0.25	0.60	0.01000	0.050	4.00	20.00	80.00	
8	4	10	0.25	0.70	0.01167	0.058	4.67	17.14	80.00	
8	4	10	0.25	0.80	0.01333	0.067	5.33	15.00	80.00	
8	4	10	0.25	1.00	0.01667	0.083	6.67	12.00	80.00	
8	4	10	0.25	1.50	0.02500	0.125	10.00	8.00	80.00	
8	4	10	0.25	2.00	0.03333	0.167	13.33	6.00	80.00	
8	4	10	0.25	2.50	0.04167	0.208	16.67	4.80	80.00	
8	4	10	0.25	3.00	0.05000	0.250	20.00	4.00	80.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure 8-foot wide x 10-foot long storage area.

Width (ft)	Depth of reservoir layer (ft)	Length (ft)	Design Porosity (% Voids)	Infiltration Rate i (in/hr)	(in/min)	cf/hr/sf	cf/hr	hrs	LID Storage Volume for Standard Design (cf)	Note
8	6	10	0.25	0.02	0.00033	0.002	0.13	900.00	120.00	Must be connected to another drainage facility
8	6	10	0.25	0.04	0.00067	0.003	0.27	450.00	120.00	Must be connected to another drainage facility
8	6	10	0.25	0.06	0.00100	0.005	0.40	300.00	120.00	Must be connected to another drainage facility
8	6	10	0.25	0.08	0.00133	0.007	0.53	225.00	120.00	Must be connected to another drainage facility
8	6	10	0.25	0.10	0.00167	0.008	0.67	180.00	120.00	Must be connected to another drainage facility
8	6	10	0.25	0.15	0.00250	0.013	1.00	120.00	120.00	Must be connected to another drainage facility
8	6	10	0.25	0.20	0.00333	0.017	1.33	90.00	120.00	Must be connected to another drainage facility
8	6	10	0.25	0.25	0.00417	0.021	1.67	72.00	120.00	Must be connected to another drainage facility
8	6	10	0.25	0.30	0.00500	0.025	2.00	60.00	120.00	Must be connected to another drainage facility
8	6	10	0.25	0.40	0.00667	0.033	2.67	45.00	120.00	Must be connected to another drainage facility
8	6	10	0.25	0.50	0.00833	0.042	3.33	36.00	120.00	
8	6	10	0.25	0.60	0.01000	0.050	4.00	30.00	120.00	
8	6	10	0.25	0.70	0.01167	0.058	4.67	25.71	120.00	
8	6	10	0.25	0.80	0.01333	0.067	5.33	22.50	120.00	
8	6	10	0.25	1.00	0.01667	0.083	6.67	18.00	120.00	
8	6	10	0.25	1.50	0.02500	0.125	10.00	12.00	120.00	
8	6	10	0.25	2.00	0.03333	0.167	13.33	9.00	120.00	
8	6	10	0.25	2.50	0.04167	0.208	16.67	7.20	120.00	
8	6	10	0.25	3.00	0.05000	0.250	20.00	6.00	120.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure
8-foot wide x 10-foot long storage area.

Width	*Depth of reservoir layer*	*Length*	*Design Porosity (% Voids)*	*Infiltration Rate*					*LID Storage Volume for Standard Design*	*Note*
				i						
(ft)	(ft)	(ft)		(in/hr)	(in/min)	cf/hr/sf	cf/hr	hrs	(cf)	
8	8	10	0.25	0.02	0.00033	0.002	0.13	1200.00	160.00	Must be connected to another drainage facility
8	8	10	0.25	0.04	0.00067	0.003	0.27	600.00	160.00	Must be connected to another drainage facility
8	8	10	0.25	0.06	0.00100	0.005	0.40	400.00	160.00	Must be connected to another drainage facility
8	8	10	0.25	0.08	0.00133	0.007	0.53	300.00	160.00	Must be connected to another drainage facility
8	8	10	0.25	0.10	0.00167	0.008	0.67	240.00	160.00	Must be connected to another drainage facility
8	8	10	0.25	0.15	0.00250	0.013	1.00	160.00	160.00	Must be connected to another drainage facility
8	8	10	0.25	0.20	0.00333	0.017	1.33	120.00	160.00	Must be connected to another drainage facility
8	8	10	0.25	0.25	0.00417	0.021	1.67	96.00	160.00	Must be connected to another drainage facility
8	8	10	0.25	0.30	0.00500	0.025	2.00	80.00	160.00	Must be connected to another drainage facility
8	8	10	0.25	0.40	0.00667	0.033	2.67	60.00	160.00	Must be connected to another drainage facility
8	8	10	0.25	0.50	0.00833	0.042	3.33	48.00	160.00	Must be connected to another drainage facility
8	8	10	0.25	0.60	0.01000	0.050	4.00	40.00	160.00	Must be connected to another drainage facility
8	8	10	0.25	0.70	0.01167	0.058	4.67	34.29	160.00	
8	8	10	0.25	0.80	0.01333	0.067	5.33	30.00	160.00	
8	8	10	0.25	1.00	0.01667	0.083	6.67	24.00	160.00	
8	8	10	0.25	1.50	0.02500	0.125	10.00	16.00	160.00	
8	8	10	0.25	2.00	0.03333	0.167	13.33	12.00	160.00	
8	8	10	0.25	2.50	0.04167	0.208	16.67	9.60	160.00	
8	8	10	0.25	3.00	0.05000	0.250	20.00	8.00	160.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure
10-foot wide x 10-foot long storage area.

Width (ft)	Depth of reservoir layer (ft)	Length (ft)	Design Porosity (% Voids)	Infiltration Rate i (in/hr)	Infiltration Rate i (in/min)	cf/hr/sf	cf/hr	hrs	LID Storage Volume for Standard Design (cf)	Note
10	2	10	0.25	0.02	0.00033	0.002	0.17	300.00	50.00	Must be connected to another drainage facility
10	2	10	0.25	0.04	0.00067	0.003	0.33	150.00	50.00	Must be connected to another drainage facility
10	2	10	0.25	0.06	0.00100	0.005	0.50	100.00	50.00	Must be connected to another drainage facility
10	2	10	0.25	0.08	0.00133	0.007	0.67	75.00	50.00	Must be connected to another drainage facility
10	2	10	0.25	0.10	0.00167	0.008	0.83	60.00	50.00	Must be connected to another drainage facility
10	2	10	0.25	0.15	0.00250	0.013	1.25	40.00	50.00	Must be connected to another drainage facility
10	2	10	0.25	0.20	0.00333	0.017	1.67	30.00	50.00	
10	2	10	0.25	0.25	0.00417	0.021	2.08	24.00	50.00	
10	2	10	0.25	0.30	0.00500	0.025	2.50	20.00	50.00	
10	2	10	0.25	0.40	0.00667	0.033	3.33	15.00	50.00	
10	2	10	0.25	0.50	0.00833	0.042	4.17	12.00	50.00	
10	2	10	0.25	0.60	0.01000	0.050	5.00	10.00	50.00	
10	2	10	0.25	0.70	0.01167	0.058	5.83	8.57	50.00	
10	2	10	0.25	0.80	0.01333	0.067	6.67	7.50	50.00	
10	2	10	0.25	1.00	0.01667	0.083	8.33	6.00	50.00	
10	2	10	0.25	1.50	0.02500	0.125	12.50	4.00	50.00	
10	2	10	0.25	2.00	0.03333	0.167	16.67	3.00	50.00	
10	2	10	0.25	2.50	0.04167	0.208	20.83	2.40	50.00	
10	2	10	0.25	3.00	0.05000	0.250	25.00	2.00	50.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure 10-foot wide x 10-foot long storage area.

Width	Depth of reservoir layer	Length	Design Porosity (% Voids)	Infiltration Rate i					LID Storage Volume for Standard Design	Note
(ft)	(ft)	(ft)		(in/hr)	(in/min)	cf/hr/sf	cf/hr	hrs	(cf)	
10	4	10	0.25	0.02	0.00033	0.002	0.17	600.00	100.00	Must be connected to another drainage facility
10	4	10	0.25	0.04	0.00067	0.003	0.33	300.00	100.00	Must be connected to another drainage facility
10	4	10	0.25	0.06	0.00100	0.005	0.50	200.00	100.00	Must be connected to another drainage facility
10	4	10	0.25	0.08	0.00133	0.007	0.67	150.00	100.00	Must be connected to another drainage facility
10	4	10	0.25	0.10	0.00167	0.008	0.83	120.00	100.00	Must be connected to another drainage facility
10	4	10	0.25	0.15	0.00250	0.013	1.25	80.00	100.00	Must be connected to another drainage facility
10	4	10	0.25	0.20	0.00333	0.017	1.67	60.00	100.00	Must be connected to another drainage facility
10	4	10	0.25	0.25	0.00417	0.021	2.08	48.00	100.00	Must be connected to another drainage facility
10	4	10	0.25	0.30	0.00500	0.025	2.50	40.00	100.00	Must be connected to another drainage facility
10	4	10	0.25	0.40	0.00667	0.033	3.33	30.00	100.00	
10	4	10	0.25	0.50	0.00833	0.042	4.17	24.00	100.00	
10	4	10	0.25	0.60	0.01000	0.050	5.00	20.00	100.00	
10	4	10	0.25	0.70	0.01167	0.058	5.83	17.14	100.00	
10	4	10	0.25	0.80	0.01333	0.067	6.67	15.00	100.00	
10	4	10	0.25	1.00	0.01667	0.083	8.33	12.00	100.00	
10	4	10	0.25	1.50	0.02500	0.125	12.50	8.00	100.00	
10	4	10	0.25	2.00	0.03333	0.167	16.67	6.00	100.00	
10	4	10	0.25	2.50	0.04167	0.208	20.83	4.80	100.00	
10	4	10	0.25	3.00	0.05000	0.250	25.00	4.00	100.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure
10-foot wide x 10-foot long storage area.

Width	*Depth of reservoir layer*	*Length*	*Design Porosity (% Voids)*	*Infiltration Rate* i					*LID Storage Volume for Standard Design*	*Note*
(ft)	(ft)	(ft)		(in/hr)	(in/min)	cf/hr/sf	cf/hr	hrs	(cf)	
10	6	10	0.25	0.02	0.00033	0.002	0.17	900.00	150.00	Must be connected to another drainage facility
10	6	10	0.25	0.04	0.00067	0.003	0.33	450.00	150.00	Must be connected to another drainage facility
10	6	10	0.25	0.06	0.00100	0.005	0.50	300.00	150.00	Must be connected to another drainage facility
10	6	10	0.25	0.08	0.00133	0.007	0.67	225.00	150.00	Must be connected to another drainage facility
10	6	10	0.25	0.10	0.00167	0.008	0.83	180.00	150.00	Must be connected to another drainage facility
10	6	10	0.25	0.15	0.00250	0.013	1.25	120.00	150.00	Must be connected to another drainage facility
10	6	10	0.25	0.20	0.00333	0.017	1.67	90.00	150.00	Must be connected to another drainage facility
10	6	10	0.25	0.25	0.00417	0.021	2.08	72.00	150.00	Must be connected to another drainage facility
10	6	10	0.25	0.30	0.00500	0.025	2.50	60.00	150.00	Must be connected to another drainage facility
10	6	10	0.25	0.40	0.00667	0.033	3.33	45.00	150.00	Must be connected to another drainage facility
10	6	10	0.25	0.50	0.00833	0.042	4.17	36.00	150.00	
10	6	10	0.25	0.60	0.01000	0.050	5.00	30.00	150.00	
10	6	10	0.25	0.70	0.01167	0.058	5.83	25.71	150.00	
10	6	10	0.25	0.80	0.01333	0.067	6.67	22.50	150.00	
10	6	10	0.25	1.00	0.01667	0.083	8.33	18.00	150.00	
10	6	10	0.25	1.50	0.02500	0.125	12.50	12.00	150.00	
10	6	10	0.25	2.00	0.03333	0.167	16.67	9.00	150.00	
10	6	10	0.25	2.50	0.04167	0.208	20.83	7.20	150.00	
10	6	10	0.25	3.00	0.05000	0.250	25.00	6.00	150.00	

Underground Storage Volume and Percolation Rates for Green Infrastructure
10-foot wide x 10-foot long storage area

Width	Depth of reservoir layer	Length	Design Porosity (% Voids)	Infiltration Rate i					LID Storage Volume for Standard Design	Note
(ft)	(ft)	(ft)		(in/hr)	(in/min)	cf/hr/sf	cf/hr	hrs	(cf)	
10	8	10	0.25	0.02	0.00033	0.002	0.17	1200.00	200.00	Must be connected to another drainage facility
10	8	10	0.25	0.04	0.00067	0.003	0.33	600.00	200.00	Must be connected to another drainage facility
10	8	10	0.25	0.06	0.00100	0.005	0.50	400.00	200.00	Must be connected to another drainage facility
10	8	10	0.25	0.08	0.00133	0.007	0.67	300.00	200.00	Must be connected to another drainage facility
10	8	10	0.25	0.10	0.00167	0.008	0.83	240.00	200.00	Must be connected to another drainage facility
10	8	10	0.25	0.15	0.00250	0.013	1.25	160.00	200.00	Must be connected to another drainage facility
10	8	10	0.25	0.20	0.00333	0.017	1.67	120.00	200.00	Must be connected to another drainage facility
10	8	10	0.25	0.25	0.00417	0.021	2.08	96.00	200.00	Must be connected to another drainage facility
10	8	10	0.25	0.30	0.00500	0.025	2.50	80.00	200.00	Must be connected to another drainage facility
10	8	10	0.25	0.40	0.00667	0.033	3.33	60.00	200.00	Must be connected to another drainage facility
10	8	10	0.25	0.50	0.00833	0.042	4.17	48.00	200.00	Must be connected to another drainage facility
10	8	10	0.25	0.60	0.01000	0.050	5.00	40.00	200.00	Must be connected to another drainage facility
10	8	10	0.25	0.70	0.01167	0.058	5.83	34.29	200.00	
10	8	10	0.25	0.80	0.01333	0.067	6.67	30.00	200.00	
10	8	10	0.25	1.00	0.01667	0.083	8.33	24.00	200.00	
10	8	10	0.25	1.50	0.02500	0.125	12.50	16.00	200.00	
10	8	10	0.25	2.00	0.03333	0.167	16.67	12.00	200.00	
10	8	10	0.25	2.50	0.04167	0.208	20.83	9.60	200.00	
10	8	10	0.25	3.00	0.05000	0.250	25.00	8.00	200.00	

Rainfall Gage Table

Gage No	Number of Rainfall Events	Number of Rainfalls Less Than 0.5 inches	Ratio
1000	12541	9555	0.76
1200	1585	1325	0.84
1300	804	674	0.84
1500	789	623	0.79
1600	1547	1206	0.78
1700	1630	1312	0.80
1800	1025	848	0.83
1900	874	741	0.85
2000	1893	1574	0.83
3000	346	294	0.85

APPENDIX C: ADDITIONAL PLANT LISTS

Arizona Municipal Water Users Association – Landscape Plants for the Arizona Desert
http://www.amwua.org/plants/

Arizona Department of Forestry and Fire Management
https://dffm.az.gov/forestry-community-forestry/urban-community-forestry/tree-care

Arizona Department Water Resources Low Water Use Drought Tolerate Plant List for the Phoenix Active Management Area
http://infoshare.azwater.gov/docushare/dsweb/Get/Document-10087/Phoenix_AMA_LWUPL_3MP.pdf

Maricopa County Air Quality Trees & Air Quality List
http://cleanairmakemore.com/wp-content/uploads/2018/08/Trees-and-Air-Quality-in-Maricopa-County.pdf

ATTACHMENT E

SONORAN DESERT GREEN INFRASTRUCTURE RESOURCE LIBRARY

Sonoran Desert Green Infrastructure Resource Library

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A Playbook for Transportation Projects in Pima County Communities

SONORAN DESERT GREEN INFRASTRUCTURE RESOURCE LIBRARY

A Playbook for Transportation Projects in Pima County Communities

This report was co-authored by Jeff Odefey (American Rivers), Mead Mier (Pima Association of Governments), and Catlow Shipek (Watershed Management Group). The authors gratefully acknowledge the contributions of Stacey Detwiler, formerly of American Rivers, whose 2015 report "*Rivers and Roads: Opportunities to Better Integrate Green Infrastructure and Transportation Projects in Atlanta, GA and Toledo, OH*" directly informed portions of this guide. The authors were also greatly assisted by input from staff at Pima Association of Governments' Transportation and Integrated Planning Departments, Pima County Departments of Housing & Urban Development and Transportation, the Pima County Regional Flood Control District and the City of Tucson's Water and Transportation Departments as well as the City Administrator's office.

The authors are responsible for any factual errors. The recommendations are those of American Rivers and any views expressed in this report are those of the authors and do not necessarily reflect the views of our funders or those who provided review.

Please note that active hyperlinks are embedded throughout the document, and indicated by red or blue text with a red underlined text.

Historic flows restored in the Santa Cruz River.
Photo: American Rivers

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Sonoran Desert Green Infrastructure Resource Library: A Playbook for Transportation Projects in Pima County Communities

Native Tucson vegetation in a curbcut.
Photo: PAG

Introduction

Many of the requirements of street construction can be addressed cost-effectively through Green Infrastructure (GI) including managing surface drainage, providing all weather crossings, mitigating transportation's surface pollutants, meeting safety goals for all transportation modes, and ensuring final stabilization of the soils.

The Tucson region is a desert community with streets designed to convey stormwater. Like much of the West, storm sewers are separated from the sanitary sewer system. Oftentimes this creates flooding issues on bicycle and pedestrian facilities. In high water situations, rainfall can also impact the safety of a roadway facility. Localized flooding deposits unwanted sediment on the region's roads, bike lanes, and pedestrian facilities. Traditional street designs also create risks including increased heat, decreased absorption, and decreased water quality. GI offers opportunities to decrease those risks and add cost-effective approaches to protect the post-construction integrity of the roadway, mitigating stormwater pollutants from transportation sources, providing drought and heat resilient landscapes, reduced ponding and flood attenuation. Benefits also include increased access to urban green space, improved air quality, and reduced demand on grey storm sewer infrastructure and the cost of constructing expensive underground pipe systems.

Purpose of the Playbook

Transportation project leaders have increasingly used GI approaches over the last few decades. This guide was created to address common issues that inhibit the implementation of GI in the Tucson region transportation network. Many of these issues can be solved by including GI in each planning phase and through policies, funding and practices tailored to the region's urban and suburban environments, each of which have a dedicated section in this guide. Metropolitan Planning Organizations (MPOs), local governments and transportation entities are important players in creating a healthy built environment and essential to successful implementation of GI since streets are where stormwater flows. Issues and corresponding solutions in this resource guide were identified by local experts in GI and transportation engineering and planning. Top local concerns that were addressed in this document include utilities, flooding, sediment, and maintenance. This playbook is a product of American Rivers based on a general national guide filled in with local details by jurisdictions within Pima County where examples were available or with other Western examples to address any remaining gaps and models. This guide is intended to be a resource for transportation-oriented staff and to provide examples and illustrations of planning, funding, and project design approaches that may be relevant to the Pima County area. It is in no way intended to be interpreted as administering official policy, preferences, or design specifications.

Green Infrastructure Pedestrian Canopy on Scott Avenue Green Street.
Photo: American Rivers

Green Infrastructure? Green Stormwater Infrastructure? WHAT'S IN A NAME?

The terminology involved in nature-based approaches to managing stormwater can be confusing. Many practitioners use the term "green infrastructure," which has recently been incorporated into the Clean Water Act:

Section 502 of the Clean Water Act defines green infrastructure (GI) as the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to server systems or to surface waters.

However, this term has a second historical usage to refer to the parks, green spaces, preservation of large scale landscapes, and other areas that provide habitat in an urban environment. In an effort to distinguish stormwater management practices from this broader definition, many people are adopting the more specific term "green stormwater infrastructure." To add further confusion, the term "low impact development" (LID) is often used to include, among other things, the types of stormwater management approaches that utilize "green infrastructure" techniques. For the sake of consistency with local design manuals and policies, the authors of this guide will use the term "green infrastructure" throughout the document except in places where it's more appropriate to echo a usage of other terms used in policies such as stormwater harvesting, low impact development or green stormwater infrastructure.

Defining the Needs

The Tucson region has several key issues that can be addressed through urban design that includes GI along streets.

Extreme heat is the leading cause of weather-related deaths in the United States and the highest rates of impact on residents nationally are found in Arizona. Heat is amplified by hardscape, such as streets, creating heat islands. Extreme heat exacerbated by urban heat islands can lead to increased respiratory difficulties, heat exhaustion, and heat stroke. Physical, social and economic factors create a disproportionate impact on older persons, children, homeless, the poor, socially isolated, and those with mobility restrictions or health concerns. As temperatures rise in Arizona, the region will have more contiguous 100+ degree days in combination with higher nighttime temperatures. Heat-related illnesses and deaths are directly related to prolonged exposure to high temperatures in the absence of intermittent cooling down periods. Unfortunately, economically disadvantaged parts of the community are often especially impacted because under-investment in urban forestry has created denuded neighborhoods where residents commonly depend on public transportation which requires walking outdoors in the heat. Tree shade can mitigate heat and provide cooling for active modes of transportation.

The Santa Cruz currently has reaches that do not meet applicable water quality standards due to pollutants associated with transportation sources including copper and zinc. These pollutants are toxic to organisms with aquatic phases that rely on the region's ephemeral waters and rare perennial and intermittent waters. Sediment from construction is also considered a pollutant and field screening has found oil sheen in runoff. The Santa Cruz River also suffers from "impaired" status due to *E. coli* contamination from animal waste. Bioretention basins along streets can prevent accumulation of pollutants in our waterways and break down hydrocarbons and pathogens.[1]

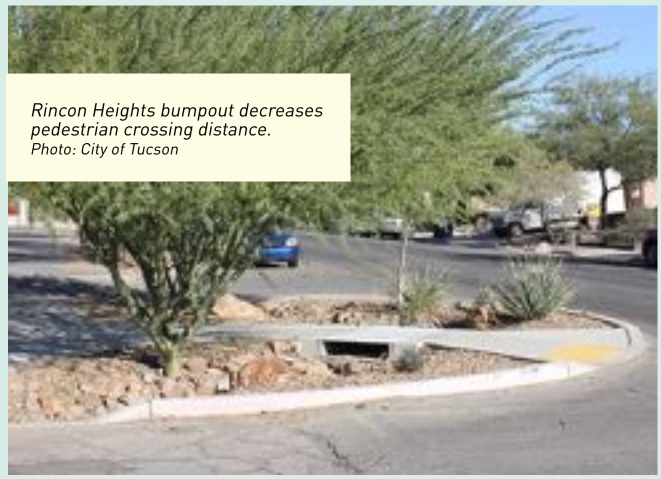
A severe local drought began in our region about 20 years ago, triggering Drought Stage 1 in local Drought Response Plans. Drought Stage 2 will occur if there are shortages on the imported Colorado River supplies. Should irrigation restrictions need to take place in Drought Stage 2, many local jurisdictions identify stormwater harvesting as a way to prepare for landscape resiliency in their Plans. It is critical

SAFER STREETS THROUGH GI

While some people may assume that trees pose risks for drivers, far less than 1% of U.S. annual vehicle crashes involve a tree on an urban street. Crash prevention efforts should address high-risk conditions, such as reducing plantings at curves, rather than generalized tree removal. The most recent research suggests that trees may improve driving safety. Drivers seeing natural roadside views show lower levels of stress and frustration compared to those viewing all-built settings. One study found a 46% decrease in crash rates across urban arterial and highway sites after landscape improvements were installed. Another study found that placing trees and planters in urban arterial roadsides reduced mid-block crashes by 5% to 20%. Several studies comparing roads with and without landscaping and trees have found a marked decrease in the number of pedestrian and bicyclist fatalities and injuries by up to 80%.*

Is GI appropriate for all street types? Yes, and different GI feature types fit each street type.

The Dallas Complete Streets Design Manual (Design Element Priorities Chart, page 85 in the document) shows an example of prioritizing trees and greenspace for almost all street types. The LA Model Design Manual for Living Streets describes which GI features work with different street typologies (Best Fit for Streetwater Tools by Street Context, Table 11.1).



Rincon Heights bumpout decreases pedestrian crossing distance.
Photo: City of Tucson

**Studies can be found in Wolf, K.L. 2010. Safe Streets - A Literature Review. In: Green Cities: Good Health (www.greenhealth.washington.edu). College of the Environment, University of Washington.*

that transportation departments work in coordination with water planners to utilize stormwater as a water resource. This will prepare a more resilient streetscape.

In the semi-arid climate of Pima County, Arizona, stormwater is a valuable resource that has historically been disposed of as a nuisance and a hazard. The rain that does reach the desert floor in a summer monsoon or a fall tropical cyclone typically does so with great vigor. The altered flow regime created by traditional roadways additionally increases runoff volume and peak flows, damaging the environment and creating a risk to property downstream. These erosive flows in receiving streams will cause downcutting, clear water scours, or excessive sedimentation. As documented in studies described later in this document, GI has been found to reduce stress on traditional stormwater infrastructure, pull sediment hazards out of the travel lane, and reduce the peak of the hydrograph, which reduces the stormwater nuisances on streets and reduces the risks of flood damage to adjacent properties.

Each year, close to 4,000 Tucsonans are injured and more than 50 people lose their lives while traveling on city streets.[2] Jurisdictional leaders are committed to changing this. According to a 2019 report released by the Governors Highway Safety Association, pedestrian deaths have increased by 35 percent in the last decade. Arizona has also been ranked the second deadliest state for pedestrians per capita.[3] According to Pima Association of Governments' (PAG's) performance measures in 2020, the fatality rate for people on bikes and people walking are unfortunately trending upward per capita even as more bicycle and pedestrian facilities are built. Through the 2045 Regional Mobility and Accessibility Plan (RMAP 2045) process, over 300 miles of bicycle and pedestrian safety facilities and over 200 miles of improved roadways have been identified to address poor or fair safety ratings. Road safety can be improved when GI is incorporated on any street size and is an important part of street modernization projects including medians/islands, crossings, curb extensions, etc.[4]

The greater purpose of the guide is to:

- Increase proper utilization of GI to provide safer road conditions with reduced flood hazards and time for streets to dry
- Improve the safety and comfort of people bicycling and walking by installing traffic calming and buffer elements
- Increase transit rider comfort with enhanced shelters, shade, and greenscape at transit stops (critical to growing transit as a mode)
- Make the biking and walking environment more healthy by reducing temperature, attenuating noise, and improving air quality
- Use trees as visual friction to increase driver self-regulation and geometric features in the road can be placed to calm traffic and improve traffic safety conditions.

(Reference: NACTO Urban Street Stormwater Guide)

Definition

Green infrastructure practices reduce stress on traditional grey stormwater infrastructure and restore natural flow functions with a variety of stacked benefits for the environment and community. Also related to Low Impact Development (LID) or stormwater harvesting, examples include structures that improve infiltration, enhance or maintain vegetation, and/or capture and reuse stormwater.
GI practices emphasize the preservation and restoration of natural landscape features and connectivity. Within the transportation network, technologies may include permeable pavements, bioretention in chicanes or parking lots, curb inlets that direct stormwater, and infiltration in check-dams in rights-of-way.

Regional Interest

With more than 300 days of sunshine each year, 60 to 70 of which exceed 100-degree temperatures, shade is a critical consideration for improving the pedestrian environment. Water conservation is key to sustaining shade in the desert.

Community support and implementation of GI has grown over time and this demand has been documented in several assessments.

The PAG 2014 Regional Pedestrian Plan found, through a survey of 670 self-selected participants, that increased shade is the most common improvement desired by pedestrians (49 percent). Obstacles such as lack of shade create barriers for people who would otherwise like to walk, in addition to presenting a hazard for people who don't have other options.

In 2015, PAG used an online public engagement tool called Engage 2045 to seek public input on future transportation investment options and long-term transportation priorities for the long range transportation plan. Once again, PAG found a strong interest in GI. Of the 1,903 people who participated, 77 percent were willing to spend at least an additional $0.30 per household per month to fund GI elements of transportation projects indicating widespread interest. Forty percent even indicated a willingness to spend the maximum choice offered - $3 per household per month, which is the typical amount needed to fund a stormwater utility.

The Pima County Department of Environmental Quality conducts an annual community survey to gauge public awareness and attitudes toward air and water quality, including GI. This statistically valid survey reaches a wide spectrum of Pima County residents and business owners and in 2019 found that at least one third of the community implemented various GI practices.[5] Using the social theory of innovation to evaluate these results, it appears our community has moved from early adopters to early majority phases. During this phase, further guidance and education can aid proper implementation.

Early regional gap and barrier assessments for GI, including a 2012 Arid LID Conference in Tucson, found that funding created limitations on implementation and there were some research areas that would help leaders feel more confident in supporting GI with policy. These areas included questions about street integrity, feasibility of GI to reduce peak flows and potable water irrigation, and whether the community would support funding. Since that time, some steady funding sources have been established and guidance is now available based on modeled scenarios, local case studies, and nation-wide research. As illustrated above in the public surveys, community support also is no longer a barrier to implementation.

PART 1
Incorporating Green Infrastructure into Project Planning

Most challenges have guidance available for solutions. Encourage education of staff about these resources and practices. Use this guide's recommendations for regionally consistent practice.

Summary Of Key Planning Recommendations

Plan for GI early in process

It is critically important to consider GI measures as appropriate stormwater management strategies early in the road project design process including coordination with utilities and appropriate planning for budget. Retrofits on a built road are a more costly effort. GI should not be thought of as optional but instead an enhanced way to achieve drainage and final stabilization goals.

Utilize Context Sensitive Solutions (CSS) Planning Process

Transportation agencies in the Santa Cruz watershed should fully implement CSS planning approaches in the programmatic and project design process in order to formalize the consideration of the environmental and community impacts (and potential benefits) of a transportation project. One of the core principles of CSS is to use flexibility and creativity to preserve and enhance community and natural environments, which supports the overall goal of green infrastructure to use natural or engineered systems that mimic natural systems to capture and filter rainwater, reducing stormwater runoff to protect water quality.

Implement Green Streets Policies and Design Guides

Many local governments across the nation have established green street policies and programs to encourage the integration of forward-thinking GI stormwater management in road and street projects. City and County planners and project engineers can better integrate GI on roads and highways by updating technical manuals and design standards to support and encourage GI.

Prioritize GI in Transportation Projects through Capital Improvement Planning Processes

The Capital Improvement Planning (CIP) process can be a valuable pathway to leverage transportation-related sources of funding to achieve community GI goals. By anticipating the GI opportunities created by transportation construction, upgrades, and repairs and allocating appropriate budget resources to GI features, local governments can meet multiple goals with their infrastructure investments.

Integrate with Available Stormwater, Climate and Tree Canopy Plans

GI associated with transportation projects can be a means to accomplish the public benefit goals of other community plans and policies. Considering these plans can both leverage transportation funding to provide these benefits and potentially provide non-transportation funding for street projects. Additionally, the coordination implicit in these integration efforts can result in greater public buy-in, increased economic, engineering and construction efficiencies and more consistent provision of public benefits. The City of Tucson, Pima County and other regional municipalities have climate adaptation, urban tree canopy, stormwater management and other plans that support GI implementation on roadway projects.

Identify Priority Locations and Targets

The effectiveness of using GI to manage stormwater and provide other benefits can be optimized when individual projects are identified and implemented as part of a cohesive, prioritized approach. Using GIS-based tools like PAG's Green Infrastructure Prioritization Tool can help transportation staff recognize priority locations for GI and tailor project designs to address high-priority issues within the project's context (e.g., lack of shade, high heat island effect, etc.).

Include GI Performance Measures within Long-Range Transportation Plans (LRTP)

PAG members and staff develop and update the region's RMAP which takes a performance based approach to achieving regional transportation and related goals. By including GI related performance measures in future planning or allowing GI features to count toward safety and environmental measures, RMAP could be an effective mechanism for driving GI implementation. Similarly, the five year Transportation Improvement Program (TIP) prepared by PAG could integrate GI measures and leverage multiple sources of funding to deliver GI benefits to regional projects.

Ensure Maintenance Provisions Are Included in Project Designs and Long Term Plans

Maintenance can be 'built in' to the project design from its early stages. The maintenance implications of plant and tree selection, drainage configuration, soil compaction and other factors need to be contemplated during the design process. Similarly, maintenance plans and resources should be coordinated with the departments that conduct maintenance and developed prior to project finalization in order to ensure that maintenance crews have proper instruction and resources to achieve long-term GI performance of the investment.

Review project proposals for compliance with GI standards and policies

While public agencies, including transportation departments, have a necessary role in advancing GI, their reach generally is limited to projects on public property. There are considerably more GI opportunities on private properties, and realizing these opportunities requires the participation of property owners, managers, real estate developers and contractors. In order to meet community GI goals, agency project review and planning staff must encourage developers to design and install GI practices as part of their compliance with local codes, ordinances, and community plans. A local successful example is the City of Tucson Commercial Harvesting Ordinance review process.

Gila Monster Reading, Dunbar Springs, Tucson.
Photo: American Rivers

Planning and Project Development Recommendations for Regional and Local Transportation Agencies

Plan for Green Infrastructure early in process

It is critically important to consider GI measures as appropriate stormwater management strategies early in the road project design process. GI should not be thought of as optional landscaping to be added or altered after other design goals have been realized. While GI measures can fulfill landscaping purposes, their primary function is to manage runoff from impervious surfaces; overall project designs succeed when they embrace GI runoff reduction and management principles from the onset. At the pre-design stage, project planners should evaluate conditions in the project area for their capability to support GI and to promote delivery of community benefits. During the scoping process, GI alternatives should be evaluated for their relative abilities to satisfy runoff reduction and management requirements and relationship to other community plans and policies. Retrofits on a built road are a more costly effort.

Utilize a collaborative team of advisors to review public and private road designs early in the process. An integrated team may include members from sustainability or water departments involved in climate and drought resilience goals, MS4s, Regional Flood Control District (RFCD) and urban forestry professionals knowledgeable about landscape and canopy requirements such as Landscape architects.

Utilize Context Sensitive Solutions Planning Process

Local transportation agencies in the Santa Cruz watershed should consider requiring CSS as a planning framework for road and highway projects. This approach has been adopted by transportation agencies for decades in order to design and plan transportation projects that maintain or enhance the existing environment. Environmental stewardship practices in line with CSS can mitigate costs associated with energy consumption, material storage, environmental mitigation, and waste generation.[6] As a design and planning process, CSS requires practitioners to understand their project corridor within the environment of community goals, the street network, and land use. This process allows practitioners to link the goals and objectives of their particular communities to the physical elements of street design that will best support those goals.[7] Most importantly, the CSS approach ensures that goals and values beyond transportation infrastructure, such as environmental and public health and safety, are considered in the design of a roadway project.[8]

CSS is defined by the Federal Highway Administration (FHWA) and American Association of State Highway and Transportation Officials (AASHTO) as "a collaborative, interdisciplinary approach that involves all stakeholders in providing a transportation facility that fits its setting. It is an approach that leads to preserving and enhancing scenic, aesthetic, historic, community, and environmental resources, while improving or maintaining safety, mobility, and infrastructure conditions."[9] Both FHWA and AASHTO encourage its use in project planning and design.[10] As part of its recommendations, the FHWA suggests that planners work collaboratively to understand the landscape, community, and resources before the engineering design stage begins.[11] One of the core principles of CSS is to use flexibility, innovativeness and creativity to preserve and enhance community and natural environments.[12] This is in line with GI goals to use low-tech natural or engineered systems that mimic natural systems to capture and filter rainwater, reducing stormwater runoff to protect water quality. Tucson area streets also function to carry stormwater and GI designs are available to fit various needs from flood reduction to pedestrian enhancements depending on the traffic flow and storm flow regimes. This is an important *context* to consider for many streets in our region. Best practices with the CSS planning approach involve developing an upfront planning process that allows stakeholders including the public and environmental agencies to identify issues as well as identifying and considering existing plans relating to land use, water and sewer, and watershed management.[13]

For roadway projects in Pima County, CSS can be valuable at both the broader scale planning level and when designing specific projects. The process envisions an iterative, step-wise approach to ensure that multimodal corridor construction and reconstruction will play a relevant role in meeting a broad array of community and General Plan goals. Because of the outsized influence that street and roadway projects have on a community, transportation planners have an opportunity, and a responsibility, to factor the broad range of impacts and benefits that can result from individual projects and long-range plans. Using a CSS approach is important as a means of planning successful transportation projects, helping facilitate community dialogue, and helping build stronger communities.[14]

It would be appropriate, even preferable for City, Town, regional and County transportation departments to adopt CSS policies and practices. In advance of formal adoption, transportation planners and engineers working in the Pima County communities should take active steps to embrace CSS approaches.

These approaches include:

- Understanding the Whole Context
- Engaging Relevant Disciplines
- Engaging Affected Stakeholders
- Beginning with an Open Mind and a Blank Sheet
- Developing Consensus on Performance-based Goals[15]

Additional detail about these approaches and their application to transportation-specific planning can be found in the Federal Highway Administration Context Sensitive Solutions Primer and the Institute of Transportation Engineers (ITE), Implementing Context Sensitive Design on Multimodal Corridors: A Practitioner's Handbook. An additional, and seemingly useful resource could be a process diagram or matrix that guides practitioners through the application of CSS to a roadway project. The City of Dallas' recently adopted Complete Streets Design Manual provides an example of such a resource.[16]

There are opportunities to bring these approaches to project planning and development at different stages.

- Planning level. As regional entities, the County or cities develop capital and strategic plans, CSS approaches can be used to broaden public engagement and support for projects, plans and funding requests. At the same time, CSS approaches will ensure that complementary plans and policies are considered in development of future and reconditioned roadways. At the local level, these plans include:
    - Regional Transportation Authority and City of Tucson Process for Grant Road Improvement Plan: The City of Tucson selected the Institute of Transportation Engineer (ITE) recommended practice, Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities, for planning and preliminary design of the Grant Road Improvement Plan, which resulted in implementation of GI along the corridor.
- Project level. When reviewing or designing individual projects, CSS approaches can help ensure that project designs best address multiple community needs and provide opportunities to realize a range of community benefits. Individual projects must reflect the designs and resilience goals embedded in city and County policies and plans. To ensure success of General Plans and transportation plans, it is essential that transportation planners and plan reviewers look for opportunities to meet these plans, goals, and policies in all project opportunities. For example, even street repaving or utility work can be leveraged to include landscaping enhancements that treat stormwater.
    - City of Tucson Transit Development Handbook: includes Context Sensitive Design in the Streetcar Corridor

Implement Green Streets Policies and Design Guides

By using CSS, Tucson-area transportation planning and project design will be better able to support the implementation of the City of Tucson's emerging Complete Streets Policy as well as similar "green streets" initiatives elsewhere in Pima County.

The City's Complete Streets Policy was adopted in February 2019 and sets out design principles that "guide the development of a safe, connected, and equitable transportation network." [17] These principles are translated into action via the design specifications

GRAND RAPIDS VITAL STREETS

The City of **Grand Rapids, MI** has adopted and is moving to implement a Vital Streets Plan. The City defines "Vital Streets" as Complete Streets plus Green Infrastructure.[21] The overall goal of the Vital Streets Program is to improve the condition of the city's streets to good or fair as measured through the PASER rating system; however, Grand Rapids has recognized that improvements in street conditions come from more than just the integrity of the asphalt, they are intertwined with core community values:safety, healthy places, vibrant economy, environmental sustainability and diverse transportation options.[22] The plan prioritizes design and construction of street projects that are developed collaboratively with community stakeholders, reflect local land use and community objectives, and protect and enhance the natural environment. The accompanying Vital Streets Design Guidelines provide detailed design specifications to ensure that street projects achieve these and other goals. The guidelines incorporate appropriate GI practices.[23]

The National Association of City Transportation Officials (NACTO) has published a series of design guides that advance innovations in community street principles and designs. The Urban Street Stormwater Guide reflects a collaboration between municipal transportation, public works, and stormwater staff to create a resource that contains national best practices for sustainable stormwater management in the public right-of-way.[24] The guide couples recommendations for planning "stormwater streets" with generalized design specifications for stormwater treatment elements.

contained in the Complete Streets Design Guide.[18] The design guide incorporates green streets principles to manage drainage and streetwater generated from the street system. The key concept of green streets for Tucson is to retain, detain, infiltrate and/or filter runoff from streets and sidewalks using adjacent landscaped areas.[19] In addition to managing runoff, these landscape-based GI practices are expected to reduce ground-level ozone and provide cooling shade for streets and sidewalks.

Peer cities have adopted and implement similar policy preferences that aim to transform traditional roadway planning into collaboratively developed, multi-benefit public infrastructure. For example, in 2014 the City of Austin (Texas) adopted a "complete streets" policy which includes "green streets" as an integral component. Austin describes green streets as public rights of way (ROWs) that are context sensitive and which include landscape features, GI and sustainability measures to enhance non-motorized transportation options. The City of Austin has recognized that the street network must be adapted to function as part of the City's ecosystem as well as its public space inventory; that it must provide economic benefits through reduced maintenance and urban energy costs; and that streets and roads have a critical role in improving resilience to climate change by managing runoff in a manner that values the water supply and heat island reduction benefits of stormwater.[20]

The Pima County Subdivision Street Standards refer to the Pima County landscaping standards for landscaping requirements in the right-of-way. An update to the Subdivision Street standards may benefit from including the "first flush" concept or other GI requirements either in the right-of-way or by directing street runoff to subdivision multi-use common areas. An updated Landscape Manual would help to provide clarification to the Pima County codes and standards where modifications of roadway rights-of-way overlap with landscape, vegetation and stormwater harvesting concerns. A manual update was initiated in 2017.

Prioritize Green Infrastructure in Transportation Projects through Capital Improvement Planning Processes

At the local level, there are also opportunities to better integrate GI into transportation projects to manage polluted runoff. Specifically, the CIP process offers an importation pathway to prioritize GI for roads and highways. Funding sources for transportation construction, upgrades, and repairs are typically much larger than those for stormwater management, which typically does not have a dedicated funding source.

THE CITY OF BREMERTON, WA

The City of **Bremerton, Washington** updated its National Pollutant Discharge Elimination System (NPDES) permit in 2009 to encourage the use of GI and, as a result, also updated its Stormwater Management Plan to be in line with the new permit's requirements. This plan was integrated into the City's Comprehensive Plan which was approved by the city council, and the capital improvement plan included a specific line item for GI projects. Additionally, Bremerton included a line item in its transportation improvement program specifically for green streets.[25]

Municipalities and MPOs should consider prioritizing GI in transportation projects within the CIP process. Examples include objective numeric performance measures, standards or criteria to mimic pre-development hydrology, specific GI requirements, or limits on the amount of effective impervious area.

The local government should implement criteria to prioritize transportation projects that incorporate GI or to set aside a small percentage of capital dollars to be used for green designs. At the department level, the capital improvement plan for the relevant transportation department should include, at a minimum, requirements for coordination among the relevant water quality, water resource, flood control, permitting, and environmental departments in the planning process. The transportation department should develop and implement criteria to prioritize transportation projects in the CIP process that integrate GI elements.

The capital planning process at both the department and municipal scales represents an opportunity to better leverage transportation dollars to fund GI elements that help to cost-effectively meet permit requirements and protect water quality while providing extensive benefits to transportation safety.

Integrate Mobility Planning with Available Stormwater, Climate and Tree Canopy Plans

Much of the preceding discussion was focused on adopting best practices for incorporating GI into transportation project design development and planning review. These efforts are critically important but can succeed more fully when they also achieve the goals adopted in municipal and/or county plans and policies that also prioritize GI. Multiple departments can achieve goals collaboratively and more efficiently for overall savings and greater benefits to the jurisdiction and residents. Plans may be merged as well, such as a Green Complete Streets Plan, for increased coordination and consistent practice.

City of Tucson Green Streets Active Practice Guidelines

The City of Tucson established its Green Streets Policy in 2013. The policy requires the Tucson Department of Transportation and Mobility (TDTM) to design new and upgraded streets that convey stormwater into GI features, capturing at least the first half-inch of rainfall onsite. Additionally, the policy requires TDTM to include native vegetation so that the streets are covered by a 25% tree canopy along with sufficient understory to ensure the function of the bioretention area. Increased water consciousness among community members and leaders about the City's drinking water sources played a large role in encouraging the Green Streets Policy.

Pima County Sustainable Action Plan

Adopted in 2018, the County's Sustainable Action Plan sets forth a broad set of actions and goals for County activities intended to foster resilience to the effects of climate change. Installing GI is one of the six climate change adaptation targets identified by the plan. Specifically, the plan sets a goal of installing at least 40 GI projects in prioritized locations on County properties; implementing the County's Green Infrastructure Action Plan; and utilizing CIP funding for GI wherever possible.[26]

City of Tucson Plan Tucson

Adopted in 2013, Plan Tucson outlines broad goals and specific targets to improve livability, reduce greenhouse gas contributions and energy consumption, increase climate change resiliency, and foster economic vitality. The plan recognizes the role that GI plays in relationship to these separate goals and includes specific policies to encourage GI projects on public and private property and as part of development and redevelopment projects.[27]

City of Tucson Mayor Romero's Million Trees Initiative

Tucson Mayor Regina Romero launched the Tucson Million Trees campaign in April 2020, which aims to plant one million native, drought tolerant trees by 2030 to help mitigate the effects of climate change by reducing utility bills, improving mobility, combating the urban heat island and cooling our city. Mayor Romero is exploring priority planting locations including schools, neighborhood streets, private properties, the city's landfill, the banks of the Santa Cruz River, and urban bosques. The program is connected to the GI fund and a large portion of tree planting in Tucson will be managed by nonprofit groups, including Tucson Clean and Beautiful, which runs the Trees for Tucson urban forestry program.

Make Marana 2040 General Plan

Subject to voter approval in August 2020, the updated General Plan for the Town of Marana reflects the town's projected growth patterns and sustainability platform. Goal RS-8 is that stormwater is efficiently and sustainably managed in a way that reduces flood risks and respects water quality. Policy RS 8-3 considers establishing sustainable stormwater methods, such as GI and permeable pavements, in new development. Under the Water Resources goal is policy RS 4-3 to identify best practices for water conservation programs that can be implemented throughout the community, such as stormwater harvesting or conservation-oriented tap fees.

Aspire 2035 - Sahuarita General Plan

Policy statements encourage the adoption of GI standards that rely on natural processes for stormwater drainage, groundwater recharge and flood management.

In addition, transportation planners and project engineers should be familiar with the following plans, standards and ordinances and their respective GI-related components. These components may be relevant to either the planning and implementation of public-sector transportation projects or the review of development proposals:

Pima County Regional Flood Control District 2020 Floodplain Management Plan

includes GI (stormwater harvesting) practices among the types of appropriate actions.

Pima County Detention and Retention Requirements

The Pima County RFCD Design Standards for Stormwater Detention and Retention include a requirement for retention of the first-flush (first 0.5 inch of rainfall). To incentivize the use of LID practices, the manual allows LID practices to mitigate first-flush retention volume and provides a method to reduce the required volume of detention facilities when stormwater harvesting basins are used throughout a site. The manual standards also incentivize other LID practices when quantifiable flood control benefits can be measured.[28]

City of Tucson Commercial Rainwater Harvesting Ordinance

This ordinance requires developers of commercial properties to harvest rainwater for at least 50 percent of their landscaping needs within three years. Development standards were created with development of the ordinance including parking lot concepts.

MS4 Stormwater Management Plans

The Town of Oro Valley, Pima County, City of Tucson and the Town of Marana each have a stormwater plan and MS4 permit responsibilities

City of Tucson Drought Response Plan and Pima County Drought Response Plan

both encourage increased stormwater use at each increased drought stage.

[Tucson Water 2020 Strategic Plan](#)

summarizes policies in Plan Tucson and the Water Infrastructure Supply study regarding increasing stormwater use as part of the water portfolio.

[City of Tucson Bicycle Boulevard Master Plan](#)

includes many design and project planning elements and encourages integration with GI approaches. Uses sample evaluation of tree canopy cover to achieve shade goals.

Resolutions have been passed by the PAG Regional Council supporting Rainwater Harvesting (2008), Low Impact Development (2012), Green Infrastructure (2015), Climate Resiliency (2016), Complete Streets (2015), and Heritage of Desert Waters (2017). Resolutions highlight benefits, commend progress, affirm regional values and provide recommendations and endorsement for future direction by regional leaders.

Identify Priority Locations and Targets

PAG created the GI Prioritization Tool to help municipalities, non-profits, and neighborhood groups to select priority locations that would benefit the most from increased GI. GI resources can be distributed to areas with opportunities for enhanced stormwater management, mobility and livability. Plans can be created dynamically by the community for various related concerns and opportunities depending on criteria for a project's funding sources, goals, and requirements. Print options available on this tool aid grant applications for municipalities, non-profits and community groups. PAG's interactive web map is a publicly available tool that was first developed by PAG in 2012 and has been used to select priority locations for GI by multiple jurisdictions. The GI Prioritization Tool helps decision-makers allocate limited financial resources and support GI efforts.

The interactive map contains multiple layers to allow users to explore the relationships between environmental conditions and social demographics. Available data layers include several layers processed from PAG LiDAR data such as regional tree canopy, impervious surfaces, and stormwater flow paths. Layers were compiled by building numerous partnerships with other agencies including RFCD, UA, the Trust for Public Lands and the State Public Health Department. PAG recommends using the following priorities when assessing multi-benefit opportunities using the PAG GI Prioritization Tool.

Location Priorities:

- Below Average (7%) tree canopy
- Proximity to shallow groundwater
- Proximity to watercourse
- Above average heat
- Heat vulnerable demographics
- Bus stops, bikeways, schools, parks
- Pedestrian activity areas

Related resources:

- PAG GI Prioritization Tool

For the City of Tucson's Green Stormwater Infrastructure Fund Proposal (2019), the City requested and utilized the diverse compilation of layers from the PAG map to assess priority locations for distribution of the funds. Prioritization of the GI projects was performed adding weights to criteria of heat vulnerable populations and low canopy as well as the City's identified priority stormwater management system areas and CIP project areas. Other example uses include City and County selection of below average canopy and above average heat for priority planting locations. In Fall 2018, the County utilized PAG's geographic assessment of those priorities to identify locations for GI on public properties in the Sustainable Action Plan for County Operations. This plan sets sustainability goals through 2025, emphasizing mitigation and adaptation measures to meet U.S. objectives for the international Paris Agreement.[29] GI prioritization examples have also been provided by PAG for the Tucson Bicycle Boulevard Plan. Landscape, transportation, and active modes plans, and guidelines would likewise benefit from GI priority location analysis and use of GI in design typologies.

PAG's 2018 Green Stormwater Infrastructure Plan includes the regional canopy cover assessments based on PAG's 2008 LiDAR datasets and recommends canopy targets based on geographic assessments. PAG found the tree cover averaged almost 8 percent in our region and approximately 3 million tree points. PAG found the region has a 4 percent lower canopy than the average for other arid Southwest urban areas. This varies widely from 1 percent to above

LONG -RANGE REGIONAL TRANSIT PLAN

Bus stop with tree shade incorporated.
Photo: PAG

RTA's Long -Range Regional Transit Plan

The RTA's Long -Range Regional Transit Plan discusses various levels of bus and streetcar stops improvement recommendations for each typology. This would be an opportunity to discuss the inclusion of GI for tree shade and other safety benefits. Planting a tree behind the bench would likely be a much more cost-effective way to provide shade than building a shade structure for all stops. Given the aforementioned risks to pedestrians on roads and the vulnerabilities of these demographics to heat related health issues, tree shade should be prioritized at the stops as well as the walksheds that users rely on to get to their stops. Appropriate contexts may be stops that are between intersections (to avoid sight visibility triangles) and that have resources for tree establishment period. If the LRRTP station typologies were translated into actual design guidelines, then GI could be incorporated at that time. While the plan is created by the RTA, the city has traditionally handled bus stop infrastructure, funding, and construction so to be implemented it would likely depend on the city adopting the idea.

District of Columbia, Sustainable DC Plan

Sustainable DC Plan calls for increasing GI in the public right-of-way (ROW) and taking actions to improve the health of the city's waterways. Under the plan, the District's Department of Transportation (DDOT) is installing GI as part of construction projects and in retrofit projects to reduce stormwater runoff. Where watershed and infrastructure improvements are prioritized, DDOT may construct green street and green alley projects that utilize GI techniques. DC's Long Range Transportation Plan includes an Environmental Inventory Map with GI features. DC's Fiscal Year 2019 - 2024 Transportation Improvement Plan, includes GI projects. In 2014, DDOT released the GI Standards which included technical drawings, specifications, design manual, plant list, and maintenance schedules. The Department has also released a GI guide, "Greening DC Streets," which summarizes GI opportunities and constraints in the District.[31]

Wasatch Front Regional Council, Regional Transportation Plan 2019-2050

This comprehensive regional plan reflects the value of integrating GI provisions throughout the planning process. The Council recognized that both green and gray infrastructure function together and that there are environmental and community benefits which arise when transportation practitioners draw from both fields to understand and respond to the complexities of the urban landscape. The plan envisions that GI will play a role in contributing to the increased resiliency of the regional transportation system by reducing or mitigating stormwater impacts.

20 percent across the region. While tree canopy provides shade benefits, understory can provide additional habitat, aesthetic and watershed health qualities. Other vegetative cover was nearly 30 percent. To reach 25 percent canopy in the urban area, the region would need a total of 7.5 million more trees. Since new hardscape, including streets, create more runoff this is sometimes referred to as "new water." Pre-development, this water would have otherwise evaporated, as very little of it naturally recharges aquifers in desert regions. "Stormwater Harvesting and Management as a Supplemental Resource Technical Paper'' from the Water and Wastewater Infrastructure, Supply and Planning Study, Phase II (Pima County and the City of Tucson, 2009) has calculated "new water" amounts that can be used as stormwater harvesting targets. That paper states that about 30,000 to 40,000 acre-feet (AF) of "new water" could be harvested from impervious surfaces in the City of Tucson in an average year. This harvestable water could theoretically support up to 4.3 million trees within the urban footprint of Pima County, depending on distribution of stormwater and vegetation types.[30] Therefore, the 25 percent canopy goal would be feasible from a stormwater availability standpoint. However, establishment periods, extreme drought, and reflective and radiant heat along streets create more stress on young trees, and so supplemental irrigation may be needed at times. Transportation projects can be a major vehicle to achieve these goals when coordinated across multiple departments.

Recommended Targets

- Create a target of 15-25% average cover over the full urban area within 20 years (by 2040)
- Focus outreach and capital improvement efforts in areas with less than average tree cover
- Implement greater cover in areas of greater mitigation need (see priorities list above)
- Utilize street runoff wherever feasible to support vegetation and achieve a goal of 40,000 AF
- At least 90% of new trees to be irrigated primarily by stormwater
- Convert impervious space to green space

Include GI Performance Measures within Long-Range Transportation Plans (LRTP)

PAG's RMAP is the region's long-range transportation plan covering a minimum of a 20-year planning period. Based on federal requirements, this plan takes a performance based approach. Performance measures were identified as targets to help the regional and operating agencies assess system wide progress relative to regional goals. This helps ensure that investments are achieving national and regional goals. Establishing similar performance based planning measures for GI, and including GI as a measurable ingredient in system wide roadway planning, could be an approach to folding GI into roadway design. Some of PAG's performance measures include System Maintenance, Safety, Multimodal Choices, System Performance, and Environmental Stewardship. Metrics toward these targets include pedestrian and bicyclist fatalities, pedestrian and cyclist facilities, air pollution and greenhouse gas emissions, and vehicle miles traveled. Performance metrics that evaluate effectiveness of the performance targets could include reduction of road closures due to water in the roadway, shade improvements (tree canopy), increased pedestrian activity, reductions in irrigation, mitigated runoff from impervious surfaces, and improved infiltration rates.

The TIP process, prepared by PAG, also utilizes the performance-based approach. Projects are reviewed for anticipated impacts to the transportation network and how they may advance the progress toward target achievement. Ideally, projects included in both the RMAP and TIP will have a positive impact in achieving the desired performance outcomes. Based on this approach, GI performance targets could be considered as part of the overall performance of the transportation network.

Related, PAG Safety Assessments gather data on incidence of trees/bushes as part of traffic incidents with injury and fatality and found that trees/bushes relate to safety in less than 1% of the incidents. Gravel and standing water are also tracked as part of the road conditions for the assessments.

Establish GI Project Performance Goals

By designing to meet performance goals for GI projects, project managers can ensure the effectiveness of the drainage benefits and of the landscape to meet its intended purposes. These are based on but may vary from Tucson's Green Streets Active Practice Guideline Performance Goals and are proposed as general minimal guidelines for use by other local jurisdictions to enhance consistency and ease of practice for practitioners and improve performance as a region.

The guiding principles for these goals include:

- Prioritize tree planting and engaging the community in areas with the greatest needs and multiple benefits.
- Use on-site non-potable water sources for irrigation before any imported water source. Invest potable water in the short term to establish trees as needed.
- Wherever possible, natural drainages should be the primary stormwater infrastructure.
- Wherever possible, canopy and natural drainages should be preserved, restored and maintained to create the primary stormwater infrastructure by protecting arroyos, creating green streets and daylighting underground systems.
- Use the conventional storm drain system as the overflow approach, not the primary system to manage stormwater. (Visible water flow systems are easier to notice and maintain.)
- Use public right-of-way stormwater installations to inspire private property installations and serve as model installations for neighborhoods.
- Decrease connectivity of impervious space and convert to green space. Use water harvesting to reduce runoff from hardscape from reaching the street. Emphasize harvesting efforts at the top of each watershed.

Drainage Performance Goals

1. **Routing and Conveyance.** Hardscape and landscape features will be designed to slow stormwater runoff and to encourage infiltration within the landscape. Additionally, design of all features will be mindful to:

   a. route stormwater runoff from the roadway and direct through GI features in parkways and medians before entering storm drains or natural drainage ways to provide moisture in the soil for plants and trees and provide stormwater pollution mitigation,

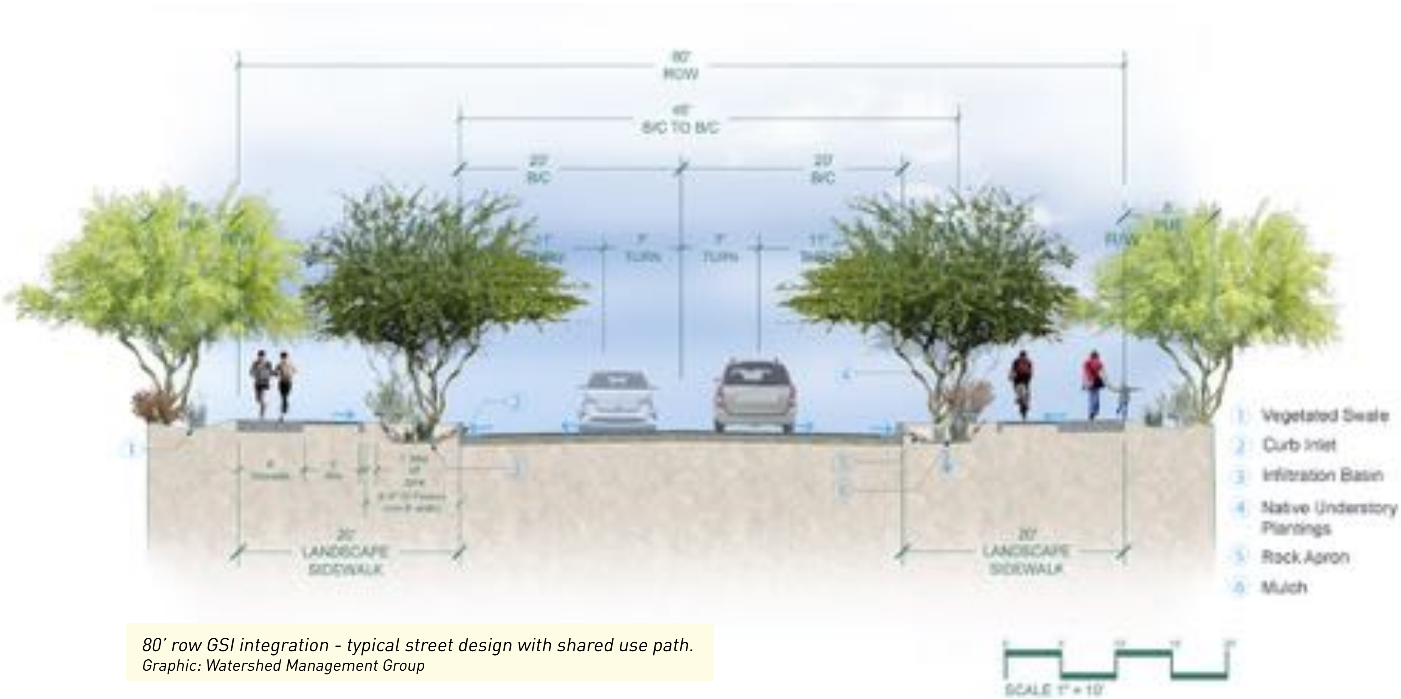
   b. ensure ease of maintenance, and

   c. use and integrate 'waste' materials (e.g. tree trimmings as mulch and salvaged concrete in place of mined rock for rip-rap or screened rock mulch).

2. **Runoff Collection.** Landscape areas along streets are designed to:

   a. retain at least the first 0.5 inch of rainfall falling on the roadway and public right-of-way (not including run-on from other streets and properties) dependent on right-of-way width, to mimic pre-development conditions and capture first flush, and

   b. accept a maximum final pooling depth of eight inches of stormwater for public safety.



80' row GSI integration - typical street design with shared use path.
Graphic: Watershed Management Group

3. **Infiltration.** Infiltration of retained stormwater runoff is a critical function of GI. Several items will be considered when designing the feature to ensure infiltration within 24 hours to prevent mosquitos and promote soil health.

   a. Compaction of landscape areas will be avoided. A 12"-18" depth for tilling or ripping will be performed in all plant-able and infiltration areas which have been compacted.

   b. On-site soil percolation tests will be used to evaluate the ability of the soil to transmit water through the soil profile. If a restrictive soil layer is present (e.g. caliche, or clay accumulation) then it is recommended to auger or rip through the restrictive layer to allow water percolation to underlying soil layers. Coarse, well drained soils often underlie caliche and clay lenses.

   c. Soil amendments and structural soils may be used if necessary, to ensure sufficient infiltration of stormwater runoff. Use of amended soils may be impractical at a larger scale due to high construction cost.

Landscape Performance Goals

1. **Irrigation.** The planting plan is based on a water budget where plants associated with GI elements can be fully supported by collected stormwater in seasons receiving 80% of average rainfall for drought resilience. Where feasible, plan for plants that require no irrigation after establishment. First and foremost, plant to capture rain that falls on the project site.

2. **Plant composition.** Plant composition must include a minimum of 75% native, low water use plants so that water demands match seasonal availability. The 25% non-native may be needed for space constraints. All plants shall be in a low water use, low water use/ drought tolerant category to reduce overall demand.

3. **Vegetation coverage.** GI is a living engineered system that requires plants as a functional element to achieve desired primary and co-benefits. The following guidelines will ensure a functional feature that safely infiltrates stormwater while providing for myriad co-benefits. When using goals to create policies, ensure they are simple to calculate and understand in order to aid compliance and review.

   a. Create a goal setting process based on street typologies that help to meet larger community canopy goals. Streets are major opportunities for increasing overall canopy coverage due to access to street runoff. Example goal: Canopy of shade trees, when mature, covers a minimum of 25% of the rights-of-way without creating sight visibility, pedestrian or utility conflicts.

   b. Coverage of understory vegetation, based on mature diameter, is a minimum of 25% of the Stormwater Infiltration Area.

Stormwater Infiltration Area is defined as the maximum pooling extent within a landscape area. This will ensure that sufficient root mass is present to facilitate infiltration and increase of soil organic content critical for long-term soil health.

   c. Coverage of understory vegetation for other permeable landscapes should resemble natural plant community densities to facilitate water savings by not requiring long-term irrigation once plants are established.

4. **Other.** As part of final landscape stabilization, 100% of disturbed and/or barren areas to be covered with native revegetation mix and equal replacement of trees, shrubs, herbaceous plants and succulents. To save expense and prevent excess heat, stabilization with hydroseed is preferred over gravel and rock and use of large rip-rap is recommended only for slope stabilization. Provide enough space to allow the tree to grow to maturity.

Ensure Maintenance Foresight is Included in Project Designs and Long Term Plans

In transportation projects, the original funding often covers only the establishment period for vegetation for a limited number of years due to restrictions on use of some funding types on maintenance. For example, RTA projects excluded maintenance due to state laws until there was a recent legislative change. A supplemental plan for ongoing maintenance resources is key to long term success of the investment. Locally, maintenance of GI along streets in subdivisions and neighborhoods relies on agreements by adjacent private homeowners and often assisted by stewards such as through Tucson Clean and Beautiful. In the City of Tucson, businesses are also responsible for maintaining the adjacent ROW and buffer yards and the City assists with maintenance when critical for safety. ROW maintenance is the County responsibility in the unincorporated County. Sites that are maintained by municipalities could improve results by setting standards for GI training for employees and qualifications for contractors. Challenges with community pushback for a tidier look could be addressed through outreach.

Design is also key to success of the project over the long term. GI sites can be designed for cost-effective maintenance from the onset. Further information on design, installation, and operations and maintenance (O&M) best practices can be found in Part 3 along with associated guidance checklists.

Additionally, it is critical to preserve future GI retrofit opportunities especially behind the street curb. This may include a review check before issuing permits for utility installations, upgrades, or other ROW infrastructure work which could limit or hinder the ability to design and install GI.

Review project proposals for compliance with GI standards and policies

Project review and permitting staff in development services have an important role in ensuring and encouraging private developers to implement GI to manage roadway and parking lot runoff and should coordinate with transportation departments and others. Existing standards and policies incentivize or require GI/rainwater harvesting for many private development projects. Staff can help leverage these projects for the benefit of the community by ensuring that development projects routinely and consistently comply with these policies/standards. It is worth noting that multiple policies may apply to a project depending on the jurisdiction. For example, a commercial development in the City of Tucson could claim that their grading addressed both the first flush requirement and the commercial water harvesting requirement.

Leadership at municipal and County levels have provided staff with a foundation of support by implementing GI policies and standards. Development services, transportation departments and their civic and community partners can assist with compliance by undertaking targeted outreach and education efforts. The resources, example design guides, and checklists provided in this document can be valuable tools in departmental efforts to resolve barriers, challenges and uncertainties about the feasibility and benefits of GI. Through consistent application of existing standards and policies, the private development community can become valuable champions of GI.

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Pima Cty Water Reclamation Campus
Photo: gmvargas.com

PART 2

Funding Green Infrastructure as Part of Transportation Projects

Assuring adequate funding for GI in transportation projects has unique challenges and opportunities. Opportunities may arise for using transportation-specific funding sources to provide GI benefits that other municipal funding sources cannot. Alternatively, transportation projects may provide an opportunity to leverage non-transportation oriented funding in order to optimize public investment in GI benefits. In general, and regardless of source, funding goes further when used for multi-benefit purposes and using an integrated approach.

Bonding and Debt Financing Green Infrastructure

The funds used for transportation projects can complete the GI aspects, or additional funds can be sought to enhance and retrofit GI features. In addition to the funds that may flow to GI from private development projects and from municipal/county Capital Improvement Projects, below are some transportation funding sources that allow and encourage GI uses.

Transportation agencies and local governments may opt to fund roadway and other transit projects through debt financing, particularly by issuing municipal bonds.[32] Debt financing should be thought of as an important option for creating sufficient capital for investments in up-to-date transportation networks, particularly because they create sufficient one-time resources for investments in major projects or multiple projects included in a CIP. In addition, financing spreads the debt burden across time, which allows the project(s) to be paid for by the people who benefit across the lifetime of the constructed infrastructure. Debt financing requires a dedicated, sustainable source of revenue for repayment of the bond principal plus interest. Often a tax or rate increase will provide that source of income. Arizona law requires that voters approve general obligation, highway user revenue and utility revenue bonds which creates both an obligation for transportation agencies to obtain voter approval and an opportunity to engage the public in a way that is consistent with a CSS approach.

There are at least three approaches to funding GI through bond financing. First, transportation related bond issuances may be an option for future city or Pima County roadway projects. As the bond package is designed and drafted it is important to include the capital costs of any associated GI components of the bond funded projects and to specifically allocate bond revenues to GI features. A second approach would be to include transit corridor GI projects as eligible features within a non-transportation bond, such as a park, flood control, or even school bonds. GI practices are appropriate for managing runoff from constructed features of many capital improvements. Finally,

Mural by El Ojito Historic Spring, Tucson. Photo: American Rivers

Tucson-area cities and towns or Pima County may consider a bond issuance that is specifically intended to fund GI projects, either as a "stand alone" effort or perhaps as part of a broader investment package intended to fund climate resiliency projects.[33]

There can be challenges associated with incurring bond debt to finance GI projects. These projects are, by their nature, distributed across many locations in contrast to more traditional, centralized assets. They may even be constructed on private property with the intention of providing a public benefit. Recent changes to accounting rules have reduced some of the obstacles, making it easier for public agencies to treat distributed infrastructure projects (even conservation programs) as assets. These changes, although arcane for most transportation planners, make it easier to contemplate bond financing for GI.[34]

Tucson Parks and Connections Bond:
Proposition 407, approved by Tucson voters in 2018, provided $225 million in general obligation bond funds to support investments in city parks, park amenities and connections projects (pedestrian pathways, bicycle pathways, pedestrian, and bicycle safety). While there are significant opportunities to incorporate GI features into parks and playgrounds, the corridor connections projects also create opportunities for integrating GI into transportation-related infrastructure.

Paying for green infrastructure with transportation funding

There may be many instances in which implementing GI is an appropriate practice for achieving transportation objectives and is eligible for funding through traditional transportation-related and funding sources.

Better Utilizing Investments to Leverage Development (BUILD) Transportation Discretionary Grants

The BUILD Grant program was launched in 2018 as a federal transportation infrastructure investment program. Formerly known as TIGER Grants, BUILD grants are intended to fund large infrastructure projects and can be used for planning initiatives. BUILD Grants include a designated allocation for rural projects in an effort to equitably distribute the funding between rural and urban areas. Although BUILD Grants are highly competitive, the criteria for developing a successful project include environmental protection, innovation, and quality of life improvements. GI design elements could factor into a successful BUILD grant application.

FAST Act Transportation Alternatives/Surface Transportation Block Grant Program (STBG)

MPOs, such as PAG, are required to consider several planning factors in the development of transportation plans and programs. The metropolitan planning process includes the following planning factors that could be applied to GI-based projects or projects which include GI:

- improving transportation system resiliency and reliability [23 U.S.C. 134(h)(1)(I)]
- reducing (or mitigating) the stormwater impacts of surface transportation [23 U.S.C. 134(h)(1)(I)]
- enhancing travel and tourism [23 U.S.C. 134(h)(1)(J)]
- reducing the vulnerability of existing transportation infrastructure to natural disasters [23 U.S.C. 134(i)(2)(G)]

The Transportation Alternatives (TA) set-aside funds from the STBG program encompass a variety of smaller-scale transportation projects, community improvements and environmental mitigation related to stormwater, and habitat connectivity. Tribal governments, local governments, transit agencies, school districts, and nonprofit organizations responsible for local transportation safety programs are eligible to apply for this competitive grant program. PAG uses its TIP for applications, and all projects included in the TIP must be drawn from the RMAP, described further in the performance measures section above. The TIP is a five-year schedule and budget of anticipated transportation improvements within eastern Pima County. The TIP is typically updated biennially through a multi-step process in association with PAG's member jurisdictions and other implementing agencies. The goal of the process is to develop a TIP that makes optimum use of available federal, state and local funds and resources to serve the region's multi-modal transportation needs. The RTA Board set policy that any funds available through the TIP process be prioritized to the delivery of RTA named projects and promises made to the voters.

FHWA Congestion Mitigation and Air Quality Improvement Program (CMAQ)

The CMAQ program provides a funding source to state and local governments for transportation projects and programs to help meet the requirements of the Clean Air Act. Funding is available to reduce congestion and improve air quality for areas that do not meet the National Ambient Air Quality Standards for ozone, carbon monoxide, or particulate matter (nonattainment areas), as well as former nonattainment areas that are now in compliance (maintenance areas). States with no nonattainment or maintenance areas may use their CMAQ funds for any CMAQ- or STBG-eligible project. Under the FAST Act, a State with PM2.5 (fine particulate matter) nonattainment or maintenance areas must use a portion of its funds to address PM2.5 emissions in such areas. Pima County is not in nonattainment for PM2.5.

List of eligible CMAQ projects: https://www.fhwa.dot.gov/environMent/air_quality/cmaq/reference/cmaq_essentials/

EPA link regarding CMAQ regarding pedestrian and bicycle projects that have GI elements incorporated: https://www.epa.gov/green-infrastructure/green-infrastructure-funding-opportunities

In Pima County, the Tucson Air Planning Area (TAPA) is under a second 10-year Carbon Monoxide (CO) Limited Maintenance Plan which concludes at the end of 2020. The region is designated attainment status for the ozone National Ambient Air Quality Standard (NAAQS). In Pima County, there are two designated PM10 nonattainment areas in Rillito and Ajo.

The Pima County region is not currently a recipient of CMAQ funds as outlined in statewide transportation funding distribution. Any receipt of CMAQ funds would impact other fund sources available to the region and the region would likely lose proportionate funding from other less restrictive funds like STBG which have greater flexibility and simpler reporting requirements. These funds may be attractive if a reliable funding source for focused air mitigation is needed but may not be an appropriate tool for the Tucson region.

Local Tax Revenue and Capital Improvement Projects

Local tax revenues are used for local funding priorities. The CIP budget is typically planned over a five-year period because it is funding construction projects rather than day-to-day operating costs. The CIP budget includes all the costs necessary for major construction projects such as land acquisition, project design, project management, and construction costs. The CIP is funded primarily through taxes, fees, grants, and bonds. Tax revenues can fluctuate with the economy and local spending so it is important to balance urban design, mobility and safety needs with a balance of other regional and federal funds. Many examples of CIP projects with GI can be found in the City of Tucson since they follow the Green Streets Active Practice Guidelines.

Special Revenue funds consist of revenue sources that are dedicated to a specific purpose. This includes state and local taxes as well as grants and certain fees. Special revenue tax funds, such as Rio Nuevo tax increment financing fund, have been used for GI projects. One such project is the Scott Avenue retrofit in downtown Tucson.

Regional Transportation Authority

The Regional Transportation Authority (RTA) is an independent taxing district within Pima County overseen by the PAG Regional Council members. The RTA delivers multimodal transportation projects that improve our region's mobility, safety and environment through a half-cent excise tax. Pima County voters approved the 20-year RTA plan in 2006.

The current RTA program is set to expire in 2026, which is prompting an "RTA Next" process. In 2020, the RTA is in the process of developing the plan for "RTA Next." Currently, as a general value engineering rule, landscape costs on RTA projects must be under 4% of the project budget. The challenge is when landscape is also performing functions for drainage management or when sufficient funds are not available for this end of a project. The current RTA has a category of funding for wildlife corridors, which in the environmental planning field are considered large scale GI projects. Voters in the future may be interested in small scale GI installation and maintenance in developed transportation corridors either as a category of funding or as a part of the enhanced drainage and safety performance for each roadway project. In Maricopa County, the half-cent sales tax for transportation approved through Proposition 400 is the comparable effort approved by Maricopa County voters in 2004. This could serve as an example of other areas the Pima County RTA could fund. The MAG Prop 400 funding goes in part toward regional and state highways and encompasses landscape maintenance and outreach.

Accessing Non-Transportation Loan and Grant Programs

604(b) Funds

The Arizona Department of Environmental Quality (ADEQ) distributes the 604(b) Water Quality Management Program with a focus on water quality management planning (not projects on-the-ground). Up to $60,000 is available annually and is currently given on a rotational basis to each of the Designated Planning Agencies (DPA) under section 208 of the Clean Water Act, across the state. The DPAs may work or pass the funds to other partners such as cities, Universities and non-profits. Allowable categories have included LID, flood control, stormwater infiltration, streambank stabilization, education/outreach, and addressing pet waste. Priority has been given to plans that address Impaired Waters. In Pima County, PAG is the DPA and the Santa Cruz River's impairment for *E. coli* contributed by stormwater can be addressed through GI planning. Past uses of these funds have included updating GI standards and specifications in the Maricopa region. This document may help prepare similar local efforts.

Urban Forestry Grants

The Urban and Community Forestry Challenge Cost-Share Grant Program is run through the National Urban and Community Forestry Advisory Council (NUCFAC) established in the 1990 Farm Bill under the U.S. Forest Service.[35] NUCFAC assists the Secretary of the U.S. Department of Agriculture in the grant application and development process. The purpose of the grant program is to fund urban and community forestry projects that have a national or regional impact.[36] While this program is not designed to fully fund capital projects or demonstration projects, it could be an important source of funding for capacity building and planning to set policies that incentivize GI for transportation. For example, the Fiscal Year 2020 funding cycle invites applications for projects that integrate urban and community forestry into all scales of planning (including transportation) or for efforts to promote health and resilience of urban and community forests. Previous funding rounds have focused on projects that will address significant barriers to GI, focusing on the role of trees and urban forests.

Palo Verde pocket park.
Photo: Watershed Management Group

The Urban Forestry Grants create opportunities for transportation agencies to work collaboratively with civic organizations and local governments to implement a green street policy, integrate GI upfront in planning processes, or address specific barriers to including GI in transportation projects.

Community Development Block Grants

The U.S. Department of Housing and Urban Development (HUD) Community Development Block Grants (CDBG) program provides annual grants through a formula to local governments and states. The CDBG program is designed to assist in community redevelopment, providing funding to expand economic activity, improve community services, and revitalize neighborhoods. Eligible activities include the construction of water infrastructure and streets.[37] States and local governments could look to the CBDG program as a potential source of funding to add GI elements into a street reconstruction project, for example.[38]

Rincon Heights Pocket Park Art.
Photo: Watershed Management Group

EPA Section 319 Funding

Authorized by Section 319 of the Clean Water Act, this program provides funding to projects that address nonpoint source pollution reduction projects.[39] These funds are distributed by the U.S. EPA to state and tribal agencies which then administer them. In Arizona, the ADEQ Water Quality Division manages the state's 319 Program. ADEQ awards Water Quality Improvement Grants to local governments, watershed partnerships, and other entities to fund projects that will quantifiably reduce nonpoint source pollution. The grant program is one element of the Department's 5-year Nonpoint Source Management Plan. At times ADEQ has targeted these funds toward waters with impairments. Since the Santa Cruz River has an impairment for *E. coli* contributions in stormwater, GI is a valid solution for treatment.

EPA/NFWF Five Star and Urban Waters Small Grants Program

This program, an evolution of an earlier EPA Urban Waters Small Grants Program, is co-sponsored by EPA and the National Fish and Wildlife Federation (NFWF). The program supports projects that develop community stewardship of natural resources and address water quality issues.[40] Urban tree canopy restoration and stormwater management are among the activities funded through the program.

FEMA Pre-disaster Mitigation Grant Program

This FEMA program is designed to assist local communities with implementing a natural hazard mitigation program in order to reduce overall risk from future disasters. This program awards planning and project grants and provides opportunities for raising public awareness about reducing future losses before disaster strikes. To be eligible, projects must be consistent with the goals and objectives identified in a current FEMA-approved Hazard Mitigation Plan.[41] GI is an eligible mitigation method.

FEMA Flood Mitigation Assistance Grant Program

FEMA's Flood Hazard Mitigation Assistance program provides funding support to communities for projects that reduce the risks associated with flood and drought conditions. Aquifer storage and recovery, floodplain and stream restoration, flood diversion and storage, and GI methods are eligible for funding.[42]

A rainy day on Scott Avenue.
Photo: PAG

Clean Water State Revolving Fund

Like the Section 319 funding, the Clean Water State Revolving Fund (CWSRF) provides federal funds to state-administered programs which, in turn, distribute money to qualifying cities, towns, special districts and tribes. These awards are typically loans, with very favorable repayment provisions and occasional interest or principal forgiveness options. In Arizona, the CWSRF is managed by the Arizona Water Infrastructure Finance Authority (WIFA).[43] Stormwater management projects, including GI, are eligible for funding. Financing GI through the CWSRF allows transportation agencies to access project funds with no application or closing fees, 30 year repayment periods, and other advantages. WIFA also provides funding for technical assistance, enabling local governments to develop, fund and implement capital improvement projects.

The City of Flagstaff, in conjunction with Tucson-based Watershed Management Group, recently used WIFA technical assistance to develop a GI-focused Watershed Action Plan. The City of Peoria recently closed a 20-year, $6.2 million dollar loan to fund several stormwater management projects. The low, 1.6% interest rate and $1 million of forgivable principal enable the City to undertake drainage and flood reduction projects affordably.[44]

Local utility fees

Two jurisdictions within Pima County have adopted specific fees, levied against water customers or property owners, that provide sustainable revenue for GI projects. Coordination with these municipalities may create opportunities to align funding for specific projects.

Tucson Water Green Stormwater Infrastructure Fund

The Green Stormwater Infrastructure (GSI) Fund adopted in 2020, creates a reliable and dedicated funding source for planning, implementing, education, and maintaining GI projects city-wide. The fund will be resourced by a fee, assessed on Tucson Water customers within the City of Tucson, generating approximately $3 to $5 million per year. The majority of this sustainable revenue stream will be allocated to installation of GI projects; however, a portion will be directed to maintenance of existing projects and administration of the City's stormwater program.

Oro Valley Stormwater Utility

Established as an enterprise fund in the stormwater code, the stormwater utility "provides for the planning, design, construction, operation, and maintenance of stormwater facilities that safely drain and control the quantity and quality of storm run-off" in accord with the Town's stormwater management plan. Projects include ROW improvements.

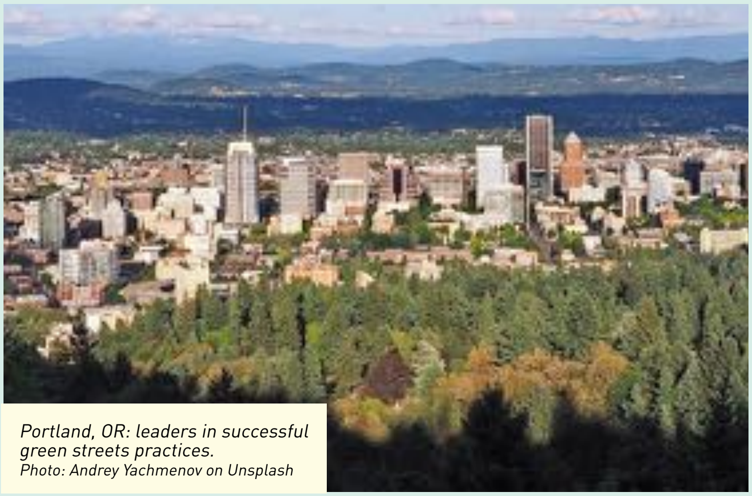
Policies that Support or Ensure Projects

Offsets/ In Lieu

In lieu fees or offsets provide flexible pathways for property developers to comply with local stormwater codes. When soil conditions or other factors limit or preclude on-site management of requisite volumes of stormwater and vegetation, these provisions allow developers the option to construct equivalent stormwater management and vegetation at an alternative location or to pay local government a fee intended to fund publicly constructed stormwater and vegetation practices. The benefit of these options is in the reduction in the number of projects granted waivers or exemptions from stormwater and vegetation management requirements. An example In-Lieu Compensation program could require that the ROW user(s) shall be responsible for covering 100% of the replacement cost for plant material removed during a project if there is no adequate space on site or nearby for replacement landscape and no space for stormwater harvesting. For retrofit sites, where the shade cover goals cannot be met, nearby sites may be used or commensurate payment into a GI fund.

CITY OF PORTLAND, OR

Any funded redevelopment or enhancement project that doesn't incorporate green street facilities as required in the Stormwater Management Manual but that requires a street opening permit or occurs in the ROW shall pay into a "% for Green" Street fund. The amount shall be 1% of the construction cost for the project. Exceptions apply such as emergency maintenance, repair of driveways, pedestrian path replacement, tree planting, and utility pole installation.



Portland, OR: leaders in successful green streets practices.
Photo: Andrey Yachmenov on Unsplash

Part 2 Endnotes

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Grant Road
Photo: Wheat Design Group

PART 3

Green Infrastructure Design, Implementation, and Maintenance for Arid Landscape Transportation Projects

The management of stormwater as a resource within and along our roadways requires establishing new guidelines at each stage of the GI project lifecycle to ensure continued public safety and overcome perceived and real barriers and challenges. The following chapter takes a solutions-based approach to addressing common challenges when considering GI features and then lays out guidance for design, implementation, and maintenance best practices to ensure a positive return on investment. This section is supplemented by the appendices including recommended design guides, plant lists, and maintenance schedules.

Terminology

Many GI related terms are used interchangeably. The information below is provided as a cross reference between terms used in various disciplines and policies. Transportation related examples are provided.

Curbless bioswale.
Photo: Watershed Management Group

Bioretention. Described as "stormwater harvesting" in many local manuals and it is important to note that these catch-basins not only retain water but also include vegetation as part of the infrastructure and function. Also called a rain garden or rain basin by the public. A shallow landscape depression sited at a low point to collect, utilize, treat, and infiltrate stormwater. Typically designed for water quality treatment; can also provide minor flood storage with enough space. Specifically, a bioretention basin design includes vegetative ground cover, organic mulch as a surface cover, and, when conditions allow, native shade trees. Pima County RFCD and City of Tucson manuals limit use of this term to GI management practices that include engineered soils.

Best management practices (BMPs). Activities, practices, or prohibitions of practices designed to prevent or reduce pollution.

Bioswale. A swale is described in local manuals as a depression that is cut into the soil for the purpose of conveying stormwater and it is important to note that although "bio" is not in those terms, in GI/LID guidance it is implied. A bioswale, or vegetated swale, is a linear vegetated landscape feature which promotes stormwater infiltration while facilitating drainage such as along roads with narrow rights-of-ways. May consist of a runnel or an earthen V-ditch if used to promote infiltration with checkdams, meanders and vegetation.

Complete Streets. An approach to transportation planning and design that guides the development of a safe, connected, and equitable transportation network for everyone - regardless of who they are, where they live, or how they get around.

Intersection bumpout with green infrastructure.
Photo: Watershed Management Group

Curb extension. A curb extension is a term for street design features where the existing curb line is extended into the parking lane of a street creating lane narrowing which may provide space for green infrastructure to manage street runoff. They can reduce impervious surfaces, reduce pedestrian crossing distances, and slow traffic as well as stormwater. Examples include bump outs, which when used with a meander is known as a chicane.

Curb inlets. Curb inlets, cuts, or cores are openings created in the curb to allow stormwater from the street or other adjacent impervious surface (e.g. parking lot) to flow into a depressed infiltration and planting area.

Crescent berms. Sometimes called "tree eyebrows" by Trees for Tucson, these round or boomerang shaped mounds of rock and soil are created perpendicular to runoff flow and may have a shallow excavation to hold water uphill of the berm. The berm is often placed outside the drip line of the tree and helps to detain the water and increase soil moisture.

Crescent berms create tree planting areas in a gravel lot previously used for parking.
Photo: Hans Huth

Daylight. To bring stormwater or street stormwater flow to the surface, exposed to open air and visible to the public.

First flush. The delivery of a highly concentrated pollutant loading during the early stages of a storm due to the washing effect of runoff on pollutants that have accumulated on drainage surfaces.

First-flush retention. Defined in the Pima County RFCD's Design Standards for Stormwater Detention and Retention as the capturing and retaining of the stormwater runoff volume from 0.5 inch of rainfall on all newly disturbed or impervious areas for new development or redevelopment. Often, requirements can be readily achieved through GI practices.

Sugar Hill neighborhood green alley during construction.
Photo: Watershed Management Group

Green Alley. Converted alleys from underutilized infrastructure into open space amenities using GI such as permeable pavement or bioswales. Benefits include reduced crime, encouraging people to walk, and creating connections between neighborhood destinations. (See Sugar Hill neighborhood in Tucson for an example).

Hardscape. Impermeable surfaces, such as concrete or stone, used in the landscape environment along sidewalks or in other areas used as public space

Infiltration Trenches and Drywells. Infiltration trenches are linear, rock-filled features that promote infiltration by providing a high ratio of sub-surface void space in permeable soils. Dry wells are typically distinguished by being deeper than they are wide but may not be applicable for the ROW depending on the jurisdiction. Dry wells are useful in densely developed areas. Any site with potential for previous underground contamination should be investigated and causes major restrictions. These features can be part of a GI system if the water is used by vegetation and can be accompanied by vegetation filter strips to treat contaminants prior to infiltration.

Low Impact Development (LID) – A management approach and set of practices that can reduce runoff and pollutant loadings by managing runoff as close to its source(s) as possible. LID includes overall site design approaches (holistic LID, or LID integrated management practices) and individual small-scale stormwater management practices (isolated LID practices) that promote the use of natural systems for infiltration, evapotranspiration and the harvesting and use of rainwater. Sometimes the term is used interchangeably with GI.

Permeable pavers reduce impervious surface areas and aid in heat island mitigation.
Photo: Watershed Management Group

Permeable Pavement. Permeable pavements include a variety of methods for paving roadways, bikepaths and pedestrian pathways to enable infiltration of stormwater runoff. Permeable pavement methods include pervious concrete, porous asphalt, paving stones, porous recycled tire products, and interlocking pavers

Pretreatment. A feature incorporated into a stormwater conveyance system to remove sediment, oil, grease, and other pollutants before they enter a stormwater basin, drywell or are discharged to receiving waters. May consist of a biological filtration.

Retention vs Detention. Retention collects and stores runoff while Detention is the temporary storage of stormwater to control discharge rates and allow for infiltration or discharge.

Stormwater Harvesting Basin. Both Pima County and City of Tucson regulatory and guidance manuals use this term to comprehensively include many GI retention practices, including bioretention basins, and roadside basins.

Urban Heat Island. An urban heat island is a metropolitan area which is significantly warmer than its surroundings. The urban heat island effect occurs as a result of buildings, roads, and other impervious surfaces absorbing the heat during the day and releasing it back slowly at night, thus increasing temperatures in urban areas. Shade-producing GI projects can reduce heat island impacts.

Common GI design challenges and potential solutions

Site characteristics can present design challenges which must be considered early in the design process. A CSS framework as outlined earlier may help overcome site challenges and foster a solution-oriented design process. When challenges are identified the project team may need to select alternate strategies or make slight design modifications to achieve the desired performance goals identified at the beginning of the project. A list of common challenges and potential solutions follows.

Underground utilities

Below ground utilities can impede green infrastructure installation but there are common solutions (see the checklist on Page 47 on early coordination and bundling lines near utilities). Excavation near utility lines is a primary concern for both project construction safety and the long-term health of the associated GI feature. Early identification of utility locations is critical to facilitate a smooth planning process for identification of GI opportunity areas and then the selection and placement of specific GI features.

It may be possible to modify the GI design to accommodate utility infrastructure situated over, under, or adjacent. For example, a basin area could transition to a shallow bioswale supporting herbaceous understory if there is concern for deeper excavation or tree roots. Alternatively, the GI features could shift in location or integrated with a meandering pedestrian and/or cycling paths to better accommodate basin areas and tree placement.

Additionally, it is recommended to coordinate with utility companies to assess when planned maintenance may occur to coordinate timing of the GI feature installation. This will prevent damage to the GI feature or potential sediment contribution into the infiltration basin area.

Prevent tree root damage to infrastructure (sidewalks, pipes, streets)

The selection and placement of appropriate trees is critical to avoid infrastructure damage. Tree roots naturally will grow to available water sources which when paired with GI will be the stormwater infiltration areas. Each tree should be paired with an ample infiltration area where pipes, sidewalks, or roadways do not need to be crossed by the tree roots. Selection of tree species with less aggressive root systems is recommended when there is concern (see recommended tree list in Appendix B). Additionally, root barriers can be installed along critical infrastructure when additional protection is desired.

Minimize flood risk

GI enables transportation engineers to avoid risks associated with traditional grey infrastructure including preventing flooding that is caused by impervious surfaces. GI can be designed to not increase flood risk, but also to reduce it.

The standard design details in the Green Infrastructure for Desert Communities developed by Watershed Management Group and reviewed by the City of Tucson Department of Transportation and Mobility highlights flow-neutral design strategies. General characteristics to allow for flow-neutral features include flush curbs where the curb is perpendicular to flow direction. Raised curbs on the street side of the GI feature are only located parallel to flow direction and used to protect from vehicles entering the structure to maintain flow-neutrality.

Common stormwater risks identified within the City of Tucson are flooding, erosion, sediment transport, and flash flood events.[45] The City of Tucson requires the following design criteria for all newly constructed or substantially improved roadways: Runoff from a ten-year storm must be contained within the curbs of

CASE STUDY

Urban runoff can be valued as a resource.
Photo: Watershed Management Group

A 2017 drainage memorandum[47] by Kimley-Horn Associates (planning and design engineering consultants) regarding a drainage analysis for the Glenn Street Neighborhood Improvement Project from Columbus Blvd to Country Club Road reviewed the potential flood risk of adjacent properties associated with the design of GI chicane (bump-out) features. Kimley-Horn assessed the additional flood risk for two design scenarios based on the concern that GI features increased the street roughness thus impeding flood flows on the street.

OPTION 1
Included a 4-ft wide opening adjacent to the existing curb to allow street runoff to flow into and out of the depressed buffer-yard with use of a vertical curb extending from the opening, around and including the parallel curb section.

OPTION 2
Eliminated all vertical curbs except the portion parallel to the existing curb. The Manning's Normal Depth calculations assumed a street with full flow.

Both design options resulted in a potential rise in flow depth within the street of less than the maximum allowable of 0.1 feet. The drainage memo recommended Option 2 to minimize drainage impacts on adjacent parcels compared to existing conditions as it would divert less than 3% of the street flow into adjacent properties compared to 15% for Option 1. Additionally, they alleviated concerns of flooding by recommending plants that will not impede runoff such as "... thin plants like grasses that would lay down during a flow event, or a small trunked tree with foliage well above the top of curb elevation. Bushes, shrubs, or other plants that increase roughness and potentially block flow should be avoided." The City ultimately allowed the use of GI chicanes and chose option 2 for the design and implementation of the Glenn Street chicanes.

the street. On multi lane roadways, at least one travel lane in each direction shall be free from flooding during a 10-year flood. Otherwise storm drains, drainage channels, or other acceptable infrastructure shall be provided to comply with all-weather access requirements. In order to meet the above design criteria, Tucson employs a mix of traditional drainage practices and water harvesting/ GI methods.[46]

Wilson Drainage flooding creates road danger.
Photo: Watershed Management Group

Mitigate peak flood flows

The ability of distributed GI to mitigate peak regulatory flood events relies largely on the scale of the intervention across a target subwatershed. Taking an integrative approach to treat both private parcels and public rights-of-way (ROWs) can substantially reduce peak flow volumes and flood depths. Two flood model case studies highlight the potential of GI under different treatment scenarios. A 2015 report by Watershed Management Group in partnership with Pima County Regional Flood Control District (RFCD) and the City of Tucson Ward 1 Council Office indicated that GI implemented broadly (25% level of adoption by residential front yards with select green streets retro-fits) across an urban subwatershed can have a significant reduction ranging from 10% to 24%) by subwatershed for a 100-year 3-hour event.[48]

A Tempe, AZ area Drainage Master Study reviewed the implications of LID interventions by type and at different adoption levels. The model results indicated the Green Street treatment scenario reduced peak flows by 58%, on-lot treatments had the highest impact to reducing peak flow (86% reduction), and Green Parking (77% reduction) the next highest. [49]

Enhanced mobility and safety

GI is compatible with enhancing the safety of alternative mobility modes. Enhanced safety often is the result by means of calming vehicular traffic, narrowing pedestrian crossing points, or providing a physical buffer to vehicles. Additional safety benefits may also include more efficiently drained pedestrian and bicycle travel lanes, reducing flood flow depths, shading and cooling the streetscape, and improving air quality. As mentioned in following sections it is important to maintain planting setbacks from travel areas and lines of sight for general visibility.

Often the GI feature can be placed and aligned to help physically buffer pedestrians and cyclists from vehicles. When creating a visually meandering roadway with chicanes or other features be sure that ample signage or reflectors are in place for nighttime safety.

Vehicle safety

While GI should enhance vehicle safety, however, design of GI is often limited by a fear of what might happen to the unsafely operated vehicle. It should be accepted that if GI is used as a vehicle buffer for bicycling and pedestrian travel lanes then vehicle encounters with the GI feature may occur. GI features should follow generally accepted roadway safety guidelines based on the road type in place by the local jurisdiction/authority and the context of the frequent user modes. See the GI feature standard designs found in Appendix A. The PAG Road Safety Assessment process has resulted in discoveries that even following all design standards doesn't guarantee the safest outcome necessarily. The standards need to take into account the impacts their application will have on performance. The answer is context sensitive, not a one size fits all distinction. Training and experience of those addressing or interpreting the standards are typically the biggest factors in this contextual approach.

Sight visibility requirements

GI features should maintain site visibility requirements associated with turn lanes, ingress and egress points, and even residential driveways. A recommended understory plant list for use in GI features is included (see Appendix B). Plants which can maintain clear site lines should be allowed in associated GI features even if adjacent to intersections or turn lanes.

By way of example see Sec. 25-52.1(4) of the Tucson City Code, 5-01.7.0 Unified Development Code STANDARDS FOR TREES IN SIGHT VISIBILITY TRIANGLES, and 10-01.5.0 Tucson Technical Standards Manual SIGHT VISIBILITY.

Soil stability

GI features if installed properly should not compromise soil stability or impair adjacent roadway infrastructure. Typically, the header curb with a depth of at least 12" in the soil profile is sufficient to protect instreet roadway surfaces or other infrastructure. GI infiltration areas are typically limited to an 8" ponding depth which facilitates rapid infiltration and minimizes the potential of full saturation of the surrounding soil or seepage underneath a compacted and well prepared roadbed.

If a soil test confirms presence of a high percentage of shrink-swell clays or presence of soil piping characteristics, then a geotechnical engineer should be consulted. See the best practices checklist for how to address limiting soil layers which can impair drainage. Lastly, piping or slumping may occur if a nearby or underlying utility line trench was not properly re-compacted when filled. This is a rare occurrence. The utility should be contacted and informed of the problem for coordinating and determining how to best address this. If there is further need for a soil moisture barrier based on the soil stability test, they can be installed vertically along roadway edges or other critical infrastructure to minimize saturation of soil adjacent to stormwater basin areas. Tree planting cells can also be used to minimize lateral moisture seepage.

Accumulation of sediment in the basin is typically only a problem if infiltration is affected by fines or retention volume is reduced. Otherwise sediment may act as a beneficial mulch. Sediment traps can be used if maintenance regimes support periodic clean out to help meet specified stormwater quality goals.

Rural Roads

Stormwater management on rural roads can have an impact on habitat, waterways, and erosion. Pima County has had success in addressing runoff on rural roads with water harvesting approaches. Pima County has trained employees with Bill Zeedyk and reference his manual Water Harvesting from Low-Standard Rural Roads. This manual uses the approach of improving common grade control practices to create vegetation and water quality benefits. For example, flow splitters and spreaders are common techniques used on rural roads to evenly distribute flow using a wing ditch off a road drain ditch. When using these practices, gradient, switchbacks, and spacing are key to creating benefits of water harvesting and effective sediment control. A media luna uses loose rock in a long band with ends pointed up-valley to prevent erosion on a hillside, which may be seen along a raised roadway. Crescent berms that are placed outside the drip line of the tree help to detain the water and increase soil moisture for vegetation use. One rock dams prevent erosion, capture coarse bedload particles, raise moisture levels uphill and help to establish vegetation. Zuni Bowls dissipate energy in water which prevents head cuts of erosion from progressing uphill in the flow path. They also trap water so that vegetation can grow. These can be used where flow paths have become incised or channelized such as after a culvert.

Design Best Practices

Below are design best practices that have been refined through practice and development and shown to provide successful GI performance in the Pima County region. The purpose of these best practices is to facilitate optimal GI performance in our arid environment to achieve intended benefits while reducing overall operations and maintenance.

GRADING, CRITICAL ELEVATIONS, INLETS, ROUTING AND RETENTION

- **Grading** Grading of the roadway surface will be planned and implemented to promote distribution of runoff into adjacent landscape areas and to minimize grey stormwater infrastructure. Grading within the landscape areas will ensure the ability to receive street runoff, distribute throughout the planting area, and promote infiltration through the use of bioretention basins, terraces, berms, and/or checkdams.
    - Landscape areas should be designed for water harvesting at every possible opportunity. Bioretention areas should be setback from roadway edges, sidewalks, utilities, and other critical infrastructure per standard setbacks set by a jurisdiction. Design safeguards (e.g. root guards, railing, etc.) to protect adjacent infrastructure may allow encroachment of these setbacks.
    - GI features should intersect with the lowest elevation (e.g. the curb and gutter drain) of the roadway to ensure collection of stormwater to capture the greatest flow and facilitate rapid draining of stormwater from the roadway.

- **Pedestrian Path Space** The City requires that a 5' pedestrian path be maintained and clear in the ROW. Any new GI behind the curb or at edge of pavement with no curb must maintain this 5'. If the GI basin is near the curb or edge of pavement and the 5' is behind it closer to the property line a 2' clear space from face of curb or edge of pavement to the top of basin must be maintained so that if a car parks next to the GI the passenger has a 2' space to step out onto. This is often a limiting factor when it comes to GI at roadside.

- **Critical Elevations** Set the inlet to a GI bioretention basin at the upstream side of a basin and ensure each basin has an associated stormwater inlet to allow collection even with the smallest of rain events. This will ensure thorough soaking to support associated plants with each rainfall runoff event.
    - Provide for a minimum of 2" drop from curb inlet to top of rock or mulch in the receiving basin to direct passage of stormwater into the basin.
    - Incorporate a sediment trap (bowl feature with rip-rap lining and a downstream rocked lip) if routing concentrated flow into and through a landscape feature. Unless annual sediment removal is available or to design to meet a specific water quality goal, GI basins do not require a sediment trap. Often the first basin in a series can function as the sediment trap for subsequent basins. It should be considered that since maintenance does not typically remove accumulated sediment in the GI basin the sediment trap becomes an added cost for little to no value added.
    - Ensure that if a sediment trap is incorporated then it is set at least 2" below the top of rock or mulch at the basin entry point for clear passage of stormwater into the basin.

- **Routing Flow** GI bioretention basins should be designed with a single inlet/outlet to allow for use of organic mulch as a surface cover. The basins function as "backwater" basins which calm the flow and promote capture and remediation of stormwater pollutants as a "first flush" to the stormwater system.
    - If flow is routed through a landscape section along a street, then multiple inlets should be placed along the curb to ensure distribution of stormwater across the entire landscape area.

- Safety spillways or drains are included if necessary to convey excess water safely to downstream stormwater infrastructure or a channel. The drain inlets (and protective grates) will be placed at an elevation that ensures retention of water in the landscape area to at least meet performance standards. Ideally, the drains are placed as far downstream in the landscape areas as possible to maximize landscape conveyance, retention and infiltration of runoff. For example, refer to Tucson's standard detail for a Type C Catch Basin.
- For in-street features, only provide a raised curb at corners of the feature to allow stormwater to evenly flow across a flush header curb into the GI feature on the street side.
- Along streets with no curb and where a V-Ditch is created for drainage, utilize check-dams to slow flow (preventing erosion) and to infiltrate stormwater (for plant use).

- **Retention Capacity**
  - Steeper or vertical slopes allow for greater basin capacity to mitigate flooding and increase storage capacity for enhanced infiltration and soil moisture storage. Slopes steeper than 3:1 must be reinforced with appropriately sized rip-rap.
  - Basin slopes can be terraced to increase understory planting area and reduce appearance of deep drop between basin bottom and adjacent curb or sidewalk. Terrace elevation should be not higher than curb inlet elevation to retain basin volume and facilitate moisture access by plants.

- **Inlets** Curb inlets vary in style and function and preference is highly context sensitive.
  - Header curbs are the preferred inlet method for plant-able landscape areas unless behind curb bioretention basins are used. Paired with appropriate lighting and striping, continuous flush curbs ensure maximum flow and uniform distribution into landscape features without potential for blockages. Two additional benefits are a) the reduction in quantity of poured concrete necessary, as compared to raised curbs, and b) flush curbs allow for shallow flow to spread into the landscape area reducing potential for concentrated flow and resulting erosion.
  - A curb cut can refer to any standard 18"- 24" opening with beveled sides in a vertical curb. A wide opening like the cut is preferred as an inlet as it is less likely to be blocked by sediment or debris.
  - A curb core inlet refers to a 3"- 4" diameter opening at street level through a vertical curb. Although more affordable, since cores are more prone to blockage by debris, they should be used sparingly, and only in cases where a) a raised curb is required or exists, b) the beveled sides of a curb cut present safety concerns, and c) the curb is a minimum of 6" above street grade. The larger diameter is preferred when possible to prevent potential clogging of the inlet.
  - A scupper is an opening with a cover plate that allows runoff to enter a roadside bioretention basin while maintaining pedestrian access and safety. Scuppers are preferred in higher pedestrian zones and/or when water needs to be conveyed through a non-landscaped area (i.e. under a sidewalk). Scuppers are preferred over curb cores, as cores are more prone to blockages and require periodic maintenance to ensure function.

SURFACE MATERIALS SELECTION

- Landscape areas will be encouraged over hardscape surfaces wherever feasible. If runoff from adjacent collection areas cannot be directed to the landscape area, then the soil surface of the landscape area should at least be depressed to retain rainfall over the landscape surface for a 2" rainfall event.
- The design of landscape areas less than 3 feet in width will be avoided; these areas are infeasible for most plantings and are difficult to maintain.
- Utilize organic mulch (preferably coarse chippings ~3-4 in. length) as a surface cover in bioretention basins applied up to 4 in. depth. Greater depths may prevent light rains from reaching the soil. The use of organic mulch promotes healthy soils, the ability to process stormwater pollutants, cooler surface temperatures, enhanced soil moisture retention, and a reduction in germination of undesirable plants. The use of organic mulch also reduces maintenance and disposal costs since plant trimmings can be incorporated directly into surface mulch. Large coarse bark may not be appropriate in areas of stronger flows that do not have features containing the material as they may float away.

- Rip-rap is necessary in areas with higher energy conveyance, such as curb inlets, spillways, and in channels with slopes > 2%. Rip-rap can consist of angular rock mulch or salvaged concrete that is at least 4" in average diameter. Rip-rap used at the bottom of sediment traps should be laid flat to assist with periodic removal of accumulated sediment.
- Rip-rap should not be used a) for lining swales, for which the use of check dams is preferred; or b) at the bottom of infiltration basins, for which organic mulch is preferred. Rip-rap increases the difficulty of maintenance of GI features, including the ability to weed and/or remove sediment. The average size of the rip-rap should be specified based on expected flow characteristics.
- Use coarse organic mulch (preferred) or ¾" gravel for basin bottoms.
- The use of decomposed granite (DG), or "minus" material that includes fines and sediment, should never be used, since it can prevent infiltration within landscape and GI basin areas.

PLANT SELECTION AND LAYOUT PLANNING

- **Plant Water Use Considerations**
    - Avoid use of "moderate" water use plants (e.g. pomegranates and ash) to allow for reliance on stormwater as primary irrigation resource and mixing of irrigation water use zones.
    - Select low-water use, locally native plants to meet performance goals that improve survivability and reliance on stormwater for irrigation. See Appendix B for recommended tree lists.

- **Choosing Plant Varieties and Species**
    - Avoid use of fast growing hybrids (e.g. Desert Museum Palo Verde tree or Chilean mesquite species) as they often result in being weakly rooted or limbed. Research shows native trees irrigated with stormwater associated with curb-side basins grow up to 30% faster and quickly reach full size.
    - Maintain an updated tree selection list that accounts for experience with tree response to local conditions and incorporates air quality considerations (e.g. avoid high VOC trees).
    - Utilize low-profile, native, low-water use understory plants that provide an engineering (e.g. infiltration) and/or habitat function (e.g. pollinator support). For example, small to midsize native bunch grasses promote infiltration and uncompact soils without becoming overwhelming like the non-dwarf muhlenbergia species can become. Milkweed species provide critical habitat for Monarch butterfly caterpillars.
    - Native bunch grasses should be part of the plant palette for bio-retention basin and drainage bottoms. The dense fibrous root systems promote water infiltration and stability along conveyance swales by reducing potential for erosional scour of the soil surface. Only utilize native grass species as non-native grasses spread easily and adversely impact urban and natural environments. To avoid grass becoming a fire hazard use in small groupings with gaps between groupings.
    - For understory along roadways, utilize only accents and shrubs that are 3ft or under in mature height / width to reduce pruning (see suggested plant list in Appendix B).
    - Where additional space allows, consider large native shrubs, yucca, agave, and cacti in upland spaces above the bioretention areas to increase diversity of streetscapes and habitat.
    - Develop an alternate plant list that can be readily used if specified plants are not available at time of project implementation. This will help to avoid the selection of an inappropriate plant that is chosen for the project context and constraints.
    - Field check plant selection based on planting plan. Ensure if a "Dwarf" species is called out that the delivered plant is the same. Otherwise this can impact maintenance and sight visibility requirements.
    - Utilize plants that emit lower levels of VOCs for improved air quality. See resources section.

- **Plant Layout and Placement**
    - Plan layout of understory vegetation based on 100% of mature diameter and height. Overplanting increases maintenance labor.
    - Plan for appropriate placement of understory species according to microclimate requirements with clump and

gap arrangement to maximize biomass and habitat benefits.

- ☐ Select and place trees with adequate spacing from pathways (minimum 3-5 feet) and roadways (minimum 5-8 feet) to allow for minimal pruning during the first 2 years of tree planting.
- ☐ Place trees on an elevated terrace equal or slightly above ponded surface elevation height adjacent to basin or swale.
- ☐ Place plants that have a lot of litter, dropping leaves etc. away from basin inlets to avoid interior sediment from building up and preventing water from entering the basin and reducing overall maintenance

☐ **Site Context Constraints**

- ☐ Select smaller stature trees if overhead utilities are present (e.g. acacia species trimmed to be multi branch).
- ☐ Select narrow species for narrow ROWs (e.g. Whitethorn Acacia or Foothills Palo Verde)
- ☐ Specify larger planting sizes for trees which may impact sight visibility in the first few years of growth. This will allow selective pruning to maintain sight lines.
- ☐ For flood prone areas decrease plant roughness by selecting thin plants like grasses, that would lay down during a flow event, or a small trunked tree with foliage well above the top of curb elevation. Low lying bushes, shrubs, or other plants that increase roughness and potentially block flow should be avoided in areas with flood risk to adjacent properties.

IRRIGATION

- ☐ Installed irrigation systems should be utilized for landscape establishment periods only (1 - 5 years) and irrigation frequency should be gradually reduced after the 2nd year to meet water use performance goals.
- ☐ If an irrigation system is not installed, then a plan should be in place for supplemental irrigation) utilizing a water truck with plants carefully located to facilitate access to moisture. Typically, this is only needed ~1-4x per month during the dry, warm months, during establishment years.
- ☐ It may be preferable to use a bubbler irrigation system for directing supplemental irrigation into basin areas to facilitate simple, low cost, and easily maintained irrigation systems.
- ☐ All GI features should be designed to be reliant on only captured and infiltrated stormwater to provide the irrigation benefit. Conventional irrigation systems inhibit this healthy root development by overwatering and keeping soil moisture artificially high in the upper soil profile near to the plant. In addition, overwatering causes plants to have longer growth periods and put more energy into the above ground portion of the plant rather than investing in robust root development. This can exacerbate maintenance costs by increasing pruning frequency and making larger plants more susceptible to wind throw during storm events.

Design Checklists

GI specific checklists can provide valuable guidance throughout the process of planning and implementing roadway projects. They can be of particular value when determining whether a GI project is feasible and how to respond to site-specific challenges. Related guidebooks and design standards drawn from comparable arid-landscape communities are also available in Appendix A.

GENERAL PLANNING & DESIGN CHECKLISTS

Utilities

- ☐ Was coordination conducted with utilities during the pre-design phase to ensure collaboration?
- ☐ Are there below ground utility conflicts located in the planned GI infiltration areas? Can the utilities or the infiltration areas be relocated to accommodate the GI strategy?
- ☐ Are there above ground (e.g. overhead) utility conflicts that interfere with tree placement or require setbacks? Can the utilities, the trees, or the GI strategy be relocated to accommodate the GI strategy? Consider alternative vegetation sizes.
- ☐ For new roadway construction planning avoid placement of utility corridors or separate utility lines within landscape areas. If utility lines must cross a landscape area, they should be pre-planned for placement and bundled together to ensure maximum landscape planting and stormwater infiltration capacity.

Trees/ Significant Vegetation

- ☐ Are there existing trees that are to remain and that are constraints to locating GI strategies?
- ☐ Has tree planting been maximized within the project boundary and is there opportunity for more?
- ☐ Are trees located along walkways and integrated with GI features to support the shade trees? Is the Pedestrian/ Multi-use path Layout (PMU) layout ideal for maximizing shade from trees in relation to solar angles?

Topography

- ☐ Does the street grading facilitate potential collection of stormwater in the planned GI feature? If not, can placement of the GI feature be adjusted, or can an alternate GI strategy be selected?
- ☐ Are there steep slopes that need to be considered when designing length of GI basins or the selection of flow routing practices that can slow and retain runoff?

Soils

- ☐ Are there soil characteristics (e.g. hardpans, caliche, clay enriched layers, shrink/swell clays, collapsible soils, bedrock, etc.) that will restrict infiltration and percolation? Soil tests can be coordinated with the road construction sample cores (e.g. soil stability tests).
- ☐ Are the soil hydrological groups C or D? If so, can mechanical intervention (ripping, augering drain holes through caliche, amending with composted organics, etc.) address the soil characteristics that is causing limiting percolation?
- ☐ Optimal soil infiltration rates are at or above 0.5 inches/hour. Soil percolation tests can confirm infiltration rates. If infiltration rates are low, consider using an excavator to rip compacted soil layers, auger through calcium-carbonate accumulation zones (caliche) or amend soils with composted materials, or installing a minimum 12-inch sand layer under certain practices (e.g., bioretention, bioswale).
- ☐ Are there environmental conditions such as contaminated soil, monitoring wells, and groundwater wells that are near to the proposed strategies? If so, GI offsets may be needed. Refer to local regulatory guidance.

Flood areas

- ☐ Is this a known area of chronic or severe flooding of adjacent properties? Yes, choose flow-neutral design strategies (e.g. flush curbs and limiting understory vegetative roughness).
- ☐ Is there known nuisance flooding? Does the selected GI strategy address the localized nuisance flooding (small, short-term flooding in street)?
- ☐ Does the bioretention strategy support the retention requirements?

Pollutants

- ☐ Does the watershed location and strategy support the TMDL implementation or stormwater permitting?

Mobility

- ☐ Does vegetation placement ensure driver sight visibility or will selected plants be 3 feet in height or less or be able to be pruned to have overhead canopies providing an 8 feet clear zone from ground elevation? On driver's side, a clear zone above ground is also required.
- ☐ Does the plan include vegetation distribution and placement to promote pedestrian and bicycle safety?
- ☐ Has vegetation been included in the plan to promote traffic calming on residential and collector streets?
- ☐ Does the selected GI practice and placement of it promote pedestrian and bicycle safety (e.g. intersection bump-outs which reduce the street crossing length)?
- ☐ Does the GI practice selected support shade trees to cool pedestrian and bicycle lanes?
- ☐ Plan layout of vegetation based on 100% of mature size.

Innovation

- ☐ Is the project area conducive for experimenting with alternative GI LID strategies (e.g. permeable surfaces for sidewalks)?

Maintenance Considerations

- ☐ Has the agency/department who will perform the maintenance been invited to participate in the design process?
- ☐ Has the access of maintenance equipment been considered in the design? For example, if a separated bike lane is designed will street sweeping equipment be able to access the bike lane?
- ☐ Does the agency/department charged with maintenance have proper training for the designed features?

GI FEATURE SELECTION CHECKLISTS

Median Bioretention

- ☐ Is the street inverse crowned such that flow is routed to or along the median (e.g. via intercept drain) for collection in the bioretention area?
    - ☐ Yes, locating the GI feature in the median will facilitate collection and infiltration of stormwater.
    - ☐ No, then select an alternate strategy (see Streetside or Chicane).
- ☐ Is there sufficient area available for creating bioretention? (review requirements)
    - ☐ Yes. Great! Proceed.

- ☐ No, but the travel lanes can be narrowed to create additional space OR the use of subsurface bioretention cells could be used to support adding shade trees.

- ☐ Can the median be excavated to install the bioretention area without being in conflict with utilities, mature trees, vehicular passage or other features that cannot support excavating the median to be below existing grade?
  - ☐ Yes, proceed with planning.
  - ☐ No, intermittent conflicts are potentially present. The bioretention areas could be designed to be discontinuous along the median to avoid conflicts.
  - ☐ No, the conflicts persist for the entire median length. Consider alternate options such as meandering the travel lanes to facilitate intermittent bioretention areas; or consider intercept drains which convey stormwater to an adjacent area; or consider the potential to relocate the conflicting element if feasible.
- ☐ Is the planned bioretention area in a high flow conveyance zone?
  - ☐ Yes, select an alternate strategy or use large substrate and flow diversion strategies to locate bioretention areas off-channel.
  - ☐ No, if the slope is minimal (< 0.1%) consider designing the median to collect stormwater in contained bioretention basins to facilitate the use of organic mulch or if the slope is greater use a step fashion to facilitate a series of micro-bioretention areas along the median.

Chicane (or Bump Out), Linear Streetside Bioretention

- ☐ Is the street crowned or can flow be routed to the street gutter edge (e.g. via intercept drain) for collection in the bioretention area?
  - ☐ Yes, locating the GI feature along the roadway edge will facilitate collection and infiltration of stormwater.
  - ☐ No, then select an alternate strategy (see Median Bioretention).
- ☐ For residential street development, are the street pavement widths (curb to curb) overwide and/ or allowed to be between 18 to 22 feet, with curb pullouts for passing of large vehicles? Or are travel lanes allowed to be 10 feet (or less) with curb pullouts for passing of large vehicles?
  - ☐ Yes, a linear streetside bioretention feature can decrease the hardscape footprint for additional density and integration of GI along the roadway. This can also help calm traffic on residential streets.
  - ☐ No, are there individual street parking slots that can be strategically converted into bioretention features (see chicane GI feature examples)?
- ☐ Can the bioretention area be depressed along most of the street or are there utilities, mature trees, driveways, or other features that cannot support excavating the area to be below existing grade?
  - ☐ Yes, consider planning a linear streetside bioretention feature.
  - ☐ No, intermittent conflicts are potentially present. Consider selecting chicanes (or bump outs) and place them where there are not conflicts.
  - ☐ No, the conflicts persist for the entire roadway length. Consider alternate options such as meandering the travel lanes to facilitate intermittent bioretention areas adjacent; or consider placing the bioretention areas behind the roadway curb edge; or place intercept drains which convey stormwater to an adjacent area; or consider the potential to relocate the conflicting element if feasible.

- ☐ For linear streetside features, will the entire length of the planned bioretention area be able to receive stormwater from the adjoining street area?
  - ☐ Yes, this is preferred to ensure support of plants. Be sure to space inlets appropriately or use a flush header curb with intermittent curb bumpers.
  - ☐ No, consider how to best route water through the feature to maximize plantable area that can be supported by infiltrated stormwater.
- ☐ Additionally, for all curb-side in-street features, are bioretention areas or bioswales allowed to replace the required “planting strip” or “parkway area” between the sidewalk and curb?
  - ☐ Yes. This can reduce the cost of adding header curb and increase potential bioretention area available.
- ☐ Lastly, for all curb-side features can stormwater conveyance under the pedestrian pathway reach plantable space?
  - ☐ Yes, consider the use of a scupper under the sidewalk to ensure conveyance does not become blocked.
  - ☐ No, a scupper will not be appropriate but a plantable space exists. Consider if there is sufficient stormwater to collect off of adjoining surfaces to support vegetation. Ideally there is a 3:1 catchment to plant canopy ratio to support low water use plants in the Pima County region.

Traffic Intersections

- ☐ Is the street inverse crowned or can flow be easily routed to the intersection center area (e.g. via intercept drain) for collection?
  - ☐ Yes, then a traffic circle or round-about is appropriate to support a bioretention infiltration area.
    - ☐ Is a sewer manhole access located within the area? Yes, sewer access typically requires wide access from one side of the street to the manhole and a tree setback from the manhole. See WMG’s GI Manual Appendix for a design example.[50] Consider protecting the existing manhole collar with a ring of rip-rap. Where feasible or in new construction, raise manhole above the basin overflow elevation and high water surface level, so that drainage is directed away from sewer manhole to prevent sewer overflows from flood events. Manhole covers and rims should be designed to be watertight.
  - ☐ No, the street is crowned with stormwater flowing along the roadway edges. Then select intersection bump outs as an appropriate GI feature. If there are stormwater drains near the intersection will stormwater be intercepted and pass through the bioretention area before entering the stormwater drain?
    - ☐ Yes. Great, an intersection bump-out with GI is the preferred approach.
    - ☐ No. Is it possible to shift and locate the bioretention area before the drain or add a chicane or another feature to be just before the storm drain inlet?
- ☐ Can the bioretention area be excavated without being in conflict with utilities, mature trees, or other features?
  - ☐ Yes, proceed with planning.
  - ☐ No, intermittent conflicts are potentially present. The bioretention areas could be designed to be discontinuous to avoid conflicts.
  - ☐ No, the conflicts persist for the entire area. Consider alternate design options to relocate the bioretention areas while facilitating a safe intersection; or consider intercept drains which convey stormwater to an adjacent area; or consider the potential to relocate the conflicting element if feasible.
- ☐ Is the planned bioretention area in a high flow conveyance zone?
  - ☐ Yes, select an alternate strategy or use large substrates (rocks instead of organic mulch) and flow diversion strategies to locate bioretention areas off-channel.
  - ☐ No, if the slope is minimal (< 0.1%) consider designing the feature with a raised curb on the downstream side to collect and infiltrate additional stormwater. Be careful to ensure a safe overflow route is planned.

Cul-de-sac with GI

- ☐ Is the diameter of the cul-de-sac greater than the necessary turning radius of emergency vehicles and trash collection vehicles?
  - ☐ Yes, consider using a landscaped bioretention feature similar to traffic circles or round-abouts.
  - ☐ No, if it is for a new development consider a different road layout that promotes connectivity and minimizes the need for large hardscape spaces which generate stormwater and contribute to urban heat island effects.

Adjacent Park or Open Space Bioretention

- ☐ Is there sufficient elevation difference to direct water from the street to the open space?
  - ☐ Yes, proceed with planning.
  - ☐ No. Can a portion of the adjacent open space be excavated to enable receiving and infiltrating stormwater runoff? Or, can the stormwater be conveyed to another area within the open space?
- ☐ Are pipes needed to connect the road to the open space?
  - ☐ Yes, consider use of larger diameter scuppers or culverts that will minimize the potential of blockages.
- ☐ Are landowners or the managing agency of the open space willing to be a partner for planning, implementation and maintenance?
  - ☐ Yes. Great! Be sure to discuss maintenance of the GI elements and if the partner will need additional resources or training in appropriate maintenance.
  - ☐ No. Can additional incentives be provided to facilitate a partnership?

Permeable Pavement

- ☐ Is permeable paving allowed for on-street parking and alleyways?
  - ☐ Yes. This is a great application of permeable paving to reduce downstream stormwater contributions.
  - ☐ No. Consider allowing a pilot project to utilize permeable paving.
- ☐ Is a bus stop present at the site or is bus traffic known to travel in the parking lane?
  - ☐ Yes, then permeable pavement may not be practical for that specific area due to the additional load on the feature.
- ☐ Is there the potential for excessive sediment load (e.g. adjacent landscaping)?
  - ☐ Yes, then plan for extra maintenance to periodically remove sediment or select an alternative practice that can better manage sediment loads.
- ☐ Are slopes >5% that would limit the ability to implement permeable pavement?
  - ☐ Yes, consider directing runoff to adjacent bioretention areas which are stepped appropriate for the slope.

Common GI Implementation Challenges

Design details can often be lost or not carefully adhered to during the construction process. These can lead to higher maintenance costs and/or a poorly performing GI feature. The following challenges are based on lessons learned from various Tucson-area GI projects and also an internal review of a completed City of Avondale Complete Streets with GI project. The project manager or inspector should pay close attention to the following during the construction process.

Critical Elevations

Construction observation should carefully review tolerances related to grading and critical elevations. This applies to inlets from the street to bioretention areas which are often set perpendicular to the direction of flow. The asphalt to concrete transition should facilitate diversion of runoff to be received by the inlet. A micro-rolling dip in the asphalt surface or poured concrete gutter and inlet may need to be formed to facilitate runoff diversion from the street. From the inlet to the bioretention landscape area it is critical to observe the elevation differences from the inlet structure to the receiving area. Lack of at least a 2" elevation drop from the concrete inlet to the top of the rock or mulch in the basin will invite maintenance issues to keep the inlet area clear as debris, trash, and plant material is carried with stormwater.

Often asphalt surfaces are imperfect and can be problematic in GI retrofit projects when flush header curbs are installed. It is important that consideration of even small runoff contributions which provide the irrigation value to the associated plants be allowed to freely flow across the header curb into the bioretention area. This may require addressing either the surrounding asphalt surface and/or slightly lowering the header curb to ensure even the smallest runoff events are not diverted around the GI feature and not provide an irrigation benefit or create nuisance ponding in the roadway.

This bumpout is choked with bermuda grass which impedes drainage.
Photo: Watershed Management Group

Plant Availability and Installation

Differences often arise in what plant species or variety is identified in the plan to what is actually planted during construction. This may be due to nursery availability at the time of construction or mistakes made in sourcing plant material. This is especially critical when a plant species variety with specific growth characteristics is required to address a design constraint. For example, the Central Avenue complete streets project in Avondale had called for Dwarf Deer Grass (*Muhlenbergia rigida x Nashville*) but the regular Deer Grass (*Muhlenbergia rigida*) was planted. This resulted in a sight visibility conflict along the roadway and led to a frequent need to prune the grass to maintain sight lines. And, in some areas the difference in growth size resulted in overplanting where the Deer grass covered over other adjacent plants.

Ensure the inspector or project manager has an understanding of plant species and expected growth form to address plant availability and species switching. Often species not even on a planting plan are planted during the project construction for one reason or another. Often species are not properly located to provide sufficient mobility access along walking or bike lanes once mature. Lastly, ensure that cacti and succulents are not planted within the ponding zone of the bioretention area and that trees are located on micro-terraces to keep them at or above the level of ponding.

It is common that trees are either planted too deep or did not have a solid soil base when planting causing the tree to settle. The increased soil moisture of bioretention areas causes a rapid consumption of the organic potting soil the plants come in which also causes the plants to settle. The planting plan should specify planting appropriately to address this and the project inspector should look to ensure this is followed.

Surface Materials Application and Sediment Concerns

Large rip-rap should not cover the surface of the bioretention area as it increases maintenance labor costs to remove weeds, litter, sediment, or replace plants. Rip-rap along slopes should not consist of more than one rock layer to allow native seed mix applications to germinate and naturalize. Rip-rap should not be placed to block inlet (maintain a 2" drop in elevation) or outlet elevations. Decomposed granite (DG) should be screened and washed so it does not contain finer particles which can clog the soil surface and prevent infiltration and never applied in or near bioretention areas.

Competing Priorities

In some contexts, it may be more important to provide a sidewalk or preserve a building than to create space in the ROW for GI. Alternative solutions could include considering alternative street widths available in complete street manuals or street tree planters with protected root areas underground.

Common Operations and Maintenance Challenges and Solutions

GI performance relies on a healthy landscape system which goes beyond just aesthetics and must promote soil and plant health to achieve desired benefits. This often requires a shift in the approach to landscape operations and maintenance (O&M) practices. The following are common challenges to making this shift and suggested solutions to facilitate shifting practices.

Irrigation

Irrigation ideally is used for only the three year plant establishment period as it is prone to leaks and failure to seasonally change irrigation schedules. Leaks and lack of schedule adjustments lead to over-watering of the plant material. This often results in saturated soil or even ponding conditions and/or larger growth than expected of the plants which increases pruning maintenance costs.

Tree pruning should be overseen by a trained arborist.
Photo: Watershed Management Group

Pruning

In the first three years only minimal and light pruning to maintain adjacent pathways and sight lines should be done. Too often maintenance crews are not properly trained or supervised resulting in improperly pruned trees. Improper pruning and care in the first few years is detrimental to the long-term health of the tree.

Know how to identify invasive species such as buffelgrass.
Photo: Watershed Management Group

Additionally, trees remain staked for too long resulting in poor strength and growth forms. Establishment maintenance schedules should provide clear guidance especially for the first few years following project installation.

Trash and Litter Removal

Bioretention areas are great trash and litter collectors for both wind and stormwater conveyed items. This should be viewed as a benefit as it is better and easier to remove trash and litter from along these roadway areas then it is from downstream channels. Trash and litter removal should be the focus of the weekly or bi-weekly visits by maintenance crews. This should not include removal of organic mulch or leaf litter within the bioretention areas. The organic material is vital for soil health development.

Herbicides and Pesticides

These chemicals should only be used in a sparingly spot application to deal with the most aggressive invasive species (e.g. buffelgrass). Mechanical removal is the preferred method and if done following rainfall events can be efficiently and easily accomplished for most "weedy" species. Maintenance crews should be trained on invasive species identification and also supervised to ensure desirable wildflower and naturalization of those species occurs.

Mowing and Weed Whacking

Mowing is typically not an expected maintenance activity for most GI unless it is incorporated into a park area that includes turf grass. If that is the case the design of the GI feature should consider access for mowing equipment around the feature and also the potential for turf grass (e.g. Bermuda) to heavily encroach into the GI feature.

Weed whacking of naturalized understory and/or native bunch grasses along roadway edges may be desirable for seasonal maintenance. Protection of tree species may need to be considered either with spacing or with adding root collar guards to the trees. Weed whacking is an effective treatment method for areas overtaken by Bermuda grass. The planning of planting trees or shrubs should be done carefully to minimize damage to these plants knowing that weed whacking will likely occur.

Failure to install plants diminishes GI function.
Photo: Watershed Management Group

Replacement of Plants in Bioretention Areas

The loss of understory plants within the bioretention infiltration areas should be quickly assessed on why and then plan to replace appropriately. These understory plants are critical to the function and performance of the bioretention system. Alternate species may need to be considered if the loss is due to soil moisture or other site context issues.

Periodic maintenance removes accumulated sediment in sediment trap.
Photo: Watershed Management Group

Sediment

Sediment may act as a beneficial mulch unless accumulation of fines in the basin affects retention, infiltration of stormwater quality goals. Sediment traps can be used in those cases if maintenance regimes support periodic clean out. Sediment maintenance is covered in detail in the Soil Stability Design and Design checklists. Be careful not to plant near the inlet which may inhibit stormwater flows into the basin.

A GI Maintenance Approach to Sustain Functionality of the Investment

The following information is specific to GI features and meant to supplement existing maintenance guidelines. GI systems utilize natural processes in a constructed environment to provide community services including stormwater pollutant filtration, infiltration, and bioremediation and support of shade trees. As a functional, engineered landscape appropriate maintenance is critical to improve system performance. By designing for maintenance and providing appropriate maintenance practices a GI system's performance should improve as the landscape matures. Appropriate maintenance should not be seen as "cleaning" the landscape rather it should be seen as "nurturing" the landscape.

GI requires a shift toward support of naturalized systems. As naturalized systems, irrigation and maintenance are focused on ensuring health during the critical establishment period in order to maintain ecological function and associated benefits in the long-term. These practices reinforce the potential benefits of GI features through conservation of water resources by reducing supplemental irrigation demands. Far too often maintenance degrades the performance of GI systems and provides little to no irrigation savings benefit.

The health and performance of GI is based on the health of the underlying soil. A Tucson, AZ based study of GI showed that within a few short years the native soil ecosystem attained the diversity of a mature forest soil if certain conditions were maintained.[51] These GI systems all utilized native soil without soil conditioning amendments and included native plant understory and trees, organic surface mulch (tree trimmings), and received street stormwater were much more diverse than surrounding soils that did not receive stormwater inputs or GI systems that utilized rock mulch instead of organic mulch.

An understory filled with native plants will enhance infiltration and reduces potential maintenance needs.
Photo: American Rivers

Soil health also relates to the ability to infiltrate, percolate, and store plant bio-available moisture. Organic content in a soil is critical to all of these processes. Urban soils typically are lifeless, dry, and compacted. Plants and their associated roots and leaf litter add organic content and maintain the bioretention function by helping to uncompact soil providing the support to re-establish a healthy soil ecosystem needed to sustain the function of processing stormwater pollutants and convert many of those pollutants to nutrients to support plant growth.

The establishment maintenance period of a GI system should focus on being a catalyst to develop soil health. This includes minimizing soil surface disturbances to promote fungal (e.g. mycorrhizal) colonization and development and minimize weedy (early colonizer) species ability to propagate. This includes applying woody mulch, not raking the soil surface, and addressing weedy species early in the growth season with appropriate maintenance techniques.

Weed management during the growth seasons should be built into the more frequent general cleaning and trash removal. GI as a stormwater collector functions as a great trash collector. This should be viewed as a positive as it is better to collect along streets versus in downstream water bodies and natural areas. Additionally, it can be informative of where/who are the major sources of trash and develop programs/messaging to reduce trash production. A suggested maintenance schedule for GI features is provided in Appendix C.

Education and training should be provided on weed identification and appropriate integrated pest management (IPM) options. Many weeds are actually beneficial annuals or perennials that can help naturalize a desert landscape, stabilize the soil surface, be a pollinator, and add organic content. Raking or scraping the soil surface to remove many of these annuals perpetuates a weed maintenance problem beyond the establishment phase and may provide seeding ground to more aggressive invasive species.

Lastly, as GI features utilize natural systems and thus should improve in performance as they mature it is critical that the landscape is nurtured to be productive. The health of the plants is far too often reduced within the first couple of years due to poor pruning practices. Ensure pruning of plants maintains natural form of plant or tree through selective pruning (no hedging, lion-tailing, topping, etc.). This will reduce the mortality rate of plants, ensure infiltration and soil remediation performance of the GI feature, and maximize the return on investment.

Agave planted in a curb cut.
Photo: PAG

GI MAINTENANCE CHECKLISTS

Maintenance Oversight Tips

- Provide inspection checklist to maintenance staff and/or contracted crews with clear seasonal and annual work plan. Include on the checklist a "No Action Needed" option to facilitate maintenance crew's recognition that maintenance is not always needed.
- Maintenance plans should address seasonal and annual variations as GI features become established.
- Provide emphasis and tips on how to promote soil health with maintenance practices for long-term sustainability of GI feature.
    - Maintain understory coverage of at least 25% with natural form.
    - Allow for leaf litter and prunings to be chipped and retained within the infiltration area as mulch if flow hydrology design permits organic mulch.
- Include in contract language maintenance expectations and results if not followed.

MAINTENANCE CHECKLISTS

- ☐ **Site visit and observed and noted performance:** ________________
    - ☐ Actions taken included: ______________________________
    - ☐ No action needed at this time
    - ☐ Suggested action for next visit: ________________________
- ☐ **Site Function and Stability**
    - ☐ Inspect stormwater conveyance and inlets/outlets for obstructions.
    - ☐ Check for signs of erosion and improper root growth. Stabilize areas to prevent erosion.
    - ☐ Inspect adjacent areas for sources of sediment, such as erosion of uphill areas.
- ☐ **Vegetation Management** Be careful in conducting vegetation management that may affect performance (e.g., clogging from grass clippings, leaves dropping/blowing onto the surface).
    - ☐ Irrigation schedule adjusted monthly (applicable if site is <3 years established)
    - ☐ Light pruning of trees and shrubs to maintain sight visibility and mobility. Allow for natural form. Do not 'hedge' vegetation.
    - ☐ Remove dead vegetation if not during the cold season (threat of frost).
    - ☐ Check for and remove invasive species.
- ☐ **Bioretention Areas**
    - ☐ Remove sediment from sediment traps/forebays in applicable practices (e.g., bioretention). Clean out sediment and debris at inlet structures.
    - ☐ If soils become compacted or surface sealed due to deposition of fine sediment and/or stormwater pollutants, turn or till them. Add or replace understory vegetation to help prevent compaction and surface sealing.
- ☐ **Other** Regularly maintain permeable pavement using a vacuum-assisted street sweeper and inspect it for proper drainage as well as to identify any deterioration, cracks and settling.

Next Steps

The region has many model programs and GI sites and a growing number of funding sources and guidelines. To further progress toward these goals the following summary of actions are recommended:

- Augment standards, details and specifications for local adoption as well as in an addendum to the PAG Book of Standard Specifications and Details with regionally consistent GI options.
- As updates occur, integrate GI into regional and local plans and programs as an acceptable and preferred option with prioritized locations and typologies. Utilize recommended GI targets, recognize GI as a feature the helps to meet performance measures and safety standards, and integrate into transportation funding.
- Continue innovative data driven planning. Coordinate continued regional investments in remote sensing data acquisitions for GI uses. Enhance PAG's GI Tool with statistical summary features, opportunity analysis, and multi-benefit queries to support programs for GI implementation.
- Support regional coordination and recommendations, update manuals to fill in gaps and modernize approaches, and collaborate on cohesive and consistent guidance such as a green streets feature decision matrix based on street typology.

Part 3 Endnotes

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[48.] Watershed Management Group. (2015). Solving Flooding Challenges with Green Stormwater Infrastructure in the Airport Wash Area. https://watershedmg.org/document/solving-flooding-challenges-green-stormwater-infrastructure-airport-wash-area

[49.] J2 Engineering and Environmental Design. (2016). Tempe Area Drainage Master Study LID Application Review and FLO-2D Modeling. http://apps.fcd.maricopa.gov/pub/docs/scanfcdlibrary/A028_100_002TempeAreaDrainageMasterStudy_LID_ApplicationReviewandFLO_2DModeling_Revised_April_2016_ADMS.pdf

[50.] Watershed Management Group. (2016). Green Infrastructure for Desert Communities. https://watershedmg.org/document/green-infrastructure-manual-for-desert-communities

[51.] Pavao-Zuckerman, M.A., & Sookhdeo, C. (2017). Nematode community response to green infrastructure design in a semi-arid city. Journal of Environmental Quality (46), 687-694.

St Marys Road
Photo: gmvargas.com

APPENDIX

Avondale Road GI
Photo: Watershed Management Group

Appendix A:

GI Design and Maintenance Guides for Transportation Projects in Arid and Semi-arid Communities: An Annotated Bibliography

The annotations below include descriptions of key unique aspects of each document and why it is recommended as a resource. This appendix also describes resources that address gaps in our region's standards and specifications identified by the Low Impact Development Working Group's (LIDWG). (LIDWG is composed of GI related professionals from around the Tucson metro area including consultants, jurisdictional staff, academics and others.) The following gaps were identified related to transportation and are called out if available in the guides below: roundabout with sanitary sewer manhole, cul-de-sac with landscaping, traffic calming and speed management with landscaping.

GI Design Guides

Arizona State University/Sustainable Cities Network, et al,,

Greater Phoenix Green Infrastructure & LID Handbook: Low Impact Development for Alternative Stormwater Management

GI practice details and specifications developed by City of Scottsdale, City of Phoenix, Sustainable Cities Network @ Arizona State University and Maricopa Flood Control.

City of Avondale (AZ)

City of Avondale: Green Stormwater Infrastructure Supplement for Avondale's Street Tree Master Plan

The city of Avondale conducted a design and maintenance performance review in collaboration with Watershed Management Group of their Central Ave road diet complete streets project which integrated green stormwater infrastructure features. The outcome of this process led to the creation of a GI Supplement to Avondale's Street Tree Master Plan. The supplement provides updated standard road typology details which integrate GI, establishes design performance goals, and suggests best practices for design, construction, and maintenance of the GI features.

Bernalillo County (NM)

"Bernalillo County Green Stormwater Infrastructure: Low Impact Design Strategies for Desert Communities"

This guide focuses on providing technical design information for GI practices that are appropriate for implementation in arid landscapes.

City of Dallas (TX)

Complete Streets Design Manual

One of the valuable elements in this Manual is the Design Element Priorities Chart on page 85 which shows an example of prioritizing trees and greenspace for almost all street types.

City of Los Angeles (CA)

Rainwater Harvesting Program, Green Streets and Green Alleys Design Guidelines Standards, 1st Edition, 2009.

One of the valuable elements in these guidelines is the information on green alleys. The Green Streets BMP summary matrix provides an overview of each BMP including a description, context for best application, cost, effectiveness, and challenges.

City of Los Angeles (CA)

Model Design Manual for Living Streets

This model was made so that local jurisdictions could customize the Manual and adopt it, or parts of it, for their own. Downloads are available in Word or InDesign versions to edit.
One of the valuable elements in the Manual is a table which explains GI features work with different street typologies (Best Fit for Streetwater Tools by Street Context, Table 11.1).

City of Mesa (AZ)

"Low Impact Development Toolkit"

This toolkit describes and provides technical information for a wide range of GI practices that are appropriate for Arizona urban landscapes, including for roadway and transit projects.

NACTO Urban Street Stormwater Guide

"A flooded street is not a complete street. During storm events, people walking, bicycling, and using transit are the first users to encounter barriers and lose access to the street, and are the last to regain it. Green street design tools for the right-of-way are a critical component of complete street design, ensuring the street remains usable and safe for all people during storm events, regardless of mode. Use this guide to take into consideration both the impacts of stormwater on multi-modal travel and the potential for green street investments to transform the public realm and create economic, social, and environmental benefits for all street users."

Pima Assn of Governments, *Inventory of GI/ LID Policies, Guidance, Education, Funds and Efforts in the Region* (updated 2017)

Over 70 policies, programs and other efforts were documented and showed that municipal support of GI/LID has increased steadily since 1985.

Pima Assn of Governments, City of Tucson, Pima County RFCD, Stantec, and Impact Infrastructure, *Return on Investment Study for GI*

A multi-partner, collaborative study conducted in 2013 and 2014 found that investing in GI or LID approaches for infrastructure projects will lead to cost-savings that benefit the community, municipalities and the private sector. As part of best tests for this study, two local projects were tested to evaluate the impact of a "green streets" policy and local commercial stormwater harvesting ordinance. The analysis of the return on investment covered the full life cycle of the projects. The study also evaluated specific local design standards. Results of the study were used to enhance the recommended design strategies in the Pima County LID Guidance Manual.

Pima County
Case Studies: Low Impact Development/ Green Infrastructure

This inventory, created by PC RFCD with the LID Working Group, features a section on local transportation projects and summaries include costs, lessons learned, before and after photos.

Pima County Subdivision Street Standards

This document guides planners and engineers in the preparation of subdivision plats and commercial/industrial site plans. This manual incorporates complete streets sustainable and low impact development which supports accessible, livable and attractive communities. The manual states that where practical, landscaped medians or median islands may be depressed to provide for stormwater harvesting and refers to the Design Standards for Stormwater Detention and Retention manual for further information.

Pima County Standard Operating Procedures: Landscape Additions in the Public Road Right-of-Way

This procedure outlines landscape additions that fulfill goals including increasing shade and vegetative cover, providing stabilization and erosion control, and taking advantage of excess roadway stormwater runoff by creating water harvesting areas. These procedures provide guidance on vegetation in clear zones and Native Place Preservation Ordinance mitigations.

San Mateo County (CA)
"Green Infrastructure Design Guide"

A comprehensive design guide targeted to assist public agencies, developers, design professionals and construction firms in their efforts to design, build and maintain GI in San Mateo County, California. Of particular relevance, the guide is intended to support the planning and development of integrated complete streets and green streets for water quality and public safety benefit.

City of Santa Fe (NM)
"Incorporating Green Infrastructure into Roadway Projects in Santa Fe"

Prepared with technical assistance from the US EPA, this document provides detailed guidance about incorporating GI into the definitional, development and design of roadway projects. It also discusses design and maintenance considerations and provides examples of GI incorporation into site locations with characteristics typical of Southwestern cities.

City of Tucson (AZ)

City of Tucson Complete Streets Design Guide

The City of Tucson has recently completed an initial draft of the new Street Design Guide. The Guide provides design guidance to city staff and project teams on how to design and construct transportation projects in a way that forwards the intent of the City's Complete Streets Policy. 2020.

City of Tucson / Pima County Low Impact Development and Green Infrastructure Guidance Manual. 2015

This manual includes a site assessment guide and information on practices. Table 7 can be used to select a structural GI practice that provides the benefits needed for a site. Design details are available in Appendix H, and Appendix F is a GI AutoCASE/BCE ROI Study summary.

City of Tucson Water Harvesting Guidance Manual. 2006

Techniques, designs and codes for compliance with the City's commercial water harvesting ordinance.

US Environmental Protection Agency, *Managing Wet Weather with Green Infrastructure: Municipal Handbook - Green Streets,* 2008.

Some of the unique features in this handbook include examples of stormwater pollutants on roads and their impacts, a survey of alternative street width usages across the county, example green street policy language, elements of a successful program.

Zeedyk, Bill, *Water Harvesting from Low-Standard Rural Roads,* 2006

Describes treatments to improve rural roadways and their impact on habitat, waterways, and erosion.

GI Maintenance Related Guides

Tucson Clean And Beautiful - Trees for Tucson:
Planting and Maintenance Webpage
Includes, location, planting, watering/stormwater harvesting, and pruning tips and illustrations and printouts

University of Arizona Extension office: *Smartscape Program*
Offers training classes including stormwater harvesting and maintenance.

Watershed Management Group:
Field Guide for Rain Garden Care
A Guide for backyard, neighborhood, and commercial gardens. Includes helpful information such as when to prune, tree life spans, good "weeds" versus invasives, and photos of common mistakes.

Watershed Management Group:
Green Infrastructure Manual for Desert Communities
This manual provides information for neighborhood residents, municipal professionals, grassroots advocates and others who seek to implement GI strategies in their communities. It is tailored to work with the unique climate conditions of the southwestern US. The guide includes detailed, step-by-step approaches for designing, constructing, and maintaining GI practices that can be used to retrofit existing neighborhoods. Includes conceptual drawings, cross sections and details for sediment traps, parking lots, and in-street practices with GI for speed management (medians, chicanes, street width reduction, and traffic circles with manholes).

Shading pathways reduces heat stress and enhances walkability.
Photo: Watershed Management Group

Appendix B:

Trees and Plants Suitable for Pima County GI Projects

The following example plant recommendations are based on lists from the following resources:

- Watershed Management Group, *Green Infrastructure Manual for Desert Communities*
- Brad Lancaster, *Rainwater Harvesting for Drylands and Beyond Volume 1, 2nd Edition*, and
- The City of Avondale, *Street Tree Master Plan Green Infrastructure Supplement*.

Additional varieties are identified on several local lists. Native plants are well adjusted to local bimodal rain seasons and frost levels.

Recommended Native Trees

Larger native, low water use, trees recommended for roadway projects:

- ***Chilopsis linearis*** **(Desert willow)** - drought tolerant, easy to establish with minimal irrigation; 20-35 feet in height and diameter, provides moderate shade, open and spreading crown; low root damage potential
- ***Celtis reticulata*** **(Canyon/Netleaf Hackberry)** - drought tolerant, easy to establish with minimal irrigation; single to multi-trunk, upright 30-40 feet in height with near equal spread, provides moderate shade; low root damage potential
- ***Olneya tesota*** **(Desert ironwood)** - drought tolerant, easy to establish with minimal irrigation; 25-30ft in height and diameter, moderate growth - can be more rapid when paired with GI basins, provides heavy shade, single to multi-trunk, typically slow growing but can be more rapid when paired with GI basins; low root damage potential
- ***Parkinsonia florida*** **(Blue Palo Verde)** - drought tolerant, easy to establish with minimal irrigation; 25-30 feet in height and diameter, fast growth, provides heavy shade; low root damage potential
- ***Prosopis velutina*** **(Velvet Mesquite)** - drought tolerant, easy to establish with minimal irrigation; 25-30ft in height and diameter, fast growth, provides heavy shade, single to multi-trunk; be sure not to use hybrid varieties as they result in weak structure and prone to fall; low root damage potential

Space constraints in relation to vehicular traffic need to be considered. Shorter native, low water use, trees recommended for height constrained areas*:

- ***Acacia constricta*** **(Whitethorn Acacia)** - drought tolerant, easy to establish with minimal irrigation; 10-15 feet in height and diameter, provides light shade; low root damage potential
- ***Acacia greggii*** **(Catclaw acacia)** - drought tolerant, easy to establish with minimal irrigation; 15-20 feet in height and diameter, multi-trunk, provides light shade; low root damage potential
- ***Fraxinus greggii*** **(Littleleaf Ash)** - drought tolerant, easy to establish with minimal irrigation; 10-15 feet in height and 6-10 feet in diameter, provides moderate shade, form of a dense screen shrub or shaped early into multi-trunk tree, moderate growth; low root damage potential
- ***Lysiloma watsonii*** **(Featherbush)** - drought tolerant, easy to establish with minimal irrigation; 15-20 feet in height and diameter, slow to moderate growth, provides light shade, form of a small tree or large shrub; multi-trunk, produces root suckers when pruned; low root damage potential
- ***Parkinsonia microphylla*** **(Foothills Palo Verde)** - drought tolerant, easy to establish with minimal irrigation; 20-25 feet in height and diameter, slow to moderate growth, provides light shade, multi-trunk; low root damage potential

**These short trees may have shrub-like growth so Sight Visibility Triangle requirements are imperative*

Common trees and large shrubs to avoid and associated reasons*:

- **Eucalyptus species** - non-native, become invasive in downstream riparian areas, does not contribute to Sonoran Desert sense of place
- ***Nerium oleander* (Oleander)** - non-native, toxic, does not contribute to Sonoran Desert sense of place; consider Arizona Rosewood or Hopseed Bush as native alternatives
- **Palm species** - higher VOC emitting, poor shade providers
- ***Parkinsonia x 'Desert Museum'* (Desert Museum Palo Verde)** - this hybrid is fast growing and when paired with GI features develops weekly limbed and easily wind-thrown trees.
- ***Prosopis chilensis*** and other non-native or hybrid Mesquite species - non-native mesquites and hybrids tend to be fast growing which results in a weak rooting and limb structure; increased susceptibility to wind-throw; GI integration tends to accelerate tree growth in these species resulting in frequent roadway problems.
- ***Quercus virginiana* (Southern Live Oak)** - Live oaks do not perform as well without regular supplemental irrigation. Oaks are also higher VOC emitting trees.
- ***Pistacia x 'Red Push'* (Red Push Pistache),** susceptible to prolonged hot dry periods, non-native, does not contribute to Sonoran Desert sense of place
- ***Ulmus parvifolia* (Chinese Elm),** susceptible to prolonged hot dry periods, non-native, does not contribute to Sonoran Desert sense of place; ability to reseed heavily; moderate potential for root damage
- ***Vachellia farnesiana* (Sweet Acacia)** - freeze, drought stress, and pest prone

**In areas with space constraints, sometimes a non-native low water use tree may be still be a good option*

Recommended Native Understory

Larger native, low water use, shrubs recommended for roadway projects**:

- ***Celtis Pallida* (Desert Hackberry)** - 8-10 feet, slow to moderate growth, dense vegetation drought tolerant, easy to establish with minimal irrigation;
- ***Dodonaea viscosa* (Hopseed Bush)** - 4-12 feet in height, moderate growth, dense screen, drought tolerant, easy to establish with minimal irrigation;
- ***Justicia californica* (Chuparosa)** - 3-4 feet in height, moderate to fast growth, drought tolerant, easy to establish with minimal irrigation;
- ***Lycium fremontii* (Wolfberry)** - 3-6 feet in height, moderate to fast growth, drought tolerant, easy to establish with minimal irrigation;
- ***Rhus microphylla* (Littleaf desert sumac)** - 8-15 feet in height, moderate growth, large shrub or pruned to be small, multi-trunked tree, drought tolerant, easy to establish with minimal irrigation;
- ***Simmondsia chinensis* (Jojoba)** - 5-7 feet, slow to moderate growth, dense screen, drought tolerant, easy to establish with minimal irrigation
- ***Atriplex canescens* (4-wing saltbush)** - 4-5 feet, moderaete growth, dense screen, drought tolerant, easy to establish with minimal irrigation.

***With large dense shrubs, Sight Visibility Triangle requirements are imperative.*

A curb inlet allows stormwater into a bioretention basin along a complete street in downtown Tucson. Photo: American Rivers

Smaller native, low water use, understory plants that grow 3ft or less to maintain site visibility and provide bioremediation function and facilitate infiltration and percolation:

Native Grass (swales, basin bottoms or sides) - can tolerate temporary inundation

- *Bouteloua curtipendula* (Sideoats Grama)
- *Digitaria californica* (Arizona cottontop)
- *Muhlenbergia emersleyi* (Bull grass)
- *Purpura aristada* (Purple three-awn)
- *Pappophorum vaginatum* (Pima pappusgrass)

Understory (upland areas and basin slopes)

- *Artemisia ludoviciana* (Western Mugwort)
- *Asclepias linaria* (Pineleaf Milkweed) - monarch butterfly host
- *Asclepias subulata* (Desert Milkweed) - monarch butterfly host
- *Baileya multiradiata* (Desert Marigold) - naturalizes easily
- *Calliandra eriophylla* (Pink Fairy Duster)
- *Chrysactinia mexicana* (Damianita)
- *Dalea greggii* (Trailing Indigo Bush)
- *Encelia farinosa* (Brittlebush) - naturalizes easily
- *Ericameria laricifolia Aguirre*™ (Turpentine Bush)
- *Penstemon parryi* (Parry Penstemon) - naturalizes easily
- *Senna covesii* (Desert Senna) - naturalizes easily
- *Sphaeralcea ambigua* (Globe Mallow) - naturalizes easily
- *Thymophylla pentachaeta* (Golden dyssodia) - naturalizes easily

Understory (basin terraces or sides)

- *Eriogonum fasciculatum v. poliofolium* (Flattop Buckwheat)

Additional Plant Resources

- If possible, avoid the "high VOC-emitting" trees to help reduce emissions that form ground-level ozone air pollution. These trees and allergen trees are covered in the "*Urban Tree Selection List*" created by Maricopa County Air Quality Department after researching information from the Desert Botanical Garden and many other organizations.

- Outside of or above the raingardens (where less stormwater is gathered with less depth) cacti, yucca and agave, ocotillo are valuable desert plants. Recommended cacti and succulent plants are included in this *Pima County Riparian Mitigation Area List*. Even desert adapted plants benefit from stormwater capture to survive such as in microbasins, terraces, and small checkdams

- *Eastern Pima County Native Plant Tool:* Identify the native plants that are best for your site's climate and soils on this interactive map.

- *Pima County Plant List:* Excel list of all native and "naturalized" or invasive exotic plants found in Pima County.

- *ADWR Plant List*

Appendix C:

GI Maintenance Schedule

Recommended Maintenance Items for Green Infrastructure Features		
Maintenance Item	**Suggested Frequency**	**Recommendation**
Cleaning/Litter Removal	Bi-weekly to Monthly	Focus on trash removal and manual spot removal of problematic weeds (no spray or raking options). Frequency should be greater during wetter months as litter accumulates in flow and basin areas with stormwater flows.
Invasives and Weed Control	Seasonal	Schedule weed whacking and/or mowing (grassland areas) of adjacent roadsides after nesting and pollinator seasons. If invasive species control is required schedule interventions before target species produces seed.
Mulch (organic) replenishment	Every 2-5 years	Inspect for need to replenish organic mulch if not sufficiently replenished during plant pruning and chipping process. Typically, plant leaf litter and pruning chippings are sufficient to maintain organic mulch cover.
Pre-Emergence	Semi-annual	Shift to an Integrative Pest Management (Organic First) system to eliminate/minimize need for herbicide applications.
Post-Emergent	Semi-annual	Shift to an Integrative Pest Management system to eliminate/minimize need for herbicide applications.
Shrub/Groundcover Maintenance	Quarterly	No topiary pruning or hedging; replace groundcover or re-seed as needed to maintain minimum 25% coverage.
Tree Maintenance	Annually	Years 1-3: Conduct semi-annually before and after growing season, light pruning to maintain site visibility and clearance, overseen by certified arborist Years 4+: Annual pruning, overseen by certified arborist; avoid summer pruning
Irrigation Inspection & Maintenance	Monthly	Years 1-2: Regular irrigation schedule Years 3-5: Reduce/eliminate irrigation during winter months (Nov – Feb) Years 5+: Reduce/eliminate irrigation unless abnormally dry & hot or to maintain aesthetics in May and June. Supplemental watering once per month during warm, dry season may be desired to maintain plant aesthetics
GI Performance Inspection & Maintenance	Semi-annual / Periodic	Sediment: accumulation of sediment in the sediment trap or basin bottom should be removed only if it reduces the ability to meet performance objectives of the GI feature from either a water quality or retention volume perspective. Often sediment acts as a mulch as long as vegetative cover is present to reduce evaporative water loss and infiltration rates are not impacted. Ponding: check for ponded water 1-3 days following rain events. If ponding persists then take appropriate action to A) decompact underlying soil, B) integrate organic mulch or compost, and C) re-establish native plants (i.e. native grasses) to facilitate infiltration. Mosquito larvae develop into an adult in 3-7 days.

Irrigation Guide for Green Infrastructure Features with Low-Water Use, Native Plants.						
Year	Months					
	Jan - Feb	Mar- April	May-June	July-Aug	Sept-Oct	Nov-Dec
1	Follow general establishment schedule based on soil type, season, and canopy size.					
2	None	deep soak 2x/ month				1x/month
3	1-2x/month	deep soak 1x/month		deep soak 1x month if no rain		none
4	none	deep soak 1x/month if no rain within 1 month				none
5	none unless replacement planting is needed					

Appendix D:

Registry of Embedded Links

Accessible as of June 2020

- **Page 14**
Federal Highway Administration Context Sensitive Solutions Primer:
https://www.tucsonaz.gov/files/projects/CSSPrimer.pdf

- **Page 14**
Regional Transportation Authority and City of Tucson Process for Grant Road Improvement Plan: http://www.grantroad.info/pdf/dcr/grant-road-dcr-chapter-02.pdf

- **Page 14**
City of Tucson Transit Development Handbook:
https://www.tucsonaz.gov/files/pdsd/transit_oriented_development_handbook.pdf

- **Page 16**
City of Tucson Green Streets Active Practice Guidelines:
https://www.tucsonaz.gov/files/transportation/Green_Streets_APG_Signed_by_Director.pdf

- **Page 16**
Pima County Sustainable Action Plan: https://webcms.pima.gov/cms/one.aspx?portalId=169&pageId=52026#

- **Page 16**
City of Tucson Plan Tucson: https://www.tucsonaz.gov/pdsd/plan-tucson

- **Page 17**
City of Tucson Mayor Romero's Million Trees Initiative: https://www.tucsonaz.gov/newsnet/mayor-romero-launches-tucsonmilliontrees

- **Page 17**
Make Marana 2040 General Plan: https://www.maranaaz.gov/make-marana-2040

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Aspire 2035 - Sahuarita General Plan: https://sahuaritaaz.gov/DocumentCenter/View/1169/Aspire-2035-Sahuaritas-General-Plan-Amended-2019?bidId=

- **Page 17**
Pima County Regional Flood Control District 2020 Floodplain Management Plan: https://webcms.pima.gov/cms/One.aspx?pageId=450475

- **Page 17**
Pima County Detention and Retention Requirements:
https://webcms.pima.gov/cms/One.aspx?pageId=65527

- **Page 17**
City of Tucson Commercial Rainwater Harvesting Ordinance: https://www.tucsonaz.gov/files/pdsd/projects/cms1_033871.pdf

- **Page 17**
Town of Oro Valley MS4 Stormwater Management Plan:
https://beta.orovalleyaz.gov/files/assets/public/documents/public-works/stormwater-utility/manuals-guides-reports/2019-stormwater-management-program.pdf

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Town of Marana MS4 Stormwater Management Plan:
https://www.maranaaz.gov/s/2018-SWMP.pdf

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Pima County MS4 Stormwater Management Plan:
https://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Environmental%20Quality/Water/Stormwater/2015_SWMP_Report.pdf

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City of Tucson MS4 Stormwater Management Plan: https://www.tucsonaz.gov/files/transportation/SWMP_2014.pdf

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City of Tucson Drought Response Plan:
https://www.tucsonaz.gov/files/water/docs/drought_plan_update_spring_2012.pdf

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Pima County Drought Response Plan: https://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Drought%20Management/Drought_Ordinance.pdf

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Tucson Water 2020 Strategic Plan: https://www.tucsonaz.gov/files/water/docs/2020_Strategic_Plan.pdf

- **Page 18**
City of Tucson Bicycle Boulevard Master Plan: https://www.tucsonaz.gov/projects/bicycle-boulevards

- **Page 20**
Wasatch Front Regional Council,
Regional Transportation Plan 2019-2050: https://wfrc.org/vision-plans/regional-transportation-plan/2019-2050-regional-transportation-plan/

- **Page 25**
Pedestrian Traffic Fatalities by State: 2018 Preliminary Data: https://www.ghsa.org/sites/default/files/2019-02/FINAL_Pedestrians19.pdf

- **Page 25**
Evaluation of the 2018-2019 Pima County Clean Air Program Campaign and Clean Water Program Campaign Survey: https://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Environmental%20Quality/Reports_and_Publications/Pima%20DEQ%202018-2019%20report%20-%20final.pdf

- **Pages 42**
  City of Tucson / Pima County Low Impact Development and Green Infrastructure Guidance Manual: https://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Flood%20Control/Floodplain%20Management/Low%20Impact%20Development/li-gi-manual-20150311.pdf

- **Page 75**
  City of Avondale, AZ, City of Avondale: GI Supplement for Avondale's Street Tree Master Plan: https://watershedmg.org/document/GI-supplement-avondale-street-tree-master-plan

- **Page 75**
  Metro Phoenix, AZ, Greater Phoenix Green Infrastructure & LID Handbook: Low Impact Development for Alternative Stormwater Management: https://sustainability.asu.edu/sustainable-cities/resources/lid-handbook/

- **Page 75**
  Santa Fe, NM, "Incorporating Green Infrastructure into Roadway Projects in Santa Fe: https://www.santafenm.gov/media/archive_center/9910_SantaFeR4.pdf

- **Page 75**
  Bernalillo County, NM, "Bernalillo County Green Stormwater Infrastructure: Low Impact Design Strategies for Desert Communities: https://www.bernco.gov/uploads/FileLinks/590808d5c7dd4e0cbfaf3009cf1affb9/Green_Infrastructure_and_Low_Impact_Design_Guide_1.pdf

- **Page 75**
  City of Mesa, AZ: "Low Impact Development Toolkit: https://www.mapc.org/resource-library/low-impact-development-toolkit/

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  San Mateo County, CA: "Green Infrastructure Design Guide: https://www.flowstobay.org/gidesignguide

- **Page 75**
  NACTO Urban Street Stormwater Guide: https://nacto.org/publication/urban-street-stormwater-guide/streets-are-ecosystems/complete-streets-green-streets/

- **Page 75**
  Pima County: Case Studies: Low Impact Development/Green Infrastructure: https://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Flood%20Control/Floodplain%20Management/Low%20Impact%20Development/lid-case-studies.pdf

- **Page 75**
  Model Design Manual for Living Streets: http://www.modelstreetdesignmanual.com/

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  PAG Regional Council resolutions: https://www.pagregion.com/Default.aspx?tabid=1273

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  PAG GI Prioritization Tool: http://gismaps.pagnet.org/PAG-GIMap

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  Watershed Management Group Green Infrastructure for Desert Communities: https://watershedmg.org/document/green-infrastructure-manual-for-desert-communities

- **Page 76**
  PAG Inventory of GI/LID Policies, Guidance, Education, Funds and Efforts in the Region (updated 2017): https://www.pagregion.com/Default.aspx?tabid=189

- **Page 76**
  Return on Investment Study for GI (PAG, City of Tucson, Pima County RFCD, Stantec, and Impact Infrastructure): https://www.pagregion.com/Default.aspx?tabid=189

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  Pima County Subdivision Street Standards: https://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Development%20Services/Building/2016%20SDSS.pdf

- **Page 77**
  City of Tucson Complete Streets Design Guide: https://www.tucsonaz.gov/tdot/complete-streets-tucson

- **Page 77**
  City of Tucson Complete Streets Tucson webpage: https://www.tucsonaz.gov/tdot/complete-streets-tucson

Tucson streets at night.
Photo: Frankie Lopez on Unsplash

Sonoran Desert Green Infrastructure Resource Library

A Playbook for Transportation Projects in Pima County Communities

American Rivers
RIVERS CONNECT US®

1101 14th Street NW, Suite 1400
Washington, DC 20005

americanrivers.org

ATTACHMENT F

POCKET PARK TOOLKIT

Pocket Park Toolkit

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THE TRUST FOR PUBLIC LAND

FOREWORD

This Pocket Park Toolkit was created to help any individual, group, or organization interested in supporting their community by building parks. Through research, discussion, and interviews with experts in the fields of community engagement and organizing, park funding, design, and ongoing park operations and maintenance, this Toolkit provides practical guidance for both the novice community leader and the seasoned government employee. It is geared toward a reader with knowledge about parks and their benefits, but still looking for some clear guidance on how to get started. This Toolkit provides a snapshot of successful strategies and case studies partnered with checklists and templates to empower folks to work with their neighbors to build more parks and stronger, healthier, and more connected communities.

This Pocket Park Toolkit works in part as a complimentary document to previously published toolkits funded by the Rosalinde and Arthur Gilbert Foundation in partnership with the UCLA Luskin School of Public Affairs including:

- Reclaiming the Right of Way: A Toolkit for Creating and Implementing Parklets
- Creating a Complete Los Angeles River Greenway For All
- Placemaking for an Aging Population: Guidelines for Senior Friendly Parks
- Smart Parks: A Toolkit

Each toolkit has been created to support a wide variety of user groups wanting to create open space in their communities.

CHAPTER 1: Introduction

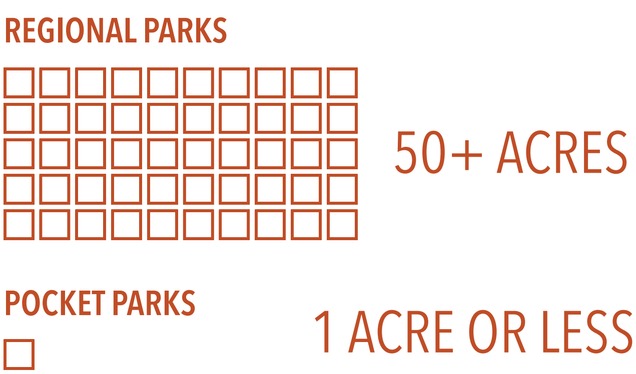
What are Pocket Parks?

The defining characteristic of a pocket park is its size. Although there is no strict definition, Pocket Parks are generally recognized as public park spaces that occupy less than one acre of land. In contrast to larger neighborhood or regional parks that attract park goers from all around a city, Pocket Parks are built with the intention of providing the community within the park's immediate vicinity with the benefits of a public park. Pocket Parks use scaled down features and recreational amenities to relay the same benefits afforded by larger parks while occupying a fraction of the space.

The defining characteristic of a pocket park is its size.

What Does a Pocket Park Look Like?

There is no uniform template for a pocket park. Because pocket parks are opportunistic, often sited on whatever available land is identified, their location might not be as obvious or central as other larger, more typical park sites. But that is the point. Pocket parks are intended to fill in the gaps in neighborhoods where there is no available park space. A pocket park might be constructed under utility power lines or beside a decommissioned railroad track. As such, the shape and dimensions of a pocket park will vary depending on the site.



Like the shape and dimensions, the look and features of the pocket park too will vary due to the site and, more importantly, those living next to it. Pocket parks are meant to serve residents within close proximity – users that will walk or bike to their new park. The character of the pocket park and the amenities selected should be based on the input of those individuals. This is especially so because the type and number of park features that can be built is restricted by the relatively smaller park size. Taking up valuable space with an item or facility the community is not interested in using would be a waste of often limited resources.

A BRIEF HISTORY OF THE POCKET PARK

The concept of a pocket park, also known as a vest park or mini park, is hardly a new idea. Pocket parks were a product of post-WWII reconstruction in Europe. Pocket parks offered previously war stricken municipalities a way to rebuild public spaces despite shortages in labor and raw materials.

Pocket parks could be built inexpensively and relatively quickly in populated areas. Street corners were cleared of rubble and debris to make way for trees and park benches. These smaller, lower maintenance parks helped restore familiar, pre-war landscapes and reestablish the neighborhood's identity.

In the United States, as cities began acknowledging the need for recreational facilities in densely populated areas, the success of pocket parks in Europe did not go unnoticed. Karl Linn, a professor at the University of Pennsylvania, began promoting the idea of using tax delinquent land to create public commons in urban areas along the east coast. The novelty of developing parks from underused lots was well received by both citizens and city officials.

By the mid-20th century, the value of a park was no longer based solely on its size but instead on its accessibility. Today, pocket parks continue to be used by municipalities as a practical method to increase park access for all communities.

Why Build Pocket Parks?

Building one, or even a few, multi-acre parks will not necessarily provide park access to all city residents. While those parks may feature numerous facilities of interest, lack of time, funds, or means to visit a park that is miles from an individual's home can be enough of a barrier to prevent the use of larger, more distant parks. Creating pocket parks that are within walking or biking distance to homes that do not currently have close access to a larger park is a viable solution for cities to increase park access throughout all neighborhoods. . Information on park access for the majority of American cities is available on ParkServe.

Additionally, pocket parks are a particularly useful tool for increasing park access for residents in communities where the development of larger parks is not feasible due to a lack of available land. Many dense urban areas do not have large tracts of available, vacant land on which to develop a new park. In many cities, building a park on a half-acre or less may be the only viable option to create new parks.

Finally, pocket parks can be used to revitalize unused or underused land. Brownfields, vacant lots, abandoned parking lots, and utility or public right-of-ways can all be transformed from neglected spaces that attract unwanted or illicit activities into community assets.

Community members look at the construction of their new park
Kellogg Park, CA
Photo: PlusM Productions

What are the Potential Benefits of Pocket Parks?

Parks, when utilized by the local community and well maintained, are invaluable features of the urban landscape. As a public resource, they provide recreational facilities that encourage active lifestyles, spaces where the community can gather and build comradery, and essential environmental services that strengthen the overall health of a community. The social, health and environmental benefits of parks should inform design decisions and be implemented into every pocket park project.

Pocket parks provide social benefits because they support neighborhood identity and make communities more livable. Numerous studies have shown that converting empty neighborhood lots into parks is associated with decreases in neighborhood crime. This in turn decreases the anxiety felt by residents living in high crime areas. Pocket parks should be designed to maximize activity and use. A well-activated pocket park will discourage illicit activities from taking place.

The presence of a pocket park attracts a wide variety of users of all ages and backgrounds who are looking for a comfortable, safe place to play and socialize. Pocket parks should be designed with places for people to gather and provide a setting for relationship building. Relationships between community members, elected officials, local parks departments, as well as established community organizations such as neighborhood councils and parent groups can be strengthened by the presence of a pocket park.

Socializing
Story Mill Community Park, MT
Photo: Bruce Muhlbradt

Human health has a direct link to the built environment. Available open space can influence the overall health of the community so a new pocket park provides a community with health benefits. In 2019, The Trust for Public Land's ParkScore Index, reported that 100 Million Americans or just over 30% of the population does not live within a 10-minute to a park. Parks within walking distance become a destination for families with children, increasing a family's overall levels of physical activity.

Parks promote physical activity that helps to combat and prevent heart disease, obesity, diabetes, cancer, and other chronic illnesses. From 1999-2016 obesity rates rose from 30.5% to 39% for adults and 13.9% to 18.5% for youth. Designing a pocket park with age appropriate recreational and fitness opportunities promotes healthy living across all age groups. Playgrounds, fitness equipment, and walking paths are all features that promote physical activity in parks.

30% OF THE US POPULATION

DOES NOT LIVE WITHIN A 10-MINUTE WALK TO A PARK

= 1 million people

Fitness equipment in use
Olympic Park, FL
Photo: Allana Wesley White

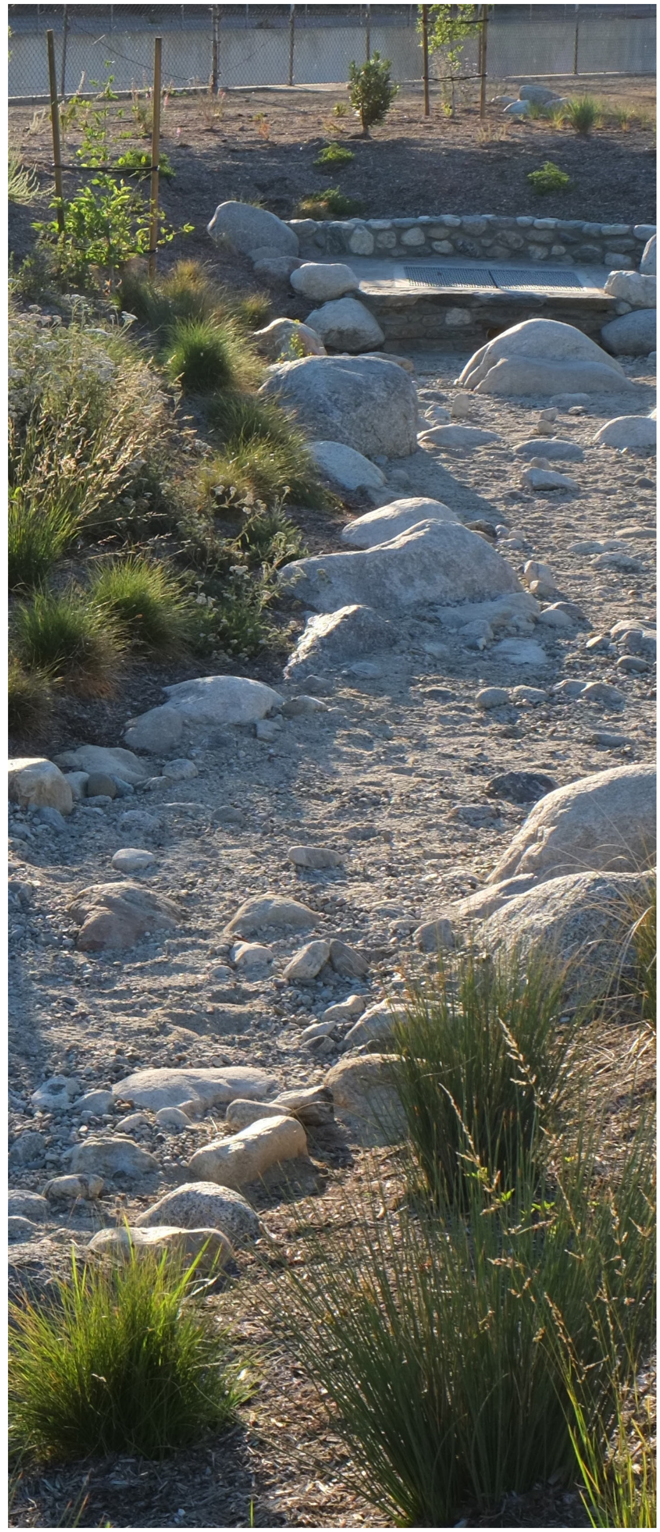
Pocket parks can provide significant environmental benefits. When thoughtfully designed, pocket parks can play a role in reducing the urban heat island effect, managing and treating stormwater, and providing native habitat for pollinators and other wildlife.

As the effects of global warming become more pronounced, heat extremes are expected to increase in frequency and intensity in most inhabited areas. Cities and other high-density urban areas with limited trees and open space experience elevated levels of urban heat island effect. Surfaces like asphalt paving absorb heat throughout the day and slowly release it back into the environment resulting in areas that are warmer than surrounding neighborhoods. This can lead to dangerous conditions, especially for vulnerable populations like seniors, people experiencing illness, pregnant women, people experiencing homelessness, and those who work outdoors. Pocket parks can be designed to use permeable surfaces that do not retain heat, as well as add trees and shrubs to shade and cool adjacent paving, thereby decreasing the urban heat island effect within and adjacent to the park. Clearly, simple park interventions have compounding climate benefits for the whole neighborhood.

As cities develop, less and less habitat is available for wildlife. Although small in size, the importance of pocket parks to insects, birds and other native wildlife can be significant. By incorporating native plants, pocket parks become patches of needed food sources for pollinators like bees and butterflies and can offer a site of relief for migrating birds. Thoughtful planning around the vegetation used in pocket parks can boost ecosystem biodiversity within the overall city.

Pocket parks play a pivotal role in the management and treatment of stormwater. Stormwater runoff becomes contaminated as it flows over city streets and into street drains. In some cities, it then flows out into rivers, streams, lakes, and oceans becoming a source of pollution in important waterways. In other cities, aging infrastructure struggles to process the volume of rain from severe storm. When those systems fail the result is flooding and erosion. The need for alternative methods of stormwater management and treatment are ever increasing and pocket parks are ideal locations for green infrastructure that treats and captures polluted stormwater through bio-filtration and infiltration.

Pocket parks are an effective way to provide the multiple benefits described above to neighborhoods that do not currently have access to parks. When carefully planned and designed with the end users in mind, pocket parks are an invaluable community resource.



Bioswale collects and filters stormwater runoff
Los Angeles River and Aliso Creek Confluence Park, CA
Photo: David Garden

CHAPTER 2: Engagement, Organizing, & Partner Building

To be truly successful, pocket parks must be designed and implemented with authentic and robust participation from local residents and community leaders. Community Engagement means creating an open dialogue with neighbors where designers can listen to and respond to the needs and wants of the community. Community engagement means organizing events to reflect the specificity and uniqueness of the neighborhood. Most importantly, community engagement should be done throughout the course of the design and construction processes to ensure local residents are well informed and have plenty of opportunity to participate.

Community engagement is an extension of Community Organizing. The goal of community organizing is to mobilize a volunteer base rooted in the community, increasing a sense of agency, so residents can advocate on their own behalf without the need for outside support. This process typically involves identifying leaders or champions within the community who can represent the interests of their neighborhood and encourage other residents to join in collective efforts towards neighborhood change.

Approaches to community engagement and organizing will vary depending on the specific neighborhood, the local stakeholders and partner organizations, and the scale of the project. Ultimately, all engagement techniques should empower community members to take part in decisions concerning development in their own neighborhoods.

Participatory design session with elementary school students
Chittick Elementary School, MA
Photo: Erin Clark

Step One: Getting Started

The community engagement and organizing process should begin by evaluating the overall feasibility of a new park development. This preliminary phase focuses on identifying possible locations for the park and the benefits each location may provide. It should also identify potential local partnerships and confirm positive community sentiment toward a new park.

STEP ONE ACTIVITIES

Establish a Baseline

1. Does the community want a park?
2. Is there a potential location that is suitable for a new park and is a park the best use of that site?
3. What social, environmental, and health benefits could the park provide?

Identify Partners

1. What nearby organizations or agencies support park development?
2. What nearby community institutions (place of worship, schools, HOAs) might use the park on a regular basis?
3. Are there community centers or business districts that might support the park once built?

Form an Outreach Team

1. What individuals or groups are important to include on the team?
2. What individuals or groups within the community could take on leadership roles within the team?
3. What team members are best able to engage with community members about the creation of a new park?

Step Two: A Shared Mission

Once an outreach team forms, the next step is to create a mission statement that clearly defines the intentions of the park. A mission statement goes beyond declaring intent to build a neighborhood park. The mission statement should unite individuals and organizations via common goals for the project. Local community groups, neighbors, and other relevant stakeholders determine this mission statement. It is important this collaborative effort happen at the beginning of the park design process. This early coordination builds trust and demonstrates community ownership from the outset.

STEP TWO ACTIVITIES

Community Asset Mapping

Identify places near the park where the community gathers, such as schools, libraries, and places of worship. These are good places to make first contact with community members about developing a park.

Pop-Up Events

Set up a booth or station organizers around areas in the neighborhood with high foot traffic to peak the community's interest and provide park development and outreach information and gather preliminary feedback.

Community Survey

Surveys can be distributed in person or online to get community feedback about the park project and is a good way to engage a large number of neighbors who may not otherwise be able to participate in meetings or events.

Step Three: The Power of the People

Now that the mission statement is clearly defined, the advocacy and education process can begin. Getting neighbors involved and committed early on is imperative for the project's success. A park project that is community driven will be the most successful over time.

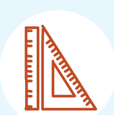
STEP THREE ACTIVITIES

Routine Community Meetings

Host regularly scheduled public meetings at a location in the neighborhood that is easily accessible (identified during step two – asset mapping). Meeting activities can include establishing park committees, brainstorming fundraising events, planning for upcoming design charrettes, among others.

Public Survey Review

Information gathered from surveys collected during step two can be summarized into a handout or infographic and presented back to community. Public review of this data supports compromise and community collaboration over shared goals for the park.



Design Charrettes

A design charrette is a collaborative public meeting where different options for the park design can be explored and prioritized. These meetings can also be used as forums for the community to select specific park amenities and features.

The education portion of this step is a two-way street between the outreach team and the community. The outreach team will explain the process of park design, fundraising activities, and stewardship practices as it relates to the project and the community will provide feedback. This process will identify possible issues and inform design decisions to help address these concerns.

Outreach needs to be proactive and the impetus of making first contact should be on the outreach team members.

Outreach needs to be proactive and the impetus of making first contact should be on the outreach team members. Methods for contacting the greatest number of community members should be shaped by suggestion from the community. Word of mouth, mailers, email, online social networks, in-person events, and pop-ups are all viable options. In addition, energy should be put into boots on the ground activities that give outreach team members a chance to speak to the community directly. Presenting at already established community gatherings such as church groups, city council meetings, PTA meetings, or wherever the community congregates is an effective way to share the project with a large group and connect with residents who may not have otherwise learned of the park project.

Early meetings should promote awareness of the project and focus on growing the number of community members involved. After that, ongoing engagement will reveal the prospective community leaders who are the most active contributors. These individuals can begin to take on more responsibility by leading ongoing outreach, advocacy, and park committees. With this increased responsibility comes the training and tools needed for these community groups to eventually operate without the help of the outreach team.

Be prepared to face some challenges in this outreach phase. Oftentimes, organizers encounter distrust among residents, especially when working in neighborhoods historically disinvested and lacking in park access. It is important to recognize this dynamic and approach engagement with the ultimate goal not to be gathering feedback, but fostering trust.

Step Four: The To-Do Lists

This step involves noting and prioritizing tasks required to move the park project forward, delegating responsibilities, and accomplishing tasks as a team. This might include hosting site clean-up events, contacting city officials to express support for the park development, grant writing, fundraising, handing out informational flyers, contacting local business and relevant stakeholders for support, etc. Every accomplishment and resolved obstacle should be celebrated. Keeping track of the park's progress shows community members that their efforts are moving the project forward and boosts community morale.

Step Five: The Life of the Park

Step Five is ongoing work. The previous steps have established a network of community members who are dedicated to the success of the park. By this point, the park is nearly or already completed. Ideally, and if the engagement has been robust, the park committees and community leaders who contributed to the creation of the park maintain their role as park stewards in addition to park users.

STEP FOUR ACTIVITIES

Community Champions

The most active community members should be recognized for their work on the project. These leaders are an invaluable resource to the park project. They can be put in charge of organizing park events and are ideal candidates for leaders in step five as they have established ties to the community and a vested interest in the park's success.

Park Progress Report

The community should be able to see the progress of a project. This could be shown in a report, checklist, or infographic. Knowing the progress of a project can help the community stay engaged over long periods.

Community member presented with a certificate of recognition from the City of Los Angeles
El Sereno Arroyo Playground, CA
Photo: The Trust for Public Land

Engagement Techniques for Long-term Park Stewardship

Park stewardship programs provide community members who are interested in actively contributing to their local parks with a platform to do so. The objective of a park steward program is to maintain the integrity of the park and park stewards are the link between the park, the long-term owner and operator, and the community. The role of a park steward goes beyond reporting graffiti or trash clean up to the parks department. Although these may be important features of the position, they represent just a small portion of a steward's potential.

Park stewards contribute to the overall management of the park. While more technical and labor-intensive park maintenance activities are reserved for the long-term operators' staff, park stewards can organize and lead smaller upkeep activities. Park stewards help maintain the momentum of community involvement created prior to the project's completion by continuing direct engagement with the community through site activation and programming. Communities evolve and park stewards can ensure park activities adapt to meet the needs of current and futures users.

A local 'friends of' group, local land trust, conservancy, or a city's parks department will often organize the park stewardship programs. In all cases, the stewardship program works in-sync with the local parks department to coordinate the scheduling of programming and larger projects taken on by the park stewards.

Employees at a local business turn out to help during a park clean up event
El Sereno Arroyo Playground, CA
Photo: The Trust for Public Land

CASE STUDY: LA Neighborhood Land Trust Stewardship

Since 2002, the Los Angeles Neighborhood Land Trust (LANLT) has been creating parks in neighborhoods that lack green space in Los Angeles County. The LANLT has participated in the successful creation of twenty-eight pocket parks and community gardens. LANLT has assumed the role of the park's managing body for seven of those completed projects.

The success of LANLT is directly linked to their stated emphasis on including community members in the decision making process throughout planning and construction. In order to maintain a high level of engagement and advance a sense of local ownership after the parks are completed, the LANLT has implemented an innovative Stewardship Program rather than relying on a volunteer base for park support.

Their Stewardship Program brings on park stewards as paid employees of the LANLT. Park stewards are chosen based on criteria including their proximity to the park, availability to perform simple and routine operations and maintenance duties, and a commitment to support the wellbeing of the community through park related activities. Responsibilities of the park stewards include:

1. Opening and closing the park,
2. Assembling volunteer groups,
3. Identifying potential programming that represents local interests and that the community wants (e.g. dance classes, gardening workshops, yoga, professional development support, etc.),
4. Working with park users to deliver park programming, and
5. Event organizing.

As employees of the LANLT, park stewards are given greater responsibility and have more authority to create and direct park programming based on the recommendations of park users.

Park programming
Mestizo Curtis Park, CO
Photo: Theo Stroomer

Attributes of a Robust Park Stewardship Program: Diversity, Accessibility, and Empowerment

A park stewardship program should reflect the diversity of the community. Park stewards with different backgrounds will have unique ideas and services to offer. Incorporating a variety of artistic, cultural, and recreational interests allows for park programming that is fresh and most likely to retain the community's continued engagement with the park.

Neither age, experience level, nor physical capabilities should prevent an individual from becoming a park steward or participating in park stewardship activities.

Moreover, providing the community with a variety of ways to participate in park stewardship activities opens the door to those who might not be interested in more typical park programming like planting or gardening. Yoga, sporting competitions, arts and craft festivals, and food concessions are all less typical options for park activation. A park steward program should utilize as many different activities as possible to draw in a diversity of park users.

A stewardship program should be accessible to all. Ensure volunteer and engagement opportunities are known to the community by posting a schedule online and on public bulletin boards within and around the park. This keeps drop-ins as well as veteran park stewards up to date on all opportunities.

Offer ample opportunities with varying levels of physical intensity so any community member, regardless of their physical ability, has a chance to attend. Neither age, experience level, nor physical capabilities should prevent an individual from becoming a park steward or participating in park stewardship activities.

The park stewardship program should accommodate and encourage participation by larger groups, such as those organized by a nearby school and other community organizations and facilities. Working with already organized volunteer groups is a great way to showcase the value of the park space to a large number of individuals. Additionally, larger volunteer groups can be leveraged to take on more demanding projects such as replanting shrubs or neighborhood clean-ups.

KEY TAKEAWAYS

- **Pocket parks begin in the community. The only way to ensure a successful pocket park is to build community support from the outset and continue engaging and organizing throughout design, construction, and after the park is complete.**
- **Understand your local resources through asset mapping. What groups, schools, churches, or other resources already exist to support community engagement.**
- **Parks are only as good as their long-term maintenance. Build a stewardship group to ensure the park stays clean, safe, and beloved by the community for years to come.**

The development of a new pocket park, just like any type of development, is not possible without financial planning. While there is no singular approach – each park project will have unique stakeholder needs and financial resources – there are a range of tools to help locate available public funding and to organize realistic budgets for both development and long-term operations and maintenance.

Budgeting

During the design process, developing a transparent and realistic budget will allow the community, the design team, and the long-term operator to make educated decisions on what they can afford to build and maintain over time. While the aim of a budget is to manage project costs, the goal of the project is to provide the greatest benefit to the park user. Developing a comprehensive budget can help ensure that funds are sufficient to provide the community-determined park priorities first.

The most well planned park design will be of no use to the community if the operator is not able to keep it clean, safe, and with all park amenities functioning in good use.

Budgeting should also be used to ensure the project remains within the financial and staffing capacity of the long-term operator. The most well planned park design will be of no use to the community if the operator is not able to keep it clean, safe, and with all park amenities functioning in good use.

Too few trash cans or too many plants can create ongoing maintenance issues
Photos: The Trust for Public Land

Types of Park Budgets

Two separate budgets are required for any new park development – the Capital Investment Budget and the Operating Budget. The two budgets are inherently connected as the long-term operating costs are heavily influenced by the original park design.

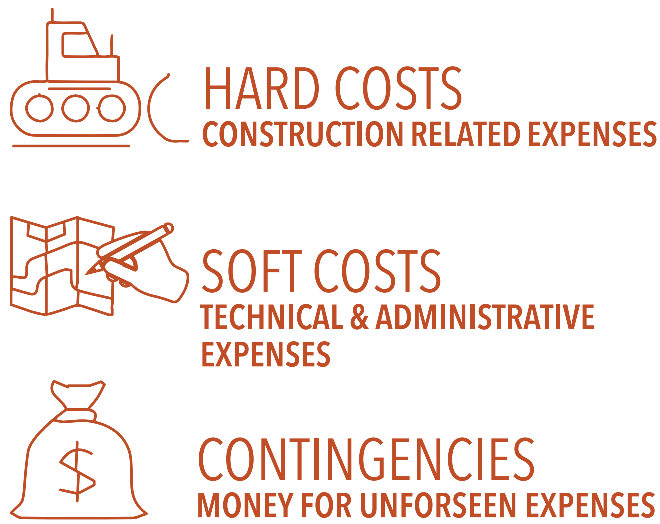
The Capital Investment Budget contains all of the expenses associated with land acquisition and site development including but not limited to permitting fees, consultant fees, as well as the general contractor's bid to build the project. The developing entity, whether it be a nonprofit, city parks department, or local land trust, is responsible for budgeting and fundraising for these expenses. Generally, the Capital Investment Budget is split into three categories: hard costs, soft costs, and contingencies.

Hard Costs are all of the expenses directly related to the physical construction of a park, including labor and materials. In other words, these costs are the hours of labor worked, plus the cost of the materials used in construction. This cost category can be thought of as the parks features that are more easily identifiable such as a drinking fountain, a play structure, walkway lighting, picnic tables, a handball court, or perimeter fencing.

Soft Costs are the expenses and fees indirectly related to the physical construction costs. These are the out-of-sight technical and administrative expenses attributed to a park development project such as site surveying, architectural and landscape design, project management, and permitting fees.

Contingencies are a crucial budget element that should not be overlooked or omitted. Contingencies are monies that will account for any unforeseen costs the project will incur. There are many scenarios in which this will come into play during the life of a project. Most often it is due to work that was not anticipated (i.e., items discovered once excavation begins) but it ensures money will be available for any items that may have been omitted in the budget due to error or lack oversight (i.e., not accounting for all of the materials required to construct a park feature). It is important to realize that even the best and most carefully crafted budget is still just an estimate. Contingencies help to ensure a project will be completed in full, without having to cut from planned park elements to pay for unforeseen costs.

A sample Capital Investment Budget is available at the end of this chapter. The budget includes hard cost line items commonly required for park development projects as well as standard percentages that can be used to estimate soft costs and contingencies. The items included in this sample budget are by no means exhaustive, this is just an example of common costs seen in a pocket park budget.



CAPITAL INVESTMENT BUDGET CATEGORIES

The Operating Budget includes the costs required to operate and maintain a park once it is open to the public. It should be comprehensive and account for all costs associated with keeping a park open, clean, and functional. These costs include utility fees, staff wages for landscape and facilities maintenance personnel, costs to replenish and replace items that will wear from regular use (i.e. sand), and other general park upkeep activities. The entity responsible for park operations will be responsible for these expenses for the life of the park. Whatever entity will be assuming operating responsibilities likely has their own costs for maintenance activities which might be wrapped into a larger budget. Work closely with the entity to create the operating budget using their standards and templates.

Tips for Managing Costs

Managing site development and maintenance expenses is critical to the success of a project throughout life of the park. Evaluating your design and creating a volunteer network are some of the best ways to manage costs.

A good way to begin is to evaluate your design, consider all the elements planned for the park and their sustainability over time. How will they hold up to regular use with potentially little maintenance? Three key factors should be included in this evaluation: 1. what is the expected use; 2. what are the materials and how well will they tolerate weather conditions (heat and cold) and the expected use, and 3. cost efficiency – is it more efficient to purchase high-end equipment and materials now, rather than replacing materials of lower quality more often?

To ensure the park design meets the maintenance budget, it is important to consider park use. A mental "walk through" of how visitors will use the park can highlight areas that might require more maintenance.

Materials and equipment that can withstand consistent, heavy use and exposure to the elements are a vital piece of a sustainable park maintenance budget.

Insufficient seating or pathways to popular park features might result in users trampling or sitting on landscaping, effectively killing plants and damaging irrigation lines. Even something as simple as installing adequate waste receptacles throughout the park and in greater quantity in areas where they are most needed, like near playgrounds and picnic tables, can reduce the need for unnecessarily frequent visits by park maintenance staff.

Materials and equipment that can withstand consistent, heavy use and exposure to the elements are a vital piece of a sustainable park maintenance budget. When materials and equipment are proposed, it is a good idea to visit multiple sites where that particular product has been installed and in place for a number of years. Generally, the manufacturer can supply those locations and the contact information for individuals responsible for maintenance and operations of those sites. Discussions with folks regarding their experience with the product can inform if this is a suitable product for your project. Deliberate and thoughtful research into all products to be used in the park can significantly reduce the likelihood of installing features that will not withstand the test of time.

TIPS FOR MANAGING COSTS

Evaluate your design

What is the expected use?

What are the materials and how well will they tolerate weather conditions (heat and cold) and the expected use?

Is it more efficient to purchase high-end equipment and materials now, rather than replacing materials of lower quality more often?

Create a volunteer network

What network of individuals and groups are already involved in the park building process that might want to volunteer?

Are there any opportunites for volunteers to locate or provide in-kind donations of needed supplies?

Is there any part of the park building process that volunteers could assist with?

Are there any park maintenance requirements that volunteers could assist with?

Products should also be evaluated for cost efficiency. Sometimes spending more on a product or feature during development in order to balance the long-term operational budget is the best use of your funding. For example, using surface materials that have a long lifespan like poured-in-place rubber safety surfacing as opposed to engineered wood mulch in playground areas is far more expensive to install but requires little to no maintenance and can remain in place for at least 10 years. The mulch, however, will need to be refilled regularly in order to continue to provide fall protection for children using the playground. Doing adequate and thorough product research is an important way to develop and vet the operating budget and provides a realistic gauge of a product's required maintenance needs over time. This allows all parties to make decisions about the most cost-effective option for the life of the park.

Creating a volunteer network entails tapping into the network of individuals and groups who are already involved in the park building process. Volunteers can be organized to make in-kind donations including needed supplies and labor. For example, community volunteers can be leveraged to assemble a play structure during the construction phase. This is an easy way to reduce labor costs for a day or two and has the added bonus of further engaging the local community by giving them a direct role in the development of the park. Volunteers may also help mitigate the maintenance requirements of a park by organizing routine clean up days so park staff can allocate their resources more efficiently.

Volunteers assist with park development
New Freedom Park, CO
Photo: FocusTree

Where to Look for Funding

Every new park project will have a unique funding structure; however, to bring the funding together new public investments almost always require good partnerships and funding support from nonprofit park-building groups, local governments, and private contributions.

Nonprofit park-building groups have the ability to secure funding through grant writing and philanthropic contributions from established donor lists. A common scenario for a new park development includes a nonprofit partner to fundraise and oversee the development of the park while a public agency partner retains the ownership and management responsibilities of the site. This is a mutually beneficial partnership. The nonprofit organization is often better able to fundraise for capital, they have grant writing and philanthropic staff who are dedicated to and experienced in fundraising for park projects, while the city parks department has the financial stream and staff infrastructure required to operate and maintain a park. This type of cost sharing partnership is a tried and true approach to building parks for community benefit.

Local governments have a range of mechanisms to fund park projects yet the majority of these funds generally flow to operations and maintenance expenses, rather than new park developments, as dollars for "O&M" are often the most difficult to secure. Local government funds stems from a general appropriations budget as well as revenue generated from public service fees. Public service fees include income generated from parking meters, concession fees, or vendor permit fees in addition to other sources. Although it is not unheard of for a municipal parks department to develop a new park project, their generally steady flow of revenue is often better suited for the long-term upkeep of their parks.

Another source is a general obligation bond. A city or state can pass obligation bonds to raise funds for capital investment projects. If the bond program criteria deals with green infrastructure, sustainable development, or community benefit, a pocket park may qualify for funding.

Private contributions are another method commonly used to fundraise for park projects. Smaller donations may be secured through a community BBQ or from the sale of inscribed plaques or bricks to be installed in the park. Larger private donations may be sourced from local business owners or institutions. Even naming rights may be sold to establish an endowment for operating expenses.

With pocket park projects often funded through a combination of all of the above, it is important to understand the myriad opportunities to develop a new park in your community.

Community places flyers in rolls of toilet paper to raise awareness about the"flush fund" for a restroom at their new park
Kellogg Park, CA
Photo: The Trust for Public Land

Moving Forward

Locating funding for a pocket park project should start by scanning programs at the local and state level. For local opportunities, look to a city's development plan or climate action plan, since these often list financing measures and incentive programs related to the development of greenspaces and parks. Government websites like grants.gov offer internal databases where a user can locate applicable regional grant programs.

Finally, do not underestimate the power of working collaboratively with neighbors. In-person meetings can offer a unique opportunity to network and share experiences with other novice park building community groups. Schedule meetings with other grassroots community groups who have been successful with any kind of development projects to gain a perspective of the process. Open space advocacy groups and nonprofits hold park building workshops and seminars all over the country. Events like these aim to bring individuals together to learn how to build a park in their own neighborhood and are a fantastic resource for any groups looking to build a new pocket park.

Wood mulch is cost efficient but requires more maintenance
Dutch Jake's Park, WA
Photos: Mae Wolfe

KEY TAKEAWAYS

- **Maintain communication with stakeholders during the budgeting process.**
- **Design for longevity and sustainability.**
- **Funding for park development can come from various sources, know what is available in your area.**

SAMPLE CAPITAL INVESTMENT BUDGET

Not all items listed will be applicable to every pocket park project.

	Item Description	Quantity	Unit	Unit Cost	Subtotal	Total
1.0	**Design, Permits and Testing**					
1.1	Construction documents (10% of construction costs)	1	LOT	$ -	$ -	$ -
1.2	Geotechnical/MT&I	1	LOT	$ -	$ -	$ -
1.3	Agornomic testing	1	LOT	$ -	$ -	$ -
1.4	Site survey	1	LOT	$ -	$ -	$ -
1.5	Plan check	1	LOT	$ -	$ -	$ -
1.6	Permits	1	LOT	$ -	$ -	$ -
1.7	Constuction Management	1	LOT	$ -	$ -	$ -
						$ -
2.0	**Demolition and Removal**					
2.1	Clearing and grubbing		SF	$ -	$ -	$ -
2.2	Remove and relocate irrigation heads		SF	$ -	$ -	$ -
2.3	Tree Removal		EA	$ -	$ -	$ -
2.4	Saw Cut - Exist. Curb		LF	$ -	$ -	$ -
2.5	Concrete		SF	$ -	$ -	$ -
2.6	Asphalt Concrete		SF	$ -	$ -	$ -
2.7	Fencing		LF	$ -	$ -	$ -
2.8	Tree Boxing and Relocation		EA	$ -	$ -	$ -
						$ -
3.0	**Earthwork and Grading**					
3.1	Cut and Fill		CY	$ -	$ -	$ -
3.2	Rough Grading		SF	$ -	$ -	$ -
3.3	Fine Grading		SF	$ -	$ -	$ -
3.4	Soil Import		CY	$ -	$ -	$ -
3.5	Soil Export		CY	$ -	$ -	$ -
						$ -
4.0	**Sidewalk and Parking Lot Paving**					
4.1	Asphalt Concrete Paving		SF	$ -	$ -	$ -
4.2	Asphalt Concrete Paving Drive Approach		EA	$ -	$ -	$ -
4.3	Concrete Curb		LF	$ -	$ -	$ -
4.4	Concrete Curb & Gutter		LF	$ -	$ -	$ -
4.5	Parking Striping		SF	$ -	$ -	$ -
4.6	ADA signs		EA	$ -	$ -	$ -
						$ -
5.0	**Hardscape**					
5.1	Integral Colored Concrete Paving		SF	$ -	$ -	$ -
5.2	4" Concrete Paving		SF	$ -	$ -	$ -
5.3	6" Concrete Paving		SF	$ -	$ -	$ -
5.4	Decorative Paving		SF	$ -	$ -	$ -
5.5	ADA Ramp		SF	$ -	$ -	$ -
5.6	Concrete Step		SF	$ -	$ -	$ -
5.7	Concrete Swale		LF	$ -	$ -	$ -
5.8	6" Mow Strip		LF	$ -	$ -	$ -
5.9	Grass Pave		SF	$ -	$ -	$ -
5.10	6" Curb		LF	$ -	$ -	$ -
5.11	Sand Set Pavers		SF	$ -	$ -	$ -
5.12	Unstabilized Decomposed Granite		SF	$ -	$ -	$ -
5.13	Stabilized Decomposed Granite		SF	$ -	$ -	$ -
						$ -

SAMPLE CAPITAL INVESTMENT BUDGET

Not all items listed will be applicable to every pocket park project.

	Item Description	Quantity	Unit	Unit Cost	Subtotal	Total
6.0	**Formed Concrete Work**					
6.1	Bench Seating		LF	$ -	$ -	$ -
6.2	Precision Block Wall		LF	$ -	$ -	$ -
6.3	Slump Block Wall		LF	$ -	$ -	$ -
6.4	Split Face Block Wall		LF	$ -	$ -	$ -
6.5	Cast in Place Concrete Wall		LF	$ -	$ -	$ -
6.6	Chain Link Fence		LF	$ -	$ -	$ -
6.7	Chain Link Gate		EA	$ -	$ -	$ -
6.8	Chain Link Double Gate		EA	$ -	$ -	$ -
6.9	Tubular Steel Fence		LF	$ -	$ -	$ -
6.10	Tubular Steel Gate		EA	$ -	$ -	$ -
6.11	Engraving		SF	$ -	$ -	$ -
						$ -
7.0	**Site Amenities**					
7.1	Picnic Table		EA	$ -	$ -	$ -
7.2	Bench		EA	$ -	$ -	$ -
7.3	BBQ		EA	$ -	$ -	$ -
7.4	Drinking Fountain		EA	$ -	$ -	$ -
7.5	Trash Recepacles		EA	$ -	$ -	$ -
7.6	Exercise Equipment		EA	$ -	$ -	$ -
7.7	Playground Equipment		EA	$ -	$ -	$ -
7.8	Playground Surfacing (PIP, Engineered Wood Mulch)		EA	$ -	$ -	$ -
7.9	Tree Grate		EA	$ -	$ -	$ -
7.10	Educational Signage		EA	$ -	$ -	$ -
7.11	Park Monument Signage		EA	$ -	$ -	$ -
						$ -
8.0	**Buildings and Structures**					
8.1	Restroom		SF	$ -	$ -	$ -
8.2	Restroom Prefab Building		LS	$ -	$ -	$ -
8.3	Shade Structure		SF	$ -	$ -	$ -
8.4	Gazebo		SF	$ -	$ -	$ -
8.5	Shade Sail		SF	$ -	$ -	$ -
						$ -
9.0	**Electrical**					
9.1	Up Lights -Solar Powered		EA	$ -	$ -	$ -
9.2	Bollards-Solar Powered		EA	$ -	$ -	$ -
9.3	Service for restroom and irrigation		EA	$ -	$ -	$ -
9.4	Solar Post and Power Assembly Panel		EA	$ -	$ -	$ -
9.5	Lighting Control		EA	$ -	$ -	$ -
						$ -
10.0	**Utilities**					
10.1	Domestic Water Service		LF	$ -	$ -	$ -
10.2	Domestic Irrigation Water Service		LF	$ -	$ -	$ -
10.3	Reclaimed Water Service		LF	$ -	$ -	$ -
10.4	Sewer Line		LF	$ -	$ -	$ -
10.5	Gas Line		LF	$ -	$ -	$ -
10.6	Electric Service		LF	$ -	$ -	$ -
10.7	Phone Service		LF	$ -	$ -	$ -
10.8	Cable Service		LF	$ -	$ -	$ -
						$ -

SAMPLE CAPITAL INVESTMENT BUDGET

Not all items listed will be applicable to every pocket park project.

	Item Description	Quantity	Unit	Unit Cost	Subtotal	Total
11.0	**Landscape**					
11.1	Planting		SF	$ -	$ -	$ -
11.2	Mulch		CY	$ -	$ -	$ -
11.3	Soil Preparation		CY	$ -	$ -	$ -
11.4	Sod		SF	$ -	$ -	$ -
11.5	Turf Sod		SF	$ -	$ -	$ -
11.6	Turf Hydroseed		SF	$ -	$ -	$ -
11.7	Groundcover		SF	$ -	$ -	$ -
11.8	1 gallon Shrub		EA	$ -	$ -	$ -
11.9	5 gallon Shrub		EA	$ -	$ -	$ -
11.10	15 gallon Shrub		EA	$ -	$ -	$ -
11.11	15 gallon Tree		EA	$ -	$ -	$ -
11.12	24" box Tree		EA	$ -	$ -	$ -
11.13	30" box Tree		EA	$ -	$ -	$ -
11.14	36" box Tree		EA	$ -	$ -	$ -
11.15	48" box Tree		EA	$ -	$ -	$ -
11.16	60" box Tree		EA	$ -	$ -	$ -
11.17	72" box Tree		EA	$ -	$ -	$ -
11.18	Irrigation System		SF	$ -	$ -	$ -
11.19	Irrigation Controller		EA	$ -	$ -	$ -
11.20	Irrigation Booster Pump		EA	$ -	$ -	$ -
11.21	90 Day Maintenance		EA	$ -	$ -	$ -
						$ -

Construction Cost	$ -
General Conditions (8%)	$ -
Contractor Bonds, Insurance, Overhead & Profit (10.2%)	$ -
SUBTOTAL CONSTRUCTION COST	**$ -**
Design Contingency Allowance (3%)	$ -
Escalation (3% Annually)	$ -
Construction Contingency (15%)	$ -
TOTAL CONSTRUCTION COST	**$ -**

CHAPTER 4: Designing a Park for All

The design of a pocket park is a key factor in how well the space ultimately serves the community. As discussed in Chapter 2, robust community engagement is the only way to ensure the park provides the amenities that best suit the local neighborhood. But how the input gathered from the community ties back into the actual design is vitally important. The design of the site, the location of the selected amenities, their orientation, color choices, texture, and materials, all should encourage use across age groups and physical abilities. Additionally, given a pocket parks' limited size and the unique constraints of each site, serving the largest number of users often requires programming every inch. This chapter will walk you through some important considerations when designing a pocket park for all. This is by no means meant to stand in for the skill of a professional landscape architect on a development project, but will provide some context for the myriad factors that lead to a successful design.

Site Specific Considerations

The existing conditions of a potential park site will present a series of opportunities and constraints. The sites' size, shape, topography, and presence of existing trees or utility poles, all influence development of the site. Understanding the limitations and possibilities of these conditions is the first step in effective planning. How can the opportunities be utilized and the constraints minimized? Are there any existing site features, like small hills, that can be activated as a play area for children to roll and slide down? Are there naturally occurring low points that support stormwater management such as bioswales or infiltration areas? Making use of these site-specific features not only supports the unique nature of a community park, but also reduces costs by avoiding excessive site grading. Any lot can be graded using heavy machinery to produce a flat-surfaced, easily developable, blank template, but the cost associated often makes such efforts prohibitive and ultimately may sacrifice the inherent interest of the site.

An active LA Metro light rail line adjacent to the park site inspired a train-themed design
Watts Serenity Park, CA
Photo: Spohn Ranch

Maximizing Benefit for All Users

To support all neighbors with one small pocket park requires careful consideration and organization of the community selected park amenities. Pocket parks by nature are limited in size and thus all features should really appeal to multiple users. These features maximize site use and reduce the amount of space dedicated solely to one group. For example, while play equipment is separated by age range, such as ages 2-5 and 5-12, play elements that are safe for all ages, like mounded rubber surfacing, can increase the overall play value at a site. Boulders and hillsides can be incorporated into the design as both a recreational element and to satisfy a natural aesthetic. Dual purpose splash pads can serve as open plazas to host community gatherings and events when water jets are turned off.

Incorporating both active and passive recreational amenities is another way to ensure a pocket park provides benefits to all users. Active recreational amenities encourage more intense physical exercise and may include fitness equipment, play structures, basketball hoops, and alternative play features like water play, among other things. Just as it sounds, passive recreational amenities require a lower level of physical intensity and include features like walking paths, garden plots, native habitat for bird watching, and picnic areas. A family with young children might want a traditional play structure for their kids, but this may not provide much benefit to older adults simply seeking time to sit outside. Incorporating a mixture of active and passive amenities, and thinking about how to maximize every feature, every square inch of a site can help ensure that your park provides something for everyone to enjoy.

Incorporating a mixture of active and passive amenities, and thinking about how to maximize every feature, every square inch of a site can help ensure that your park provides something for everyone to enjoy.

Game tables work for eating, resting, and multi-generational play
Nat Turner Park, NJ
Photo: J. Avery Wham Photography

CASE STUDY: Madison Avenue Park and Community Garden

Madison Avenue Park and Community Garden was developed out of a combination of opportunity and need. The project site was an empty lot adjacent to an apartment complex and down the street from the City of Los Angeles Cahuenga Branch Library, multiple schools, and a light rail station. As there was almost no other parkland within a half-mile radius, the site was the perfect location for a new park. When it opened to the public in June of 2019, Madison Avenue Park and Community Garden added an additional half-acre of parkland to the East Hollywood community. Public-private partnerships and a robust community design process ensured the new pocket park would provide a variety of recreational opportunities for a diverse community.

The idea for the new pocket park came to fruition when the Los Angeles Community Garden Council reached out to the Trust for Public Land inquiring about creating a new park that could appeal to a broad range of local residents by including the combined benefits of an urban garden and recreational facility. This partnership, with support from Los Angeles Department of Recreation and Parks and City Council District 13, utilized the skills and expertise of each organization to create the unique pocket park.

The half-acre pocket park was developed through a community-driven design process. Local residents were involved in the creation of the park design and selection of park elements through a series of design charrettes. This helped to ensure the final product would be a park that adequately satisfied the neighborhood's wants and needs.

The design packs as many elements as possible into a small space. Divided into two distinct zones, a playground and community garden, the park attracts a variety of community members with different interests and lifestyles. The park successfully defines areas for designated use while making each accessible and useable to anyone interested. Adults can exercise on the fitness equipment, watch their children play on the play structure, or participate in gardening activities. Likewise, younger children have multiple options for play including the play structure, swings, sand pit, and basketball tree with hoops at different heights. Providing such a diversity of park elements provides recreational opportunities to the greatest number of park users and widest range of ages and physical abilities.

Diverse play options in a compact space
Madison Avenue Park and Community Garden, CA
Photo: EPTDesign

Major Design Elements of a Pocket Park

There are many ways to break down the major design elements of a pocket park. For the purposes of this Toolkit, we have separated them into the following categories: Open Space, Playgrounds, Community Gardens, and Urban Plazas. Each element presents an opportunity to support park activities and recreation for various groups. As discussed above, the limitation of space in a pocket park means that some combination of these design elements should be used to make the site attractive to many different users.

Open Space is one of the more versatile design elements. This concept is just as it sounds – it provides a space in the park, such as a grassy field, that can support active and passive recreation activities. Open space can be programmed as the community sees fit – age groups from older adults down to young children determine how they want to use the space whether it be for physical exercise, leisure, socializing, creative play, or wildlife viewing. Furthermore, walking paths, planters, bioswales, shade structures, and other design elements can be easily incorporated.

Open space
Rudolph Park, CA
Photo: Annie Bang

Depending on the demographics of a community, playgrounds can be an important feature in a pocket park. They provide opportunities for families to get outside and give kids a place to focus their energy and get some exercise. A playground can take different forms in order to fit into any pocket park size. Traditional playgrounds might include a jungle gym and swing set whereas creative or non-traditional playgrounds use alternative play features such as a water spout or small rock wall. Non-traditional playgrounds are less prescriptive and can inspire creative free play. Studies show that engagement in free play directly correlates to an increased capacity for problem solving and overcoming obstacles later in life. In addition, non-traditional playgrounds can be accessible to multiple age groups and physical abilities. For example, toddler swings are designed for the youngest of park goers and their guardians but provide little to no benefit for older children. What is more, without play structures accommodating to older children, they might be tempted to "misuse" and then damage the structure by climbing up its supporting bars or chains. Misuse of equipment can result in frustration among other park users and reduced satisfaction in the park. When used together traditional and non-traditional playgrounds help bridge the gap between age groups and maximize recreational opportunities within the pocket park.

Playground
Paul Habans Charter School, LA
Photo: Bryan Tarnowski

Including a community garden in a pocket park provides a unique benefit to local residents. Particularly in dense neighborhoods lacking yard space to grow food, community gardens provide residents with healthy food sources and a low intensity recreational outlet. From 2008 to 2013, the number of American households who participated in community gardens rose from 36 to 42 million and American's who grow their own food tend to be from various age groups. The appeal of community gardens spans broadly across age groups and can nurture a relationship with the natural world.

Urban Plazas or green courtyards can be incorporated into a pocket park as a space for passive recreation. As a standalone design concept, the urban plaza park has been popular in large, highly developed urban areas and promoted as a place of refuge from the hustle and bustle of city life. Primarily a rest area with tables and seating, an urban plaza may also include some aspects of the natural landscape such as trees, vines, or water features. Urban plaza elements can be integrated as designated seating or picnic areas separate from where children play. As with other passive design concepts, plazas and courtyards promote access to parks for those who are less physically active but still want to spend time outdoors in a safe and communal space.

Community gardening
Towerside Park, MN
Photo: Andy Richter

Planting Design

The planting design of a pocket park should create a sustainable and beautiful landscape that attracts the attention of park goers throughout the year and provides environmental benefits, like urban cooling and habitat for birds and insects. Select plant material that can stand up to a bit of trampling, requires little maintenance, and is appropriate for the specific weather conditions at the site. While the topic of planting design may warrant its own Toolkit, four concepts are most useful to consider when thinking about the role of the landscape in a pocket park: site appropriateness, ecosystem services, and site visibility and safety.

Plants should be selected based on site appropriateness. The soil chemistry and properties, sunlight and water exposure, and variable changes from season to season will all factor into the plants ability to thrive once placed on-site. Native plant species that are already adapted to regional climate conditions are generally always a good choice. Native plants require less maintenance and inputs like water and fertilizer than ornamental species and can even provide an educational benefit to park users when coupled with interpretive signage explaining their significance.

While native species should be considered first, there is also opportunity to bring non-native but regionally adaptive plants into a landscape. Fruit trees, for example, give shade cover and offer a source of healthy food to park goers. Whenever using non-native plants, it is critical to consult the local invasive species databases to prevent further expansion of these plants. Invasive species should not be used.

Durability is another factor of a plant's site appropriateness. Shrubs and ground covers that can bounce back after trampling, such as native grasses or monocots, should be used especially in areas adjacent to playgrounds or other high traffic areas. Examine trees and remove any low branching or vulnerable limbs that may be snapped or broken in the first year after planting. Creating a landscape that can withstand high use and minimal maintenance requires careful plant selection by the design team.

Plant selection should also consider ecosystem services. Ecosystem services refers to a site's ability to contribute to the environmental health of an area. Pocket parks should be designed to passively manage stormwater, filter and mitigate pollution, and offer valuable wildlife habitat.

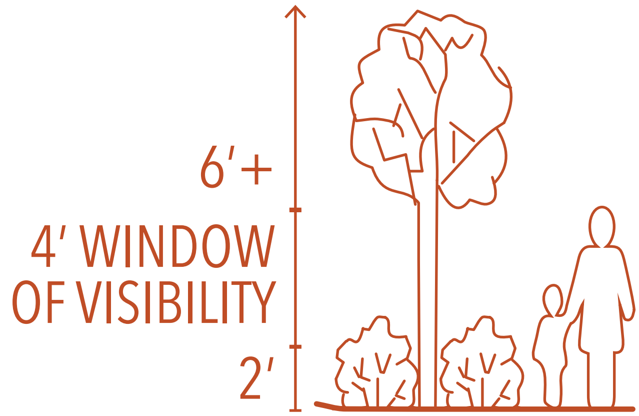
Stormwater management devices like bioswales or raingardens can mitigate flooding in and around the neighborhood. Bioswales and raingardens guide excess stormwater runoff into low points within the park. Often lined with riparian or native plant species, the bioswales and raingardens allow stormwater runoff to slowly infiltrate and recharge groundwater supplies. Stormwater management devices like these can be particularly useful in areas with prolonged periods of drought followed by extreme rain events.

Simple, educational plant label
La Cima Playground, NY
Photo: Nomi Ellenson

Planting design in pocket parks can also mitigate pollution. Grass channels and vegetated areas are effective at filtering sediment, nutrients, and other non-point source pollutants from stormwater runoff. Additionally, plants and trees can be used to filter pollution from the air. For example, conifer species, with their needle like leaf structure, are effective at capturing large particulate matter whereas tree species with broader leaf structures are better equipped to capture small particulate matter.

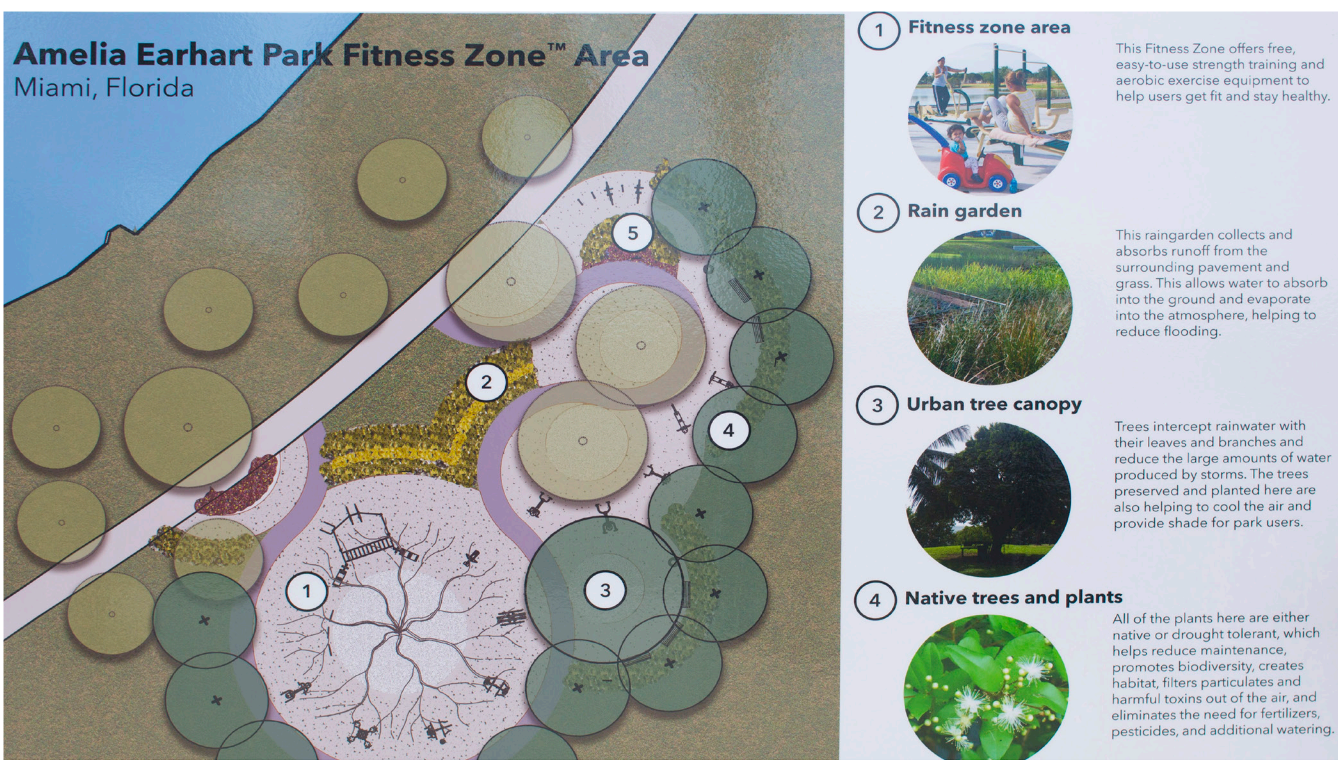
Pocket parks represent an opportunity to establish much needed wildlife habitat in urban areas. Studies have shown a strong correlation between native vegetation cover and total wildlife density in urban areas. Plants can be selected to attract desirable wildlife into the park. For example, milkweed is the singular plant that monarch butterflies require as habitat for their larva. These plants require slightly more maintenance than other ornamental flowers, but the value as critical pollinator habitat might justify implementation in some scenarios.

Planting design should consider and promote site visibility and safety of users within the pocket park. Plant material, both trees and shrubs, should not obstruct a clear line of sight throughout the park or create clusters of vegetation where people can hide



PLANTING DESIGN FOR SITE VISIBILITY AND SAFETY

and engage in undesirable activities. A good rule of thumb is to ensure the plant material selected provides a 2'-6' window of visibility. Shrubs should not grow taller than approximately two feet tall and trees should not have large limbs that grow lower than six feet from the ground. This creates a four-foot window of visibility throughout the park. Being able to see throughout a park gives users peace of mind while visiting and allows parents to participate in an activity on one side of the park while their child plays on the other.



The design for new fitness equipment added native habitat planting and a rain garden for stormwater treatment
Amelia Earheart Park, FL
Photo: Alana Wesley White

Site Utilities

Site utilities are necessary for a pocket park to function. Where other aspects of park design guide how a space is used by the public, utilities are required to ensure the park is safe and comfortable to use. While not an exhaustive list, common utilities to consider in pocket park design are electricity, water, and waste disposal, and sanitary sewer.

Electricity is needed to provide lighting which allows access to the park after dark and can prevent unwanted activities from occurring under the cover of darkness. Some parks even feature electrical outlets for public use.

Access to water is necessary for maintenance staff and the general public. Irrigation for planted areas and trees and hose bibs for cleaning and maintenance purposes are critical for keeping a park looking beautiful. While drinking fountains, dog bowls, and splash pads or other water play features can all be important and even necessary features of the design.

Planning for waste disposal facilities is an important part of the design process. Waste receptacles are needed to provide park visitors with an easy way to dispose of their trash and keep the park free of litter. Simply having an adequate number of trash cans at a park can drastically reduce the number of maintenance staff hours required to keep the space clean. Design consideration must also be given to how maintenance staff will access the waste receptacles in order to empty them and if there needs to be a centralized trash enclosure for dumpsters.

Even dogs need water
Kellogg Park, CA
Photo: Annie Bang

Water used for play
Jose Manuel Collazo Park, PA
Photo: Jenna Stamm

Another utility that may be required is a connection to the sanitary sewer system. This is commonly needed for restrooms but also at times for excess water produced by drinking fountains and splash pads.

As with all park design considerations, utility requirements will largely depend on the size of the park and financial capacity of the agency responsible for operations and management. The Luskin School of Public Affairs published a SMART Parks toolkit that can be referenced as a guide to inform utility design decisions. The toolkit features discussion and analysis of park technologies, including irrigation and greywater recycling systems, energy efficient lighting, and dynamic input monitoring tools that can be integrated into a park to maximize cost effective and environmentally responsive use of utilities.

Considerations for Long-term Success

Although the design of a park is fixed once development is complete, seasonal environmental factors and daily use of the facilities will continuously alter conditions on the site. The longevity of a pocket park relies in part on ease of site maintenance. A newly developed, beautifully designed park can fall into disrepair quickly if upkeep of the grounds, features, and amenities is inadequate.

From a design perspective, the long-term success of a park is determined by the selection of long-lasting, durable materials and features that are easily maintained. The selection of site materials requires consideration of the relationship between the upfront development costs and the future costs to maintain the facility. There is typically a tradeoff between present and future expenses where a higher initial investment leads to lower maintenance costs. For example, a weather-based irrigation controller that automatically adjusts the watering schedule based on local weather conditions may have a high installation cost but will result in reduced water waste and lower utility expenses in the long term. There will have to be some negotiating and compromise in order to determine the best option for all involved parties (see Chapter 3: Financial Planning).

Material selection impacts various tiers of stakeholders in the park building process. Considering project investment costs, usability, utility, community satisfaction, and operation and maintenance costs together can promote a park's long-term success. A more in-depth discussion of effective operations and management practices can be found in Chapter 5: Operations & Maintenance.

Although the design of a park is fixed once development is complete, seasonal environmental factors and daily use of the facilities will continuously alter conditions on the site.

KEY TAKEAWAYS

- **Design with the intention of serving the entire community. Organize your site to make the most out of every square inch.**
- **Pocket parks not only offer social and cultural benefits to a community, they provide environmental benefits like urban cooling through shade trees and stormwater management via bioswales or permeable surfaces.**
- **Make design choices now that consider how the park will last over time. Parks that age well ultimately provide the most benefit to the community.**

CHAPTER 5: Operations & Maintenance

A park is truly only as good as the maintenance it receives. If the community perceives a park as unsafe because the trashcans are overflowing or park amenities need repair, they lose incentive to visit the site. The goal of park operations and maintenance (O&M) is to keep the park safe, functional, and open to the public so that the local community can continue to enjoy the park as originally intended.

Before a park opens, a management structure must be determined and an O&M strategy put in place. Whether the site owner is a municipal parks department or local land trust, the management responsibilities of a park largely remain the same: day-to-day operations include trash pick-up and opening and closing of the park gates, while more infrastructural maintenance includes keeping the water and electricity running, trimming overgrown vegetation, and repairing damage or vandalized park amenities.

While park O&M activities share commonalities across all parks, each park will have specific management requirements of its own.

While park O&M activities share commonalities across all parks, each park will have specific management requirements of its own. The park's size, location, features, vegetation type, amount of use by the public and overall wear-and-tear will determine the maintenance required to keep the space in working order. Further, the managing entity will have their own operational capacity determining the frequency of site visits. Funding for operations and maintenance is one of the biggest challenges for parks of any size. Because public grants are rarely designated for maintenance expenses and general bonds are typically reserved for capital investment projects (new parks), funding site operations in the long term is limited to a few sources like the local parks department's general fund, special district generated revenue allocated through an inter-agency partnership, and private sector funds like those contributed through a Business Improvement District. Park operators must work within their own financial and staffing abilities to keep a pocket park in good condition. This means implementing an O&M plan that recognizes each site's specific demands and utilizes available resources efficiently.

FACTORS AFFECTING O&M REQUIRMENTS

There are a variety of resources available to support the development of an O&M plan. The Association of Higher Education Facilities Officers, National Recreation and Park and Professional Grounds Management Society prepared a comprehensive resource entitled Operational Guidelines for Grounds Management. In addition, Best Management Practices Used at Urban Parks in National and International Locations prepared by the National Park Service is a free resource with clear best management practices for operations and maintenance. Finally, the New York City Department of Parks and Recreation's Parks Inspection Program can be useful in determining a protocol for establishing a system to conduct ongoing park evaluations.

CREATING AN O&M STRATEGY

Parks are not static. Once built, they continue to require maintenance and care to truly serve the community. An effective O&M strategy should reflect the ever-changing social and environmental conditions in the community and may include the following five steps:

1 Evaluate park design

Take a look at the elements in the park such as landscaping, play equipment, trash cans, lawn area, benches, paving, etc. Make a list of all these elements; include details like size and/or quantity.

2 Define O&M standards

Once a list of park elements is created, define the maintenance goal for each. For example, the goal for trashcans may be that they do not overflow or have a noticeable smell while the goal for a lawn may be that it is trimmed and green with no yellow spots or visible dirt patches. Assign tasks required to meet the maintenance goal for each element. For example, trashcans will need to be emptied and sprayed out with water or cleaner. Turf will need to be watered, mowed, fertilized, and reseeded. These are your O&M standards, the maintenance tasks required for each element to ensure the park remains safe, functional, and a beloved resource for the community.

3 Create an O&M schedule

Review the list of O&M standards and make estimates about how often tasks will need to be performed to meet the maintenance goals. Organize these tasks by frequency: daily, weekly, monthly, or annually depending on the task. Park gates need to be opened and closed daily while tree health should be checked annually. The frequency of maintenance tasks for each element may change seasonally. Watering requirements for lawns generally increase during hotter, summer months. Project out a year of tasks based on the estimated frequency and anticipated seasonal needs.

4 Regularly examine site conditions

Because weather and community use will change the condition of the park throughout the year, creating and maintaining a system to regularly examine and track site conditions will help determine how the O&M budget and requirements fluctuate seasonally. Monitoring these changes does not necessarily require high tech tools or software. Data collected through observation by staff and park users can help inform O&M standards and schedules. This is especially true for a newly developed park. Documenting staff time, materials required, and frequency of each maintenance activity throughout the first year (and biannually/annually thereafter) will help estimate future O&M requirements and allow for better management of resources.

5 Evaluate O&M standards & schedule

After the first six months, or at the end of every year thereafter, take time to evaluate how the existing O&M standards support the park. At this point, a thorough review of the park's overall condition will help fine tune and update the O&M standards based on any maintenance deficiencies noted at the park. The O&M standards themselves should also be evaluated for any inefficiencies. It may not be worth replanting an area where plants are consistently trampled–adding mulch and allowing the area to become a pathway might be more sensible and a better use of resources. These yearly evaluations are a great opportunity to further engage the community. The community can be involved in the park evaluation or an annual clean up or mulching day. Information gathered from surveys collected during step two can be summarized into a handout or infographic and presented back to community. Public review of this data supports compromise and community collaboration over shared park goals.

Management Structures

There are generally two available options for managing a newly developed park: public management by one or more government agencies or private management conducted by a local nonprofit organization usually in coordination with a public entity. Each park management structure has their pros and cons.

Parks are most commonly under public management structures allowing new parks to be incorporated into an already established parks and recreation framework. City or County level park agencies provide an experienced workforce and dedicated park budget necessary for O&M activities in the new park.

Publicly managed parks tend to use a mixture of funding sources to meet park operating demands with the most significant funding generated from tax revenue. On average, park agencies derive 60% of their operating expenditures from tax generated sources. This provides a reliable source for O&M activities, and accounts for half of the total responsibilities assigned to park agency staff, year after year.

Public agencies employ seasoned park and recreation professionals trained in O&M activities. From landscape maintenance to administrative duties like staff scheduling, park agencies have the internal infrastructure to support the maintenance of a new park. This effectively reduces any lag time between the creation of a new park and the integration of routine operational and maintenance activities.

In addition to having maintenance equipment and supplies on hand, a skilled workforce, and potential funding, parks departments also have the opportunity to form inter-agency partnerships with other public service providers to form a more holistic management strategy. Public partnerships, between a parks and recreation department and a water district, health department, or transportation agency, for example, can be used to strengthen the efficiency of O&M. Parks often touch on the interests of multiple public agencies and these partnerships create the potential for data sharing, additional funding support, and the availability of specialized staff who can help provide analysis on best management practices ultimately offering a better experience for park goers. Additional support available as a result of the partnership might include site electricity and water use monitoring to better manage resources or access to local grants or special district revenue generation. Another potential avenue is around park programming.

School community playgrounds are an example of successful public-public partnerships
PS 62, NY
Photo: Jennifer Causey

CASE STUDY: Shape Up NYC

The Shape Up NYC program in New York City is a good example of the benefits of inter-agency public partnerships. For a number of years Shape Up NYC has provided free fitness classes specifically targeted at neighborhoods with higher rates of obesity and other chronic illnesses. Initially started as a partnership between the New York City Department of Parks and Recreation (NYC Parks) and the New York City Department of Health and Mental Hygiene (NYC DOHMH) in 2003, the program has since expanded its inter-agency partnerships to increase the number of classes and reach even more residents.

NYC Parks has been working with the New York City Public Library, New York City Department of Education, New York City Department for the Aging, and the New York City Housing Authority, among others, to use parks and recreation centers for programming. These partnerships have facilitated the addition of over 100 new classes, 80% of which are in neighborhoods with disproportionately high rates of chronic diseases. Additionally, NYC Parks is training community volunteers to lead these classes for their neighbors, thereby supporting social capital throughout the City.

In addition to providing a range of fitness classes with varying degrees of intensity, like Zumba, kickboxing, dance, and yoga, Shape Up NYC conducts annual surveys to track the progress and satisfaction of the participants and note improvements in health. The surveys are also used to collect data on how to improve the program. The partnership provides the additional support needed for NYC Parks to enhance their existing park programming and for various City departments to positively affect the health of their communities.

Shape Up NYC
Photo: Daniel Avila/NYC Parks

In some localities, the addition of a new park in a neighborhood can present challenges from an O&M perspective. Budget cuts and reallocated discretionary spending can leave a parks department's resources spread thin. In these cases, the decentralized location of a pocket park can be particularly challenging for a parks department since their location will have a disproportionate impact on O&M costs. Increased travel time and staffing may be required to reach the new park. Fortunately, private management via a public-private partnership is an alternative management strategy that can support park operations.

Public-private partnerships offer an alternative to traditional park management strategies where public and private sector entities share the financial liability, maintenance responsibility, and community benefit. Organized community stakeholders such as land trusts, 'friends of' groups, or other local nonprofit conservancy groups can adopt, own, or lease newly developed park spaces and provide basic O&M activities. The idea behind this management structure is that a private group solely focuses on the management of a single park, thereby providing a higher level of attention to the site.

These partnerships have become an increasingly important method used to support parks all over the country. The Central Park Conservancy in New York is cited as one of the most successful examples of private sector group supplementing public park O&M activities. Since the group's establishment in 1980, they have grown to provide almost 85% of the park's $46 million annual budget through fundraising and other revenue generating processes. The group even conducts meaningful O&M activities usually restricted to public agency park staff. Pocket parks will require a much more modest commitment from local private partners, but the private management structure is a replicable model for any size park.

Parks under private management have unique opportunities to fund their ongoing O&M that is not readily available for publicly managed parks. For example, business improvement districts (BID) can be a significant funding source for a privately-operated park. In this structure, nearby private sector businesses voluntarily and routinely contribute money to a park's O&M budget with the goal of supporting the health and resiliency of a neighborhood. Under a privately managed park, larger, more technical maintenance activities beyond the capacity of the private group can be outsourced to a third-party contractor or to the city's maintenance staff.

KEY TAKEAWAYS

- Planning for O&M begins in the design phase.
- O&M standards should be tailored to each individual park, not a general O&M plan for a larger park system.
- Evaluate the site after the first six months and then yearly thereafter to determine how existing O&M standards are working, and then adapt accordingly.
- Use O&M as an opportunity to engage local volunteers or paid stewards and incorporate community or non-profit led maintenance structures where possible.

CHAPTER 6: Common Challenges

Park building is important and rewarding work but does not come without challenges. The process is complex, involves multiple stakeholders, organizations, and agencies, and it requires a significant amount of time and resources. The previous chapters have provided tips on how to pull together all the pieces needed to build a park, the community, funding, design and ways to structure operations and maintenance. But, there are still common challenges that inevitably arise. Below are some examples of those challenges and suggested solutions.

Challenge: Measuring the Success of a Completed Park Project

The best way to measure the impact of a new park is to talk to the community before the park is built, and then after. Include questions that provide insight into how the park has affected the community. Questions may be; 'How safe do you feel in your neighborhood?,' 'How often do you currently visit parks/greenspaces?,' 'How often do you exercise?' Quantitative data is hard to collect but establishing a mechanism, such as a survey, to collect qualitative data from park users can be equally insightful. The answers will likely change from before to after the project is built. Measuring the impact of your park project not only can help make a case of allocating resources for maintenance, but demonstrates success for future funding and park development endeavors.

Solutions:

- ➔ Create a survey format the community will respond to and collect surveys online and in-person before building the park and then again, six months after it is open. Surveys should be in all appropriate languages for the local community.
- ➔ Take survey results into consideration for future park programming and staffing. Adapt operations accordingly to create a better user experience.

Challenge: Community Distrust

Communities and neighborhoods that have been historically marginalized, underrepresented, and left out of the decision making process can be skeptical about outside organizations or agencies attempting a park development project. This lack of trust can limit community member participation in the park planning process.

Solutions:

- ➔ Design outreach specifically around the community and provide project information in a variety of languages relevant to each specific neighborhood.
- ➔ Actively seek out community members who are historically less likely to voice their opinions. Door knocking and phone banking are great ways to engage residents who don't come out to larger meetings.
- ➔ Partner with local community members, leaders, and groups that can act as a bridge between the community and the park building group. Bring locals on as team members, pay them for their work, and support them to guide the conversation and inform the initial direction of the outreach.
- ➔ Plan engagement and outreach activities that help to build trust with the community. Create an atmosphere where the community feels safe to openly share ideas, such as small table discussions and comment cards for those who are not comfortable speaking in front of a large group.

Challenge: Staff and Community Member Turnover

From the early planning phase until it is open to the public, many individuals and organizations will work on a park project. Turnover of staff and community members can slow down development progress and jeopardize the ongoing activities of stewardship groups.

Solutions:

- Ensuring multiple staff are up-to-speed on high-level project details provides a safety net to keep the project moving if staff is lost and can help bring new staff up to speed quickly.
- Maintain a well-informed community base. Staying in touch with the community throughout the course of a project will create long-term relationships that are critical. If one community member leaves the neighborhood, you will not lose your entire base.

Challenge: Diminishing Park Use

A decrease in park use can be caused by a variety of reasons. Lack of maintenance, the presence of illicit activities, changing neighborhood demographics, and neighbors not being aware of the park due to its small size are all factors that can result in less people using the park. A park, particularly a pocket park, should always feel safe, clean, and comfortable for its users. One of the best ways to accomplish this is to activate the park.

Solutions:

- Implement community events, workshops, volunteer days, and other events at the park to up attendance and make it an active space.
- Increase the presence of park staff and encourage the local police department to increase their presence in the area as well.
- Designate community stewards to keep an eye on the park and report any problems to the police and maintenance staff. Ensure the community knows who the best person to contact is and how to contact them.

Challenge: Support for Green Infrastructure

All park projects are green infrastructure projects. Although some pocket parks may include more robust green infrastructure technologies than others, anytime a site transforms from a vacant lot to a place with trees and greenery the surrounding environment cools and stormwater is more effectively managed. That said, some green infrastructure technologies can place a strain on the project budget. Therefore, it is imperative to communicate the green infrastructure benefits and how they support community priorities.

Solutions:

- Make the benefits of green infrastructure more accessible to neighbors and park supporters, limit technical jargon and use graphics and relatable examples.
- Outline a local issue affecting neighborhood that the green infrastructure will help to fix (i.e. using permeable surfaces in the park can reduce the risk of nearby flood damage).
- Partner with the municipal environmental department, such as the sanitation department, or the public works department to identify funding incentives for green infrastructure.

Challenge: Fundraising as a Grassroots Organization

While grassroots organizations can be very successful at fundraising for a park project, they may not have a structure in place for accepting donations without taxes or other fees being assessed. Grassroots organizations should look for partners with access to tax advantaged fundraising accounts to ensure all money raised supports the park development work.

Solutions:

- Partner with an IRS approved 501(c)(3) organization that can manage a tax-exempt fundraising account for the project.
- Identify and reach out to qualifying local nonprofits and charitable organizations that specialize in greenspace and other neighborhood development projects.

Creative placemaking
EM Stanton School, PA
Photo: Jenna Stamm

Challenge: Lack of funding for Creative Placemaking Activities

Arts and cultural design elements may at first appear to be superfluous for a tight budgeted project, but it is in fact a core facet to ensuring capital investments are meaningful to and successful in the community. While paying an artist to paint a mural or design sculptures may not always be feasible, much of creative placemaking is about the process of convening residents and stakeholders in a culturally-specific and engaging ways, which is not only affordable, but priceless.

Solutions:

- Start early. Identify local artists in the beginning of community outreach who can be advocates as much as designers in the park planning. You can turn on your artist brain, too.
- Thoughtfully incorporating arts and culture in feedback and community engagement strategies lends itself to rich and often more accurate local needs
- Do not be afraid to scale back ambitions in the short term so that creative placemaking can happen immediately. Start small and make it easy, keeping supplies to a minimum. Prioritize the social aspects over the materials.
- Examples of easy creative placemaking events include: story gathering activities where community members gather to tell stories about what their neighborhood and community means to them or create a pop-up playground on a vacant site using simple loose parts like cardboard boxes and tubes, tape, string and fabric.
- Hosting routine events can be especially successful because consistency gives community members a chance to engage.

KEY TAKEAWAYS

Every project has its challenges, work with your community to resolve them and keep people engaged.

CHAPTER 7: Pocket Park Toolkit Checklist

ENGAGEMENT, ORGANIZING, & PARTNER BUILDING

- ❑ **Reach out to local residents and existing stakeholder groups/local organizations**
  - ○ Form an outreach team
  - ○ Draft mission statement and express intent
- ❑ **Find a suitable location for a pocket park**
  - ○ Asset mapping
  - ○ Community surveys
  - ○ Pop-up events
- ❑ **Begin collaborating with the community**
  - ○ Host routine community meetings
  - ○ Organize community driven charrettes
  - ○ Education/Leadership Building – support community champions to take on leadership roles
- ❑ **All outreach materials are translated into the appropriate language(s) for your community**

FINANCIAL PLANNING

- ❑ **Locate funding**
  - ○ Preliminary research should include scanning the internet for local, state, and federal grant programs
  - ○ Reach out to an organization with experience in fundraising activities
- ❑ **Budgeting**
  - ○ Outline both development and operation costs
  - ○ Work with the community to ensure transparency and clarity on budget decisions

DESIGNING A PARK FOR ALL

- ❑ **Consider what existing site elements can be preserved**
  - ○ Historical or cultural
  - ○ Existing landforms, trees, etc.
- ❑ **Does the design accurately reflect the community's input and needs? Examples include:**
  - ○ Will sensitive populations such as seniors, mothers, or children feel welcome using the space?
  - ○ Is community culture reflected in the design?
- ❑ **Ensure environmental benefits are inherent to the design. Examples include:**
  - ○ Stormwater management through bioswales, cisterns, infiltration areas
  - ○ Urban cooling through tree planting and shade structures
- ❑ **Select durable amenities that will stand up to heavy use, extreme weather conditions, and limited maintenance**

OPERATIONS & MAINTENANCE

- ❑ **Identify who will manage the park space**
  - ○ Define whether a public or private entity will be taking ownership of the park
- ❑ **Create an O&M Strategy**
- ❑ **Engage local residents to participate in park stewardship**
- ❑ **Evaluate the park after it has been opened to ensure it is meeting the initial intent**

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