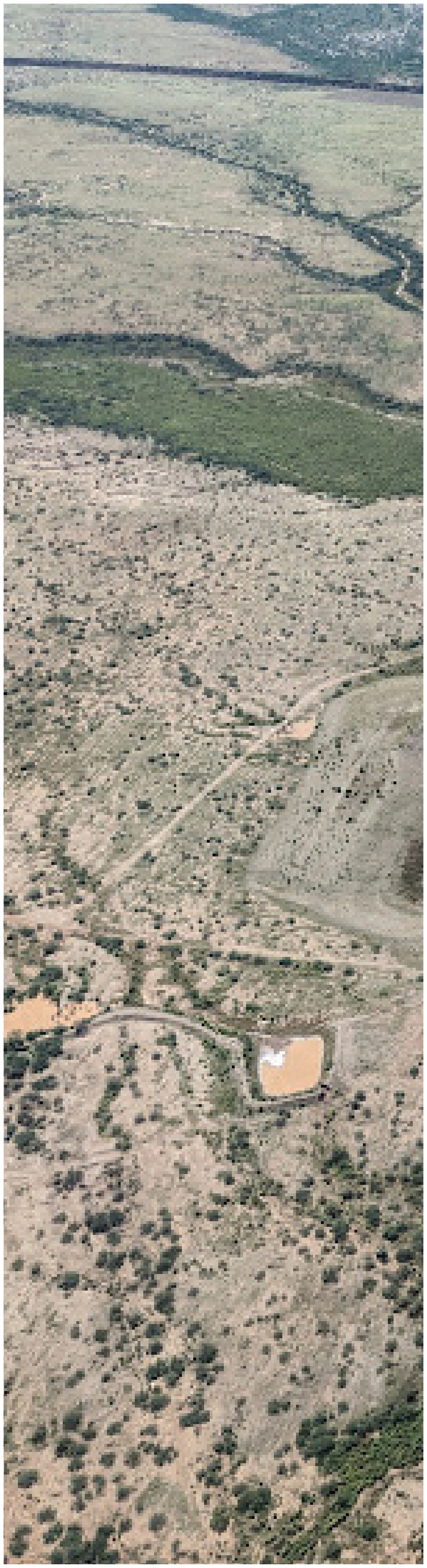
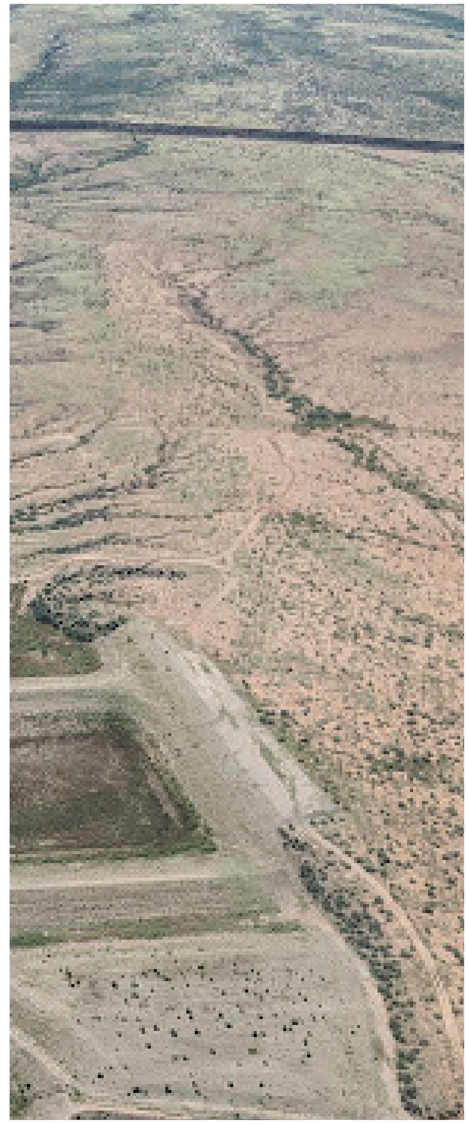




Introduction to

STORMWATER RECHARGE

to Benefit Streams in Arizona

Revised April 4, 2023

The Nature Conservancy

MONTGOMERY & ASSOCIATES
Water Resource Consultants

An Introduction to Stormwater Recharge to Benefit Streams in Arizona

Contents

This introductory guide was developed by Montgomery & Associates, a water resources consulting firm, under contract with The Nature Conservancy. Stakeholders that provided valuable input include Salt River Project and the Flood Control Districts of Cochise, Maricopa, Pima, Pinal, and Yavapai Counties. Cooperating partners were Culp & Kelly, LLP and researchers from the University of Arizona.

On the Cover: Photo of Horseshoe Draw Sediment Control and Stormwater Recharge Project in the Cochise Conservation Recharge Network, courtesy of Mark Apel and Lighthawk Conservation Flying

An Introduction to Stormwater Recharge to Benefit Streams in Arizona

Introduction

Stormwater runoff has the potential to damage property from flooding and impair water quality in lakes and streams. Historically, flood control initiatives have involved directing flood flows away from buildings and roadways and limiting downstream impacts from runoff. As water resources become more constrained in Arizona, stormwater runoff is increasingly regarded as a valued water resource to supplement local water supplies and sustain water-dependent ecosystems. Flood control projects that are developed to address problems caused by excessive stormwater runoff can provide multiple benefits and increase community resiliency. While a multi-benefit approach to flood management is not new, flood districts and other local planning agencies are becoming more interested in implementing flood control projects that support water supplies and important ecological areas and take advantage of new state and federal funding opportunities.

This Introduction to Stormwater Recharge to Benefit Streams in Arizona focuses on flood control projects that have a substantial recharge component near streams. This document does not consider the much broader category of "green infrastructure" that generally define using natural or lightly engineered systems to manage stormwater. It includes a general framework, and outlines opportunities in Arizona. It also highlights some policy issues, contains examples of projects, and includes a bibliography of additional resources. The guide is intended to inspire a multi-benefit approach to stormwater management that is used as a reference and educational tool for water resource managers, floodplain administrators, planning agencies, and elected officials across the state.

Motivation: Declining Groundwater and Dwindling Streams

Most of Arizona's extractable groundwater has accumulated over several millennia and is being replenished naturally at a much lower rate than it is being pumped. Pumping of groundwater and declining flows on the Colorado River due to climate change—which includes a decades-long megadrought—are further straining Arizona's water supplies. This strain is especially felt in rural areas of the state that lack access to Colorado River and other surface water supplies and thus rely exclusively on local groundwater. This groundwater "mining" causes groundwater levels to decline (Figure 1). Some more densely populated areas of the state face cuts in deliveries of Colorado River water via the Central Arizona Project (CAP) and face the need to pump more groundwater to meet future demands. Stormwater is an increasingly important resource, but natural systems need to be protected and downstream water rights need to be considered when developing stormwater management projects.

Streamflow consists of baseflow from groundwater discharge and surface runoff from precipitation. Groundwater discharge occurs where and when the water table intersects the surface and is the “baseflow” in perennial and intermittent streams. Baseflow can change over time due to changes in groundwater pumping, natural or artificial recharge, vegetation, and climate. Flood flows have also changed over time because of watershed condition changes due to urbanization and other land use practices. As a result, many hundreds of miles of stream that were formerly perennial no longer flow year-round. Likewise, intermittent stretches flow less frequently for shorter distances or only flow in response to flooding and are now ephemeral. Projects that maintain or increase groundwater levels can restore and sustain these valuable ecological areas. As these projects are developed, the natural flood regime needs to be considered and protected.

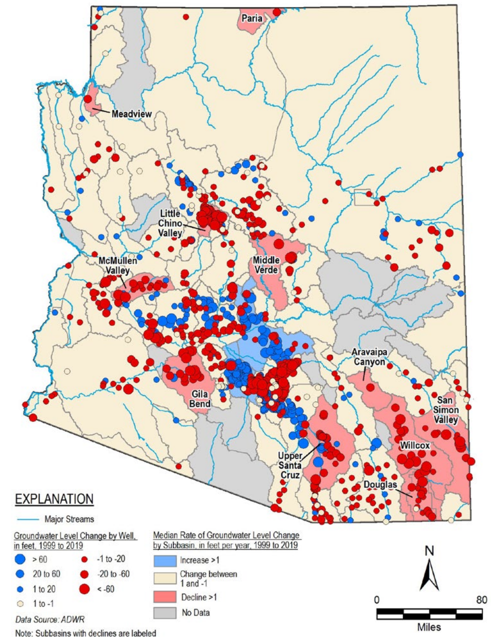


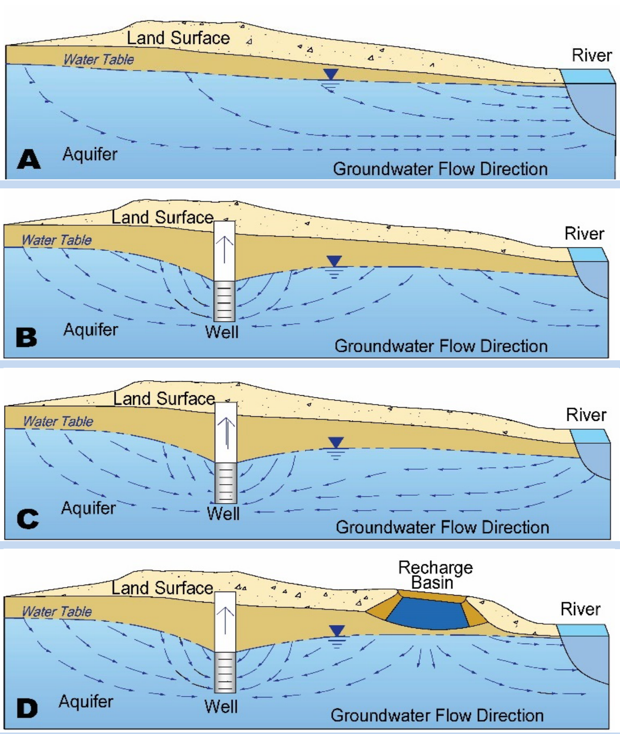
Figure 1. Groundwater Level Changes in Arizona, Water Years 1999-2019

Opportunity: Stormwater Recharge

Because of strict requirements to address groundwater mining in the 1980 Groundwater Management Act, Arizona became a leader in managed artificial recharge, which is the process of adding water to aquifers when it's legally and physically available. Traditional sources of recharged water include surface water—primarily from the Colorado River—and treated wastewater effluent or “recycled water”. In the past few decades, aquifer recharge and limits imposed on groundwater pumping resulted in dramatic recovery of groundwater levels in the Active Management Areas (AMAs) in the heavily populated central and southern parts of the state. The rest of the state outside these AMAs has been characterized by steady and in some cases large groundwater level declines (Figure 1).

How Recharge Benefits Streamflow

Aquifer recharge is a well-established practice that can be applied to stormwater projects to maximize the capture and infiltration of water underground. When located in key areas along streams, stormwater recharge projects can augment groundwater levels in riparian areas and sustain baseflow in streams. Well-designed projects can increase the number of days and miles with flowing water without impacting the natural flood flow regimes. Every location is unique so localized groundwater modeling can help identify the best location for potential benefits. Figure 2 demonstrates how recharge projects may benefit streamflow.



Under natural conditions where the water table is a higher elevation than the streambed, groundwater is discharged into streams.

Groundwater pumping the water table, increasing the depth to groundwater around large pumping centers and reducing streamflow by intercepting groundwater that is flowing toward the stream.

Over time, the cone of depression expands toward the river and "captures" or removes water from the stream. This same effect can be caused by reduced natural recharge from changes in climate or vegetation.

Recharging water underground in key near-stream areas can stabilize or even increase groundwater levels and restore streamflow.

From the Cochise Conservation and Recharge Network, modified from the USGS

Figure 2. Recharge in Key Locations Can Enhance Streamflow

Opportunities in Arizona for Recharge to Benefit Streamflow

The optimal location for a recharge project to benefit streamflow is along a stream in younger basin-fill and stream alluvium sedimentary deposits. Figure 3 shows these areas in Arizona that were identified using methodology set forth by the Arizona Department of Water Resources (ADWR 2021). These areas are concentrated in the Basin and Range geologic province in the southern and western parts of the state where basin-fill aquifers predominate. Pima County has the highest density of streams overlying sedimentary deposits, followed by Maricopa, Cochise, and Mohave Counties. This is an initial screening criterion for recharge opportunities to enhance rivers, that requires additional steps and considerations for site selection and project implementation.

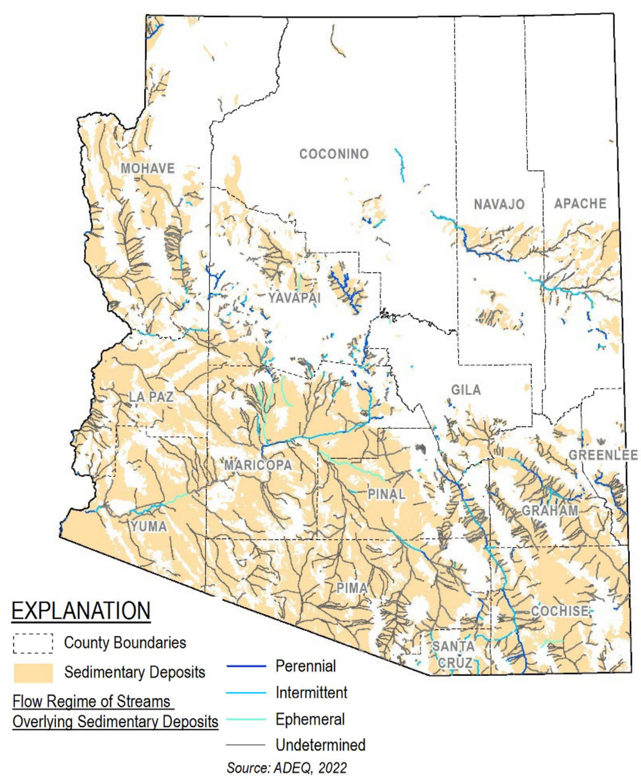


Figure 3. Optimal Locations for Recharge Projects

Major streams and flow status where defined by ADEQ are also shown on Figure 3. **Ephemeral streams** only flow or contain water in direct response to precipitation and stormwater runoff and do not receive discharge from groundwater. These dry washes typically have high infiltration rates and groundwater is generally deep. Recharge in these areas may mitigate groundwater level declines in the regional aquifer and support riparian vegetation in the stream channel. Along **perennial and intermittent streams** where groundwater is shallow, recharge can sustain shallow groundwater levels, discharging to streams and augmenting streamflow.

Gravel Pits

One innovation is to repurpose gravel pits adjacent to streams for stormwater recharge and/or storage basins. Depending on the hydrogeology and the flow characteristics, gravel pits can enhance infiltration or slow down flow for gradual release to infiltration areas or stream channels. As shown on Figure 4, many gravel pits are located along some of the major streams in the state, including the Santa Cruz, Gila, and San Pedro Rivers.

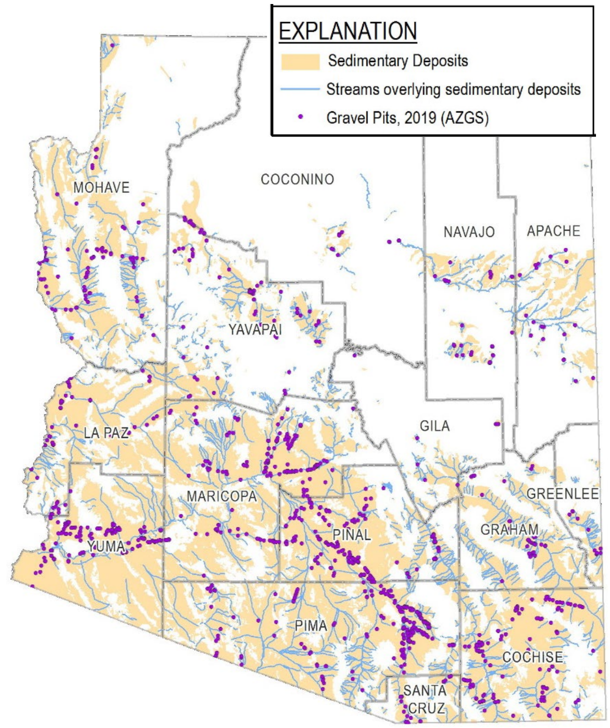


Figure 4. Gravel Pits Along Stream Channels in Areas of Favorable Geology for Recharge Projects

Framework: Stormwater Recharge Projects

Stormwater recharge projects are framed by 3 important factors: the source of water, the type of project, and the benefits or project objectives. Each of these factors are described in more detail in this section, followed by a list of references.

Water Source
Where is the water? How much is there?

Type of Project
How will the water be captured and stored?

Multiple Benefits
What are the project objectives? Who are key partners?

Water Source: Precipitation and Runoff

The availability of source water for recharge at these locations is another key consideration. Precipitation is an important consideration for locating stormwater recharge projects that may correlate with increased stormwater runoff. Therefore, areas with favorable geology (Figure 3) and relatively higher precipitation such as in the Verde Valley and parts of southeastern Arizona, may be attractive areas for stormwater recharge projects. The seasonality, frequency, and intensity of precipitation and the quantity and rate of runoff are all important factors for assessing stormwater recharge feasibility.

Pressures from population growth have led to more development and urbanization across the state, and rural areas that were formerly irrigated or are being grazed can lead to compacted soils and loss of vegetation, resulting in urban runoff and sheetflow, respectively, during storm events. Precipitation totals and patterns vary from year to year across the state, but rainfall events that result in rapid and damaging runoff and flooding are common in both urban and rural areas, and the frequency of these high-intensity storms may increase according to climate change projections. As flood control infrastructure is maintained and rehabilitated in areas with existing populations and new projects are constructed in areas experiencing growth and development, this increased runoff from urban and rural areas presents the opportunity to design projects with multiple benefits (Figure 5).

Some watersheds experience accelerated runoff due to either the impacts of urbanization or from poor watershed conditions. Stormwater recharge projects can be designed to help restore flows to those that would have occurred without the influences of development or poor watershed conditions. A more natural, pre-development rainfall-runoff relationship can be restored through carefully designed stormwater recharge projects, and water quality benefits can also result from reducing the negative impacts of accelerated runoff, erosion, and sedimentation. The use of hydrologic or integrated models to quantify the amount of additional runoff, such as percent urbanized runoff, that may be available for recharge will improve project design while protecting natural flow systems.

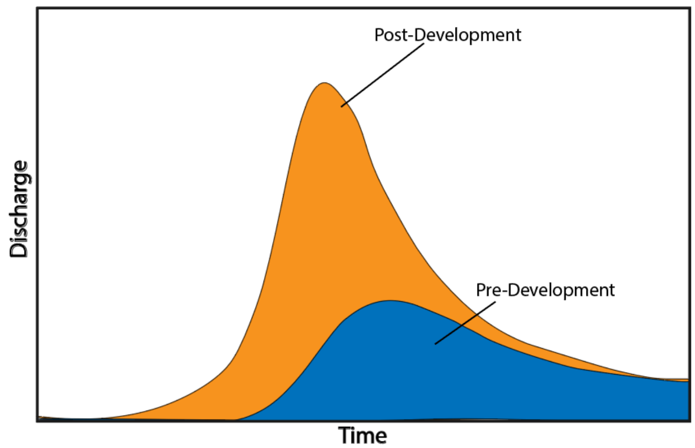


Figure 5. Pre-Development and Post-Development Runoff

Project Types

Designing a stormwater recharge project requires evaluating source of water and how the water will be captured and stored. The International Groundwater Resources Assessment Centre (IGRAC) categorizes recharge into 4 technologies or project types: surface infiltration/spreading, subsurface boreholes, in-channel modification, and runoff harvesting. Each of these categories is further divided into subcategories, which are summarized in Table 1 and described in detail on the next page.

Table 1. Recharge Methods (modified from IGRAC)

Recharge Technology	Subtypes
Spreading Methods	Infiltration Basins Flooding Ditches, furrows, drains Irrigation
Boreholes	Deep well injection (with or without recovery) Shallow wells
In-channel Modifications	Dams to divert or recharge Channel spreading
Runoff Harvesting	Barriers and bunds Trenches

Recharge Technologies and Project Types (from IGRAC, 2007)

1. **Spreading Methods:** Water spreading is applied in cases where the aquifer to be recharged is at or near to the ground surface, and the surface consists of permeable material. Most water spreading schemes use a system of ditches and banks, or pipes to convey water to the spreading area, and to control the spreading process.
   - Infiltration ponds and basins: These structures are either excavated, or are enclosed by dikes or levees which retain the recharge water until it has infiltrated through the floor of the basin.
   - Flooding: Water is spread as a thin sheet, which moves at a minimum velocity to avoid disturbance of the soil cover.
   - Ditch, furrow, drains: A system of shallow, flat bottomed and closely spaced ditches and furrows is installed through which water is introduced and allowed to infiltrate. Underground networks of perforated drainage conduits, from which later infiltrates into the soil, are also included here. ·
   - Irrigation: In irrigated areas, water can be deliberately spread by irrigating cropland with excess water during dormant or non-irrigating seasons. Sprinkling techniques are also included here.
2. **Boreholes:** Structures designed or adapted to recharge the groundwater by injection or infiltration of water.
   - Deep well injection: A technique used where thick, low permeability strata, overlie target aquifers, in order to recharge water directly into the aquifer. Aquifer Storage and Recovery (ASR) is a technique where the borehole is used for both injection and recovery of water.
   - Shallow well/ shaft/ pit infiltration: These structures are used to recharge shallow aquifers, especially at locations where surface layers are of low permeability and spreading methods are not effective.
3. **In-channel Modifications:** Structures that intercept or detain the stream flow through a natural drainage channel, and enhance the natural groundwater recharge. Generally, the purpose is to enhance groundwater recharge by storage of flood events and a controlled release, in order to facilitate its infiltration into the subsurface.
   - Dams: Groundwater recharge dams are designed to collect stream runoff water in a surface water reservoir. To provide recharge to groundwater, either the surface water reservoir serves as a percolation pond, or water is released through pipes or an open channel to infiltrate into the downstream riverbed.
   - Channel spreading: These techniques increase the wetted area and infiltration rate of the streambed. Widening, levelling, scarifying, dredging, and the use of "L"-shaped levees are all examples of this technology.
4. **Runoff Harvesting:** This includes all techniques to collect overland flow for productive use. It usually involves the concentration of rainfall or overland flow from a larger area for use in a smaller area as soil moisture, or for recharging the groundwater.
   - Barriers and bunds: These structures act as an obstruction to overland flow on hill slopes. Flow velocity is reduced, and water percolates behind the structure, increasing soil moisture and/or recharging the groundwater
   - Trenches: These manmade depressions in the hill slope or in paved surfaces will catch overland flow and infiltrate it through the bottom and sides of the structure, thus increasing soil moisture and/or recharging the groundwater.

Multiple Benefits and Partnerships

Often, flood control is the primary driver behind stormwater management projects. However, stormwater projects can be designed to accomplish multiple **benefits**, including:

- Flood control
- Recharge aquifer
- Support streamflow
- Improve water quality
- Reduce erosion
- Open space/recreation

Because stormwater management projects often involve multiple jurisdictions, they can be designed to accomplish a variety of objectives and goals for diverse interests and agencies. Land ownership and jurisdiction often lead to key partnerships and help target potential funding sources for stormwater recharge projects. Land management/ownership in areas of favorable geology are shown on Figure 6. The largest non-private landowner in these areas is the BLM (18%), followed by state and local governments (17.7%).

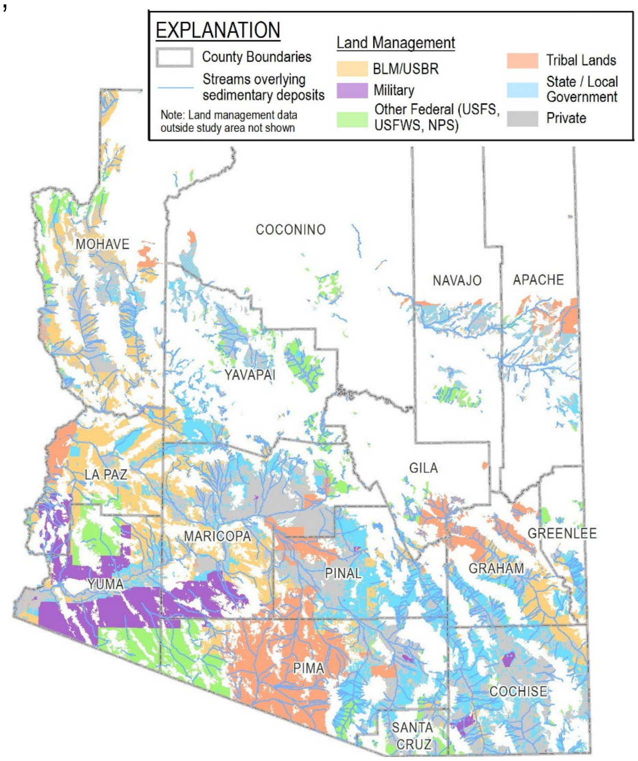
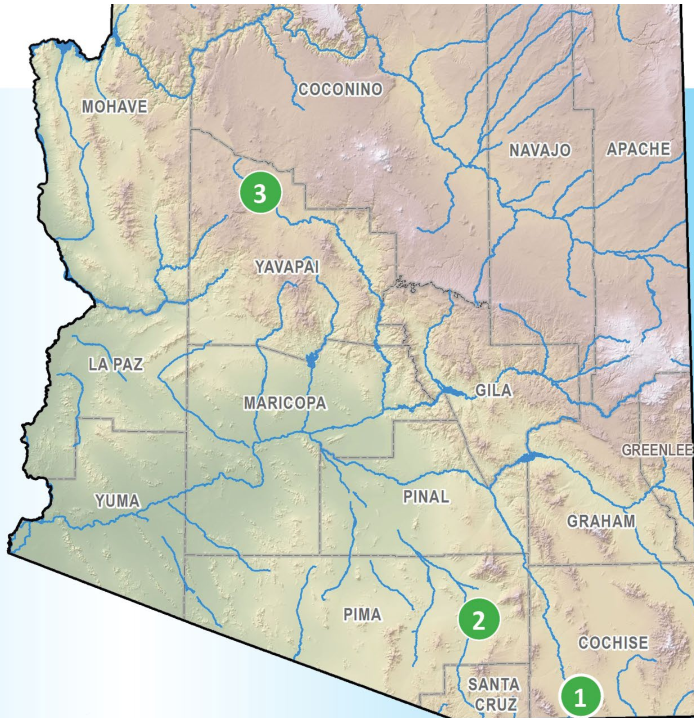
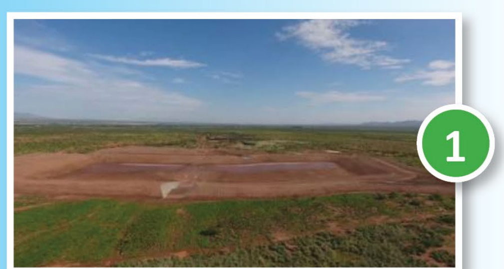


Figure 6. Land Management and Ownership in Areas of Favorable Geology

Example Stormwater Recharge Projects in Arizona





Horseshoe Draw Sediment Control and Stormwater Recharge Project

Primary Sponsor: Cochise Conservation and Recharge Network, Cochise County

Water Source: Accelerated runoff of undeveloped land

Project Type: Recharge in detention basin and downstream ephemeral channel

Benefits: Recharge, erosion control of ranch land, improve water quality and baseflow in San Pedro River

Status: Operating since 2017

Kino Environmental Restoration Project

Primary Sponsor: Pima County

Water Source: Accelerated runoff from urban areas

Project Type: Recharge in detention basin

Benefits: Flood control, recharge, irrigation, wildlife habitat, recreation

Status: Operating since 2002

Big Chino Recharge Project

Primary Sponsor: Yavapai County

Water Source: Accelerated runoff of undeveloped land

Project Type: Recharge in channel

Benefits: Flood control, recharge, erosion control, improve baseflow in Verde River

Status: Under development

Important Policy and Technical Considerations

Stakeholders and potential project partners have identified potential policy issues and important technical considerations for implementing stormwater recharge projects. Each potential stormwater recharge project in Arizona should be evaluated to determine the following:

- Which agencies have jurisdiction and what are their relevant authorities? For example, is the key project partner a Flood Control District or ADEQ-regulated municipal stormwater entity (an "MS4")?
- Are Arizona's water rights laws implicated? For example, does the potential project involve a diversion of appropriable surface water or alter flood flows in a manner that may affect downstream water rights?
- Is there value in or a need to quantify the potential project impacts? Conceptual tools may exist to determine that a project captures and recharges only stormwater that would otherwise damage property or that is a product of new development, i.e., "urban enhanced runoff."
- Will the project impact downstream natural flood flows? Natural flood flows are critical for riparian health by redistributing sediment and supporting riparian species.
- Will the project impact downstream water users? Water users downstream may have claims to flood flows that need to be considered and discussed.
- Can project location and design provide increased benefits for streams? Benefits may include increased recharge and improved water quality. Where a project is located influences how it can benefit streams. Modeling tools can be used to evaluate impacts and choose the most effective project location and design.

Each potential project should be designed and evaluated individually as these issues will be unique to each situation and must be addressed on a case-by-case basis. Fortunately, Arizonans have the experience of flood control districts, municipal flood and stormwater agencies, and other implementers of stormwater infrastructure projects across the state to draw upon.

Select References and Resources

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Professional Organizations with Resources for Recharge and Stormwater

American Water Works Association

Groundwater Protection Council

National Groundwater Association

Water Research Foundation

WateReuse