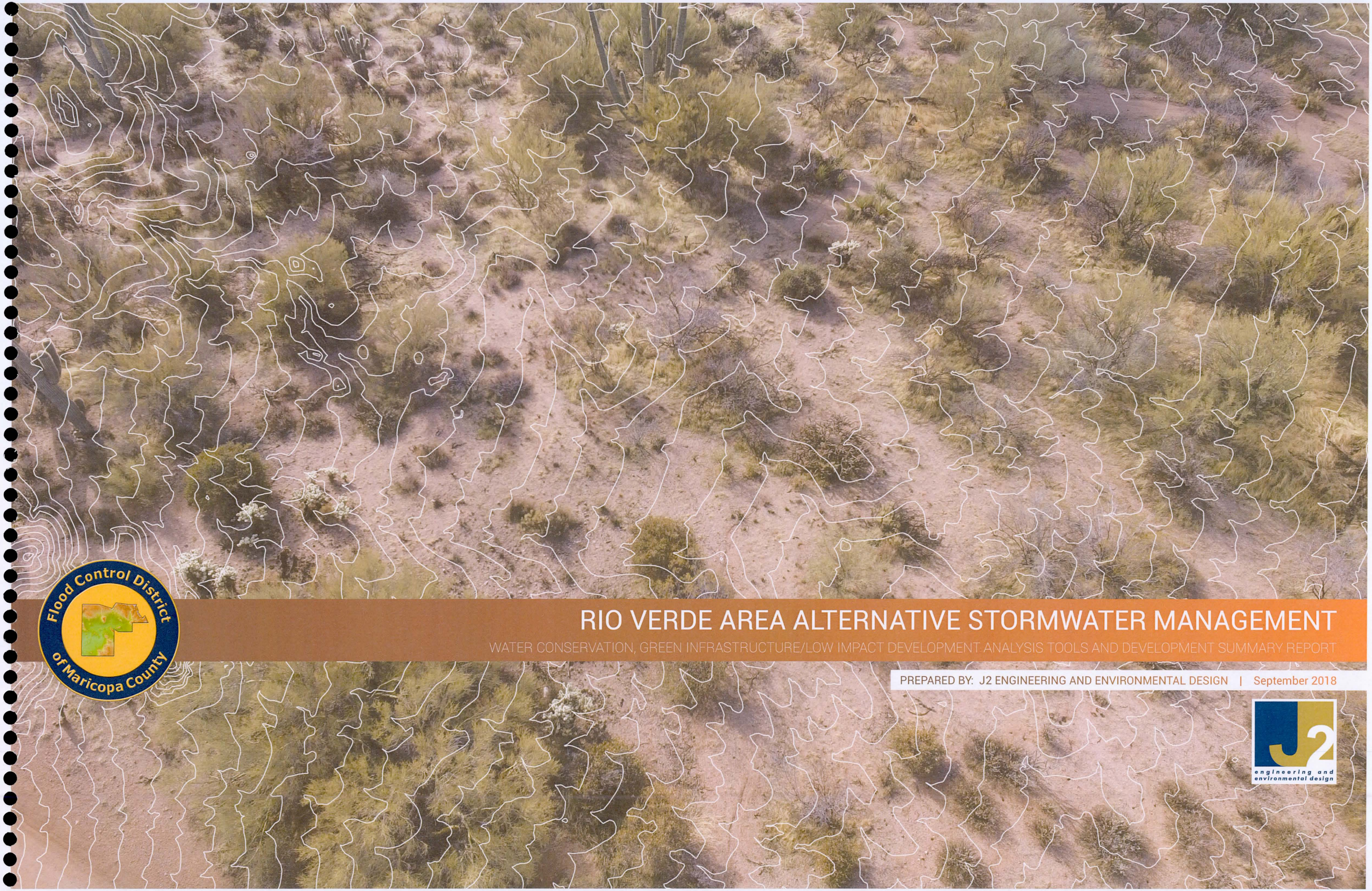

Flood Control District of Maricopa County

RIO VERDE AREA ALTERNATIVE STORMWATER MANAGEMENT

WATER CONSERVATION, GREEN INFRASTRUCTURE/LOW IMPACT DEVELOPMENT ANALYSIS TOOLS AND DEVELOPMENT SUMMARY REPORT

PREPARED BY: J2 ENGINEERING AND ENVIRONMENTAL DESIGN | September 2018

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Part 1 - Introduction

When precipitation falls from the sky, it has multiple pathways it may take as it winds through the environment. These pathways include infiltration, evaporation, transpiration, and runoff. Infiltration occurs when water is absorbed into the soil profile. Evaporation occurs when the water in the ground becomes vapor and returns to the air. Transpiration is water that escapes from plants in the form of vapor. Stormwater runoff occurs when rainfall, that is unable to be absorbed by the soil, flows across the land surface. This can occur as sheet flow without an established pathway or in defined washes, arroyos or streams.

The Rio Verde area - a rural part of Maricopa County - drains eastward toward the Verde River. The Verde River connects with the Salt River upstream of the Granite Reef Dam in eastern Maricopa County and then flows westerly, eventually joining the Agua Fria and Gila Rivers on its journey west toward the Colorado River. The community is located within the upper Sonoran desert landscape characterized by a series of rolling washes along a mountain front, often called a "bajada" in Spanish for descent or area of inclination. Rio Verde is comprised of rural residential, equestrian, and ranching properties accessible mostly via unpaved roads. There are no formal stormwater drainage collection systems (catch basins, storm drains) in this rural community and rainwater generally flows overland as sheet flow or in desert washes toward the Verde River.

The Rio Verde area has unique site attributes, including slope, soil composition, sediment transport, stands of native vegetation, braided washes and swales. Additionally, there exists a strong desire by residents to preserve their rural equestrian lifestyle, which will challenge the typical implementation of green infrastructure and low impact development (GI/LID) techniques. The promotion and encouragement in the use of GI/LID techniques offers residents and land owners in the Rio Verde area a potential opportunity to help reduce erosion and sediment flow, and to supplement and potentially lower overall use of potable water on their individual properties. These techniques also offer benefits to the overall Rio Verde community that can include helping reduce overall stormwater runoff volumes, decreasing or delaying peak stormwater discharge events, improving stormwater quality, reducing erosion and sedimentation, improving soil moisture, and - over a long period of time - benefiting the replenishment of groundwater. In addition, GI/LID techniques can enhance the long-term survival of the existing native desert vegetation that helps to define the Rio Verde area's natural and rural character.

Study Goals and Objectives

This report is intended to introduce green infrastructure and low-impact development techniques and strategies that may be applicable to rural Maricopa County residents. Although not exhaustive in its evaluation of GI/LID techniques, this report provides a framework in which a rural homeowner or a landowner can evaluate their residence and property for possible voluntary implementation of GI/LID techniques. The overall goals and objectives of this report are as follows:

- Define GI/LID strategies and highlight potential applications for a rural Arizona environment
- Promote use of stormwater as a valuable resource rather than being viewed as a nuisance or waste product
- Provide GI/LID methods that, slow, sink, and spread rainfall to maximize on-site infiltration
- Provide GI/LID techniques to assist in reducing potable water use for landscape irrigation and other outdoor uses
- Provide GI/LID techniques to assist in slowing and reducing erosion on residential properties
- Provide GI/LID techniques to assist in reducing the movement of sediment, nutrients, pollutants or debris from individual parcels into adjacent washes, arroyos, and roadways
- Provide GI/LID techniques and strategies for the above goals, while maintaining, or improving on, Rio Verde's rural community character and environmental health

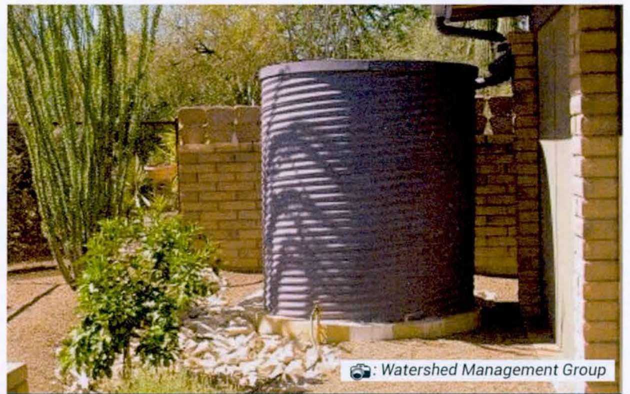
Historically, stormwater that was not absorbed into the soil (or used by surrounding vegetation) would typically flow as runoff into nearby washes, arroyos, creeks or streams. Human-induced changes to the Rio Verde area, such as vegetation removal, new roadways, rooftops, barns, and other impervious surfaces, are changing the water balance and the natural hydrology of the area. These modifications have resulted in less rainfall being absorbed naturally into the soil and an increasing stormwater runoff. By slowing the water and allowing it more time to be absorbed into the natural ground surface, GI/LID techniques offer an opportunity to help offset the impacts of increased imperviousness and can assist in maintaining portions of the pre-development hydrology of the area. GI/LID strategies include methods and practices that attempt to mimic natural processes where rain water can be slowed, collected, and delayed close to where it fell, allowing time for some of the rainwater to soak into the soil, feed surrounding vegetation, and eventually - over a long period of time - be filtered back into the ground water system, local aquifers, mimicking the pre-development drainage systems of the area.

The long term results of implementing GI/LID techniques can have direct and tangible benefits to individual land owners, but can provide benefits to the overall community through habitat preservation and enhancement, reduction in soil erosion and sediment transport, and air quality improvements.

What is Green Infrastructure (GI) ?

The U.S. Environmental Protection Agency (EPA) defines GI as "a cost-effective, resilient approach to managing wet weather impacts that provides many community benefits. While single-purpose gray stormwater infrastructure—conventional piped drainage and water treatment systems—is designed to move urban stormwater away from the built environment, green infrastructure reduces and treats stormwater at its source while delivering environmental, social, and economic benefits."

Conventional Arizona stormwater drainage and flood control systems typically involve a system of interconnected traditional gray infrastructure systems by managing runoff at its source (storm drains, channels, basins, and flood retarding structures). These capture, redirect, and transport stormwater to local outfalls or store the water in regional detention basins. These infrastructure systems, while effective, are costly to install (land and right-of-way purchases, materials etc.), expensive to maintain and operate, and do not offer additional multi-benefit opportunities. Several traditional storm drainage infrastructure alternatives were evaluated in the Rio Verde Area Drainage Master Plan. That plan, completed by the Flood Control District of Maricopa County in 2004, estimated the cost for traditional structural solutions to drainage issues to be between $86 million and $169 million.



Example of Above Ground Rainwater Tank

Green Infrastructure (GI) can be a cost-effective alternative approach to managing rain and stormwater runoff. The use of GI offers an opportunity to potentially reduce the size and complexity of the traditional gray drainage infrastructure systems through managing runoff at it source and reducing overall runoff volumes.

What is Low Impact Development (LID) ?

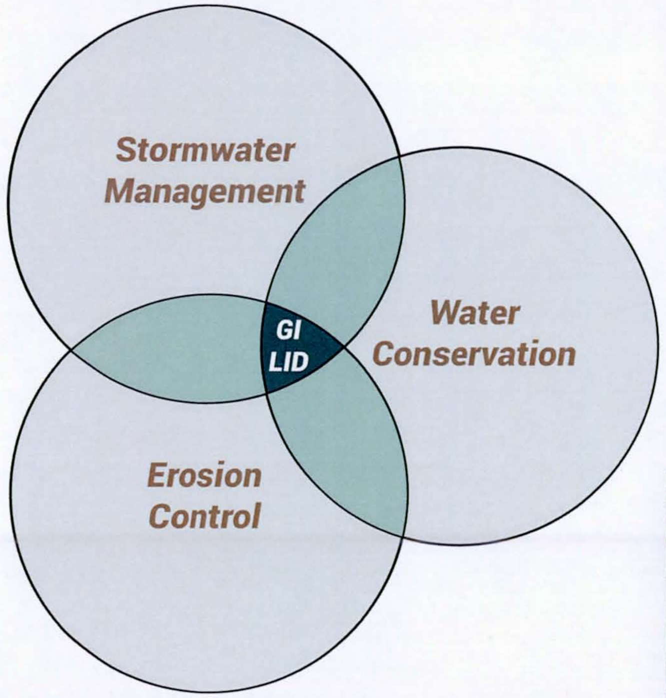
The EPA considers LID to be "a management approach and set of practices that can reduce runoff and pollutant loadings by managing runoff as close to its source(s) as possible."

The typical approach to managing stormwater runoff from streets and other urban areas revolves around the evaluation and use of existing traditional, gray infrastructure of curbs and gutters, catch basins, and storm pipes to capture and quickly divert stormwater runoff to local channels and detention basins or regional outfalls. The application of LID in urban areas considers the use of other techniques and alternative management approaches to divert stormwater runoff away from the typical curb collection and stormwater piping approach. These techniques emphasize diverting stormwater runoff into landscape areas through a variety of features and methods to allow the stormwater to be temporarily held, slowing runoff velocities and allowing the water to soak into the soil, where it can be cleaned of pollutants and sediment and utilized by surrounding vegetation. Reading lists, provided at the end of this report, provide additional resources for use and further reference and help to increase understanding of suburban/urban LID applications.

This suburban/urban LID approach to managing stormwater runoff in rural Arizona can often be challenging due to the lack of defined drainage infrastructure, which includes the concrete curb and gutters, properly sized storm drains, catch basins, and paved roadway surfaces found in typical urbanized environments. LID applications in rural areas, such as Rio Verde, have to address additional concerns including, but not limited to: addressing the area's irregular development patterns, unpaved/dirt roadways, runoff laden with sediment, braided washes, and higher densities of equestrian and ranching facilities. Applying LID techniques in these rural settings requires a broader evaluation of the area's overall drainage patterns, detailed review of individual site conditions, and the application of a more "bio-engineered/low-tech" stormwater management approach. This can be accomplished through the use of naturally occurring materials on each project site, such as: rock, fallen logs/green waste and the dedicated revegetation and stabilization of disturbed areas. The key element of LID use in a rural setting is to try and mimic a site's pre-development hydrology, which refers to the way in which stormwater is handled in a naturally vegetated area. LID use in a rural setting should attempt to slow, sink, and spread out rainfall and stormwater runoff as close to the source as possible. By implementing LID principles and practices on a site-by-site basis, stormwater can be managed in a way that reduces the impact of built, and often impervious, features on individual site hydrology, and promotes the natural slow movement of water within an ecosystem or watershed. Applied on a broad scale, LID can help maintain, or partially restore, a watershed's ecological and pre-development hydrologic functions.

What is the Difference Between GI and LID?

The terms GI and LID are often used interchangeably, with the difference between the two terms being mostly one of scale. GI generally refers to a broader, 'big picture' view of a watershed and focuses on coordinated efforts to utilize these practices along with land conservation and the preservation of open space and natural wash corridors. GI focuses on the re-creation of systems that mimic the natural hydrologic processes and aids in an alternative approach to stormwater management. LID can be seen as a subset of practices/approaches within the larger GI approach. LID refers to designing and implementing stormwater management practices at a more detailed level on a lot-by-lot basis. LID can be employed at this site-level to control stormwater runoff and to replicate the pre-development hydrology of the site on a much more refined scale by collecting, slowing, sinking, and spreading rainfall.



The Venn diagram to the left graphically shows how GI/LID techniques share key attributes with Stormwater Management, Water Conservation and Erosion Control. GI/LID techniques hit the "sweet spot", providing assistance in all three of these water resource management areas when properly implemented and maintained.

A 5,000 square foot residential roof can generate over 2,300 gallons of rainwater runoff during a typical 0.79" Arizona rainfall event. What are you doing with that water?

The Rainfall

- An average rain event in the Rio Verde Area is 0.79 Inches.
- The Rio Verde Area average precipitation per year is approximately 10.7 Inches.*
- The Rio Verde Area average precipitation per year during Arizona's summer monsoon season is 2.66 Inches.*

*META Stats FCDMC McDowell Mountain Park Rain Gage Data

What if rural applications of GI/LID techniques enhanced ecological function, lowered dependence on potable water for outdoor uses, and served as an asset to the homeowner rather than a negative environmental impact on your neighbor?

The Area

- Elevation of the area rises from around 1,700 feet above sea level near the Verde River to over 2,700 feet above sea level at the western edge of the Rio Verde study area.*
- There are 10 major soil association types in the Rio Verde planning area. Alluvial soils are prevalent in the Rio Verde area impacting structure and septic system designs.*
- The study area is characterized by wide, essentially flat, alluvium filled valleys surrounded by rugged, low relief, mountain ranges.*

* Rio Verde Foothills Area Plan

What GI/LID techniques (active and passive collection systems) can rural Arizona residents and land owners implement and maintain? What will they cost? How long will they last?

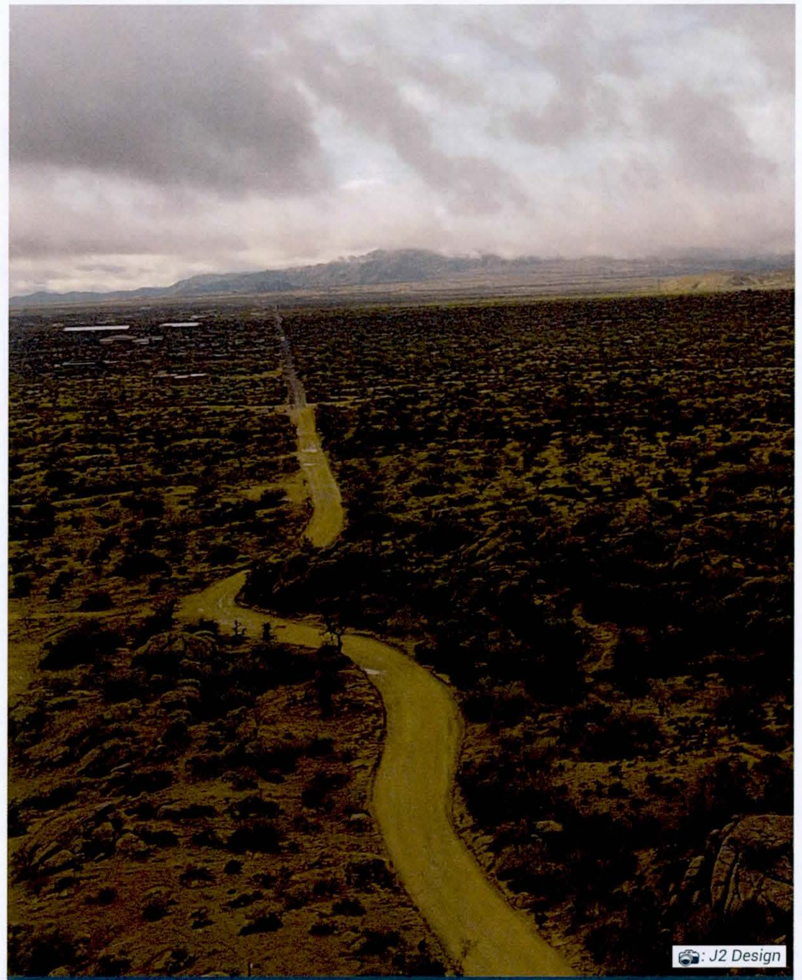
GI/LID Techniques

Delayed Reuse of Rainwater
- Above Ground Rain Tank
- Below Ground Rain Tank

Direct Rainwater Reuse
- Rain Gardens
- Bio-Swales
- Terraces
- Check Dams
- Infiltration Trenches
- Labyrinth Infiltrator
- Spiral Infiltrator
- Zuni Bowls

Part 2 Study Area Context

The Rio Verde Area is located in northeast Maricopa County, Arizona and, for the purposes of this study, is generally bounded by the Tonto National Forest on the north, the McDowell Mountain Regional Park to the south, the Verde River to the east and approximately 136th Street alignment to the west (Figure 1 - Rio Verde Planning Area). The study area is composed of braided, ephemeral, desert washes, a natural sloping terrain, and large lot single-family residential development.



Aerial View of 136th Street Looking South - Rio Verde

This region of Maricopa County is mostly privately-held land comprised of single family residential lots of one acre or larger, many with equestrian facilities. County zoning in this area is both Rural-43 and Rural-190. Rural-43 permits one single-family dwelling per minimum lot area of 43,560 square feet (one acre) while Rural-190 permits one single-family dwelling per minimum lot area of 190,000 square feet (4.36 acres). Both of these zoning districts allow for residential, agricultural, recreational, and institutional uses.

The majority of roads in the project area are graded and unpaved with the exception of Rio Verde Drive and portions of: North 136th Street, 139th Place, East Desert Vista Trail, North 144th Street, North 150th Street, North 152nd Street, North 160th Street, and North 172nd Street (all of these roadways are north of Rio Verde Drive). Paved streets within the master planned communities, or newer developments in the area, have not been included here.

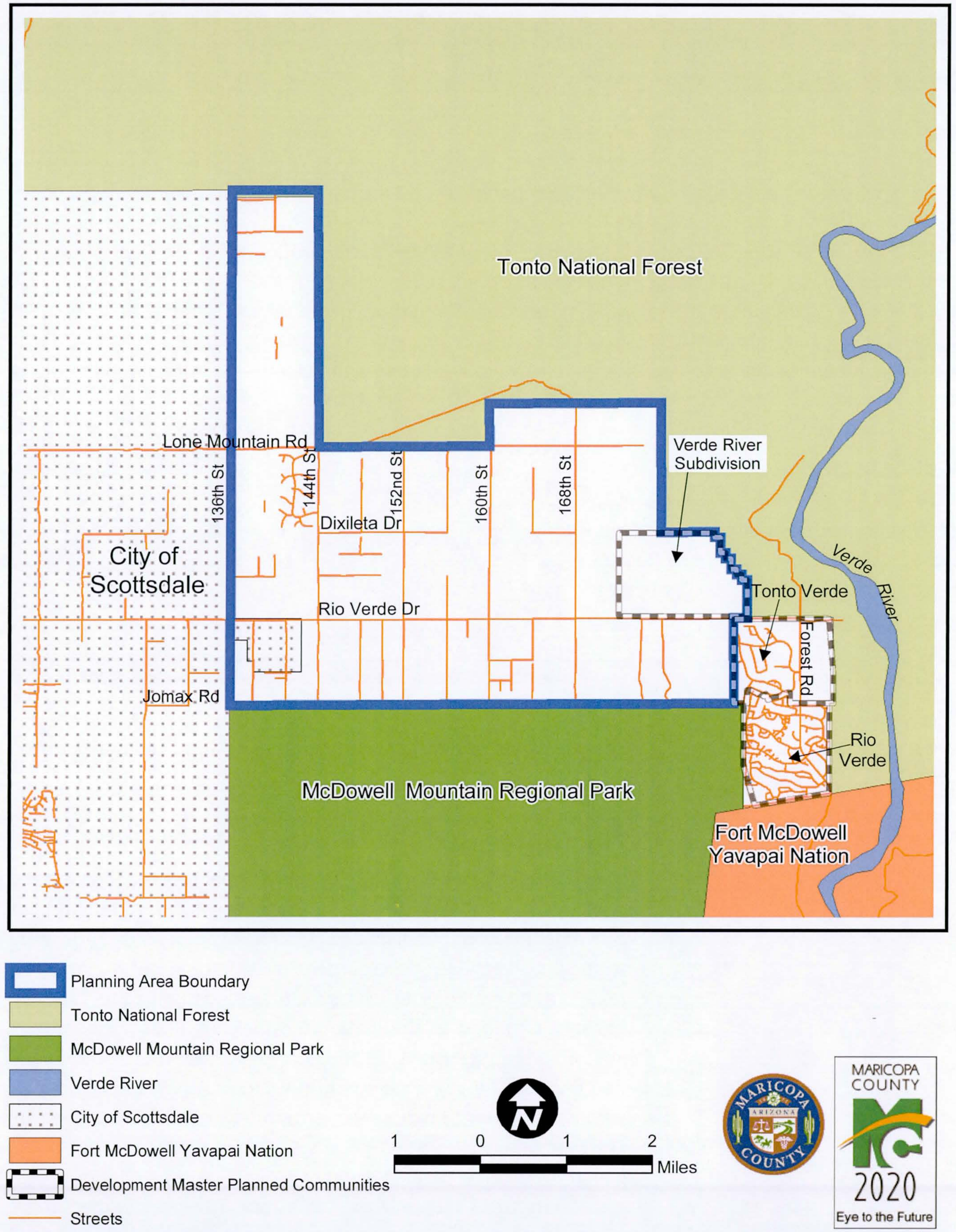


Figure 1 - Rio Verde Planning Area

Previous Studies in Rio Verde Area

The Rio Verde Area has been studied with several published reports, including but not limited to:

(1)-"2005 Rio Verde Foothills Area Plan" prepared by Maricopa County Planning Department (reference:https://www.maricopa.gov/2336/Rio-Verde-Foothills-Area-Plan)
(2) - "2004 Rio Verde Area Drainage Master Plan" prepared by Maricopa County Flood Control District 2004 Rio Verde Area Drainage Master Plan (available upon request from FCDMC)
These reports are referenced in the following paragraphs by number designation (1) and (2).

These studies identified the following issues relative to water use and stormwater impacts in the study area:

Potable Water Delivery Truck In Rio Verde Community

Water Supply

Water supply for all residential uses in the project area comes from either groundwater sources or is hauled in water by private water supply companies. There are no public water delivery systems in place for non-subdivision residential units. (1)

Water Availability

Residents report that water is generally less available and drilling more expensive in the eastern portion of the planning area than in the western area. (1)

Rio Verde Foothills Area Plan - Cover

Development Patterns

Ongoing development in the Rio Verde Area is comprised mostly of one-acre lot split single family residences and a limited number of master planned subdivisions. The County has limited authority to regulate single lot development outside of subdivisions. As a result, road crossings, stock tanks, diversions, and other human-induced changes to the watershed have resulted in increased soil erosion, sediment deposition, and the redistribution of flooding and erosion hazards in the area. Activities associated with development such as vegetation removal, soil compaction, and the introduction of impervious surfaces like roof tops, paved roads, and parking areas will likely increase flooding and erosion hazards in the area in the future. The cumulative impact of lot splitting and single lot development under existing limited regulation has the potential to exacerbate these problems. (2)

Rainfall Patterns

Rainfall occurs predominantly in one of two seasons; the winter rainy season is defined as October through the end of March; and the summer monsoon season is defined as beginning on June 15th through the end of September (See Figure 5). Winter rainfall events tend to be characterized by longer duration, lower intensity cyclonic storms, while the summer events are usually thunderstorms with short duration, high intensity rainfall. Occasionally, tropical storms or hurricane remnants cross the area in the late summer and early fall. These storms can generate moderate duration, relatively high intensity rainfall. During either of these rainy seasons, stormwater runoff may occur, resulting in flood inundation, erosion, and sediment transport across the ground plane. (2)

Topography/Slope

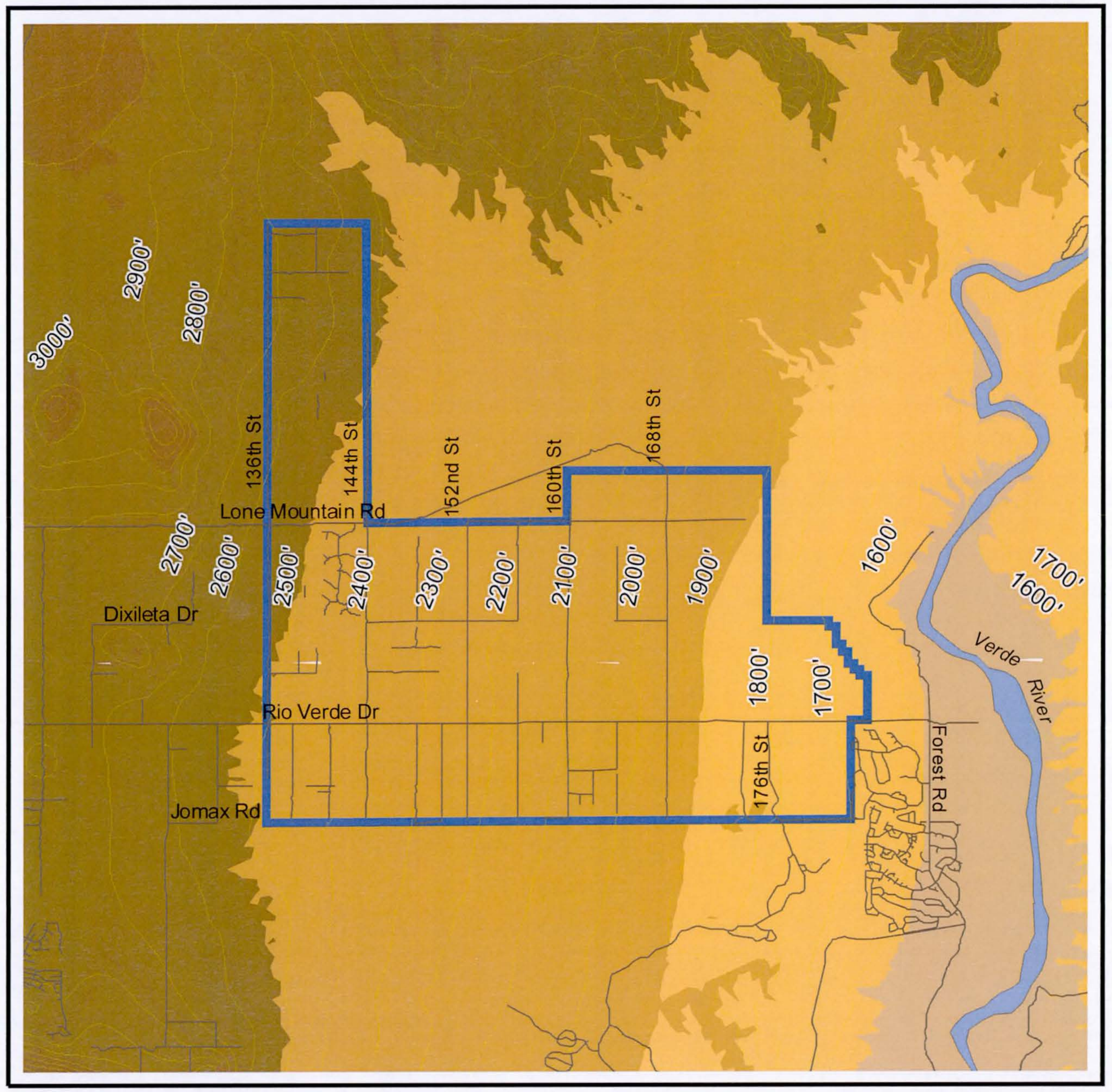
The topography/slope of the area is characterized by gently sloping terrain from west to east toward the Verde River. (Refer to Figure 2 - Elevation). This graphic depicts general elevations within the planning area, ranging from less than 1,700 feet above sea level near the Verde River to 2,700 feet above sea level near the northwestern portion of the study area. The study area can be characterized as a broad, gently sloping valley with Asher Hills in the southeast corner as the only significant topographical feature. The study area slopes approximately three percent (3%) over nearly six miles as measured from west to east.

Rio Verde Area Drainage Master Plan - Cover

Geology/Soils

The Rio Verde Foothills planning area lies within the Sonoran Desert region of the Basin and Range geographic province that has been formed over billions of years. The region is characterized by wide, essentially flat, alluvium filled valleys, surrounded by rugged, low relief mountain ranges. The geologic record of this area is vast. The geology and weather of the area have sculpted the escarpments, giant boulder outcrops, vast mountain ranges and alluvial deposited soils evident in the existing Sonoran Desert landscape.

The description of the soils of the area was well encapsulated in the "Rio Verde Foothills Area Plan" which provided an overview of the soils of the area. Soil types are categorized by associations. Soil associations, typically named for the major soil it represents, describe a group of soils that occur in a repeating pattern and usually consist of one or more dominant soil types, along with at least one minor soil type. There are ten major soil associations in the Rio Verde Foothills study area (Figure 3 Soil Associations). (1)

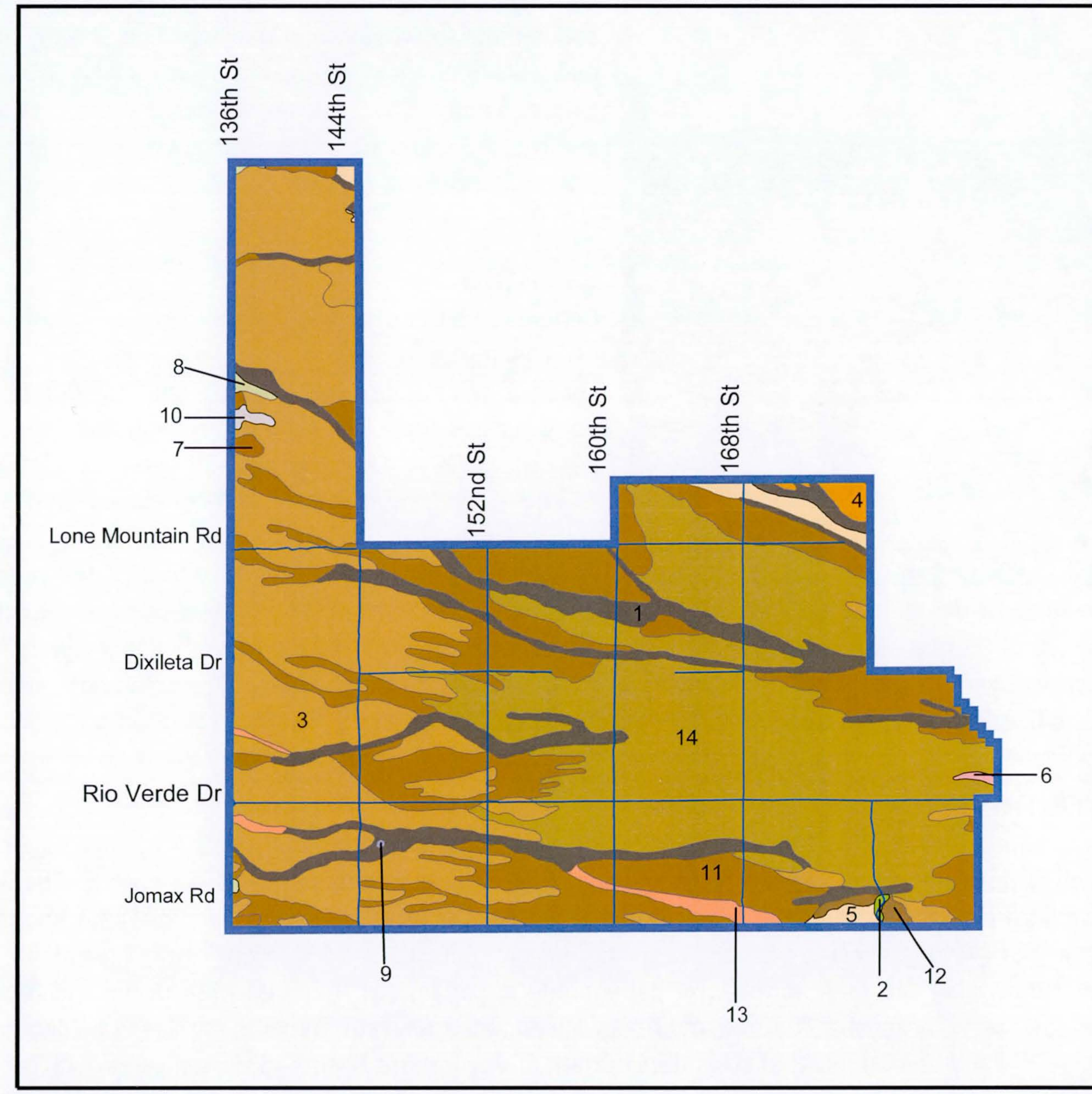


Arterial Streets
Planning Area Boundary
Contour Lines

1 0.5 0 1 2 Miles

MARICOPA COUNTY 2020 Eye to the Future

Figure 2 - Elevation



Soil Association

1 Anthony-Arizo complex
2 Carefree cobbly clay loam
3 Eba very gravelly loam Series
4 Eba-Continental-Cave association
5 Eba-Pinaleno complex Series
6 Gila fine sandy loams
7 Gran-Wickenburg complex
8 Gran-Wickenburg-Rock outcrop complex
9 Lakes, ponds, reservoirs - perennial
10 Nickel-Cave complex
11 Pinaleno-Tres Hermanos complex
12 Torriorthents
13 Tres Hermanos-Anthony complex
14 Vado gravelly sandy loam

0.5 0 0.5 1 Miles

MARICOPA COUNTY 2020 Eye to the Future

Figure 3 - Soils Associations

Typical Sandy Wash Bottom - Rio Verde

The soils that have developed in this area are highly susceptible to erosion and gullying. The underlying granite bedrock weathers to pebble sized pieces with smaller sands, silts, and some clays. These weathered sediments are highly erosive and channels within this zone are subject to some lateral and vertical erosion. (2)

Climate

Generally, climate in the planning area is similar to the Phoenix metropolitan area, with mild fall, winter, and spring seasons and hot, dry summer weather. Any differences that do occur are due to the higher elevation and its location on the urban fringe. Over the past 30 years, precipitation has averaged 10.7 inches per year compared with only 8.29 inches for Phoenix. Precipitation can be three times greater in wet years than in dry years. Most of the precipitation occurs in the winter months and in July, August, and September. From mid to late summer, moist air from the Gulf of Mexico influences weather patterns. From November through March, the region is impacted by storm systems from the Pacific Ocean and the northwest United States. Storms in both seasons can create flooding and drainage problems based on their intensity and duration. (1)

Groundwater

The primary source of water in the Rio Verde Foothills area is groundwater; the withdrawal and use of which is governed by the 1980 Arizona Groundwater Management Act (ARS, 45 – 451). The Rio Verde Foothills area is within the Phoenix Active Management Area (AMA) where the Arizona Department of Water Resources (ADWR) oversees groundwater rights; prohibits the development of new farmland; requires new subdivisions to have long-term, dependable supplies; and requires measuring and reporting of groundwater withdrawals. Assured and Adequate Water supply requirements are based on demonstration of a 100-year water supply that considers current and committed demand, as well as growth projections. There are seven criteria for the Assured Water Supply Program which includes the availability of physical, legal, and continuous water. The Assured Water Supply Rules are designed to protect groundwater supplies within each Active Management Area (AMA) and to ensure that people purchasing or leasing subdivided land within an AMA have a water supply that is adequate with respect to quality and quantity. This means the amount of groundwater pumped from AMA aquifers on an average annual basis must not exceed the amount that is naturally or artificially recharged. These provisions were enacted to help the Phoenix area achieve safe-yield by 2025. Safe-yield would be achieved when no more groundwater is being withdrawn than is being annually replaced.

ADWR divides wells into two reporting categories: exempt and non-exempt. Exempt wells are those with a pump capacity of 35 gallons per minute or less and are exempt from ADWR reporting requirements. These smaller wells are generally for home use or livestock watering purposes. Non-exempt wells are those with a pump capacity of greater than 35 gallons per minute and are required to report annual pumpage if within an AMA. Most non-exempt wells are used for agricultural irrigation or belong to a city, town, or private water company.

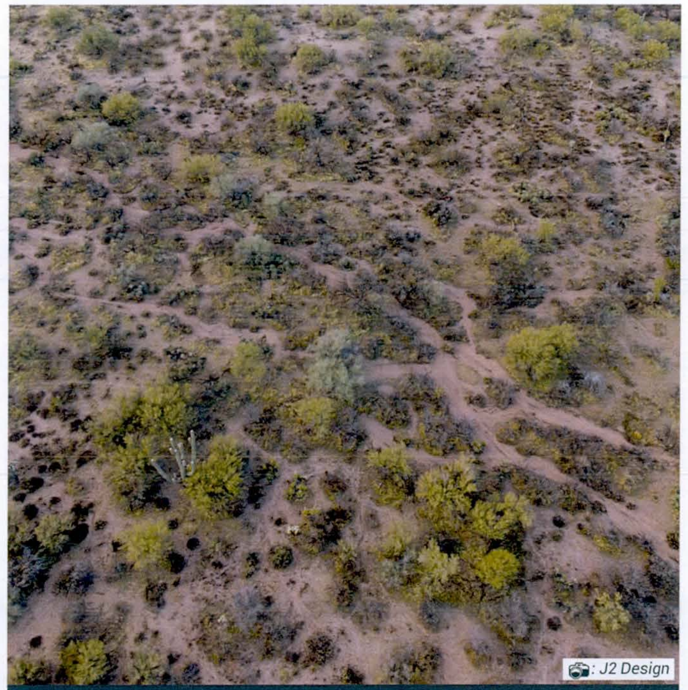
Currently, individual wells are the largest users of groundwater in the study area. In 2003, approximately 570 acre-feet of groundwater was withdrawn by all users, and projections for 2020 indicate that over 2,100 acre-feet could be pumped, not including the Vista Verde development.

ADWR conducted a depth to bedrock study in 2000 that revealed groundwater conditions in the Rio Verde Foothills area. A hydrologic boundary is estimated to occur near 136th Street, where hard rock gives way to a trough-like structure filled with decomposed and fractured granites. Groundwater tends to accumulate in this sediment-filled trough. A clay sequence forms a barrier to groundwater flow between the shallow alluvial aquifer along the Verde River and decomposed and fractured granites that exist north and east of the McDowell Mountains (ADWR, 2001). Groundwater is difficult to find east of this area until the clay transitions to alluvium near the Verde River. In addition, ADWR estimates two cones of depression are beginning to form within the trough. Lowering of the groundwater table occurs in times of prolonged drought and in response to significant withdrawal/pumping. The trough and cones of depression are replenished by rainfall and sheet flow that wash across the desert and runoff from the hard rock northwest of the trough.

The information for the groundwater text above was compiled from a combination of sources: The Rio Verde Foothills Plan, the Arizona Department of Water Resourced web site, the Water Resource memo, and the ARS 11-804.B.3 review memo both developed by J2 for Maricopa Planning.

Aquifer and Geology Illustrative Cross Section

These geologic features and soil compositions have a direct impact on the cost of installation and maintenance, and on GI/LID effectiveness. The varying depth of the deposited alluvium soils, their compositions, and any associated rock outcroppings or depth to bedrock, can influence how effectively these GI/LID techniques manage rainwater and their corresponding percolation rates. This is best illustrated in Figure 4 (Illustrative Geologic Cross Section), which is synthesized from information gathered in review of the "Rio Verde Area Drainage Master Plan," the "Rio Verde Foothills Area Plan," and from existing ADWR well data. This illustrative graphic shows that there are pockets of impervious geologic formations with potential to hold some groundwater in specific and limited areas within the Rio Verde study area. These pockets are not interlinked and their random distribution and interrelationships result



Dense Vegetation Along Braided Wash - Rio Verde in a range of outcomes within the study area. Some locations have access to these groundwater holdings through drilling and well pumping, while other areas remain dry or require excessive well depths to reach groundwater not related to these pocket groundwater holding areas. The random nature and diversity of these ground water pockets can result in disparity between adjacent land owners and their access to ground water supply.

The effectiveness of any GI/LID technique is influenced, in part, by the combined effects of geology and soils. The geology of any subsurface formations that could result in little to no infiltration, could result in ponding water that fails to percolate in a reasonable (36 hour) period. Investigating subsurface soil layers and compositions will influence the location and the ultimate design of any GI/LID technique. Land owners and residents are encouraged to consider evaluation of their soils by a qualified geotechnical engineer with experience in the Rio Verde area before embarking on the use of any of these GI/LID techniques.

The surface soils, from on-site field observations, appear to be granular and readily transported by stormwater runoff. The result is the potential for heavy siltation when impediments such as GI/LID diversion techniques are encountered within a typical rainwater flow regime. The effect from these granular deposits is the potential for additional maintenance to keep several of the GI/LID techniques viable and effective. Soil stabilization should remain a key objective in any effort.

Typical Well Pump Enclosure - Rio Verde

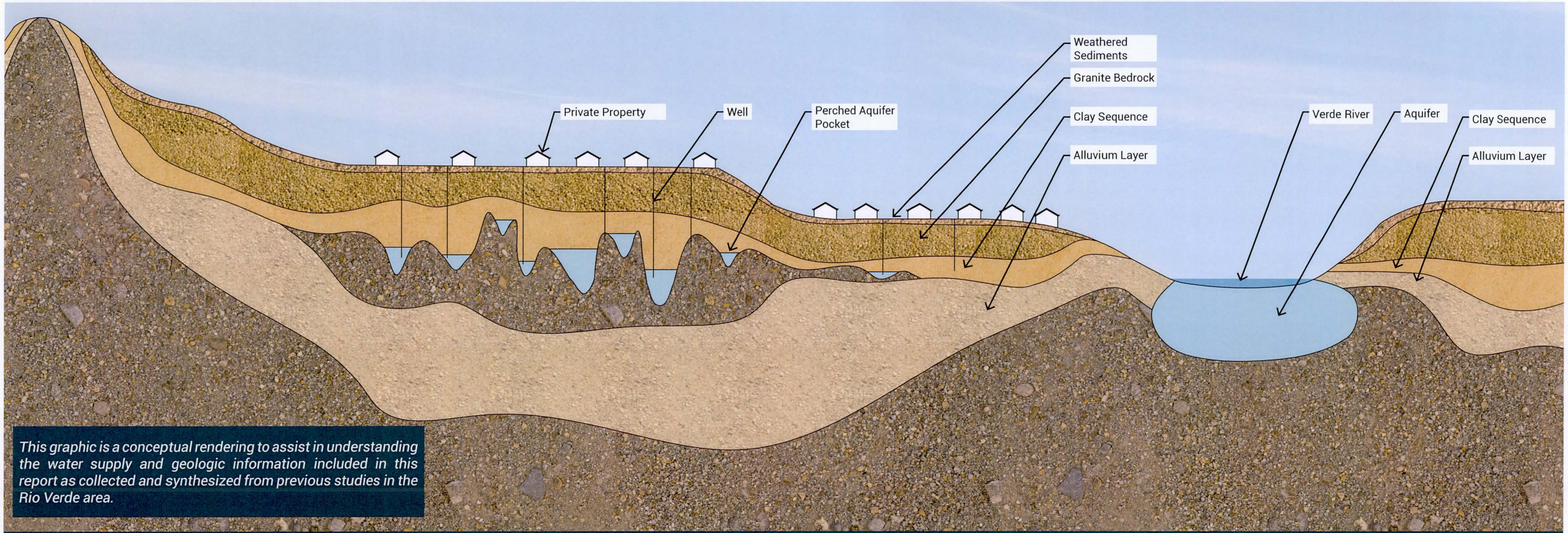


Figure 4 -Aquifer and Geology Illustrative Cross Section

Part 3 - Applications of GI/LID Techniques for Rural Arizona and Arid Lands

The application of GI/LID techniques for rural Arizona and arid lands, in general, carries multiple unique site considerations that need to be addressed. These include: distributed, unregulated development patterns, stormwater sheet flows laden with sediment, equestrian facilities, increases in non-permeable pavements and roof tops, and sites punctuated and crossed by natural drainage ways. To adequately and effectively address GI/LID techniques in this unique setting, will require that each site be evaluated on a case by case basis, including but not limited to the following:

1. Identify the stormwater "Runoff Creators" (See Table 1) on your individual property. These are the areas, or structures, that will create stormwater runoff. They will vary in the amount and velocity of runoff and sediment that is carried based upon their permeability, site location, slope and material.
2. Identify if your individual property and your budget can accommodate an "Active Stormwater Collection System" to reduce potable water use for landscape Irrigation. These "active" systems provide for the direct collection of rainwater into a cistern, tank or rain barrel for later distribution as part of a landscape irrigation system or other non-potable water use. An "active" system requires evaluation and analysis of your non potable water needs and potential uses (landscape irrigation, construction water, etc.) to determine how to appropriately size your system to be the most effective for your individual needs.
3. Identify if your individual property and your budget can accommodate a "Passive Stormwater Collection System". "Passive" systems would be the design and installation of rain gardens, bio-swales, terracing, check dams, infiltration trenches, or Zuni bowls placed within your landscape areas. Evaluating your specific site for a "passive" system will require a site assessment to include: current and potential site development strategies, slope conditions, location of existing vegetation, impacts to existing washes, roadway and driveway locations, and adjacent development potential.
4. Identify the potential costs for installation and maintenance with each "Active" or "Passive" Stormwater Collection System.

First Flush

Pollutants deposited on exposed areas of impervious surfaces can be dislodged and entrained/collected by the rainfall runoff process. Usually the stormwater that initially runs off an area will be more polluted than the stormwater that runs off later - after the rainfall has 'cleansed' the catchment area or surface. Stormwater containing this higher initial pollutant load is called the 'first flush'.

The capture and control of this "first flush" of stormwater provides an opportunity for controlling stormwater pollution. "First flush" collection systems such as rain gardens, bio-swales, terraces, and infiltration trenches can be employed to capture and isolate this runoff as close to its source as possible. The use of GI/LID techniques in concert with other stormwater policies will help to advance water harvesting potential, improve water quality, and reduce the impact of increased run-off downstream.

GI/LID techniques have been shown to be effective at collecting and treating this "first flush" rainfall runoff through a series of natural biological processes that make these techniques and treatments of "first flush" rainfall capture systems so successful and viable.

The Flood Control District of Maricopa County (FCDMC) established a minimum level of control for stormwater pollution prevention practices that includes a "First Flush" policy. This policy (Policy 3.6.6 of the Drainage Policies and Standards for Maricopa County, Arizona) consists of retaining or treating the first 0.5 inch of direct runoff from a storm event. This first flush policy was established by the FCDMC and is the result of ARS 48-3622, where the District may require any action or impose any restriction that the District considers reasonably necessary to meet the District's obligations, if any, to comply with local, state or federal water quality laws.

Existing Rural GI / LID Applications - Rio Verde

Table 1

Runoff Creators	Amount of Runoff Created	Solutions – Base Components: Active Collection (Delayed Reuse)		Passive Collection (Direct Reuse)							
		Above Ground Tank	Below Ground Tank	Rain Garden	Bio-Swale	Terrace	Check Dam	Infiltration Trench	Labyrinth Infiltrator	Spiral Infiltrator	Zuni Bowl
On Private Property											
1.Roof	💧💧💧	X	X	X	X	X	X	X	X	X	X
2. Driveway (paved)	💧💧💧			X	X	X	X	X	X	X	X
3. Driveway (soft surface)	💧💧			X	X	X	X	X	X	X	X
4. Patio/ Sidewalk (paved)	💧💧💧			X	X	X	X	X	X	X	X
5. Yard / Lot (native desert)	💧			X	X	X	X	X	X	X	X
6. Yard / Lot (inert mulch)	💧💧			X	X	X	X	X	X	X	X
7. Horse Arena / Stock Pen	💧💧			X	X	X	X	X	X	X	X
8. Road (paved)	💧💧💧			X	X	X	X	X	X	X	X
9. Road (unpaved)	💧💧			X	X	X	X	X	X	X	X

Rainwater Runoff Legend

💧	Low Level of Runoff / High Infiltration
💧💧	Moderate Level of Runoff / Partial Infiltration
💧💧💧	High Level of Runoff / No Infiltration

Definition of Terms

Runoff Creators - These are the areas or structures located on your property that will create stormwater runoff. They will vary in the amount and velocity of runoff and sediment that is carried based upon their permeability, site location, slope, and material.

Inert Mulch – A layer of decomposed granite or rock applied to the surface of soil and is considered a permanent surface treatment.

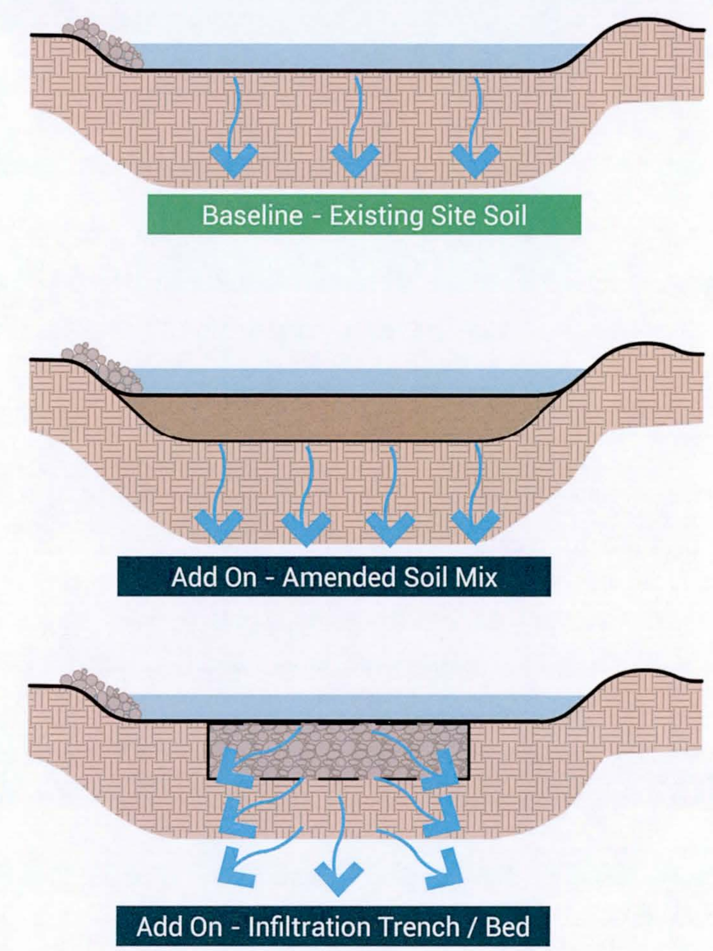
Active Collection –Active systems include direct collection of stormwater from the runoff creators into a cistern, tank or rain barrel for later use as part of a landscape irrigation system or other non-potable water use.

Passive Collection System - Passive systems include rain gardens, bio-swales, terracing, check dams, infiltration trenches, or Zuni bowls placed in landscape areas that result in the slowing, spreading, and absorption of rainwater into the soil and subsequent use by surrounding vegetation.

Table 2

Accessory Modifications

Infiltration
Baseline - Existing Site Soil
Add On - Amended Soil Mix
Add On - Infiltration Trench / Bed



Annual rainfall for the Rio Verde Community can vary, but on average is approximately 10.7 inches per year. This value has been calculated from four FCDMC rain gage stations that have been recording data in close proximity to Rio Verde area for the last 30 years (Figure 6). The Rainfall Event (Table 4) is a summary of the statistical rainfall data for the Rio Verde Community. Prior to designing or laying out your GI/LID feature, refer to this data to determine what size storm event you will use for your calculations. If you were to design your feature to capture all 10.7 inches of annual rainfall your feature would be unnecessarily large and may be cost and size prohibitive. Therefore, it is more practical to design your feature to accommodate the amount of rain that is likely to fall in an average storm event. This way you will get the benefit of mitigating runoff from the majority of storms in the Rio Verde area and you will spend less money by not oversizing the feature.

Table 3 - Recurrence intervals and probabilities of occurrences

Rainfall Event	Probability of occurrence in any given year	Percent chance of occurrence in any given year
100	1 in 100	1
50	1 in 50	2
25	1 in 25	4
10	1 in 10	10
5	1 in 5	20
2	1 in 2	50

So where do you start?

In the Rio Verde Community, we recommend using 0.79" for calculations to assist you in designing and locating your GI/LID feature. This number represents the amount of rainfall that 90% of storm events in the Rio Verde area produce. Utilizing this number will help ensure that your GI/LID feature will be large enough to capture rain from 90% of storm events that occur in the Rio Verde area. Depending on your circumstances, you may find that you would like to collect more or less water - so we have provided data for additional storm sizes in Table 4. However, it is important to clarify what the storm events identified in the table actually mean. The first three values - 80%, 90%, and 95% - refer to the statistical average of storm events that may occur in the area and provide the corresponding rainfall depths, as calculated from almost 30 years of data from FCDMC rain gages. The next set of values - 2 Yr, 5 Yr, etc. - refer to the probability that a storm with the corresponding rainfall value (in inches) will occur within a given year. For example, a 100-year storm has a 1% chance of occurring each year. This does not mean that the storm occurs only once every 100 years. The Recurrence Intervals and Probabilities of Occurrences Table 3, provides statistical averages and percentage of occurrence in any given year, as determined by the United States Geological Service (USGS).

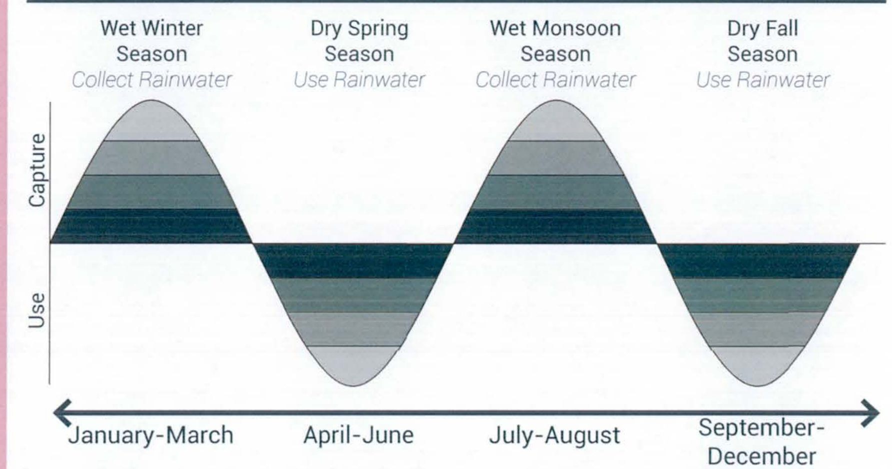
The nature of floods and their related storm events in the Rio Verde area and in the Desert Southwest tend to be more flash events where rainfall depths and durations are increased. These types of events are difficult, if not impossible, to contain or regulate solely through the use of GI/LID techniques, and tend to require larger investments in drainage infrastructure due to the scale and complexity of the area and these flash occurrences. However, GI/LID still remains a viable 'tool' in the flood control/stormwater toolkit to help address smaller local stormwater flows, while providing additional community benefits.

Table 4 - Rainfall Event

This data is based on the average 6 hour storm event

Rainfall Event	Depth of Rainfall Event (Inches) or Less
80%	0.51
90%	0.79
95%	1.10
2 Yr.	1.44
5 Yr.	1.82
10 Yr.	2.13
25 Yr.	2.55
50 Yr.	2.88
100 Yr.	3.22
500 Yr.	4.03

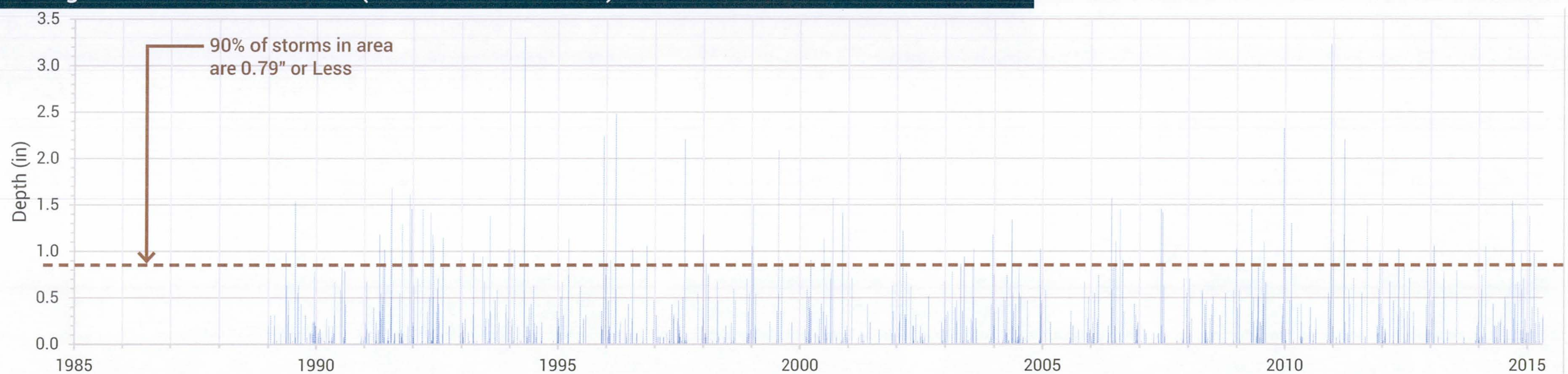
Figure 5 - Bi-Annual Rainfall

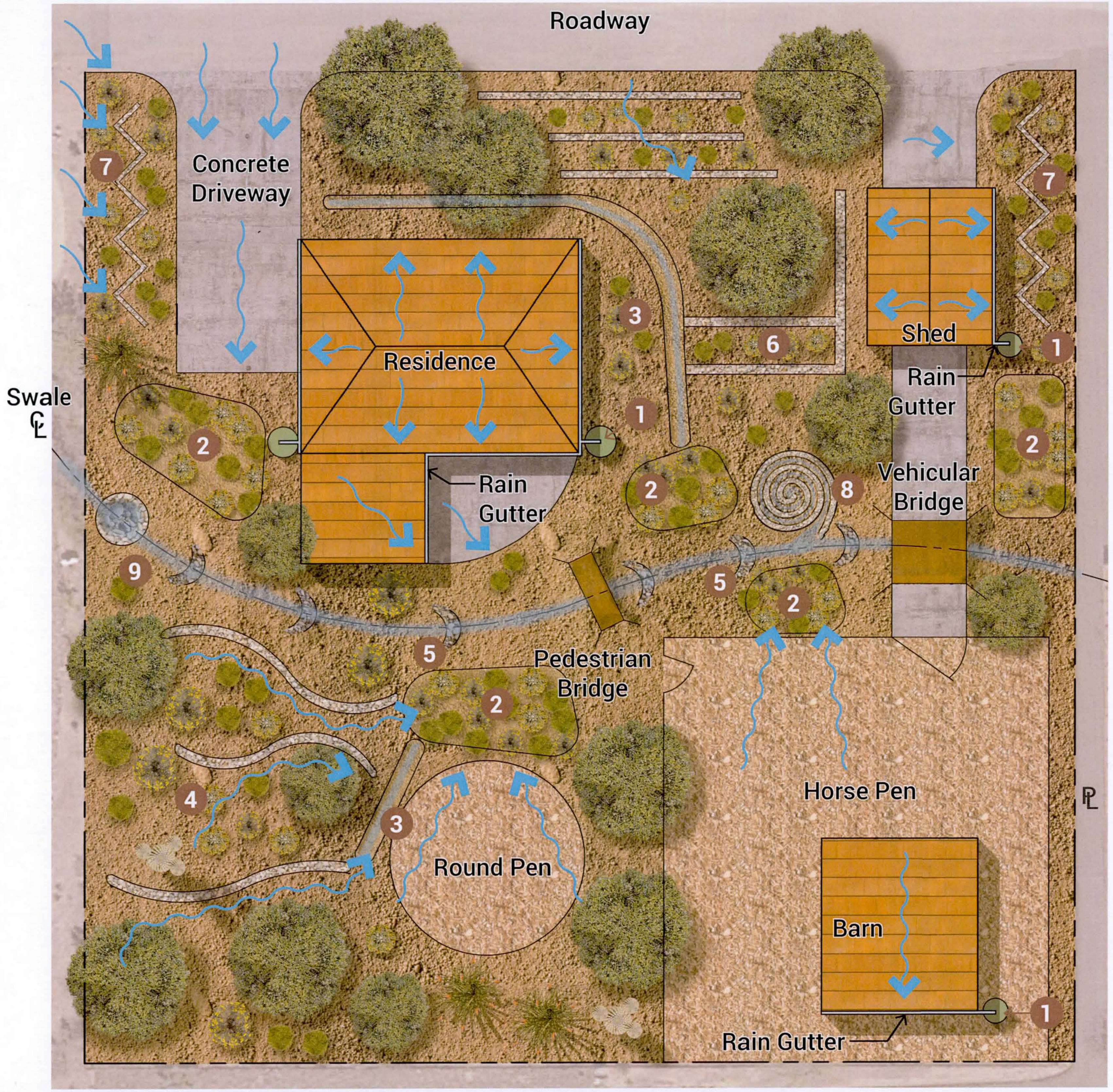


The figure above illustrates the seasonal and cyclical opportunities associated with Arizona's bi-annual rainfall seasons and their ability to be utilized as a means of borrowing the rainfall during the wet cycles and reusing that water during the dryer cycles to water landscape and other non-potable water uses.

Figure 6 - Rio Verde Rainfall (All Events Since 1989)

This figure represents the varied daily precipitation depths for storms that have been recorded in the Rio Verde Area. The flash rainfall events that result in greater depths are depicted by the taller peak events. This data collected over a 30 year period of time in the Rio Verde Area provides a statistically valid basis from which to determine average rainfall depths associated with this area. The data used to create this figure was collected from Maricopa County Flood Control District Official Precipitation Records for the rain gages at:
Asher Hills (Gage ID # 75500)
McDowell Mountain Park (Gage ID # 75800)
Fraesfield Mountain (Gage ID # 76200)
http://alert.fcd.maricopa.gov/alert/Rain/FOPR/





Opportunities for GI/LID Techniques on a Typical One Acre Lot

How much rainwater could be collected from your existing lot ?

In order to determine the amount of rainwater capture that can be potentially collected from your on-site structures (House, Barn, Shed, etc.), other impervious surfaces (concrete driveways, patios) or natural open space, the following items will need to be assessed:

1. Catchment area in square feet (width x length)
2. Average yearly rainfall for Rio Verde has been provided on the tables within this report. We suggest using 0.79 inches as a reasonable approach.
3. Runoff coefficient for the surface material that the rainwater is falling on (Refer to Runoff Coefficient Table below)

Once those items above have been determined, plug them into the formula below:

Annual rainfall in inches X .623 conversion factor X catchment area X runoff coefficient = Gallons of water collected

In the Rio Verde community, we recommend using 0.79" for calculations to assist you in designing and locating your GI/LID feature. 90% of storm events in the Rio Verde area are less than or equal to this rainwater value. Using this number will help assure that your GI/LID feature will be large enough to capture rain from 90% of storm events that occur in the Rio Verde area. Depending on your circumstances, you may find that you would like to collect more or less water.

GI / LID Techniques

1. Rainwater Tank
2. Rain Garden
3. Bio-Swale
4. Terrace
5. Check Dam
6. Infiltrator Trench
7. Labyrinth Infiltrator
8. Spiral Infiltrator
9. Zuni Bowl

Stormwater Flow

Material	*Runoff Coefficient Rate*
Roof Structure	.95
Pavement	.95
Landscaping	.5
Horse Pen	.35
Vegetable/Flower Garden	.35

Rainwater Catchment Opportunities - Barn

A Example Using a 50' x 55' Barn as the Catchment Area :

0.79	X	0.623	=	0.492
Average Rainfall Event For Rio Verde (in Inches)		Conversion Factor From Inches to Gallons		Gallons Per Square Foot

Now take the gallons per square foot and multiply it by the square footage of catchment area to determine the total yield of harvested rainwater in gallons per the suggested 0.79 inch storm event

0.492	X	2,750	=	1,353
Gallons Per Square Foot		Square Footage of 50' x 55' Barn Catchment Area		Gross Gallons of Rainfall Per .79" Storm Event

Once the gross gallons of rainfall per year has been determined we need to multiply it by the coefficient rate of the roof material. In this example the roof is metal which has a coefficient rate of .95

1,353	X	0.95	=	1,285
Gross Gallons of Rainfall Per .79" Storm Event		Structure Coefficient		Total Yield of Harvested Water in Gallons During Typical .79" Storm Event

Suggested Minimum Tank Size 1,500-2,500 Gallons

Rainwater Catchment Opportunities - Concrete Driveway

B Example Using a 40' x 95' Concrete Driveway

0.79	X	0.623	=	0.492
Average Rainfall Event For Rio Verde (in Inches)		Conversion Factor From Inches to Gallons		Gallons Per Square Foot

Now take the gallons per square foot and multiply it by the square footage of catchment area to determine the total yield of harvested rainwater in gallons per the suggested 0.79 inch storm event

0.492	X	3,800	=	1,870
Gallons Per Square Foot		Square Footage of 40' x 95' Concrete Driveway Catchment Area		Gross Gallons of Rainfall Per .79" Storm Event

Once the gross gallons of rainfall per storm event has been determined we need to multiply it by the coefficient rate of the driveway material for our example the driveway is concrete which has a coefficient rate of 0.95

1,870	X	0.95	=	1,776
Gross Gallons of Rainfall Per .79" Storm Event		Concrete Runoff Coefficient		Total Yield of Harvested Water in Gallons During Typical .79" Storm Event

Suggested Minimum Rain Garden Size : 242 Cubic Feet (22' x 22' x 6" Deep)

Rainwater Catchment Opportunities - Round Pen

C Example Using a 62' Diameter Round Horse Pen as the Catchment Area :

0.79	X	0.623	=	0.492
Average Rainfall Event For Rio Verde (in Inches)		Conversion Factor From Inches to Gallons		Gallons Per Square Foot

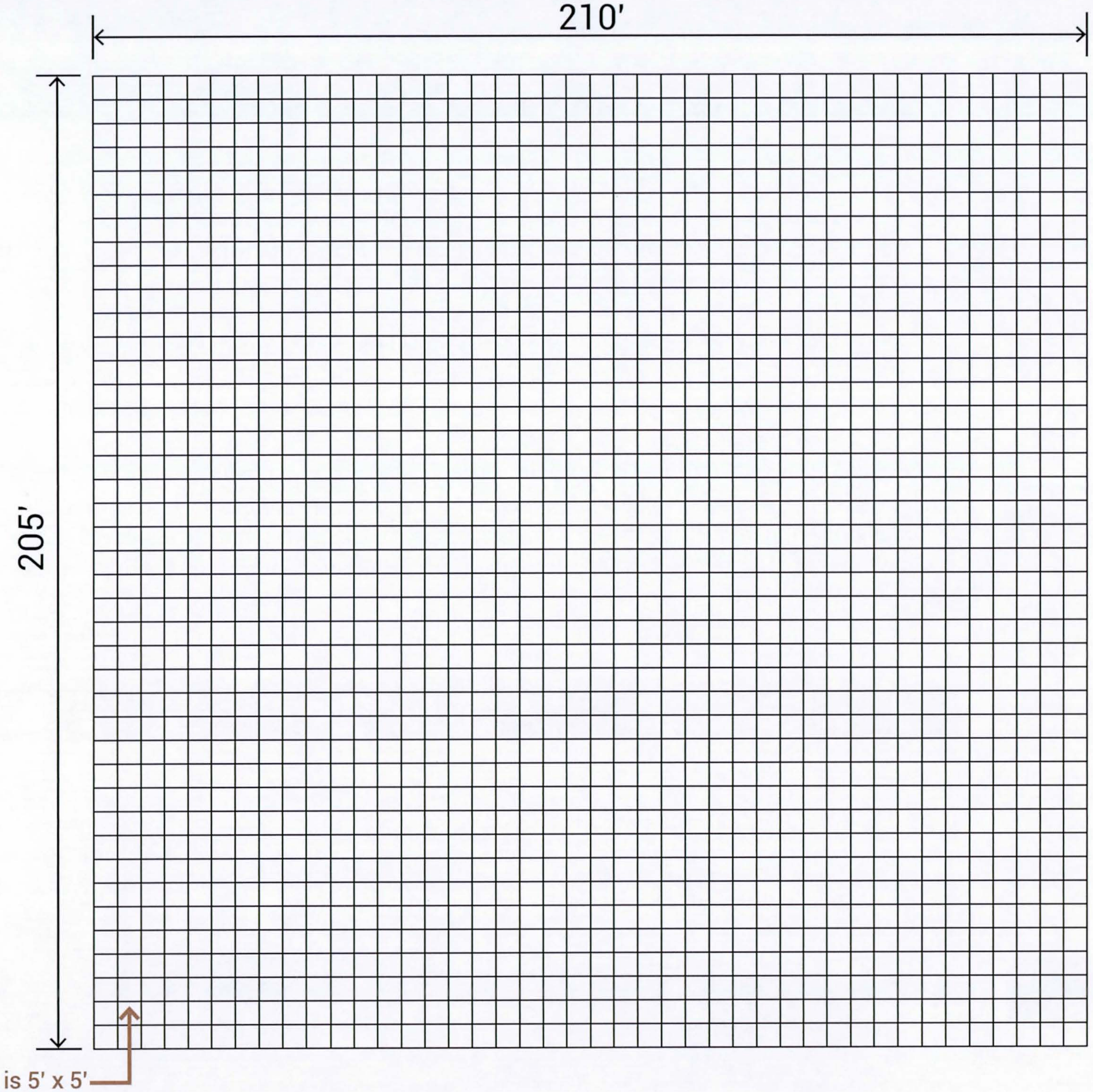
Now take the gallons per square foot and multiply it by the square footage of catchment area to determine the total yield of harvested rainwater in gallons per .79" storm event

0.492	X	3,019	=	1,485
Gallons Per Square Foot		Square Footage of 62' Dia. Round Pen Catchment Area		Gross Gallons of Rainfall Per .79" Storm Event

Once the gross gallons of rainfall per year has been determined we need to multiply it by the coefficient rate of the round pen surface material for our example the material is native soil which has a coefficient rate of .35

1,485	X	0.35	=	519
Gross Gallons of Rainfall Per .79" Storm Event		Native Soil Runoff Coefficient		Total Yield of Harvested Water in Gallons During Typical .79" Storm Event

Suggested Minimum Rain Garden Size : 72 Cubic Feet (12' x 12' x 6" Deep)



Typical 1 Acre Lot - Worksheet

0' 15' 30' 60'
Scale in Feet

This grid can be utilized to layout your specific and unique lot. It provides an easy method to help calculate the square footage (length x width) of the areas on your lot that are your runoff creators (roofs, driveways, landscape etc,). The grid also can provide a way to size and locate the GI/LID techniques relative to your runoff creators as described within this report.

D Rainwater Calculator

0.79 X 0.623 = 0.492

Average Rainfall Event For Rio Verde (in Inches) | Conversion Factor From Inches to Gallons | Gallons Per Square Foot

Now take the gallons per square foot and multiply it by the square footage of catchment area to determine the total yield of harvested rainwater in gallons per 0.79" storm event

0.492 X ______ = ______

Gallons Per Square Foot | Square Footage of Catchment Area | Gross Gallons of Rainfall Per .79" Storm Event

Once the gross gallons of rainfall per storm event has been determined we need to multiply it by the coefficient rate of the material

______ X ______ = ______

Gross Gallons of Rainfall Per .79" Storm Event | Runoff Coefficient (Refer to Table Below) | Total Yield of Harvested Water in Gallons During Typical .79" Storm Event

Material	Runoff Coefficient Rate
Roof Structure	.95
Pavement	.95
Landscaping	.5
Horse Pen	.35
Vegetable/Flower Garden	.35

General Notes to Homeowner

Locating GI /LID Techniques On Your Lot

1. Call 811(Blue Stake, Inc.) a few days before you dig to have all utilities marked in the field. This is a free service to help prevent unintentionally damaging existing utilities.
2. Locate away from any sewage disposal facilities (septic tanks, sewer lines, leach fields).
3. Avoid placement immediately adjacent to any well or potable water source supply.
4. Stay at least 10 feet (minimum) away from a building/structure's foundations (see 45 degree rule, this page).
5. Avoid impacts to existing vegetation zones.
6. Make sure you do not increase runoff volume amounts or change historic location(s) of runoff leaving your property.
7. Gain all necessary and required permits and clearances from appropriate regulatory agencies prior to initiating construction.

Notice of Regulatory Requirements

1. It is OK to collect water that originates on your property. BUT per ARS 45-141, waters of all sources, flowing in streams, canyons, ravines or other natural channels, cannot be captured unless you have legal appropriation rights. If you detain appropriated waters with passive harvesting structures, you must allow the water to pass through the structures.
2. Stormwater drainage in Rio Verde is very dynamic and no two lots are the same. Due to these unique circumstances, residents and property owners are advised that they should be aware of potential water rights and permitting requirements. Residents are encouraged to contact Arizona Department of Water Resources (ADWR) (water rights), Maricopa County Planning and Development (grading and drainage and floodplain-use permits), and the Arizona Department of Environmental Quality (ADEQ) (Arizona Pollutant Discharge Elimination System (AZPDES) and water quality), to understand applicable rules and regulations and address individual site conditions. Other permitting agencies may need to be contacted pending the type of work involved.

Rural Character

The Rio Verde area has maintained a strong connection to the surrounding native Sonoran Desert and the "rural character" that defines this area. These connections are reflected in the efforts to preserve and protect open space, maintain a lower density residential zoning footprint, utilize native desert landscape, preserve natural washes and arroyos, accommodate and integrate equestrian uses, maintain the dirt roadways and other features that are unique to this area, and contribute to reinforcing and maintaining the existing Rio Verde character. Application of GI/LID techniques in the Rio Verde area requires a more bio-engineered approach utilizing the natural slope of the land and naturally available materials to provide an opportunity to create rainwater harvesting techniques that ultimately blend into, and become an integral part of, the landscape. The correct application and placement of these techniques will ultimately contribute to maintaining and promoting Rio Verde's unique rural character and the goals and objectives described within this report.

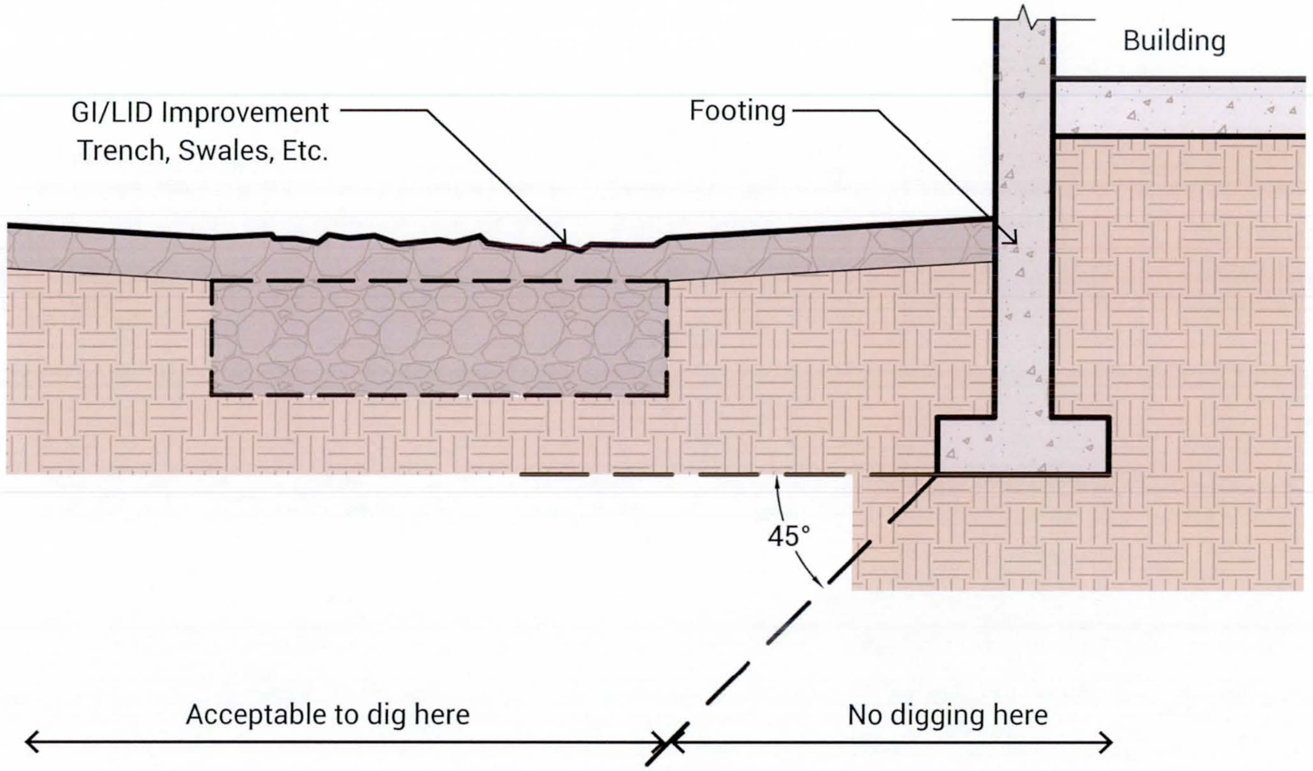
Percolation Testing

- Step 1: Dig a hole at least 12" in diameter by 12" deep, with straight sides.
- Step 2: Fill the hole with water and let it sit overnight to saturate the area.
- Step 3: Place a ruler or tape measure plumb from the bottom of the hole to the top of the hole with inches visible and then refill the hole with water the next morning.
- Step 4: Measure the water level when the hole is full.
- Step 5: Measure and record the drainage, or drop, in the water level in inches every hour.

The ideal soil drainage is around 2" per hour, with readings between 1"- 3" are generally OK for GI/LID applications that have average drainage needs. If the rate is less than 1" per hour, infiltration is too slow, and you'll need to improve drainage.

Note: If you've ever installed a septic system in your yard, you're probably familiar with soil percolation tests. Professional percolation tests are measured in minutes per inch (MPI). To convert your DIY percolation test to MPI, divide the time (in minutes) by the distance (in inches) the water level fell. For example, a rate of 2" per hour would correspond to a perk rate of 30 MPI (60 minutes ÷ 2 inches = 30 MPI).

45° Degree Rule



Above Ground Rain Tank

Description:

An Above Ground Rain Tank (tank), also called a Rainwater Cistern, is a reservoir tank system used for storing rainwater. Rainwater runoff from roofs and other structures can be directed to these tanks from a gutter/collection system for storage and later use. Tank designs can range from a simple rain barrel at the bottom of an existing downspout to a more extensive higher volume system that can provide a substantial amount of rainwater storage for landscape watering and other outdoor non-potable water uses. The distribution and reuse of rainwater from an above ground cistern is typically provided through a gravity-fed system of a garden hose connected to the water spigot. The homeowner would have the option of adding in a small electric or solar powered irrigation controller and associated irrigation valve and distribution piping, if desired, to make the system automatic.

Base Components:
- A roof/structure rain gutter water collection system that directs rainwater to the rain tank
- A rain tank at the low point of the rain gutter collection system (downspout)

At a minimum, the tank system should include:
- A rain tank selected based on size to meet your specific rainwater runoff calculations (see runoff worksheet pg.17) and non-potable water use needs
- A gravity fed water spigot for easy access to the contained water supply
- A sediment trap, leaf, and debris separator
- A secure screen on the tank rainwater inlet to prevent mosquitoes, insects, animals or debris from directly entering your tank, but sized to allow air to escape as the tank fills
- An overflow or outlet pipe from your tank in case of overfilling

Additional Performance Components/Accessories:
- Tank size may dictate the need for a manhole access port and ladder for periodic maintenance and cleaning.
- A first flush diverter system on the gutter or water collection system
- A water level indicator on the outside of the tank to show the amount of water in the tank
- A lock on the water spigot and cover access limiting access to the water
- Submersible pump, if location does not allow the use of a gravity distribution system (spigot and hose)
- Electric or solar irrigation controller with connected irrigation valve(s) and irrigation piping for automated approach to landscape irrigation

1 Location:

A rain tank should be located as close as possible to the source of the rainwater capture system from the roof or structure. The surrounding area must be graded to provide positive drainage of surface water away from the structure and the tank foundation. Avoid placing tanks in low areas subject to flooding. Due to the weight of a tank when full, it should not be located over any sewer lines, water lines, septic tanks or leach fields.

2 Installation:

Each rain tank system is unique in size, shape, material, and weight and should be evaluated on a case by case basis prior to initiating any installation efforts.

To initiate your installation follow these steps:
1. Call 811 before you dig to have all utilities marked in the field.
2. Ensure that your tank location is not in conflict with your septic system, sewage delivery system, or potable water lines and utilities.
3. Stake layout of tank to verify dimensions on the ground.
4. Check the grade of the area around the rain tank location to ensure positive drainage away from any adjacent structures.
5. Create an emergency spillway for any possible overflow issues away from all structures.
6. Create a level pad of crushed stone or concrete for the tank to sit on.
7. Connect rain tank to roof rainwater collection system.
8. Maintain and enjoy your rain tank!

3 Maintenance:

Once the rain tank is installed, maintenance is limited, but should occur on a monthly and yearly basis to ensure proper operation.
- Clean debris out of the gutter system and ensure downspout operation at least two times a year, ideally prior to Arizona's monsoon season in July and before the winter rainy season in December.
- If you have installed a first flush separator, this system should be cleaned out after each rain event.

Monthly
- Inspect tank for leaks or settlement issues and check rainwater inlet to ensure that mosquito control screen is in place and secure.
- Inspect all piping and connections to ensure they remain watertight.

Yearly
- Clear roof and gutters of any debris accumulation. Clear any vegetation overhanging the roof that could contribute to roof litter.
- Clean out tank and remove sediment buildup that will occur in the bottom.
- If an optional pump was installed, check the pumps operation and condition.
- Inspect tank and base pad for stability and proper drainage.
- Inspect the grade around the tank to ensure drainage is away from all structures and away from the tank.
- Inspect the pad (concrete or gravel) for the tank to ensure that it is sloped away from any adjacent structures, that the pad appears stable and that there are no signs of deterioration or excessive settlements.

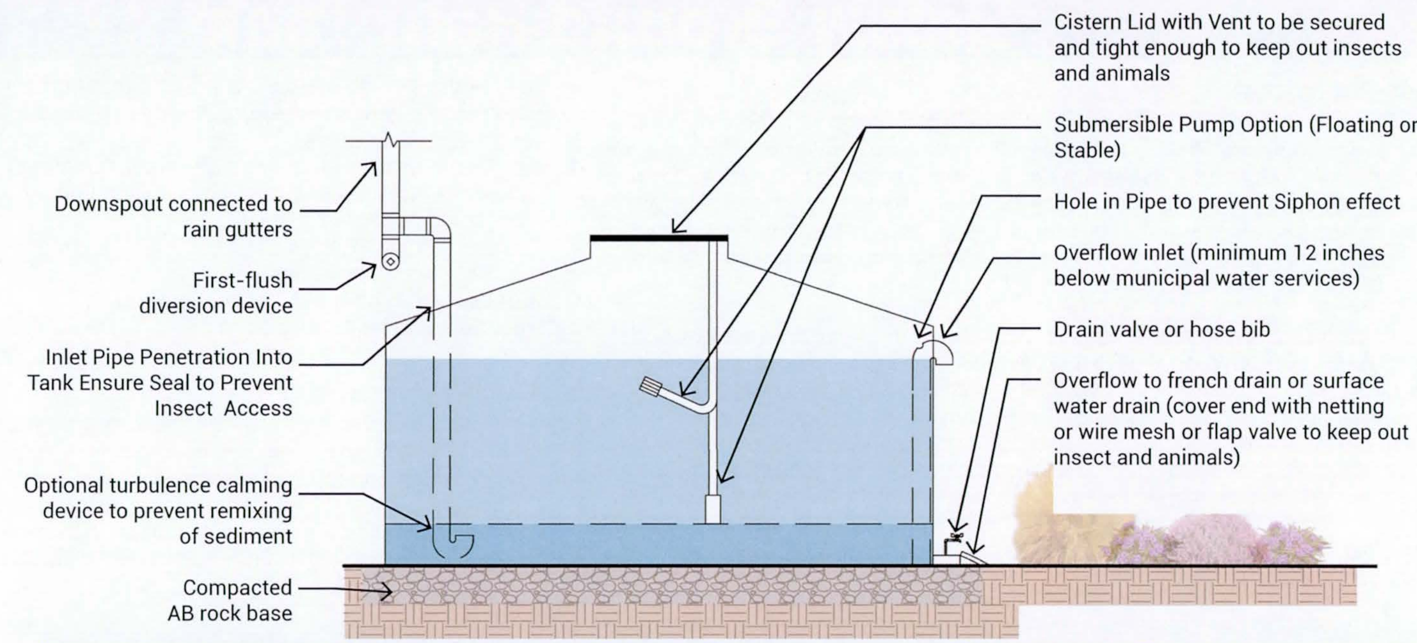
4 Cost:

- Rain tank costs are based on a number of variables; size, shape, and material. It will likely be one of the more costly GI/LID techniques to implement, but provides the most effective collection, storage, and reuse of rainwater.
- Rain tank $$$$
- Gutter/rainwater capture system $$
- Tank foundation gravel $$ /concrete $$$
- Grading pad $$
- Grading for a spillway away from tank and structures $$

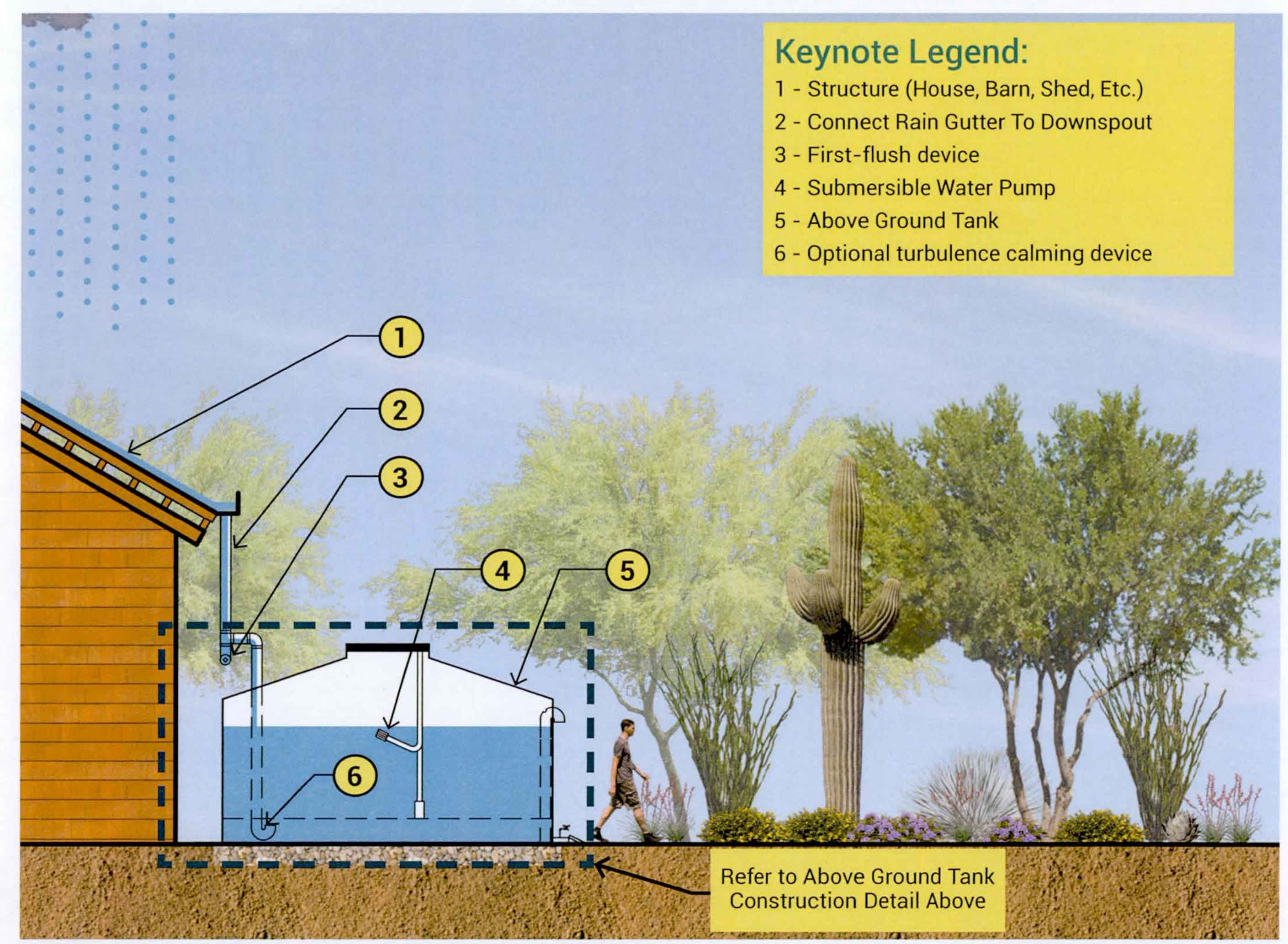
Additional Performance Components:
- A sediment trap, leaf, and debris separator $
- A first flush diverter system on the gutter system $$
- Water level indicator $$
- Locking mechanism $
- Irrigation pump system to a garden hose $$
- Electric or Solar irrigation controller, valve and piping $$$

General Note:

Residents are informed that they should be aware of potential water rights and permitting requirements. Residents are encouraged to contact Arizona Department of Water Resources (ADWR) (water rights), Maricopa County Planning and Development (grading and drainage and floodplain-use permits), and the Arizona Department of Environmental Quality (ADEQ) (Arizona Pollutant Discharge Elimination System (AZPDES) and water quality), to understand applicable rules and regulations and address individual site conditions. Other permitting agencies may need to be contacted pending the type of work involved.



Above Ground Tank Construction Detail



Above Ground Tank Illustrative Cross-Section

Below Ground Rain Tank

Description:

A Below Ground Rain Tank (tank), also called a Rainwater Cistern, is an in-ground reservoir tank system used for storing rainwater. Rainwater runoff from roofs and other structures can be directed to these tanks from a gutter/collection system for storage and later use. Tanks located below grade can provide a substantial amount of water storage for non-potable use and being below grade removes the tank from any visual intrusion into the landscape around a residence.

Each rain tank system is unique in size, shape, material, and weight and should be evaluated on a case-by-case basis, as these choices will have a direct effect on location, installation, maintenance, and costs. Proper material selection, based on use below grade and the sizing of the system, is important when selecting and designing your rain tank system. You will need to know that the system selected has the structural integrity for use below grade and that the system has been sized to collect and store the water you reasonably expect to use. Determining the rain tank materials and right sizing the system will affect installation, operation, and on-going maintenance costs.

Base Components:
- A gutter/collection system from the roofs or structures located on site that directs water to the tank
- A below ground tank is located underground so that there is no interference with any site utilities (sewage collection system, septic systems, water delivery, electrical, gas, etc.)

At a minimum the rain tank system should include
- A rain tank selected, based on size, to meet your specific rainwater runoff calculations (see runoff worksheet pg.17) and non-potable water needs
- Water spigot for easy access to the water supply
- A sediment trap, leaf, and debris separator
- A secure screen on the tank rainwater inlet to prevent mosquitoes, insects, animals or debris from directly entering your tank but sized to allow air to escape as the tank fills
- A submersible pump system to bring the water above ground

Additional Performance Components/Accessories:
- Tank size may dictate the need for a manhole access port for periodic maintenance and cleaning
- A first flush diverter system on the gutter or water collection system
- A water level indicator on the outside of the tank to show the amount of water in the tank
- A lock on the water spigot and cover access

1 Location:

A below ground rain tank should be located as close as possible to the source of the rainwater capture system from the roof or structure. The surrounding area must be graded to provide positive drainage of surface water away from the structure and the tank foundation. Avoid placing tanks in low areas subject to flooding. Due to the weight of a tank when full, they should not be located over any sewer lines, water lines, septic tanks, or leach fields.

2 Installation:

Each rain tank system is unique in size, shape, material, and weight and should be evaluated on a case-by-case basis prior to initiating any installation efforts.

To initiate your installation follow these steps:

Call 811 before you dig to have all utilities marked in the field.

1. Ensure that your tank location is not in conflict with your septic system, sewage delivery system, or potable water lines and utilities.
2. Stake the layout of the tank to verify dimensions on the ground.
3. Installation of the below ground tank must be done to be in complete compliance with the manufacturer's specifications for base support and backfill materials.
4. Check the grade of the area around the tank location to ensure proper positive drainage away from any surrounding structure and away from the tank location.
5. Create a spillway from the tank lid away from all structures for any possible overflow issues
6. Connect to downspout and rain gutters.
7. Maintain and enjoy your tank!

3 Maintenance:

Once the rain tank is installed, maintenance is limited, but should occur on a monthly and yearly basis to ensure proper operation.
- Clean debris out of the gutter system and ensure downspout operation at least two times a year, ideally prior to Arizona's monsoon season in July and before our winter rainy season in December.
- If you have installed a first flush separator, this system should be cleaned out after each rain event.

Monthly
- Inspect the collection container and check and maintain mosquito control.
- Inspect all piping and connections to ensure they remain watertight.

Yearly
- Clear roof and gutters of any debris accumulation. Clear vegetation overhanging the roof that could contribute to roof litter
- Clean out tank and remove sediment buildup.
- Check that the pump is maintained and in operational condition.
- Inspect grade above tank to ensure drainage is away from area and all adjacent structures.
- Inspect the area above the tank for signs of moisture seepage (perpetually wet surface) and any excessive settlements.

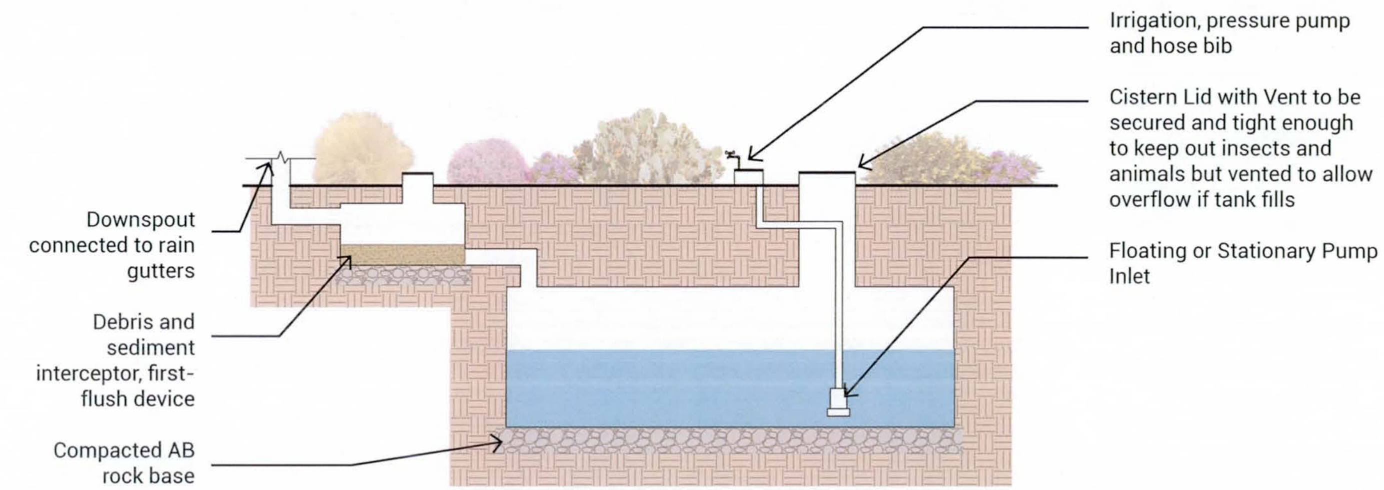
4 Cost:

Rain tank costs are based on a number of variables: size, shape material, piping distances, and excavation. A below grade rain tank will be one of the more costly GI/LID techniques, but it can provide the most effective reuse of rainwater, while not being visually intrusive in the landscape.
- Rain tank $$$$
- Excavation for tank $$$
- Gutter/rainwater capture system $$
- Submersible Pump $$$
- Grading for a spillway away from tank and structures $$

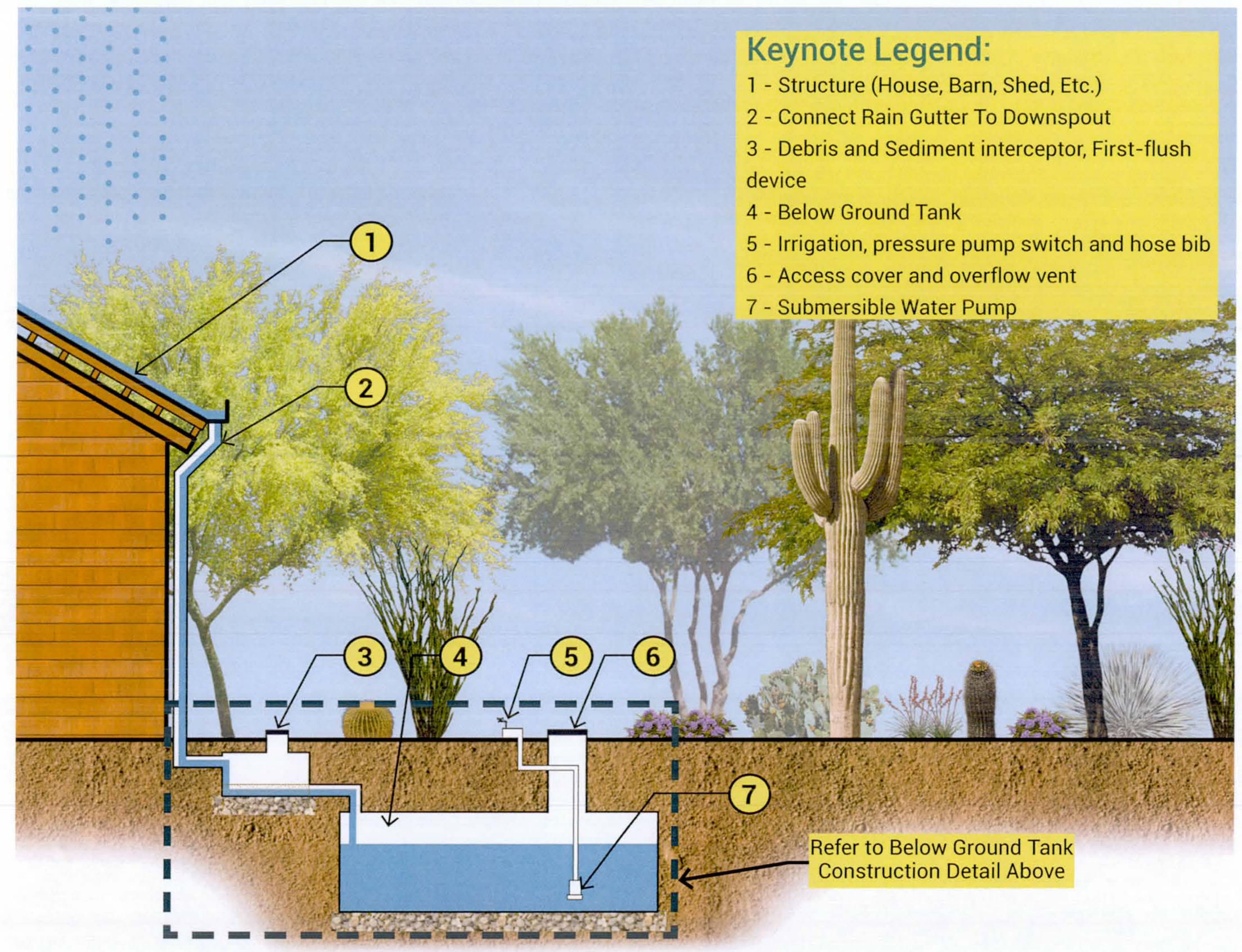
Additional Performance Components:
- A sediment trap, leaf, and debris separator $
- A first flush diverter system on the gutter system $$
- Water level indicator $$
- A lock $

General Note:

Residents are informed that they should be aware of potential water rights and permitting requirements. Residents are encouraged to contact Arizona Department of Water Resources (ADWR) (water rights), Maricopa County Planning and Development (grading and drainage and floodplain-use permits), and the Arizona Department of Environmental Quality (ADEQ) (Arizona Pollutant Discharge Elimination System (AZPDES) and water quality), to understand applicable rules and regulations and address individual site conditions. Other permitting agencies may need to be contacted pending the type of work involved.



Below Ground Tank Construction Detail



Below Ground Tank Illustrative Cross-Section

Rain Garden

Description:

A rain garden is a shallow depression (basin) with plants, typically native, where stormwater is collected for use by the plants and infiltrated into the ground. Stormwater runoff generated from roofs, landscape areas, and impervious surfaces (such as pavements and roofs) can be directed to these rain gardens from downspouts and piping, or directional swales and berming.

Base Components:

- Basin depth varies dependent upon rainwater volume, but should be 6" minimum (flood irrigated depth), 36" maximum depth due to multiple factors, including but not limited to: percolation, vector control, fall height, and costs to construct
- Planting in bottom and side slopes

Additional Performance Components / Accessories:

- Amended soil (layers of organic matter and sandy soil) for infiltration and facilitating the distribution of stormwater to the plants
- Rip-rap on side slopes steeper than 4:1 to reduce slope erosion
- Infiltration Trench (Addition of the optional infiltration trench should only be used when the natural soils are slow to drain.)

1 Location:

Locate rain gardens "down slope" from structures or pavement and in open land areas making use of natural/manmade graded slopes to direct stormwater to the basin.

Avoid placing rain gardens under existing tree canopies and native vegetation areas to protect root zones.

The top edge of the rain garden slope should be located a minimum of:

- 10 feet away from any structures
- 3 feet away from pavement edge

2 Installation:

After reviewing the location(s) best suited for collecting the maximum amount of run-off, construct your rain garden. Locate the rain garden on site by marking the layout on the ground, while meeting the location criteria. Visualize the run-off pattern from structures (home, barns, and out buildings), pavement (driveways, parking areas, patios), and adjacent landscape areas into the rain garden and adjust shape and location to maximize sheet flow collection.

Call 811 before you dig to have all utilities marked in the field.

1. Dig out the soil forming the basin. (Side slopes should not exceed a 4:1 (4 vertical to 1 horizontal) ratio side slope.)
2. Utilize the soil removed from the basin to form a berm on the down slope edge of the basin or use elsewhere onsite for directing storm water to basin.
3. If additional performance components/accessories are to be used, install at this time.
4. Install plants or seed.
5. Place rip-rap (angular rock) at rain garden edge where stormwater enters or on steep side slopes to avoid erosion.
6. Water plants/seed to establish.
7. Maintain and enjoy your rain garden!

3 Maintenance:

Once your rain garden is built, maintenance is relatively easy and straightforward:

1. Provide supplemental irrigation to plants until established.
2. Visually check for erosion after large (runoff producing) rain events - If erosion has occurred, repair accordingly.
3. Remove sediment and debris from rain garden to maintain infiltration.
4. Small erosion (rills) may occur on slopes. Place the soil back to original grade or adjust to better spread runoff. Seed or mulch disturbed soil to protect it from future erosion.
5. Large erosion (gully/cut) will require more action. Break up any rough cut edges to form a new swale area. Place larger rock, mulch, or rip-rap in the swale to prevent future erosion. Remember the simple rule: "you can't defy the laws of gravity" (big runoff requires bigger rock rip-rap, small runoff smaller rock).
6. Maintain organic material on the surface and rake it into the soil to promote infiltration, to cool the soil, and provide a healthier growing media for the plants.
7. Maintain plants by removing dead materials. Healthy growing plants will help the rain garden systems uptake water in the basin.

4 Cost:

Rain garden installation costs are similar to general landscape installations; grading, planting and mulch. Additional performance components/ accessories will add cost, but will increase the infiltration performance of the system.

Base components;

- Basin/planting: $

Additional Performance Components:

- Amended soil $$
- Rip-rap $$
- Optional infiltration trench $$$
- Spillway overflow construction $$

General Note:

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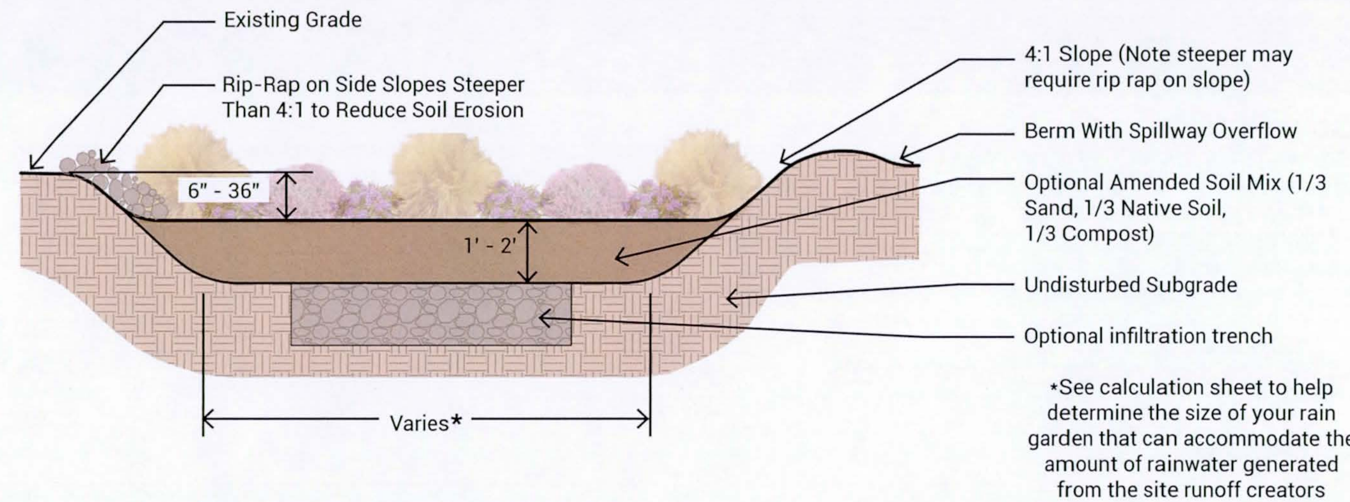
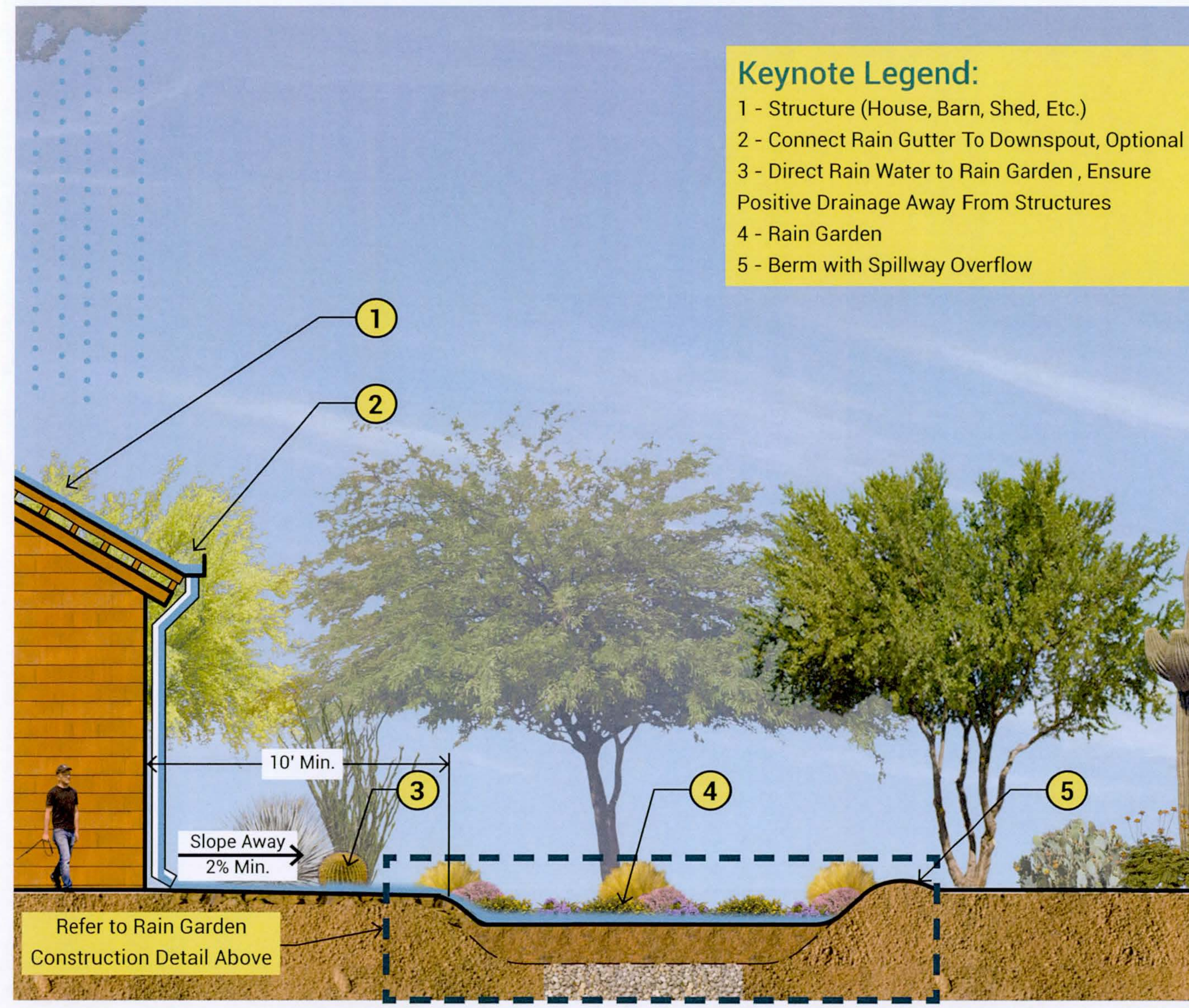


Rain Garden Construction Detail



Rain Garden Illustrative Cross-Section

Bio-Swale

Description:

Bio-swale is a shallow, linear, drainage ditch (swale) with plants that serves to collect, direct, and infiltrate rainwater runoff. A bio-swale collects rain water and directs that rainwater through a site while allowing it to slowly infiltrate into the soils.

Base Components:

- A bio-swale is an excavated drainage swale lined with erosion control materials (rock, broken concrete, logs, mulch) and planted with low water using plants.

Additional Performance Components/Accessories:

- Infiltration Trench (Addition of the optional infiltration trench should only be used when the natural soils are slow to drain.)
- Check Dams

1 Location:

The use and applicability of a bio-swale on a site depends on factors including soils, slope, depth to bedrock or any impermeable layer, the contributing watershed area, the surrounding land use, the proximity to wells, septic systems, any surface water, foundations, and other factors. Generally bio-swales are suitable to sites with gentle slopes and permeable soils.

Location Considerations

- Distance from septic system leach field location(s)
- Located in compliance with the 45° rule (page 18)
- Avoid trenching under existing tree canopies and native vegetation areas to protect root zones

2 Installation:

After you have sited your bio-swale where it would be most effective and safely away from any septic system, water wells, foundations, etc., it's time to construct.

Start:

1. Call 811 to have all utilities marked in the field.
2. Stake out the location and route of the bio-swale on the site and adjust to avoid items and areas noted above.
3. Excavate bio-swale to depth and width needed, based on the target volume of water that the bio-swale may carry.
4. Check the grade of bio-swale to ensure that positive drainage is maintained away from buildings, pavement, and neighboring properties.
5. Plant your bio-swale with native desert vegetation to stabilize the banks, assist with infiltration, and utilize the water running through.
6. Maintain and enjoy your bio-swale!

3 Maintenance:

Once the bio-swale is installed, maintenance is easy and straight forward. The overriding issue that results in a bio-swale operation being altered is sediment and other debris that will collect in the bio-swale. If debris fills in a bio-swale, making water conveyance inconsistent, over-topping and erosion may occur. If the debris is routinely removed, the swale should continue to operate effectively for years to come.

- Remove any buildup of sediment and debris that is limiting or effecting water percolation from the bio-swale.

During First Year of Operation

- Inspect the bio-swale after each major rain event - restore any bank erosion and remove any debris or sediment that may have accumulated within the flow line of the bio-swale that would affect infiltration.
- Inspect and remove any vegetation that may be blocking the water flow through the bio-swale. However, it is a "bio"-swale. We want the plants in place, so only clear blockage.

Yearly

- Ensure that any buildup of sediment and debris that may result in limiting water flow and percolation is removed regularly.
- Inspect and remove any vegetation that may be blocking the water flow through the bio-swale.

4 Cost:

A bio-swale is one of the least costly GI/LID techniques available to a home owner as it utilizes the natural slope of the site and enhances the current drainage flow patterns onsite.

- Excavation $$
- Native seed $
- Native plants $$
- Rock and inert mulch cover material $

Additional Performance Components:

- Infiltration trench $$$
- Check dams $$

General Note:

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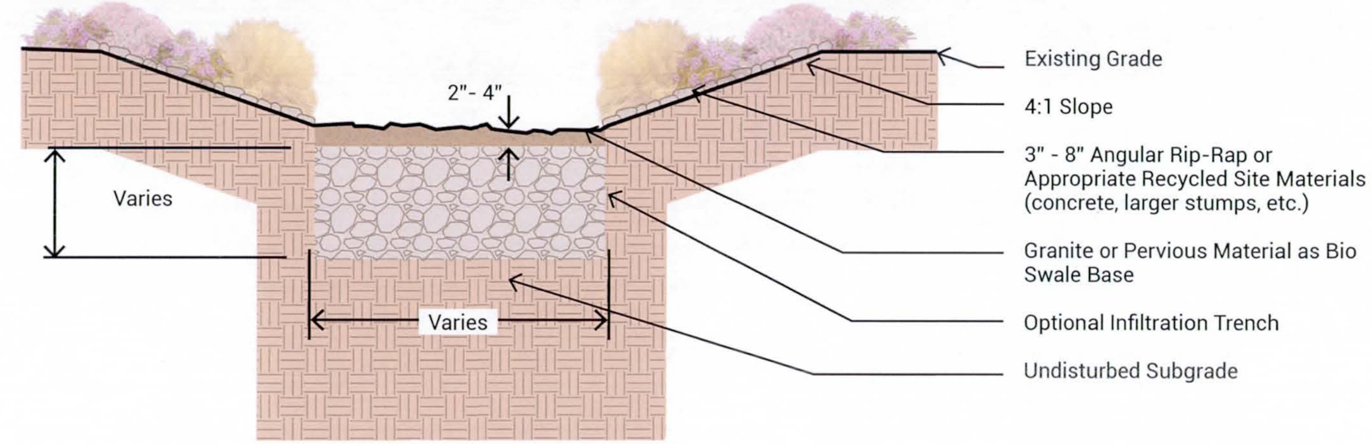

Bio-Swale Construction Detail

Bio-Swale Illustrative Cross-Section

Terrace

Description:
A Terrace, or Berm, is an earthen embankment, or a combination ridge and channel, constructed across the site's natural slope. Terracing is also an effective soil conservation practice that helps to prevent rainfall runoff on sloping land from increasing in velocity, resulting in severe erosion and loss of valuable topsoil.

Base Components:
- A terrace is a series of gentle soil steps created by regrading an existing slope. The spacing between terraces can vary but typically are uniform.

Additional Performance Components/Accessories:
- Adding larger materials, such as rock, logs or brush, on the sloped areas to assist in slowing the rainwater and allowing more time for it to be absorbed into site soils
- Amended soil mix to improve water holding capacity

1 Location:
The number and location of terraces will depend on existing drainage patterns, the steepness of any slopes, the length of any slopes, existing vegetation, and any existing structures. Terracing should be used in combination with other erosion control/stabilization measures that provide cover for exposed soils such as: combinations of native seeding, landscape plant materials, erosion control wattles or logs, decomposed granite and other inert materials, along with other measures to help slow rainwater as it flows down the slope and is intersected by the terrace structures.

Location Considerations
- Avoid grading terraces through established vegetation zones so that these zones can continue to provide vegetative cover.
- Avoid extending terraces under existing tree canopies and through existing vegetation areas to protect root system.
- Review ends of terraces to evaluate potential impacts and treatments that might be needed (erosion protection, rainwater route, etc.) to minimize terrace area overflows or rainwater seeps around ends.
- Located in compliance with the 45° rule (page 18).

2 Installation:
After you have located where on your property a terrace or series of terraces is most appropriate, it's time to construct. It is important to note that terrace installation may be more of a "process approach" that has to be adjusted over time through a series of site observations and some trial and error. This may require adjusting constructed terraces for varying slopes, areas of higher impact from parcel development or site features that result in terrace adjustments being needed to address excessive erosion or higher rainwater flows.

Start:
1. Call 811 to have all utilities marked in the field.
2. Stake out the locations of the terraces on the site and adjust to avoid items and areas noted above or other site obstructions.
3. Create terraces by re-grading the existing slope into a series of repeating steps that maintain a positive grade in the direction of the natural slope. The grading operation will involve creating the berms to contain the rainwater.
4. Cover the slopes and terraces with surrounding landscape material (native seed, plantings, decomposed granite, rip rap, etc.) to help the terrace performance by slowing the water down as it moves across the slope.
5. Maintain and enjoy your terraced landscape!

3 Maintenance:
- Once the terrace is installed and established, maintenance is easy and straightforward and should remain operational for decades.
- Repair any rill erosion on the slopes by re-compacting the area and replacing the cover material.
- Repair any erosion or degradation of the containment berms.
- Ensure that any plantings or cover crop are well established to help minimize erosion down the terrace

Monthly
- Walk the terrace and the berms, repairing any rilling or erosion that is present by filling, re-compacting and replacing the cover material.

Yearly
- Ensure that the slopes, berms, and terrace area ground cover materials are maintained to prevent erosion from occurring.

4 Cost:
A terrace is a moderately priced GI/LID technique available to a home owner. The bulk of the cost will be in the earthwork grading, operation required to construct and form the terraces, and any adjustments needed over time as site observations are adjusted.
- Grading of terrace $$$
- Cover material, seeding, mulch, etc. $

Additional Performance Components:
- Collected rock, brush, logs on slopes $
- Sediment wattles $
- Larger rock on slope $$
- Amended soil mix $$

General Note:
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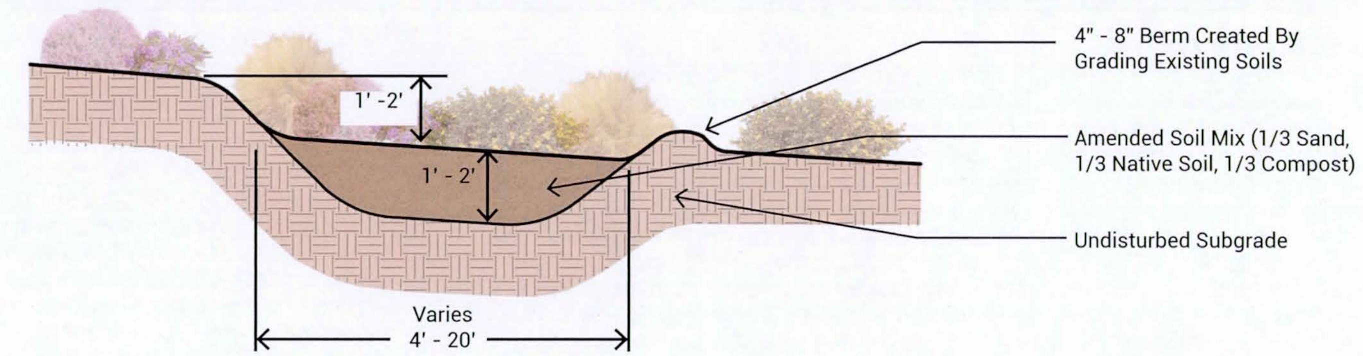
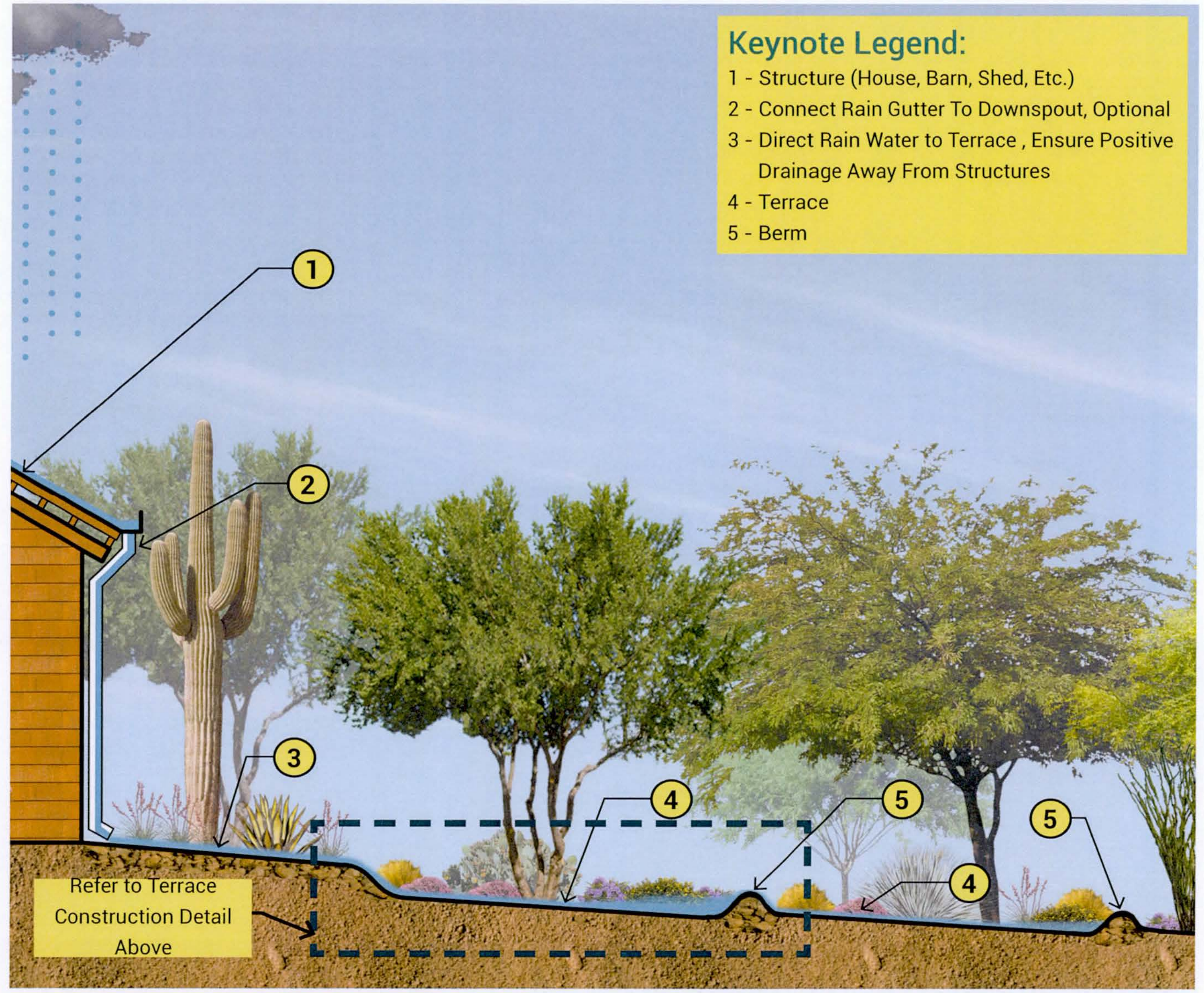


Terrace Construction Detail



Terrace Illustrative Cross-Section

Check Dam

Description:

Check dams are generally used in concentrated rainwater flow areas such as bio-swales, minor washes, and ditches on your property. Check dams are placed perpendicular to the direction of flows or across ditches to reduce stormwater flow velocities, prevent channel erosion, and to filter out sediment. Check dams can be both permanent and temporary barriers, constructed from a variety of materials including rock, sand bags, and other materials found on site (logs, native materials, etc.). Residents should be aware that the use of a check dam is only meant to slow the water, and these check dams should not be placed where it will change the flow patterns of the wash or affect any downstream neighbors. Overflow and end-around drainage issues associated with any check dam needs to be immediately addressed to ensure that overflow and out-of-bank flows are not occurring.

Base Components:
- A check dam is a structure designed to slow the movement of water across a slope or inside of a defined swale, wash or arroyo.

Additional Performance Components/Accessories:
- Site adjustments may result in additional materials, such as additional rock or erosion control measures, to address site-specific conditions

Common causes for check dam issues where additional performance components may be needed include but are not limited to the following:
- Failure to account for high intensity rain storms when evaluating locations and designing a check dam
- Use of rock that is too small for the flow velocities/volumes present

1 Location:

Locating a check dam on site depends on numerous site factors including: soils, slope, wash carrying capacity, current erosion, evaluation of the contributing watershed area, the surrounding land use, and the proximity to wells, septic systems, and foundations, as well as other factors. Generally, check dams are suitable to sites with a small contributing watershed, as check dams are not designed to accommodate heavy rainwater impacts or to be placed within major desert washes, arroyos, or well defined waterways.

Location Considerations

- Evaluate the slope of the area where the check dam is planned. If the slope of the bio-swale, minor wash, or ditch is steep, has excessive erosion, or where head cutting is already prevalent, another location should be selected and a different approach to address these issues should be investigated
- If the placement of the check dam will result in excessive re-grading of the wash, arroyo or swale, another location should be selected.
- Check dams should not be located over or near any septic system leach field location(s).
- Check dams should be located away from any drinking water wells.
- Located in compliance with the 45° rule (page 18).
- Avoid locating a check dam in a swale that tends to carry large amounts of woody debris.

2 Installation:

It is important to note that check dam installation may be more of a "process approach" where check dams have to be adjusted over time through a series of site observations and some trial and error. This approach may require adjusting constructed check dams or adding check dams as a result of higher rainwater flows, erosion of side walls, and modification of the size of the weir, or overflow area, associated with each check dam. These adjustments may require additional materials to protect side slopes, adjusting weir openings or addressing other observed issues. After you have located on your property where check dams would be most appropriate and effective, it's time to construct.

Start:
1. Call 811 to have all utilities marked in the field.
2. After identifying the wash, arroyo or swale for the check dam, stake out the location on the site and adjust to avoid items listed above.

Inert Material Check Dam
- Concrete or inert materials (large angular rip rap rock etc.) are considered more permanent check dam materials and, if properly sized and installed, should result in longer use compared to the filter logs described as part of the Best Management Practices sheet in this report.
- Select rock sized to accommodate and withstand the observed flow events.
- The rock must be placed by hand or mechanical placement (do not dump rock to form check dam) to achieve complete coverage of the ditch or swale.
- The center of a check dam should be lower than the edges, creating an area for higher water flows to cascade over the top. This notch in the crest of the check dam will allow water to pass over the top of the dam and help to avoid dam overflows and end runs.
- Create a sediment basin on the upslope area of each check dam to collect and hold the sediment that will drop out when the water is slowed.
- A rock apron upstream and downstream of the check dam may be necessary to further control erosion.
- Spacing of check dams is variable dependent upon the slope of the existing wash or channel and the soils, but the rule of thumb is that the toe of the upstream dam is at the same elevation as the top of the downstream dam.

3 Maintenance:

Check dam maintenance includes continual evaluation after each rain event. The overriding issue that results in a check dam operation being altered is sediment and other debris that will collect in the bio-swale upstream of the dam. If debris fills in a check dam, making water conveyance inconsistent, it could result in over topping and erosion. Check dam locations should be observed in operation during a rain event or reviewed following an event to inspect them for excessive erosion or degradation. Areas around the check dam that are experiencing excessive erosion or degradation due to water flows, should be reinforced through the use of rock reinforcement or adding in vegetation. If the erosion is excessive, additional check dams may be needed, or another method may be required to address the issue.

Yearly Maintenance
- Remove any buildup of sediment and debris from the check dam before it reaches halfway to the top of the dam.
- Restore dislodged or washed out check dams to their original configuration.
- Fill in, or otherwise repair, areas where check dam undercutting, or bypasses, have occurred. Evaluate if these repairs can be permanently stabilized by the addition of more check dams or if the check dam needs to be removed and another approach taken in these areas.
- Add stones to check dams as needed to maintain design height and cross section. Use larger stones, if necessary, to counter higher-than-expected flow velocities.
- Repair ditch/channel areas where excessive downcutting, or side scour, has occurred, and evaluate if check dam quantity or location can permanently address this issue.

4 Cost:

The cost to install a check dam will vary dependent upon the material selected and size of the check dam structure.
- Excavation of check dam subgrade $$
- Rock or inert material and installation for check dam $$

General Note:

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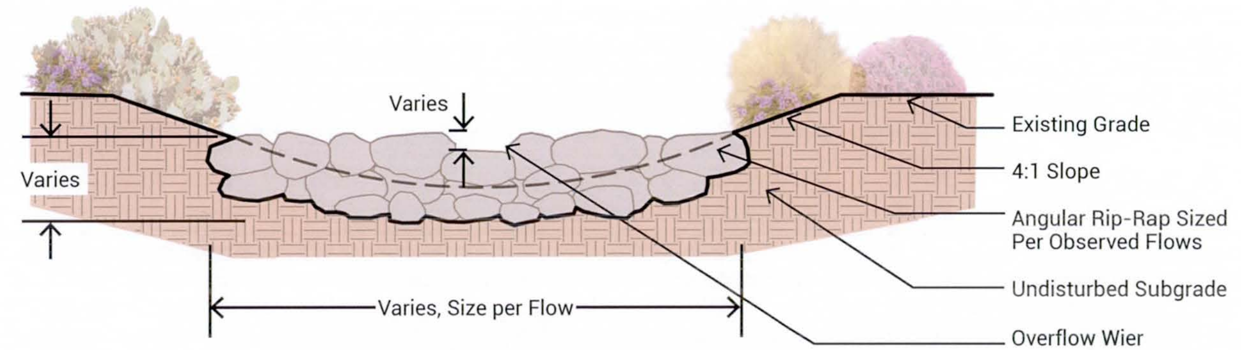
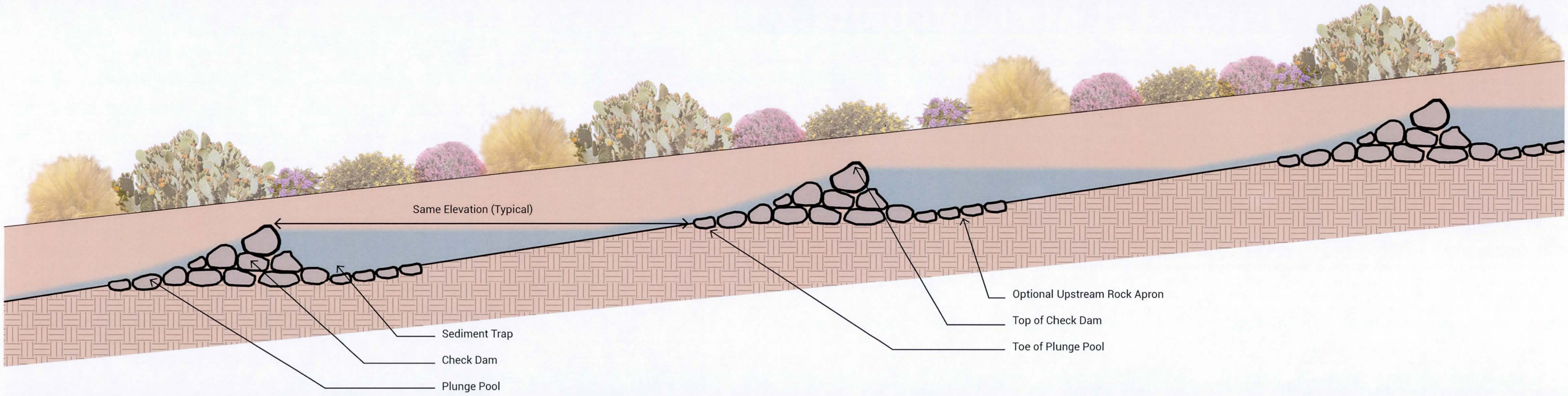
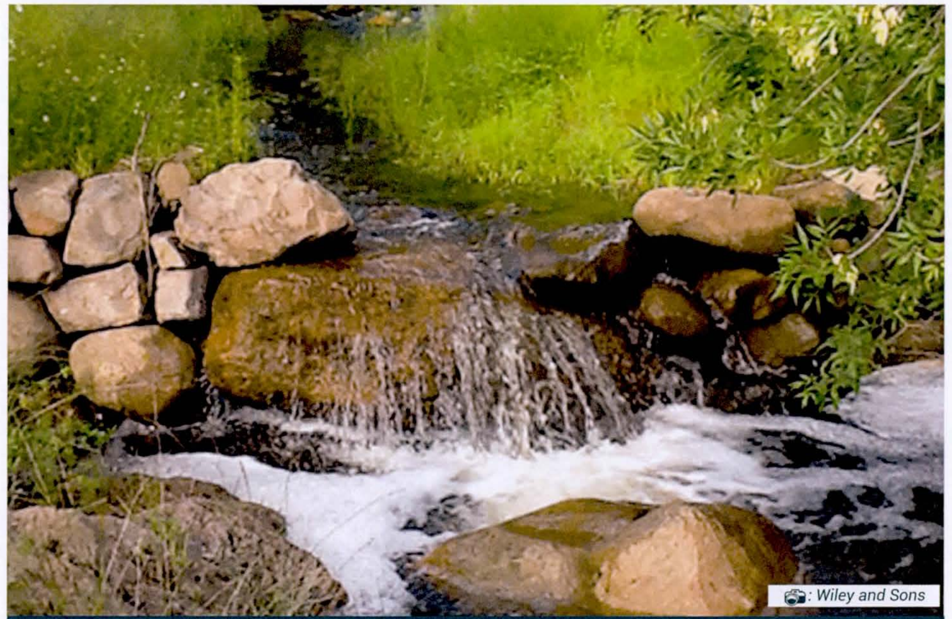


Rock Check Dam Construction Detail

Check Dam Illustrative Cross-Section



Longitudinal Check Dam Cross Section



Example of Rainwater Check Dams

Example of Rainwater Check Dams

Example of Rainwater Check Dams

Infiltration Trench / Labyrinth Infiltrator

Description:

An infiltration trench is a type of rainwater runoff management technique that collects rainwater as sheet flow, as it crosses the ground, and directs it to slowly infiltrate into the surrounding soil. Infiltration trenches are typically shallow excavations that are lined with filter fabric and filled with stone to create an underground void. An optional configuration of an infiltration trench is a "Labyrinth infiltrator" which is the same as the basic trench, but is in a "zig-zag tooth" form folding the trench line into a smaller area to gain more infiltration.

Base Components:
- An infiltration trench always wider than deeper.

Additional Performance Components/Accessories:
- None

1 Location:

The use of an infiltration trench depends on site factors including: drainage pattern, soils, slope, proximity to buildings and utilities. Infiltration trenches are very suitable to sites with gentle slopes, where rainwater runoff can be easily directed to the trench. An infiltration trench should only be used when the natural soils are slow to drain.

Location Considerations for Infiltration Trenches
- Avoid all septic system leach field location(s).
- Locate away from any drinking water wells.
- Located in compliance with the 45° rule (page 18).
- Soil percolation (perc) rate (see how to do a perc test on page 18).
- Avoid trenching under existing tree canopies and native vegetation areas to protect root zones.

2 Installation:

An infiltration trench, or series of trenches, should be located safely away from any septic systems, water wells, etc., and in an area where they will be most effective at capturing rainwater. Note that trenches should be installed after all site development has been completed to avoid additional grading, compaction or siltation.

Start:
1. Call 811 to have all utilities marked in the field
2. Stake out the locations of the infiltration trenches on the site and adjust to avoid items and areas noted above.
3. Dig trench to depth and width needed based on the target volume of water storage desired. When excavating, avoid compacting the sides and bottom of the trench as this will inhibit percolation.
4. Once the trench is dug and all loose material has been removed, line the trench with filter fabric (also called geotextile fabric) with sufficient fabric to create a "cocoon" that can wrap around the rock infill material.
5. Fill trench and fabric "cocoon" with clean washed rock. This rock will create the voids for water storage. When the trench is full of rock wrap the remaining filter fabric over the top of the stone.
6. Cover the trench fabric "cocoon" with surrounding porous landscape material (decomposed granite.) to conceal the fabric and secure it in place while still allowing rainwater to enter the trench below.
7. Maintain and enjoy your infiltration trench!

3 Maintenance:

The maintenance involved with an infiltration trench is easy and straight forward and these systems should remain operational for decades. The single most detrimental impact to an infiltration trench is sediment (silt) and other debris that can accumulate over the top of each trench resulting in the inability of rainwater to enter the trench.
- Try and remove any buildup of silt over the infiltration trench that creates an impermeable layer.

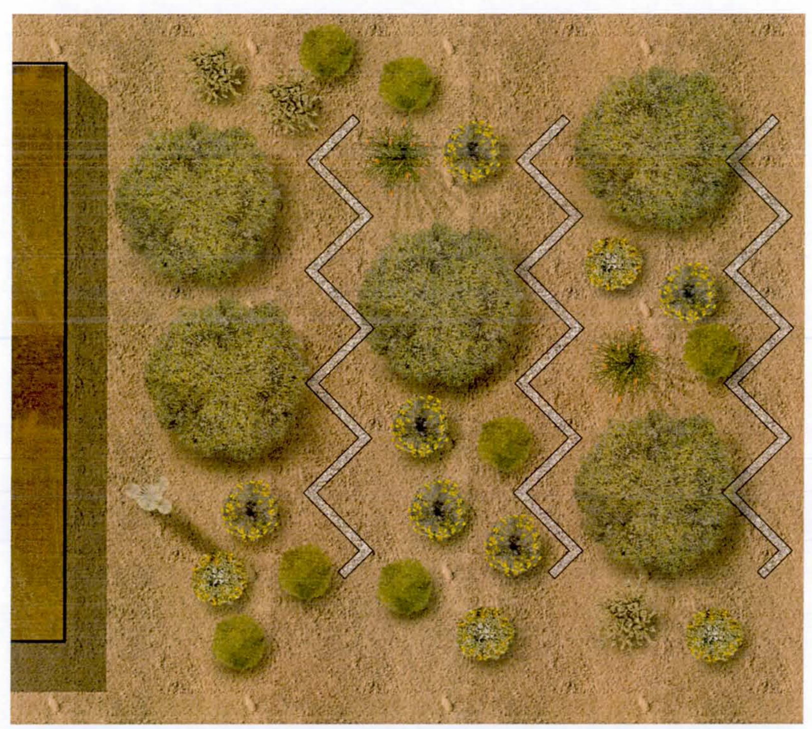
Monthly or after a major rain event
- Inspect the top of each trench for silt build up.

Yearly
- Ensure that silt build up is removed from the top of the infiltration trenches.

4 Cost:

An infiltration trench is one of the more costly GI/LID techniques available to a home owner due to the excavation and rock materials involved.
- Excavation of trench $$$
- Filter fabric $
- Clean washed rock $$$

Additional Performance Components:
- None



Plan View Example of Labyrinth Infiltrator

General Note:

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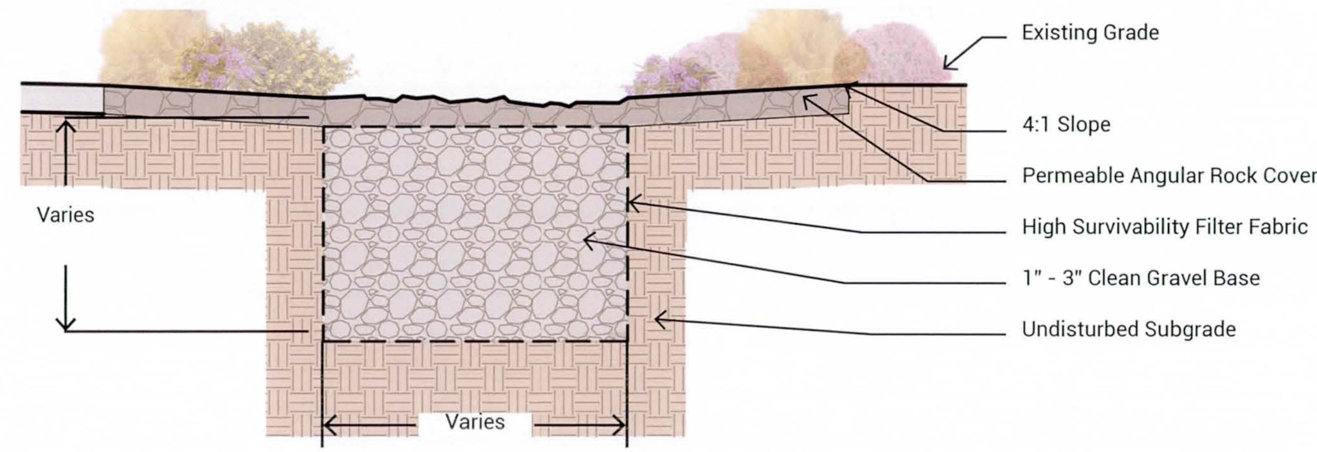
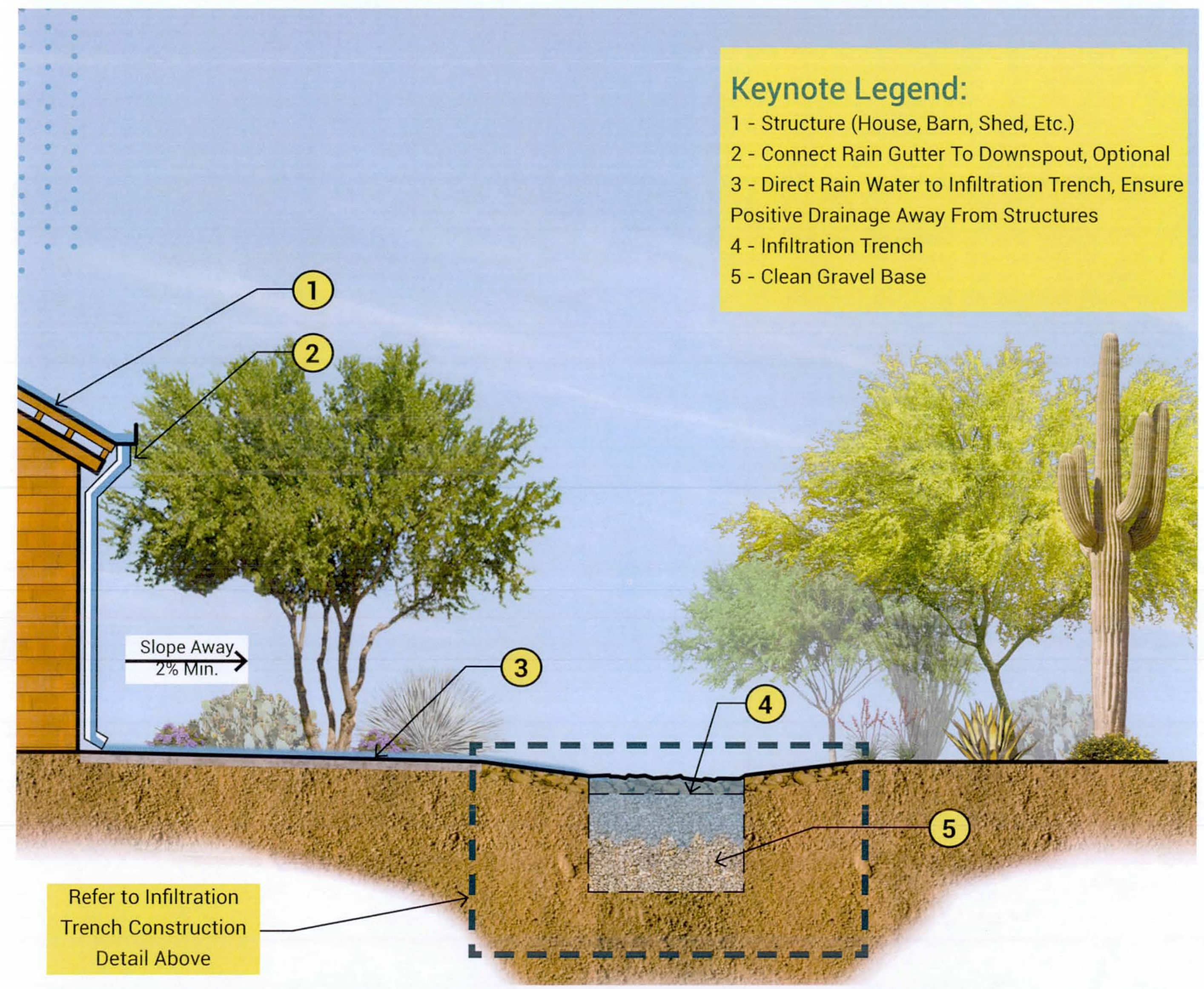


Infiltration Trench Construction Detail



Infiltration Trench Illustrative Cross-Section

Spiral Infiltrator

Description:

A Spiral Infiltrator is similar to both a Zuni Bowl and a Bio-Swale, but the spiral shape is a way to redirect and slow water runoff to reduce erosion and allow water to slowly percolate.

Base Components:

- A spiral infiltrator is excavated to a certain depth, lined with rock and native seeds or plants.

Additional Performance Components/Accessories:

- Infiltration trench below
- Landscape plantings

The use and applicability of a spiral infiltrator on a site depends on factors including: soils, slope, depth to bedrock or any impermeable layer, the contributing watershed area, the surrounding land use, the proximity to wells, septic systems, any surface water, foundations, and other factors. Generally, spiral infiltrators are suitable to sites with gentle slopes and permeable soils, as well as adjacent to bio-swales or minor flow concentration points. The addition of the optional infiltration trench should only be used when the natural soils are slow to drain.

1 Location:

Location Considerations

- Distance from septic system leach field location(s).
- Located in compliance with the 45° rule (page 18).
- Avoid trenching under existing tree canopies and native vegetation areas to protect root zones.
- Adjacent to established swales and washes.

2 Installation:

It is important to note that a spiral infiltrator installation may be more of a "process approach" where the actual shape of the spiral has to be adjusted over time through a series of site observations and some trial and error. This approach may require adjusting the constructed spiral infiltrator as a result of higher rainwater flows, erosion of side walls, and the movement and extent of diverted rainwater into the structure. These adjustments may require additional materials to protect side slopes, adjusting the orientation of the spiral opening, and perhaps even changing the depth or width of the structure to help minimize any excessive erosion or other observed issues. Based upon your site evaluation and confirmation of the staked layout, it's time to construct.

Start:

1. Call 811 to have all utilities marked in the field.
2. Stake out the location and route of the spiral infiltrator on the site and adjust to avoid items and areas noted above.
3. Excavate the spiral infiltrator by hand or with mechanical equipment to a depth and width based on the calculated target volume of water.
4. Check the grade of the spiral infiltrator to ensure that positive drainage is maintained away from buildings, pavement, and neighboring properties.
5. Plant your spiral infiltrator with native desert vegetation to stabilize the banks, assist with infiltration, and use collected runoff.

3 Maintenance:

The overriding maintenance issue with spiral infiltrators is sediment and other debris that will, collect in the base of this structure. If debris fills in a spiral infiltrator making water conveyance inconsistent, it could result in over topping and erosion. If the debris is routinely removed, the spiral infiltrator should continue to operate effectively for years to come.

- Inspect the spiral infiltrator after each major rain event - restore any bank erosion and remove any debris or sediment that may have accumulated within the flow line of the spiral infiltrator.
- Inspect and remove any vegetation that may be blocking rainwater through the flow line. However, it is a part of a "bio"-swale and we want the plants to remain, so only clear blockages to the flow line.

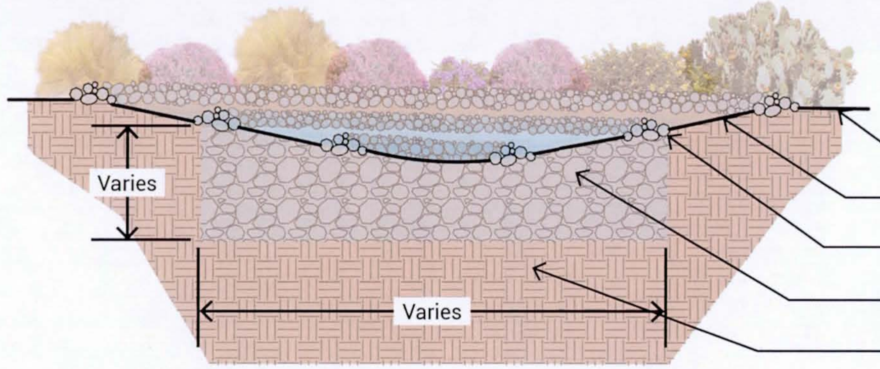
4 Cost:

A spiral infiltrator offers an artistic approach to a bio-swale rainwater diversion technique where naturally flowing rainwater is diverted to slow the water down and allow infiltration to occur. The cost to construct a spiral infiltrator will be moderate to high depending on the complexity of the spiral and the excavation and bank stabilization involved.

- Excavation $$$
- Rock material $$
- Native seed $
- Native plants $

Additional Performance Components:

- Infiltration trench $$$



Spiral Infiltrator Construction Detail

Plan View Example of Spiral Infiltrator

General Note:
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Spiral Infiltrator Illustrative Perspective

Zuni Bowl

Description:

A Zuni Bowl is a type of rainwater runoff management technique that can be utilized to address minor washes, bio-swales, and concentrated flow areas that are experiencing head cutting (a sharply eroded vertical drop) and erosion. It will slow the water down and reduce erosive energy while also allowing some remaining rainwater captured within the Zuni Bowl to slowly infiltrate into the surrounding soil, while allowing flows to continue to move downstream. Zuni Bowls are excavations that are lined with filter fabric to help stabilize the structure and layered with large stones to create steps for energy dissipation, and a bottom plunge pool for rainwater capture and diversion.

Base Components:

- A Zuni Bowl is a swale, wash, or arroyo head cutting/ erosion control structure composed of rock lined steps, and a plunge pool that helps prevent additional erosion and degradation of the existing swale, wash or arroyo.

Additional Performance Components/Accessories:

- Grouted stones on the stair steps to secure rocks in place.

1 Location:

The location of a Zuni Bowl is typically located where severe erosion and head cutting is occurring in an existing wash or channel.

Location Considerations

- Distance from septic system leach field location(s).
- Located in compliance with the 45° rule (page 18).
- Avoid trenching under existing tree canopies and dense native vegetation zones to preserve existing roots.

2 Installation:

After you have located the washes or channels experiencing head cutting that are candidates for the construction of a Zuni Bowl, you need to verify that they will be located safely away from any septic system water wells, etc. With that clearance confirmed, Zuni Bowl construction can begin.

Start:

1. Call 811 to have all utilities marked in the field.
2. Stake out the locations of the Zuni Bowls on the site and adjust to avoid items and areas noted above.
3. At the Zuni Bowl locations, mark the limits of the erosion and head cutting and then grade the face of the Zuni Bowl wall back (typically the eroded head cut area) to a uniform angled slope. The top of this slope will form the limits of the Zuni Bowl "pour over wall" or where water will first enter the Zuni Bowl feature.
4. Measure the vertical height of the head cut area, based on this new slope and the pour over wall location.
5. Mark the Zuni Bowl splash apron, measured from the base of the head cut wall, making it 3 to 4 times the height of the head cut dimension taken in step 4.
6. From the marked Zuni Bowl splash apron, excavate the shape of the plunge pool bowl using the head cut and erosion limits that were marked prior to the excavation. Try and avoid compacting the bottom of the Zuni Bowl as this will slow infiltration.
7. Once the Zuni Bowl plunge pool is dug and all loose material has been removed, line the plunge pool excavation with filter fabric to help stabilize the base by keeping the finer silt and sand particles of the subgrade in place during a flow event. The filter fabric should be overlapped a minimum of 12", with the upstream portion lying over the downstream portion.
8. Select the largest rocks available and use them to install the splash apron.
9. The pour over wall final elevation should be established so that it is approximately ½ of the total height of the head cut measurement taken in step 4. This lower wall will form the lower "pour over wall" for water to exit and continue to move down slope.
10. Next, armor the bottom of the plunge pool area with a single layer of rocks. The rocks selected for use in the plunge pool should be as uniform in thickness as possible to minimize the occurrence of an uneven base or "bowl" bottom. Once the "bowl" bottom is in place the plunge pool construction should be initiated at the lower pour over wall and proceed around the Zuni Bowl, layer by layer, creating the round plunge pool "bowl" structure. After the "bowl" plunge pool structure is in, start the next layer, working up the slope by creating small steps (off sets) from the layer below. The use of this offset wall technique should be utilized until you reach the top of the head cut or the established "pour over" limits, as established in step 3. Make sure that the final layer is at the correct elevation and not above the "pour over wall" elevation, so that water can freely enter the Zuni Bowl from above
11. Install a "one rock high" check dam downstream of the Zuni Bowl, approximately 12' downstream (not shown due to scale) to help dissipate the energy of the water leaving the Zuni Bowl.
12. Maintain and enjoy your Zuni Bowl!

3 Maintenance:

The maintenance of the Zuni Bowl is focused on the removal of sediment, leaves, and other debris that will fill the plunge pool bowl portion of the structure, making it inoperable, or less effective, at energy dissipation.

- Remove any buildup of sediment and debris from the plunge pool.
- Replace any dislodged rocks.

Monthly

- Inspect the Zuni Bowl after each major rain event during the first rainy season and remove any debris or sediment that may have accumulated within the bowl. Replace any missing rocks from the structure.

Yearly

Ensure that sediment and debris are removed yearly from the bowl and inspect the rock walls to ensure that they are intact.

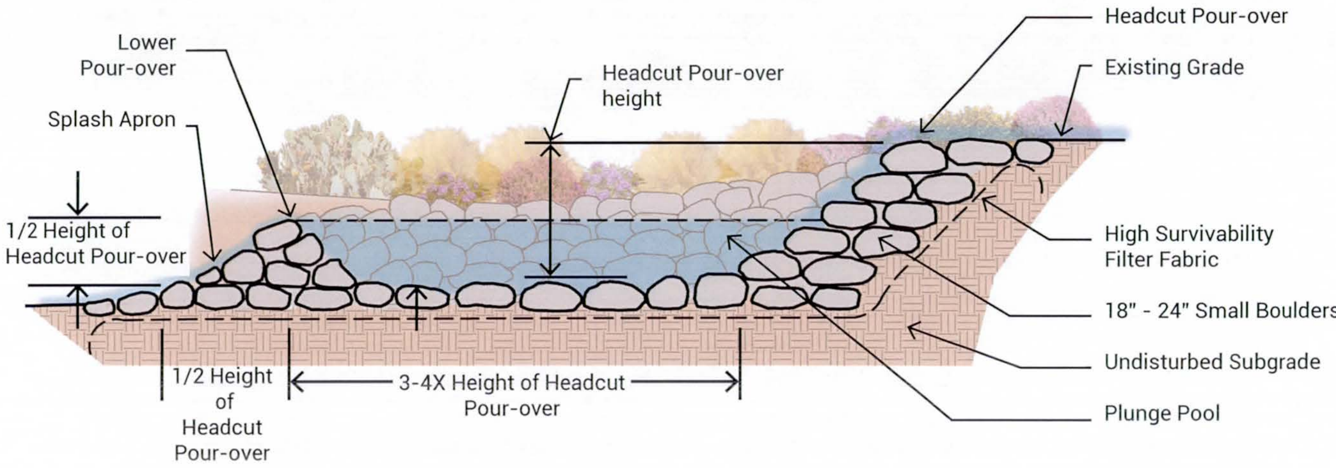
4 Cost:

A Zuni Bowl has some significant upfront cost with the excavation and rock work associated with its structure, but the long term maintenance is much lower.

- Excavation of erosion and head cut area $$$
- Filter Fabric $$
- Rock to Line Zuni Bowl and for Wall Work $$$

General Note:

Residents are informed that they should be aware of potential water rights and permitting requirements. Residents are encouraged to contact Arizona Department of Water Resources (ADWR) (water rights), Maricopa County Planning and Development (grading and drainage and floodplain-use permits), and the Arizona Department of Environmental Quality (ADEQ) (Arizona Pollutant Discharge Elimination System (AZPDES) and water quality), to understand applicable rules and regulations and address individual site conditions. Other permitting agencies may need to be contacted pending the type of work involved.



Zuni Bowl Construction Detail

Zuni Bowl Illustrative Perspective

Temporary Sediment / Erosion Control

Description:

Temporary Sediment / Erosion Control is part of an overall stormwater management approach aimed at reducing or eliminating the negative impacts of stormwater runoff. Today, stormwater management includes control of flood flows, reducing erosion, and improving water quality. This can be accomplished by implementing what are known as Best Management Practices (BMPs). BMPs are structural, vegetative (seeding or planting) or other managerial practices used to treat, prevent or reduce water pollution. BMPs, such as the GI/LID techniques presented within this report, are considered permanent - while other BMPs are considered temporary - but both are part of much larger BMP approach to stormwater management. There are a number of BMP approaches that often include native hydroseeding as a component to sediment and erosion control efforts. The temporary sediment wattles described below are an excellent example where native hydroseeding working in conjunction with these BMP practices can assist in permanently rehabilitating disturbed soils. The implementation of these temporary BMP sediment wattles with native seeding can have multiple benefits that include:

- Sediment wattles and fiber logs can be filled with organic materials that add to the surrounding soil profile as they degrade providing an improved soil interface for native seed establishment.
- Sediment wattles and fiber logs provide greater surface area that is physically in contact with the soil as compared to the older practice of using straw bales or silt fence.
- Sediment wattles and fiber logs are lightweight, and easy to transport and install.
- Sediment wattles and fiber logs help to slow water down and provide critical moisture to the surrounding native hydroseeded areas.

Base Components:
- Fiber log check dam, sediment wattles for sloped areas

Additional Performance Components/Accessories:
- Native Hydroseeding.

1 Location:

Locating and using a sediment wattle, or fiber log, on site depends on numerous site factors including: soils, slope, existing erosion, evaluation of the contributing watershed area, surrounding land use, and other site development considerations. Generally, fiber log wattles are suitable to sites with a small contributing watershed similar to rock check dams, but they are not designed to accommodate heavy rainwater impacts, or to be placed within major desert washes, arroyos, or well defined waterways. Their use on slopes has been proven to be very effective in slowing rainwater, retaining soil, and helping to establish vegetation (seeding) or planted vegetation on slopes that have been graded or disturbed.

Location Considerations:
- Evaluate the slope of the minor wash or swale where the wattle check dam is planned. If the slope of the minor wash or swale is steep, has excessive erosion, or where head cutting is already prevalent, another location should be selected and a different approach to address the issue should be investigated, as a wattle check dam may not be the most appropriate approach.
- If the placement of the wattle check dam will result in excessive re-grading of the minor wash, arroyo or swale another location should be selected.
- On a slope where sediment wattles are to be utilized, the erosive nature of the slope should be considered, and the spacing of the sediment wattles may need to be decreased (placed closer together) to address the erosive character of the soils.
- Sediment wattles and check dams should be located in compliance with the 45° rule (page 18).

2 Installation:

It is important to note that the use of wattles as either check dams or sediment control measures on slopes is considered a temporary installation until such time as a more permanent practice and approach (vegetative cover) has taken hold. This temporary nature may result in re-installation being required until the permanent vegetative cover has matured enough to address the erosion issue.

Start:
1. Call 811 to have all utilities marked in the field.
2. After identifying the wash, arroyo or swale for the wattle check dam(s), or the slopes identified for sediment wattles, stake out the location(s) on the site and adjust to avoid items listed above.

Fiber Wattle Check Dams and Sediment Wattles on Slopes
- At the location where the check dam or sediment wattle is to be located, excavate a 2-3" deep trench at a width that is as long as the fiber log or sediment wattle. Excavated materials can be placed along the upslope side of these fiber logs or sediment wattles.
- Place the fiber log or sediment wattle in the excavated trench, ensuring that it is in contact with the soil along the base. Adjacent fiber logs and sediment wattles shall abut tightly together and be staked.
- Secure the fiber log or sediment wattle with 1" square or diameter wood stakes driven 24" into the ground and spaced as shown on the details, ensuring that there is a stake at each end and a stake in the middle of each fiber log and sediment wattle. Each stake shall extend above the fiber log 2-3". Each stake shall be intertwined with the netting on the downstream side of the log. The soil shall be tamped against the upstream side of the fiber log or sediment wattle to assure that rainwater is forced to flow through the fiber log or sediment wattle and not under it.
- The fiber logs and sediment wattles shall be placed perpendicular to the flow of the water and, when used as a check dam, shall continue up the side slope of the wash and extend two feet above the high water flow line
- Spacing of these fiber logs and wattles will vary dependent upon the slope involved and needs to be evaluated on a case-by-case basis.

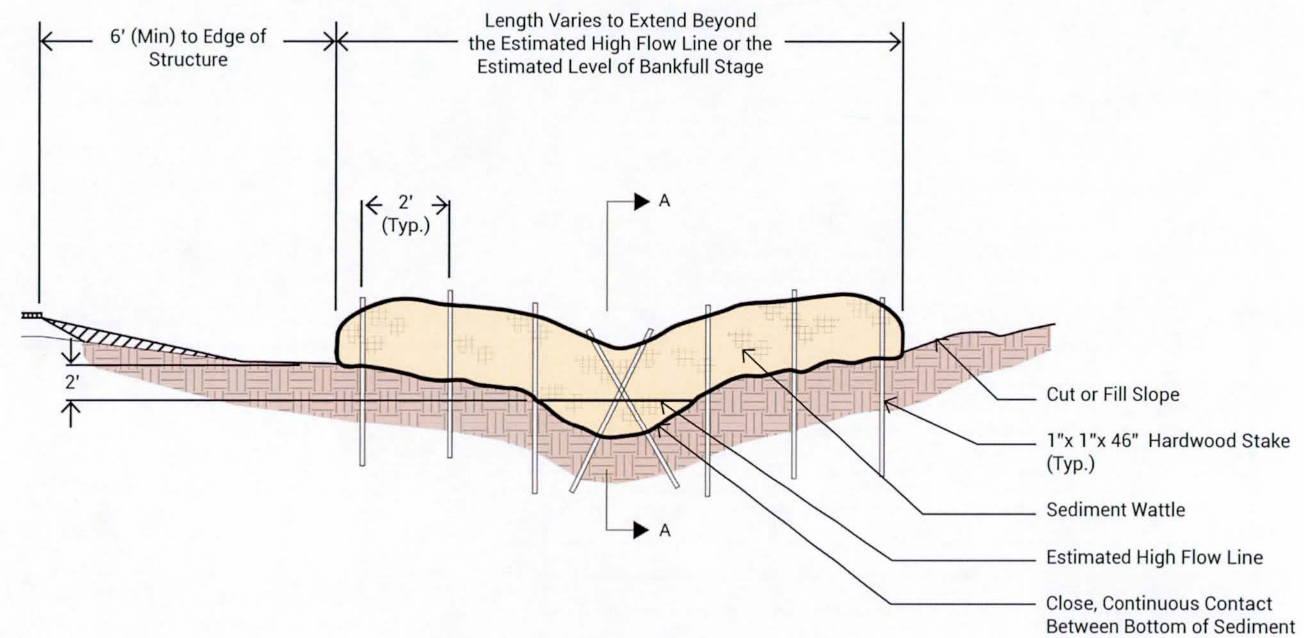
3 Maintenance:

The temporary nature of these BMP's will result in continual evaluation after each rain event as to their continued effectiveness and/or necessary replacement. The use of fiber logs as a check dam, or sediment wattles as slope protection, should be observed in operation during a rain event or reviewed following any event to inspect them for displacement, degradation, and evaluate their possible replacement. The maintenance of these BMP's is directly related to the establishment of the vegetative cover that these devices are meant to promote. Maintenance, therefore, needs to include an evaluation of the vegetative cover establishment associated with these techniques which may require additional seeding or vegetative plantings.

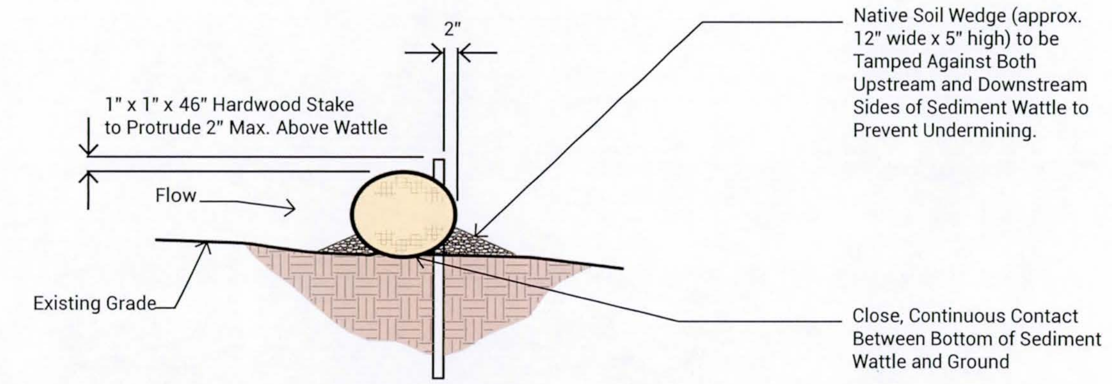
Maintenance:
- Where fiber logs or sediment wattles become dislodged due to excessive water velocities, use longer stakes and reduce the spacing between stakes.
- For a Fiber log check dam, these devices are considered temporary and are typically biodegradable, so they are not a long-term solution and may only survive for one rain event. With these temporary devices, replacement will be required most likely every year. The old materials that remain should be removed and new fiber log material should be reinstalled as detailed above.
- Reseeding or planting of new vegetation in the areas above these fiber logs or sediment wattles may be necessary if vegetative establishment is not sufficient to secure the soils.

4 Cost:

The cost to install these temporary BMP's will vary dependent upon the amount of materials needed.
- Excavation of subgrade $$
- Temporary fiber log check dam or sediment wattle $



Sediment Wattle In Ditch/Channel
Sectional Elevation (NTS)

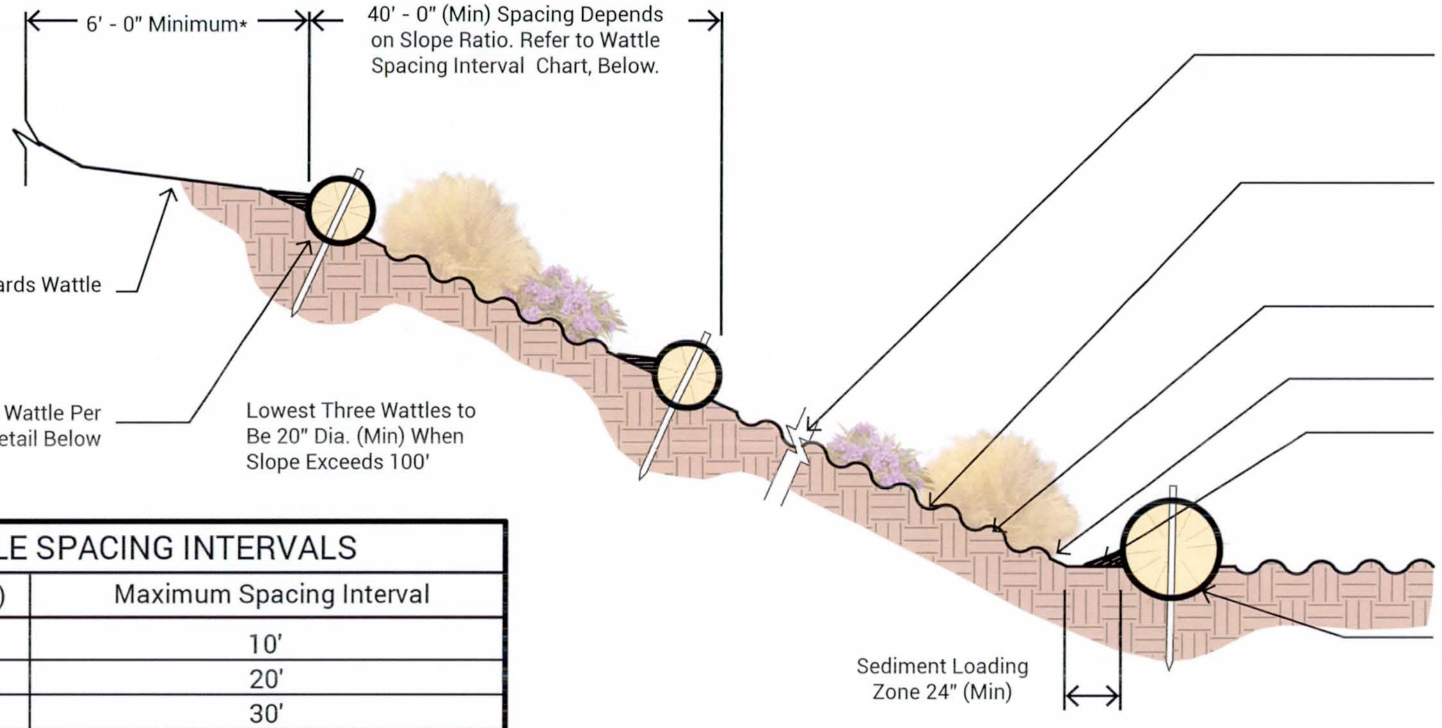


Section A-A (NTS)

Fiber Log (Wattles) Check Dam Construction Detail

General Note:

Residents are informed that they should be aware of potential water rights and permitting requirements. Residents are encouraged to contact Arizona Department of Water Resources (ADWR) (water rights), Maricopa County Planning and Development (grading and drainage and floodplain-use permits), and the Arizona Department of Environmental Quality (ADEQ) (Arizona Pollutant Discharge Elimination System (AZPDES) and water quality), to understand applicable rules and regulations and address individual site conditions. Other permitting agencies may need to be contacted pending the type of work involved.

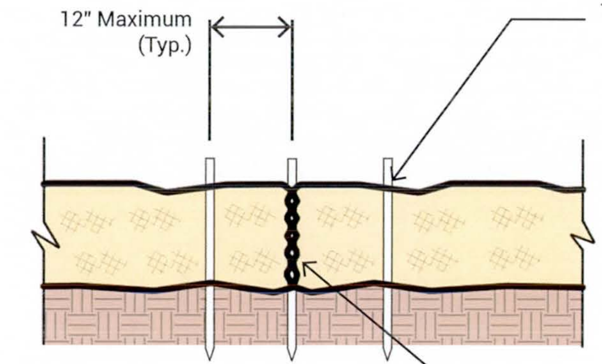


WATTLE SPACING INTERVALS	
Slope Ratio (H:V)	Maximum Spacing Interval
2:1	10'
3:1	20'
4:1	30'
5:1	40'
6:1	40'

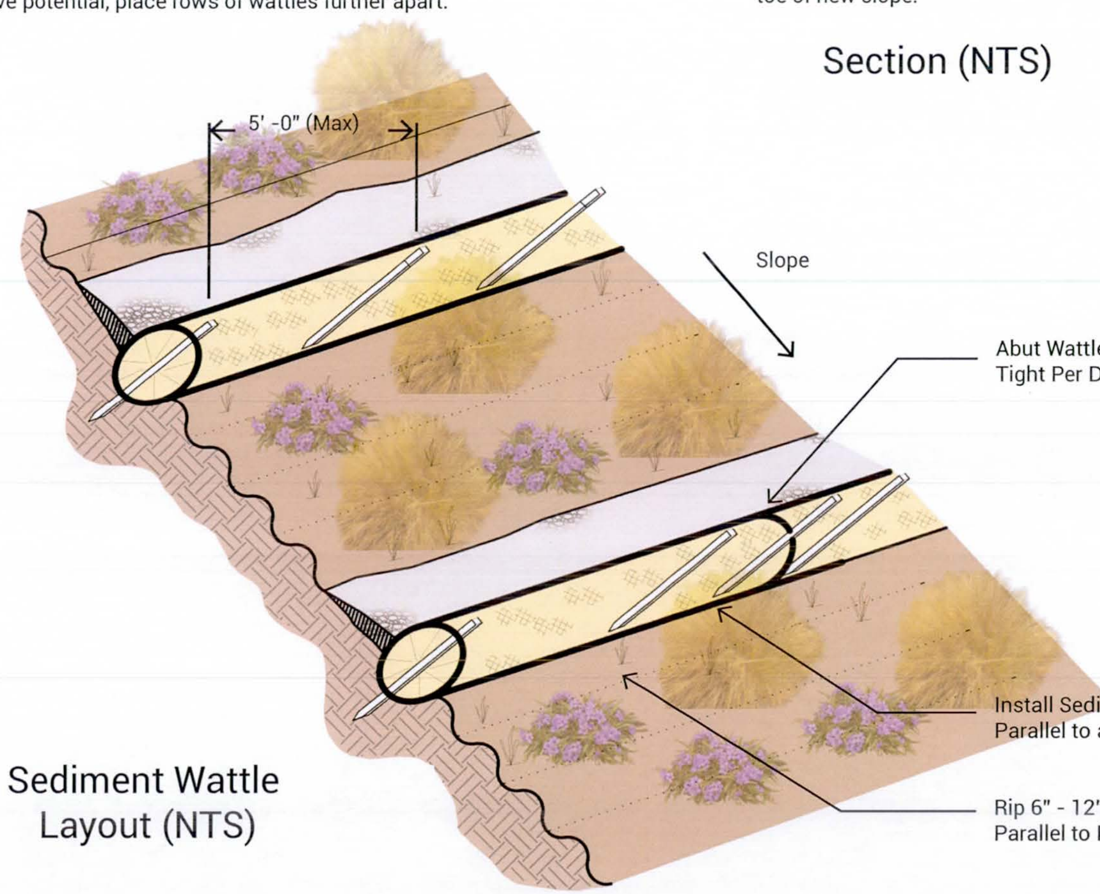
* Notes:
1) Top Row Shall Not be Placed within 6' - 0" of Edge of Structure
2) For erosive soils, place rows of wattles closer together.
3) For soils with low erosive potential, place rows of wattles further apart.

NOTE:
Construct bottom wattle above estimated bankfull level of adjacent ditch, when the ditch is installed at toe of new slope.

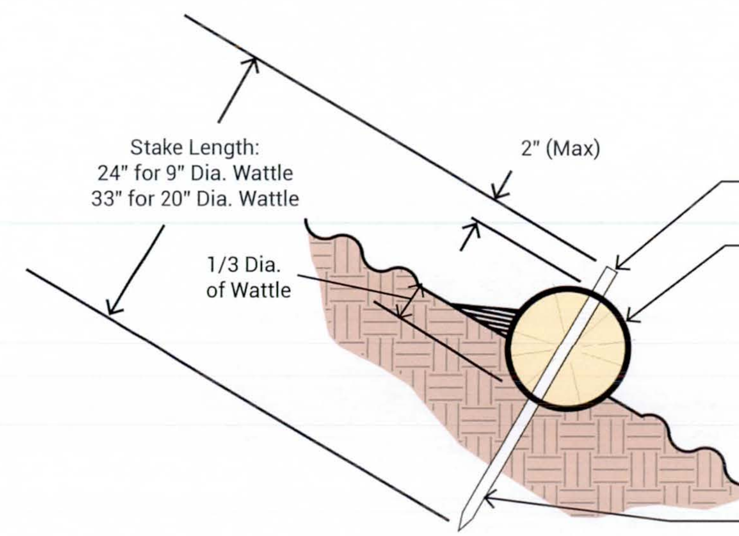
Section (NTS)



Sediment Wattle Overlap (NTS)



Sediment Wattle Layout (NTS)



Sediment Wattle Staking Detail (NTS)

Part 4 - Appendix

Water Conservation

The GI/LID techniques included in this report are designed to make use of local rainfall events and stormwater runoff to reduce reliance on potable water for outdoor uses. Listed below are additional water conservation considerations that a homeowner may elect to employ as a standalone approach or in conjunction with the strategies discussed earlier. They have been organized into several groups, based on areas of effort that often coincide with outdoor home improvement projects and where water conservation can be incorporated.

Site Work

- Preserve as much existing native vegetation on your site, as is feasible.
- Minimize 'clearing and grubbing' activities and limit the footprint of construction disturbance to preserve the existing vegetation and reduce soil compaction on your site.
- When there are opportunities associated with parcel development or renovations, disturbed slopes should be fine graded so that they are as gentle as possible (terraced) to slow down runoff and allow rainwater ample time to infiltrate into the soil.
- Preserve and protect existing topsoil and organic material (deadfall and leaf litter) to improve soil conditions for areas that are targeted for outdoor landscape and revegetation projects.
- Rehabilitate disturbed soils during site work activities through the use of soil stabilization techniques that include but are not limited to the use of rock and rip rap materials, native plantings, hydroseeding and other erosion control techniques and best management practices that help to permanently rehabilitate and restore any disturbed soils.

Landscape and Irrigation

- Use native and/or desert-adapted plant materials (refer to seed/plant mix sheet contained within this appendix and the ADWR drought tolerant species list available at: http://www.azwater.gov/AzDWR/StatewidePlanning/Conservation2/LandscapePros/PlantLists_Landscaping.htm
- Increase percentage of vegetative cover by adding native, low water using plants to help increase shade on site, resulting in a cooler ground surface, retaining soil moisture, and reducing overall outdoor water needs.
- Utilize high-efficiency "smart" irrigation control systems with water-saving features that include sensors to automatically adjust sprinkler run times based on the local weather conditions for specific sites. Smart controllers can be used in conjunction with rain gauges and soil moisture sensors to adjust irrigation run times based on localized rain events and available soil moisture.
- Establish irrigation watering schedules for infrequent, deep soak cycles versus short, frequent cycles.
- Utilize drip irrigation vs. spray irrigation for all tree and shrub irrigation needs.
- Use underground drip irrigation systems for lawns, instead of traditional spray irrigation, to minimize evaporation and maximize efficiency.
- Design, locate, and install turf lawn in slightly depressed areas (versus elevated or perched conditions) to allow them to function as shallow stormwater collection areas and increase infiltration in the most useful locations
- Capture and reuse gray water (defined as any domestic wastewater (sinks, laundry, showers, etc.), excluding sewage (water from toilets)) from your home and for use as supplemental landscape irrigation.
- Research and install low water, desert-adapted turf varieties (buffalo grass, blue grama, etc.) when considering lawn areas.
- Minimize the size of your existing lawn or consider replacing it with artificial turf.
- Remove high water use landscape and lawn areas with native and desert-adapted plant materials.
- Remove weed species from your landscape in a timely manner to limit competition with desired natives and other landscape plants for water and vital nutrients.
- Properly prune plants using standard horticultural practices, as improper pruning allows for greater water loss from the plant and increases the likelihood of plant disease and pests.

Soil Modifications

- Add composted organic matter to site soils to increase water retention and soil moisture, when practical.
- Amend existing soils for higher storm water infiltration by incorporating porous materials into your soil (i.e. sand, gypsum, etc.).
- Scarify, or otherwise 'break up', compacted soil surfaces in flat and low-lying areas where stormwater can collect to increase absorption and minimize run off.

Website links that offer additional resources for home owners to investigate additional water conservation ideas:

- Water Use It Wisely
  https://wateruseitwisely.com/100-ways-to-conserve/
- Arizona Municipal Water Users Association (AMWUA)
  http://www.amwua.org/what-you-can-do
- Brad Lancaster's website (Author of several books for water harvesting in Arizona)
  https://www.harvestingrainwater.com/

Suggested Reading List

Title - Author - Publication Date

2012 Green Infrastructure Technical Assistance Program, City of Phoenix, United States Environmental Protection Agency, August 2013

ADOT Post-Construction Best Management Practices Manual For Water Quality, ADOT, January 2016

Arroyo Closing the Water Demand-Supply Gap in Arizona, The University of Arizona, 2015

Assessing The Economic Value of Green Infrastructure: Green Paper, Roger Jones, John Symons, Celeste Young, 2015

Backyard Conservation - Terracing, United States Department of Agriculture Natural Resources Conservation Service

Bernalillo County Water Conservation Development Standards and Guidelines, Bernalillo County

Best Management Practices Manual, Idaho Transportation Department, August 2011

Consider Rainwater Harvesting and Reuse, Glumac Design Strategies

County-Scale Rainwater Harvesting Feasibility in the United States: Climate, Collection Area, Density, and Reuse Considerations, Mounir William Ennenbach, Paulina Concha Larrauri, Upmanu Lall, February 2018

Design Handbook for Low Impact Development Best Management Practices, Riverside County Flood Control Water Conservation District, September 2011

Eastern Washington Low Impact Development Guidance Manual, AHBL HDR, June 2013

Erosion Control Field Guide, Watershed Artsans, 2010

Erosion and Pollution Control Manual For Highway Design and Construction, Wheat Scharf Associates/ ADOT, December 2012

Erosion and Sediment Control Best Management Practice Manual, West Virginia Department of Environmental Protection Division of Water and Waste Management, 2006

Green Infrastructure in Arid and Semi-Arid Climates, EPA, May 2010

Harvesting Rainwater - Guide to Water-Efficient Landscaping - City of Tucson, September 2013

Harvesting Rainwater for Landscape Use, Patricia H. Waterfall, October 2004

How to Construct a Swale in the Residential Landscape, Tenth Acre Farm, 2018

Landscape Water Use in Phoenix, Arizona, Chris A. Martin, 2001

Low Impact Development Manual for Southern California: Technical Guidance and Site Planning Strategies, The Low Impact Development Center Inc., April 2010

Middle Rio Grande Low Impact Developments: Projects for Stormwater Management, Fourth Edition February 2016

Passive Water Harvesting Rainwater Collection, The University of Arizona College of Agriculture and Life Sciences Cooperative Extension, October 2012

Rainfall frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years, Department of Commerce, May 1963

Rainwater Cisterns: Design, Construction, and Treatment, Penn State Extension, 2017

Rainwater Harvesting, Building Codes Division Oregon Smart Guide, June 2010

Rainwater Harvesting, Texas A&M AgriLife Extension Dana O. Porter, Russell A Persyn, Valeen A. Silvy,

Rainwater Harvesting: Conservation, Credit, Codes, and Cost Literature Review and Case Studies, United States Environmental Protection Agency, January 2013

Rainwater Harvesting Guide, Albuquerque Bernalillo County Water Utility Authority,

San Mateo County Sustainable Green Streets and Parking Lots Design Guidebook, San Mateo

Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act, EPA, December 2009

Terracing as a 'Best Management Practice' for Controlling Erosion and Protecting Water Quality, Purdue University Cooperative Extension Service, April 2001

The Texas Manual on Rainwater Harvesting, Texas Water Development Board, 2005

Urban Storm Drainage Criteria Manual Volume 3, Urban Drainage and Flood Control District Colorado, November 2010

Water Resources Development Commission Final Report, October 2011

Wills Canyon Headcut Repair, United States Forest Service Sacramento Ranger District, Lincoln National Forest, Otero County, New Mexico, March 2018

Yakima Regional Low Impact Development Stormwater Design Manual, AHBL URS, September 2011

Glossary of Terms

100 year storm – A storm that has a 1% chance of happening in any given year

ADWR – Arizona Department of Water Resources

ARS – Arizona Revised Statutes

Aquifer -A porous deposit of rock, such as a sandstone, containing water that can be used to supply wells

Bajada - A broad slope of alluvial material at the foot of an escarpment or mountain

Berms – Mounds of soil used to retain stormwater or to direct its flow

Bimodal rainfall patterns – In Arizona we typically receive the majority of our rain events in either the winter months (December - February) or monsoon season (July - September)

Cistern – A tank used to store collected rainwater

Downspouts – Vertical pipes that drain stormwater downward from the gutters

Flash Flood – Rapidly rising water in a wash or river that is usually caused by heavy rainfall

French Drain (Rock Chimney) –Gravel-filled hole or trench placed so that stormwater can seep in

FCDMC – Flood Control District of Maricopa County

GI – Green Infrastructure

Gutters – Channels along a roof's edge to catch and direct stormwater

Impervious – Not allowing water or other liquids to pass through a surface

Infiltration – The movement of water through the soil surface into the soil

LID –Low Impact Development

Monsoons – A seasonal pattern of wind and rainfall

Perched aquifer -An aquifer that occurs above the regional water table in a layer of impermeable rock

Percolate – The movement of water through the soil to the water table

Pervious – Allowing the passage of water or liquids through a surface

Precipitation – Water falling from the atmosphere in the form of rain, snow, sleet, or hail

P&D – Planning and Development

Run-off Coefficient – An estimated proportion of rainfall that "runs off" a specific surface, depending on how much water can be absorbed

Soil – Composed of gravel, sand, silt, and clay, soil is the growing medium for plants and can be a great place to store captured storm water

Stormwater Runoff – Rainwater that hits the ground and flows over the earth's surface

Swale –A long, shallow trough between two areas of higher ground in the yard

Water Cycle – The natural sequence through which water passes into the atmosphere as water vapor, precipitates to earth in liquid or solid form, and ultimately returns to the atmosphere through evaporation

Water Harvesting – Collecting and putting rainwater or stormwater to beneficial use

Watershed – An area of land that sheds water and directs it downhill to a particular watercourse or point

Native Seed and Plant Mix for Arizona Upland Subdivision

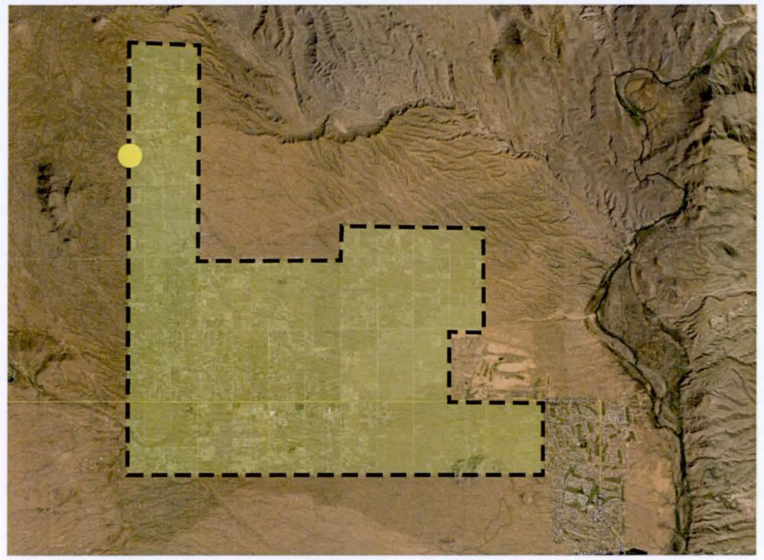
Botanical Name	Common Name
1 - Acacia constricta	Whitethorn Acacia
2 - Acacia greggii	Catclaw Acacia
3 - Ambrosia deltoidea	Triangle-leaf Bursage
4 - Aristida purpurea	Purple Three-Awn
5 - Atriplex canescens	Fourwing Saltbush
6 - Baileya multiradiata	Desert Marigold
7 - Bouteloua curtipendula	Sideoats Grama
8 - Castilleja exerta ssp. exerta	Purple Owl's Clover
9 - Cercidium (Parkinsonia) florida	Blue Palo Verde
10 - Encelia farinosa	Brittlebush
11 - Eschscholtzia mexicana	Mexican Poppy
12 - Hilaria berlangeri	Curly Mesquitegrass
13 - Kallstroemia grandiflora	Arizona Poppy
14 - Larrea tridentata	Creosote Bush
15 - Lesquerella gordonii	Gordon's Bladderpod
16 - Lupinus arizonica	Arizona Lupine
17 - Olneya tesota	Desert Ironwood
18 - Phacelia crenulata	Arizona Desert Bluebells
19 - Plantago ovata	Desert Indian Wheat
20 - Prosopis velutina	Velvet Mesquite
21 - Salvia columbariae	Desert Chia
22 - Simmondsia chinesis	Jojoba
23 - Sphaeralcea ambigua	Desert Globemallow
24 - Sporobolus airoides	Alkali Sacaton
25 - Zinnia acerosa	Desert Zinnia

Site Visit

Four representatives of the J2 Design Team toured the Rio Verde study area on Wednesday, February 28, 2018. The weather was partly cloudy and temperatures in the low 60's. The day was preceded by one of the area's winter rain events and the evidence of that event was still obvious in the wet roads, standing water and displaced sediment from the numerous washes that cross the area. This site visit provided the Team the opportunity to walk portions of the roads and washes and experience the environment of this area. J2 was equipped with our FAA licensed drone, as well as cameras, to capture the area's unique desert habitats and the development that has, and is, occurring in the area.

This site visit provided us the opportunity to see firsthand the disruptive nature of a sediment laden desert wash on the surrounding area. It allowed us to witness the fact that most of the land owners understand the impacts that desert living has on their property. We saw evidence of both wash and roadway improvements that mimic many of the ideas presented within this report relative to using simple GI/LID approaches to address the drainage issues around their respective properties through the use of check dams, terracing, and even some temporary BMP's.

The following pages represent the areas were the J2 Design Team photographed and captured some drone images of the region.



Site Context

1 Looking North Along 136th Street

2 Looking West Towards Scottsdale Sonoran Preserve

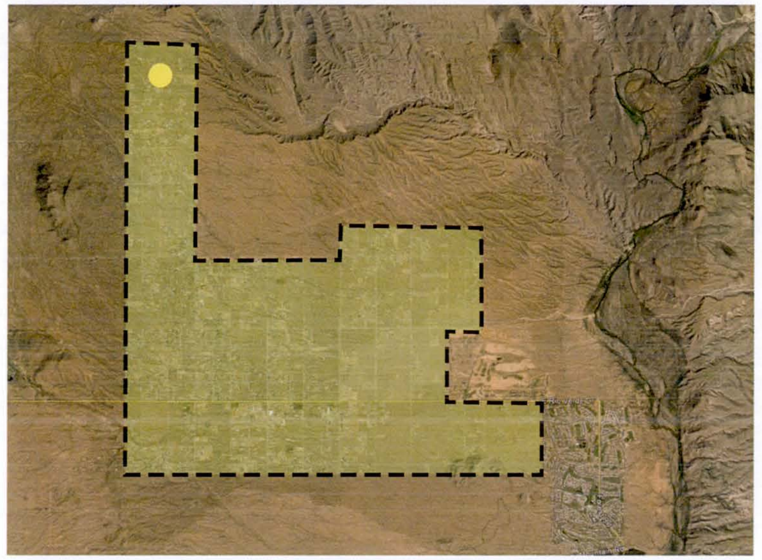
Site Context Photos - Near 136th Street and Westland Drive

3 Looking West Towards Scottsdale Sonoran Preserve

4 Aerial View Looking South Along 136th Street

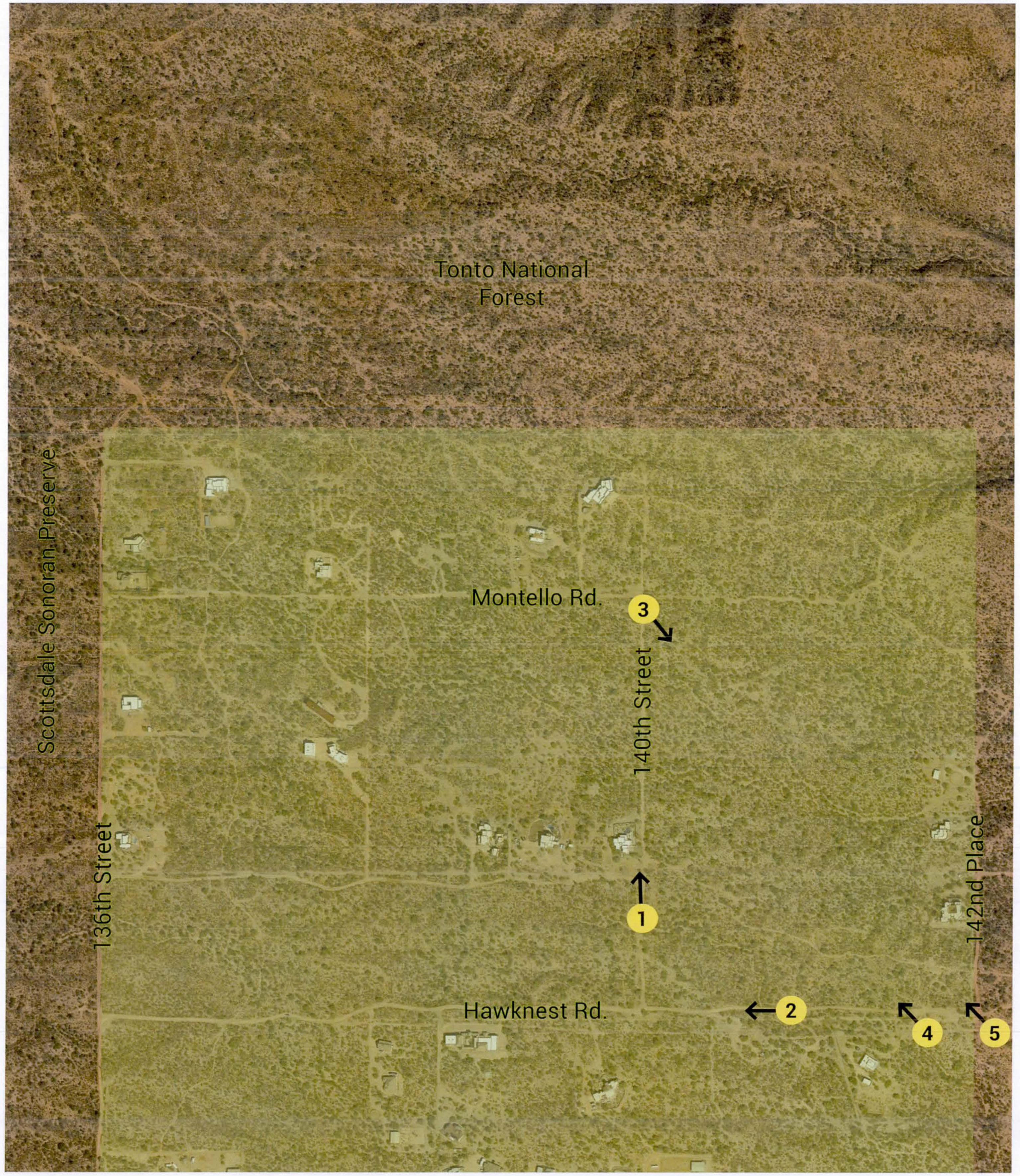
5 Looking North Along 136th Street

J2 Design


Site Context


1 Wash Crossing Along 140th Street


2 Typical Ponding Along Hawknest Road



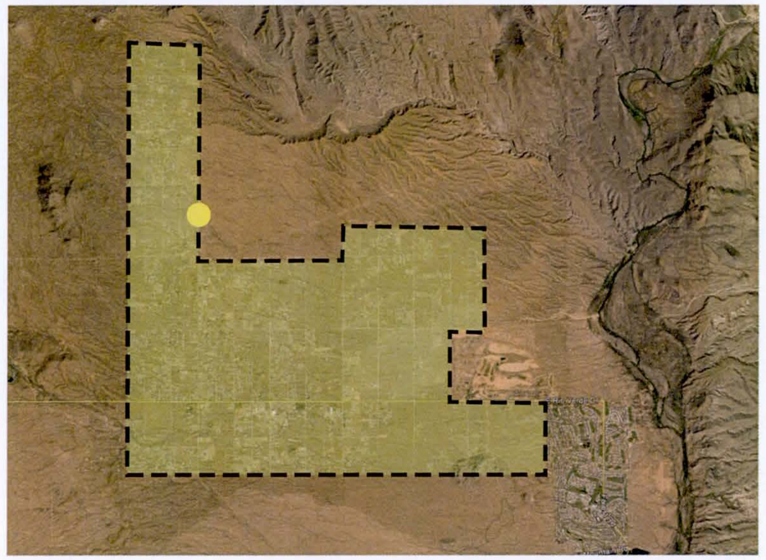
Site Context Photos - Near 140th Street and Montello Road


3 Looking Southeast


4 Make Shift Check Dam Constructed with CMU Block


5 Make Shift Check Dam Constructed with Rip Rap

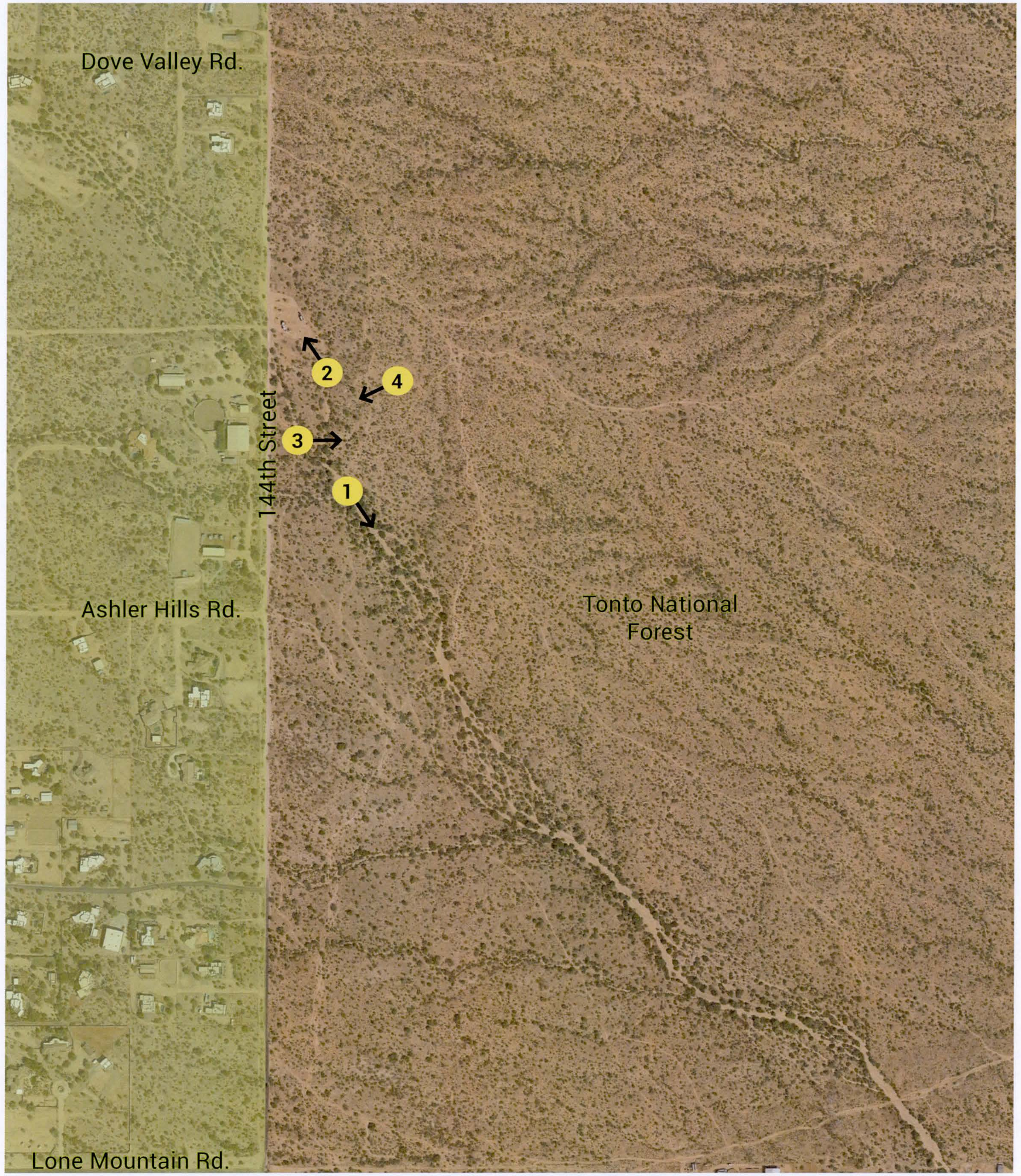
J2 Design



Site Context

1 Looking Southeast Along Wash Bottom

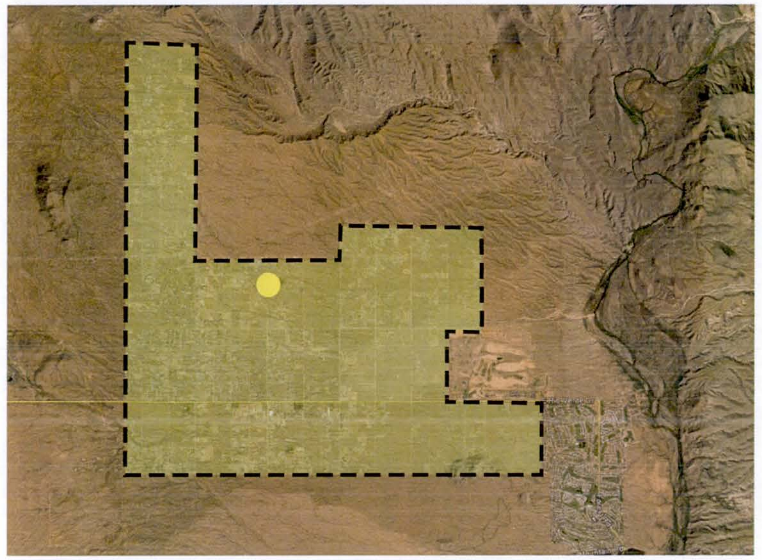
2 Aerial View of Tonto National Forest Parking Area



Site Context Photos - Near 144th Street and Ashler Hills Road

3 Aerial View Looking East

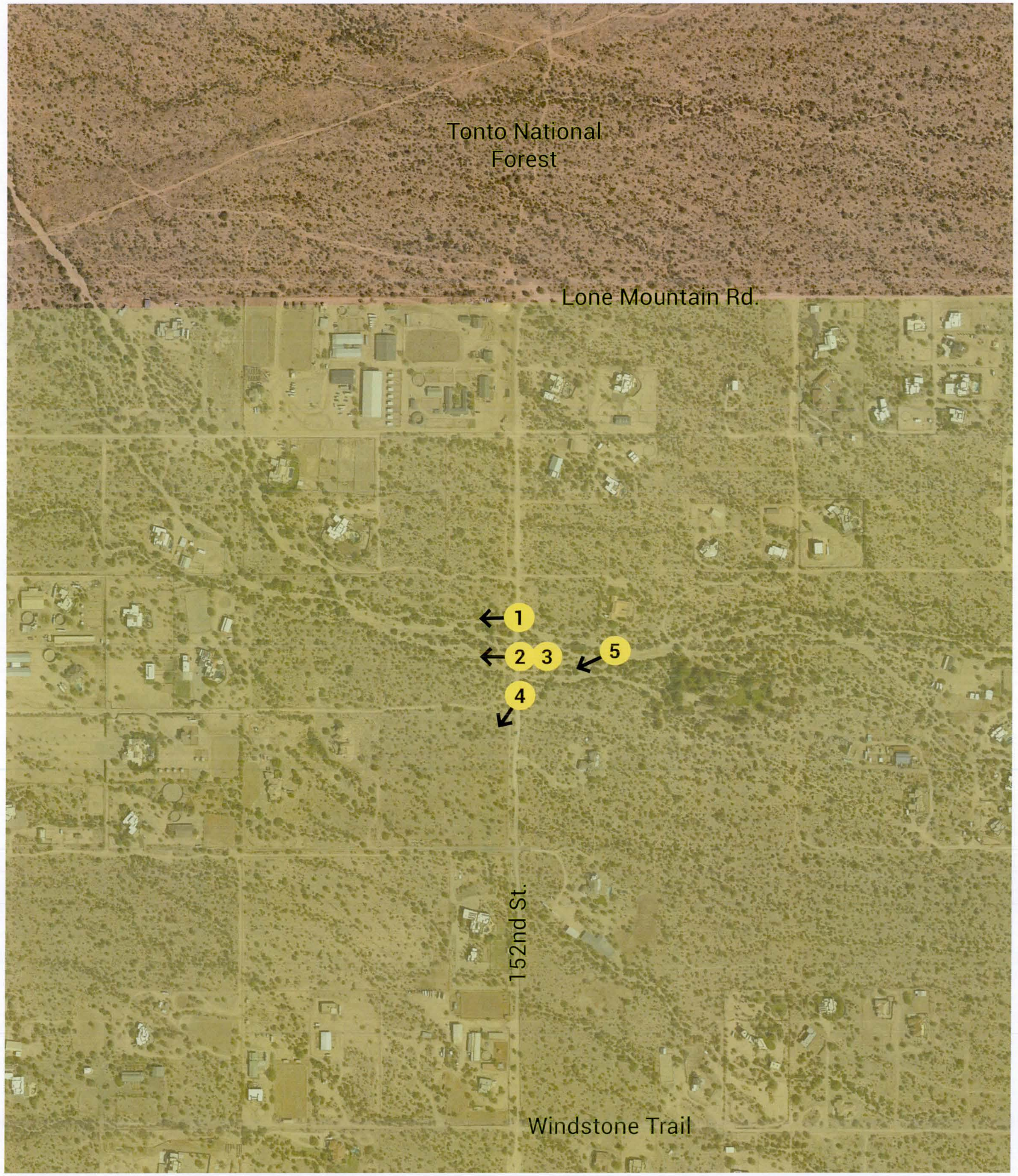
4 Aerial View Looking Southwest Towards 144th Street



Site Context

1 Wash Crossing Over 152nd Street

2 Wash Crossing Over 152nd Street



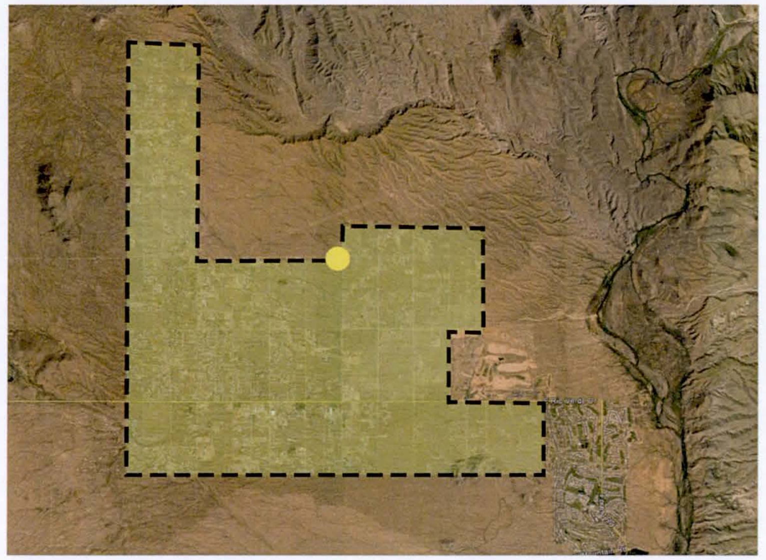
Site Context Photos - Near 152nd Street and Lone Mountain Road

3 Wash Crossing Over 152nd Street

4 Wash Crossing Over 152nd Street

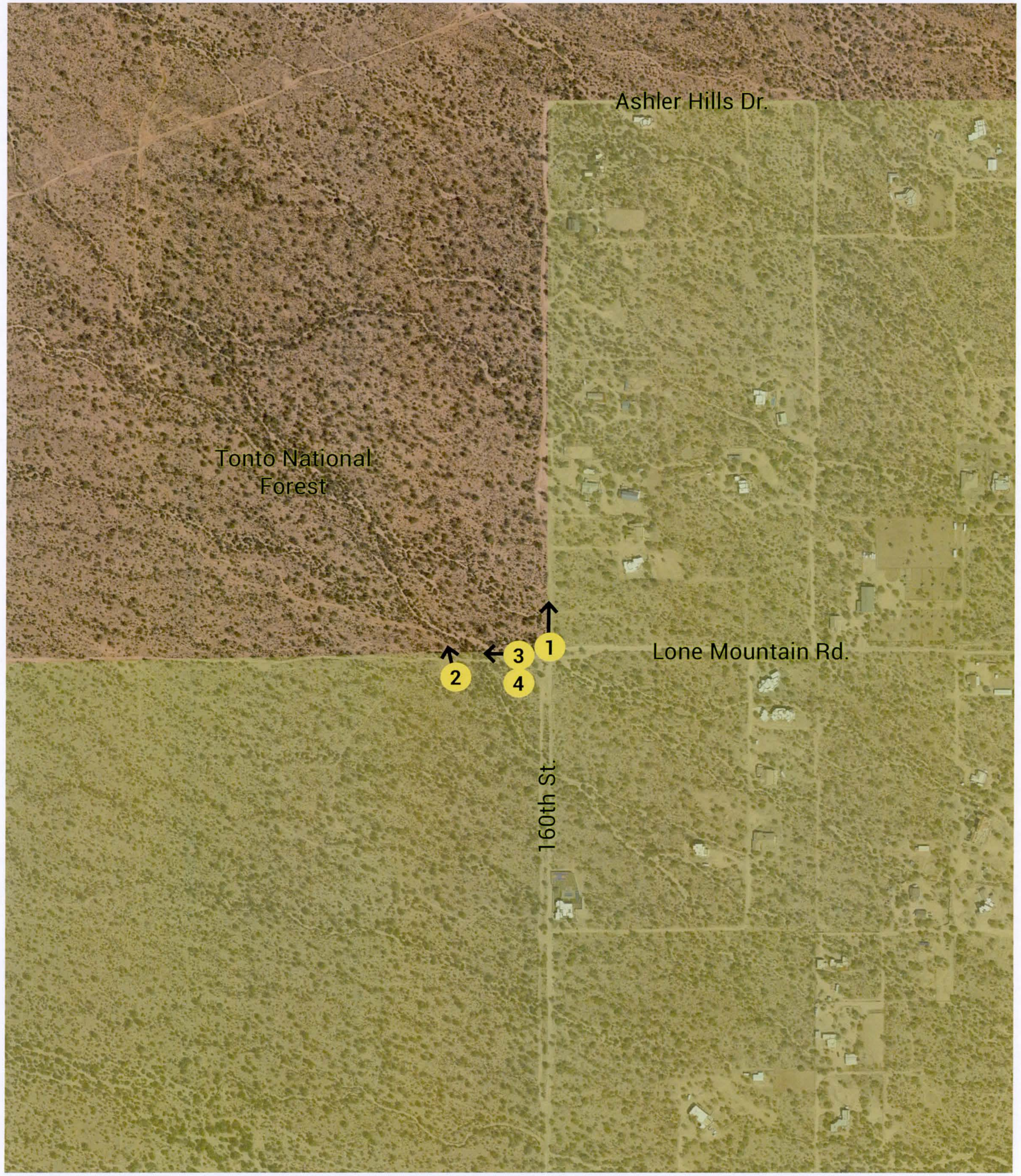
5 Wash Crossing Over 152nd Street

J2 Design


Site Context


1 Looking North on 160th Street

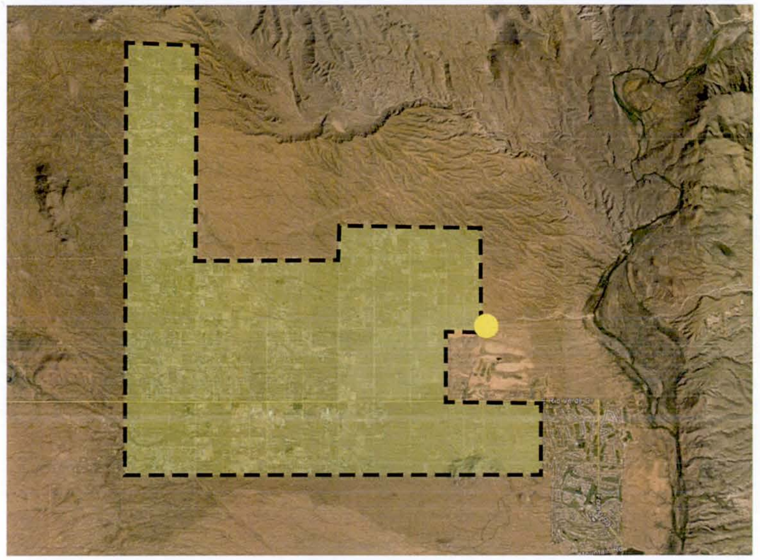
2 Tonto National Forest Information Kiosk



Site Context Photos - Near 160th Street and Lone Mountain Road


3 Looking West Along Lone Mountain Road

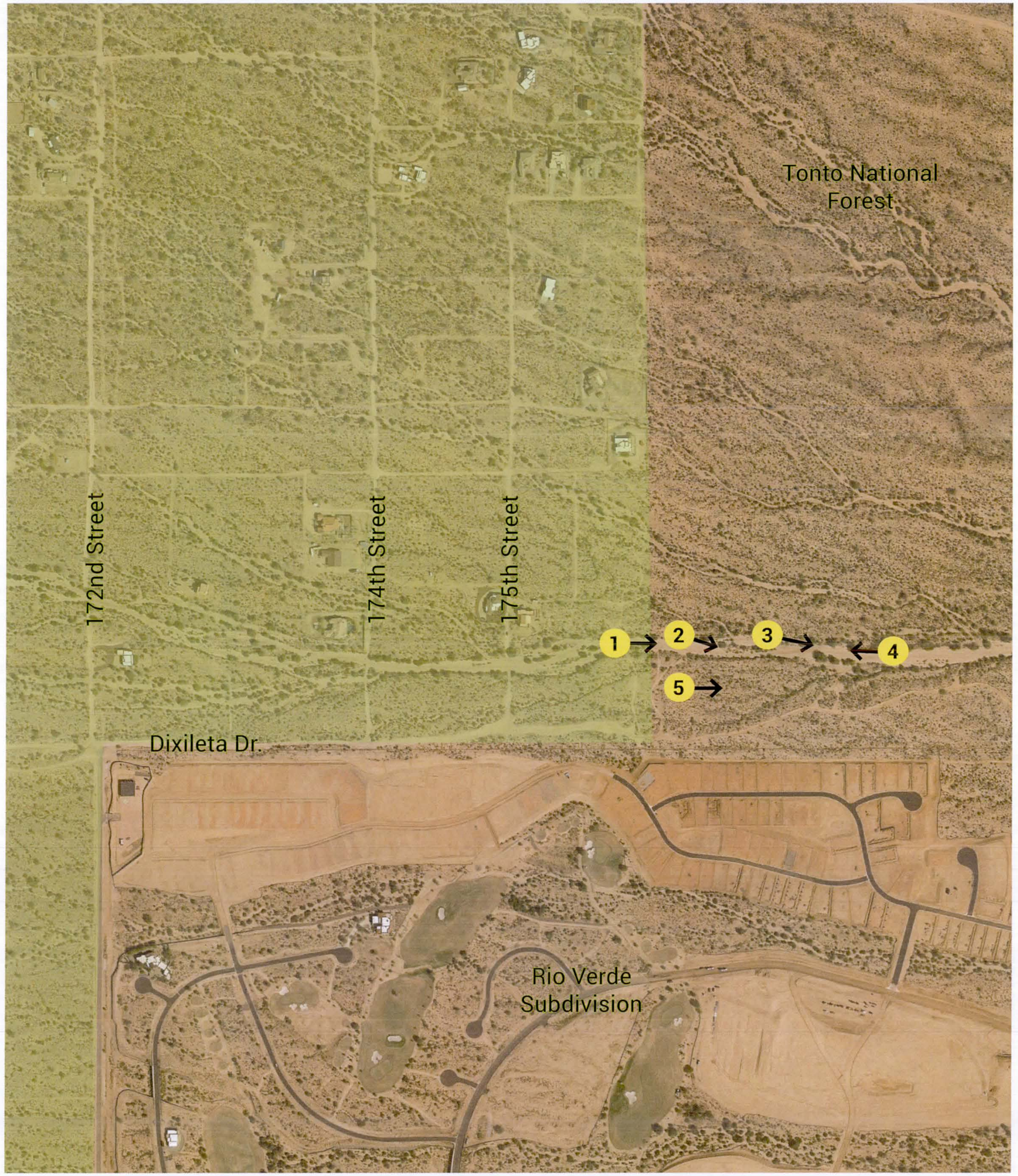

4 Site Context



Site Context

1 Looking East From Wash

2 Example of Head Cut Along Wash Bank



Site Context Photos - North of Rio Verde Subdivision

3 Looking East from Wash Bottom

4 Looking West From Wash Bottom

5 Looking East