

# Green Stormwater Infrastructure and Low Impact Development Standard Details and Site Guidance



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## Acknowledgements

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*“Action on behalf of life transforms. Because the relationship between self and the world is reciprocal, it is not a question of first getting enlightened or saved and then acting. As we work to heal the earth, the earth heals us.”*

*~ Robin Wall Kimmerer*

*“The true foundation of all culture is the knowledge and understanding of water.”*

*~ Viktor Schauberger*

*“When life places stones in your path, be the water. A persistent drop of water will wear away even the hardest stone.”*

*~ Autumn Morning Star*

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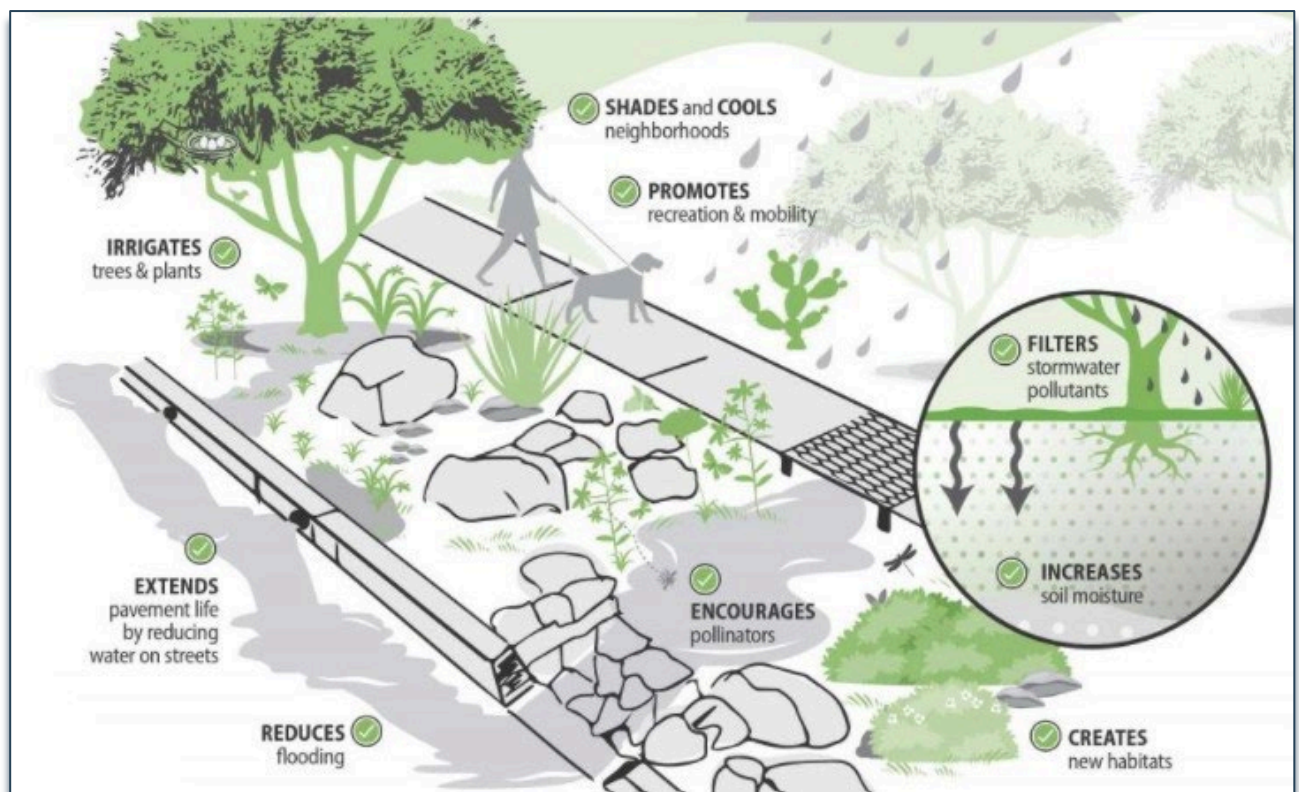
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## Abbreviations

ADEQ	Arizona Department of Environmental Quality
COT	City of Tucson
DSSDR	Design Standards for Stormwater Detention and Retention
DTM	Department of Transportation and Mobility
GI	Green Infrastructure
GSI	Green Stormwater Infrastructure
LID	Low Impact Development
NOAA	National Oceanic and Atmospheric Administration
PAG	Pima Association of Government
PCRFC	Pima County Regional Flood Control District





## 1. Introduction

This guide provides planners, designers, and contractors with clear documentation of the current best practices for planning, design, and construction of green stormwater infrastructure (GSI) and low impact development (LID) for the City of Tucson and Pima County. It aims to complement and work well with other relevant resources. GSI specifications and standard construction details enable local communities to adopt decentralized stormwater management consistently and successfully in new and existing development while ensuring improved, long-term performance with cost-effective maintenance. To create a more livable desert community based in sustainable and resilient water resource management, all new public projects modifying landscapes will want to use best practices for GSI to reduce long-term costs for the region.

The provided guidance and details aim to maximize the benefits of GSI. Some of these benefits include enhanced shade, urban cooling, wildlife habitat, traffic calming, quality of life, mitigation of nuisance flooding, as well as improved stormwater quality, critical in our region in which the Santa Cruz River is considered impaired for E. coli. With a highly effective network of deep plant roots and robust biologically diverse soils, GSI filters and treats E. coli and other surface transportation contaminants affordably. Because untreated stormwater does not combine with sanitary sewers going to wastewater treatment plants and instead is conveyed directly to our rivers, improving stormwater quality is critically important. Increased GI implementation will directly benefit the impaired Cañada del Oro stretch of the Santa Cruz River by allowing stormwater to infiltrate into soil and to flow through water quality-improving structures before it can carry E. coli and other pollutants into the river.



**GSI Benefits**

- ◆ Enhanced shade
- ◆ Urban cooling
- ◆ Wildlife habitat
- ◆ Traffic calming
- ◆ Quality of life
- ◆ Mitigation of nuisance flooding
- ◆ Improved stormwater quality

The included set of GSI construction details and relevant specifications emerged from input from the technical stakeholder group outlined in the acknowledgement section as well as others from Pima County Regional Flood Control District (PCRFC), City of Tucson (COT) Storm to Shade Program, Pima Association of Governments (PAG), and COT Department of Transportation and Mobility (DTM). These details apply to all public projects, large or small. The details communicate the essential functions of GSI to maximize their benefits and allow designers and engineers to modify their approaches based on site context (e.g., utilities, soils, water volumes, slope, aesthetics, sight visibility, and safety).

A matter of inches means the difference between a GSI project's success or failure. Following the guidance in this document will help ensure success for all GSI projects!

## 2. Helpful Resources

The City of Tucson and Pima County have developed numerous resources to support the development of GSI. While not comprehensive, the list of relevant tools, guidance documents, and supporting materials below will help facilitate planning, design, and implementation of GSI in arid climates.

### [Design Standards for Stormwater Detention and Retention \(DSSDR\):](#)

**What:** The manual supersedes the Pima County/City of Tucson *Stormwater Detention/Retention Manual*. Substantive changes include replacing the threshold retention requirement with a first flush retention requirement (retaining the first 0.5 inches of rainfall), introducing the use of integrated site planning and other LID practices, describing acceptable methodology for hydrologic and hydraulic analysis, providing more specific design standards, and describing inspection and maintenance responsibilities for detention and retention facilities.

**Where:** [webcms.pima.gov/cms/One.aspx?pageId=65527](http://webcms.pima.gov/cms/One.aspx?pageId=65527)

**Notes:** See Chapters 2 and 3 to calculate the GSI retention and detention benefits for new development.

### [Pima Association of Governments Resilience Planning Tool:](#)

**What:** This free, publicly accessible, regionwide resource supports the integration of a variety of planning disciplines benefitting from green infrastructure or can work together to address heat impacts. Example data layers from partnerships include extreme heat vulnerable populations, cooling centers, park score, impervious cover, and stormwater flowlines.

**Where:** [gismaps.pagnet.org/pag-gimap/](http://gismaps.pagnet.org/pag-gimap/)

**Notes:** Use the stormwater flowlines to estimate contributing watershed areas.

### [Sonoran Desert GI Resource Library: Transportation Playbook:](#)

**What:** This guide is for transportation professionals and community planners working in arid environments. It provides examples and illustrations on planning, funding, and project design approaches that may be relevant to the Pima County area.

**Where:** [watershedmg.org/sites/default/files/documents/sonoran-desert-green-infrastructure-resource-library.pdf](http://watershedmg.org/sites/default/files/documents/sonoran-desert-green-infrastructure-resource-library.pdf)

### [Pima County City of Tucson GI/LID Guidance Manual:](#)

**What:** This manual provides non-regulatory technical guidance for implementing neighborhood-scale water harvesting and GI/LID practices throughout Pima County to improve surface water quality. It intends to be technical guidance for professionals on using neighborhood-scale LID practices within Pima County, the City of Tucson, and similar areas in the desert Southwest.

**Where:** [webcms.pima.gov/UserFiles/Servers/Server\\_6/File/Government/Environmental%20Quality/Water/Stormwater/2015\\_LID-GI-Manual.pdf](http://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Environmental%20Quality/Water/Stormwater/2015_LID-GI-Manual.pdf)

#### [City of Tucson Compete Streets Design Guide:](#)

**What:** This document provides design guidance to City staff and project teams for the design and construction of transportation projects consistent with the City's 2020 Complete Streets Policy.

**Where:** [www.tucsonaz.gov/files/transportation/files/Tucson Street Design Guide Approved.pdf](http://www.tucsonaz.gov/files/transportation/files/Tucson_Street_Design_Guide_Approved.pdf)

#### [GI/LID AutoCASE Cost Benefit Case Study:](#)

**What:** This report used AutoCASE™ to assess the costs and benefits of GI/LID for stormwater management in Pima County, looking at the value to the community, government, and the environment. The analysis indicates that GSI investments pay far more than financial dividends to a wide range of stakeholders. The report also demonstrates that the approach in AutoCASE™ can use regionally specific values to inexpensively calculate costs and benefits as the design changes.

**Where:** [webcms.pima.gov/UserFiles/Servers/Server\\_6/File/Government/Flood%20Control/Floodplain%20Management/Low%20Impact%20Development/autocase-testing-final-report-20140711.pdf](http://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Flood%20Control/Floodplain%20Management/Low%20Impact%20Development/autocase-testing-final-report-20140711.pdf)

#### [GI/LID Project Case Study Library:](#)

**What:** The PCRFC is compiling local case studies that reflect design solutions embracing the evolving mandate for sustainable design: GI/LID practices. Groups, professionals, or individuals can use the case studies to learn more about the value of GI/LID development, what worked, lessons learned, etc.

**Where:** [webcms.pima.gov/UserFiles/Servers/Server\\_6/File/Government/Flood\\_Control/Floodplain\\_Management/Low Impact Development/lid-case-studies.pdf](http://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Flood_Control/Floodplain_Management/Low_Impact_Development/lid-case-studies.pdf)

#### [Greater Regional Phoenix GI/LID Handbook:](#)

**What:** This handbook includes guidance and technical standard details and specifications for select LID techniques to help local design, planning, and development professionals more easily integrate GI and LID in new and/or retrofit projects throughout Maricopa County.

**Where:** [sustainability-innovation.asu.edu/sustainable-cities/resources/lid-handbook/](http://sustainability-innovation.asu.edu/sustainable-cities/resources/lid-handbook/)

#### [COT Rainwater Harvesting Guidance:](#)

**What:** This guide provides residents an overview of rainwater harvesting systems and tools to implement these practices at an individual home.

**Where:** [www.tucsonaz.gov/files/water/docs/Rainwater Harvesting Guide.pdf](http://www.tucsonaz.gov/files/water/docs/Rainwater_Harvesting_Guide.pdf)

#### [Cost Benefit Analysis of Local Sustainable Food Production: A Las Milpitas Case Study:](#)

**What:** This report summarizes the range of benefits from local food production including the financial benefits of improving soil health while also using rainwater for food production.

**Where:** [webcms.pima.gov/UserFiles/Servers/Server\\_6/File/Government/Sustainability\\_and\\_Conservation/Sustainability\\_and\\_Conservation\\_newsroom/Sustainable Action Plan/AutocaseReport\\_FullColor\\_Final.pdf](http://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Sustainability_and_Conservation/Sustainability_and_Conservation_newsroom/Sustainable_Action_Plan/AutocaseReport_FullColor_Final.pdf)

#### [Quivira Coalition Erosion Control Field Guide:](#)

**What:** Gives an overview of rock structure best practices and tools such as the One Rock Dam, Zuni bowl, and Media Luna (sheet flow spreader).

**Where:** [quiviracoalition.org/product/erosion-control-field-guide/](http://quiviracoalition.org/product/erosion-control-field-guide/)

### 3. Overview of Details and Specifications

Table 3.1 below summarizes GSI details, including typical applications, costs, and implementation challenges. See chapter 5 of the *Pima County City of Tucson LID/GI Guidance Manual* for more specific design guidance. The descriptions and figures on the following pages explore site and other considerations for these practices in more detail. Detail numbers were selected to fit into PAG Standard Details Series 300 – Drainage and Series 400 – Landscape.

**Table 3.1. GSI Details.**

Detail	GSI Practice	Description	Application	Cost	Challenges
315	Stormwater Harvesting Basin	Captures stormwater flowing from hardscape surfaces (streets, driveways, sidewalks, and roofs) to remove pollutants and beneficially irrigate native vegetation	Best used in areas with at least 5 feet of unconstrained width	Low, typically \$1/sf without irrigation system, \$2/sf with irrigation	Planning and design critical for appropriate vegetation location, maintenance, soil health, and sediment management
316	Domed Overflow Structure	Directs ponded stormwater beyond design capacity to additional GSI or storm drain system	All practices with retention: 315, 319, 328, 329, 330	Domed: \$3,500 Type 4: \$4,800	Ensuring floatable debris will not clog drain grate design
317	Curb Opening	Allows stormwater to enter landscapes below street grade safely through a 30" max opening	Where a curb is obstructing water into desired landscape	Type 1: \$5,000 TYP Type 2: \$500 TYP	Changes in street surface elevation that prevents low flows from entering opening
318	Flush Curb Inlet	Allows stormwater to enter landscapes below street grade safely	Parking lots, in-street features	N/A	Stabilizing landscape surface for design sheet flow conditions
319	Bioretention Basin	High infiltration soil mix design combining coarse sand, compost (fungal dominant is ideal such as mature leaf & worm compost), and topsoil and/or native soil with low clay content	Areas with high design flows and low landscape area, best used in areas with at least 5 feet of unconstrained width	Expected \$2/sf without irrigation system, \$3/sf with irrigation	Survival of vegetation in dry conditions by minimizing sand composition, ensuring sufficient biological activity with high quality compost, native soils with high clay content not suitable
320	Infiltration Trench	Provides underground storage, infiltration (if soils allow or are amended), and conveyance (with optional underdrain)	All practices with retention: 315, 319, 328, 329, 330	\$185/cy	Preventing sediment and other fines from clogging pore spaces
321	Sediment Trap	Dissipates energy of stormwater entering feature to capture sediment	All practices with retention: 315, 319, 328, 329, 330	\$1/sf	Sizing for sediment load and maintenance schedule

Detail	GSI Practice	Description	Application	Cost	Challenges
322	Vegetated Swale	Conveys stormwater and protects soil with the use of vegetation and 323	Where conveyance is needed, and design velocities do not exceed 3 fps	\$1/sf	Protecting soil while vegetation establishing
323	Check Dam	Rock or concrete structure that slows run-off and prevent erosion	Slopes, eroding water courses, vegetated swale	Rock: \$185/cy Concrete: \$11/sf	Ensuring erosion does not occur at bottom of spillway
324	One Rock Dam	Rock structure the height of one rock to stabilize soil, slow water, and facilitate vegetation establishment	Slopes, eroding water courses, vegetated swale	\$180/cy	Top of downstream row of rock must be flush with grade
325	Zuni Bowl	Rock structure used to dissipate energy and manage sediment often to arrest a head cut	Slopes, eroding water courses, vegetated swale	Varies depending on material availability and dimensions	Anchoring rocks to build strength opposing the force of run-off flows
326	Sheet Flow Spreader	Rock structure shaped to spread concentrated run-off to reduce erosive forces by creating sheet flow conditions	Slopes, eroding water courses, vegetated swale	\$180/cy	Top of downstream row of rock must be flush with grade
327	Cistern	Plastic or metal container for storage of rainwater from hardscapes, most often roofs	Sites where supplemental irrigation is needed to establish and maintain vegetation	\$1-3/gal of capacity depending on cistern size and material	Creating a balanced water budget to effectively utilize stored rainwater in cistern
328	Traffic Circle Planting	Utilizes practices from 315 for landscape areas for traffic circles	Street intersections where utility conflicts are minimal and traffic calming needed	Varies	Locating vegetated traffic circles where topography allows for stormwater irrigation while also minimizing maintenance
329	Stormwater Harvesting Basin Chicane	In-street traffic calming feature with practices from 315	Crowned streets in need of traffic calming	\$5-20/sf	Managing sediment to ensure long-term infiltration, invasive plants
330	Stormwater Harvesting Basin Street Width Reduction	In-street traffic calming feature with practices from 315	Crowned streets in need of traffic calming	\$5-20/sf	Managing sediment to ensure long-term infiltration, invasive plants
410	Tree Planting (Container)	Utilizes practices from 315 to maximize health of trees and minimize maintenance and water consumption	Every tree planted, ever	Less than \$1/sf of basin area	Maximizing basin area to provide irrigation benefit if space is highly constrained

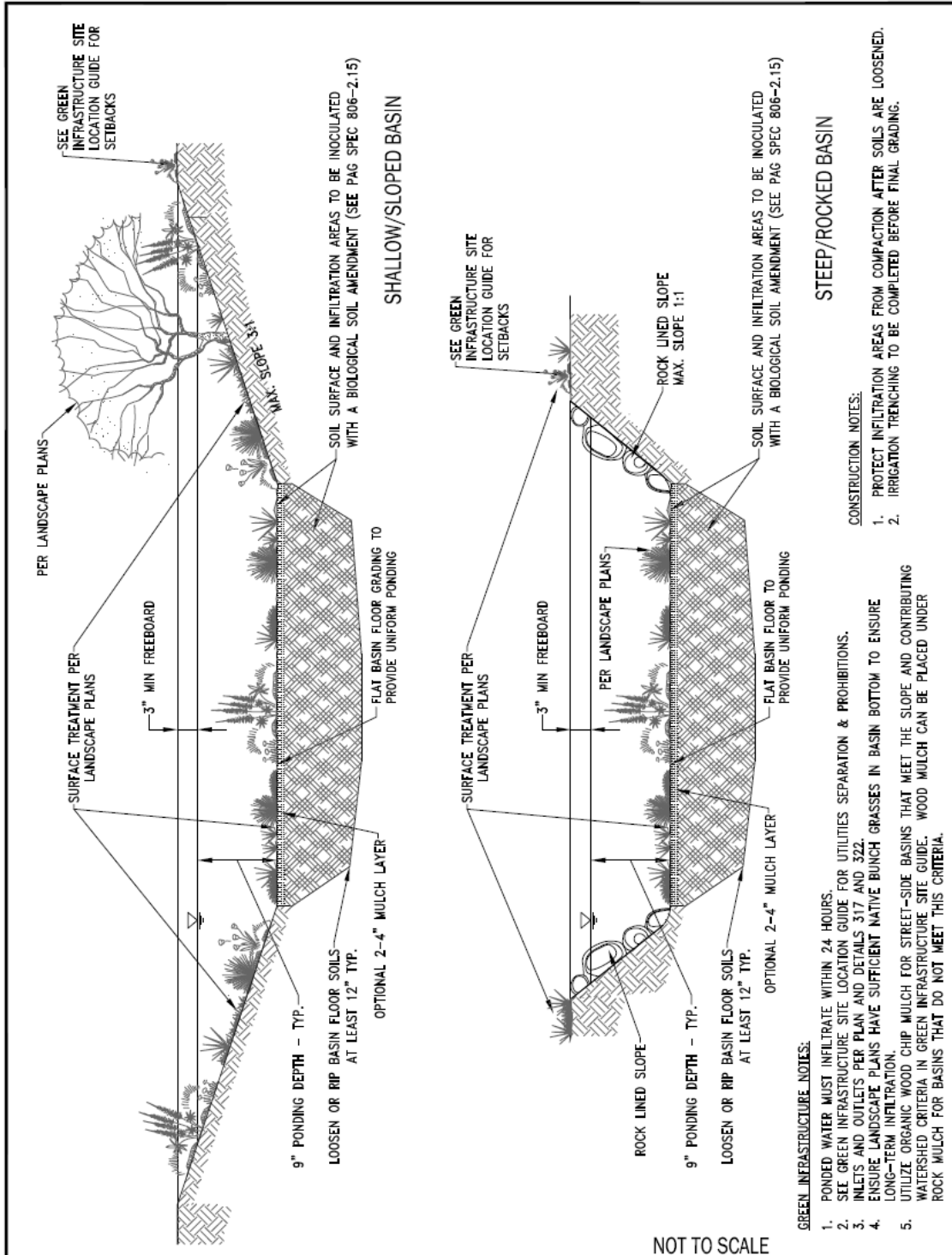
### 3.1. Stormwater Harvesting Basin

A successful stormwater harvesting basin depends on infiltration. Compared to poorly draining basins, those with infiltration rates greater than 1 inch/hr promote healthy vegetation, create drought resilience, and greatly improve water quality benefits. To maximize soil health benefits, use biological soil amendments prepared according to PAG Spec 806-2.15 in ripped soils and organic wood mulch to cover the soil surface with a system of native bunch grasses, shrubs, and trees. Native bunch grass (e.g., sideoats grama, purple three awn, and deer grass) and tree roots along with maintenance practices that incorporate vegetation prunings to restore soil carbon help maintain and improve soil infiltration rates over time. Basins in watersheds with high sediment runoff should include sediment traps to minimize clogging of infiltration areas. See Figure 3.1 – Figure 3.3 for details.

*“Individually, we are one drop.  
Together, we are an ocean.”*  
~Ryunosuke Satoro

Compared to rock, organic mulch increases water quality and soil health benefits. Because large storm events can cause organic wood mulch to float, for basins that may be overtopped, consider placing mulch under riprap at least 4 inches large or larger depending on design storm. See Section 4.1. Planning to understand the potential of mulch floating out of streetside features.

Using the right plant in the right place minimizes maintenance and ensures successful vegetation establishment. Do not place trees near inlets, outlets, and overflows or in basin bottoms. For the health of the tree and enhanced feature performance, where possible, use native trees with healthy tap roots grown in “tall pots” or “tree pots” to ensure a robust root system.



	DETAIL NO.	STANDARD DETAIL	ISSUED:
	315	STORMWATER HARVESTING BASIN	1/21
	SHEET 1 of 3		REVISED: 1/22

Figure 3.1. Stormwater harvesting basin detail.

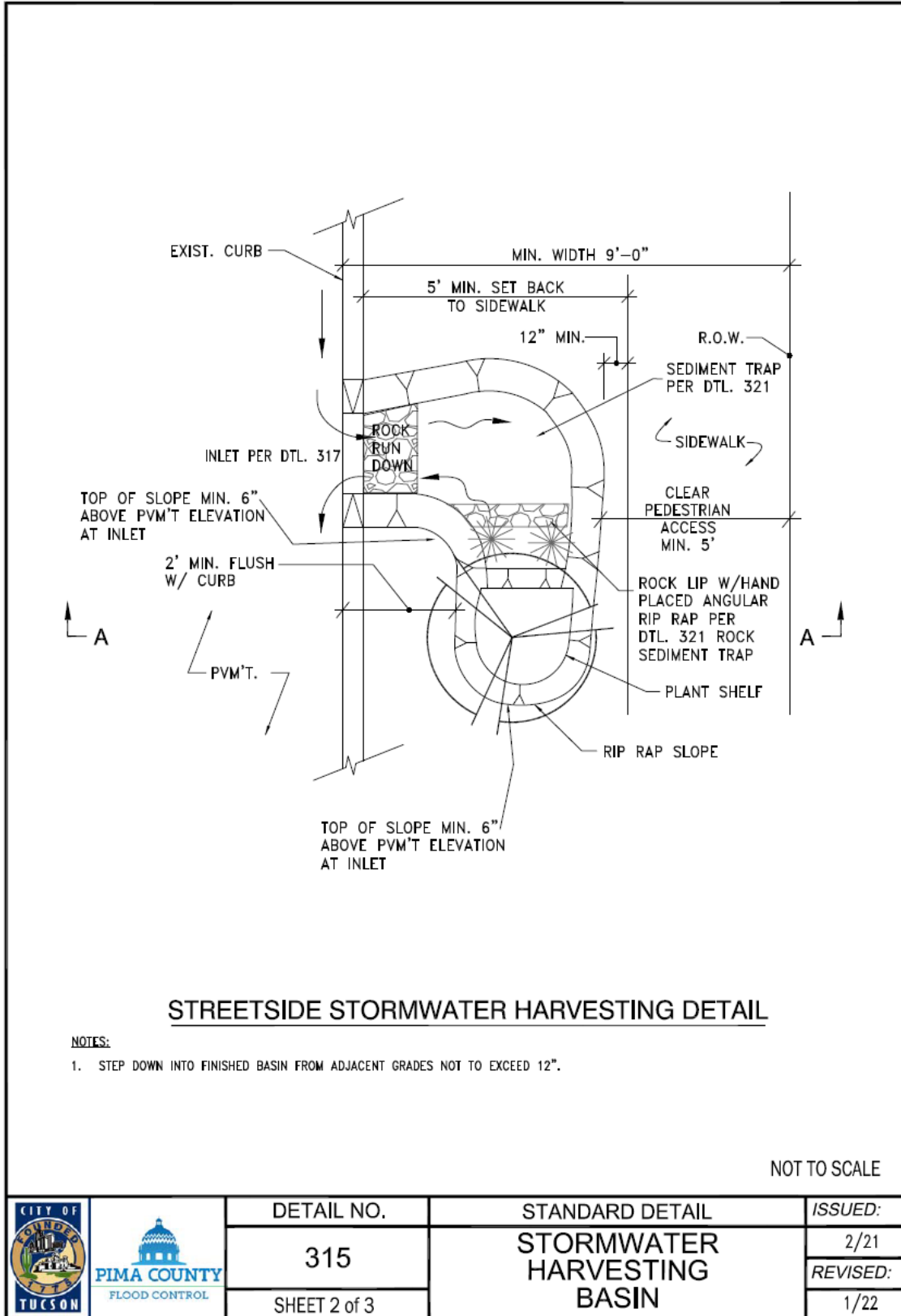
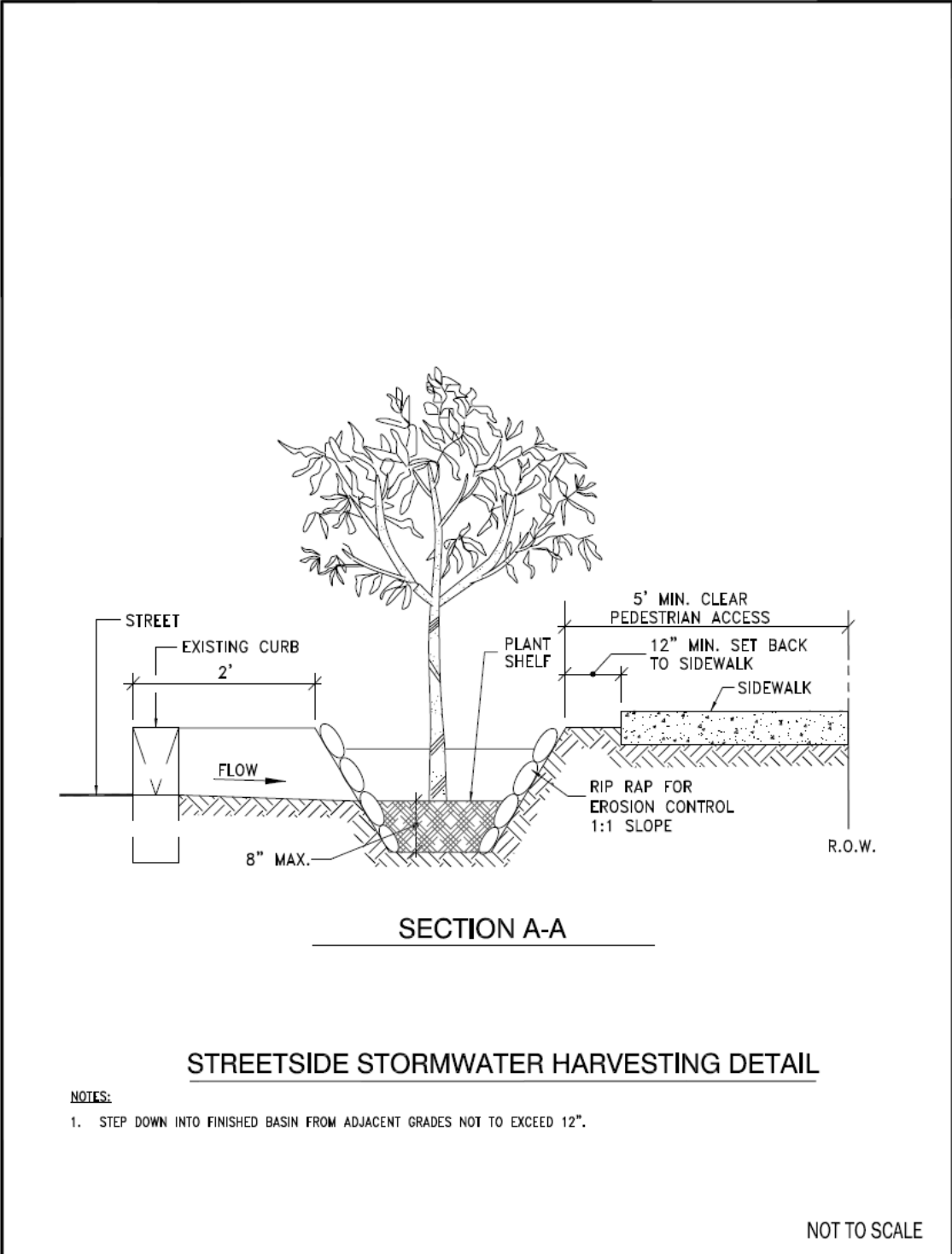


Figure 3.2. Streetside stormwater harvesting basin detail.







 	DETAIL NO.	STANDARD DETAIL	ISSUED:
	315	STORMWATER HARVESTING BASIN	2/21
	SHEET 3 of 3		REVISED: 1/22

Figure 3.3. Streetside stormwater harvesting basin detail.



Figure 3.4. Rocked streetside stormwater harvesting basin. Source: Watershed Management Group

### 3.2. Domed Overflow Structure

Domed overflow structures capture runoff volumes greater than the designed capacity and direct them to a downstream facility, storm drain, basin, swale, or natural wash. Infiltration rates and design goals for retention/detention determine an appropriate dome elevation. Domes help in watershed conditions with a greater likelihood of floatable debris. For watersheds with minimal trash and floatable debris, a PAG Type 4 catch basin may be appropriate. Figure 3.5 shows a dome at ground level without any resulting basin retention. Raising the dome as shown in Figure 3.6 creates more retention/infiltration opportunities while minimizing long-term maintenance. See Figure 3.7 for details.



Figure 3.5. Dome overflow grate flush with the surface. Source: Aaron Volkening



Figure 3.6. Dome overflow with riser. Source: City of Lake Oswego, D Avenue Improvement Project.

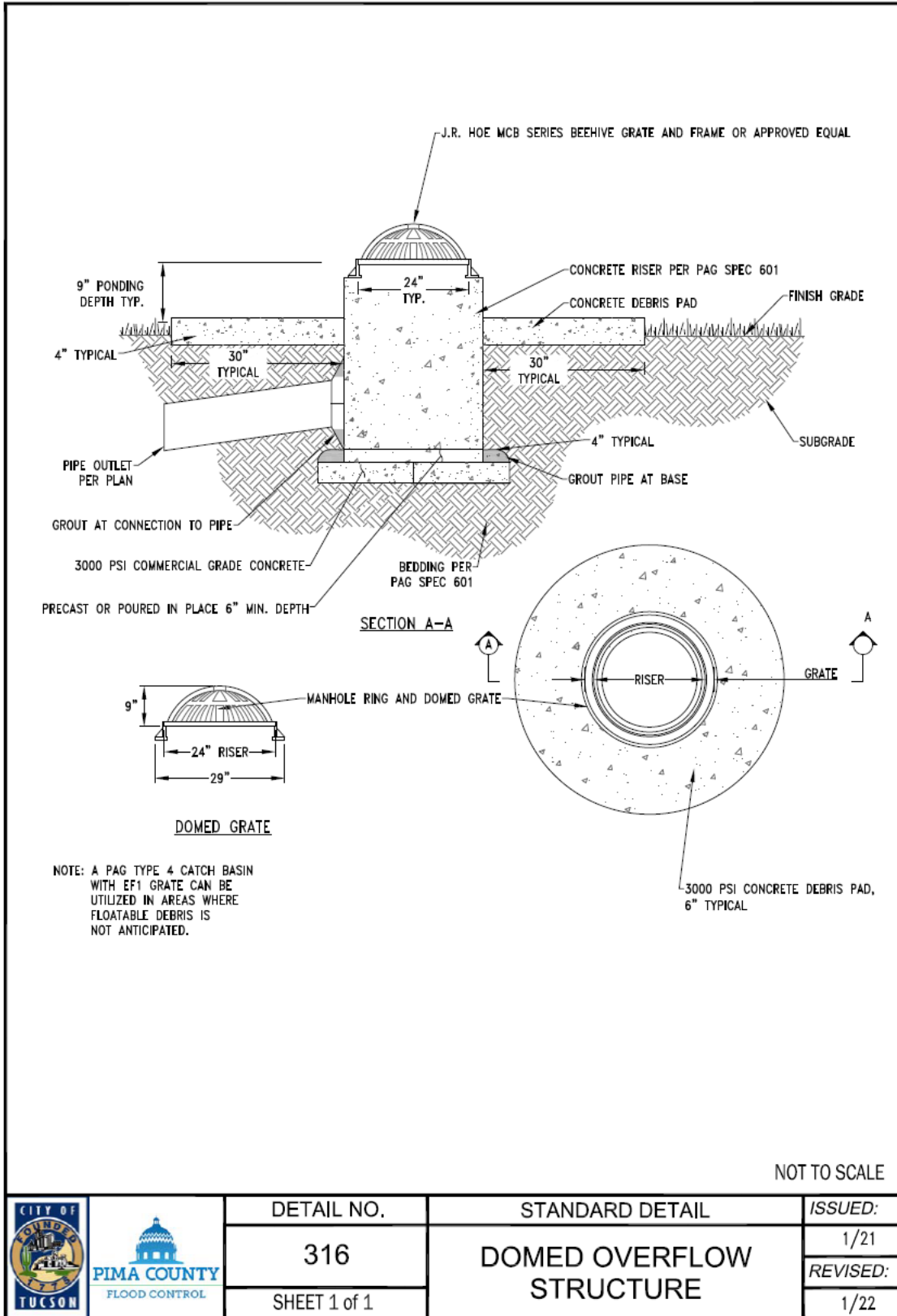


Figure 3.7 Domed overflow structure detail.

### 3.3. Curb Opening

Areas with curbs that restrict the flow of stormwater to landscape areas can benefit from curb cuts (Figure 3.8). They incorporate well into new development (Figure 3.9) and when retrofitting developed communities (Figure 3.10). Ensuring conveyance of water is not restricted at the curb opening entrance and exit is critical. Changing street grades over time and/or with street maintenance and paving imperfections commonly create high or low points that prevent flows from entering the curb opening. The optional concrete apron addresses this challenge. A common oversight during design and/or project implementation is exclusion of a 2-inch drop in grade between curb inlet and basin entry, causing basin materials such as rock or mulch or incoming debris to restrict the flow of water entering the basin. See Figure 3.11 Section A-A. This causes a backup of water and can completely prevent water from entering the basin.

*“There can be no life without soil and no soil without life; they have evolved together.”*  
~Charles E. Kellogg



Figure 3.8. Curb opening Type 1, Grant Rd. Source: Google.



Figure 3.9. Type 2 Curb Opening for a new curb, Scott Ave. Source: Wheat Design Group.



Figure 3.10. Type 2 curb retrofit, Tucson Association of Realtors. Source: Watershed Management Group.

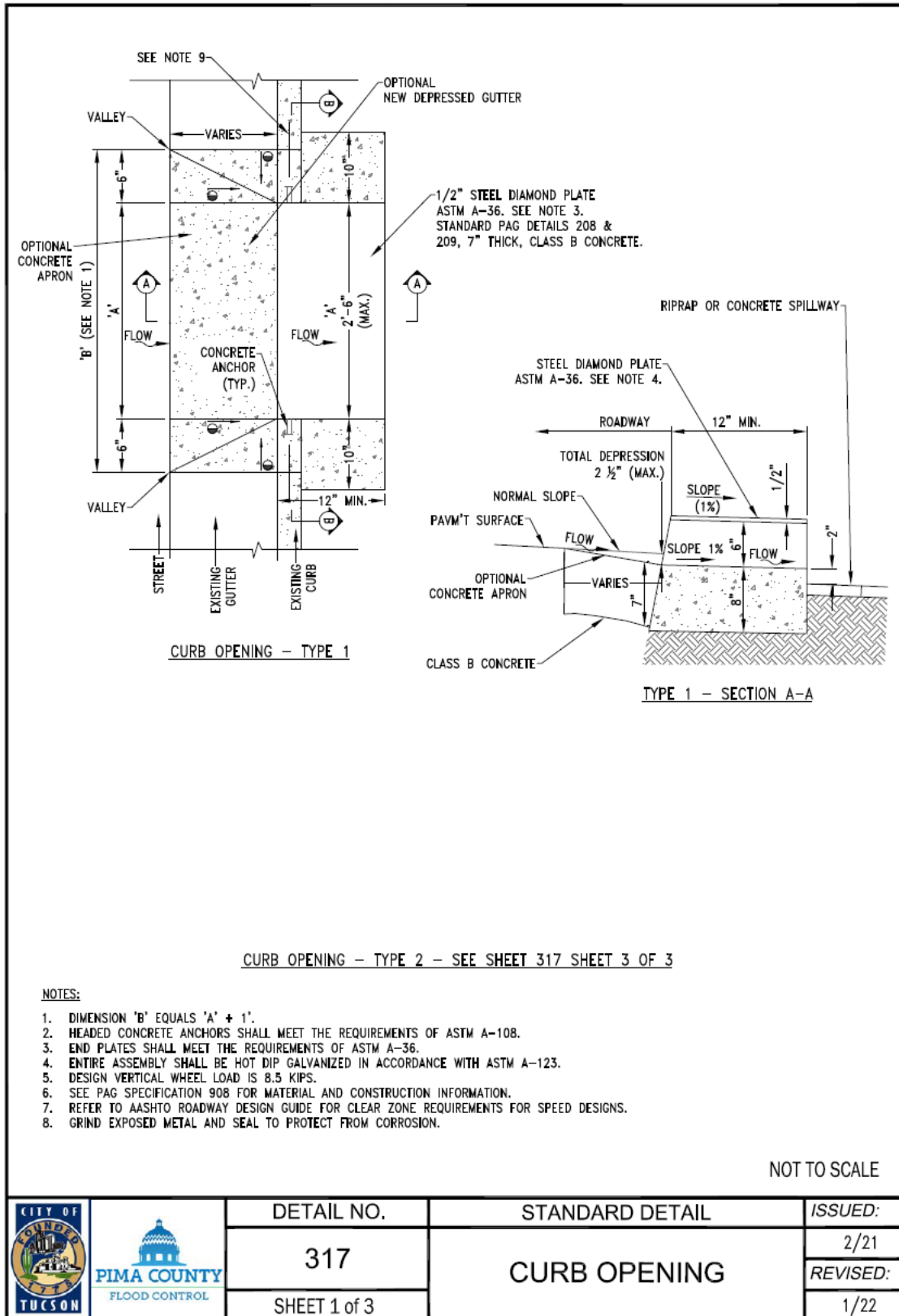


Figure 3.11. Curb opening detail 1 of 3.



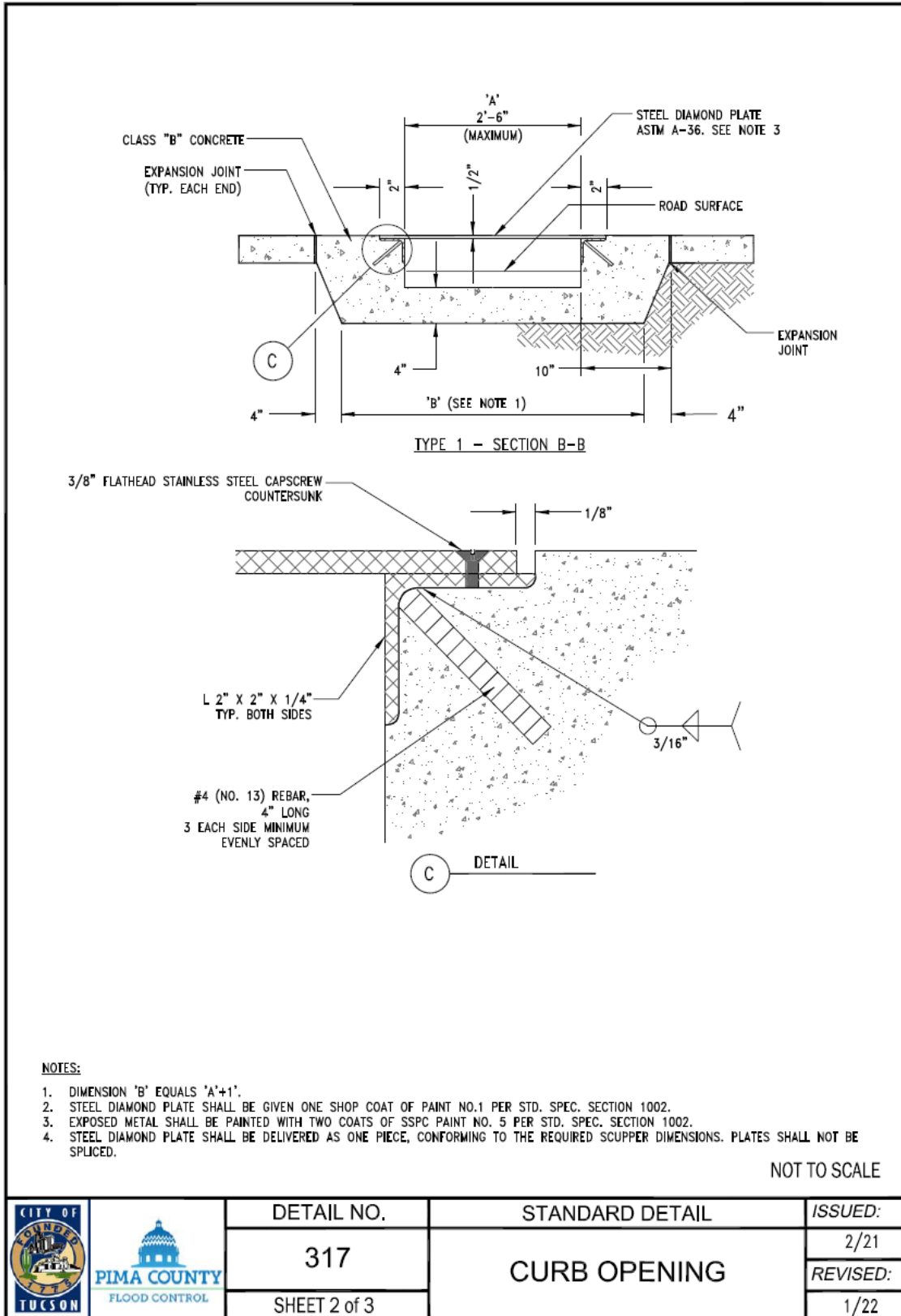


Figure 3.12. Curb opening detail 2 of 3.

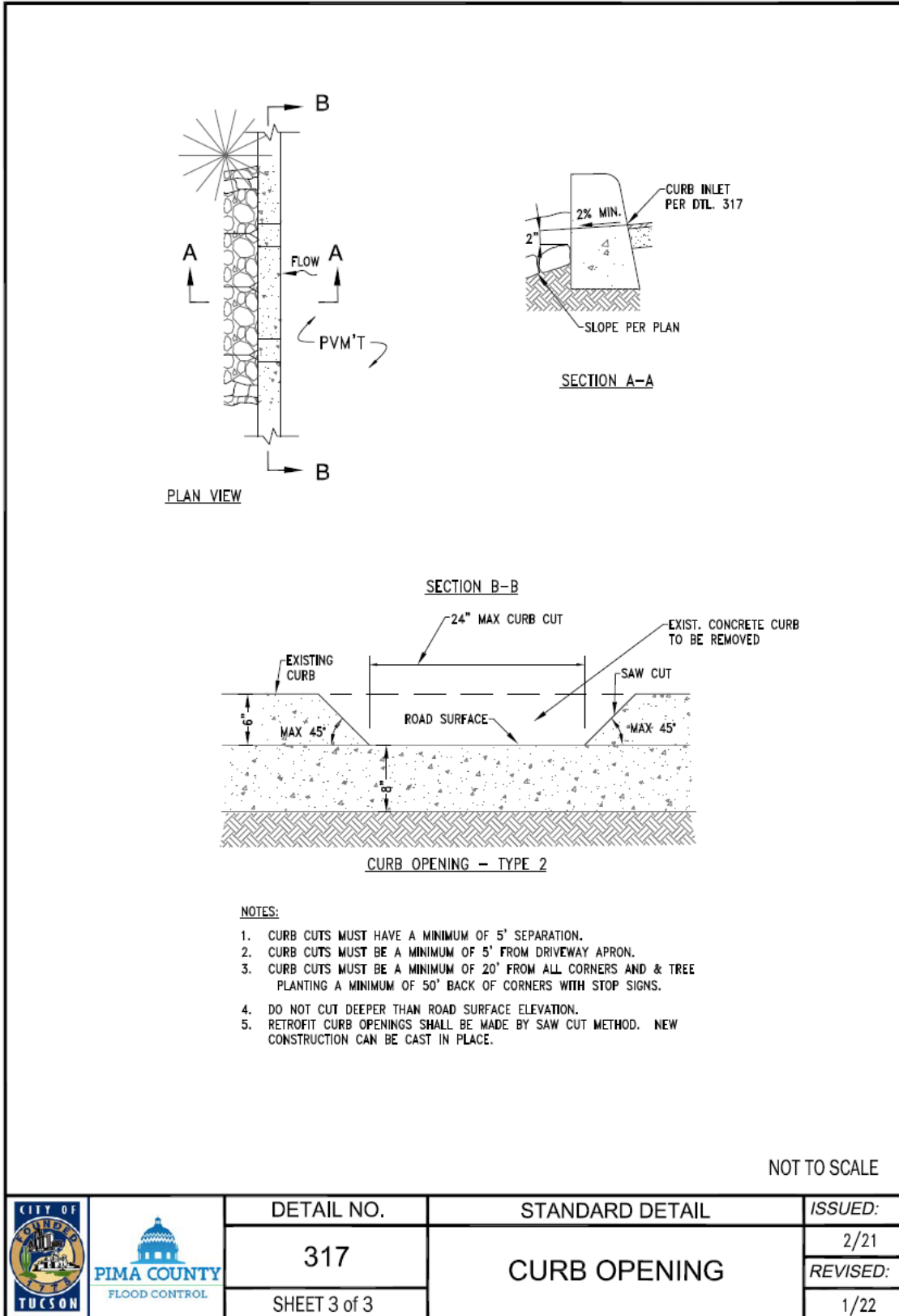


Figure 3.13. Curb opening detail 3 of 3.

### 3.4. Flush Curb Inlet

Distributed stormwater management can benefit greatly from flush curbs (Figure 3.14 & Figure 3.15). Flush curbs can retain sheet flow conditions, and compared to the concentrated flows created by raised curbs and curb openings, can be easier to manage. A common oversight during design and/or project implementation is exclusion of the 2-inch reveal behind the curb, causing basin materials such as rock or mulch or incoming debris to restrict the flow of water entering the basin. This causes a backup of water and can completely prevent water from entering the basin.

*“Floods do not begin as floods. They begin with drops of rain hitting dry earth.”*  
~Allan Savory



Figure 3.14. Flush curb at edge of asphalt parking lot. Source: Watershed Management Group.

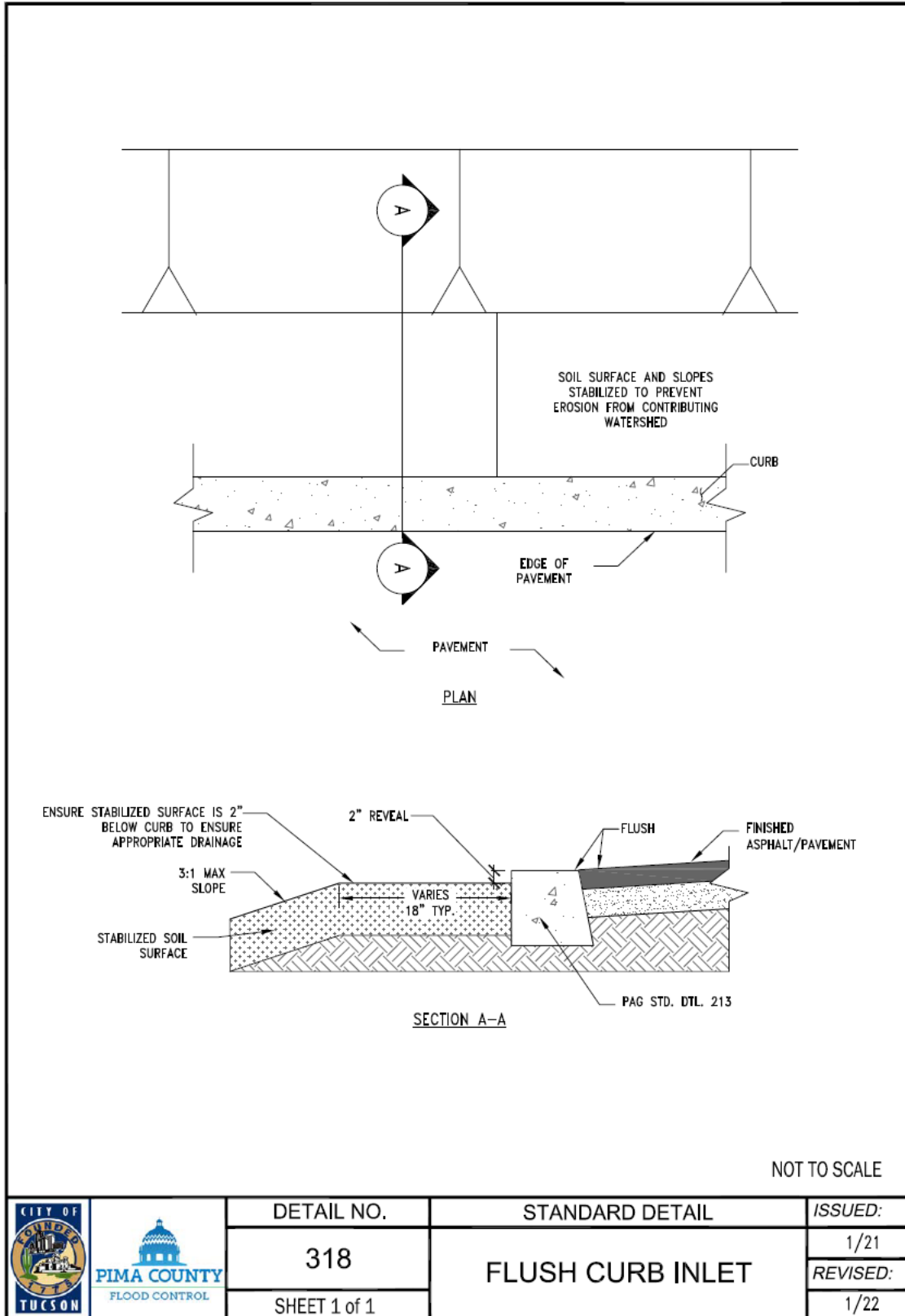


Figure 3.15. Flush curb inlet detail.

### 3.5. Bioretention Basin

Successful bioretention depends on having sufficient soil biological activity to create the beneficial relationships between the soil food web and vegetation. This is especially true for a bioretention basin (Figure 3.16 and Figure 3.17) intended to provide a water quality benefit with high infiltration rates. Without attention to soil health, focusing exclusively on water quality and high infiltration will harm vegetation, especially in the face of drought and/or extreme temperatures.

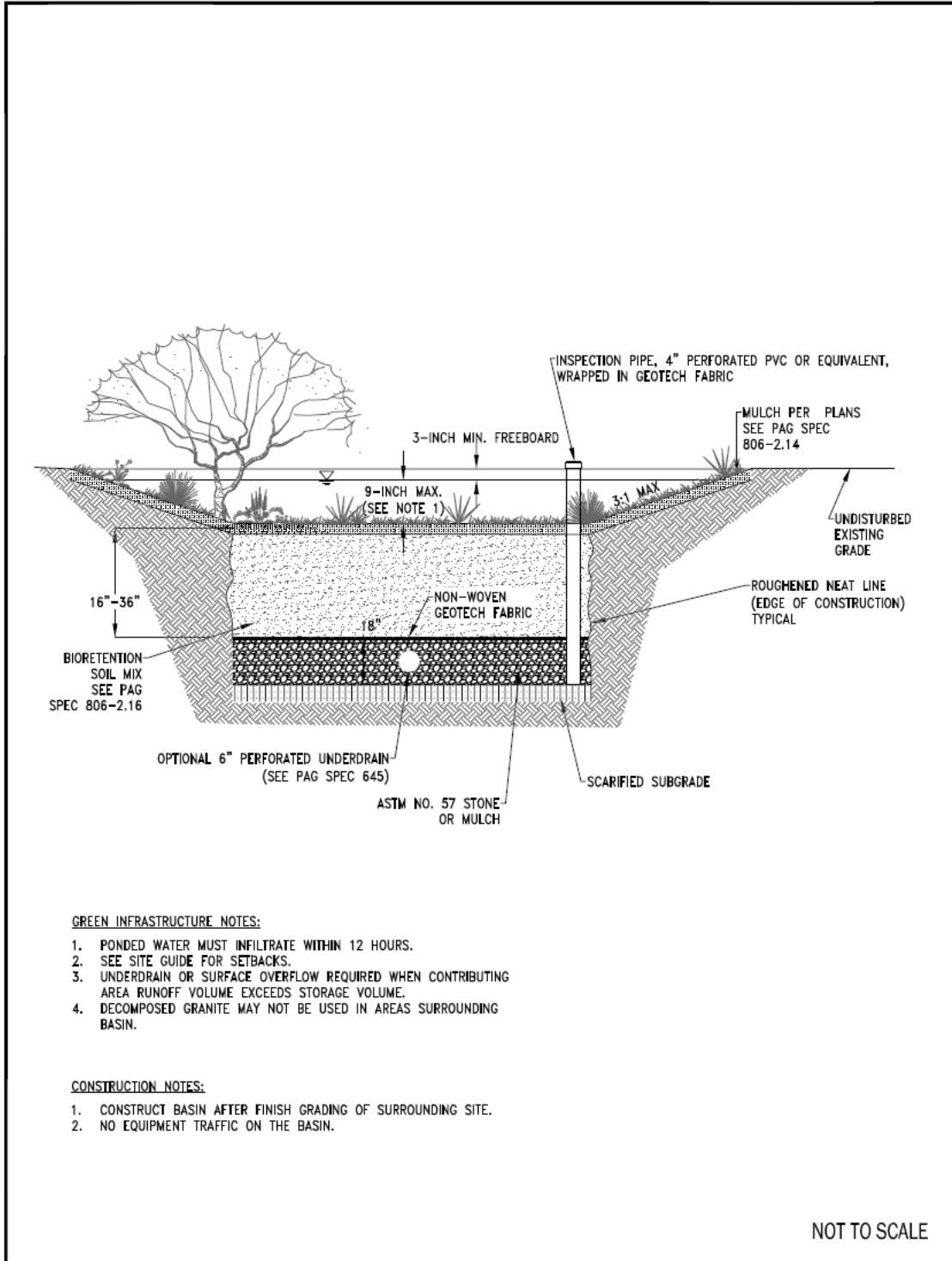
The PAG Specification 806-2.16 **Bioretention Soil Mix** is designed to address this issue. This constructed soil medium consists of coarse sand (not more than 15% ASTM C-33 sand by volume); organic mature compost (15-25% leaf, worm, or equivalent) mixed in a drum mixer; and excavated and/or topsoil (70%) per PAG Specification 804.

*“Ultimately, the only wealth that can sustain any community, economy or nation is derived from the photosynthetic process—green plants growing on regenerating soil”*

~Allan Savory



Figure 3.16. Shallow residential bioretention basin. Source: EcoSense Sustainable Landscapes.



	DETAIL NO.	STANDARD DETAIL	ISSUED:
	319	BIORETENTION BASIN	1/21
	SHEET 1 of 1		REVISED: 1/22

Figure 3.17. Bioretention basin detail

### 3.6. Infiltration Trench

Infiltration trenches (Figure 3.18 and Figure 3.19) apply to a variety of contexts, whether used on their own or in combination with such elements as stormwater harvesting basins (Section 3.1), in-street features, and vegetated swales (Section 3.8). Infiltration trenches should only be used in watersheds with sediment-free runoff and/or where practices like sediment traps (Section 3.7), check dams (Section 3.9), One Rock Dams (Section 3.10), Zuni bowls (Section 3.11), or sheet flow spreaders (Section 3.12) provide sediment management benefits upstream of infiltration trenches. Ensure regular inspection and removal of surface sediment build up.



Figure 3.18. Infiltration trench. Source: Wheat Design Group.

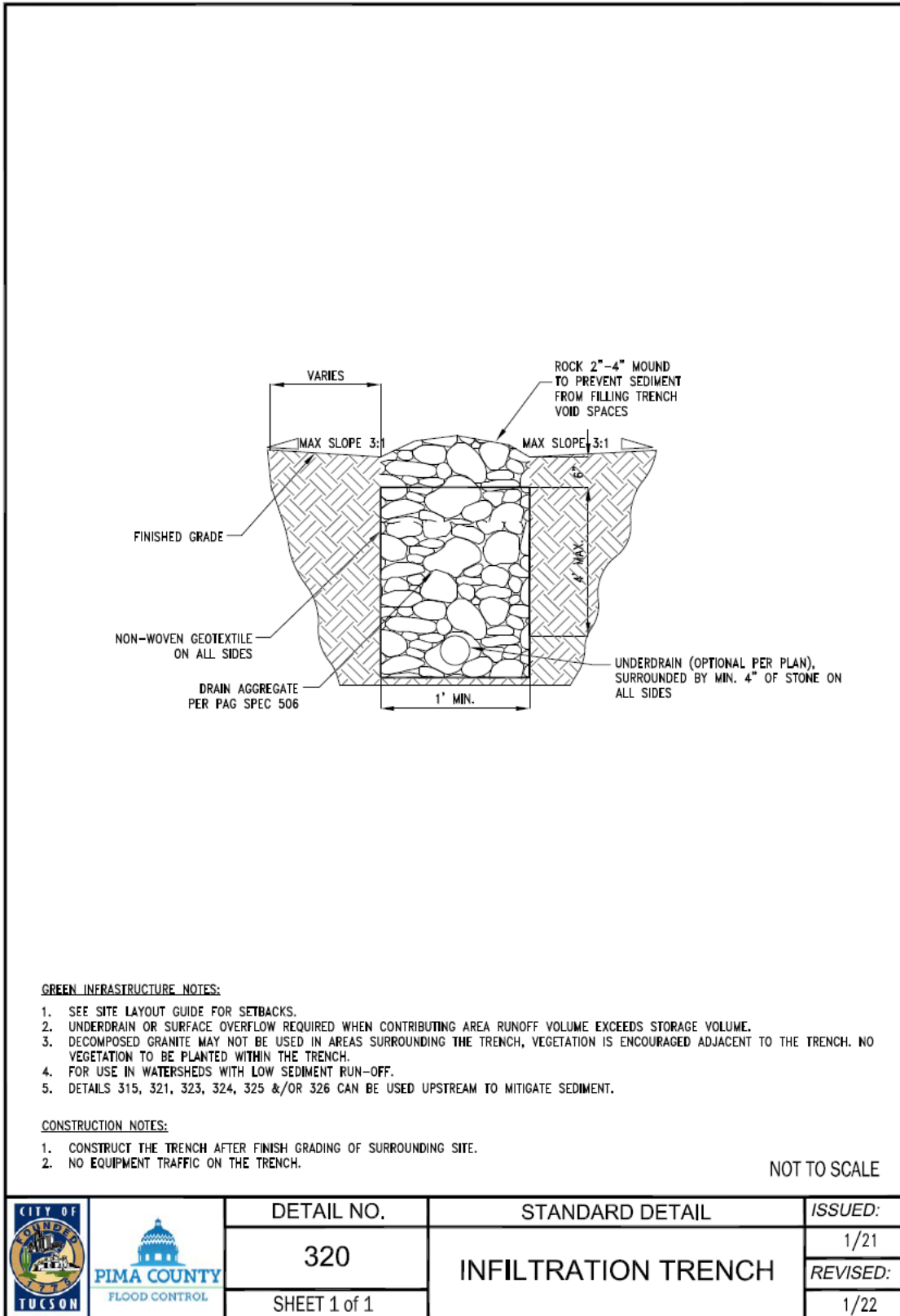


Figure 3.19. Infiltration trench detail.



### 3.7. Sediment Trap

Any infiltration area that could receive sediment-laden stormwater will benefit from having a sediment trap (Figure 3.20 and Figure 3.21) upstream. Sediment traps minimize or eliminate sediment entering infiltration areas. Their sizing should focus on appropriate energy dissipation, sediment storage based on stormwater characteristics and watershed size, and ease of maintenance. A poorly designed or non-existent sediment trap can cause reduced feature capacity, decreased infiltration rates, and even complete elimination of stormwater infiltration.

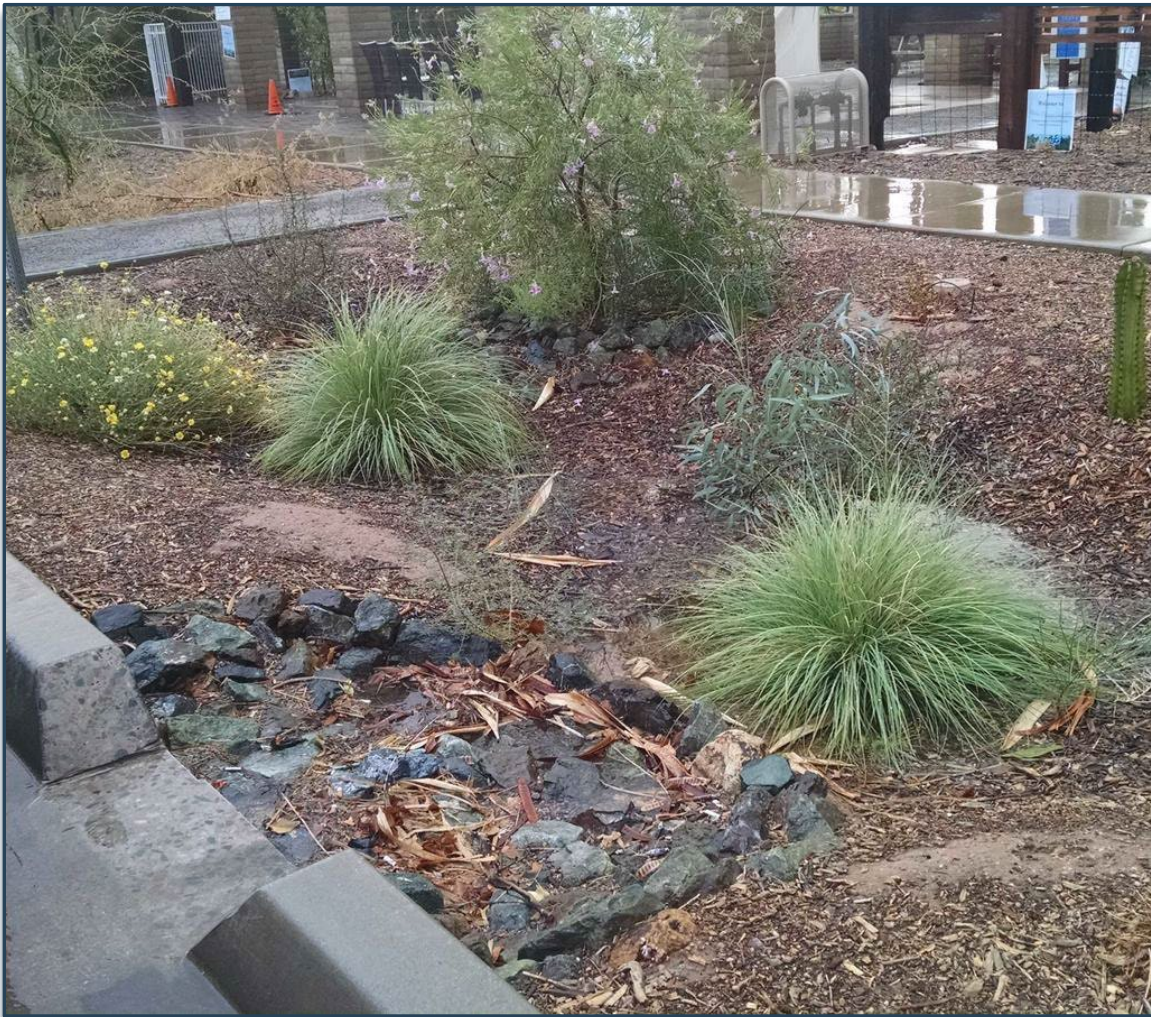


Figure 3.20. Mesa Urban Garden rock sediment trap. Source: Watershed Management Group.

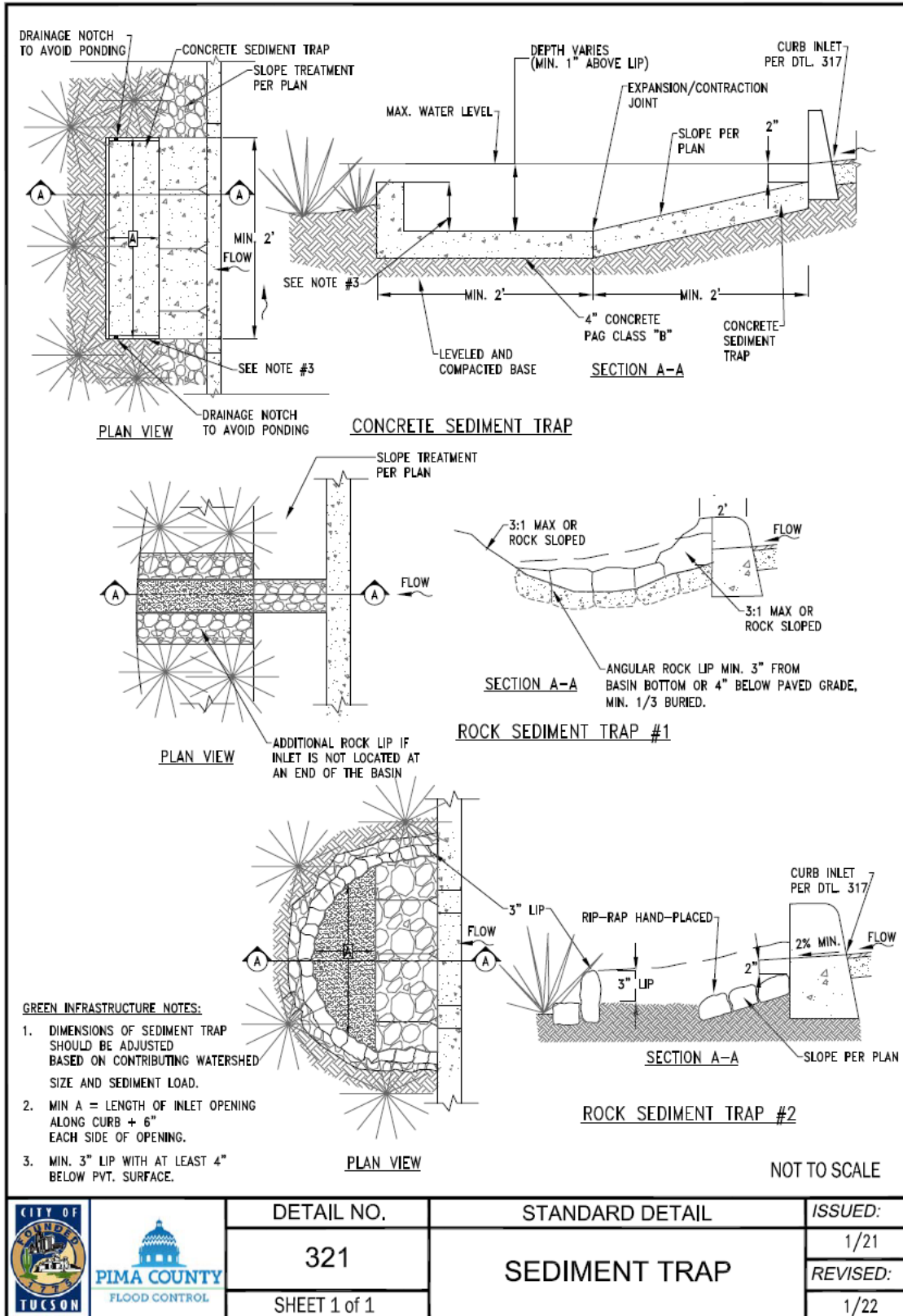


Figure 3.21. Sediment trap detail.

### 3.8. Vegetated Swale

A swale provides conveyance of flows while minimizing erosion with native vegetation and rock (Figure 3.22 and Figure 3.23). Most residential applications do not require rock unless flows and/or slope are significant and/or where design velocities exceed 3 feet/sec. Consult an engineer to determine the necessity of rock and its appropriate sizing for expected high-flow conditions.



Figure 3.22. Glendale library vegetated swale at the. Source: Joanne Toms, Glendale Water Conservation.

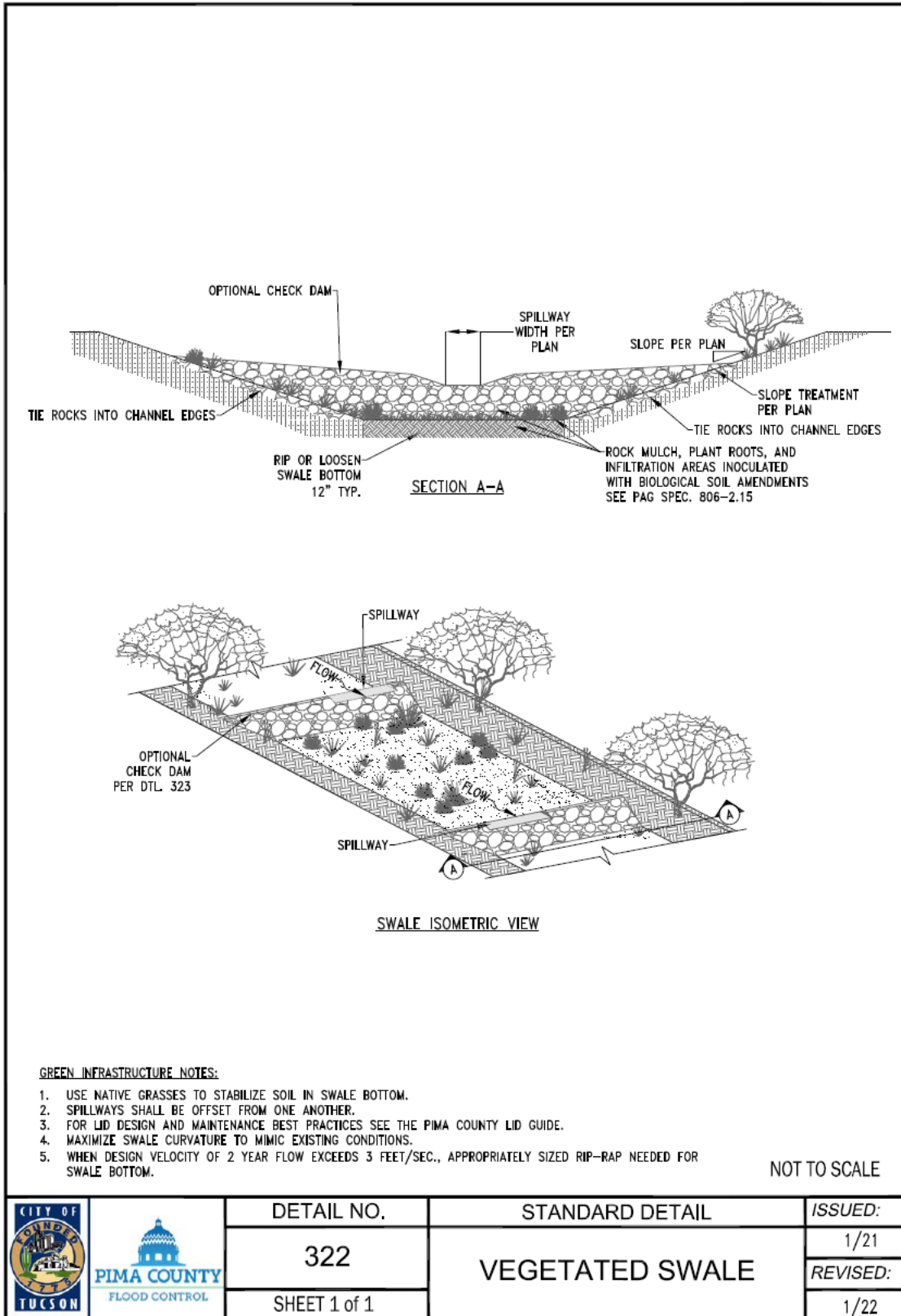


Figure 3.23. Vegetated swale detail.

### 3.9. Check Dam

Check dams slow surface runoff to reduce erosion. As Figure 3.25 shows, alternating low-flow notches in check dams with native bunch grasses on the downstream side provides meandering flows while protecting from erosion.

Check dams have some serious potential drawbacks, including their relative difficulty of construction, their potential for failure, and their potential to increase erosion and flood risks. Ensure check dams direct the force of water away from check dam edges/swale banks by raising rock that interfaces with the soil banks above the main level of the check dam. If this not done, water will cut around the edges of dams.



Figure 3.24. Saint Mary's Road concrete check dam. Source: Wheat Design Group.

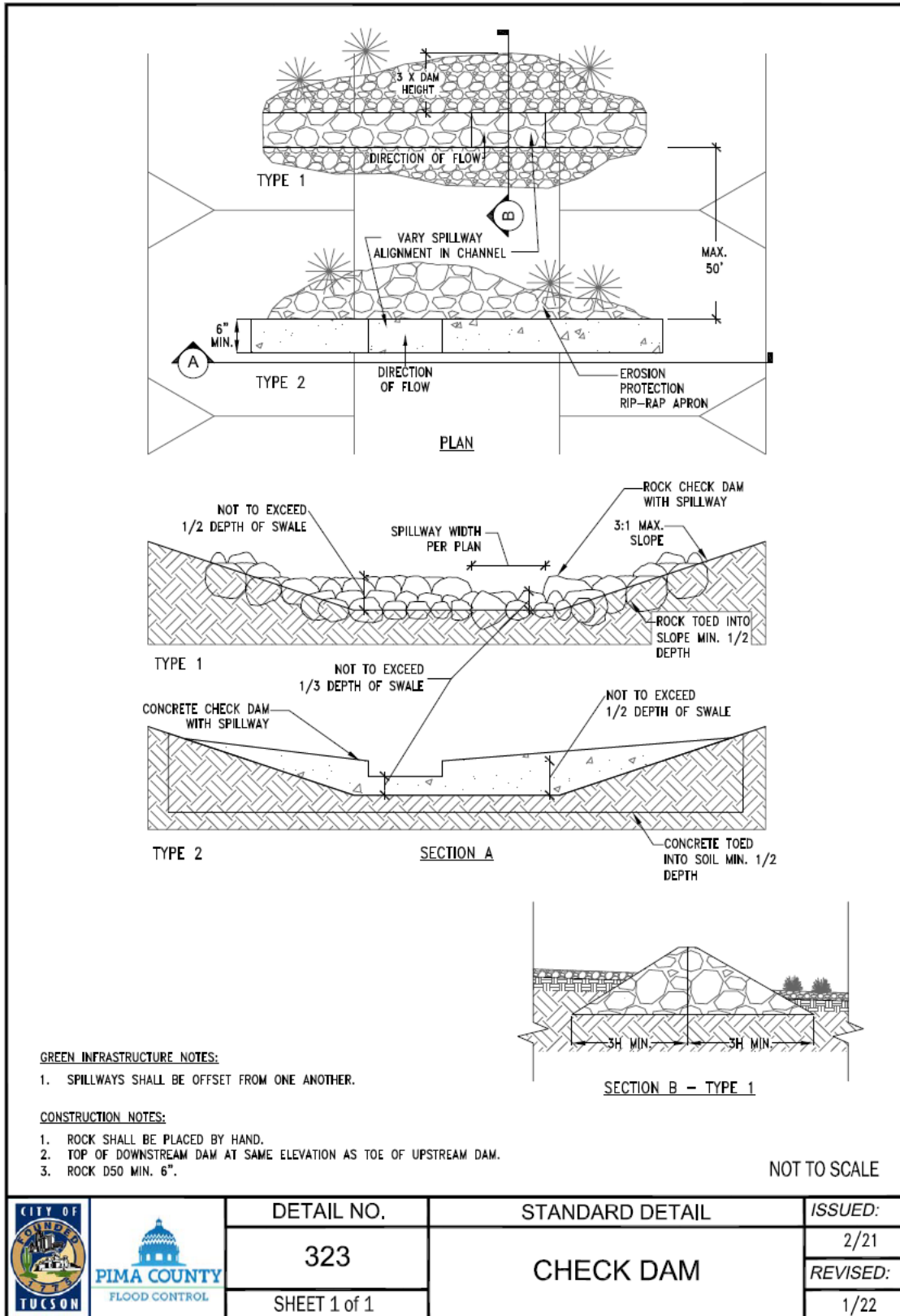


Figure 3.25. Check dam detail.

### 3.10. One Rock Dam

One Rock Dams (Figure 3.26, Figure 3.27, and Figure 3.29) are an important tool for erosion control, especially as an alternative to a check dam. In a wash or erosive flow path, a series of well-built One Rock Dams can be much more effective than difficult-to-construct and failure-prone check dams.

To construct a One Rock Dam, tie rock into the adjacent banks and secure the low flow rock below the channel bed as shown in Figure 3.28 to create sufficient strength to resist the expected scour/erosion forces. Size rock for the largest expected flows to ensure features remain in place. This will minimize erosion in all expected design conditions.



Figure 3.26. One Rock Dam. Source: Holistic Engineering and Land Management.

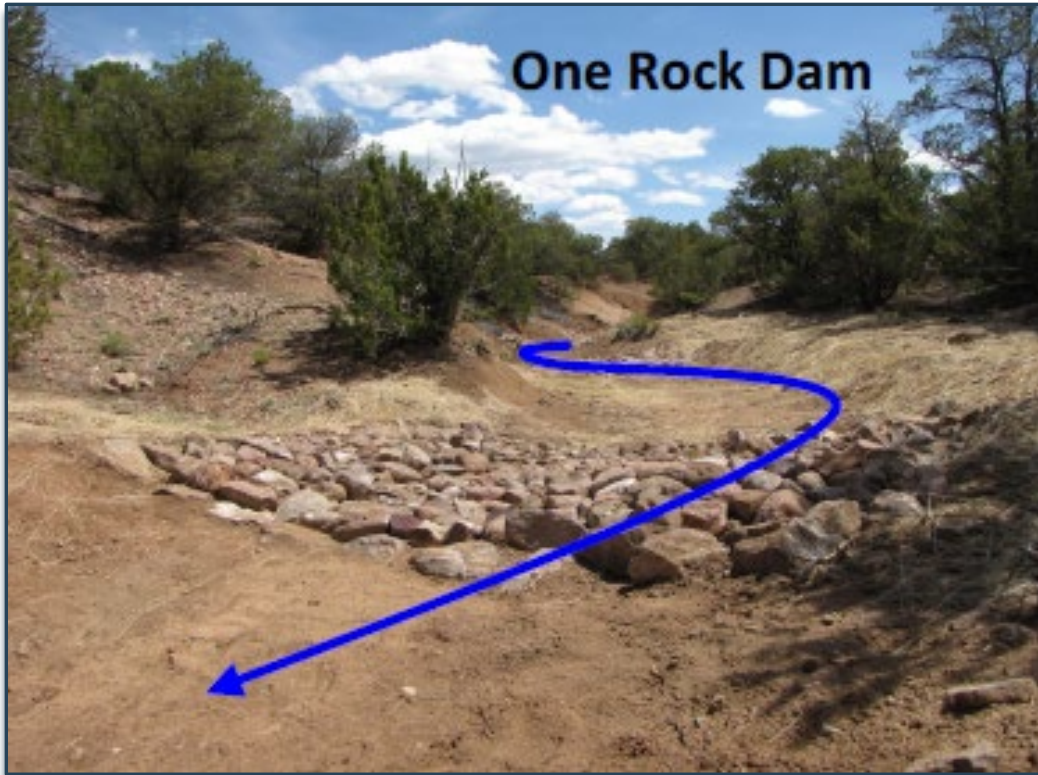


Figure 3.27. Photo of One Rock Dam showing flow path. Source: Quivira Coalition.

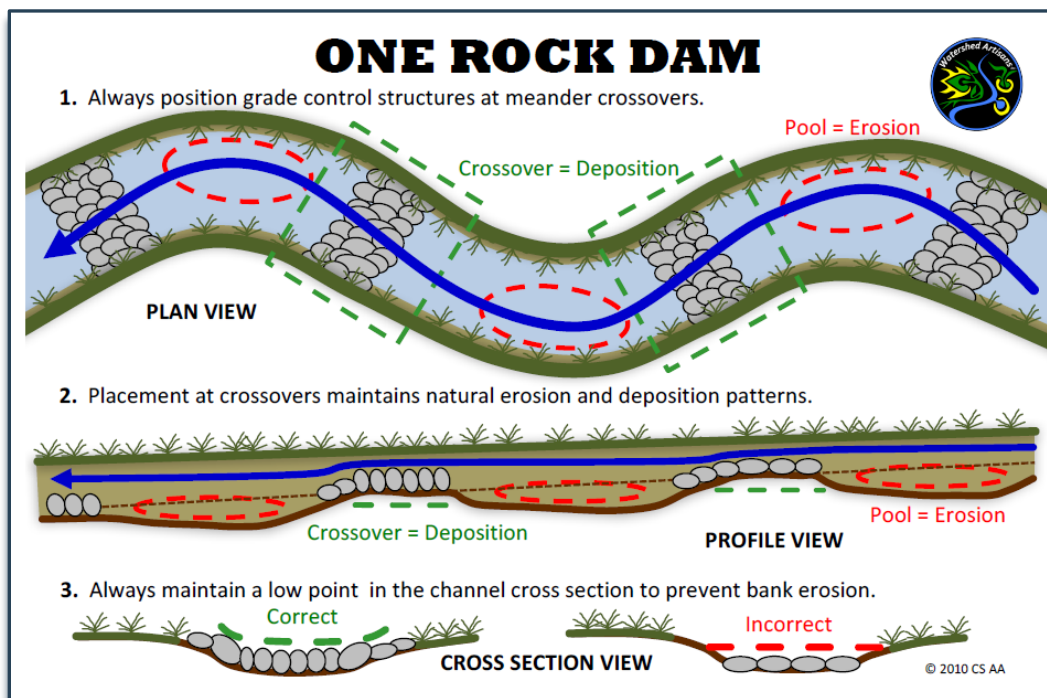


Figure 3.28. Diagram of a One Rock Dam. Source: Quivira Coalition.



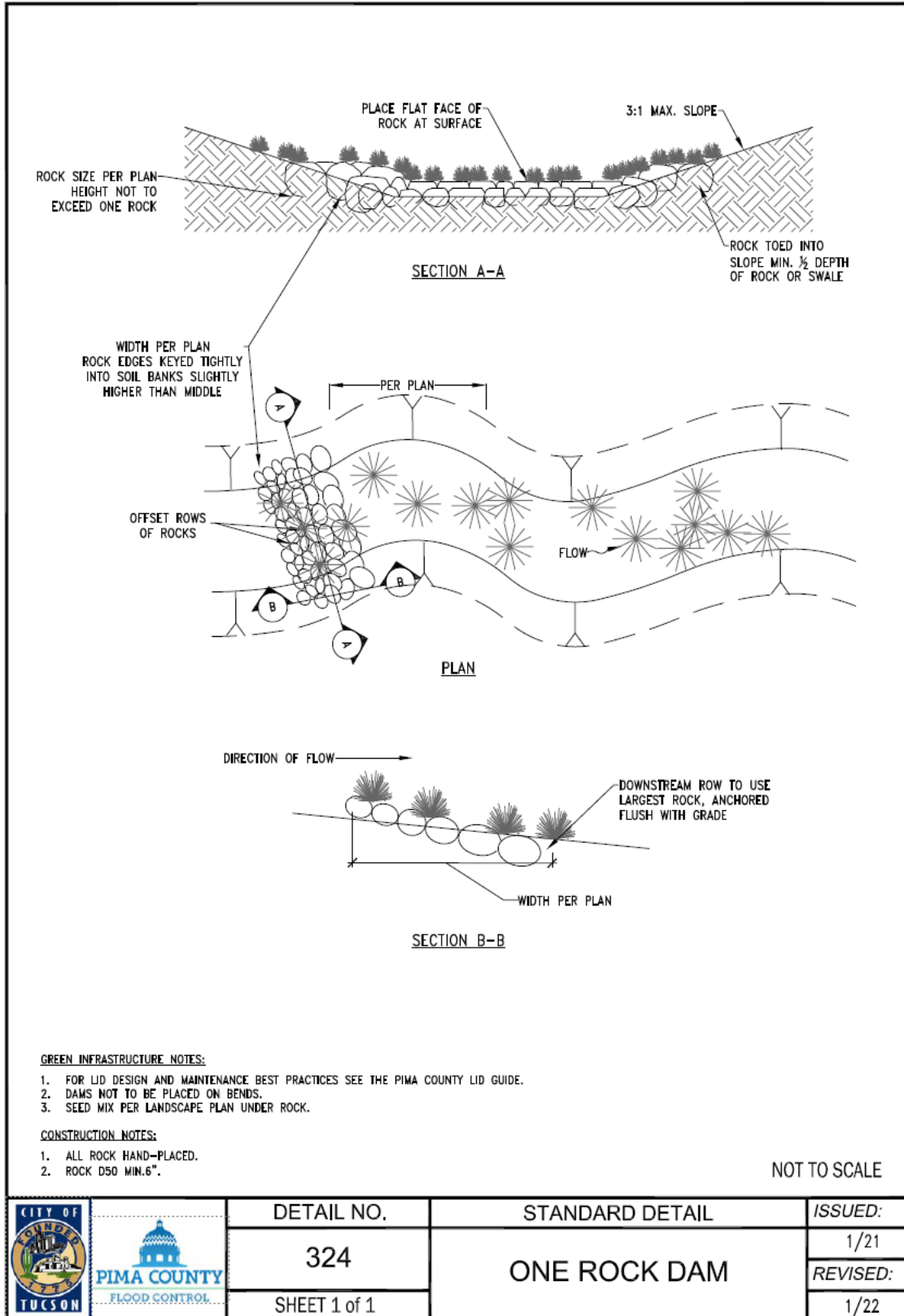


Figure 3.29. One rock dam detail.

### 3.11. Zuni Bowl

Used in washes/channels or in the uplands, Zuni bowls (Figure 3.30 and Figure 3.32) can dissipate energy, manage sediment, and stop erosion and head cutting. Always use experienced, skilled labor to effectively place rock to resist the forces of flows and to ensure large rocks key in at the bottom of the bowl and at the edges of the banks where erosive forces will be greatest.



Figure 3.30. Photo of Zuni bowl showing flow path. Photo Credit: Quivira Coalition.

Figure 3.31 shows a Zuni bowl during and after construction. The design guides water in three ways: down the creek over the grade control and into both the right and left diversion basins. This is a Rosgen cross-vane with an “A” arm and a Zuni bowl (see NRCS Part 654 Stream Restoration Design National Engineering Handbook Chapter 11 Rosgen Geomorphic Channel Design 11–59). The cross vanes retain water, irrigating new vegetation while also protecting the edges of the Zuni bowl. The design defines a riffle-run-pool-glide sequence in the creek (Van Clothier, Stream Dynamics, Inc. [streamdynamics.us/blog-entry/san-vicente-creek-project-action](http://streamdynamics.us/blog-entry/san-vicente-creek-project-action)).



Figure 3.31. During- and post-construction of a large Zuni bowl. Source: Stream Dynamics, Inc.

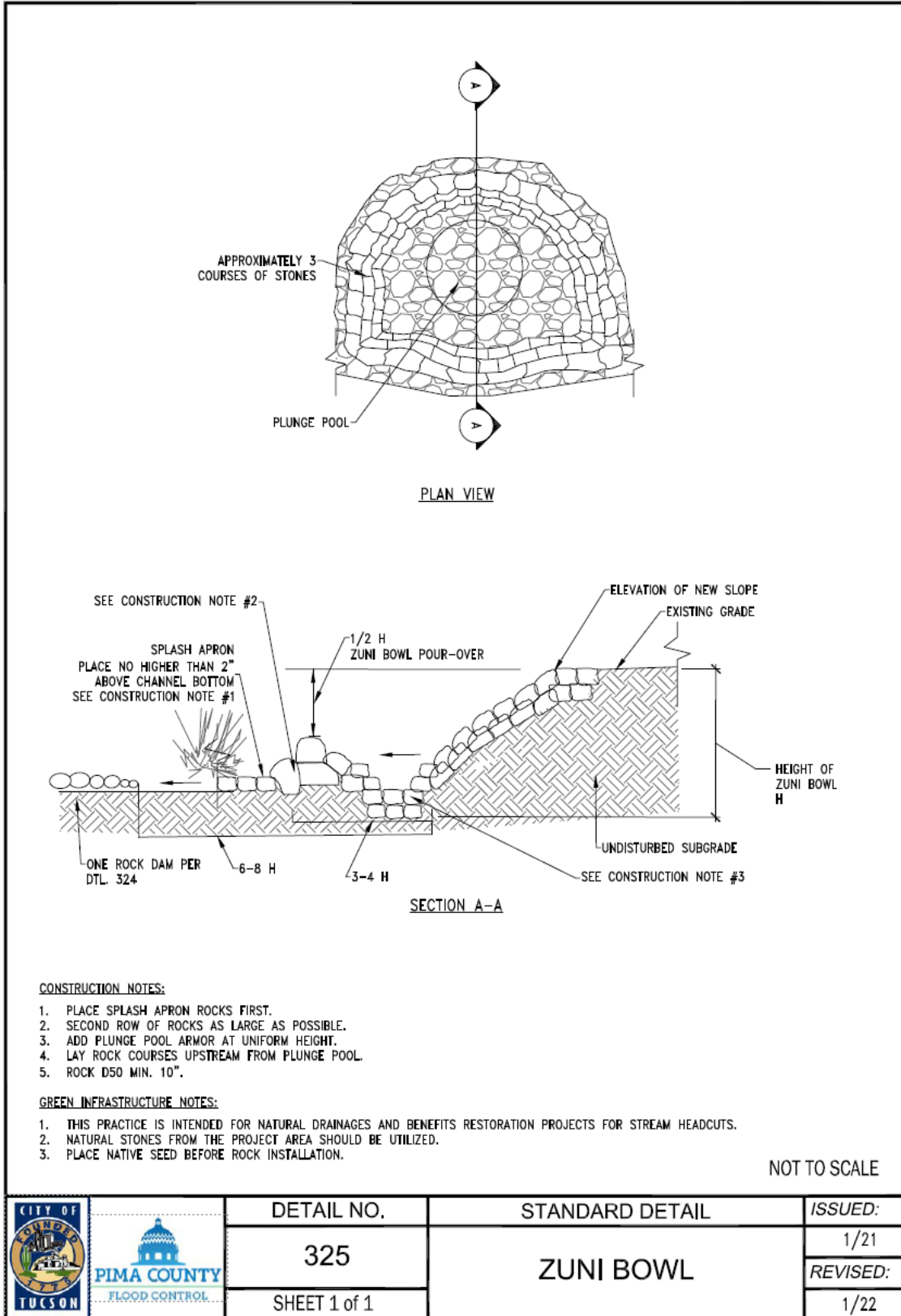


Figure 3.32. Zuni bowl detail.

### 3.12. Sheet Flow Spreader

A sheet flow spreader (Figure 3.33, Figure 3.34, and Figure 3.35) can also be called a Media Luna. It creates sheet flow from concentrated flows. To build a strong structure capable of resisting the forces of runoff, ensure that the most downstream anchor rock is fully buried to be flush with the surface of the adjacent grade.

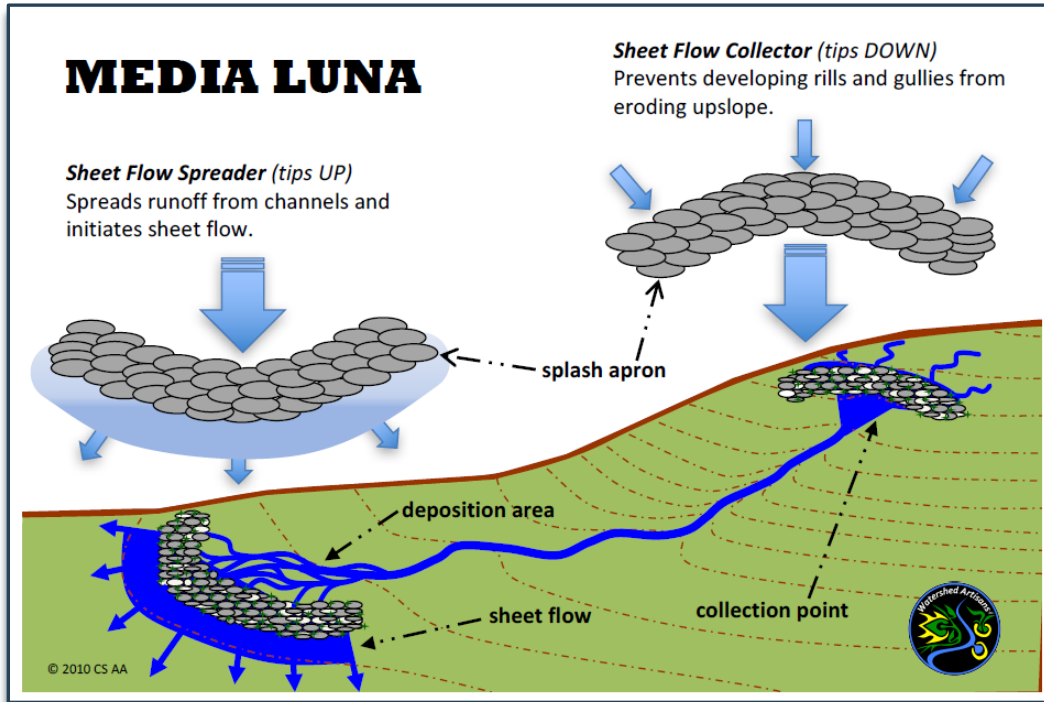


Figure 3.33. Diagram of Media Luna. Source: Quivira Coalition.

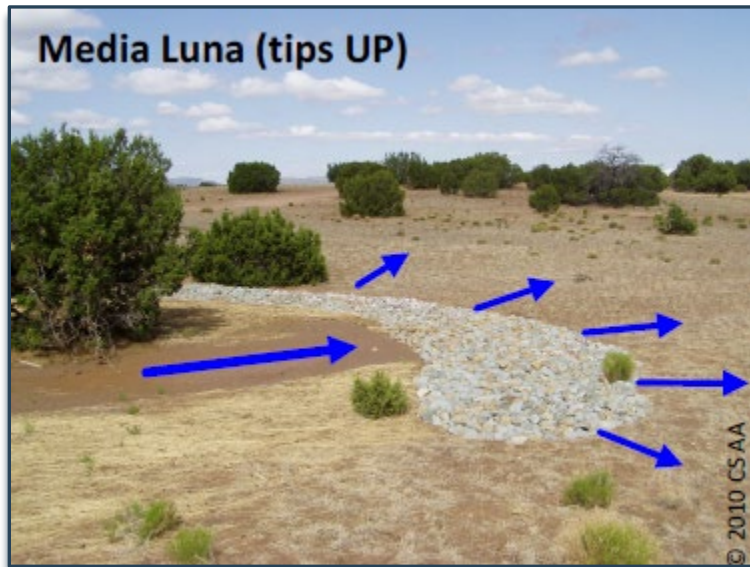


Figure 3.34. Photograph of Media Luna/sheet flow spreader tips up. Source: Quivira Coalition.

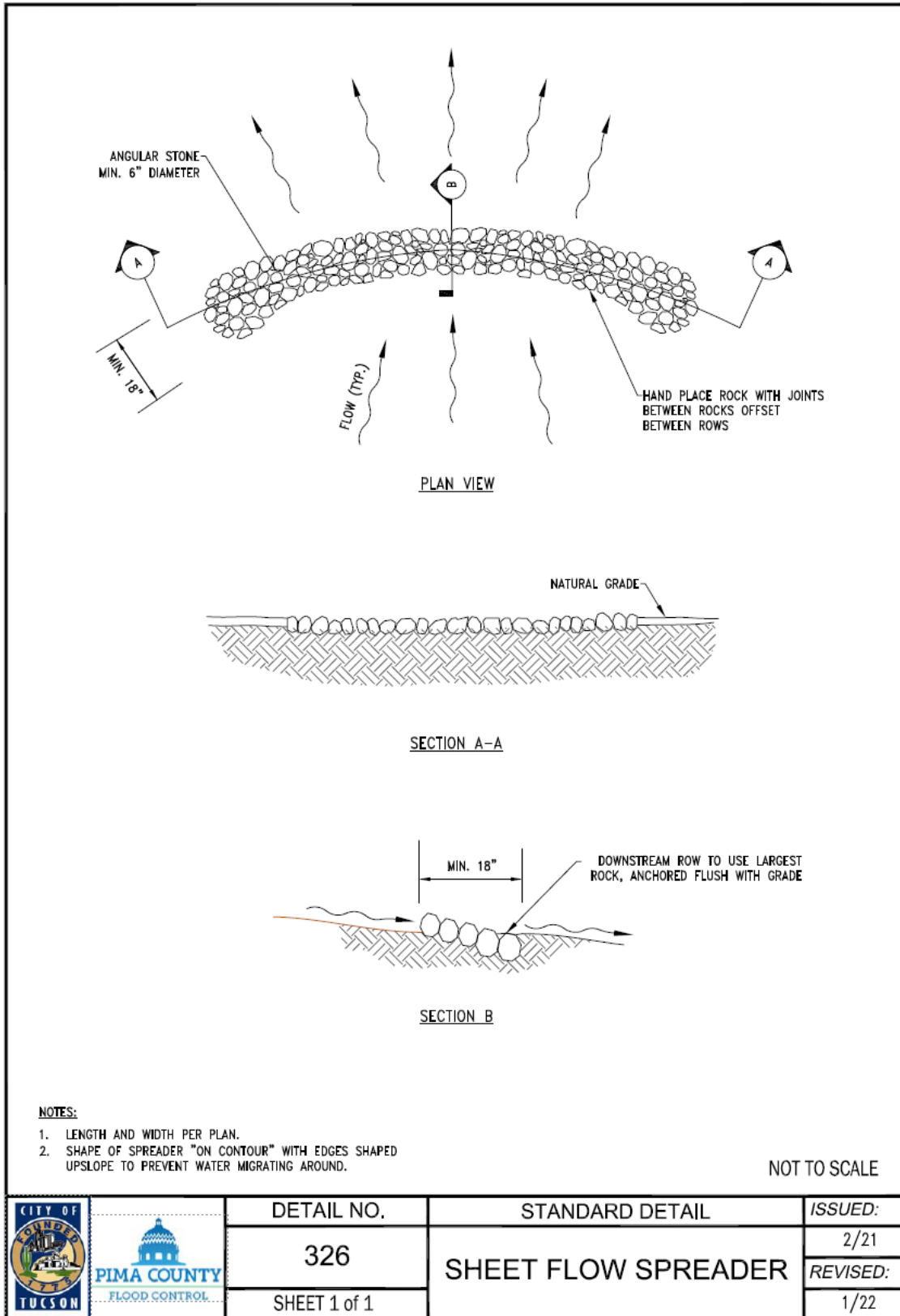


Figure 3.35. Sheet flow spreader detail.

### 3.13. Cistern

During dry periods in arid regions, cisterns (Figure 3.36 and Figure 3.37) provide important water storage for outdoor water use and indoor uses (if treated appropriately). Typical indoor rainwater treatment systems use a combination of sand, activated carbon, and ultraviolet processes. When installing a rain tank, follow these guidelines to ensure optimal system function:

*“A nation that destroys its soil, destroys itself.”*

~Franklin D. Roosevelt

- ◆ Design first flush systems and debris filters to be self-cleaning and easily accessible.
- ◆ Remove internal debris screens included in any plumbing or tank fitting. Any screens the homeowner cannot see will eventually clog and create a flood risk.
- ◆ Locate tank overflow popup at least 10 feet away from any structures and rain tanks.
- ◆ Maintain existing drainage patterns with overflow location.
- ◆ Maximize benefits of tank overflow by directing flows to basins where possible.
- ◆ If flood risk mitigation is a primary goal, install a bleed off pipe to ensure availability of a minimum flood storage capacity when back-to-back storms occur.



Figure 3.36. Metal cistern. Source: Southern Arizona Rain Gutters.

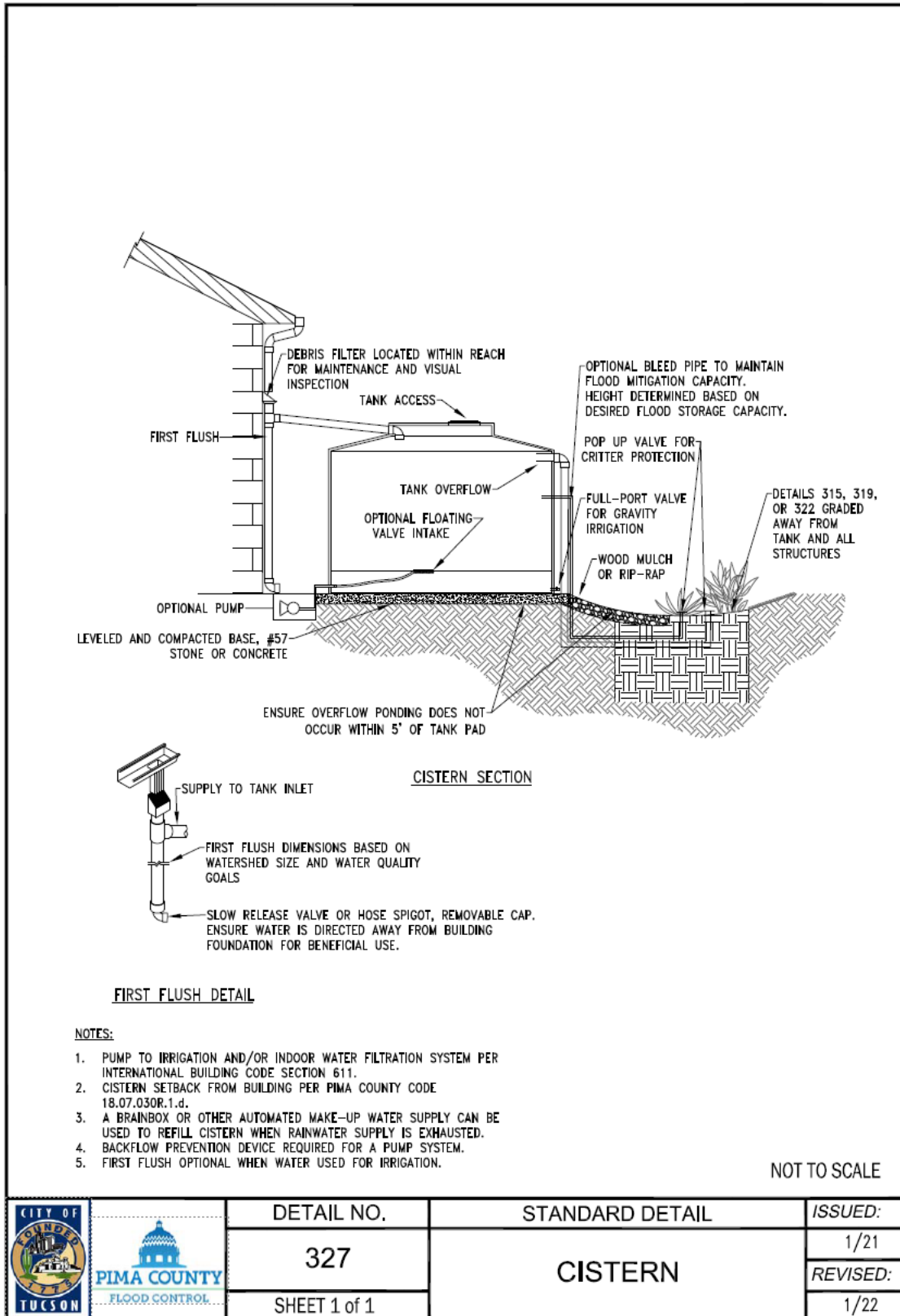


Figure 3.37. Cistern detail.



### 3.14. Traffic Circle Planting

Traffic circles with stormwater harvesting basins in the planting areas (Figure 3.38 and Figure 3.39) can provide important traffic calming and nuisance flooding benefits. Many utilities located in roads create potential conflicts with traffic circle plantings. All designs and plantings must comply with guidance in *Pima County Regional Wastewater Reclamation Department Engineering Design Standards Chapter 7*.



Figure 3.38. Newly planted traffic circle. Source: Tucson Clean and Beautiful.

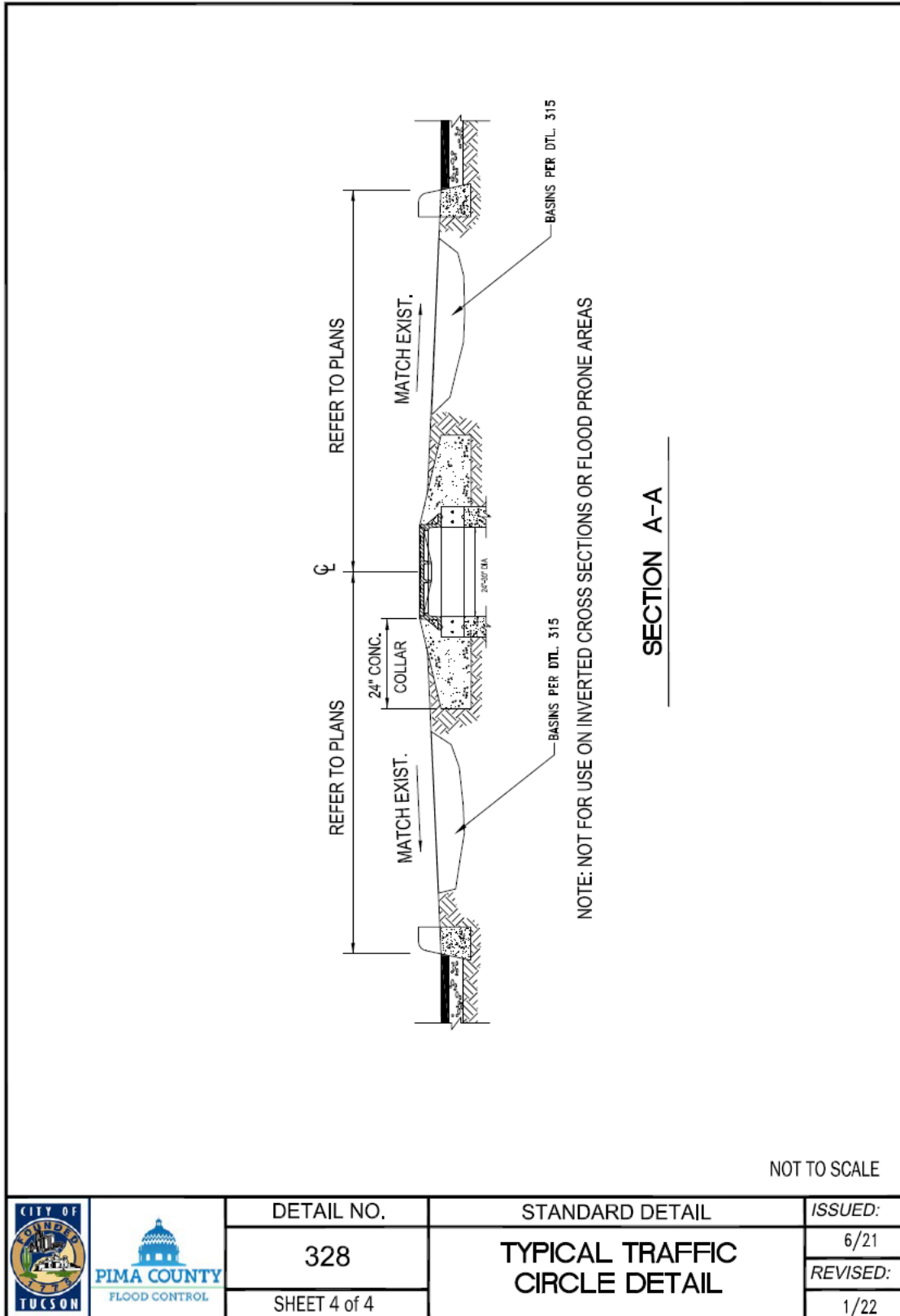


Figure 3.39. Typical traffic circle detail.

### 3.15. Stormwater Harvesting Basin Chicane

Streets represent a significant source of runoff. They also add thermal heat, contributing to the urban heat island. Chicanes (Figure 3.40 and Figure 3.41) mitigate these negative impacts. A chicane (detail 329) can also incorporate details 315 through 321 (see Sections 3.1–3.7). Detail 329 is applicable for more constrained spaces. For larger in-street features use detail 330, Street Width Reduction. If using domed overflows for conveyance, ensure low flows are retained and/or will flow downstream. This maximizes the irrigation benefit while minimizing maintenance by effectively managing sediment and debris.



Figure 3.40. Newly planted chicane. Source: Tucson Clean and Beautiful.



### 3.16. Stormwater Harvesting Basin Street Width Reduction

As discussed above, streets contribute substantially to runoff and the urban heat island. Reducing street width mitigates these negative impacts. Incorporating details 315 through 321 (Sections 3.1–3.7) into a street width reduction project maximizes benefits. Detail 330 (Street Width Reduction) is applicable for long and wider in-street interventions. Detail 329 (Chicane) better serves more constrained sites. If using domed overflows for conveyance, ensure low flows are retained and/or will flow downstream. This maximizes the irrigation benefit while minimizing maintenance by effectively managing sediment and debris.



Figure 3.42. Street width reduction. Source: Tucson Clean and Beautiful.

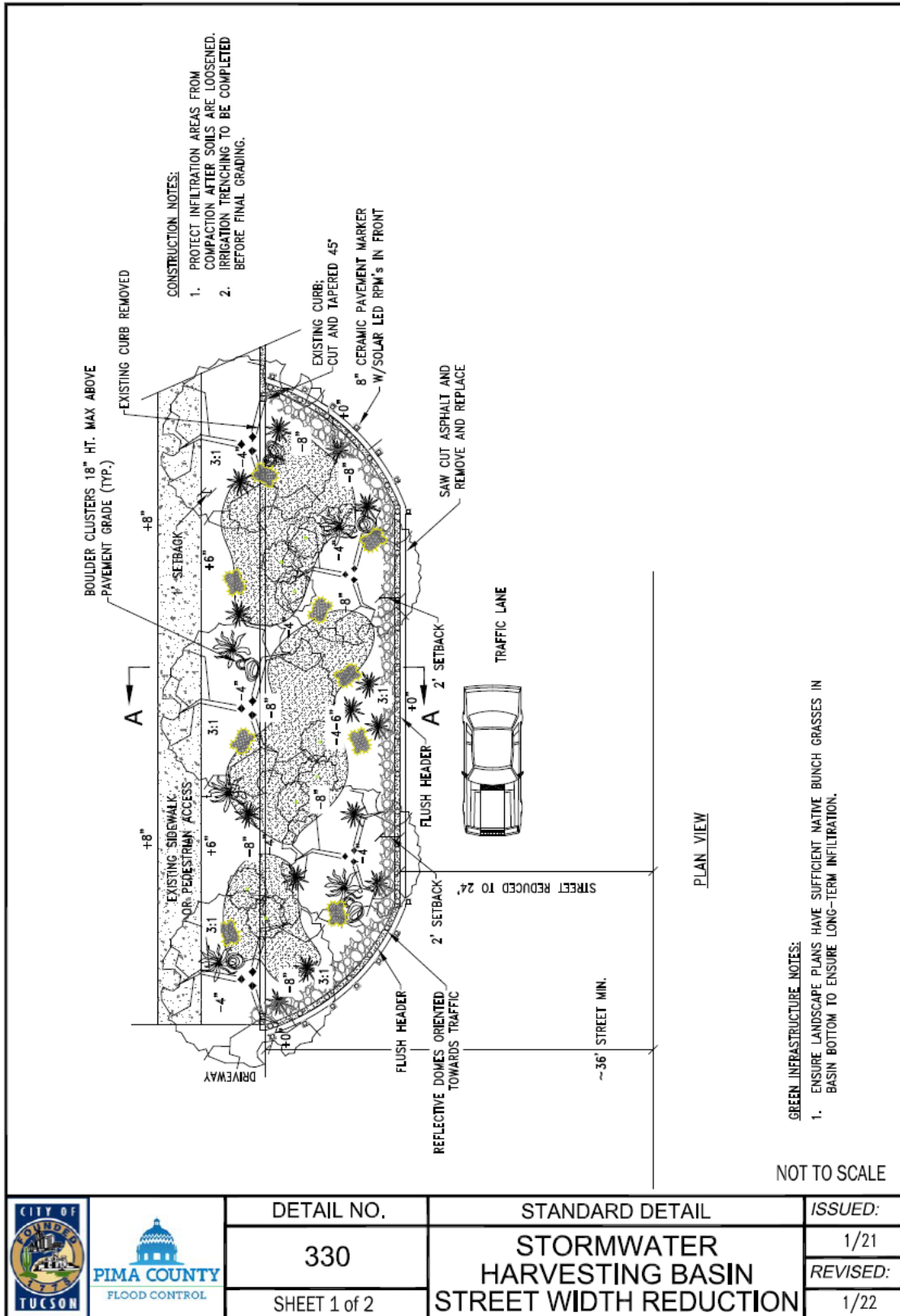


Figure 3.43. Stormwater harvesting basin street width reduction detail.

### 3.17. Tree Planting (Container)

All trees planted in the desert deserve a basin at least a little bigger than their mature canopy! The basin can be larger than the tree canopy, but it should have a tree well or small irrigation basin graded to provide an irrigation benefit during establishment to ensure enough water is provided to the establishing tree (Figure 3.44 and Figure 3.45). This smaller well can be removed as the tree canopy expands. Using biological soil amendments with organic wood mulch is critical for tree establishment. Degraded urban soils do not have soil life, especially the fungal networks that help vegetation get water and nutrients during drought and heat stress.



Figure 3.44. Water harvesting basin around a mesquite tree to capture rainwater. Source: Oscar Medina.

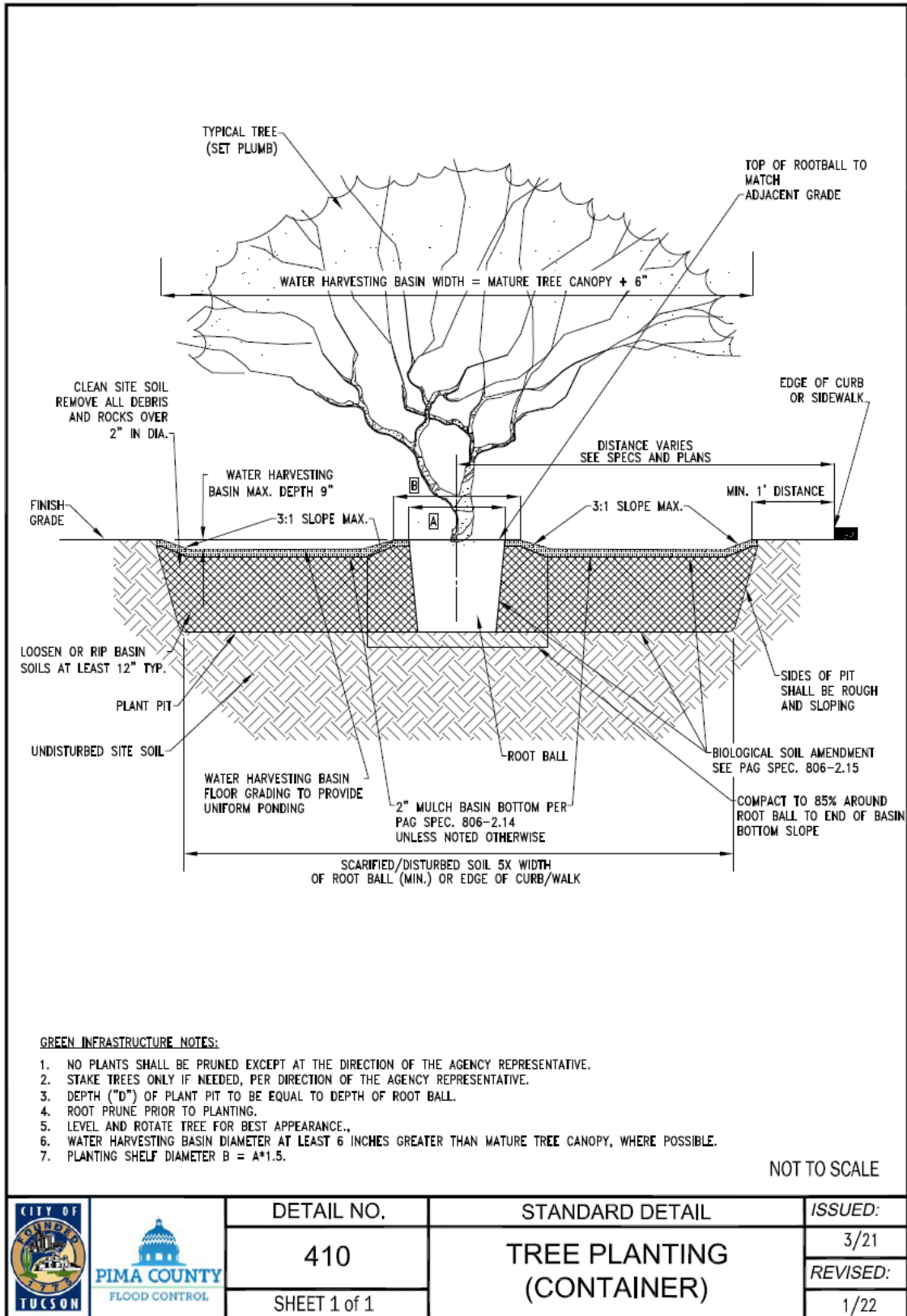


Figure 3.45. Tree planting (container) detail.



## 4. Site Guidance Considerations

The distributed use of GI/LID to manage stormwater close to where it falls improves quality of life in the desert and reduces urban heat islands by maximizing shade from native trees. Chapters 4 and 5 of the *Pima County City of Tucson LID/GI Guidance Manual* contain more specific design guidance. Chapters 2 and 3 of the *Pima County City of Tucson Design Standards for Stormwater Detention and Retention* have information for quantifying first flush runoff benefits and peak discharge reductions.

Despite available guidance and policies, new developments have not always effectively implemented GI/LID as intended by local best practices. GI construction details, site planning guidance, and training will help both adoption of GI in new development and the use of best practices. This section outlines several tools and resources for appropriate GI/LID planning and design.

### 4.1. Planning

The [Pima Association of Governments Resilience Planning Tool](#) provides a variety of helpful layers planners and designers can use in prioritizing GI/LID throughout the region and in finding specific locations for further design. Designers can also use this tool to identify areas where it may be safer to use organic wood chip mulch in streetside basins. By calculating the contributing watershed at a desired point for an in-street or street side basin, the designer can estimate watershed area and slope of the street as Figure 4.1 and Figure 4.2 show.

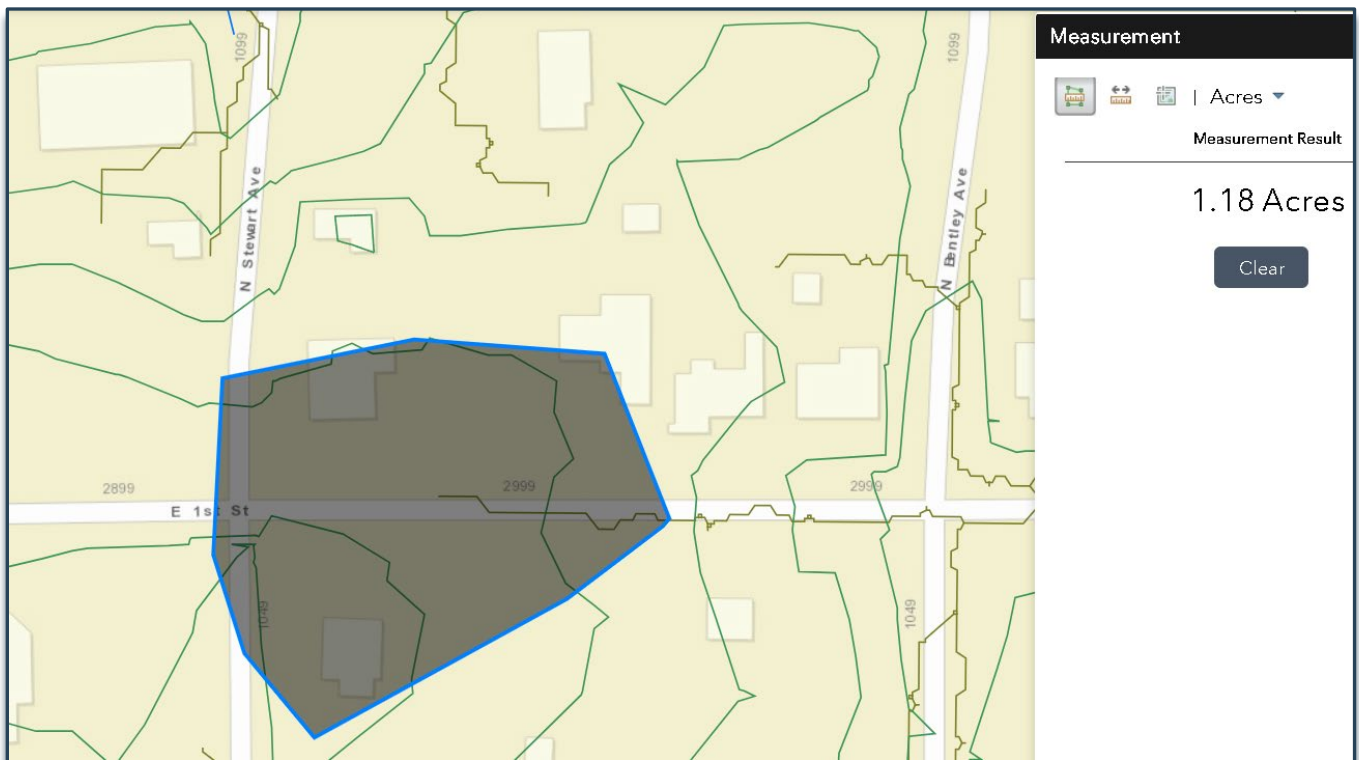


Figure 4.1. PAG Resilience Planning tool showing watershed area estimate. Source: PAG.

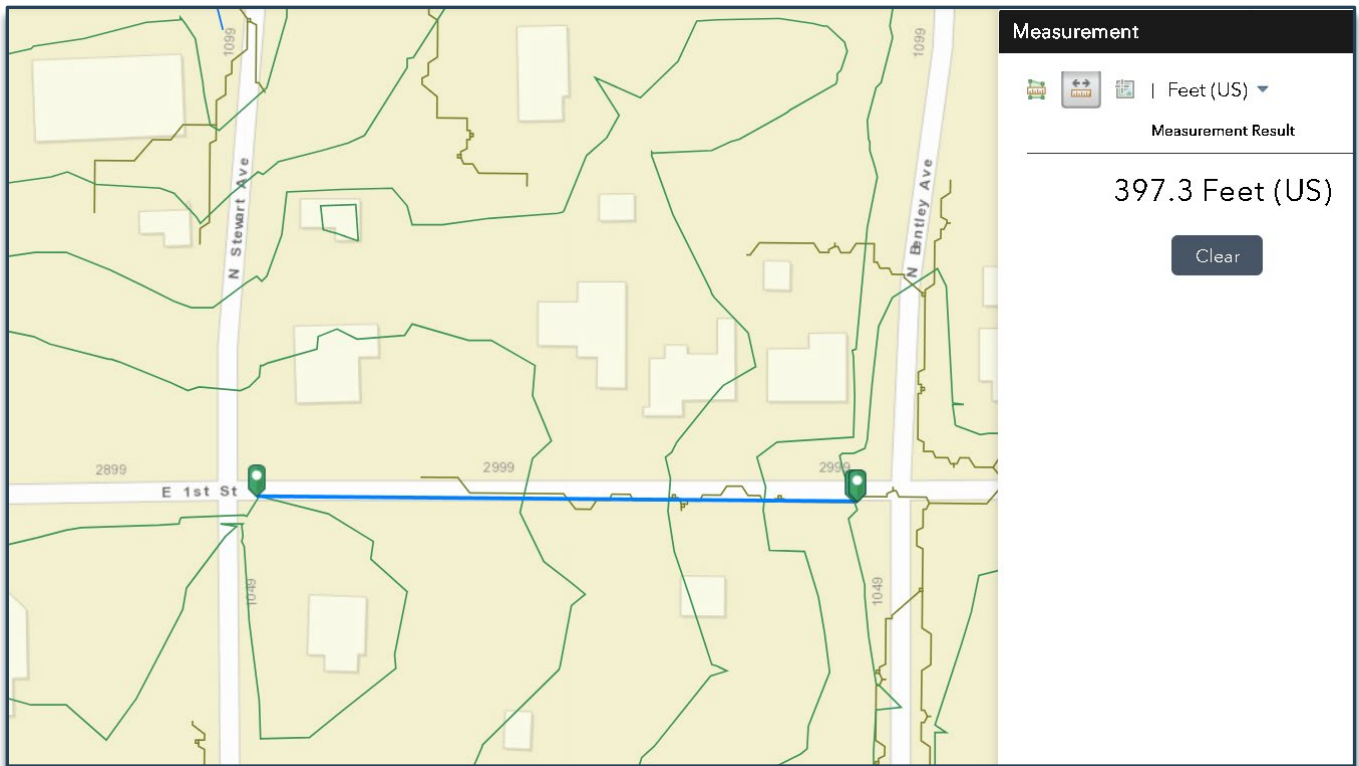


Figure 4.2. PAG Resilience Planning tool showing street slope estimate. Source: PAG.

Figure 4.3 presents a summary graph of the results from the Resilience Planning Tool showing in green the areas where stormwater flows will not likely overtop the curb, and thus where wood mulch can be used.

Calculation assumptions:

- ◆ Rational method for 100-year, 24-hr storm for Tucson from National Oceanic and Atmospheric Administration (NOAA) Atlas 14
- ◆ 6-inch curb
- ◆ 36-ft street width
- ◆ Crowned road with crown slope of 2%

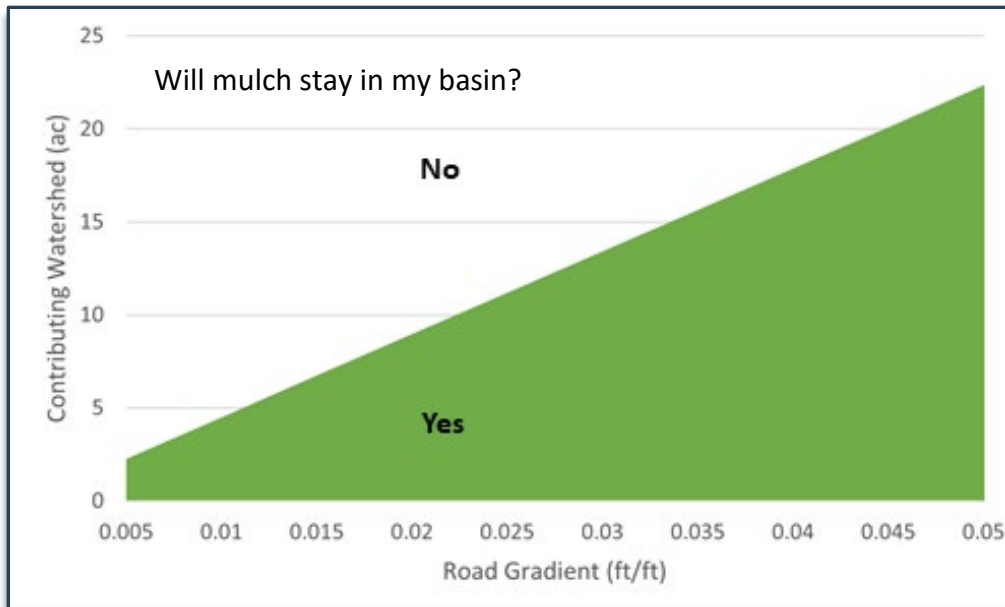


Figure 4.3. Decision tool for wood mulch for street basins. Source: WEST Consultants, Inc.

## 4.2. Design

The following sections describe specific design considerations as they pertain to soil suitability, setbacks, and integrated design and planning.

### 4.2.1. Soil suitability

The Tucson/Pima County region have a great diversity of soils, including Hydrologic Soil Groups A, B, C, and D. GI/LID projects most commonly have Groups B, C, and D. While A and B soils perform better, integrating the following best practices will improve soil health and reduce compaction during construction and maintenance, allowing successful performance of GI/LID in any soil type:

- ◆ Establish native bunch grasses and/or other shrubs or plants with deep fibrous roots.
- ◆ Inoculate infiltration areas and roots with beneficial microbes (see PAG Spec 806-2.15 Biological Soil Amendment) to improve soil structure and infiltration rates.
- ◆ Over excavate and uncompact stormwater harvesting basin areas to break through difficult soil layers.
- ◆ Ensure construction scheduling will not compact infiltration areas.
- ◆ Cover infiltration areas with plants; organic wood mulch; and/or rock, compost, wood mulch mix.

### 4.2.2. Setbacks

Setbacks are critical for safety and protecting infrastructure. For safety and access purposes, stormwater harvesting basins need the following setbacks, as measured from the top of the basin slope:

1. Minimum of 1 foot from a sidewalk or other pedestrian access path and from off-street parking areas.
2. Minimum of 2 feet from back of curb or edge of pavement for streets with on-street parking.
3. Minimum of 6 inches from back of curb or edge of pavement for streets with no on-street parking.
4. Minimum of 10 feet from structures, or minimum setback specified in a geotechnical report for the project.
5. Minimum of 4 feet from the property boundary or other access space for maintenance access.

See Table 4.1 below from City of Tucson Street Design Guide for utility setbacks for planting.

**Table 4.1. Required Plant Setbacks from Underground Utilities.**

UNDERGROUND UTILITY	LARGE TREE OVER 20 FEET	PLANTS UNDER 20 FEET TALL	PLANTS UNDER 3 FEET
SW Gas	8 feet	5 feet	3 feet
Pima C. Sewer	16 feet; 10 feet if sewer line is deeper than 8 feet	10 feet	5 feet
Electric Underground	3 feet	3 feet	3 feet
Tucson Water	10 feet	5 feet	3 feet
Cable / Fiber Optic	5 feet	5 feet	3 feet
*No planting in El Paso Gas easements.			

### 4.2.3. Integrated Design and Planning

For additional GI/LID planning and site assessment guidance, see Chapters 3 and 4 of the *Pima County City of Tucson LID/GI Guidance Manual* and Chapters 1 and 2 of the *Pima County City of Tucson Design Standards for Stormwater Detention and Retention*.

Conventional infrastructure as shown in Figure 4.4 on the left shows a residential development that does not harness the power of GI/LID to create a vibrant, healthy, clean, and cooling neighborhood for residents. On the other hand, the illustration on the right and in Figure 4.5 shows the integration of multiple GI/LID practices to achieve a multiplier effect of benefits from the practices used in combination. For example, stormwater harvesting occurs throughout the development to maximize the native shade tree canopy that can be supported by renewable stormwater resources. Figure 4.6 shows similar benefits in a commercial development setting. Figure 4.7 and Figure 4.8 show example feature integration within typical neighborhood and arterial streets.



Figure 4.4. Conventional centralized infrastructure and decentralized GSI for an example residential area.



Figure 4.5. Zoomed in illustration of decentralized GI/LID infrastructure.



Figure 4.6. Centralized infrastructure and decentralized GSI for an example commercial development.

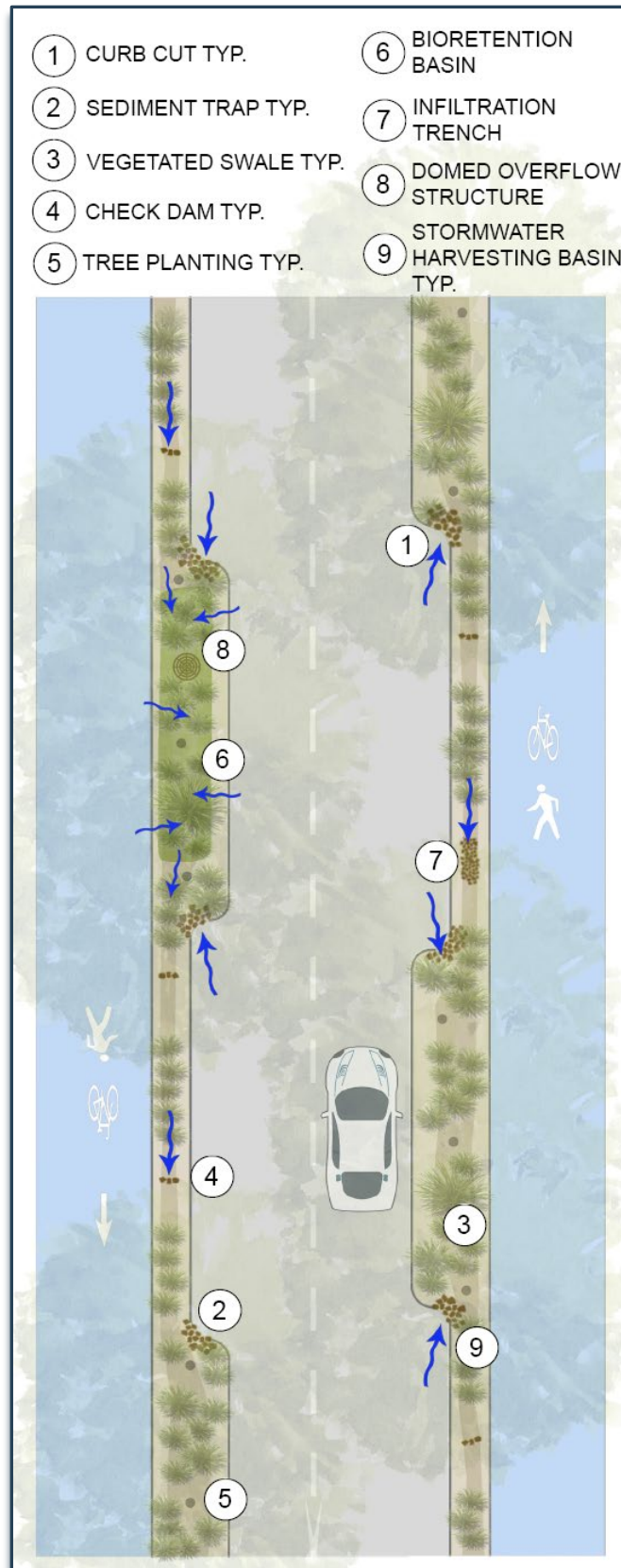


Figure 4.7. Conceptual layout of GI/LID for a neighborhood road.



- |                        |                                    |
|------------------------|------------------------------------|
| ① CURB CUT TYP.        | ⑤ TREE PLANTING TYP.               |
| ② SEDIMENT TRAP TYP.   | ⑥ BIORETENTION BASIN               |
| ③ VEGETATED SWALE TYP. | ⑦ INFILTRATION TRENCH              |
| ④ CHECK DAM TYP.       | ⑧ STORMWATER HARVESTING BASIN TYP. |

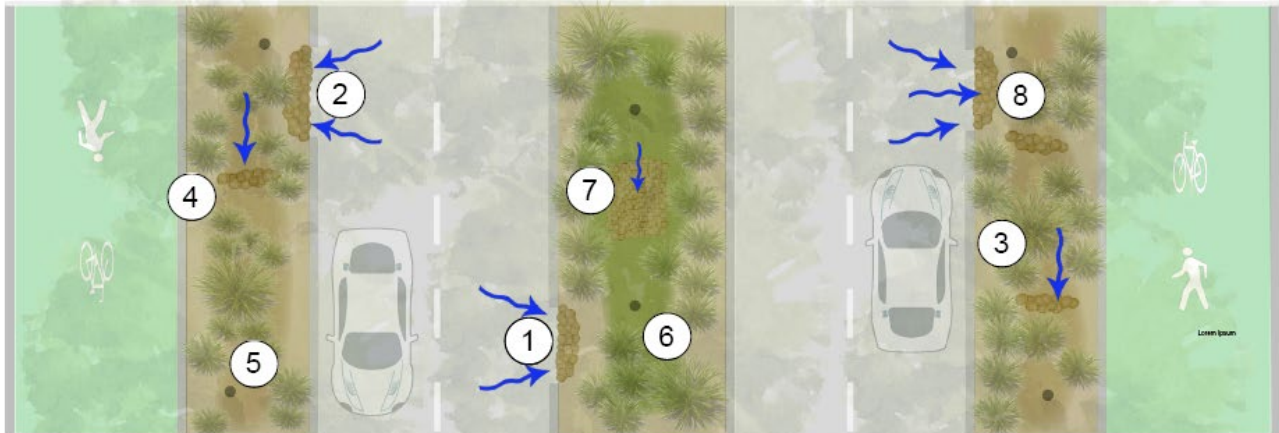


Figure 4.8. Conceptual layout of GI/LID for an arterial roadway.

## Appendix A: Stakeholder Engagement Process

To mitigate regional water quality challenges, the Arizona Department of Environmental Quality (ADEQ) provided funding to the City of Tucson Green Stormwater Infrastructure Program to improve the adoption of GI/LID throughout the region. Wider adoption of GI practices is necessary to address stormwater quality and quantity concerns, while providing much needed amenities like tree canopy. Long-term, this will transform littered and unsafe waterways and streets that convey stormwater into green, inviting areas. To create buy-in and refine the GSI details, the ADEQ grant was used to engage a group of dozens of technical stakeholders (both practitioners and experts) from multiple jurisdictions to review the current set of GSI details.

Stakeholders were recruited based on their technical expertise and knowledge of standard details. The acknowledgements section contains a complete list of stakeholders. An introductory webinar along with individual review and follow up emails and video calls were conducted with all stakeholders. Stakeholders reviewed a copy of the draft details, list of specifications, and an outline of this site guidance document. All stakeholder comments were collected and summarized in an Excel spreadsheet with notes regarding comment resolution.

In collaboration with City of Tucson, Pima County, and Pima Association of Governments staff, the relevant GSI details from a variety of local and arid region cities were assembled to gather a baseline of existing information, examples, and AutoCAD files. These details were brought together into one .dwg CAD file, formatted for consistency with PAG formatting to create the foundational materials for adoption of PAG details in the future. These selected details address essential needs for roadways that double as stormwater management infrastructure in this region. They were recommended for regional adoption because they fit several criteria used for other specifications before regional adoption. These criteria include being a core element of design, widespread use by private and public sectors, safety and quality of life benefits conferred by using the designs, that they are essential for the function of roadways and achieving local GI related policies, their applicability to numerous road contexts, and sponsorship and use by multiple jurisdictions.

Before PAG adopts the GSI details, PAG committees will likely undertake an adoption process including regional stakeholder review of their success in addressing local concerns and building consensus. The process used to develop these specifications and this guidance will aid that adoption process since it included vetting by multiple experts and jurisdictions.

## Appendix B: Pima Association of Governments Specifications

Below is a summary of the recommended additions to the PAG Specifications to improve implementation of best practices for GSI.

### PAG Specification Additions

- **Division 101**
  - **Green infrastructure (GI) or Green Stormwater Infrastructure (GSI):** An adaptable term used to describe an array of products, technologies, and practices that use natural systems—or engineered systems that mimic natural processes—to enhance overall environmental quality and provide utility services including capturing, cleaning, and infiltrating stormwater; creating wildlife habitat; shading and cooling streets and buildings; and calming traffic. As a general principle, GI techniques use soils and vegetation to infiltrate, evapotranspire, and/or recycle stormwater runoff.
  - **Low Impact Development (LID)** – Practices that utilize basic principles modeled after the natural environment by managing runoff and urban water use at the source using uniformly distributed small-scale controls.
  - **Stormwater** – Rainwater that has landed on a surface.
  - **Stormwater Harvesting** – The process of intercepting stormwater from a surface such as a roof, parking area, or land surface, and putting it to beneficial use.
  
- **Division 203**
  - 203-4 DRAINAGE EXCAVATION – changes below in bold
  - 203-4.01 Description. Drainage excavation shall consist of the excavation of ditches, **stormwater harvesting basins**, channels or waterways, except that excavation which is required to construct ditches paralleling the roadway and constituting a part of the roadway prism shall be considered as roadway excavation as provided under Subsection 203-3.
  - 203-6.02 Materials.
    - See PAG Specifications 201 Clearing and grubbing, 203 Drainage excavation, 801-810 landscaping, planting, topsoil, Riprap and rock mulch, seeding, erosion control, pollution prevention.
  - 203-6.03 Construction Details. In general, stormwater harvesting basins shall be constructed to the lines and at the locations designated on the project plans; however, the Engineer will consider the topography and will determine the location and dimensions, and the stormwater harvesting basins are to be constructed and will stake the ditches to provide level bottom slopes so that each basin will provide a water conservation benefit from retention and serve as an effective part of the overall drainage system.

- 203-6.04 Method of Measurement. The unit of measure for stormwater harvesting basin will be cubic yards.
- 203-6.05 Basis of Payment. The payment will be in accordance with the following PAG Specification Sections, including all labor, materials, tools, equipment and incidentals needed to complete work specified.
  - Section 201 – Clearing and Grubbing
  - Section 203 – Drainage excavation
  - Section 801-810 – landscaping, planting, topsoil, Riprap and rock mulch, seeding, erosion control, pollution prevention.
- 203-10 STORMWATER HARVESTING BASINS
  - 203-10.01 Description. Stormwater harvesting basins shall consist of excavating and finishing stormwater harvesting basins, as detailed on the project plans, to slow, spread, and infiltrate surface water with the exception that stormwater harvesting basins paralleling the roadway and constituting a part of the roadway prism shall be considered as roadway excavation as provided for under Subsection 203-3. Bottom of basins need to be ripped to ensure infiltration of ponded water within 12 hours.

- **Division 800**

- 806-2.14 **Organic Wood Mulch.** Mulch shall consist of composted, ground, or shredded fir or Ponderosa pine bark shavings with at least 85 percent able to pass through a 3-inch screen. The pH shall not exceed 7.5. The mulch shall be hygroscopic, free of chemicals weed seeds, debris, and trash.
- 806-2.15 **Biological Soil Amendment.** The amendment shall contain a minimum of aerobic beneficial components as outlined in the table below. The water used to apply amendment shall be free of chlorine and disinfection byproducts.

	Minimum Biological Requirements
Bacterial Biomass (ug/g)	135
Fungal Biomass (ug/g)	135
F:B ratio	>3:1
Protozoa (ug/g)	10,000
Beneficial Nematodes (count per g)	100
Ciliates (count per g)	<5

- 806-2.16 **Bioretention Soil Mix.** A constructed soil medium that is a mixture of coarse sand (not more than 15% ASTM C-33 sand by volume), organic mature compost (15-25% leaf compost, vermicompost or equivalent) mixed in a drum mixer; and excavated and/or topsoil (70%) per PAG Specification 804.