Restoring the Riparian Forest along the Upper Gila River in Arizona: Phase II



Submitted By:

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Executive Summary

Gila Watershed Partnership of Arizona (GWP) will complete Phase II of the restoration of 200 acres of riparian lands along the Upper Gila River. GWP is a non-profit organization based in Thatcher, Arizona (Graham County) that has been working with stakeholders in the Upper Gila Watershed for 27 years to restore functions and flow to the Gila River and its tributaries. Salt cedar (*Tamarix* spp.) has established dense, monotypic forests throughout the riparian corridor, outcompeting native plant species, increasing wildfire frequency and intensity, and altering terrestrial and aquatic wildlife habitat. The Southwestern willow flycatcher (SWFL), listed in 1995, is an endangered, migratory bird species that depends on breeding sites located in the Upper Gila River- one of the most productive breeding areas remaining in Arizona. SWFL site fidelity is strong, with greater than 2/3 of individuals returning to the same site to breed. Therefore, current threats to critical habitat in the Upper Gila pose serious risks to the survival of this species. SWFL has adapted to invasive salt cedar, using it for protective cover and shade for nests. However, tamarisk stands burn more frequently and more intensely than native forests, putting SWFL at extreme risk during its summer breeding season and reducing available nesting habitat. The tamarisk leaf beetle (TLB) was released as a biocontrol agent to defoliate and limit tamarisk invasions. In June of 2020, TLB will arrive in the Upper Gila Watershed, making proactive salt cedar biomass management, revegetation, and habitat restoration critically important. GWP works closely with public and private partners to secure the necessary funding to implement riparian restoration throughout the river corridor. This proposed project is an important continuation of this effort. Adaptive management and monitoring are supported long-term by the organizational capacity and science-based protocols of GWP.

In Phase I, GWP completed an eco-hydrological assessment to determine high and medium priority sites for habitat restoration. Permits covering Section 401 and 404 of the Clean Water Act were acquired for 400 acres of private land in the Gila Valley. Between 2015 and 2019, mechanical removal and herbicide treatments on salt cedar were successfully completed on 212.9 acres of critical habitat. An additional 145.5-acres of habitat have been retreated for salt cedar regrowth and secondary weed infestations and 105.6-acres of native revegetation. Phase II will continue these efforts by installing native vegetation on 30 acres and removing secondary weeds on 100 acres where tamarisk removal has been completed.

Healthier and more resilient riparian systems benefit wildlife, water resources, and Arizonans. With support from BOR, this project will promote more diverse and functioning riparian areas, increase water availability by reducing demand from dense salt cedar forests, reduce wildfire risk, protect and enhance wildlife habitat, and provide a replicable example for similar efforts around the state. This project would be scheduled to start in September of 2021 and would last for 2 years, ending in August of 2023. It would not involve any Federal facility or Federal land; the project sites are all on property that is privately-owned.

Project Background

The Gila River was once one of the longest continuous rivers in the Western United States, flowing from its headwaters in the Gila Wilderness in Southwestern New Mexico nearly 500 miles to its intersection with the Colorado River near Yuma, Arizona. Traveling through an arid desert landscape, the Gila provides critical riparian habitat for an abundance of fish and wildlife, and the watershed serves as a crucial economic and cultural resource for communities throughout the region. Along its path, the Gila River passes through the Phoenix metroplex as well as many small municipalities and rural communities, such as the City of Safford and the adjacent Town of Thatcher.

The Gila Watershed Partnership (GWP) was founded in 1991 to improve the condition of the Upper Gila Watershed. Since its inception, GWP has been successful in implementing over $8 million in projects and programs to improve water quality, conserve water, and restore riparian habitat. GWP's success is due to the strong working relationships it has developed with state and federal agencies, community organizations, educational institutions, local governments, businesses, and local citizens. GWP has a professional team of 7 full-time staff members including a Native Plant Nursery Manager, Habitat Restoration Manager, and Science and Outreach Coordinator, who work collaboratively to plan and implement restoration actions along the Gila River. In addition, GWP is developing a Science and Technical Advisory Committee composed of a diverse array of scientific and land management professionals who will advise on restoration and other plans.

Salt cedar was brought to the United States over a century ago as an erosion control measure. It quickly propagated and spread, and now covers approximately 80% of the floodplain area along the Upper Gila River. Salt cedar alters soil chemistry, drastically reduces biodiversity, and its dense roots cause sediment aggradation over time, altering channel morphology and interfering with the natural functioning of the riparian buffer. Salt cedar also burns hotter and longer than other vegetation, creating river fires that burn more intensely than in other vegetation, and negatively impact water quality.

To complicate matters, a biocontrol agent, the tamarisk leaf beetle (*Diorhabda* sp.; TLB) arrived in the Upper Gila Watershed in June of 2020, and is expected to reach the restoration sites in the summer of 2021. Upon arrival it will defoliate large amounts of tamarisk in a matter of months. This will leave the federally-endangered southwestern willow flycatcher (*Empidonax traillii extimus*; SWFL) and other birds without nesting habitat, increase fire risk within the river corridor, and result in large scale losses of sediment and channel change. SWFL depend on breeding sites in the Upper Gila River- one of the most productive breeding areas remaining in Arizona. SWFL site fidelity is strong, with most birds returning to the same site to breed. Therefore, current threats to Critical Habitat in the Upper Gila pose serious risks to the survival of this species.

SWFL has adapted to the presence of salt cedar, using it for protective cover and shade for nests in the absence of native riparian trees. However, salt cedar stands burn more frequently and roe intensely than native forests, putting SWFL at extreme risk during its summer breeding season. The TLB is a very effective salt cedar control agent and has moved through riparian systems of the western US fairly quickly. In areas of SWFL habitat, this is problematic; areas of native vegetation need to be pre-emptively established so that suitable nesting habitat is available for SWFL when the existing breeding sites within salt cedar stands are impacted by the TLB. Previously, researchers had estimated that the TLB would arrive in the Upper Gila within 3-5 years, making proactive salt cedar biomass management, revegetation, and habitat restoration critically important. However, the TLB was documented in the Upper Gila Watershed this June 2020 on the San Francisco River, adding new urgency to this work.

Healthy, functioning riparian areas provide critically important habitat and watershed services by recharging groundwater, filtering runoff, moderating water temperatures, providing habitat for resident and migratory wildlife, stabilizing soils, and reducing erosion. GWP has been working since 2014 to remove tamarisk in sections or "islands" along the Gila River and replace them with native riparian vegetation. These islands are not only important for sustaining wildlife, they also act as passive seed sources that aid in revegetation of the area.

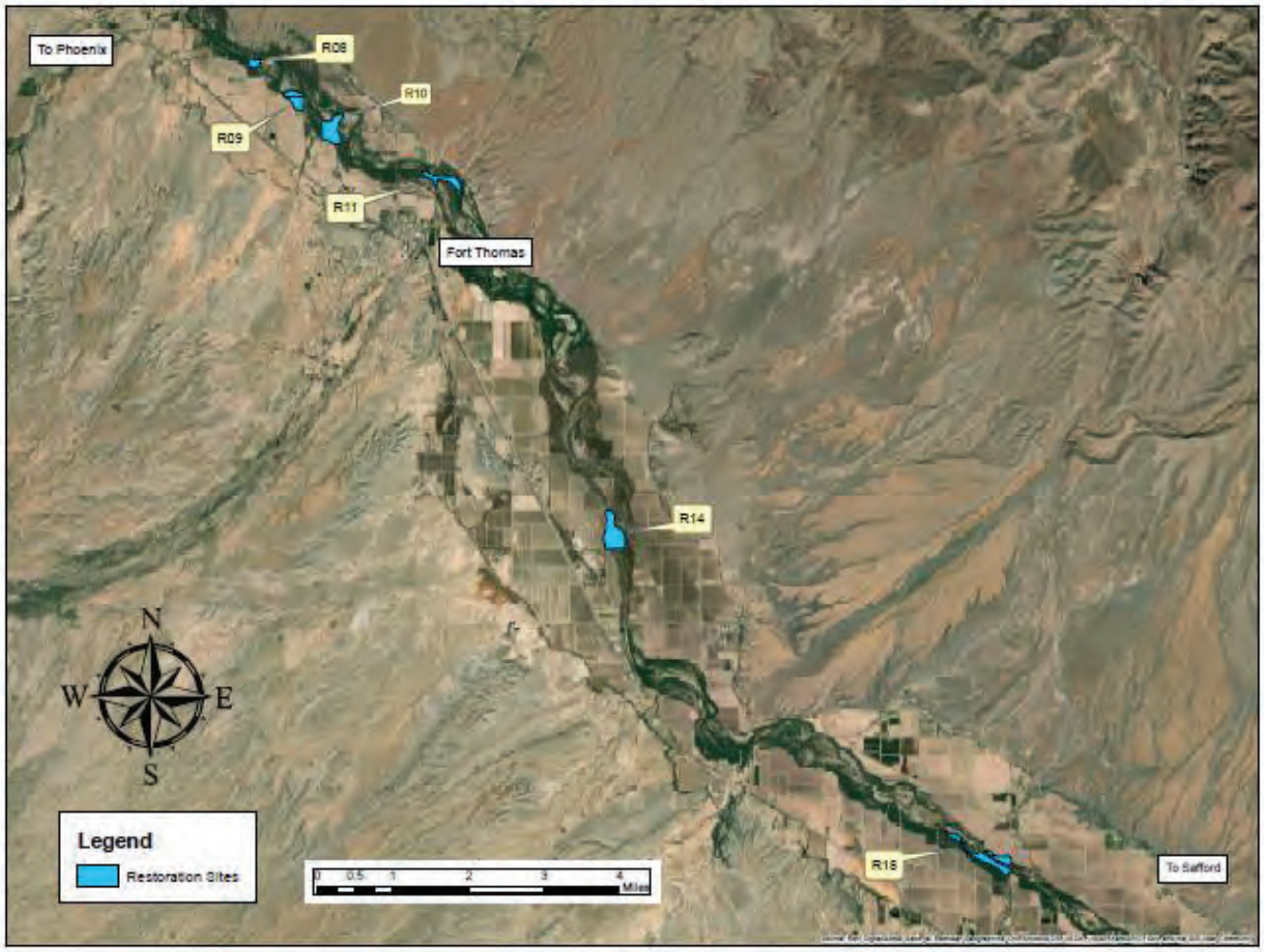
Project Location

The GWP Gila River rehabilitation program is currently being implemented along a 25-mile stretch of the Gila River from Pima, AZ to Geronimo, AZ (Figure 1). At present all work sites are privately owned. Work areas were established in discrete management zones along the river in order to create 'islands' of native vegetation ranging in size from 10-acres to 62-acres. Currently, GWP is in the process of actively rehabilitating six distinct sites. These sites are both upstream and downstream of Ft. Thomas, AZ which specifically located at 33°2'14"N, 109°57'58"W, and at an elevation of 2822 feet above sea level (Figure 2).

Each site is situated adjacent to the Gila River, which is dominated by an estimated 80% total cover of old-growth tamarisk. However, each site contains habitat zones that will support native riparian species, such as Freemont's cottonwood (*Populus fremontii*), Gooding's willow (*Salix goodingii*), and coyote willow (*Salix exigua*), and native upland species, such as velvet mesquite (*Prosopis velutina*), giant sacaton grass (*Sporobolus wrightii*), and other grasses and shrubs.



Figure 1. Map of the Upper Gila River Watershed. From Orr et al. 2014.



Technical Project Description

GWP's primary goal for Phase II of this project is to transition restoration project sites from where tamarisk has been removed from invasive-dominated landscapes to native-dominated landscapes. GWP has been working with the AZ Department of Forestry and Fire Management to implement fuels control treatments by removing invasive salt cedar and to complement this with the control and removal of invasive herbaceous weeds that often grow densely following the removal of woody species. The activities proposed for this grant include: a detailed geomorphological assessment of the riverbanks for enhanced phreatophyte planting opportunities; installation of riparian and upland native plants on 30 acres, and removal of secondary weeds on 100 acres. These project elements are detailed below.

Geomorphological Assessment

GWP will work with the environmental engineering firm Natural Channel Design, Inc (NCD). to complete a detailed geomorphological assessment of the restoration sites. The goal of this

assessment will be to identify site-specific opportunities for grading and riverbank rehabilitation that will enhance opportunities to establish phreatophyte riparian tree and shrub species that require a shallow depth to groundwater. The outcome of this task will be a set of plans for each restoration site that will guide the site preparation and grading work described in the next task.

NCD utilizes a combination of stream assessments and geomorphic evaluations supplemented by analytic assessments. Stream channel assessment requires three distinct steps: characterization of existing conditions, identification of the potential, or reference condition, for the system, and finally comparing the existing condition against the potential of the system to identify stream needs and design criteria. Once these parameters are established, an analytical assessment of critical velocities, shear stresses, and other physical processes are incorporated to complete the design to meet project objectives.

Stream channels are created and maintained by the processes of their watersheds. In simplistic terms, their primary functions are to convey flood flows, transport sediment, and dissipate energy. The inherent stability of any natural channel is dependent on an appropriate dimension, pattern, and profile of the bankfull channel and associated floodplain and terraces. Closely matching the central tendencies of the natural channel in both form and process results in a design that works with the existing stream processes rather than against it reducing instability and long-term maintenance cost.

Installation of Native Plants

Active revegetation strategies are the crux of this project proposal - it is the most critical component of our work to support SWFL along the Gila River. This project will result in the installation of at least 4,000 plants across 30 acres, in six distinct habitat islands that span 25 miles of the Gila River. The urgency of this need is accelerating with the imminent arrival of the tamarisk beetle, which will soon be defoliating the dense stands of salt cedar throughout the valley. It is imperative to get native vegetation established within the islands of breeding habitat that our restoration areas will provide , so that nesting habitat remains available even as salt cedar stands are decimated by the beetle and replaced by other invasive weeds

The Gila Native Plant Nursery is expert in producing restoration-quality materials that are genetically appropriate for the Gila Valley and acclimated to local conditions (Figure 3). Source plants and seeds are collected from the Gila River watershed. Native plants are already in production at the nursery to assure they are as large and resilient as possible by the time of installation. The Gila Native Plant Nursery specializes in producing native plant materials that are pre-disposed to restoration success – they are grown in long, narrow containers to encourage a high root to shoot ratio that will perform best under the conditions of the restoration sites. They are well-acclimated to the elements prior to out-planting.

Native vegetation will be installed in areas where salt cedar has already been removed to suppress expected secondary weed invasion and to re-establish the native ecosystem. Distance from the river, depth to groundwater, and other microhabitat characteristics will guide the

particular suites of species installed in given locations; a generalized approach is presented below.

Riverbank planting: Cuttings and potted phreatophyte species will be installed along riverbanks in locations where the groundwater is shallow enough (up to 5 feet) to support this method. When possible, hand augers will be used to confirm the depth to groundwater before planting. Focal phreatophyte species include the riparian trees necessary to support SWFL breeding: coyote willow (*Salix exigua*), Goodding's willow (*Salix gooddingii*), and Fremont cottonwood (*Populus fremontii*). Additional species may be added to diversify stands and attract additional species of insects and birds. Small-scale flood irrigation will be conducted when precipitation is insufficient to support plantings as they become established.



Figure 3. Native mesquite seedlings propagated at the Gila Native Plant Nursery.

In certain locations at our restoration sites, we will use an irrigation scheme in which plantings are placed in clusters within small basins, each approximately 0.2 acres in size. We will flood each basin periodically, allowing water to penetrate deeper into the soil than it would with drip irrigation, so that the roots of the young plantings can extend closer to groundwater.

The river is a busy wildlife corridor, and plantings will need to be protected from herbivory until they are well-established and/or large enough to withstand some herbivory pressure. Species of concern along the riverbank include elk, beaver, rodents, and other wildlife. Protective wire cages (at least 4 feet in height) will be installed around riparian tree plantings. Additionally, large elk exclosures will be used for plantings within washes and irrigation basins, both to prevent both predation and to inhibit damage from debris during flood events.

Upland/Terrace planting: Farther from the bank, where groundwater is deeper, we will install drought-tolerant species such as velvet mesquite (*Prosopis velutina*), whitethorn acacia (*Acacia constricta*), catclaw acacia (*Senegalia greggii*), and wolfberry (*Lycium* sp.). Holes will be pre-dug with an auger extension on the skid steer machine whenever possible to encourage the deep roots to grow toward the groundwater. Similar to riparian species, some terrace species may be planted using a basin scheme.

Terrace plantings will be protected with chicken mesh cages; here the herbivore species of concern are underground mammals, most notably ground squirrels, that consume seedling and sapling roots, and in many cases, entire seedlings. In addition to protective cages, other deterrents such as sound emitters may be used.

Seeding of grasses and ruderal herbaceous species. As the trees grow and begin to provide shade, native understory plantings will be incorporated within and around caged infrastructure/basins. Grasses and ruderal herbaceous species will be established through seeding and/or container planting to support diverse insect populations and enhance the prey base for SWFL and YBC. Example species include giant sacaton (*Sporobolis wrightii*), sacred datura (*Datura wrightii*), globemallow (*Sphaeralcea* sp.), and milkweed (*Funastrum cynanchoides* and *Asclepias* spp.).

Contracted crews

The GWP restoration professional will work with the Arizona Conservation Corps (16 weeks), Americorps volunteers, and National Civilian Community Corps (4-6 weeks) to provide the labor necessary to complete the extensive planting task at all restoration sites.

Arizona Conservation Corps (AZCC) provides training and certification to young people 18-24 to complete all aspects of restoration projects. One 8-person crew will be contracted through AZCC per year for 15 weeks between January and April. The National Civilian Community Corps (NCCC) is an Americorps program that provides training, career experience, and leadership development to 18-24 year olds from all over the United States. Crews are awarded to non-profit organizations for 12 months per year. GWP has been awarded a 12-person NCCC crew between January – April for the past 3 years. NCCC crews help augment the work of the AZCC crew by assisting with planting, creating fencing, watering, and secondary weed removal. Last, GWP is awarded 3, part time Americorps positions per year to assist with growing restoration plants in the nursery,

Performance Measures

Evaluation Criteria

Evaluation Criterion A: Project Benefits

Water Quantity

The Gila River is the lifeblood of the both the agricultural and natural communities in the Valley (Figure 4). This project will improve water quantity along the Gila River and in its watershed in several ways:

- Strategic grading and earth contouring that will create shallow basins for water to pool during flood events, allowing it to stay onsite and support native phreatophyte vegetation.
- Salt cedar is known to consume large amounts of water, draining river and groundwater levels; its replacement with native riparian vegetation will counteract these impacts.



Figure 4. Views of the Gila River, courtesy of Stillwater Sciences.

Water Quality and Aquatic and Riparian Ecosystem Benefits

Conversion of salt cedar to natural vegetation communities will improve the water quality and alter the aquatic and riparian ecosystems in a variety of ways:

- Salt cedar changes the river morphology and flood dynamics through resisting erosion, which is why the species was originally introduced in the early 1900s (e.g., Auerbach et al. 2013). Dense stands of salt cedar provide greater stability to the river and floodplain substrates than do native vegetation (e.g., willows and cottonwoods) and, as an unintended consequence, progressively narrow the active channel thereby increasing the frequency of floodplain inundation (Graf 1978). Tamarisk is further favored over natives in this setting due to its longer seed-release timing that extends into late summer when monsoon-induced floods can re-expose fresh surfaces upon which tamarisk may more readily colonize (Shafroth et al. 1998). Revegetation with native species will reconnect the floodplain to the river and the project will restore stable geomorphology to the riverbanks in the restoration areas.
- The upper Gila River naturally experiences a wide variation of flows, punctuated episodically by short-duration but intensive high-flow events. These flashy discharge dynamics, which are common to large, dryland riverine systems, periodically result in dramatic geomorphic change (Graf 1988). And while climate change models predict less total precipitation for the southwest region, increased frequency of intense storms and

more precipitation falling as rain versus snow are expected to make southwest rivers more susceptible to flooding (USGCRP 2009). Through replacement with native vegetation, GWP's restoration program will promote a long-term transition from a more channelized river to a wider, more meandering river system that is better able to absorb the impact of larger floods.

- Salt cedar oozes salt that accumulates in the soil and prevents the growth of native species; it also negatively impacts plant and animal biodiversity by crowding and shading out native plants, creating a near-monoculture which degrades the watershed. Other negative impacts include bank impoundment and river channelization due to the thick root structures that prevent natural scouring and meandering of desert rivers, and a subsequent decrease in water quality. Adding diverse native vegetation and returning natural meandering flow will help flush out salts over time by allowing the salts and minerals to be flushed from the system by more frequent inundation.

Specific Species and Habitat Benefits

Species and habitat benefits are the main drivers of this project. 130 acres of newly-restored native riparian forest and upland habitat will be available to wildlife as a result of this project.

Despite the dominance by salt cedar and impacts from other natural and anthropogenic factors, the riparian corridor continues to provide some active breeding habitat for the endangered SWFL, along with habitats of other sensitive fish and wildlife species. In 2011, the U.S. Fish and Wildlife Service (USFWS) designated the upper Gila River as Critical Habitat for SWFL, as it is known to be occupied by the species during the breeding season and provides the primary constituent elements essential to the species' long-term conservation. It is therefore a major goal of the federal designation and the SWFL Recovery Plan (USFWS 2002) that habitat conservation on the upper Gila and San Francisco rivers will lead to species recovery throughout the region.

Salt cedar defoliation from the TLB will be problematic in the Gila Valley as virtually all SWFL nest sites are currently located in tamarisk along the river. If defoliation by the beetle occurs simultaneously with nesting, the loss of cover could result in juvenile mortality, as has recently been observed along the lower Virgin River. Other special status wildlife species, such as the threatened western population of yellow-billed cuckoo (*Coccyzus americanus*), are also associated with many riparian systems in which salt cedar is a major component. It is critical to establish new native riparian vegetation to avoid declines in local wildlife species, including the SWFL population.

Benefits for Multiple Water Uses

The Gila Watershed Partnership stands on a 27-year history of working with multiple stakeholders and water users in Graham and Greenlee Counties. Graham County has approximately a dozen farms that grow cotton, winter wheat, alfalfa, and industrial hemp. These water users are bound by decrees to specific water allotments per year for maintaining their crops. With climate models predicting less precipitation but larger flood events, farmers risk water allotment restrictions in the future, as well as loosing land to larger, more catastrophic

floods. The GWP restoration project will benefit farmers by establishing vegetation that will create a broader, more meandering floodplain that will be more resilient to catastrophic flooding and will allow more water infiltration, thus keeping water within the system.

The San Carlos Apache Tribe resides immediately downstream and is another major water user in the area. The Tribe holds water rights to all flowing water in the river, with the exception of the upstream allotments. A repaired river system will benefit The Tribe in the same way that it benefits upstream water users; by creating conditions favorable for increased infiltration during floods and keeping more water within the system. Additionally, water will be higher quality and better able to support agriculture and aquatic life.

Restored riparian buffers will result in improved water quality, and replacing dense stands of tamarisk with less water-intensive plant communities will improve water conservation. Wildlife will benefit from improved habitat, and local communities, landowners, and future generations of Arizonans will benefit from healthy, diverse, functioning riparian areas on the Gila River, in perpetuity.

Other Benefits for Watershed Stakeholders

The values of this project extend to a variety of other watershed stakeholders as well.

- Salt cedar negatively impacts the local Native American culture, as it a leading cause for the degradation of traditional San Carlos Apache ceremonial sites. Coyote willow (*Salix exigua*), is a native tree that grows on river banks and is used by the San Carlos Apache to construct temporary lodges for religious ceremonies. Due to the density and extent of salt cedar, there are very few sites which support coyote willow, and members of the Apache Tribe have begun working to locate areas where they can harvest cuttings from this tree for propagation and re-planting to restore ceremonial sites. The restoration sites in this project will provide new populations of coyote willow that can be used as collection sites. In addition, once the TLB defoliates the salt cedar in surrounding areas, the restoration sites will serve as propagule sources for additional passive restoration along the Gila River.
- Wildfire is an increasingly common disturbance along the Gila River. Although riparian areas are generally considered to be barriers to wildfire spread, the replacement of fire-resistant native vegetation with higher moisture content (e.g., willows and cottonwoods) by flammable salt cedar has reversed this relationship, with salt cedar-dominated areas burning approximately 10 times more frequently than native-dominated counterparts (Busch 1995). Defoliation by the TLB are not likely to help this situation, as studies in Nevada show that tamarisk is highly flammable regardless of whether it is “browned-out” by defoliation or in a “healthy green” state (Dudley and Brooks 2010). Escaped fire from land-clearing on adjacent agricultural areas has become a serious concern for land managers in the Gila Valley, particularly where weedy forbs next to fields carry fire into the arid, salt cedar-dominated riparian edges, and then into the mixed native/salt cedar vegetation along the river. This establishes a feedback loop in which fire promotes salt cedar, which recovers readily from burning to become even more abundant, eventually

displacing native elements in the stand. The active restoration efforts included in this project are needed to speed up the process of reducing riparian fire risk in critical areas.

Multiple Watershed Issues of Concern

The proposed project addresses multiple issues of concern, as demonstrated above. In 2018, GWP commissioned a Watershed Assessment Plan, which provided a comprehensive evaluation of the challenges, needs, current actions, and knowledge gaps within the Upper Gila Watershed. Continuing the riparian restoration project described in this proposal was identified as one of the highest priority needs (University of Arizona, p. 15). Creating a native plant dominated floodplain will increase the resiliency of the riparian system in all areas of concern. These include improving the water availability, decreasing the likelihood of catastrophic floods, decreasing the risk of riparian fires, improving wildlife habitat, and improving the water quality for all users.

Evaluation Criterion B: Watershed Restoration Planning

The *Riparian Restoration Framework for the Upper Gila River* (Orr et. al 2014) was prepared by Stillwater Sciences, a science-based watershed restoration firm. This framework was delivered via a detailed technical report that was developed with the express purpose of guiding GWP's restoration efforts, ensuring that restoration actions and locations are based on sustainable eco-hydrology. The comprehensive riparian restoration planning effort covered an approximately 53-mile portion of the upper Gila River in Arizona and delivered science-based guidance on suitable riparian restoration actions within the ecologically sensitive river corridor. The framework development was conducted by a restoration science team, led by Stillwater Sciences with contributions from researchers at the Desert Botanical Garden (DBG), Northern Arizona University (NAU), University of California at Santa Barbara (UCSB), and U.S. Geological Survey (USGS). All work was coordinated GWP, with funding from the Walton Family Foundation's Freshwater Initiative Program.

The overarching goals of the Restoration Framework for the upper Gila River in Arizona were to:

1. Prepare for anticipated impacts to the existing riparian system following TLB colonization;
2. Promote recovery of native riparian habitat and subsequent local increases in SWFL population size, and, ultimately, to re-establish their metapopulation structure across the greater Colorado River Basin;
3. Facilitate implementation of a comprehensive approach toward riparian restoration by a collaborative group of stakeholders, resource managers, and scientists; and
4. Inform recommendations to be incorporated into the Restoration Implementation Plan to be authored by GWP.

Satisfying these goals will enable sustained survival of the endangered SWFL (and other sensitive riparian and aquatic wildlife) and subsequently lead to its de-listing based on quantitative evidence of species recovery. Meeting these goals involves development of a framework that maximizes the likelihood of creating sustainable native riparian vegetation in a cost-effective

manner, while simultaneously building the capacity of local communities to support and participate in achieving restoration success.

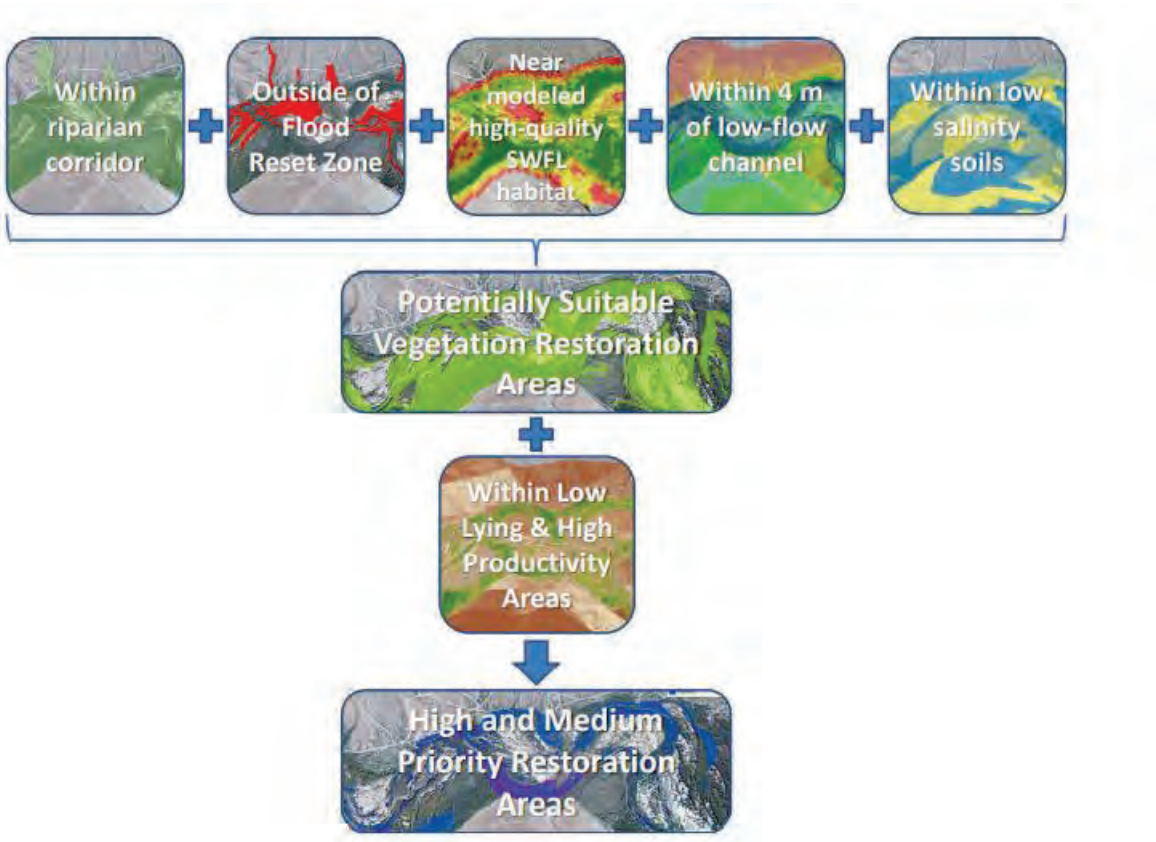
The objectives of the Restoration Framework program included:

1. Conduct a restoration action feasibility assessment that identifies appropriate locations for strategic salt cedar treatment and long-term, sustainable revegetation with native riparian species, based on ecological and hydrological factors—an Ecohydrological Assessment. Integrate vegetation and wildlife status into the framework to promote natural plant recruitment processes and enhance the capacity of SWFL and other wildlife species of interest to respond based on current distributions and habitat associations. Avoid salt cedar treatment impacts to SWFL and other wildlife. Help organize plant propagation capacity for riparian restoration applications using genetically appropriate native plants.
2. Implement an ecosystem assessment protocol to evaluate progress toward restoration program objectives and to apply adaptive management to enhance the likelihood of success in achieving those objectives. Monitoring provided baseline information to evaluate and plan for anticipated future establishment of the tamarisk leaf beetle.
3. Lay the foundation for implementing rapid active restoration of appropriate native vegetation to create refugia for avian species potentially displaced by salt cedar defoliation.

The “ecohydrological assessment,” which is the centerpiece of the Restoration Framework, considered reach-scale river hydrology, geomorphology, vegetation conditions, and wildlife needs to identify potentially suitable areas for active restoration; see summary in Figure 5. The selection process was further refined with site-scale information on plant productivity, soil conditions and salinity, surface and groundwater availability, and SWFL-habitat suitability.

From the ecohydrological assessment, nearly half of the riparian corridor of the Planning Area was predicted to be suitable for supporting active riparian restoration, amounting to about 4,800 acres. The "High" and "Medium" Priority Areas each accounted for nearly 400 acres (750 acres in total), which is a more manageable size for rapid and effective active restoration involving some level of salt cedar removal and native re-planting which began in 2014. The Potentially Suitable Vegetation Restoration Areas are concentrated more downstream of Thatcher where flood-scour risks are lower, vegetation-growth potential is greater, SWFL habitat quality is greater, soil salinity and alkalinity are reasonably low, and lower-lying areas potentially supporting wetter soils are readily available.

GWP uses the Riparian Restoration Framework to guide its internal annual project plans. In addition, GWP worked with Geosystems Analysis, Inc. to draft the Monitoring and Adaptive Management Plan for Rehabilitation in the Upper Gila Watershed of Southeastern Arizona (Drahota and Caplan 2019).



Evaluation Criterion C: Stakeholder Support

GWP was founded in 1991 to improve the condition of the Upper Gila Watershed. Since its inception, GWP has been successful in implementing over $8 million in projects and programs to improve water quality, conserve water, and restore riparian habitat. GWP's success is due to the strong working relationships it has developed with state and federal agencies, community organizations, educational institutions, local governments, businesses, and local citizens. GWP has a professional team of 7 full-time staff members including a Native Plant Nursery Manager, Habitat Restoration Manager, and Science and Outreach Coordinator, who work collaborate to plan restoration actions along the Gila River. In addition, GWP is developing a Science and Technical Advisory Committee composed of a diverse array of scientific and land management professionals who will advise on restoration and other plans. GWP is the only organization doing riparian restoration work in the Upper Gila River Valley of Arizona.

With this proposal, we have provided letters of support from:

- **Freeport McMoRan.** Freeport operates open pit copper mines in nearby Safford and Morenci, and is a major employer in the Gila Valley. Freeport is the landowner of the

restoration sites addressed in this proposal and has been an active partner, providing grant funding for past projects.

- **United Way of Graham and Greenlee Counties** is an active supporter of GWP's restoration program and community outreach, and recently funded a portion of a related GWP project – The Gila River Linear Park and Trail.
- **Graham County** has been an excellent partner and supporter of GWP's restoration program, recognizing the value that a thriving river brings to the local economy.
- The **Jackson Heights Fire District** is an all-volunteer fire district that protects the area from the Town of Pima through Fort Thomas, where many of the GWP restoration sites are situated. The JHFD has, on more than one occasion, utilized GWP restoration sites as fire breaks to control river fires, and has stated their immense benefit.

GWP has garnered support throughout the rural Gila Valley community. Agricultural producers adjacent to the river appreciate the restoration of native vegetation from the perspective of providing fire breaks that lessen the risk to their crops, and GWP is actively working with local fire districts and the Arizona Department of Fire and Forestry Management to strategically phase and locate restoration projects to lower fire risk and enhance suppression operations. This project is part of a multi-phased fuels mitigation effort that builds upon 7 years of previous work to create landscape-level change in the Upper Gila floodplain along areas near the communities that exist along the river. GWP is now working with Graham County Supervisor's Office and Graham County Cooperative Extension to map infrastructure and high-priority Wildland Urban Interface areas along the length of the Upper Gila extending from Geronimo through the Safford Fire District.

The San Carlos Apache Tribe supports the increased access to hard to find native riparian plants for traditional uses, and their widespread re-establishment along the river. Eastern Arizona College provides student interns and leases the land to GWP for its Gila Native Plant Nursery operation. The Town of Thatcher and the City of Safford are active partners of the Gila Watershed Partnership, and provide $15,000 annually to help support GWP operations.

There is no known public opposition to GWP's riparian restoration work. Rather, landowners and partners see it as a benefit to the river and to the community.

Evaluation Criterion D: Readiness to Proceed



Figure 6. GWP staff are ready to implement this project.

With a 27-year history, core staff, board, and Science and Technical Advisory Committee, GWP is well-positioned to continue this work long-term. Restoration case studies and experience have shown that invasive plant removal and planting require intensive resources within the first 3 years. If weeds are managed properly and restoration plantings are provided with enough water and protection to establish robust root systems, the cost and investment decreases after the first 3 years and again after 5 years. GWP intends to monitor and maintain these sites for the next 20 years, and is actively seeking funding to do so. The GWP long-term funding plan builds upon our current relationships with numerous funding organizations and includes sales revenue from our Gila Native Plant Nursery, along with a new membership and fundraising program. With the anticipated decrease in costs after the first 3 years and an increase in sales and fundraising revenue, GWP will have additional financial backing to continue this work throughout economic fluctuations that occur over the course of this long-term project.

Implementation Plan

GWP has all staff, equipment, and permissions to proceed upon funding award. Our implementation schedule for the project is shown in Table 1.

Table 1. Implementation Plan through 2022-2023. This plan is tentative and is subject to funding, weather, crew availability, and other outside forces. Sites R03 and R04 are excluded from the plan due to permitting and access limitations (as of November 2020), but these sites will be added when access is granted.

Site Name	Season	Primary Tamarisk Treatment	Tamarisk Retreatment	Planting	Maintenance & Secondary Weed Treatment
R08	2020-2021	0.00 acres	If time allows, the entire site will be machine re-treated	Coyote willow will be planted along the bankline where access is available; grass plugs and seeding in the interior if time allows	If time allows, secondary weeds will be treated according to the weed management plan with an emphasis on kochia, *Arundo donax*, and *Rumex* spp.
	2021-2022	Dense stands may be thinned as needed to promote native growth	Dense re-growth may be machine re-treated as needed	Additional phreatophyte species will be planted along the bankline to increase diversity; additional grass plugs and seeds will be planted in the interior	Planted areas will be maintained through secondary weed management and protective measures (e.g. discouraging herbivores)
	2022-2023	Dense stands may be thinned as needed to promote native growth	Dense re-growth may be machine re-treated as needed	The site will be evaluated for new bank line planting locations, and to determine the feasibility of planting upland shrubs in the interior	Secondary weeds will continued to be managed as necessary and as time and funding allow
R09	2020-2021	0.00 acres	Remaining tamarisk piles (in previously cut areas) will be Rx burned as time and weather allow; any previously cut areas that cannot be burned will be machine re-treated	In the area where the *Suaeda* mulching occurs, an irrigated upland area will be planted (300-400 trees) combined with seeding and grass plugs	The secondary management plan will be implemented more heavily during this year since primary tamarisk treatment will not occur; dense patches of *Suaeda* sp. will be mulched; any burned areas will be a priority for maintenance
	2021-2022	Dense stands may be thinned as needed to promote native growth	Rx burns will be conducted if they haven't been already; dense re-growth may be machine re-treated as needed	Additional grass plugs and seeding may occur in the upland areas	Secondary weeds will continue to be managed as necessary and as time and funding allow; any burned areas will be a priority for maintenance

	2022-2023	Dense stands may be thinned as needed to promote native growth	Given that Rx burns have been conducted, dense re-growth may be machine re-treated as needed	Not likely this year	Secondary weeds will continue to be managed as necessary and as time and funding allow
R10	2020-2021	0.00 acres	A previously cut section on the northeast side of the site will be machine re-treated; remaining tamarisk piles near the irrigation zone will be Rx burned as time and weather allow, but if these areas cannot be burned then they will be machine re-treated	We will complete planting along the final irrigation line within the western irrigation zone (~150 additional plants) and continue planting grass plugs and seeds in the upland area; saltbush will be seeded in areas with badger sign; if time allows, we will continue bankline planting where access is available	Secondary weeds will continue to be managed according to the weed management plan as necessary and as time and funding allow; any burned areas will be a priority for maintenance; we will maintain previously planted areas through weeding, irrigation, and protective measures (e.g. discouraging herbivores)
	2021-2022	Dense stands may be thinned as needed to promote native growth	Dense re-growth may be machine re-treated as needed; if time and resources allow, Rx burning will occur in the previously cut section on the northeast side	Additional species may be planted or seeded to increase diversity, but new irrigation will not be built	Secondary weeds will continue to be managed according to the weed management plan as necessary and as time and funding allow; we will continue to maintain previously planted areas as needed; any burned areas will be a priority for maintenance
	2022-2023	Dense stands may be thinned as needed to promote native growth	Dense re-growth may be machine re-treated as needed	If time and funding allow, an additional irrigated planting zone will occur in the Rx burn zone from 2020	Secondary weeds will continue to be managed according to the weed management plan as necessary and as time and funding allow; we will continue to maintain previously planted areas as needed
R11	2020-2021	0.00 acres	If time allows, previously cut areas will either be Rx burned or mulched	Coyote willow poles and other phreatophytes will be planted along the bank where access is	Secondary weeds will be managed according to the weed management plan as necessary and as time and funding allow; any burned

				available; grass plugs, grass seeds, and saltbush seeds will be spread in more upland areas	areas will be a priority for maintenance
	2021-2022	Dense stands may be thinned as needed to promote native growth	Rx burns will be conducted if they haven't already; dense re-growth may be machine re-treated as needed	Coyote willow poles and other phreatophytes will be planted along the bank where access is available; grass plugs and seeds and saltbush seeds will be spread in recently burned areas	Secondary weeds will be managed according to the weed management plan as necessary and as time and funding allow; we will maintain previously planted areas
	2022-2023	Dense stands may be thinned as needed to promote native growth	Dense re-growth may be machine re-treated as needed	An irrigated zone will be planted in the burned area (from 2021, 300-400 plants)	Secondary weeds will be managed according to the weed management plan as necessary and as time and funding allow; we will maintain previously planted areas
R14	2020-2021	0.00 acres	If time and weather allow, the previously cut section of this site will be machine re-treated	Not likely this year	Not likely this year
	2021-2022	Dense stands may be thinned as needed to promote native growth	Dense re-growth may be machine re-treated as needed	Bankline planting tentatively planned if time allows and the bank is accessible	Secondary weed management will be conducted in re-treated areas; dense patches of *Suaeda* sp. will be mulched as time allows
	2022-2023	Dense stands may be thinned as needed to promote native growth	Dense re-growth may be machine re-treated as needed	Bankline planting tentatively planned if time allows and the bank is accessible; may plant additional species in the treated area to increase species diversity	Secondary weed management will be conducted as necessary and as time and funding allow
R15	2021-2023	This site is not likely to be opened up for	NA	NA	NA

		restoration work during this period			
R18	2020-2021	Cutting as complete as possible with endangered bird buffer zones	Re-growth in the burned area (Rx burn and wildfire) will receive foliar re-treatment	We will construct 3-5 irrigation "basins" to be irrigated using a flooding strategy; each basin will be planted with either upland or phreatophyte species depending on the location of each basin; potentially some additional bankline planting and additional grass/saltbush seeding	Secondary weeds will be managed according to the weed management plan as necessary and as time and funding allow; we will maintain previously planted areas and irrigate newly constructed "basins"
	2021-2022	Cutting as complete as possible with endangered bird buffer zones	Dense re-growth may be machine – retreated as needed	If the "flooded basin" irrigation strategy is successful, we will construct and plant 3-5 additional basins; there may be additional grass plugs and seeding in the burned areas (from 2020)	Secondary weeds will be managed according to the weed management plan as necessary and as time and funding allow; we will maintain previously planted areas
	2022-2023	Cutting as complete as possible within endangered bird buffer zones	Dense re-growth may be machine re-treated as needed	We will evaluate the success of the "flooded basins" and determine the feasibility of expanding these basins using microclimates created by the existing plantings	Secondary weeds will be managed according to the weed management plan as necessary and as time and funding allow; we will maintain previously planted areas

Permits and Agency Approvals

GWP currently holds Clean Water Act Section 401 and 404 permits for conducting work described in this proposal. SHPO clearance has also been obtained.

Engineering and Design Work

GWP will work with the environmental engineering firm Natural Channel Design, Inc (NCD). to complete a detailed geomorphological assessment of the restoration sites. The goal of this assessment will be to identify site-specific opportunities for grading and riverbank rehabilitation that will enhance opportunities to establish phreatophyte riparian tree and shrub species that require a shallow depth to groundwater. The outcome of this task will be a set of plans for each

restoration site that will guide the site preparation and grading work prior to plant installation. This work is not season-dependent and will be completed concurrently with the finalized permits and approvals described above.

Land Access

GWP has full access to the restoration sites that are privately owned by Freeport McMoRan. GWP is currently funded by the Arizona Department of Fire and Forestry Management to conduct the necessary invasive species treatments (salt cedar and secondary invasives) to prepare the sites for this project, and the work is ongoing with full support from the landowner. Plants are irrigated with municipal water, not water from the river.

Compliance

GWP has included 5 percent of the total project cost in the project budget for compliance review.

Evaluation Criterion E: Performance Measures

Rehabilitation in the arid southwest is replete with challenges, and as a result, GWP has a strong emphasis on adaptive management. Adaptive management is dictated by challenges and lessons learned in the field with an effort towards linking project actions with monitoring results to better inform future rehabilitation (Geosystems Analysis 2014, Parametrix 2010, Thom and Wellman 1996). GWP has recently completed its Monitoring & Adaptive Management Plan for Rehabilitation in the Upper Gila Watershed of Southeastern Arizona (Drahota & Caplan 2019).

GWP defines an area as rehabilitated when it has reached the following conditions:

- Less than 10% total salt cedar cover
- Less than 25% total secondary weed cover
- At least 75% relative canopy cover by native woody species
- Natural recruitment of phreatophytes is observed annually

The GWP habitat rehabilitation program has two overarching goals: (1) reduce wildfire risk, and (2) transition work sites from non-native to native-dominated vegetation. Field treatments are prescribed to achieve both goals, and GWP uses various monitoring methodologies to document and evaluate whether these goals have been achieved within different project sites.

To guide both rehabilitation and monitoring work, each project site is divided into discreet “map units” based primarily on dominant vegetation composition and structure using the modified Hink & Ohmart vegetation classification system (Callahan & White 2002; Hink & Ohmart 1984). These data are collected in the field along with other management-relevant field attributes (e.g., previous treatments, differences in land use history, unique soil or topographic conditions, etc.). These field-based vegetation and site attribute data are entered into a Geographic Information System (GIS).

Dividing project sites into discreet MUs enables us to develop spatially explicit maps of pre- and post-rehabilitation vegetation conditions. In turn, these data, along with other management-

relevant information collected during vegetation mapping (e.g., soils, topography, previous management activities, etc.) are used to develop fuels treatment prescriptions, revegetation plans, and estimate implementation costs (McKenna et al 2019).

Another advantage of MUs is it provides a foundation for planning and implementing monitoring procedures and to track and quantify spatially explicit changes in relative cover of native and invasive species and for generating maps and other visual tools to aid in reporting monitoring results.

GWP conducts several types of monitoring, described below.

Compliance Monitoring

Certain regulatory agencies require monitoring of the work done along the river to evaluate whether a state or federal regulations are being followed and whether further action needs to be taken. GWP is legally required to implement certain monitoring protocols to comply with the requirements of the Clean Water Act (CWA) – Section 404 Nationwide Permit #27 Endangered Species Act (ESA) Compliance. The US Fish and Wildlife Service (USFWS) issued a Biological Opinion (BO) on September 19, 2016 that evaluated the effects of vegetation management work along the Gila River on threatened and endangered species (consultation number: 02EAAZZ00-2015-F-0151). The Biological Assessment (BA; Stillwater Sciences 2014) concluded that our project may affect, is likely to affect both the SWFL and the yellow-billed cuckoo (YBCU) because of the immediate removal of potential nesting and foraging habitat. However, the BO concluded that our actions were "neither likely to jeopardize the continued existence of the SWFL [or YBCU], nor likely to destroy or adversely modify critical habitat for the species" (USFWS 2016). Accordingly, the BO requires three monitoring actions to occur on an annual basis: 1) monitoring of riparian plantings to assess survival, determine the need for replacement plantings, alternative species, or alternative planting locations; 2) monitoring presence/absence of threatened and endangered species (SWFL & YBCU); and 3) annual overall monitoring reports.

Implementation Monitoring

Implementation monitoring evaluates and documents whether a project was carried out according to its original design (Geosystems Analysis 2014). The main type of implementation monitoring occurring with GWP projects is GPS (Global Positioning System) and photo documentation of plantings, salt cedar removal, and retreatment work that was implemented as originally planned. GPS points and polygon data are integrated into a GIS. Supporting photographs are organized in an electronic folder associated with each project area.

Validation Monitoring

Validation monitoring assesses the correctness of basic assumptions about how management actions will affect biological outcomes; GWP monitors its restoration sites for presence/absence of SWFL and YBCU.

Effectiveness Monitoring

The majority of the monitoring conducted by GWP to evaluate restoration success utilizes effectiveness monitoring procedures (Table 2). Effectiveness monitoring is conducted to directly assess whether restoration project actions produce a desired physical habitat response (Woodward and Hollar 2011). It involves assessing restoration progress in relation to project objectives and is the primary informative mechanism used to guide adaptive management. Several management objective statements were developed to guide monitoring procedures for assessing whether GWP's project goals are being achieved over the life of the monitoring program. The following monitoring activities are designed to assess the achievement of objectives and/or need for adaptive management:

Table 2. GWP Monitoring Calendar.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Photo Points			Plant Survival	Plant Survival	Plant Survival	Relative Cover	Relative Cover	Relative Cover	Photo Points		
			Photo Points	Natural Rec.	Weed Surveys	Photo Points	Seed Survival	Seed Survival	Seed Survival		
				SWFL Surveys			Natural Rec.				

- **Vegetation cover surveys** that evaluate the presence of a minimum of 11 woody species are conducted every year during the summer season (between July and September), with more extensive vegetation identification every third season. Monitoring during the summertime captures potential spring germination of native phreatophyte species. Surveying at this time also allows for data to be analyzed prior to the fall field season and thus inform rehabilitation actors as annual field plans are being finalized.
- **Survival of Out-Planting Surveys** are conducted annually in early summer, approximately 12-15 months following the original planting date. This will happen between April and June annually, assuming that planting occurred the previous year. Surveys are only done once for each new planting area in part because the first year following planting is when the most tree death is likely to happen, and partly to account for the inherent challenge of identifying planted trees versus natural sprouts more than a year later.
- **Survival of Seeding Surveys** to check applicable management units for plant cover by seeded species will occur every other year, with the first survey following a seeding event occurring two years later. This timing is designed to allow for the natural tendency of seeds to wait on the weather, making it challenging to determine success after only one year's time. Seed surveys will occur between August and October.

- **Photo Points** are marked and set up in two locations within each site and photos are taken from each point quarterly.
- **Natural Recruitment Surveys** evaluate natural recruitment of woody phreatophyte species and are conducted annually between May and August. Since we are only looking for natural recruitment of several specific species, the ideal time to do this is after germination is likely (spring). Surveys done later in the summer are also likely to indicate recruitment survival through the hot season.

Evaluation Criterion F: Department of the Interior and Bureau of Reclamation Priorities

This project aligns most strongly with these Department of Interior priorities:

Creating a conservation stewardship legacy second only to Teddy Roosevelt

- Utilize science to identify best practices to manage land and water resources and adapt to changes in the environment: GWP bases its work on best practices in restoration science and management, and is constantly updating techniques and plans based on the results of monitoring and the Adaptive Management Plan.

Restoring trust with local communities

- Be a better neighbor to those closest to our resources by improving dialogue and relationships. GWP works with private landowners and those who own adjacent lands to find win-win solutions to common problems, such as salt cedar and other invasive plants. The river restoration work provides many opportunities to interface with landowners and community members. We are careful to acknowledge our funding partners in our work and assist in building trust between government agencies and local communities.
- Expand the lines of communication with governors, state natural resource officers, Fish and Wildlife officers, water authorities, county commissioners, tribes, and local communities. GWP works with all of the above groups and seeks to bring them together once per year for the Upper Gila Watershed Forum, for the purpose of expanding communication between these groups.

Striking a regulatory balance

- Ensure that ESA decisions are based on strong science and thorough analysis. GWP's restoration program is based on a very detailed ecohydrological analysis that ensures the work that is undertaken is sustainable both now and into the future. A robust monitoring program ensures that there is adequate data to make adaptive management decisions to course-correct and make adjustments to management when objectives are not being met.

This project aligns most strongly with these Bureau of Reclamation priorities:

- The GWP riparian restoration program increases water supplies over the long term by re-building riparian systems that support water infiltration, therefore keeping water within

the system. Additionally, native vegetation requires less water acre by acre than salt cedar.

- GWP leverages the available science and best practices in watershed and riparian restoration by maintaining a strong network of scientific partners who work with the staff to ensure restoration is done in the most efficient and effective way possible.
- The GWP riparian restoration addresses ongoing drought by changing the vegetation and eventually the geomorphology of the Upper Gila River to promote water savings and infiltration, thus keeping it within the system. Additionally, GWP educates the public about water conservation and drought.
- The GWP riparian restoration project improves water supply for both Tribal and Rural communities by creating conditions of water conservation and retention within the system. This will benefit users throughout the Upper Gila Watershed, which include numerous rural communities and the San Carlos Apache Tribe.

Project Budget

Funding Plan

This Arizona Department of Fire and Forestry Management has funded the treatment of salt cedar and other invasives on the restoration sites, providing the 1:1 non-federal matching contribution required for the BOR WaterSmart Cooperative Watershed Management Program Phase II Grant Program. GWP was awarded an Invasive Plant Grant by the Department on January 9, 2020 in the amount of $405,000. This works is currently ongoing and will be complete by December 31, 2022. This funding is supported by a letter of commitment submitted with this proposal. The Funding Plan is presented below in Table 3.

Table 3. Project Funding Plan.

SOURCE	AMOUNT
Costs to be reimbursed with the requested Federal funding	$299,637.55
Cost to be paid by the applicant (AZDFFM Invasive Plant Grant #IPG# 19S-702)	$405,000
Value of third-party in-kind contributions (AZ Conservation Corps and National Civilian Community Corps)	$75,000
TOTAL PROJECT COST	**$779,637.55**

Budget Proposal

BUDGET ITEM DESCRIPTION	COMPUTATION $/unit	COMPUTATION qty	Qty type	Total BOR Request	Non-Federal Match	Project Total
Salaries and Wages						
Restoration Manager	25	1500	hours	$ 37,500	$ 37,442	$ 74,942
Field Coordinator	18	2000	hours	$ 36,000	$ 25,988	$ 61,988
Monitoring Technician	16	250	hours	$ 4,000	$ 22,275	$ 26,275
Plant Nursery Manager	28	200	hours	$ 5,600	$ -	$ 5,600
Plant Nursery help	20	300	hours	$ 6,000	$ -	$ 6,000
Summer crew	14	350	hours	$ 4,900	$ 35,284	$ 40,184
Science & Outreach Manager	26	325	hours	$ 8,450	$ -	$ 8,450
Executive Director	32	200	hours	$ 6,400	$ -	$ 6,400
Fringe Benefits						
Full-Time Employees	1000	6	cost/month	$ 6,000	$ -	$ 6,000
Part-Time Employees	500	6	cost/month	$ 3,000	$ -	$ 3,000
Travel						
Fuel for vehicles	0.575	13000	cost/mile	$ 7,475	$ 1,485	$ 8,960
				$ -		
Equipment						
Equipment maintenance	3750	2	cost/year	$ 7,500	$ 7,425	$ 14,925
Equipment fuel	2.25	500	cost/gallon	$ 1,125	$ 1,485	$ 2,610
Supplies and Materials						
Barbed wire (5, $72/1320')	3	$ 72.00	Wire	$ 216	0	$ 216
Wire stretcher	1	$ 40.00	stretcher	$ 40		$ 40
T-posts	60	$ 6.00	t-post	$ 360	$ 752	$ 1,112
T-post ties (4/post; 25-pack)	10	$ 3.00	ties	$ 30	$ 30	$ 60
Rebar (160/acre)	300	$ 1.01	rebar	$ 303	$ 5,000	$ 5,303
Wire caging	0	$ -	0	$ -	$ 3,767	$ 3,983
Water (purchased from munic	24	$ 63.00	cost/month	$ 1,512	$ 575	$ 2,087
PVC (20-ft); 1.5" (ft)	125	$ 0.55	feet	$ 69	$ 1,000	$ 1,069
Spaghetti Line (1000-ft roll)	4	$ 38.02	rolls	$ 152	$ 1,000	$ 1,152
Polyline (per roll, 500 ft/roll)	2	$ 27.00	rolls	$ 54	$ 500	$ 554
Connectors	50	$ 3.00	connectors	$ 150	$ 100	$ 250
Tanks	2	$ 1,100.00	tanks	$ 2,200	$ 1,000	$ 3,200
Baling wire	5	$ 5.00	wire rounds	$ 25	$ -	$ 25
Emitters	550	$ 0.84	emitters	$ 462	$ 441	$ 903
Filters	5	$ 15.00	filters	$ 75	$ -	$ 75
Herbicide backpacks, sprayers	0	0	sprayers	$ -	$ 459	$ 459
Herbicide	100	18	gallons	$ 1,800	$ 24,194	$ 25,994
Contractual/Construction						
Natural Channel Design	20000	1	Design plan	$ 20,000	$ -	$ 20,000
Arizona Conservation Corps	6600	16	cost/week	$ 105,600	$ 166,320	$ 271,920
Third-Party In-Kind Contributions						
National Civilian Community C	25	2000	hourly	$ -	$ -	$ 50,000
Arizona Conservation Corps	25	1000	Hourly	$ -	$ -	$ 25,000
Environmental and Regulatory Compliance Costs						
BOR Review of Permits				$ 15,000	$ -	$ 15,000
Other						
Other						$ -
TOTAL DIRECT COSTS				$ 281,998	$ 336,522	$ 693,736
Indirect Cost						
Percentage minus contractor	10%	$ 176,398		$ 17,639.78	$ 68,478	$ 86,118
TOTAL ESTIMATED PROJECT COSTS				$ 299,637.55	$ 405,000.00	$ 779,853.55

Budget Narrative

Salaries and Wages

Kiera Kauffman (project manager), Habitat Restoration Manager, will work 1,500 hours over 2 years (750 hours per year) at the rate of $25/hour for a total of $37,000. Kiera will provide project oversite and leadership, develop and refine plans, manage data and GIS files, develop reports, provide training to field crews, and ensure project is meeting it's reporting requirements and goals.

Lance Vaughn, Restoration Field Coordinator, will work 2,000 hours over 2 years (1,000 hours per year) at $18/hour for a total of $36,000. Lance will provide in-the-field logistics, manage crews, run machinery, maintain vehicles, supplies, and inventory, and provide day-to-day guidance for crews.

Josh Lightner, Monitoring Technician, will work 250 hours over 2 years (125 hours per year) at the rate of $16/hour for a total of $4,000. Josh will conduct the monitoring necessary to determine if the success metrics are being reached, and to adapt the techniques if they are not.

Steve Plath, Plant Nursery Manager, will work 200 hours over 2 years (100 hours/year) at the rate of $28/hour for a total of $5,600. Steve oversees the operations of a greenhouse and plant nursery that houses over 30,000 native plants annually for restoration, contract grows, and retail, including the 4,000 plants that will be used for this project.

Tim Goodman, Plant Nursery Help, will work 300 hours over 2 years (150 hours per year) at the rate of $20/hour. Tim provides specialized watering, fertilization, propagation, and plant care for the Gila Native Plant Nursery.

Summer Crew consists of 2 seasonal interns who will work 350 hours over 2 years (87.5 hours per person per year) at the rate of $14/hour, for a total of $4,200. The summer crew will water the plants in the field and remove secondary weeds from the restoration sites.

Kara Barron, Science and Outreach Manager, will work 325 hours over 2 years (162.5 hours per year) at the rate of $26/hour for a total of $8,450. Kara manages the volunteer program that is critical to accomplishing much of the work in the Gila Native Plant Nursery, manages the NCCC program and crews, and works with partners to ensure a high level of scientific integrity is brought to the work.

Melanie Tluczek, Executive Director, will work 200 hours over 2 years (100 hours per year) at the rate of $32/hour for a total of $6,400. Melanie oversees GWP and provides high-level support to project managers. She is responsible for ensuring projects stay on track, financial records are maintained, working with partners to complete environmental compliance, and grant obligations are delivered.

Fringe Benefits

Fringe benefits, which includes health insurance, for full time employees is approximately $1,000 per month. We have requested 6 months (3 months per year) for a total of $6,000. For part time employees, fringe benefits (workers comp, sick pay) is approximately $500 per month. We are requesting 6 months (3 months per year) for a total of $3,000.

Travel

The GWP restoration sites are an average of 25 miles from the GWP headquarters at 1651 W. Discovery Park Blvd. Safford, AZ 85546 to Fort Thomas 33.03722°N 109.96611°W. A round trip for one day is approximately 50 miles. We are requesting funding to cover 130 trips per year for a total of 260 trips at 50 miles each. This totals 13,000 miles over 2 years. At the federal rate of 0.575 reimbursement per mile, this totals $7,475 for mileage reimbursement.

Equipment

GWP spends an average of $10,000 per year on equipment and vehicle maintenance. Equipment consists of a skidsteer used to control vegetation and dig holes for planting and a water truck for hauling water from municipal sources to restoration sites. We are requesting $3,750 per year for a total of $7,500 to ensure equipment and vehicles are in safe working order.

Materials and Supplies

Materials and supplies needed are for fencing to reduce predation on plantings, municipal water to water plantings for the first year, piping, tanks, and pumps to construct irrigation systems, and herbicide to control secondary weeds. Requested items for fencing are: Barbed wire, 3 1320’ rolls at $72 each = $216; 1 wire stretcher at $40 = $40; 60 t-posts at $6/each = 360; 10 packs t-post ties (25/pack) at $3 each = 30; 300 pieces of rebar at $1.01/piece = $303; 5 rounds of baling wire at $5/round = $25. Requested items for irrigation are: water purchased from Graham County Electric Cooperative via a metered pump - 24 months at an average of $63/month = $1,512; 125 feet of 1.5 inch PVC Pipe at 0.55/foot =m $69; 4 rolls of spaghetti line (1,000 ft/roll) at $38.02 per roll = $152; 2 rolls polyline (500 ft/roll) at $27/roll = $54; 50 PVC connectors at $3 each = $150; 2, 2,500 gallon water tanks at $1,100 each = $2,200; 550 emitters for drip irrigation at $0.84 each = $462; 5 filters at $15/each = $75. Requested items for secondary weed treatment are: 100 gallons of herbicide at $18/gallon = $1,800.

Contractual

Natural Channel Design, an environmental contractor specializing in channel restructuring, will develop a plan for maximizing the water retention at each site using low-cost, strategic, and pinpointed bank restructuring. Plan development, remote sensing, and fieldwork are quoted at $20,000. This will include a detailed assessment of the areas using remote sensing and groundwater modeling ($10,000), 4 field visits for data collection and resonance ($6,000),

development of report and detailed plans for enacting bank modifications. ($4,000). Natural Channel Design will be procured through a sole-source contract due to their past work with GWP and familiarity with the Upper Gila Watershed and GWP restoration sites.

Arizona Conservation Corps is a non-profit organization that recruits, trains, and deploys at-risk youth to do restoration work including removal of invasive trees and other plants, planting, irrigation, seeding, and other manual labor. A 7 person AZCC crew costs $6,600 per week. We are requesting 16 weeks to be split over 2 years (8 weeks per year) for a total of $105,600. AZCC will be procured through a sole-source contract due to their familiarity with GWP and its work, the specialized nature of their training and work, and the cost-effectiveness of using a non-profit organization.

Third-Party In-Kind Contributions

The National Civilian Community Corps (NCCC) is a division of the Americorps program which deploys teams of 8-12 youth 18-24 years old on assignments to assist non-profit organizations for the duration of 12 weeks. NCCC crews are paid for by the federal government through the Americorps program and come free of cost to the non-profits in exchange for mentorship, education, and job experience. GWP has, for the past 3 years, been awarded a January – April crew, which is shared between 2 other non-profit organizations. GWP utilizes the crew for 4-6 out of the 12 weeks for planting, secondary weed removal, cage and irrigation construction, and plant nursery labor. With 12 crew members working 40 hours per week for 4.165 weeks at $25/hour (1 2x 40 x 4.165 = 2,000 x 25) = $50,000 in kind contributions.

Arizona Conservation Corps (AZCC) underwrites a portion of their cost. Their in-kind rates are calculated based off of the current independent sector rate minus the member's hourly pay plus FICA. Although this fluctuates slightly depending on the current rates, a contract for $105,000 will typically have an in-kind value of $25,000.

Environmental and Regulatory Compliance Costs

GWP has reserved approximately 5% of total costs, or $15,000 for compliance and regulatory review and paperwork.

Other Expenses

There are no other expenses.

Indirect Costs

Indirect costs are calculated as 10% of the total cost of the proposed budget, minus any contractor fees over and above $20,000. Indirect costs include administrative salary (336 hours at $25/hr = $8,400), general liability and other insurance ($7,500), telephone and internet ($1,000), and tax reporting fees ($739.78).

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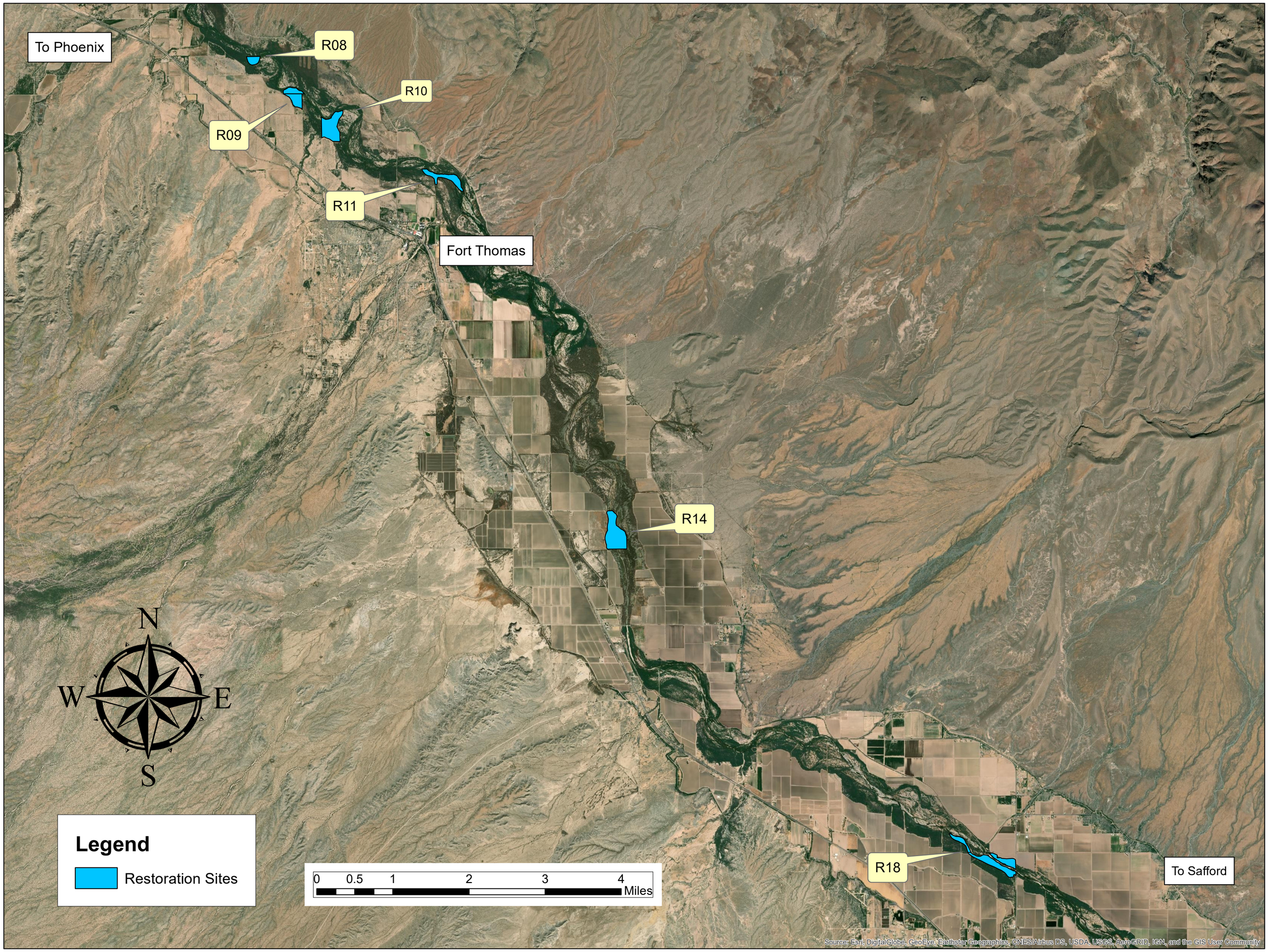
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To Phoenix
R08
R10
R09
R11
Fort Thomas
R14
R18
To Safford
N
W
E
S
Legend
Restoration Sites
0 0.5 1 2 3 4
Miles
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

N

Retreat tamarisk (machine) across entire site, focusing more on the southeastern portion.

Treat secondary weeds in the interior, avoiding areas with successful cottonwood recruitment.

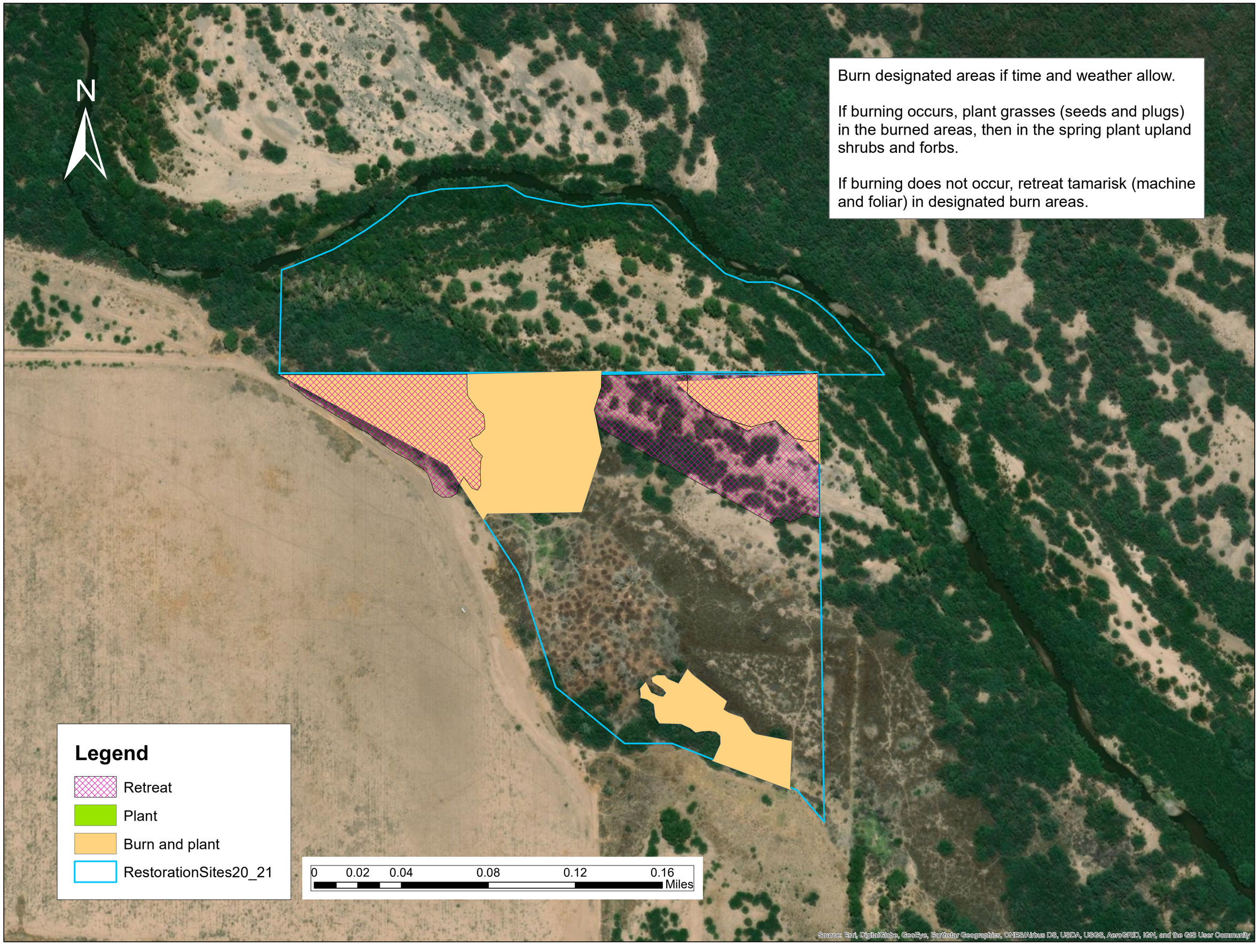
Plant grasses (seeds and plugs) in the interior after secondary weed treatment or tamarisk removal. In the spring, plant upland shrubs and forbs.

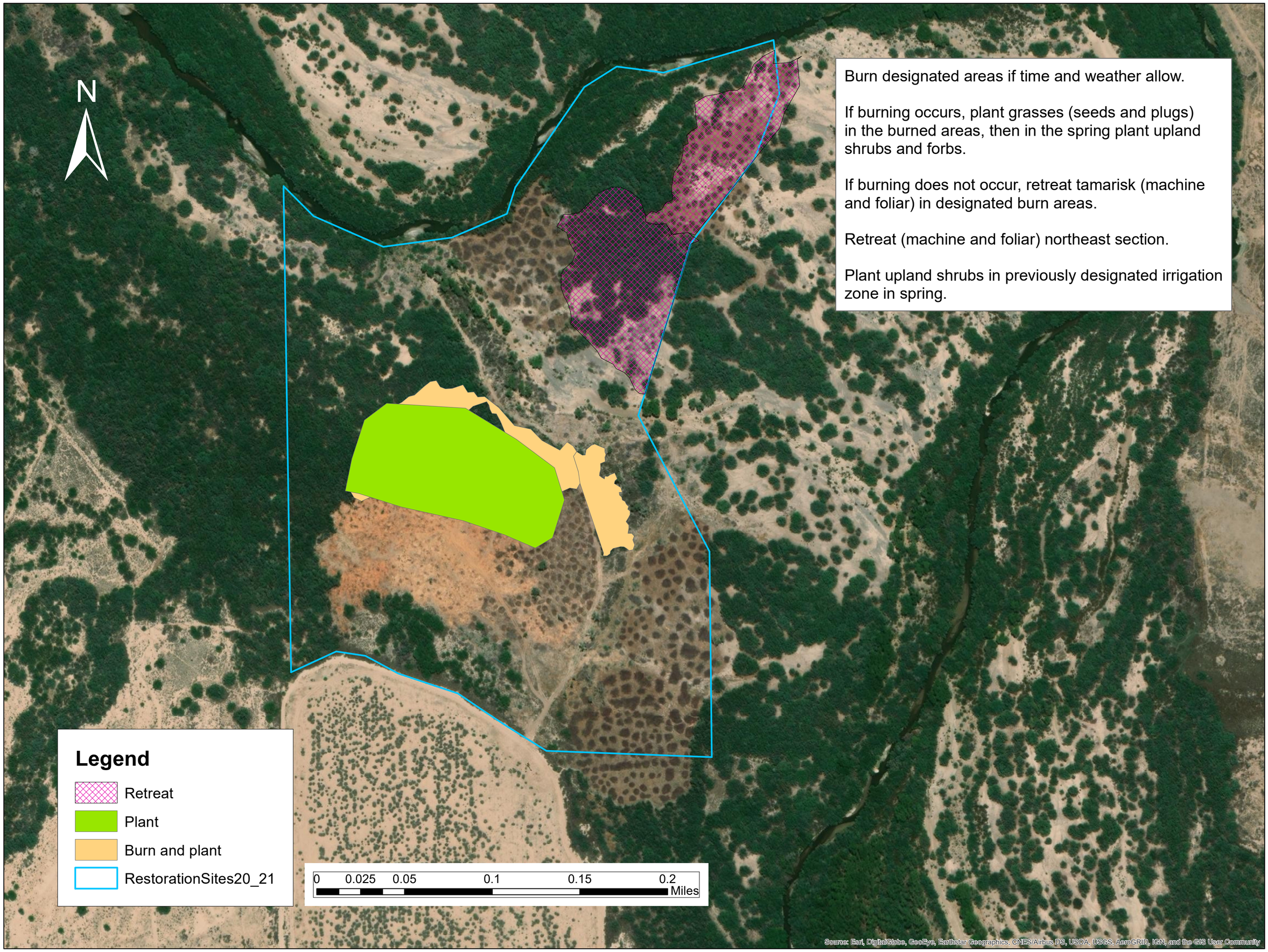
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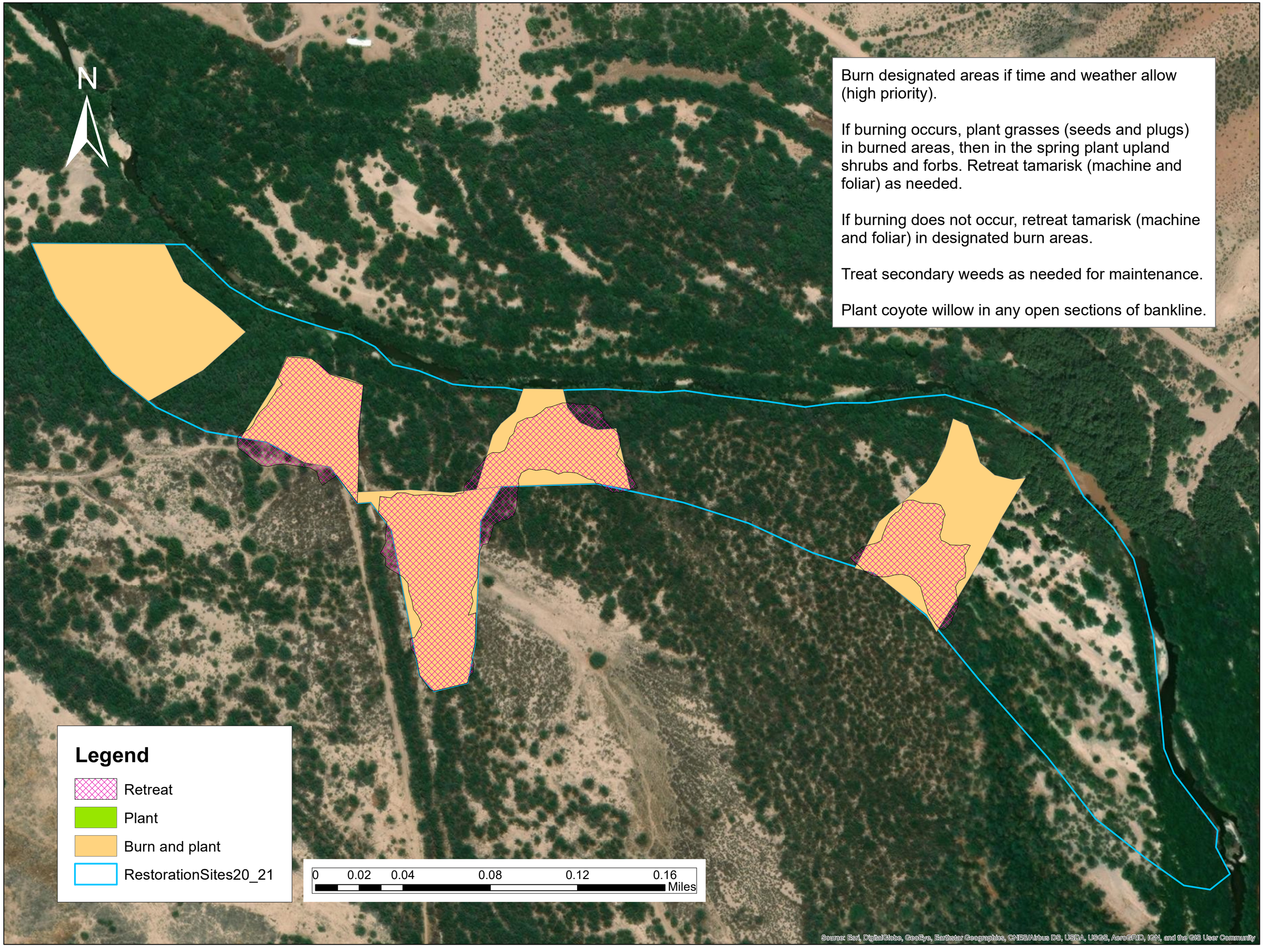
- Retreat
- Plant
- Burn and plant
- RestorationSites20_21

0 0.0125 0.025 0.05 0.075 0.1
Miles

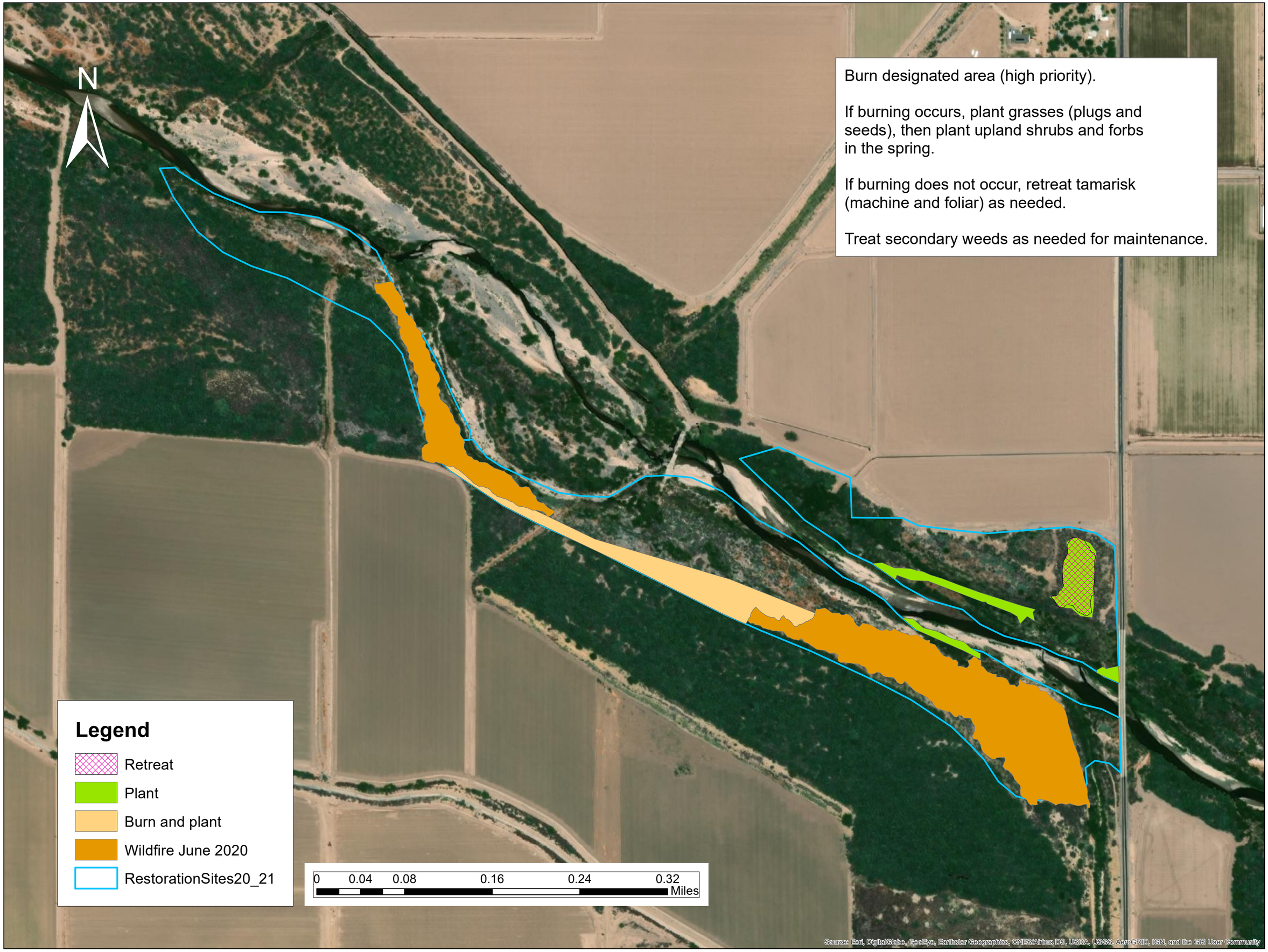
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community


N
Burn designated areas if time and weather allow.
If burning occurs, plant grasses (seeds and plugs) in the burned areas, then in the spring plant upland shrubs and forbs.
If burning does not occur, retreat tamarisk (machine and foliar) in designated burn areas.
Legend
Retreat
Plant
Burn and plant
RestorationSites20_21
0 0.02 0.04 0.08 0.12 0.16
Miles
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community


N
Burn designated areas if time and weather allow.
If burning occurs, plant grasses (seeds and plugs) in the burned areas, then in the spring plant upland shrubs and forbs.
If burning does not occur, retreat tamarisk (machine and foliar) in designated burn areas.
Retreat (machine and foliar) northeast section.
Plant upland shrubs in previously designated irrigation zone in spring.
Legend
Retreat
Plant
Burn and plant
RestorationSites20_21
0 0.025 0.05 0.1 0.15 0.2
Miles
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community


N
Burn designated areas if time and weather allow (high priority).
If burning occurs, plant grasses (seeds and plugs) in burned areas, then in the spring plant upland shrubs and forbs. Retreat tamarisk (machine and foliar) as needed.
If burning does not occur, retreat tamarisk (machine and foliar) in designated burn areas.
Treat secondary weeds as needed for maintenance.
Plant coyote willow in any open sections of bankline.
Legend
Retreat
Plant
Burn and plant
RestorationSites20_21
0 0.02 0.04 0.08 0.12 0.16
Miles
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community


N
Retreat tamarisk (machine and foliar) in southwest corner.
Treat secondary weeds as needed for maintenance.
Legend
Retreat
Plant
Burn and plant
RestorationSites20_21
0 0.03 0.06 0.12 0.18 0.24
Miles
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community


N
Burn designated area (high priority).
If burning occurs, plant grasses (plugs and seeds), then plant upland shrubs and forbs in the spring.
If burning does not occur, retreat tamarisk (machine and foliar) as needed.
Treat secondary weeds as needed for maintenance.
Legend
Retreat
Plant
Burn and plant
Wildfire June 2020
RestorationSites20_21
0 0.04 0.08 0.16 0.24 0.32
Miles
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

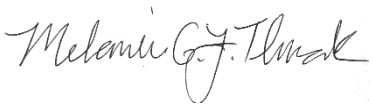
Bureau of Reclamation
WaterSmart Cooperative Watershed Management Program
P.O. Box 25007, MS 84-27814
Denver, CO 80225
November 16, 2020

RE: Self-Certification of GWP Regular Meetings

Dear WaterSmart Cooperative Watershed Management Program Selection Committee:

I certify that the Gila Watershed Partnership holds monthly meetings of the Board of Directors as required by the GWP bylaws. GWP also holds four events per year that are open to the public. The first is the Upper Gila Watershed Forum, wherein community members, industry leaders, local elected officials, scientists, and land managers gather to share and learn about issues affecting the Upper Gila Watershed. The second is a large public plant sale, which also serves to educate the public about the benefits of native plants. The third is a landowner focused meeting that addresses various topics as they affect landowners in Graham and Greenlee Counties. The fourth is an end-of-year event designed to provide updates and opportunity for interaction with stakeholders and the general public. It also serves as a thank you event for volunteers and donors. Please contact me with any questions.

Sincerely,



Melanie Tluczek
Executive Director
Gila Watershed Partnership
melanie@gwpaz.org
(602) 909-3713

Form **872-C**

(Rev. September 1998)

Department of the Treasury
Internal Revenue Service

Consent Fixing Period of Limitation Upon Assessment of Tax Under Section 4940 of the Internal Revenue Code

(See instructions on reverse side.)

OMB No. 1545-0056

To be used with Form 1023. Submit in duplicate.

Under section 6501(c)(4) of the Internal Revenue Code, and as part of a request filed with Form 1023 that the organization named below be treated as a publicly supported organization under section 170(b)(1)(A)(vi) or section 509(a)(2) during an advance ruling period,

Gila Watershed Partnership
(Exact legal name of organization as shown in organizing document)

305 E. 4th Street Safford, AZ 85546
(Number, street, city or town, state, and ZIP code)

and the District Director of Internal Revenue, or Assistant Commissioner (Employee Plans and Exempt Organizations)

consent and agree that the period for assessing tax (imposed under section 4940 of the Code) for any of the 5 tax years in the advance ruling period will extend 8 years, 4 months, and 15 days beyond the end of the first tax year.

However, if a notice of deficiency in tax for any of these years is sent to the organization before the period expires, the time for making an assessment will be further extended by the number of days the assessment is prohibited, plus 60 days.

Ending date of first tax year December 31, 2002
(Month, day, and year)

Name of organization (as shown in organizing document)	Date
Gila Watershed Partnership	1/27/03
Officer or trustee having authority to sign Signature ▶	Type or print name and title GEORGE W. LEMON CHAIRMAN
For IRS use only	
District Director or Assistant Commissioner (Employee Plans and Exempt Organizations) Director, Exempt Organizations Rulings and Agreements By ▶ Group Manager	Date FEB 06 2003

For Paperwork Reduction Act Notice, see page 7 of the Form 1023 Instructions. Cat. No. 16905Q

INTERNAL REVENUE SERVICE
P. O. BOX 2508
CINCINNATI, OH 45201

DEPARTMENT OF THE TREASURY

Date: FEB 06 2003

GILA WATERSHED PARTNERSHIP
305 E 4TH ST
SAFFORD, AZ 85546-0000

Employer Identification Number:
86-0917031
DLN:
17053324077012
Contact Person:
ELIZABETH WAGNER ID# 31380
Contact Telephone Number:
(877) 829-5500
Accounting Period Ending:
December 31
Foundation Status Classification:
509(a)(1)
Advance Ruling Period Begins:
November 12, 2002
Advance Ruling Period Ends:
December 31, 2006
Addendum Applies:
No

Dear Applicant:

Based on information you supplied, and assuming your operations will be as stated in your application for recognition of exemption, we have determined you are exempt from federal income tax under section 501(a) of the Internal Revenue Code as an organization described in section 501(c)(3).

Because you are a newly created organization, we are not now making a final determination of your foundation status under section 509(a) of the Code. However, we have determined that you can reasonably expect to be a publicly supported organization described in sections 509(a)(1) and 170(b)(1)(A)(vi).

Accordingly, during an advance ruling period you will be treated as a publicly supported organization, and not as a private foundation. This advance ruling period begins and ends on the dates shown above.

Within 90 days after the end of your advance ruling period, you must send us the information needed to determine whether you have met the requirements of the applicable support test during the advance ruling period. If you establish that you have been a publicly supported organization, we will classify you as a section 509(a)(1) or 509(a)(2) organization as long as you continue to meet the requirements of the applicable support test. If you do not meet the public support requirements during the advance ruling period, we will classify you as a private foundation for future periods. Also, if we classify you as a private foundation, we will treat you as a private foundation from your beginning date for purposes of section 507(d) and 4940.

Grantors and contributors may rely on our determination that you are not a private foundation until 90 days after the end of your advance ruling period. If you send us the required information within the 90 days, grantors and contributors may continue to rely on the advance determination until we make

a final determination of your foundation status.

If we publish a notice in the Internal Revenue Bulletin stating that we will no longer treat you as a publicly supported organization, grantors and contributors may not rely on this determination after the date we publish the notice. In addition, if you lose your status as a publicly supported organization, and a grantor or contributor was responsible for, or was aware of, the act or failure to act, that resulted in your loss of such status, that person may not rely on this determination from the date of the act or failure to act. Also, if a grantor or contributor learned that we had given notice that you would be removed from classification as a publicly supported organization, then that person may not rely on this determination as of the date he or she acquired such knowledge.

If you change your sources of support, your purposes, character, or method of operation, please let us know so we can consider the effect of the change on your exempt status and foundation status. If you amend your organizational document or bylaws, please send us a copy of the amended document or bylaws. Also, let us know all changes in your name or address.

As of January 1, 1984, you are liable for social security taxes under the Federal Insurance Contributions Act on amounts of $100 or more you pay to each of your employees during a calendar year. You are not liable for the tax imposed under the Federal Unemployment Tax Act (FUTA).

Organizations that are not private foundations are not subject to the private foundation excise taxes under Chapter 42 of the Internal Revenue Code. However, you are not automatically exempt from other federal excise taxes. If you have any questions about excise, employment, or other federal taxes, please let us know.

Donors may deduct contributions to you as provided in section 170 of the Internal Revenue Code. Bequests, legacies, devises, transfers, or gifts to you or for your use are deductible for Federal estate and gift tax purposes if they meet the applicable provisions of sections 2055, 2106, and 2522 of the Code.

Donors may deduct contributions to you only to the extent that their contributions are gifts, with no consideration received. Ticket purchases and similar payments in conjunction with fundraising events may not necessarily qualify as deductible contributions, depending on the circumstances. Revenue Ruling 67-246, published in Cumulative Bulletin 1967-2, on page 104, gives guidelines regarding when taxpayers may deduct payments for admission to, or other participation in, fundraising activities for charity.

Contributions to you are deductible by donors beginning November 12, 2002.

You are not required to file Form 990, Return of Organization Exempt From Income Tax, if your gross receipts each year are normally $25,000 or less. If you receive a Form 990 package in the mail, simply attach the label provided, check the box in the heading to indicate that your annual gross receipts are normally $25,000 or less, and sign the return. Because you will be treated as

a public charity for return filing purposes during your entire advance ruling period, you should file Form 990 for each year in your advance ruling period that you exceed the $25,000 filing threshold even if your sources of support do not satisfy the public support test specified in the heading of this letter.

If a return is required, it must be filed by the 15th day of the fifth month after the end of your annual accounting period. A penalty of $20 a day is charged when a return is filed late, unless there is reasonable cause for the delay. However, the maximum penalty charged cannot exceed $10,000 or 5 percent of your gross receipts for the year, whichever is less. For organizations with gross receipts exceeding $1,000,000 in any year, the penalty is $100 per day per return, unless there is reasonable cause for the delay. The maximum penalty for an organization with gross receipts exceeding $1,000,000 shall not exceed $50,000. This penalty may also be charged if a return is not complete. So, please be sure your return is complete before you file it.

You are not required to file federal income tax returns unless you are subject to the tax on unrelated business income under section 511 of the Code. If you are subject to this tax, you must file an income tax return on Form 990-T, Exempt Organization Business Income Tax Return. In this letter we are not determining whether any of your present or proposed activities are unrelated trade or business as defined in section 513 of the Code.

You are required to make your annual information return, Form 990 or Form 990-EZ, available for public inspection for three years after the later of the due date of the return or the date the return is filed. You are also required to make available for public inspection your exemption application, any supporting documents, and your exemption letter. Copies of these documents are also required to be provided to any individual upon written or in person request without charge other than reasonable fees for copying and postage. You may fulfill this requirement by placing these documents on the Internet. Penalties may be imposed for failure to comply with these requirements. Additional information is available in Publication 557, Tax-Exempt Status for Your Organization, or you may call our toll free number shown above.

You need an employer identification number even if you have no employees. If an employer identification number was not entered on your application, we will assign a number to you and advise you of it. Please use that number on all returns you file and in all correspondence with the Internal Revenue Service.

You have agreed on your application for exemption under section 501(c)(3) of the Code that your exemption is effective November 12, 2002, the date your completed application was filed.

This determination is based on evidence that your funds are dedicated to the purposes listed in section 501(c)(3) of the Code. To assure your continued exemption, you should keep records to show that funds are spent only for those purposes. If you distribute funds to other organizations, your records should

show whether they are exempt under section 501(c)(3). In cases where the recipient organization is not exempt under section 501(c)(3), you must have evidence that the funds will remain dedicated to the required purposes and that the recipient will use the funds for those purposes.

If you distribute funds to individuals, you should keep case histories showing the recipients' names, addresses, purposes of awards, manner of selection, and relationship (if any) to members, officers, trustees or donors of funds to you, so that you can substantiate upon request by the Internal Revenue Service any and all distributions you made to individuals. (Revenue Ruling 56-304, C.B. 1956-2, page 306.)

If we said in the heading of this letter that an addendum applies, the addendum enclosed is an integral part of this letter.

Because this letter could help us resolve any questions about your exempt status and foundation status, you should keep it in your permanent records.

If you have any questions, please contact the person whose name and telephone number are shown in the heading of this letter.

Sincerely yours,

Lois G. Lerner

Lois G. Lerner
Director, Exempt Organizations

Enclosure(s):
Form 872-C

BYLAWS
OF
The Gila Watershed Partnership

An Arizona Nonprofit Corporation

As amended on November 13, 2013

ARTICLE I: OFFICES

The corporation may have offices at such places as the Board of Directors may from time to time determine or the business of the corporation may require.

ARTICLE II: DIRECTORS

1. The affairs of the corporation shall be managed by the Board of Directors. The number of Directors to constitute the Board of Directors shall be determined by the Board of Directors, provided, however, that there shall always be at least three Directors. Directors shall be elected at the annual meeting of the Directors to serve for a term of two years or until his or her successor shall have been elected and qualified. Directors may be removed, with or without cause, by the vote of at least two-thirds of all the Directors at a meeting of the Directors called expressly for that purpose. Any vacancy created by such removal shall be filled for the unexpired term in respect of such vacancy by majority vote of the Directors present at such special meeting or, in the absence of such action at such special meeting, by resolution of the Board of Directors.

2. The Directors may keep the books of the corporation at the principal business office of the corporation in this state or at such other place as they may from time to time determine and as may be permitted by law.

3. If the office of a Director becomes vacant for any reason, other than by removal of the Director in the manner described in paragraph 1 hereof, the remaining Directors shall choose a successor or successors which successor(s) shall hold office for the unexpired term in respect of which such vacancy occurred or until the next election of Directors.

ARTICLE III: COMPENSATION OF DIRECTORS

Directors, as such, shall not receive any stated salary for their services, but by resolution of the Board, expenses of attendance, if any, may be allowed for attendance at each regular or special meeting of the Board; provided that nothing herein contained shall be construed to preclude any Director from serving the corporation in any other capacity and receiving compensation or reimbursement of expenses therefor.

ARTICLE IV: MEETINGS OF THE BOARD

1. The annual meeting of the Board shall be held at such time and place as shall be determined by the Board. Regular meetings of the Board may be held without notice at such time and place as shall from time to time be determined by the Board.

2. Special meetings of the Board may be called by the Chair, the Secretary/Treasurer, or 25 percent of the Directors on not less than two days' notice to each Director, either personally or by first class mail, telegram, telephone, facsimile, or email.

3. A Director's attendance at or participation in a meeting waives any required notice of the meeting unless the Director upon arriving at the meeting or prior to the vote on a matter not noticed in conformity with the law, the Articles or Bylaws, objects to lack of notice and does not vote for or assent to the objected to action. Neither the business to be transacted at, nor the purpose of, any regular or special meeting of the Board of Directors need be specified in any notice or waiver of notice of such meeting.

4. At all meetings of the Board, a majority of all the Directors in office shall be necessary and sufficient to constitute a quorum for the transaction of business, and the act of a majority of the Directors present at any meeting at which there is a quorum shall be the act of the Board of Directors, unless the action is one upon which, by express provision of the statutes, the Articles of Incorporation, or these Bylaws, a different vote is required, in which case such express

provision shall govern and control. If a quorum shall not be present at any meeting of Directors, the Directors present thereat may adjourn the meeting, from time to time, without notice other than announcement at the meeting, until a quorum shall be present.

5. Members of the Board of Directors may participate in a meeting of the Board by means of a conference telephone or similar communications equipment whereby all persons participating in the meeting can hear each other, and participation in a meeting in this manner shall constitute presence in person at the meeting.

6. Action required or permitted by law to be taken at a Board of Directors' meeting may be taken without a meeting if the action is taken by all members of the Board. The action shall be evidenced by one or more written consents describing the action taken, signed by each Director, and included in the minutes filed with the corporate records reflecting the action taken. Such action shall be effective when the last Director signs the consent, unless the consent specifies a different effective date.

ARTICLE V: COMMITTEES

1. The Board of Directors, by a resolution adopted by a majority of the Directors in office, may designate an Executive Committee, which shall consist of at least three Directors of the corporation. The Executive Committee shall have and exercise the authority of the Board of Directors between meetings of the Board of Directors.

2. The Board of Directors, by a resolution adopted by a majority of the Directors in office, may designate one or more other Board committees, each of which shall consist of at least two Directors. Such committees shall, to the extent provided in such resolution, have and exercise the authority of the Board of Directors.

3. At all meetings of committees, a majority of the members of the committee shall be necessary and sufficient to constitute a quorum for the transaction of business, and the act

of a majority of the members of the committee present at any meeting at which there is a quorum shall be the act of the committee, unless the action is one upon which, by express provision of the statutes, the articles of incorporation, these bylaws, or a resolution of the Board of Directors, a different vote is required, in which case such express provision shall govern and control. Provisions in these bylaws pertaining to meetings of the Board shall also apply to a committee or committees of the Board.

ARTICLE VI: NOTICES

1. Whenever, under the provisions of the statutes, the Articles of Incorporation, or these Bylaws, notice is required to be given to any Director, such notice may be given orally or in writing. Notice may be communicated in person; by any form of wire or wireless communication such as telephone or telegraph; by mail or private carrier; by electronic mail; or if the preceding forms of personal notice are impracticable, by a newspaper of general circulation in the area where published; or other form of public broadcast communication such as radio, or television.

2. Whenever any notice is required to be given, a waiver thereof in writing signed by the person or persons entitled to said notice, whether before or after the time stated therein, and filed with the minutes or corporate records, shall be deemed equivalent thereto.

ARTICLE VII: OFFICERS

1. The officers of the corporation shall consist of the Executive Committee, which includes the Chair, Vice Chair, Secretary/Treasurer. The Board of Directors may also elect such other officers and agents as it shall deem necessary, who shall exercise such powers and perform such duties as shall be determined from time to time by the Board of Directors. The compensation of all officers, if any, shall be fixed by the Board of Directors.

2. The officers of the corporation shall hold their offices for a term of two years. Officers may be reelected to two successive terms. Any officers may be removed at any time

by the Board of Directors. An officer may resign at any time by delivering notice to the corporation. A resignation is effective when the notice is delivered unless the notice specifies a future effective date. If the office of any officers becomes vacant for any reason, the vacancy may be filled by the Board of Directors.

ARTICLE VIII: CHAIR

The Chair of the Board, if any, shall preside at all meetings of the Directors at which he or she is present, and shall perform such other duties as the Board of Directors or these Bylaws may prescribe.

ARTICLE IX: VICE CHAIR

The Vice Chair, if any, in the order of their seniority shall, in the absence or disability of the Chair, perform the duties and exercise the powers of the Chair, and shall perform such other duties as the Board of Directors may prescribe.

ARTICLE X: SECRETARY/ TREASURER

1. The Secretary/Treasurer shall keep or cause to be kept a record of all meetings of the Board of Directors and shall record all votes and the minutes of all proceedings in a book to be kept for that purpose. He or she shall give, or cause to be given, notice of all special meetings of the Board of Directors, and shall perform such other duties as may be prescribed by the Board of Directors or Chair, under whose supervision he or she shall be. He or she shall be responsible for authenticating the records of the corporation.

2. The Secretary/Treasurer or such other person or persons as the Board of Directors may designate shall have the custody of the corporate funds and securities, shall keep full

and accurate accounts of receipts and disbursements in books belonging to the corporation, shall deposit all moneys and other valuable effects in the name and to the credit of the corporation in such depositories as may be designated by the Board of Directors and shall perform such other duties as the Board of Directors may prescribe.

3. The Secretary/Treasurer or such other person or persons as the Board of Directors may designate shall disburse the funds of the corporation as may be ordered by the Board, taking proper vouchers for such disbursements, and shall render to the Chair and Directors, at the regular meetings of the Board, or whenever they may require it, an account of all his or her transactions as Treasurer and of the financial condition of the corporation.

ARTICLE XI: CHECKS

All checks or demands for money and notes of the corporation shall be signed by such officer or officers or such other person or persons as the Board of Directors may from time to time designate.

ARTICLE XII: FISCAL YEAR

The fiscal year of the corporation shall begin the first day of January in each year.

ARTICLE XIII: SEAL

The corporation shall not have a seal.

ARTICLE XIV: ALTERATION, AMENDMENT OR REPEAL OF BYLAWS

These bylaws may be altered, amended or repealed at any regular or special meeting of the Directors by the affirmative vote of a majority of all the Directors in office.

Adopted on _____

ARTICLE XV: RECORDS

1. The corporation shall keep as permanent records minutes of all meetings of its Board of Directors, a record of all actions taken by the Directors without a meeting, and a record of all actions taken by committees of the Board of Directors.

2. The corporation shall maintain appropriate accounting records. A copy of the following records shall be kept at the corporation's principal office: the Articles of Incorporation and all amendments to them currently in effect, these Bylaws and all amendments to them currently in effect, a list of the names and business or home addresses of the current Directors and Executive Committee, the most recent annual report delivered to the Arizona Corporation Commission, and appropriate financial statements of all income and expenses.

Adopted on _____

Gila Watershed Partnership

Mission Statement and Goals

Mission Statement

To engage the community in improving the water quality and ecosystem condition of the Upper Gila Watershed through education and economic opportunity.

Goals

1. Conserve natural resources
2. Increase river-based recreational opportunities for all users
3. Teach the importance of water resources
4. Maintain and improve the local economy
5. Improve water quality and availability
6. Plan and act to avoid and minimize damage from larger storms, floods, fire, and other natural disasters.

Approved, January 2019

Douglas A. Ducey
Governor

Office of the State Forester

Arizona Department of Forestry and Fire Management

David Tenney
State Forester

November 10, 2020

Bureau of Reclamation
WaterSmart Cooperative Watershed Management Program
P.O. Box 25007, MS 84-27814
Denver, CO 80225

Subject: Letter of Support for Gila Watershed Partnership Grant Proposal

Dear WaterSmart Cooperative Watershed Management Program Selection Committee:

The Arizona Department of Fire & Forestry Management (DFFM) is pleased to provide this letter of support for the Gila Watershed Partnership of Arizona's application to the BOR WaterSmart Cooperative Watershed Management Program for "Restoring the Riparian Forest along the Upper Gila River in Arizona."

DFFM has committed $405,000 to this effort through our Invasive Plant Grant Program (IPG# 19S-702) for the treatment of nonnative invasive plants on 200 acres. Although some of these grant funds have already been expended, activities are ongoing through 2021 and 2022. The grant was awarded on January 9, 2020 and closes on December 31, 2022. These non-federal funds have already been committed, and do not include any time constraints or other contingencies, except those contained in the grant agreement.

Please do not hesitate to contact me with any additional questions or concerns.

Sincerely,

Willie Sommers

Willie Sommers
Invasive Plant Program Coordinator

cc: Cori Dolan, Program Manager

FREEPORT-McMoRan

Freeport-McMoRan
Safford Operations
8500 N. Freeport-McMoRan Road
Safford, AZ 85546

Sean Wenham
Community Development Manager
Tel (928)792-5937
swenham@fmi.com

November 16, 2020

Bureau of Reclamation
WaterSmart Cooperative Watershed Management Program
P.O. Box 25007, MS 84-27814
Denver, CO 80225

RE: Letter of Support for Gila Watershed Partnership Grant Proposal

Dear WaterSmart Cooperative Watershed Management Program Selection Committee:

Freeport-McMoRan Safford Operations is pleased to provide this letter of support for The Gila Watershed Partnership of Arizona's application to the Bureau Of Reclamation's WaterSmart Cooperative Watershed Management Program for "Restoring the Riparian Forest along the Upper Gila River in Arizona."

FM Safford owns 279 acres of land, some of which is part of this restoration project, and we have been collaborating with The Gila Watershed Partnership of Arizona for 8 years on their river restoration efforts in Graham County.

We enthusiastically support this project because it advances our goals of enhancing local biodiversity, protecting habitat and water resources, and enriching the local community. We will continue our support by allowing GWP access and permits to conduct restoration work on selected FMI lands.

Please do not hesitate to contact me with any additional questions or concerns.

Sincerely,

Sean Wenham
Community Development Manager – Safford Operations

Graham County Board of Supervisors

921 Thatcher Blvd
Safford, AZ 85546
Phone: (928) 428-3250
Fax: (928) 428-5951

Paul R. David, Chairman
Danny Smith, Vice Chairman
James A. Palmer, Member

Dustin Welker, County Manager/Clerk

Bureau of Reclamation
WaterSmart Cooperative Watershed Management Program
P.O. Box 25007, MS 84-27814
Denver, CO 80225

November 9, 2020

RE: Letter of Support for Gila Watershed Partnership Grant Proposal

Dear WaterSmart Cooperative Watershed Management Program Selection Committee:

Graham County is pleased to provide this letter of support for the Gila Watershed Partnership of Arizona's application to the BOR WaterSmart Cooperative Watershed Management Program for "Restoring the Riparian Forest along the Upper Gila River in Arizona."

Graham County has worked with the Gila Watershed Partnership for nearly 27 years, providing financial support, technical assistance, and access to knowledge and resources. We enthusiastically support GWP's river restoration work, as it improves the habitat and water quality along the Gila River, provides job and internship opportunities for local youth, and brings in over $300,000 per year to the county. We are happy to support their continued restoration work along the Gila River.

Please do not hesitate to contact me with any additional questions or concerns.

Sincerely,

Dustin Welker
Manager/Clerk Board of Supervisors

United Way

United Way of Graham & Greenlee Counties

Bureau of Reclamation
WaterSmart Cooperative Watershed Management Program
P.O. Box 25007, MS 84-27814
Denver, CO 80225

November 9, 2020

RE: Letter of Support for Gila Watershed Partnership Grant Proposal

Dear WaterSmart Cooperative Watershed Management Program Selection Committee:

United Way of Graham and Greenlee Counties is pleased to provide this letter of support for the Gila Watershed Partnership of Arizona's application to the BOR WaterSmart Cooperative Watershed Management Program for "Restoring the Riparian Forest along the Upper Gila River in Arizona."

We recently provided GWP a grant of $43,534 in support of the Gila River Linear Park and Trail, a new amenity that will be developed between the Town of Thatcher and the City of Safford, AZ. The Linear Park and Trail is going to be a place where locals and visitors can safely connect with the river, the lifeblood of our region – and see firsthand what a restored riparian forest is like. We have also provided GWP with over $100,000 in grants to support river restoration and related work.

We enthusiastically support GWP's river restoration project, as it improves the habitat and water quality in our service area, provides economic benefits through employment, internships, and purchasing, and provides environmental education benefits for community members through involving school groups and volunteers.

Please do not hesitate to contact me with any additional questions or concerns.

Sincerely,

Adam O'Doherty

Adam O'Doherty
CEO

Central Jackson Heights Fire District
PO Box 430
Central, AZ 85531
928-965-0903
chairman@c-jhfd.com

Bureau of Reclamation
WaterSmart Cooperative Watershed Management Program
P.O. Box 25007, MS 84-27814
Denver, CO 80225

November 16, 2020

RE: Letter of Support for Gila Watershed Partnership Grant Proposal

Dear WaterSmart Cooperative Watershed Management Program Selection Committee:

The Jackson-Heights Fire District is pleased to provide this letter of support for the Gila Watershed Partnership of Arizona's application to the BOR WaterSmart Cooperative Watershed Management Program for "Restoring the Riparian Forest along the Upper Gila River in Arizona."

The Jackson Heights Fire District covers the area encompassing Thatcher, Pima and other smaller communities where GWP is currently doing restoration work. We enthusiastically support the GWP river restoration project. The restoration plots that GWP has created by removing tamarisk and strategically planting native plants has reduced the fire risk on the Gila River by creating fire breaks. On several occasions, fire crews have utilized the GWP restoration sites as fire breaks, allowing quicker and safer access to the riverbed to fight fires. Not only does this kind of restoration benefit habitat for all wildlife, but they also have clear benefits for human safety.

From first-hand knowledge, GWP is one of the top run Nonprofits in Graham and Greenlee counties. Simple say, if you award this grant, you can be confident that the dollar will be used in an efficiency manner.

Please do not hesitate to contact me with any additional questions or concerns.

Sincerely,

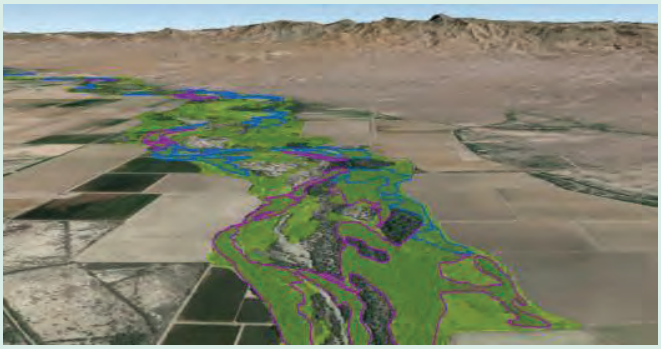
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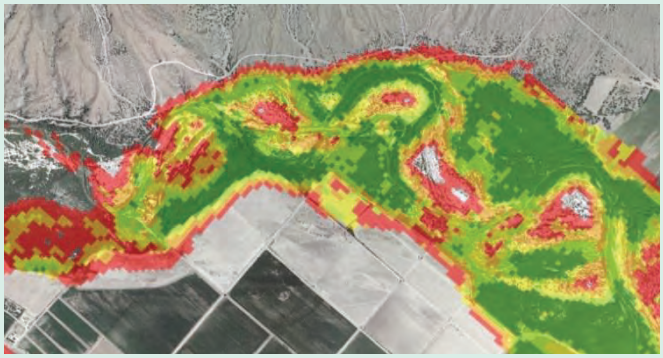
Chairman, Central Jackson Height Fire District

TECHNICAL REPORT ◦ JUNE 2014

Riparian Restoration Framework for the Upper Gila River, Arizona









PREPARED FOR

Gila Watershed Partnership of Arizona
711 South 14th Avenue
Safford, AZ 85546

FUNDED BY

Walton Family Foundation
Freshwater Initiative
P.O. Box 2030
Bentonville, AR 72712

PREPARED BY

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James R Hatten – *Columbia River Research Laboratory, U.S. Geological Survey*
Kevin R Hultine – *Desert Botanical Garden*
Matthew P Johnson – *Colorado Plateau Research Station, Northern Arizona University*
Devyn A Orr – *Marine Science Institute, U.C. Santa Barbara*

Riparian Restoration Framework for the Upper Gila River, Arizona

Bruce K. Orr[1], Glen T. Leverich[1], Zooey E. Diggory[1], Tom L. Dudley[2], James R. Hatten[3], Kevin R. Hultine[4], Matthew P. Johnson[5], and Devyn A. Orr[2]

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June 2014

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Cover graphics:

Upper left: Photograph of tamarisk stands along the upper Gila River near Safford, Arizona (photo taken on August 22, 2012 by T. Dudley)

Upper right: Restoration suitability mapping produced by Stillwater Sciences from ecohydrological analysis: oblique view using Google Earth is of the river looking north toward Ft. Thomas, Arizona

Bottom left: Breeding-habitat suitability modeled by J. Hatten along the upper Gila River near Ft. Thomas, Arizona for southwestern willow flycatcher

Bottom right: Photograph of a mixed stand of cottonwood (*Populus fremontii*) and Goodding's willow (*Salix gooddingii*) trees located near Ft. Thomas, Arizona (photo taken May 3, 2013 by B. Orr)

Acknowledgements:

Our sincere thanks go to Ms. Jan Holder of the Gila Watershed Partnership of Arizona for coordinating development of the Riparian Restoration Framework for the Gila River Restoration Planning Area, and to Mr. Tim Carlson and Ms. Margaret Bowman for facilitating project funding through the Walton Family Foundation, Freshwater Initiative Program. We acknowledge valuable assistance from the Cross-Watershed Network, Southwest Decision Resources, and Tamarisk Coalition, as well as representatives from Bureau of Land Management, Bureau of Reclamation, Freeport McMoRan Copper & Gold, Inc., Graham County, and Salt River Project. And, Mr. Bill Brandau of the Graham County Cooperative Extension of University of Arizona provided invaluable watershed information and assistance with river access.

Project team:

The Restoration Science Team included: Dr. Bruce Orr and Glen Leverich of Stillwater Sciences, Dr. Tom Dudley of the Marine Science Institute at U.C. Santa Barbara; Jim Hatten of the Columbia River Research Laboratory, U.S. Geological Survey; Dr. Kevin Hultine of the Desert Botanical Garden, and Matthew Johnson of the Colorado Plateau Research Station at Northern Arizona University.

Report compilation was led by Stillwater Sciences. The project team at Stillwater Sciences included Dr. Bruce Orr as the principal investigator, Glen Leverich as lead hydrologist/geomorphologist and project manager, Zooey Diggory as lead riparian botanist, Rafael Real de Asua as lead GIS analyst, and Karley Rodriguez as support GIS analyst and cartographer.

Field surveys and supplemental analysis were assisted by Devyn Orr and Dan Koepke.

Remote sensing data collection and processing conducted for this study were led by Drs. Christopher Neale and Robert Pack at Utah State University's Remote Sensing/Geographical Information Systems Laboratory (http://www.gis.usu.edu/).

Suggested citation:

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Appendix F. SWFL Breeding Habitat Prediction Modeling – *James R. Hatten and Matthew P. Johnson*
Appendix G. Restoration Site Monitoring: Vegetation, Soils, and Groundwater – *Tom L. Dudley, Kevin R. Hultine, and Devyn A. Orr*

1 INTRODUCTION

This technical report summarizes the methods and results of a comprehensive riparian restoration planning effort for the Gila Valley Restoration Planning Area, an approximately 53-mile portion of the upper Gila River in Arizona (Figure 1-1). This planning effort has developed a Restoration Framework intended to deliver science-based guidance on suitable riparian restoration actions within the ecologically sensitive river corridor. The framework development was conducted by a restoration science team, led by Stillwater Sciences with contributions from researchers at the Desert Botanical Garden (DBG), Northern Arizona University (NAU), University of California at Santa Barbara (UCSB), and U.S. Geological Survey (USGS). All work was coordinated by the Gila Watershed Partnership of Arizona (GWP), whose broader Upper Gila River Project Area is depicted in Figure 1-1, with funding from the Walton Family Foundation's Freshwater Initiative Program.

1.1 Planning Area Location

The overarching project area of the Gila Watershed Partnership of Arizona entails the 120 miles (193 km) of the upper Gila River in Arizona upstream of the San Carlos Reservoir, and the lower 40 miles (64 km) of its major tributary, the San Francisco River (both reaches within Arizona only). The current restoration planning effort focuses primarily on the Gila Valley area of the upper Gila River in Graham County, Arizona: the "Gila Valley Restoration Planning Area," or simply "Planning Area." This more focused extent was selected in order to provide effective guidance for high priority restoration implementation projects in 2014–2015. The Planning Area spans approximately 53 miles (85 km) along the riparian corridor from the Gila Box east of Solomon (at the Bonita Creek confluence) downstream to the eastern boundary of the San Carlos Apache Reservation near Geronimo (see Figure 1-1).

1.2 Need for Riparian Restoration

Like many ecologically important riverine systems in the southwest, the upper Gila River and its major tributary, the San Francisco River, are sensitive to natural and anthropogenic stressors, including invasion by non-native plants, flooding, wildfire, urban encroachment, and various land- and water-use activities. The riparian corridor is thus under constant pressure as it responds to these ongoing perturbations. In the Gila Valley, invasion by salt cedar (*Tamarix ramosissima* and other *Tamarix* species or hybrids, hereafter "tamarisk") is particularly intense as it has become the dominant woody plant species in the riparian corridor since it was first introduced in the early 20th century to control river erosion (see photo at right). Tamarisk has now densely covered the riparian corridor out-competing native tree species, including Fremont cottonwood (*Populus fremontii*) and Goodding's willow (*Salix gooddingii*).



Tamarisk along the upper Gila River
(Photo by Stillwater Sciences)



Figure 1-1. Map of the upper Gila River watershed in eastern Arizona and the Gila Valley Restoration Planning Area.

Despite the dominance by tamarisk and impacts from other natural and anthropogenic factors, the riparian corridor continues to provide some active breeding habitat for the endangered southwestern willow flycatcher (*Empidonax traillii extimus*; SWFL) (see photo at right), along with habitats of other sensitive fish and wildlife species. In 2011, the U.S. Fish and Wildlife Service (USFWS) designated the upper Gila River as Critical Habitat for SWFL, as it is known to be occupied by the species during the breeding season and provides the primary constituent elements essential to the species' long-term conservation. It is therefore a major goal of the federal designation and the SWFL Recovery Plan (USFWS 2002) that habitat conservation on the upper Gila and San Francisco rivers will lead to species recovery throughout the region.



Southwestern willow flycatcher nest and female in dense tamarisk (Photo by USGS)

1.2.1 Tamarisk leaf beetle arrival



Tamarisk leaf beetles (*Diorhabda carinulata*) feeding on tamarisk near the Virgin River, Nevada (Photo by Tom Dudley, UCSB)

A key concern in the watershed and, accordingly, the impetus for the present riparian restoration planning effort, is the anticipated arrival of the tamarisk leaf beetle (*Diorhabda elongata* species group) which has the potential to disturb existing riparian habitat conditions, particularly for SWFL.

Four of five distinct species of the *D. elongata* complex were introduced into portions of Colorado, Nevada, Texas, Utah, and Wyoming during 2001–2009 by the U.S. Department of Agriculture (USDA) for biological control of tamarisk (Tracy and Robbins 2009, Tamarisk Coalition 2009). As intended, the beetle expanded its range and has led to widespread defoliation of tamarisk-dominated habitats in many other southwestern watersheds (see photo at left). Individual plant mortality typically occurs after 3+ years of repeat defoliation (Bean et al. 2013). Somewhat surprising is that the "northern leaf beetle" (*D. carinulata*) has evolved its physiological ability to establish farther south than the originally introduced insects would have tolerated (south of 38°N latitude), so it is likely that that species is, or will soon be, capable of establishment in the Gila Valley (near 33°N latitude). Currently, *D. carinulata* is present to the northeast (upper Rio Grande River), north (San Juan and Little Colorado Rivers), and west (Virgin River/Lake Mead), and beetle establishment in 2012 below Hoover Dam marks their arrival into the lower Colorado River basin. The "subtropical leaf beetle" species (*D. sublineata*) released in Texas on the Rio Grande River is now moving westward through New Mexico (J. Tracy, pers. comm., 2014). Thus, one or more species of the tamarisk leaf beetle is likely to arrive in the Gila Valley in the foreseeable future (potentially within 2–3 years) and have impacts to tamarisk similar to those seen elsewhere.

While there are numerous benefits to tamarisk suppression (e.g., water conservation, riparian habitat recovery, fire risk reduction), and by biocontrol in particular (e.g., reduction in biomass allowing restoration practitioners to more easily treat affected tamarisk and simultaneously replant native species in a more cost-effective manner), short-term negative consequences are

also possible. Tamarisk defoliation from the leaf beetle will be problematic in the Gila Valley as virtually all SWFL nest sites are currently located in tamarisk along the river. If defoliation by the beetle occurs simultaneously with nesting, the loss of cover could result in juvenile mortality, as has recently been observed along the lower Virgin River (see photo at right). Other special status wildlife species, such as the proposed threatened western population of yellow-billed cuckoo (*Coccyzus americanus*), are also associated with many riparian systems in which tamarisk is a major component. It is thus important to plan now for the arrival of the leaf beetle in the Gila Valley, both to take advantage of the biocontrol benefits and to mitigate for its indirect impacts to SWFL and other potentially sensitive wildlife. Alternatively, inaction has the very real probability of leading to declines in the local SWFL population.



An exposed SWFL nest and female in defoliated tamarisk along the Virgin River (Photo by Utah Division of Wildlife Resources)

1.2.2 Flood disturbance



Repeat views of the river near Calva: from 1932 showing a wide, braided channel bordered by a willow-cottonwood forest *(top)*; and from 2000 following several large flood events showing dense establishment of tamarisk *(bottom)* (Photos from USGS archives)

Flooding through the upper watershed is another concern of land- and water-use and restoration planners due to the dramatic changes that have taken place along the river corridor. The river has experienced several notable floods, most recently in 1983, 1993, and 2005. The flood records reveal a relatively quiescent period during the middle half of the 20th century, followed by a period of larger, more frequent flood events since the late 1960s (see Section 2.1 Flood-Scour Analysis below). This recent hydrological condition reinforces the importance of considering flood dynamics in any restoration planning effort on the Gila and San Francisco rivers, especially in light of its influence on tamarisk density in the riparian corridor, and vice-versa.

It has been well documented that tamarisk acts as a positive feedback on river morphology and flood dynamics through resisting erosion, which is why the species was originally introduced in the early 1900s (e.g., Auerbach et al. 2013) (see photos above left). Dense stands of tamarisk provide greater stability to the river and floodplain substrates than do native vegetation (e.g., willows and cottonwoods) and, as an unintended consequence, progressively narrow the active channel thereby increasing the frequency of floodplain inundation (Graf 1978). Tamarisk is further favored over natives in this setting due to its longer seed-release timing that extends into late summer when monsoon-induced floods can re-expose fresh surfaces upon which tamarisk may more readily colonize (Shafroth et al. 1998).

1.2.3 Wildfire exacerbation



Wildfire in tamarisk-dense stands along the upper Gila River near Bylas in June 2013 (Photo by Jon Johnson, courtesy of Eastern Arizona Courier)

Wildfire is an increasingly common disturbance in western rivers owing, in part, to infestation by tamarisk. The Gila Valley experienced two notable fire events in 2013: the "Clay Fire" near Ft. Thomas and another near Bylas (see photo at right). Riparian areas are considered to be barriers to wildfire spread, but the replacement of fire-resistant native vegetation with higher moisture content (e.g., willows and cottonwoods) by flammable tamarisk has reversed this relationship, with tamarisk-dominated areas burning approximately 10 times more frequently than native-dominated counterparts (Busch 1995). Defoliation by the leaf beetle would appear to exacerbate this situation, but studies in Nevada show that tamarisk is highly flammable regardless of whether it is "browned-out" by defoliation or in a "healthy green" state (Dudley and Brooks 2010). Escaped fire from land-clearing on adjacent agricultural areas has become a serious concern for land managers in the Gila Valley, particularly where weedy forbs next to fields carry fire into the arid, tamarisk-dominated riparian edges, and then into the mixed native/tamarisk vegetation along the river. This establishes a feedback loop in which fire promotes tamarisk, which recovers readily from burning to become even more abundant, eventually displacing native elements in the stand. Biocontrol eventually reduces tamarisk volume, and after 3+ years of repeat defoliation can lead to mortality (Bean et al. 2013), thereby gradually reducing fire risk over the long term although active restoration efforts are needed to speed up the process of reducing riparian fire risk in critical areas.

1.3 Purpose of the Restoration Framework

The overarching goals of the Restoration Framework for the upper Gila River in Arizona are to:

1. Prepare for anticipated impacts to the existing riparian system following beetle colonization;
2. Promote recovery of native riparian habitat and subsequent local increases in SWFL population size, and, ultimately, to re-establish their metapopulation structure across the greater Colorado River Basin;
3. Facilitate implementation of a comprehensive approach toward riparian restoration by a collaborative group of stakeholders, resource managers, and scientists; and
4. Inform recommendations to be incorporated into the Restoration Implementation Plan to be authored by the Gila Watershed Partnership.

Satisfying these goals will enable sustained survival of the endangered SWFL (and other sensitive riparian and aquatic wildlife) and subsequently lead to its de-listing based on quantitative evidence of species recovery. Meeting these goals involves development of a framework that maximizes the likelihood of creating sustainable native riparian vegetation in a cost-effective manner, while simultaneously building the capacity of local communities to support and participate in achieving restoration success.

The objectives of the Restoration Framework program have been to:

1. Conduct a restoration action feasibility assessment that identifies appropriate locations for strategic tamarisk treatment and long-term, sustainable revegetation with native riparian

species, based on ecological and hydrological factors—an Ecohydrological Assessment. Integrate vegetation and wildlife status into the framework to promote natural plant recruitment processes and enhance the capacity of SWFL and other wildlife species of interest to respond based on current distributions and habitat associations. Avoid tamarisk-treatment impacts to SWFL and other wildlife. Help organize plant propagation capacity for riparian restoration applications using genetically appropriate native plants.

2. Begin to implement an ecosystem assessment protocol to evaluate progress toward restoration program objectives and to apply adaptive management to enhance the likelihood of success in achieving those objectives. Monitoring would provide baseline information to evaluate and plan for anticipated future establishment of the tamarisk leaf beetle.
3. Lay the foundation for implementing, in a subsequent project phase, rapid active restoration of appropriate native vegetation to create refugia for avian species potentially displaced by tamarisk defoliation.



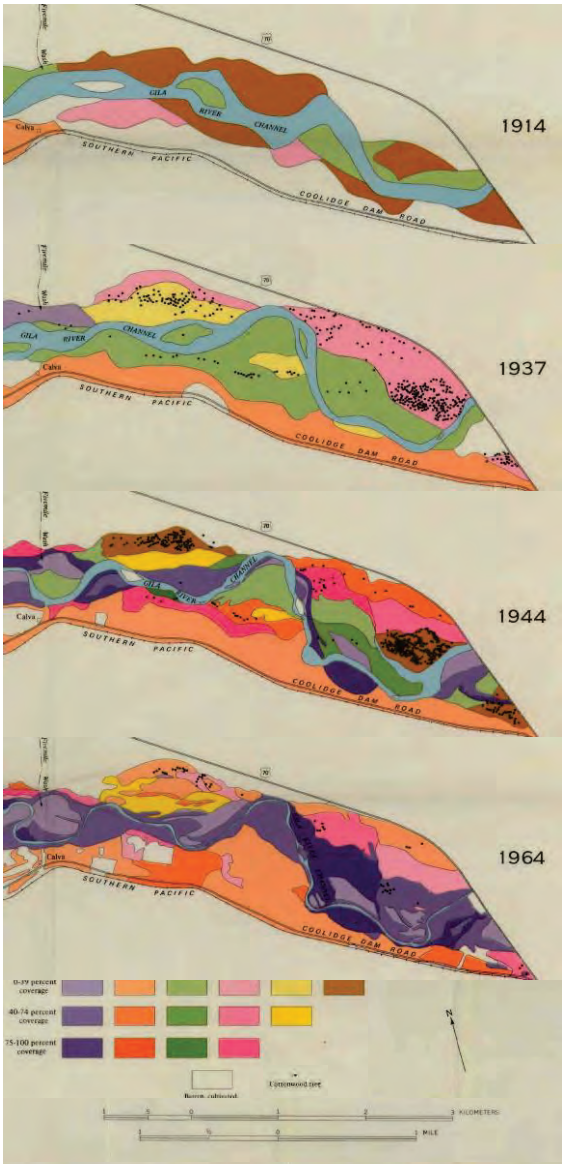
1.4 Physical Setting

The Gila River is the last major tributary to the Colorado River and courses 650 mi (1,040 km) from its headwaters in western New Mexico nearly due west across the southern part of Arizona. As part of the Mexican Highland section of the Basin and Range physiographic province, the watershed drains a vast area of rugged mountain ranges and broad desert lowlands totaling about 58,000 mi^2 (150,000 km^2). The "upper watershed" is most often considered as that part of the drainage area upstream of Coolidge Dam (Cohen et al. 1997) (see Figure 1-1). The Gila Valley, within which the Planning Area is situated, is a broad, alluvial basin trending southeast-to-northwest between the Gila Box canyon and Coolidge Dam. High-relief mountain ranges border the valley: the Gila Mountains to the east and the Pinaleno-Santa Teresa mountains to the west. The valley is topographically extended outside the Planning Area up through the San Simon River Valley from its upper end near the town of Solomon. Both valleys are composed of a ~3,000-ft (~900-m) thick sequence of young alluvium overlying deep basin-fill (lacustrine and conglomerate) deposits, which in turn overlie much older volcaniclastic rocks (Houser et al. 1985).

The region experiences a warm, high desert climate with air temperatures varying seasonally. The average monthly maximum temperature occurs in June (99 °F [33 °C]) and minimum temperature occurs in December (29 °F [-2 °C]), as recorded at the Safford Agricultural Center during 1981–2010 (NOAA NCDC 2013). Evaporation rates follow the same seasonal trend with June having the highest monthly average rate of about 15 in. and December with the lowest of about 2.5 in. (6 cm), as monitored in Safford during 1948–2005 (WRCC 2013). Precipitation patterns are bi-seasonal, with cold, winter frontal storms arriving between December through March and tropical monsoons arriving in July through October. The wettest month is typically August (1.9 in. [4.8 cm]) while the driest month is May (0.25 in. [0.6 cm]), based on rainfall measurements in Safford during 1981–2010 (NOAA NCDC 2013). River hydrology closely follows the rainfall patterns,

exhibiting perennial flow punctuated by flashy runoff events during winter storms and summer monsoons (see Section 2.1.1.1 Hydrology below).

Vegetation coverage through the upper watershed includes montane conifer forests on higher-altitude mountain ranges, desert scrub and semi-desert grasslands on the river terraces and uplands, and riparian vegetation along the river corridor. Historically, the river bottom was lined with willow, cottonwood, and mesquite based on surveys made in the mid- to late-1800s (Burkam 1972, Turner 1974, Webb et al. 2007). It was noted that most of this native riparian vegetation was severely scoured during the 1905–1909 flood period and subsequently replaced by tamarisk soon after its introduction in the early 1920s (Burkham 1972) (see graphic at right). Tamarisk was planted along the river channel to control riverbank erosion, thereby protecting adjacent cultivated fields. Tamarisk continues to be the dominate tree species in the riparian corridor, while some isolated stands of native species, including Fremont cottonwood (*Populus fremontii*), Goodding's willow (*Salix gooddingii*), narrowleaf (coyote) willow (*Salix exigua*), mulefat (*Baccharis salicifolia*), and mesquite (*Prosopis* spp.) persist (see Section 2.2 Riparian Vegetation Characterization below).



Repeat map views of the river corridor near Calva showing spread of tamarisk ("salt cedar" in purple color) and reduction of native trees (green, pink, and brown colors) between 1914 and 1964 (Maps adapted from Turner 1974)

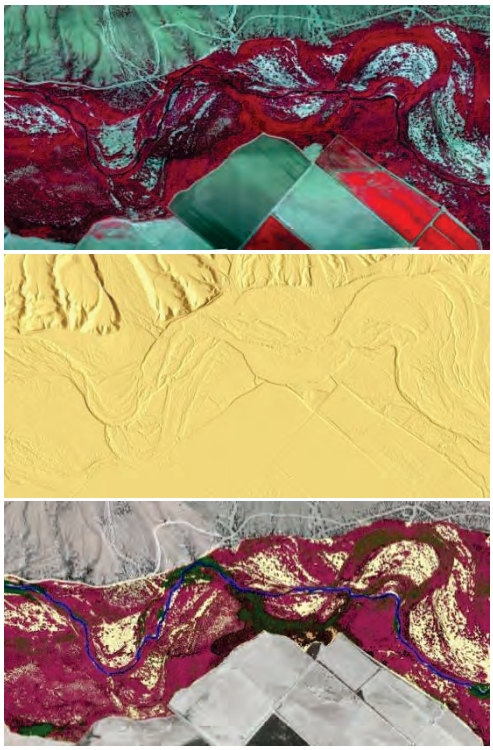
The majority of the valley floor is privately owned and cotton farming has been the dominant land-use activity since the mid-20th century (see Figure 2-5 below). While much of the area is sparsely developed, the largest urban center (and County Seat) is in Safford, which supports a growing population of around 10,000 according to the 2010 U.S. Census. Much of the upland areas are held by the Bureau of Land Management, including the Riparian National Conservation Area in the Gila Box. In recent years, several parcels overlapping the river corridor have been purchased by Freeport McMoRan Copper & Gold (formerly Phelps Dodge Corporation)—an international mining company headquartered in Phoenix—to serve as mitigation sites. The Salt River Project (SRP) also manages a group of mitigation parcels near Ft. Thomas (see Figure 2-13 below for their locations).

2 ECOHYDROLOGICAL ASSESSMENT

The "ecohydrological assessment," which is the centerpiece of the Restoration Framework, considers reach-scale river hydrology, geomorphology, vegetation conditions, and wildlife needs to identify potentially suitable areas for active restoration. The selection process is further refined with site-scale information on plant productivity, soil conditions and salinity, surface and groundwater availability, and SWFL-habitat suitability. This chapter describes methods and results of the ecohydrological assessment, beginning with discussion on its individual component studies, and concluding with identification of the "potentially suitable vegetation restoration areas."

2.1 Remote-Sensing Data Collection

Remote-sensing data collection and processing conducted in support of restoration planning on the upper Gila River was performed by Utah State University's Remote Sensing/Geographical Information Systems Laboratory (USU RS/GIS) under the direction of Drs. Christopher Neale and Robert Pack. The entire extent of the Upper Gila River Project Area (yellow-colored extent shown in Figure 1-1) was flown in October 2012 to obtain high-resolution, orthorectified aerial imagery and topographic data. The products specifically included color and multispectral orthoimagery, and LiDAR surfaces (first-return and bare-earth) (see product examples at right). A vegetation-classification layer depicting the dominant native and non-native, invasive plant species, as well as land-cover/-use types, was generated based on the multispectral imagery.



Example remote-sensing products from USU RS/GIS: multispectral orthoimagery *(top)*, LiDAR bare-earth topography *(middle)*, and vegetation classification *(bottom)*

The remote-sensing data products were subsequently used to analyze hydro-geomorphic and vegetation conditions in the Planning Area (see below).

A copy of the technical documentation authored by USU RS/GIS is presented in Appendix A.

2.2 Flood-Scour Analysis

For the flood-scour analysis of the Gila Valley Planning Area, we first performed a brief evaluation of the hydrogeomophic character of the river corridor to understand the historic flood hydrology and contemporary channel morphology. From there we performed a detailed analysis using aerial photograph interpretation to delineate flood-induced channel disturbance. The hydrogeomorphically active channel, or "active channel area," is considered here as that part of the mainstem channel bed that carried a significant part of the flood and sediment discharge during the recent flood event.

2.2.1 Hydrogeomorphic characterization

Characterization of the upper Gila River's hydrology and geomorphology, along with riparian ecology, relied on review of available literature and remote sensing products, in addition to field reconnaissance along much of the river. A key technical study utilized here was the U.S. Bureau of Reclamation's (BOR's) *Fluvial Geomorphology Study* conducted in the early 2000s (e.g., BOR 2004). Other useful information sources included the U.S. Geological Survey's (USGS's) *Gila River Phreatophyte Project* conducted in the early 1970s (e.g., Burkham 1970, 1972), along with historic flow records held by the USGS and geologic maps published by the USGS and the Arizona Geological Survey.

2.2.1.1 Hydrology

The arid climate in eastern Arizona is interrupted by periods of intense winter and late-summer storms that often flood the mostly quiescent rivers and ephemeral tributaries. Streamflow data from five long-term gaging stations along the mainstem upper Gila River and the lower San Francisco River were obtained from the USGS's National Water Information System website: http://waterdata.usgs.gov/nwis. These spatially distributed stations provide a reliable characterization of the river's average daily flows, as well as its episodic hydrologic regime responsible for driving the flood-scour processes and geomorphic expression that are a primary subject of our ecohydrological assessment. Basic information for the five gages is summarized in Table 2-1. The two lowermost gages listed here are located at approximately the upstream and downstream ends of the Gila Valley and therefore best represent hydrologic conditions within the Planning Area.

Table 2-1. USGS discharge gaging stations on the upper Gila River used in the Ecohydrological Assessment.

USGS gaging station [a] [upstream to downstream]	Total period of record in water years [b, c]	Drainage area [d]		Maximum peak discharge (cfs)	Mean daily discharge (cfs)
		(mi^2)	(km^2)		
09432000 Gila River below Blue Creek, near Virden, NM	1927–present	3,203	8,296	52,700 [Dec 19,1978]	210
09442000 Gila River near Clifton, AZ	1911–1917, 1928–1946, 1948–present	4,010	10,386	57,000 [Dec 19, 1978]	194
09444500 San Francisco River at Clifton, AZ	1891, 1905–1907, 1911–present	2,763	7,156	90,900 [Oct 2, 1983]	215
099448500 Gila River at head of Safford Valley, near Solomon, AZ	1914–present	7,896	20,451	132,000 [Oct 2, 1983]	453
09466500 Gila River at Calva, AZ	1916, 1930–present	11,470	29,707	150,000 [Oct 3, 1983]	363

Table footnotes continued on next page.

[a] Weblinks to source data:
[1] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09432000
[2] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09442000
[3] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09444500
[4] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09448500
[5] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09466500

[b] Water year (WY) is the 12-month period from October 1 through September 30.

[c] Period of records utilized in the flood-frequency and daily-duration analyses slightly differ from the total period of record due to data gaps and/or unreliable historical data:
[1] Flood-frequency analysis: Virden=WY 1927–2013; Clifton=WY 1911–1917, 1928–1946, 1948–2013; SF at Clifton=WY 1911–2013; Solomon=1914–2013; and Calva=1930–2013.
[2] Daily-duration analysis: Virden=July 1, 1927–Sept 30, 2013; Clifton=Nov 1, 1910–Sept 30, 2013; SF at Clifton=Oct 23, 1910–Sept 30, 2013-09-30; Solomon=Oct 1, 1920–Sept 30, 2013; and Calva=Oct 1, 1929–Sept 30, 2013.

[d] Drainage areas from USGS station information.

The river's bi-seasonal hydrologic pattern is apparent in examination of the river's mean monthly discharge, as depicted graphically in Figure 2-1. March typically experiences the highest mean monthly flows over a given water year, and August experiences the highest flows in summer-fall. Also visible here is the near doubling of discharge below the confluence of the San Francisco River, indicating that this tributary has a significant effect on downstream hydrology in the Gila Box and Gila Valley. Daily flows in a given water year average about 400 cfs in the Gila Valley (from gages near Solomon and at Calva), but decrease along its length, which is likely due to human water-uses (e.g., diversions, wells) and riparian vegetation water-uses in the valley (see Table 2-1). Overall, mean daily flows in the valley are typically less than about 1,000 cfs for 90 percent of the time (as recorded at both gages), and less than 100 cfs and 10 cfs for 10 percent of the time near the upstream and downstream ends of the valley (as recorded near Solomon and at Calva), respectively (Figure 2-2).

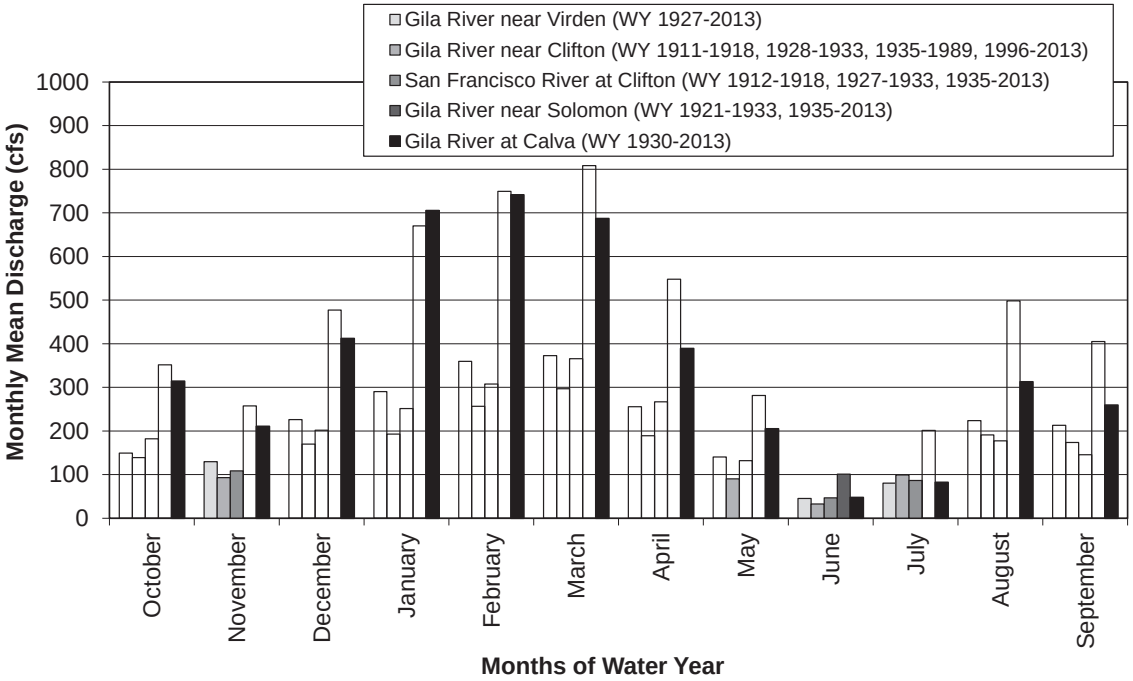
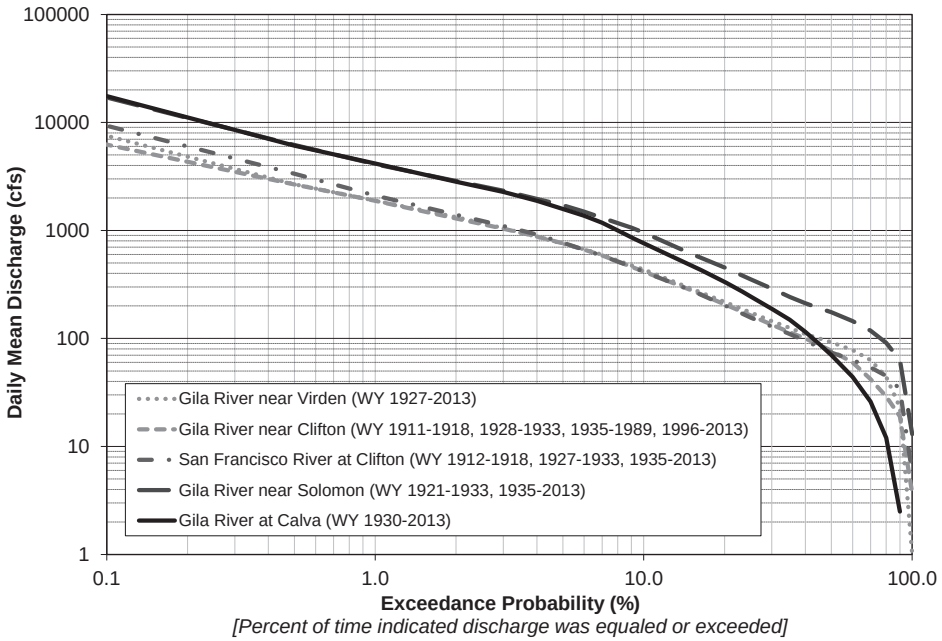


Figure 2-1. Monthly mean discharge at five long-term streamflow gages on the mainstem upper Gila River and lower San Francisco River used in this study.

a)



[Percent of time indicated discharge was equaled or exceeded]

b)

Parameter			Stream Gage Location				
			Gila River near Virden	Gila River near Clifton	SF River at Clifton	Gila River near Solomon	Gila River at Calva
Water Years			1927–2013	1911–1917, 1928–1946, 1948–2013	1911–2013	1914–2013	1930–2013
Number of Samples			30,986	30,955	33,016	33,391	30,680
Flow (cfs)	Mean		209.91	194.41	215.45	452.54	362.75
	Std. Dev.		584.7	526.0	767.8	1,422.5	1,601.0
	Minimum		1.0	3.7	5.6	13.0	0
	Exceedance Probability (%)	100%	1	4	6	13	0
		90%	23	19	34	63	3
		80%	44	29	45	91	12
		70%	63	42	54	118	26
		60%	78	60	63	145	44
		50%	92	77	74	175	70
		40%	110	100	95	212	115
		30%	145	134	129	289	188
		20%	218	207	203	454	333
		10%	435	416	415	954	761
		5%	756	759	771	1,710	1,580
		1%	1,890	1,880	2,108	4,100	4,160
		0.1%	7,540	6,243	9,329	17,061	17,532
		0.01%	33,100	27,100	52,200	90,000	90,000
	Maximum		33,100	27,100	52,200	90,000	90,000

Figure 2-2. Mean daily flow duration curves and statistics for the five long-term streamflow gages on the mainstem upper Gila River and lower San Francisco River used in this study.

Annual peak flows in the Gila Valley can be characterized as "flashy": they are massive in comparison with the mean daily flows (e.g., 453 cfs versus 132,000 cfs [see Table 2-1]), but usually span only a few hours to days. The 10 largest floods recorded to date in the valley occurred in water years (WY) 1915, 1916, 1917, 1973, 1979, 1984, 1985, 1993, 1995, and 2005, based on gage data from the Solomon and Calva stations. A graphical plot of peak discharge measured at the five gages is presented below as Figure 2-3, which was used to help select the three most recent flood-scour events for the ecohydrological assessment. These records highlight the flood period initially observed in the early 20th century, a relatively quiescent 50-year period up through the mid-1960s, and a 40-year period of larger, more frequent flood events since the late 1960s.

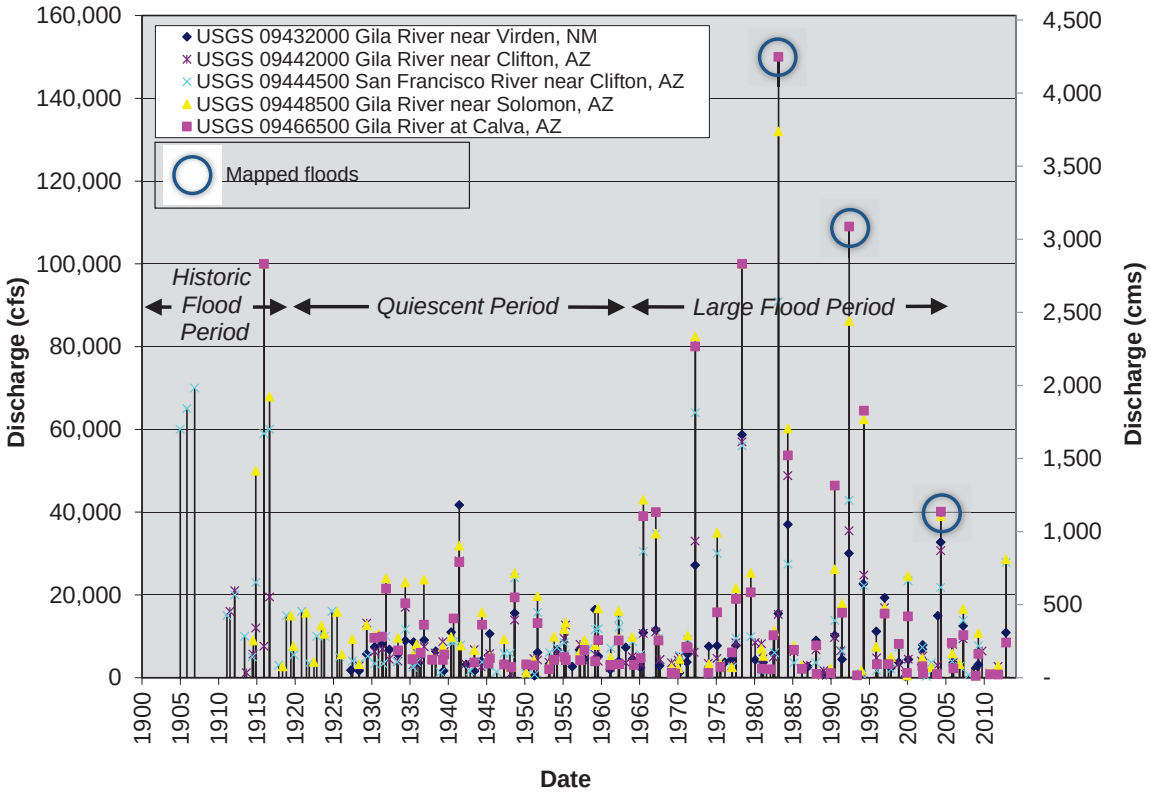


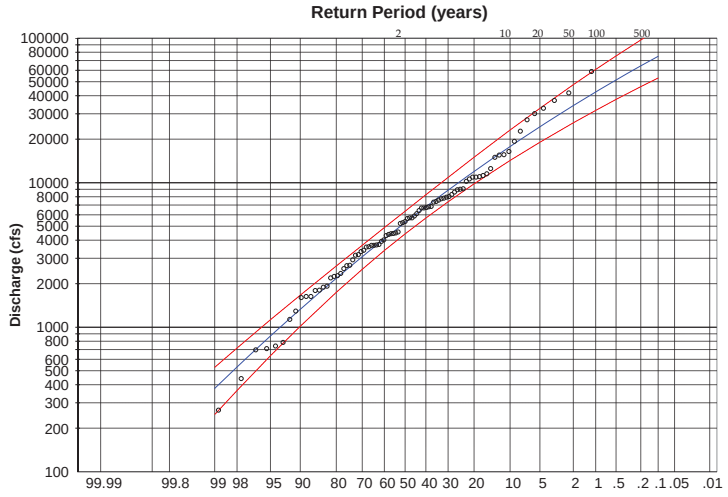
Figure 2-3. Historical flood peaks through water year 2013 at five long-term streamflow gages on the mainstem upper Gila River and lower San Francisco River used in the Ecohydrological Assessment. Flood-scour mapping focused on three of the most recent large flood peaks, as indicated with blue circles.

While the data shown in Figure 2-3 suggest that the recent large-flood period has been waning in absolute magnitude since the 1990s, it should be cautioned that the potential for channel-scouring floods to occur in the near-future remains high in any given water year. To further characterize the river's flood hydrology for this assessment, we calculated the flood recurrence intervals at the five gages using available data through water year (WY) 2013 (Figure 2-4). The flood-frequency analysis (Log-Pearson III) was performed using the Natural Resources Conservation Service's (NRCS's) Frequency Curve Determination spreadsheet tool (NRCS 2012). These data individually provide a statistical basis of flood-level prediction for a given recurrence interval

(RI) at each gaging station. The data can in turn be used to determine the RI-value per flood event, such as those considered in our study. Our computed values are similar to those previously computed for the BOR's fluvial geomorphology study (BOR 2001a), which provides an added level of confidence when using these updated values for restoration planning purposes. Differences between the BOR and our updated RI values are chiefly due to differences in the analyzed time periods. The Calva gage data best represents the largest flood events experienced near the downstream end of the Gila Valley:

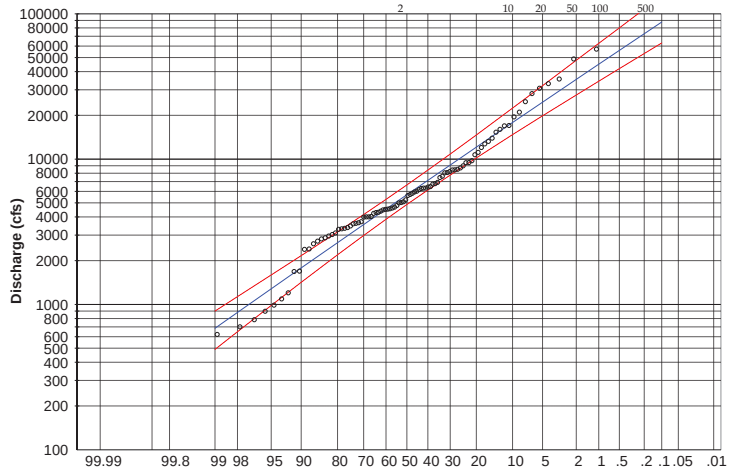
- October 3, 1983: 150,000 cfs RI≈101 yrs
- January 20, 1993: 109,000 cfs RI≈57 yrs
- December 19, 1978: 100,000 cfs RI≈51 yrs
- October 20, 1972: 80,000 cfs RI≈35 yrs
- January 6, 1995: 64,500 cfs RI≈25 yrs
- December 29, 1984: 53,700 cfs RI≈19 yrs
- March 3, 1991: 46,400 cfs RI≈15 yrs
- February 14, 2005: 40,100 cfs RI≈12 yrs

a)



USGS 09432000 GILA RIVER BELOW BLUE CREEK, NEAR VIRDEN, NM	
[WY 1927–2013]	
Return Period (years)	Discharge (cfs)
1.2	1,800
1.5	3,400
2	5,300
5	12,000
10	17,800
50	34,100
100	42,400
500	64,300
1000	74,900

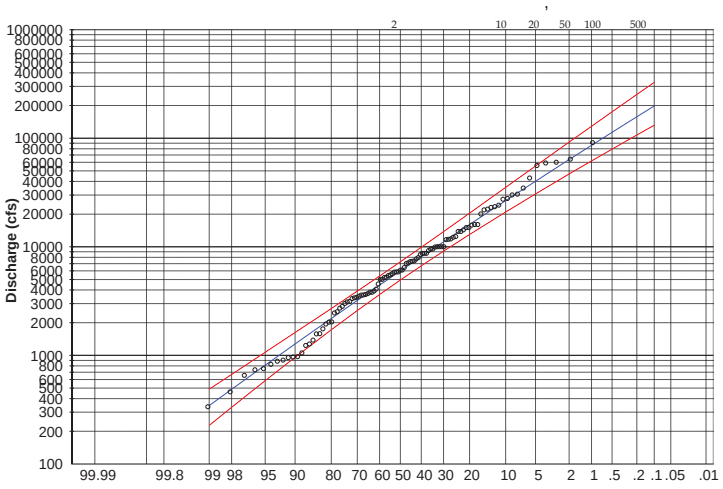
b)



USGS 09442000 GILA RIVER NEAR CLIFTON, AZ	
[WY 1911–1917, 1928–1946, 1948–2013]	
Return Period (years)	Discharge (cfs)
1.2	2,300
1.5	3,800
2	5,700
5	12,100
10	17,900
50	35,400
100	45,000
500	72,900
1000	87,700

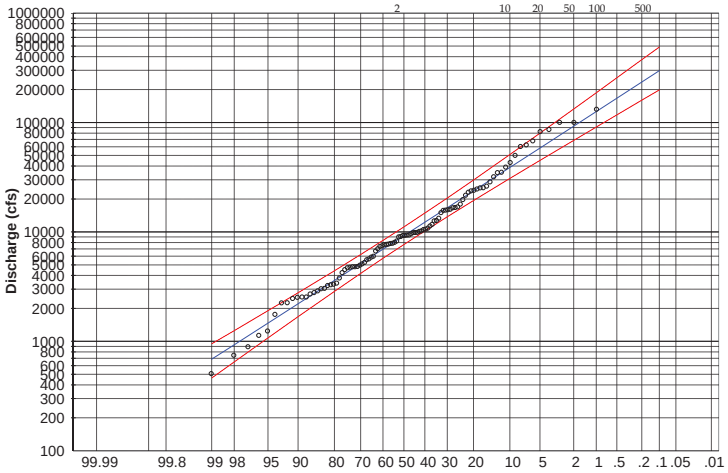
(Figure 2-4 is continued on next page.)

c)



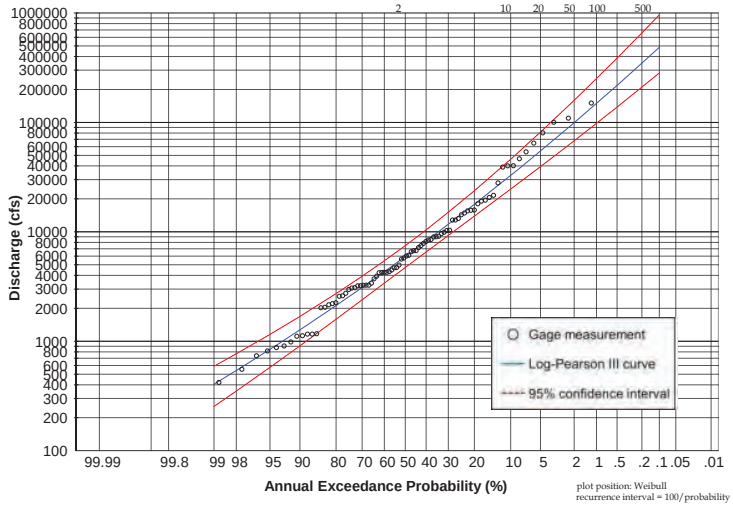
USGS 09444500 SAN FRANCISCO RIVER AT CLIFTON, AZ	
[WY 1911–2013]	
Return Period (years)	Discharge (cfs)
1.2	1,800
1.5	3,600
2	6,000
5	16,100
10	26,600
50	63,600
100	86,000
500	157,400
1000	198,000

d)



USGS 09448500 GILA RIVER AT HEAD OF SAFFORD VALLEY, NR SOLOMON, AZ	
[WY 1914–2013]	
Return Period (years)	Discharge (cfs)
1.2	3,100
1.5	5,700
2	9,200
5	23,700
10	38,900
50	92,600
100	125,800
500	234,300
1000	297,600

e)



USGS 09466500 GILA RIVER AT CALVA, AZ	
[WY 1930–2013]	
Return Period (years)	Discharge (cfs)
1.2	1,800
1.5	3,500
2	5,900
5	17,900
10	32,700
50	99,300
100	149,100
500	347,800
1000	485,800

Figure 2-4. Flood frequency [Log-Pearson III] for the five long-term streamflow gages used in the Ecohydrological Assessment, including (from upstream to downstream): Gila River near Virden (a), Gila River near Clifton (b), San Francisco River near Clifton (c), Gila River near Solomon (d), and Gila River at Calva (e).

In summary, the upper Gila River naturally experiences a wide variation of flows, punctuated episodically by short-duration but intensive high-flow events. These flashy discharge dynamics, which are common to large, dryland riverine systems, periodically result in dramatic geomorphic change (Graf 1988). And while climate change models predict less total precipitation for the southwest region, increased frequency of intense storms and more precipitation falling as rain versus snow are expected to make southwest rivers more susceptible to flooding (USGCRP 2009). Thus, any restoration planning effort on the upper Gila River demands consideration of flood dynamics to best ensure long-term success.

2.2.1.2 Sub-reach delineation

The hydrogeomorphic character of the river varies widely along its entire run, but is essentially a broad, low-gradient (0.18%), braided system in the Gila Valley where it also retains much of its historic floodplain within which to laterally adjust in response to large runoff events. There are, however, reach-level differences in channel morphology that strongly influence the types of management and restoration actions that may be suitably applied. For example, the active channel is broader in the upper end of the valley than it is downstream of Safford, where the channel becomes progressively narrower (and more densely vegetated).

To assist our ecohydrological assessment, we sub-divided the river channel into discrete, hydrogeomorphically similar reaches based on dominant physical characteristics. Our reach locations are shown in Figure 2-5, and their salient attributes are summarized in Table 2-2. The designated reaches covered the entire river length in the valley beginning at the San Carlos Reservoir and continuing upstream to the Gila Box. We elected to include the river portions downstream of the current Planning Area to allow consistency in reach delineation and numbering starting from a logical downstream location: Coolidge Dam. This is the first continuous reach delineation in the Gila Valley; the aforementioned USGS *Gila River Phreatophyte Project* (e.g., Burkham 1970, 1972) and BOR (2004) *Fluvial Geomorphology Study* each developed their own reach designations, but these were limited to isolated river segments.



Downstream views in the Planning Area: mouth of Gila Box in reach 3a *(top)*; near Safford in reach 2g *(middle)*; and near Eden in reach 2d *(bottom)* (Photos by Stillwater Sciences)

Within the Planning Area, the river is generally a vegetated, low-gradient, braided river corridor bordered by a broad floodplain supporting crop cultivation and some urban developments. The corridor generally ranges in width from 1,000 to 4,600 ft (300–1,400 m), and typically narrows where it encounters mountain-front cliffs and coalesced alluvial fans (bajadas). Along its course through the valley, the corridor transitions from a canyon-confined, coarse- grained (gravel/cobble-bedded) channel with limited floodplain and some

native riparian forest (cottonwood-willow galleries) at the mouth of the Gila Box (reach 3a), to a wide, drier, braided/ meandering channel with sparse to moderately dense riparian vegetation (mostly tamarisk) bordered by a broad, cultivated and developed floodplain near Safford (reaches 2f–2j), and finally to a moister, fine-grained, braided/ meandering channel system composed of a narrow single-thread channel during lower flows that is encroached upon by dense riparian vegetation (mostly tamarisk), which is in turn bordered by a broad, cultivated floodplain with few developments downstream of Pima (reaches 2c–2e) (see photos insert above). During high-flow events, side-channels also convey flow giving a more pronounced braided appearance to the river corridor. The entire corridor and some portion of its floodplain become inundated during the largest floods.

The natural flow and sediment-transport regime is also strongly influenced by the presence of in-channel irrigation diversions, bridge crossings, and agricultural levees. A total of 6 irrigation canal diversion dams span at least part of the river corridor in the Planning Area (listed from upstream to downstream): Brown, San Jose, Graham, Smithville, Curtis, and Ft. Thomas. Additionally, there are 6 bridge crossings (listed from upstream to downstream): East Sanchez Road, North 8th Avenue, North Reay Lane, Bryce Road, Bryce-Eden Road, and River Road. The BOR's (2004a) *Fluvial Geomorphology Study* mapped numerous occurrences of historic and existing levees and pilot channels, all of which appear to have been constructed in response to flooding.

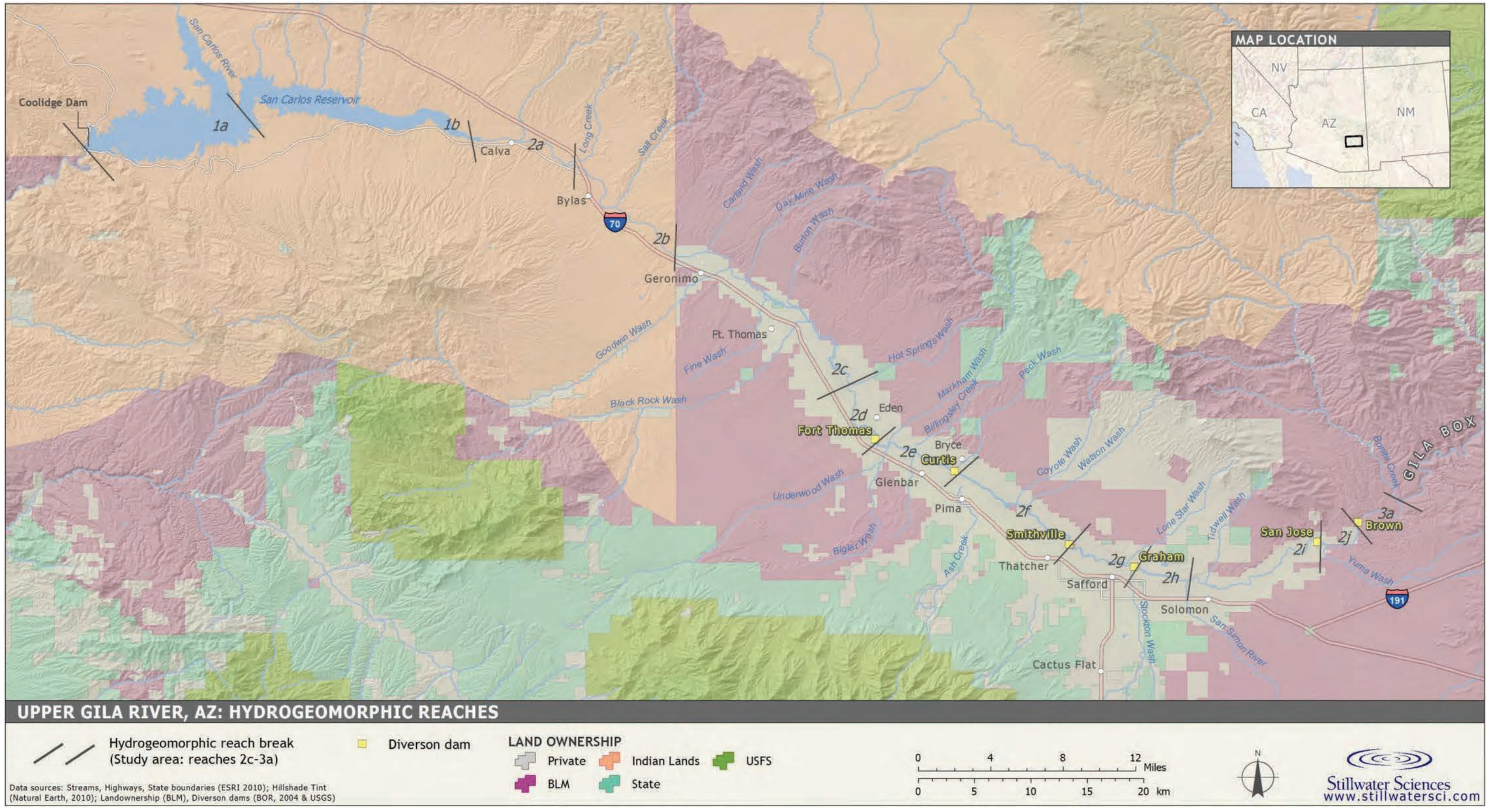


Figure 2-5. Location of hydrogeomorphic reaches delineated along the upper Gila River in the Gila Valley for the Ecohydrological Assessment. See Table 2-2 for descriptions of reach attributes.

Table 2-2. Description of hydrogeomorphic reaches delineated along the upper Gila River in the Gila Valley for the Ecohydrological Assessment. See Figure 2-5 for locations of sub-reaches.

Reach group		Sub-reach number	Sub-reach name	Sub-reach end feature (upstream limit)	Sub-reach length [a]		Sub-reach description [b]
					(mi)	(km)	
San Carlos Reservoir	San Carlos Apache Reservation	1a	Main Reservoir	San Carlos River (drowned) confluence	8.0	12.9	Reservoir-drowned, lowermost reach of upper Gila River between Coolidge Dam and San Carlos River confluence (near Graham-Gila county line); fed by short washes and alluvial fans from mountain ridges and cliffs along both sides (north and south sides)
		1b	Reservoir Backwater	Bone Spring Canyon confluence (at railway bridge)	15.7	25.3	Narrow, single-thread river channel meandering through a broad, very densely vegetated (tamarisk) floodplain fed by short washes and alluvial fans along both sides (north and south sides); no agriculture within hydraulic backwater zone of San Carlos Reservoir
Gila Valley		2a	Calva	Highway 70 bridge	7.0	11.3	Densely vegetated (tamarisk), braided river corridor with a dominant single-thread river channel meandering through a broad floodplain fed by short washes and alluvial fans on both sides; cultivated fields limited to upstream end on right-bank (north) side
		2b	Bylas	Eastern boundary of San Carlos Apache Reservation	8.6	13.8	Densely vegetated (tamarisk), braided river corridor with a dominant single-thread river channel meandering through a broad floodplain bordered by Gila Mountains' bajadas on right-bank (east) side and some cultivated fields and town of Bylas on left-bank (west) side; Salt Creek feeds into reach on right-bank side across from Bylas
	Restoration Planning Area	2c	Ft. Thomas	Hot Springs-Wide Hallow-Spring Creek channeled confluence	17.1	27.5	Well vegetated (mostly tamarisk), braided river corridor with a dominant single-thread river channel (with some agricultural levees) meandering through a broad floodplain bordered by Gila Mountains' bajadas and some narrow, disconnected floodplain areas on right-bank (east) side and cultivated fields and town of Ft. Thomas on left-bank (west) side; Goodwin and Black Rock washes drain Pinaleno Mountains feeding into reach on left-bank side near Ft. Thomas
		2d	Eden	Ft. Thomas Canal Diversion Dam	3.9	6.3	Narrow single-thread, well vegetated (mostly tamarisk) river corridor constricted by agricultural levees and bordered by broad, densely cultivated floodplain along both sides; hydrology also influenced at upstream end by Ft. Thomas Canal Diversion Dam (near natural valley constriction at Markham Wash confluence on right-bank [north] side and Underwood Wash confluence on left-bank [south] side)
		2e	Bryce	Curtis Canal Diversion Dam	5.1	8.2	Braided river corridor with dominant single-thread river channel meandering through well vegetated riparian forest (mostly tamarisk) bordered by some agricultural levees and broad, densely cultivated floodplain on both sides; receives irrigation runoff via drainage ditches; downstream end at valley constriction near Markham and Underwood washes; hydrology also influenced at upstream end by Curtis Canal Diversion Dam (near Peck Wash on right-bank [north] Cottonwood Wash and town of Pima on left-bank [south] side)
		2f	Pima	Smithville Canal Diversion Dam	7.5	12.1	Moderately vegetated, braided river corridor bordered by some agricultural levees and broad, densely cultivated floodplain on both sides and urban centers of Pima, Central, and Thatcher on left-bank (west) side; receives irrigation runoff via drainage ditches and channelized tributary confluences (e.g., Ash Creek draining Mt. Graham); hydrology also influenced at upstream end by Smithville Canal Diversion Dam (near town of Thatcher)
		2g	Safford	Graham Canal Diversion Dam	3.6	5.8	Moderately vegetated, braided river corridor with dominant single-thread river channel bordered by some agricultural levees and broad, densely cultivated floodplain on both sides and urban centers of Thatcher and Safford on left-bank (southwest) side; receives irrigation and urban runoff via drainage ditches and channelized tributary confluences; hydrology also influenced at upstream end by Graham Canal Diversion Dam (near Stockton Wash draining Mt. Graham)
		2h	East Safford	San Simon River confluence	2.8	4.5	Moderately vegetated, braided river corridor with dominant single-thread river channel bordered by upland terrace at base of Gila Mountains on right-bank (north) side and densely cultivated floodplain and urban developments between Safford and Solomon on left-bank (south) side; receives irrigation and urban runoff via drainage ditches and channelized tributary confluences; hydrology also influenced by San Simon River confluence at upstream end—largest tributary in the Gila Valley
		2i	Solomon	San Jose Canal Diversion Dam	8.2	13.2	Sparsely vegetated, coarse-grained, braided river corridor with dominant single-thread river channel bordered by broad, mostly continuous, densely cultivated floodplain on both sides; valley narrows in upstream direction toward transition with Gila Box; receives modest irrigation and tributary runoff; hydrology also influenced by San Jose Canal Diversion Dam at upstream end
		2j	Earven Flat	Brown Canal Diversion Dam at Gila Box mouth	3.1	5.0	Upstream extent of Gila Valley: sparsely vegetated, coarse-grained, mostly braided river corridor with dominant single-thread river channel narrowly bordered by cultivated floodplain on right-bank (north) side and short washes and alluvial fans on left-bank (south) side; hydrology also influenced by Brown Canal Diversion Dam
Gila Box		3a	Lower Box	Bonita Creek confluence	3.4	5.5	Downstream end of Gila Box: moderately vegetated (cottonwood-willow gallery forests), confined river corridor meandering through sinuous canyon bottom bordered by short washes and alluvial fans draining arid uplands

[a] Sub-reach length measured in a GIS along a digitized interpretation of the low-flow channel pathway visible in 2011 aerial imagery.
[b] Names of physical features from USGS topographical quadrangle maps.

2.2.2 Aerial imagery analysis

Historical aerial imagery was utilized in a geographic information system (GIS; ESRI ArcGIS 10) to delineate areas of flood disturbance for selected historical floods along the upper Gila River in the Planning Area. Three of the most recent, large flood events were selected: 1983, 1993, and 2005. Also utilized, although not mapped here, were the remote-sensing products generated in support of this project by USU RS/GIS based on the flight made in October 2012 of the entire Upper Gila River Project Area (see Section 2.1: Remote-Sensing Data Collection above and Appendix A). Many aspects of our flood-scour analysis were modeled on similar work done by Graf (2000), Tiegs et al. (2005), and Tiegs and Pohl (2005). Details of the methods employed here and the mapping products are summarized in Appendix B.

For purposes of aerial-photographic interpretation, the flood-scour areas were defined as follows:

High disturbance: These areas were characterized by distinct channel and floodplain areas severely disturbed by flow (i.e., scoured to bare substrate), typically with 10% or less apparent remaining riparian vegetative cover.

Medium disturbance: These areas were characterized by distinct areas of low to moderate apparent disturbance by flow, typically defined as areas with more than 10% but less than 80% apparent riparian vegetative cover.

Low disturbance (riparian vegetation): These areas were characterized by distinct zones of apparently natural riparian vegetation with little to no apparent disturbance by flood, typically containing more than 80% riparian vegetation.

All flood-scour areas were then classified as being either within or outside of the "active channel," with the active channel defined as areas of medium to high disturbance. Areas of riparian or non-riparian vegetation with no apparent disturbance were excluded.

2.2.3 Results of flood-scour analysis

The results of our flood-scour analysis are presented graphically in two sets of maps: "Areal extent of active channel in successive floods" and "Frequency of active channel position" (see Appendix B). The first set of maps represents the active-channel areas during the 1983, 1993, and 2005 flood events. The second set of maps highlight those channel areas most frequently disturbed by repeat flood events.

The flood-scour analysis reveals that the low-flow channel position changes rapidly and completely during flood events according to the magnitude of the event and other factors, whereas the boundary of the broader active-channel area changes less frequently. Also revealed is that the >66% frequency flood-scour area decreases in the downstream direction, which is primarily a reflection of the scour patterns of the 2005 flood event that were concentrated in the upper half of the Planning Area. Thus, the flood-scour extent is generally greater above Pima, and lower below.

The "Flood Reset Zone" was then identified to inform restoration area suitability as part of the ecohydrological assessment—suitable restoration areas are considered to be found safely outside of the Flood Reset Zone (see Section 2.6 Potentially Suitable Vegetation Restoration Areas below). This zone includes areas having both 100% flood-scour frequency (i.e., scoured in 3 out

of the 3 mapped events [1983, 1993, and 2005]) *and* "high" flood-disturbance activity—areas severely disturbed by flow, typically scoured to bare substrate retaining <10% apparent riparian vegetative cover—during the most recent flood of 2005. The size of the Flood Reset Zone progressively decreases in the downstream direction below the Gila Box (i.e., reaches 2c–2j), where it accounts for over 80% of the riparian corridor near the upstream end of the Planning Area (reach 2j) and only about 20% near the downstream end (reach 2c) (see Section 2.3 for explanation of characterizing vegetation within the riparian corridor).

The maps presented in Appendix B are meant to guide restoration planning and implementation at multiple scales, ranging from restoration strategy development at the full river corridor and reach levels to site-specific restoration design and implementation. However, the maps are only one tool and need to be combined with a variety of other information to develop the most effective and efficient strategies and designs for riparian restoration, such as riparian vegetation classification (see below). In particular, more detailed field-based information and geomorphic interpretation may be warranted to refine the fine-scale delineation of the Flood Reset Zone and predictions of likely future flood paths when designing and implementing site-specific plans for invasive species removal and revegetation of native riparian species.

2.3 Riparian Vegetation Characterization

Here we describe methods and results of our effort to characterize riparian vegetation composition and distribution patterns in the Planning Area, and to better understand the relationships between vegetation and physical conditions in the riparian corridor. The primary goal of the vegetation characterization was to inform the selection of suitable restoration areas based on the understanding of the physical conditions that do, and could, support the establishment and growth of native riparian trees and shrubs. A secondary objective of the effort was to review the remotely-sensed datasets produced by USU RS/GIS for the Restoration Framework.

2.3.1 Plot surveys and remote sensing methods

To characterize riparian vegetation patterns in the Planning Area, we collected vegetation composition and physical condition data for over 80 plots spread across 20 transects (Figure 2-6, Appendix C). We first reviewed aerial photography, flood-scouring mapping, hydrogeomorphic reach boundaries, relative elevation data, available vegetation data, and USU RS/GIS's vegetation-classification map to select transects that represented the variety of hydrogeomorphic and vegetation conditions in the Planning Area. The available vegetation data included a vegetation-communities map prepared by SRP for their Ft. Thomas Preserve properties and vegetation plot data collected by UCSB in support of developing monitoring protocols for the Restoration Framework.

Transects spanned the entire width of the active channel, ranging in length from 1,000 to 4,600 ft (300 to 1,400 m), and were positioned to overlap with as much existing native vegetation as possible. Each transect was visited in early November 2013, after obtaining permission to access the mix of private and publically owned parcels in which selected transects were located, by a two-person field crew with knowledge of the plant species of the Gila River Valley and Sonoran Desert. In the field, and using aerial photographs and field maps of relative elevation and USU RS/GIS's vegetation map, the field crew identified distinct bands of vegetation and relative elevation across each transect and collected data at plots in as many of those distinct bands as possible.

The number of plots sampled across each transect ranged from 3 to 6, depending on vegetation complexity, topographic complexity, and plot accessibility. Plots varied in size based on the stature of the vegetation and the area visible to the field crew, but were typically 400 m^2 (20 x 20 m). At each plot, a geotagged photograph was taken to both record the location of the plot and document plot conditions, and the following data was recorded:

- **Estimated time since last flooded:** <1, 1–2, 3–5, 6–10, or >10 years
- **Soil texture:** gravel, silt, loam, clay, sand
- **Topography:** convex, flat, concave, undulating
- **Percent ground cover of:** water, vegetation, organic debris, cobble/boulder, gravel, and fine sediments
- **Evidence of:** flooding, fire, soil moisture, and agricultural return flows
- **Types and intensities of unnatural disturbances:** competition from nonnative invasive species, off-road vehicle use, and bulldozing/earth moving
- **Vegetation-type dominance:** trees, shrubs, or forbs
- **Tree, shrub, and herb phenology:** early, peak, or late
- **Species:** name, age (e.g., seedling, mature, decadent), and percent cover of all prevalent plants
- **Vegetation type:** name and vegetation type name of any adjacent, un-sampled vegetation

Before leaving each transect, the field crew delineated the boundaries of the various vegetation types encountered across the transect. Back in the office, the relative elevation, canopy height, our flood frequency, USU RS/GIS's vegetation type, and NRCS's soil type of each plot were queried in GIS and appended to the field-collected data in a Microsoft Excel spreadsheet. The frequency at which several native species occur in different elevation zones above the stream channel (referred to as relative elevation) was plotted. All plot data, whether collected in the field or derived in GIS, are tabulated in Appendix C.

2.3.2 Vegetation types and distribution patterns

The following sections describe the primary vegetation types in the Planning Area, as documented during the transect surveys, and the major cross-sectional and longitudinal patterns in their distribution in the Planning Area. The vegetation types correspond to either the group or alliance level of the U.S. National Vegetation Classification (NVC) system (http://usnvc.org/). For readers unfamiliar with species' scientific names and/or NVC classification terminology, we have used the common name and typical structure of the dominant species to name each vegetation type. To facilitate comparison and coordination with the NVC, however, we also provide the NVC association and/or group name in the description.

During the plot surveys, distinct patterns in the cross-sectional distribution of vegetation types were observed, and a representative example is illustrated in Figure 2-7. There are, however, variations in this cross-sectional distribution and in the composition of vegetation types depending on their location along the river. Three transects were located upstream of the San Jose Diversion Dam, in hydrogeomorphic reaches 2j and 3a (see Figure 2-6). These reaches are the narrowest in the Planning Area with a large proportion of the floodplain affected by flood scour (see Figures B-2.1 through B-2.10 in Appendix B), have little to no adjacent agriculture, and are subjected to the least consumptive water use, which together help explain much of the difference

in vegetation patterns observed in these reaches. Seven transects were located within the drier reaches between the San Jose Diversion Dam and the town of Pima (reaches 2f through 2i). Because they are immediately downstream of the San Jose Diversion Dam, with less opportunity for tributary contributions or agricultural return flows, riparian vegetation in these reaches appears to be the most negatively affected by water diversion. These reaches are also subject to significant amounts of flood scour (see Figures B-2.1 through B-2.10 in Appendix B). Ten transects were located downstream of Pima, in reaches 2c through 2e, where the river corridor supports a much more dense riparian cover benefiting from agricultural return flows and reduced flood scour in portions of the floodplain compared to upstream reaches, although that vegetation is overwhelmingly dominated by tamarisk. The cross-sectional illustration in Figure 2-7 is based on transect 19, which was one of the transects located downstream of Pima (see Figure 2-6, Appendix C). The influence of reach characteristics on vegetation-type composition and distribution is described in greater detail below.

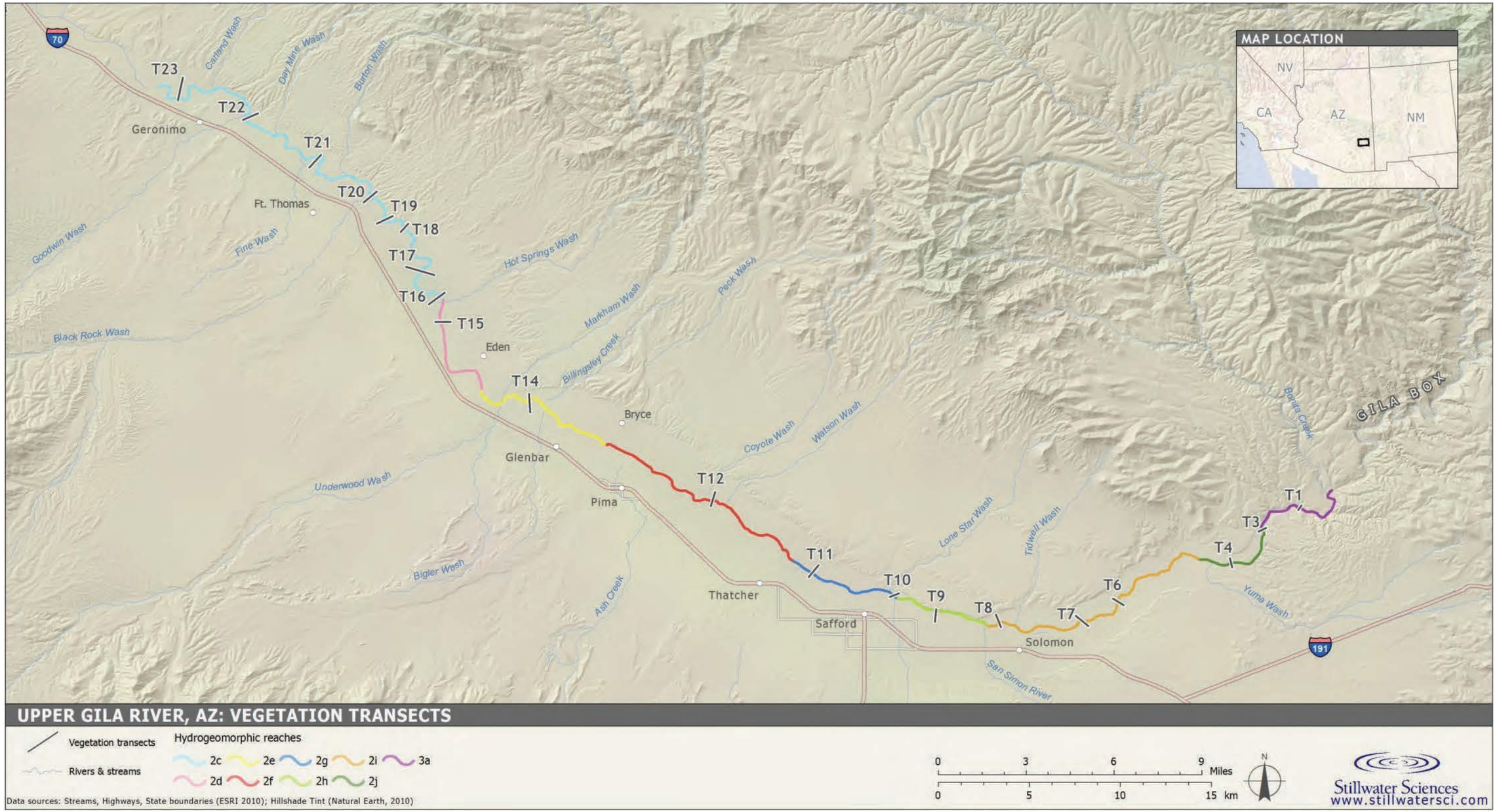


Figure 2-6. Map of vegetation transects along the upper Gila River within the Restoration Planning Area.

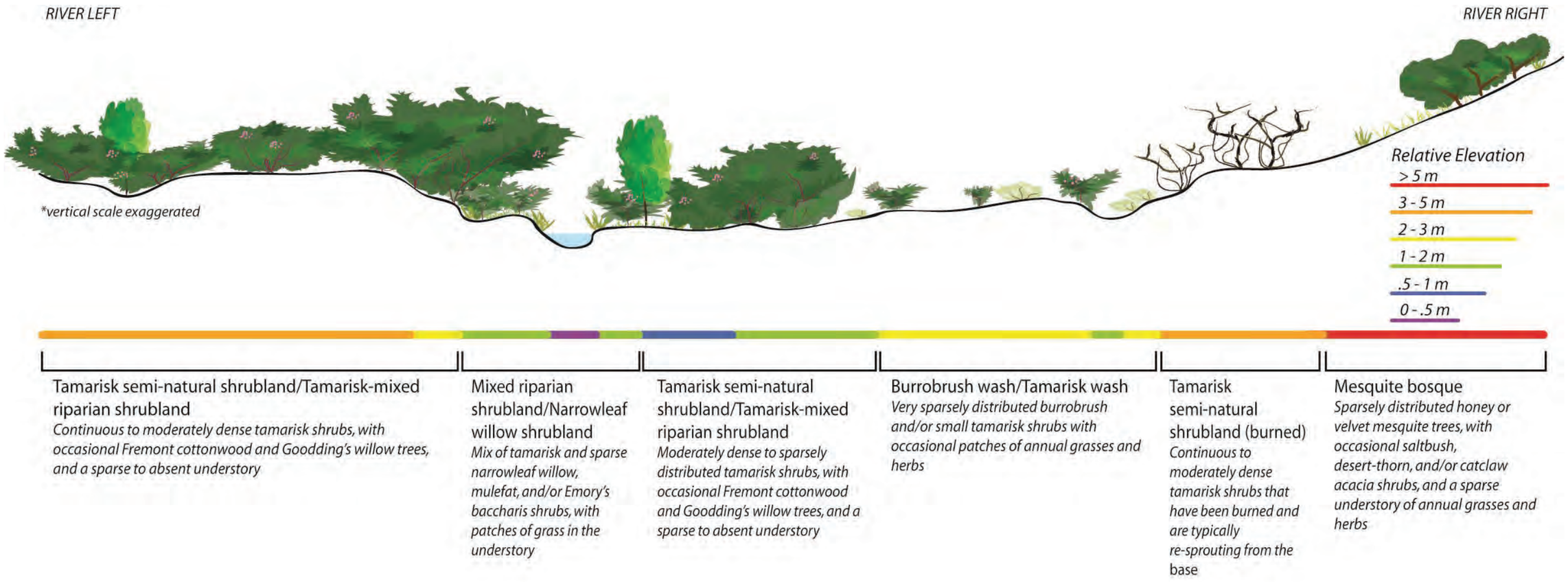


Figure 2-7. Illustration of the typical cross-sectional distribution of vegetation in the Gila Valley Planning Area downstream of Pima.

2.3.2.1 Tamarisk semi-natural shrubland/Tamarisk-mixed riparian shrubland

The most common vegetation types in the Planning Area are tamarisk-dominated shrublands and, as shown in Figure 2-7 (specifically the 3–5 m relative elevation band on river left), are found under a relatively wide range of conditions and are generally the most widely distributed vegetation types across a typical channel cross-section. "Tamarisk semi-natural shrublands" refer to areas where tamarisk is very nearly the only species present (see photo inserts at right), while "tamarisk-mixed riparian shrublands" include areas where tamarisk is still the dominant species, but Fremont cottonwood (*Populus fremontii*), Goodding's willow (*Salix gooddingii*), narrowleaf willow (*S. exigua*) (also known as coyote willow), mulefat (*Baccharis salicifolia*), desert broom (*B. sarothroides*), Emory's baccharis (*B. emoryi*), and/or mesquite (*Prosopis glandulosa* and/or *P. velutina*) occasionally occur at very low cover. Vegetation density can range widely, from nearly continuous to only 10% tamarisk cover, and canopy heights are typically no more than 16 ft (5 m). Native species face extreme competitive pressure in these tamarisk dominated stands and woody material from dead cottonwoods and willows is often present. The herbaceous layer in tamarisk-dominated shrublands is low in floristic diversity, comprised mostly of a sparse cover of bermudagrass (*Cynodon dactylon*) or johnsongrass (*Sorghum halepense*). Tamarisk-dominated shrublands typically occur on silty substrates, but may also be found on sand and gravel. Soil moisture conditions in these vegetation types can vary from wet to dry, depending on the proximity to the river, relative elevation from the low-flow channel, time since last rain or flood, and agricultural return flows. Tamarisk-dominated shrublands can tolerate a wide variety of flood and scour frequencies, and are found from stream banks to more mesic upland areas. Tamarisk semi-natural shrubland and tamarisk-mixed riparian shrubland correspond most closely to the NVC's *Tamarix* spp. Temporarily Flooded Semi-natural Shrubland alliance in the Southwest North American Ruderal Riparian Scrub Group.



Dense, tall tamarisk semi-natural shrubland downstream of Pima *(top)*, dead and dying tamarisk between San Jose Diversion Dam and Pima *(middle)*, and burnt tamarisk with vigorous re-sprouting near Ft. Thomas *(bottom)* (Photos by Stillwater Sciences)

Downstream of Pima, tamarisk-dominated shrublands are typically continuous to moderately dense tamarisk shrubs, with occasional Fremont cottonwood and Goodding's willow trees, and a sparse to absent understory (see Figure 2-7 and photo inserts above). Tamarisk is highly flammable and has fueled a number of fires in the riparian corridor of the Planning Area. In areas burned by the Clay Fire in March 2013 near Fort Thomas, nearly all of the tamarisk biomass was burned away—only the main trunks and branches remain, as illustrated in Figure 2-7—and there

is typically a bit more understory vegetation, as would be expected with less shading by tamarisk. Nearly all burnt tamarisk trees were observed to be re-sprouting vigorously from the base (see photo insert above), indicating there is only a fairly limited window of opportunity to establish native species before tamarisk biomass once again dominates the site. Between the San Jose Diversion Dam and Pima, tamarisk-dominated shrublands are typically much less dense and tall, and much of the tamarisk appears to be stressed or even dying. Upstream of the San Jose Diversion Dam, this zone is much narrower and typically with a higher proportion of native shrubs and trees.

2.3.2.2 Fremont cottonwood-Gooding's willow woodland

The "Fremont cottonwood-Goodding's willow woodland" vegetation types typically have Fremont cottonwood and/or Goodding's willow trees present at 20–60% cover each, which form a dense, high canopy 15–30 ft (4.5–10 m) tall (see photos insert below). In the Planning Area, most Fremont cottonwood and Goodding's willow trees are mature or decadent appearing to have been established soon after the 1993 flood event, and there appears to be very little to no recent natural recruitment of either species. Tamarisk, and less often mesquite, dominates the sub-canopy. Emory's baccharis, mulefat, and/or desert broom typically occur in the shrub layer at 10–60% cover. Bulrush (*Schoenoplectus* spp.) may occur in low-laying swales where water can pond within these vegetation types, while common reed (*Phragmites australis*), arundo (*Arundo donax*), and bermudagrass may occur where these vegetation types are adjacent to the river channel. In general, however, the herbaceous layer is very sparse to absent and the ground layer has a moderate cover of downed wood and other organic litter. Fremont cottonwood-Goodding's willow woodland typically occurs where substrates are silty or sandy, and generally dry, and at elevations where they are frequently inundated by lower velocity floods but are not subject to intense scouring. This vegetation type corresponds to the NVC's *Populus fremontii-Salix gooddingii* Woodland alliance in the Sonoran-Chihuahuan Warm Desert Riparian Scrub Group.

Fremont cottonwood-Goodding's willow woodland is not illustrated in Figure 2-7 because areas with sufficient cover of these native tree species to be classified separately from tamarisk-mixed riparian shrubland are relatively uncommon. They occur most frequently downstream of Pima, typically along the outer margin of the riparian corridor and the banks of abandoned and/or high flow channels, and upstream of the San Jose Diversion Dam in the Gila Box, typically near the river channel or along the outer margin of high-flow floodplains. Fremont cottonwood-Goodding's willow woodland is nearly entirely absent in the reach between the San Jose Diversion Dam and Pima. Fremont cottonwood and Goodding's willow trees were documented in 29 and 20 plots, respectively (see Appendix C), and were found to occur most frequently between 10 and 13 ft (3 and 4 m) above the low-flow river channel (Figure 2-8).



Fremont cottonwood-Goodding's willow woodland downstream of Pima *(left)*, and Fremont cottonwood-Goodding's willow woodland upstream of the San Jose Diversion Dam *(right)* (Photos by Stillwater Sciences)

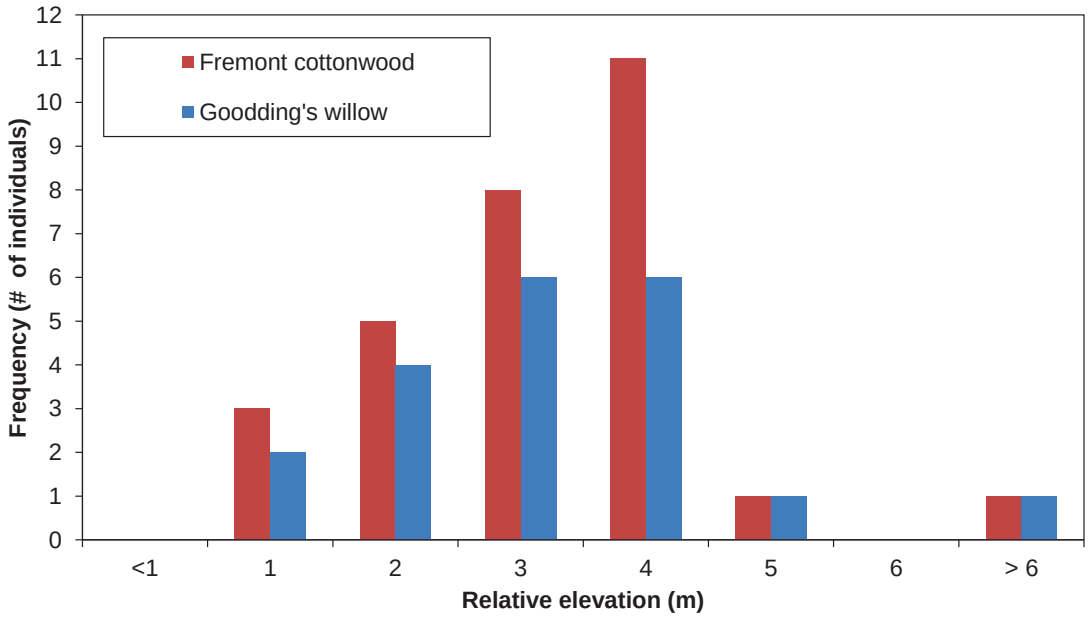


Figure 2-8. Histogram of Fremont cottonwood and Goodding's willow occurrence by relative elevation above the low-flow river channel water surface.

2.3.2.3 Mixed riparian shrubland/Narrowleaf willow-mulefat shrubland

Mixed riparian shrubland and narrowleaf willow-mulefat shrubland are both characterized as sparse shrublands usually found along the river banks, with a total vegetative cover ranging from 25–70%. A combination of tamarisk, mulefat, and/or narrowleaf willow typically dominant the shrub layer, while bermudagrass, sacaton (*Sporobolus* spp.), and/or johnsongrass may occur at low cover in the herb layer. The tree layer is nearly always absent, although Goodding's willow can occasionally occur at low cover. Typically 30–40% of the area is unvegetated sand or silt. These vegetation types occur along the active channel, as well as side channels, on silty, typically moist substrates, where they are frequently inundated. Mixed riparian and narrowleaf willow-mulefat shrublands correspond most closely to the NVC's *Salix exigua-Baccharis salicifolia* Shrubland alliance in the North American Warm Desert Riparian Low Bosque and Shrubland Group.

Both downstream of Pima and upstream of the San Jose Diversion Dam, mixed riparian shrubland—a mix of tamarisk, narrowleaf willow, mulefat, and/or Emory's baccharis shrubs, with patches of grass in the understory—or narrowleaf willow shrubland occur more or less continuously in narrow, sparse strips along the banks of the active channel (see the riverbanks in Figure 2-7 and photo insert at right). Between Pima and the San Jose Diversion Dam these vegetation types are relatively uncommon and even narrower in distribution (generally only one-shrub wide) when they do occur, and are typically replaced by



Sparse patches of mixed riparian shrubland along the stream bank downstream of Pima (Photo by Stillwater Sciences)

tamarisk wash and floodplain herbaceous vegetation (see descriptions below). In many instances, these vegetation types appear to be limited in extent as a result of shading from adjacent and taller-stature tamarisk-dominated shrublands (as illustrated in Figure 2-7). Narrowleaf willow and mulefat, both of which can be important nesting habitat for SWFL, were documented in 27 and 21 plots, respectively (see Appendix C), and were found to occur most frequently between 2 and 3 m above the river channel (Figure 2-9).

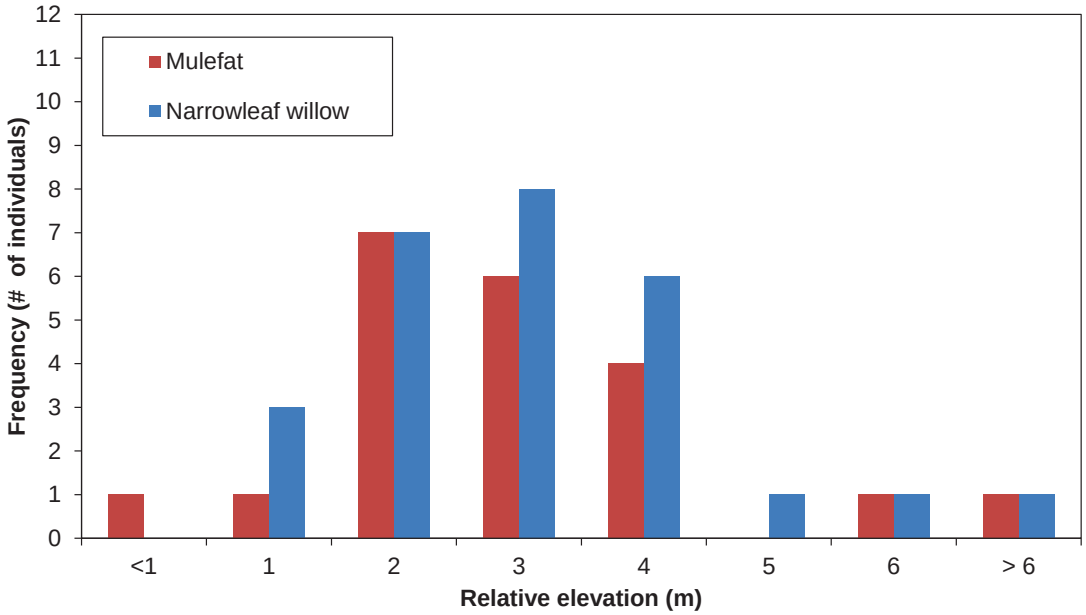


Figure 2-9. Histogram of mulefat and narrowleaf willow occurrence by relative elevation above the low-flow river channel water surface.

2.3.2.4 Burrobush wash

Burrobrush washes are sparsely vegetated shrublands that are dominated by burrobrush (*Hymenoclea monogyra*), although this species may only occur at 15–25% cover. Desert broom and/or tamarisk are also frequently present at less than 5% cover. Herbaceous species can include prickly Russian thistle (also referred to as tumbleweed, *Salsola tragus*), common purslane (*Portulaca oleracea*), and other annual grasses and forbs, and typically account for 25–50% of the total cover. Mesquite may very rarely be present at 0–10% cover. Burrobrush wash typically occurs on flat to undulating floodplains with silt and gravel substrates that are 7–10 ft (2–3 m) above the active channel (see Figure 2-7 and photo insert at right). Although these areas are not generally adjacent to the river channel and soils are typically dry, burrobrush wash appears to occur where there is regular and intense flood scour. They are also frequently subject to disturbances from bulldozing, levee maintenance, and off-road vehicles. Burrobrush wash corresponds to the NVC's *Hymenoclea monogrya* Thicket Shrubland alliance in the Warm Semi-Desert Shrub and Herb Wash-Arroyo Group.



Burrobrush wash on coarse-grained river substrates
(Photo by Stillwater Sciences)

This vegetation type is common throughout the Planning Area, except between the San Jose Diversion Dam and Pima, where tamarisk-mixed riparian shrubland, tamarisk wash, and floodplain herbaceous vegetation (see descriptions below) are more prevalent in the same relative-elevation zone.

2.3.2.5 Tamarish wash



Tamarisk wash on mixed-grained river substrates
(Photo by Stillwater Sciences)

Tamarisk wash is very similar to burrobrush wash in both distribution (i.e., scoured floodplains) and structure (i.e., only sparsely vegetated) (see photo insert at right). The primary difference is that small-statured tamarisk shrubs, typically 3–10 ft (1–3 m) tall, are dominant, although always at low percent cover (10–15%). Burrobrush, mulefat, narrowleaf willow, bermudagrass, and johnsongrass may all co-occur in this vegetation type, contributing an additional 5–40% cover to the vegetation layer. As with burrobrush wash, this vegetation type is found on relatively coarse—while still predominantly silt, substrates nearly always include up to 30% gravel and some boulders and cobbles—flat to undulating floodplains that appear to be regularly and intensely scoured by floods. Soils are typically dry, with the exception of depressions where water may pond and when this vegetation type occurs adjacent to the river channel. Also similar to burrobrush wash, this vegetation type is frequently subject to disturbances from bulldozing and off-road vehicles. Although notably different in terms of stature and density from the tamarisk-dominated shrublands described above, tamarisk wash also corresponds most closely to the NVC's *Tamarix* spp. Temporarily Flooded Semi-natural Shrubland alliance in the Southwest North American Ruderal Riparian Scrub Group.

Although tamarisk wash occurs throughout the Planning Area, it accounts for a greater proportion of the vegetation between the San Jose Diversion Dam and Pima.

2.3.2.6 Floodplain herbaceous



Floodplain herbaceous vegetation in the fall after a high flow event
(Photo by Stillwater Sciences)

Floodplain herbaceous vegetation type is similar to burrobrush and tamarisk wash in distribution and its sparse density (i.e., only 15–35% vegetative cover), but is made up predominantly of herbaceous species (see photo insert at right). Dominant herbaceous species include cocklebur (*Xanthium strumarium*), johnsongrass, and bermudagrass. In some cases, mulefat and/or tamarisk may occur as well, but these constitute less than 10% of the total vegetative cover; there is no tree canopy. It can also establish in disturbed areas following earth moving activities on the floodplain. Floodplain herbaceous vegetation is typically found no more than 7 ft (2 m) above the low-flow channel, in flat, open areas with silty substrates. A thin layer of organic litter sometimes

covers up to 15% of the ground surface, resulting in moderate, patchy exposure of bare soil. Soils where this vegetation type occurs may retain moisture in depressions where water can pond, but are otherwise dry. Floodplain herbaceous vegetation corresponds most closely to the NVC's *Iva annua*–(*Xanthium strumarium*) Temporary Flooded Herbaceous Vegetation alliance in the Southeastern Ruderal Wet Meadow and Marsh Group.

Floodplain herbaceous vegetation is found throughout the Planning Area, although most notably immediately downstream of the San Jose Diversion Dam, on portions of the floodplain subject to frequent flood-scour activity, along with tamarisk wash.

2.3.2.7 Floodplain wetland

Floodplain wetland vegetation type typically has high cover (50-100%), but with low species diversity. Cattails (*Typha* spp.) are typically the most common species and contribute to a thick litter layer, although bulrush and narrowleaf willow may also be present at low densities. Tamarisk saplings are often abundant and can exert high competitive pressure on native species; tamarisk is able to significantly out-compete species such as cattails in ponded areas, as well as species such as narrowleaf willow along drier banks. The herbaceous layer is typically absent or very sparse. Floodplain wetland vegetation corresponds most closely to the NVC's *Typha domingensis* Western Herbaceous Vegetation alliance in the Arid West Emergent Marsh Group.



Dense floodplain wetland (cattails) vegetation near Pima
(Photo by Stillwater Sciences)

Areas where floodplain wetland vegetation occurs are always flat to convex, allowing water to pond, and substrates are typically silty. Floodplain wetland vegetation is primarily found downstream of Pima, where it occurs in isolated patches independent of relative elevation from the channel (see photo insert at right). Floodplain wetland vegetation is highly influenced by agricultural return flows; nearly all wetland areas are supported by a drainage ditch or pond where water flows from adjacent fields.

2.3.2.8 Mesquite bosque

Mesquite bosque vegetation type occurs broadly throughout the Sonoran Desert. The tree canopy is moderately open, with only 25–50% cover, and is composed entirely of mesquite, which rarely exceeds 30 ft (10 m) in height (see photo insert at right). A variety of shrubs and other understory vegetation are also supported, such as wheelscale saltbush (*Atriplex elegans*), desert willow (*Chilopsis linearis*), rabbitbrush (*Ericameria* spp.), Torrey wolfberry (*Lycium torreyi*), creosote (*Larrea tridentata*), palo verde (*Parkinsonia aculeatae*), prickly Russian thistle, seepweed (*Suaeda* spp.), and annual grasses. Tamarisk may



Mesquite bosque along upland boundary of riparian corridor
(Photo by Stillwater Sciences)

also be present at very low cover (<5%). This vegetation type corresponds most closely to the NVC's *Prosopis glandulosa-Atriplex* spp. Shrubland in the Tamaulipan Dry Mesquite and Thornscrub Group.

Subjected to only infrequent flood events, mesquite bosque occurs in dry silty or sandy soils with generally flat topography. Patches of mesquite bosque are found along the upland boundary of the riparian corridor throughout the Planning Area, occurring along xeric portions of the floodplain greater than approximately 16 ft (5 m) above the active channel (see the >5 m relative elevation band in Figure 2-7) and at the mouths of incoming arroyos.

2.3.3 Vegetation restoration opportunities and constraints

The following is a summary of considerations that should be taken during riparian restoration planning, based on the vegetation transect-plot data collected and general observations made during the field effort.

- Very few instances of natural recruitment of native riparian trees and shrubs were observed during the plot surveys, and much of what was observed appeared to have been recruited in association with the 1993 flood event. Recruitment potential under more recent conditions appears to be limited by high density of tamarisk coverage and sufficient water availability. This condition indicates that active planting will be needed to restore native species downstream of the San Jose Diversion Dam. Upstream of the San Jose Diversion Dam (reaches 2j and 3a), however, where there are fewer water diversions and a greater proportion of native trees and shrubs, natural recruitment may be adequate to restore native species as tamarisk dies back following the arrival of the tamarisk beetle.
- Active planting and restoration infrastructure should generally be avoided in the Flood Reset Zone to prevent the loss of restoration resources. Between the San Jose Diversion Dam and Pima, where there are few areas suitable for restoration outside of the Flood Reset Zone (see Section 2.6 Potentially Suitable Vegetation Restoration Areas below), opportunities to replace tamarisk wash with burrobrush wash could be evaluated if desirable, although these functionally equivalent vegetation types provide little to no potential habitat for SWFL.
- Vegetation composition and cross-sectional distribution, and the physical conditions that shape these attributes, vary as a function of position along the river corridor (i.e., specific to hydrogeomorphic reach). Upstream of the San Jose Diversion Dam in reaches 2j and 3a, the higher proportion of native species, fewer water diversions, and higher potential for natural recruitment suggest that these reaches are of relatively lower priority for restoration. Between the San Jose Diversion Dam and Pima in reaches 2f though 2i, the sparse vegetation, relatively greater influence of water diversion, and large areas of flood scour suggest that successful restoration will require careful planning to avoid scour and to provide adequate soil moisture. Downstream of Pima, the extent and density of vegetation and influence of agricultural return flows suggest that a greater variety of vegetation types could be successfully restored with minimal or no long-term irrigation.
- Fire-contingent restoration actions such as herbicide applications on re-sprouting tamarisk and/or active planting of native species should be planned for suitable areas downstream of Pima, and to a lesser extent upstream of the San Jose Diversion Dam, to take advantage of the removal of tamarisk biomass by wildfire. The suppression of tamarisk cover for just a few years may be sufficient for Fremont cottonwood and Goodding's willow cuttings or poles planted shortly after a fire to grow above the existing tamarisk canopy.

- Current locations of native riparian plant species are indicative of where these species, once restored, should persist in the future. However, many other areas are likely to have suitable biophysical conditions for successful restoration as well but natural recruitment of natives is not occurring and/or tamarisk has out-competed all other species. As such, it is recommended that the physical conditions under which native species have been documented to occur be used to help select restoration sites, rather than the locations of natives themselves, which is likely to underestimate the area potentially suitable for restoration. Figures 2-8 and 2-9, which present the range of relative elevations under which several native riparian trees and shrubs were observed during the plot surveys, were specifically developed for this purpose. In addition, the height of the current vegetation canopy, even in tamarisk-dominated stands, provides a useful indicator of site productivity for native woody species.
- Many occurrences of native trees and shrubs, and nearly all occurrences of floodplain wetlands, in the Planning Area appear to be highly influenced by, if not dependent upon, channelized tributary and/or agricultural return flows. The presence of such flows should be a factor considered in the selection of restoration sites, since they offer opportunities to successfully establish and grow native species without the need for irrigation. However, during this consideration, the seasonality and constancy of the tributary and/or agricultural return flows should be assessed, as flow patterns may vary depending upon the water year type and crop(s) being grown. The strong influence of channelized tributary and/or agricultural return flows as suggests that, outside of these zones of influence, irrigation may be needed to establish some native species in certain areas.
- Although they are miniscule in extent in comparison with tamarisk-dominated shrublands, unique native vegetation types, such as freshwater wetlands, burrobrush wash, mesquite bosque, and herbaceous species tolerant of more saline soils, occur in the Planning Area. These vegetation types may be appropriate to restore in less-suitable areas in order to enhance vegetation and habitat diversity. Similarly, where areas become available for restoration, but may not be appropriate for the planting of Fremont cottonwood, Goodding's willow, mulefat, or narrowleaf willow, these other native vegetation types could be considered. To help inform such planning, the growing requirements for many of the native plant species that may be appropriate to restore in the Planning Area, as identified by the USDA, are provided in Appendix D.

2.4 SWFL Habitat Evaluation and Modeling

Information on reach-scale SWFL conditions supported by habitat-prediction modeling performed specifically for the Restoration Framework is briefly presented here. Field surveys were conducted in 2013 to characterize existing and potential SWFL-habitat quality throughout the Planning Area. Background information on general species conditions are presented in Appendix E, as authored by Matthew Johnson of NAU. Methods and results of the SWFL habitat modeling are presented in Appendix F, as authored by James Hatten of the USGS and Matthew Johnson.

The objectives of the SWFL existing conditions review and habitat prediction modeling are to:

1. Develop a conceptual model of SWFL breeding requirements (see Figure F-1 in Appendix F), which include physiological and other environmental processes that were identified by previous research as important determinants of species survival and reproduction, and are conceptual links to the spatially and temporally comprehensive variables that were available for us to use in our statistical modeling.

2. Gather and synthesize historical SWFL presence/absence and breeding data along the upper Gila River (Arizona/New Mexico boundary–Gila River/San Pedro Confluence);
3. Estimate existing potentially suitable breeding habitat for SWFL in the Planning Area by characterizing existing habitat conditions and running the SWFL habitat models (satellite and vegetation aerial);
4. Apply two sets of models to estimate potential suitable habitat for SWFLs within the Planning Area: (1) satellite models, which characterize vegetation from Landsat Thematic Mapper (TM) imagery; and (2) aerial models using finer-scale remote sensing data, characterizing vegetation from orthorectified digital aerial photography and LiDAR collected in October 2012;
5. Incorporate the effects that tamarisk biocontrol will have on SWFL habitat over a period of 3 to 5 years following expansion of the beetle into the Gila Valley area. The modeling effort can potentially map likely defoliated areas under future scenarios and help detect trends in SWFL habitat suitability caused by changes in vegetation over time; and
6. Communicate the progress of model development and results with Gila Watershed Partnership, U.S. Fish and Wildlife Service, Bureau of Reclamation, Arizona Game and Fish, and Salt River Project.

2.4.1 Existing conditions and challenges

SWFLs are present in the Planning Area, which has been designated as critical habitat for the species by the USFWS. They typically establish nesting territories, build nests, and forage where mosaics of relatively dense and expansive growths of trees and shrubs are established near or adjacent to surface water and/or underlain by saturated soil (Sogge et al. 2010). SWFL exist and interact as groups of metapopulations—a group of geographically separate breeding populations connected to each other by immigration and emigration—and are considered most stable where many connected sites or large populations exist. Metapopulation persistence or stability is more likely to improve by adding more breeding sites rather than expanding existing sites, which would distribute birds across a greater geographical range, minimize risk of simultaneous catastrophic population loss, and avoid genetic isolation. Approximately twice the amount of suitable habitat is therefore needed to support the numerical territory goals because the long-term persistence of SWFL populations cannot be assured by protecting only those habitats in which the species currently breeds.

It is also important to recognize that most breeding habitats are susceptible to future changes in site hydrology (natural or human-related), human impacts such as development or fire, and natural catastrophic events such as flood or drought (Hatten and Sogge 2007). Furthermore, as the vegetation at sites matures, it can lose the structural characteristics that make it suitable for breeding individuals. These and other factors can destroy or degrade breeding sites making their suitability ultimately ephemeral. Thus, it is necessary to have additional suitable habitat available to which SWFLs can readily move if displaced by such habitat loss or change.

The recent establishment of the tamarisk leaf beetle in parts of the southwest introduces a new dynamic factor affecting habitat suitability. Therefore, measuring and predicting SWFL habitat—either to identify areas that may develop into appropriate habitat for SWFL or that, with intervention by active restoration could support future SWFL nesting—requires knowledge of recent/current/future habitat conditions and an understanding of the dynamic processes and ecological factors that determine SWFL use of riparian breeding sites.

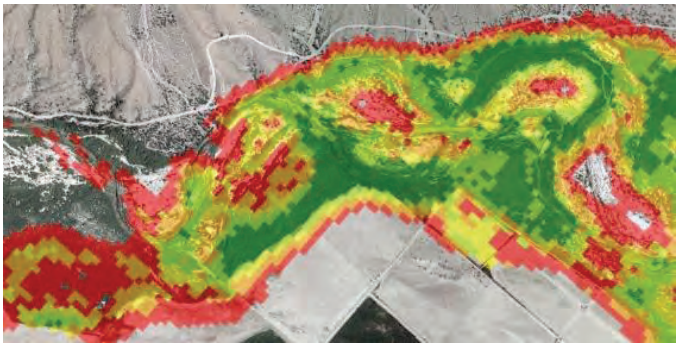
Within the Planning Area, SWFL habitat observations are regularly performed by SRP on their Ft. Thomas Preserve properties (SRP 2013) and were made in spring/summer 2013 at nearby parcels by NAU and UCSB in support of the Restoration Framework development[1]. NAU will survey and evaluate SWFL habitat at all proposed Planning Area sites in spring/summer 2014.

2.4.2 SWFL breeding habitat modeling

In 1999, Arizona Game and Fish Department (AGFD) developed a GIS-based model (Hatten and Paradzick 2003) to identify SWFL breeding habitat from Landsat Thematic Mapper (TM) imagery and 30-m resolution digital elevation models (DEMs). The model was developed with presence-absence survey data acquired along the San Pedro and (lower) Gila rivers, and from the Salt River and Tonto Creek inlets to Roosevelt Lake. This GIS-based model has been tested by predicting SWFL breeding habitat at multiple locations around Arizona and New Mexico, and has performed as expected by identifying riparian areas with the highest SWFL nest densities (Hatten and Sogge 2007, Hatten et al. 2010).

2.4.2.1 SWFL satellite model

We have successfully applied the "SWFL Satellite Model" (30-m resolution) to the Planning Area using Landsat 8 imagery. Satellite-model output included a continuous probability grid, a five-class probability grid, and a binary habitat grid, with higher cell values in each case indicating relatively better SWFL habitat. Figure F-2 in Appendix F displays the results of the five-class probability grid, with green areas representing the greatest breeding habitat suitability and red areas representing the lowest suitability (see graphic at right). The highest quality areas are concentrated downstream of Thatcher in reaches 2c–2f.



Example mapping results from the "SWFL Satellite Model" downstream of Ft. Thomas, where suitability grades from green (greatest) to red (least) (see Figure F-2 in Appendix F)

In addition, we created a habitat time series for the project area by populating the SWFL Satellite Model with 27 Landsat scenes from 1986–2013. The habitat time series served two purposes: (1) it allowed us to create a bar graph that depicts how much potential SWFL breeding habitat was in the project area between 1986 and 2013 (Figure F-3 in Appendix F); and (2) it enabled us to create time-lapse videos of how SWFL habitat changes year to year between 1986 and 2013 over the entire project area. We now have a baseline of SWFL suitable habitat that can be compared to future conditions.

2.4.2.2 SWFL LiDAR model

We are currently in the process of incorporating additional critical landscape and vegetation features to improve the SWFL model's ability to identify nest site suitability. This will integrate

[1] Because of the sensitive nature of publically distributing locational information on endangered species, locations of observed SWFL activity in the Planning Area are not published herein. These data may be provided by request through the U.S. Fish and Wildlife Service office in Phoenix, Arizona (http://www.fws.gov/southwest/es/arizona/).

vegetation species composition and structural traits from aerial imagery and field surveys with landscape-level vegetation height and channel topography generated from the LiDAR dataset collected by USU RS/GIS in October 2012. The results of the "SWFL LiDAR Model" will be concluded after the 2014 spring/summer field season when we have a larger set of observed SWFL territories from which to build a more robust model. This larger set will be obtained from the 2014 SWFL surveys to be conducted by NAU at the proposed Planning Area sites.

2.5 Soils and Groundwater Monitoring

Information on site-scale soil sampling and groundwater-level monitoring performed for the Restoration Framework is briefly presented here. The results briefly reported here helped confirm reach-scale soil and groundwater conditions, as estimated with a relative-elevation surface and regional soil mapping compiled for the ecohydrological assessment, which all together helped further characterize planting suitability in the Planning Area. Additional details on the site monitoring efforts performed by DBG and UCSB are presented in Appendix G, as authored by Tom Dudley, Kevin Hultine, and Devyn Orr.

2.5.1 Soil sampling

Shallow soil samples collected at the initial vegetation-monitoring sites located near Ft. Thomas were analyzed for soil texture, electrical conductivity (EC), and pH to assess suitability of active planting in the Planning Area. Measurements of EC and pH help to characterize soil physical and chemical properties, namely salinity, which can be a limiting factor for successful propagation of many types of riparian vegetation, such as cottonwood and willows.

The sampled soils were found to be composed of medium-sized sands with variable proportions of finer-grained silts and sands and coarser-grained sands and gravels. The measured EC values were broad, ranging from about 0.1 to 2.6 millimhos per centimeter (mmhos/cm) (100 to 2600 microSiemens per centimeter [uS/cm]). The shallower profiles sampled (0–10 cm below ground surface [bgs]) generally had greater EC values than the deeper profiles sampled (20–30 cm bgs). Measured values of soil pH exhibited a narrow range between about 7.8 and 8.6 for both sampled soil profiles, indicating the soils were slightly alkaline. All results are reported in Appendix G.

Riparian plant species requirements are described in Appendix D, with specific values of key environmental factors (e.g., soil texture, salinity) summarized in Table D-1 for the native species likely to be planted with active restoration efforts in the Planning Area. Overall, the soil sampling results indicate that the measured soil texture, and salinity and alkalinity levels were within the ranges of tolerance for most species. Thus, shallow soils (<30 cm [<1 ft]) present near the sampled locations should be suitable to support plantings of cottonwood, narrowleaf and Goodding's willow, and other native woody riparian (e.g., *Baccharis* spp.) and upland species (e.g., *Atriplex* spp.). The soils in a few areas may, however, be too saline and/or alkaline to support plantings of some native species, such as willow and cottonwood, which have low tolerance for salinity or higher pH (see Table D-1).

2.5.2 Groundwater-level monitoring

Shallow groundwater levels were monitored close to the active river channel at 6 locations throughout the Planning Area to better understand shallow groundwater patterns and, ultimately, water availability for active plantings. Paired piezometer wells were aligned perpendicular to the primary river channel with one well located near the water's edge and the second well located

farther out into the riparian forest. The initial groundwater measurements made in January 2014 reveal that depth to the water table was fairly shallow (~6–16 ft bgs), and remained fairly static across the width of the riparian corridor and was not wholly dependent on proximity to the wetted river channel (Figure 2-10).

As part of the ecohydrological assessment, the initial groundwater measurements were compared to relative elevations at each of the piezometer locations (see Figure 2-10). A relative-elevation surface was produced by Stillwater Sciences using the high-resolution, bare-earth topographic data produced from USU RS/GIS's October 2012 LiDAR data. This surface represents the land surface height above the low-flow channel, which is intended to serve as a proxy for depth to groundwater. Comparisons between the groundwater measurements and the corresponding relative-elevation values at all but two of the piezometer locations reveal close agreement ($\leq$1 ft difference), indicating that use of the relative elevation surface to estimate depths to groundwater is an appropriate method for restoration planning in the Gila Valley. The two locations with greater differences (>1 ft) are believed to be caused by recording error in the GPS-recorded coordinates, for which we recommend re-taking of the coordinates during future monitoring efforts.

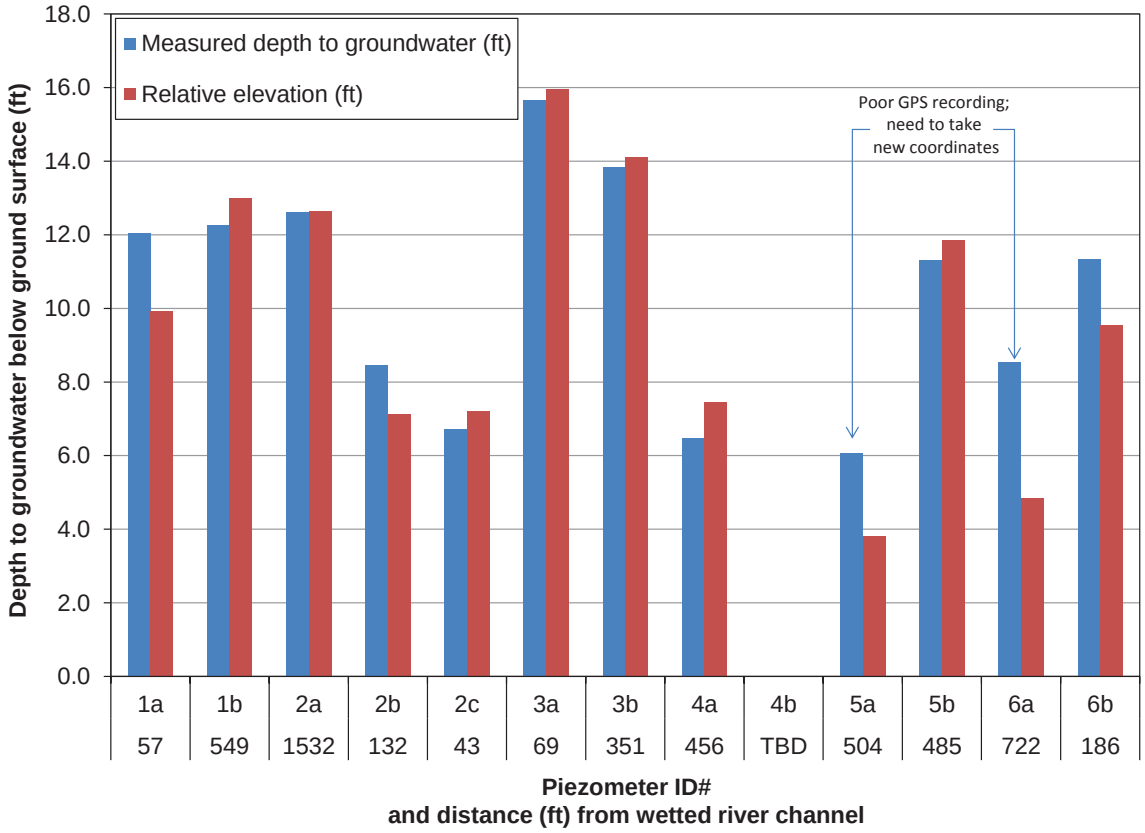


Figure 2-10. Plot of measured groundwater depths in the Planning Area taken in January 2014. Measurements are compared to relative ground-surface elevations above the low-flow river channel water surface elevation.

2.6 Potentially Suitable Vegetation Restoration Areas

Here we describe how the results of the ecohydrological assessment and its supporting studies were synthesized to identify areas within the Planning Area's riparian corridor having the greatest potential for effective and successful native vegetation restoration. Briefly, the "Potentially Suitable Vegetation Restoration Areas" were based on those areas of the riparian corridor outside of the Flood Reset Zone, near modeled high-quality SWFL habitat, within non-saline to slightly saline soils, and within low-lying areas relative to the low-flow channel. Vegetation-growth potential was used to further refine the priority areas into those having highest and medium priority. The analysis was performed in a GIS using spatial data for the environmental factors having restoration-suitability criteria pre-determined during our field surveys and related analyses. The environmental factors considered and methods of the data synthesis are described below. Figure 2-11 graphically describes the data-synthesis process.

Although not included here, it is important to note that many other ecological factors, including shade tolerance and other competitive abilities, proximity to seed source, intensity of herbivory, and presence of disease, can contribute to the success of plant establishment and species distributions within riparian zones and should be considered when determining site-specific restoration activities. In addition, this level of screening does not incorporate a variety of other important factors that will need to be considered in identifying specific sites and priorities for the next phase of restoration planning, design, and implementation. Such factors include, but are not limited to, landowner willingness, existing conservation easements or related land use requirements, presence of key infrastructure, water rights, and initial and long-term costs and maintenance requirements.

Riparian corridor

Areas considered suitable for active restoration were within the boundaries of the Planning Area's riparian corridor. The riparian corridor was mapped in GIS using color aerial imagery collected by USU RS/GIS in October 2012 and was based essentially on the existing river bottom comprised of the active channel and forested portions of the valley floor, including a few well-connected tributary mouths. The riparian corridor did not include cultivated or urbanized floodplain or other upland areas.

Flood Reset Zone

Suitable active vegetation restoration areas would generally be those found safely outside of the Flood Reset Zone, which was mapped during the flood-scour analysis previously described in Section 2.2 Flood-Scour Analysis and shown in Figures B-2.1 through B-2.10. Again, the Flood Reset Zone includes areas having both >66% flood-scour frequency (i.e., scoured in 3 out of 3 of the mapped events [1983, 1993, and 2005]) *and* "high" flood-disturbance activity—areas severely disturbed by flow, typically scoured to bare substrate retaining <10% apparent riparian vegetative cover—during the most recent flood of 2005.

Modeled SWFL habitat

Suitable vegetation restoration areas would be those found near areas modeled to currently host high quality SWFL habitat, which was represented in the "SWFL Satellite Model" results described in Section 2.4.2 SWFL Breeding Habitat Modeling and Appendix F, and shown in Figure F-2. Because the high quality areas correspond strongly with vegetation density and, as already understood, the riparian vegetation is mostly composed of tamarisk, it is anticipated that these areas will experience the greatest impact initially following beetle colonization unless strategic planting of native vegetation is undertaken in 2014–2015.

Shallow groundwater depth (relative elevation)

Existing information in the scientific literature and personal observations and unpublished data indicate that native riparian plant species tend to occur in particular topographic positions relative to the river channel. In particular, we have found that relative elevation above the low-flow, or baseflow, water surface in the river channel is a useful indicator for restoration potential. Relative elevation in a floodplain is generally correlated with depth to groundwater, and frequency of surface saturation and inundation.

Thus relative elevation, which combined with other GIS layers and field data, provides a powerful tool for assessing restoration potential via passive (natural recruitment processes) or active (horticultural restoration) approaches. Although successful germination of native riparian seedlings depends on a variety of hydrologic and geomorphic variables, seedling survival of phreotophytes such as cottonwoods and willows following germination (or of planted cuttings or container stock under horticultural restoration) is above all contingent on constant contact with the water table and/or its capillary fringe throughout the growing season (McBride and Strahan 1984, Stromberg et al. 1991). Research indicates that when the water table decline is more rapid over a long period than the rate of root growth, seedlings of phreatophytic species become isolated from their water source and suffer high mortality (McBride et al. 1989, Stromberg et al. 1996). In addition to the importance of groundwater levels for seedling survival, research indicates that groundwater levels play an integral role in determining sapling survivorship and adult riparian community composition (Smith et al. 1991).

Furthermore, comparative studies indicate that some non-native invasive plant species (such as tamarisk) tend to be more drought-tolerant than natives, and thus better able to compete along reaches with extreme inter- and intra-annual water table fluctuations (Smith et al. 1991, Friedman et al. 1995, Shafroth et al. 1998, 2000). Thus, in order to restore self-sustaining hardwood riparian forest, we need to better understand the role of groundwater in species survivorship across time and across species.

In the absence of a Planning Area-wide compilation of shallow groundwater levels, relative elevation can serve as a very useful proxy. As previously mentioned in Section 2.5.2 Groundwater-level monitoring, we produced a relative-elevation surface using the available LiDAR data. The initial groundwater measurements shown in Figure 2-10 (and further described in Appendix G) helped to validate the use of the relative elevation surface to estimate depths to groundwater in the Planning Area. Our vegetation-transect surveys described in Section 2.3 Riparian Vegetation Characterization found that native willows and cottonwoods are most numerous upon surfaces situated within 4 m of the low-flow channel (see Figures 2-8 and 2-9). **Therefore, suitable areas for active restoration included those lying within the 0–4 m elevation range above the low-flow channel.** These areas were delineated for the ecohydrological assessment using the bare-earth LiDAR data.

Soil salinity

Analysis of soils data contributes to more realistic projections of potential woody riparian vegetation expected under various management scenarios, as we can exclude areas with soils unsuitable for hardwoods such as cottonwoods and willows by using NRCS information on salinity at the reach scale. By linking our understanding of natural riparian vegetation recruitment processes and native woody plant life history requirements with soils information, our predictions of locations and total area suitable for passive revegetation (i.e., revegetation via restoration of natural seed dispersal/germination/root growth/inundation and water table recession processes) can be made more reliable. However, our primary purpose in the present analysis is to use soils

data to explore the potential for use of active revegetation techniques (i.e., horticultural restoration) to establish various native riparian trees, shrubs, and herbaceous species in the study area to restore or enhance suitable habitat for SWFL and other wildlife species of interest.

Salinity tolerances reported for plant species common to the Planning Area area described in Appendix D. Species such as cottonwood, narrowleaf willow, and Goodding's willow have a "None" to "Low" tolerance for saline soils, whereas some other native woody riparian (e.g., *Baccharis* spp.) and upland species (e.g., *Atriplex* spp.) have "High" tolerance (see Table D-1). The tolerance categories are as follows:

- None (i.e., minimal tolerance): 0–2 mmhos/cm
- Low: 2–4 mmhos/cm
- Medium: 4–8 mmhos/cm
- High (i.e., maximum tolerance): >8 mmhos/cm

While the soil sampling efforts in the Ft. Thomas area provided initial confirmation that salinity levels were generally low and will likely not pose an issue to active plantings, we utilized the NRCS's SSURGO spatial dataset to locate saline soils throughout the entire Planning Area. Again, soil salinity was based on the EC attribute in the SSURGO dataset (section 618.20 of NRCS Soil Properties and Qualities). Salinity classes present within the Planning Area include:

- Non-saline: 0–<2 mmhos/cm
- Very slightly saline: 2–4
- Slightly saline: 4–8
- Moderately saline: 8–16
- Strongly saline: >16

Suitable areas for active restoration included those with soils having non-saline to very slightly saline conditions, and excluded those areas with soils having slightly saline to strongly saline conditions. Overall, the vast majority of the riparian corridor was composed of soils of lower salinity and alkalinity.

Vegetation canopy height

The Planning Area is dominated by dense stands of tamarisk, particularly downstream of Pima, with smaller patches of Goodding's and narrowleaf willows, Fremont cottonwood, and other native vegetation (see Section 2.3 Riparian Vegetation Characterization above). The main patches of Fremont cottonwood and Goodding's willow can be identified in a GIS using vegetation canopy height information derived from the LiDAR data. Specifically, the canopy surface is formed from the first-return data points contained in the LiDAR data (as opposed to the bare-earth data). Mature trees of Fremont cottonwood and Goodding's willow tend to form an emergent crown greater than 7 m in height, which extends above the typically dense layer of tamarisk, so we can readily pick up individual trees and stands by mapping all vegetation >7 m in canopy height. Most tamarisk stands do not exceed 5 m in canopy height, but in the most productive sites taller plants are found and canopy height may be in the 5–7 m range. If other factors (such as relative elevation and soil salinity) are suitable, these taller, more productive tamarisk stands can be used as an indicator of areas likely to be suitable for revegetation by native woody species. The relationships between vegetation canopy height and presence of Fremont cottonwood and Goodding's willow, and likely restoration potential, are also supported by our

November 2013 vegetation-transect surveys and careful review of natural color aerial imagery collected by USU RS/GIS in October 2012.

Using canopy height as a proxy for vegetation productivity potential, the Potentially Suitable Vegetation Restoration Areas determined from synthesis of above environmental factors were further refined based on canopy height criteria to locate areas having the highest and medium priority for immediate, active restoration; the remainder being considered to have the lowest priority. That is, **the high and medium priority areas included those areas having lower-lying elevations (i.e., shallow water table) and tall canopy heights (i.e., most productive for woody vegetation growth).** The criteria were as follows:

- "High" restoration priority:
  - Relative elevation = <0–0.5 m and Canopy height = >5 m
  - Relative elevation = 0.5–2 m and Canopy height = >7 m
- "Medium" restoration priority:
  - Relative elevation = 0.5–2 m and Canopy height = 5–7 m
  - Relative elevation = 2–3 m and Canopy height = >5 m

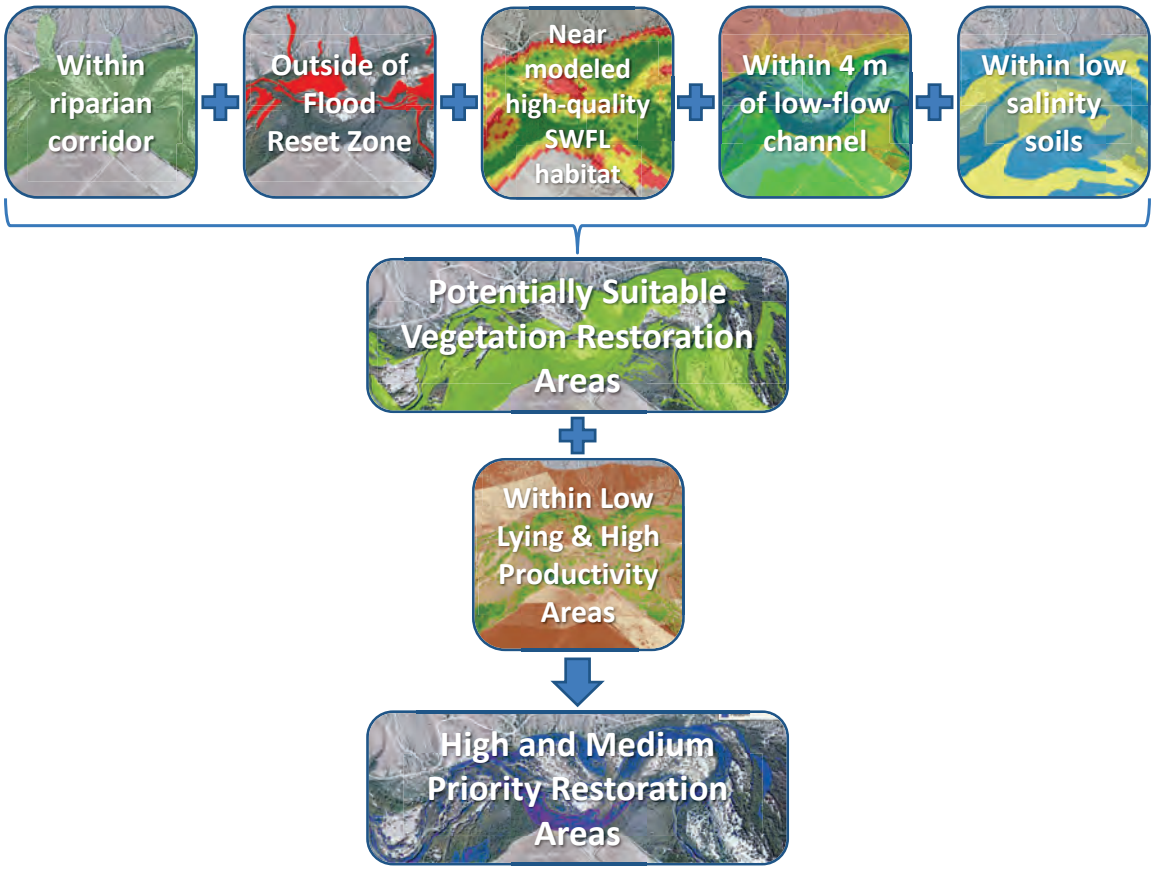


Figure 2-11. Process of the Ecohydrological Assessment to identify the Potentially Suitable Vegetation Restoration Areas in the Planning Area.

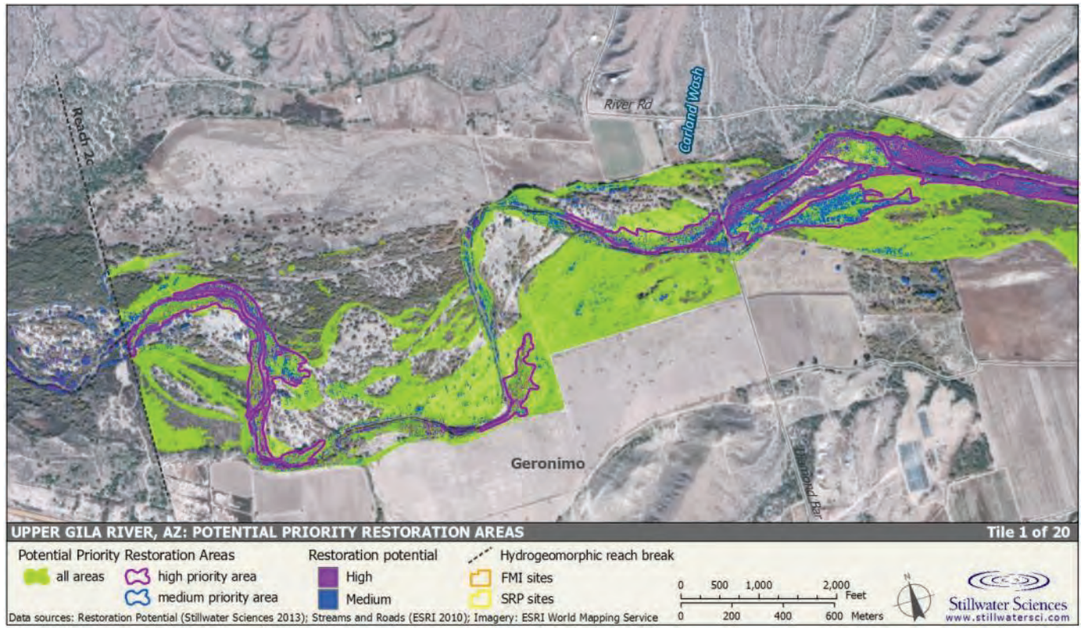
The above analysis resulted in a series of map tiles of the Potentially Suitable Vegetation Restoration Areas (green) along the riparian corridor within the Planning Area. Also produced were distributions of color-coded pixels representing points of "High" (purple) or "Medium" (blue) restoration potential. The pixel-distributions displayed discrete groupings of suitable areas that were finalized by manually encircling groupings larger than 10 acres with polygons of the same priority classification.

The High and Medium Priority Restoration Areas are presented in Figure 2-12 below. Also shown for reference on the maps are the previously established restoration/mitigation sites managed by Freeport McMoRan Copper & Gold, Inc. (FMI) and the Salt River Project (SRP).

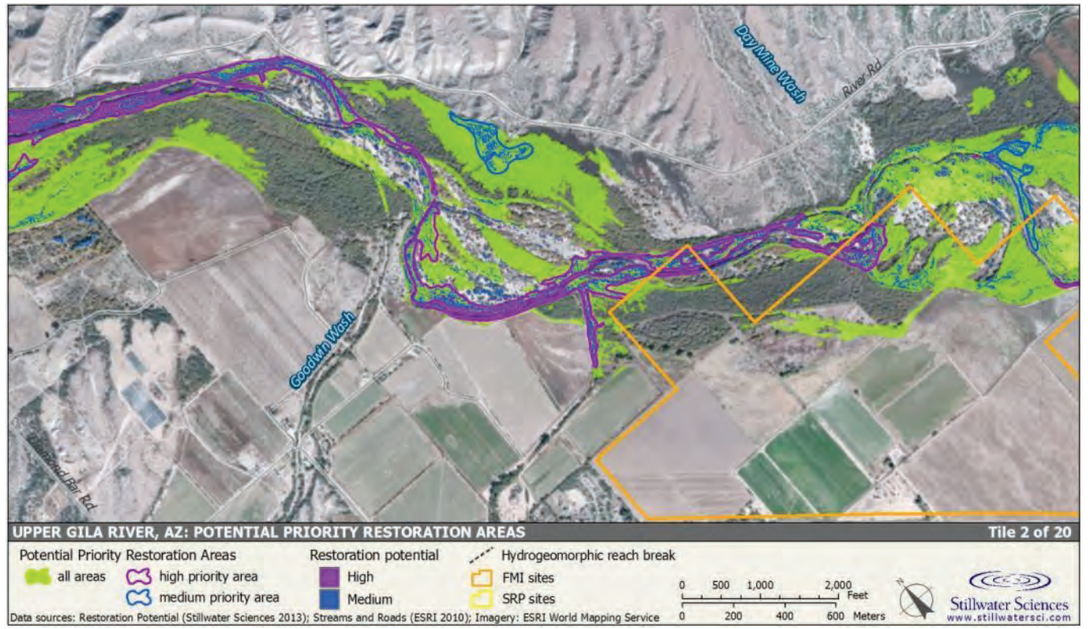
The results shown in the below maps reveal that nearly half, or 42%, of the riparian corridor qualifies for inclusion in the general Potentially Suitable Vegetation Restoration Area category, amounting to about 4,800 total acres (Figure 2-13). The size of the areas within any given hydrogeomorphic reach generally increases with downstream direction, with those below Thatcher (reaches 2c–2f) each having more compared with those reaches upstream of Thatcher (reaches 2g–3a). Further, the areas accounted for at least half of the riparian corridor in each of the lower reaches (2c–2f), while areas accounted for as low as a tenth of the riparian corridor in the upper reaches and were generally confined to the outer margins of the corridor (e.g., 2j and 3a). Not surprisingly, the High and Medium Priority Areas were more abundant in the lower reaches, and were all but absent in the upper reaches by virtue of there being minimal low-lying areas supporting tall woody vegetation. In total, the High and Medium Priority Areas each account for nearly 400 acres (750 acres in total)—a manageable size for rapid active restoration involving tamarisk removal and native re-planting in 2014.

While the results presented here are based upon the best available science, we caution any potential user of these results that the areas identified here have been done so without regard to land ownership or owner interest. The GWP or others with plans to implement tamarisk treatment and/or vegetation restoration will still need to consider site-specific opportunities or constraints related to nearby land uses.

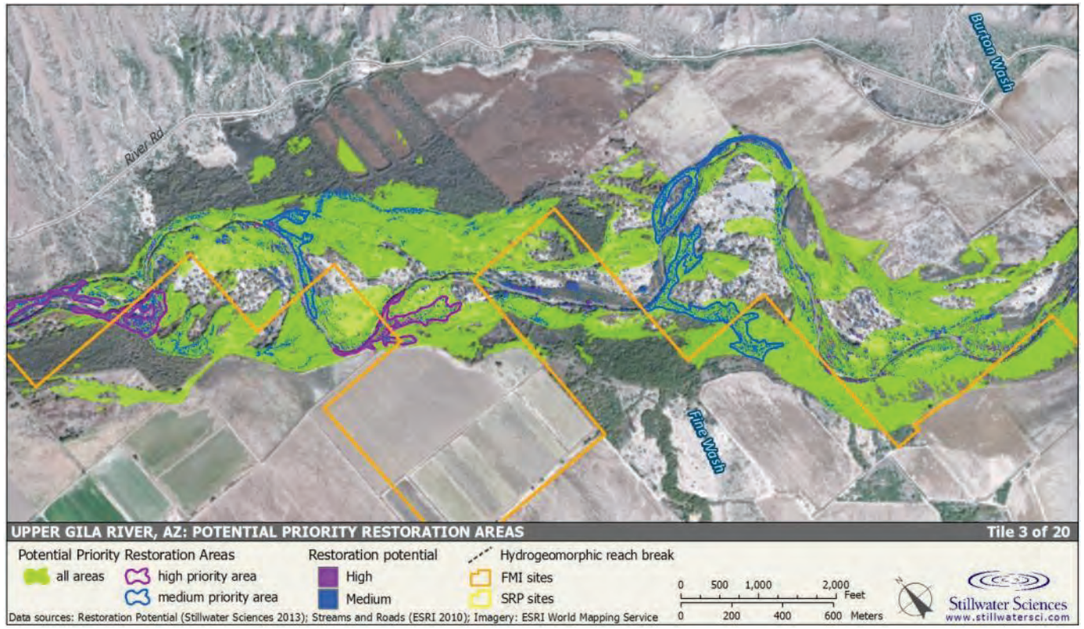
a)



b)



c)



d)

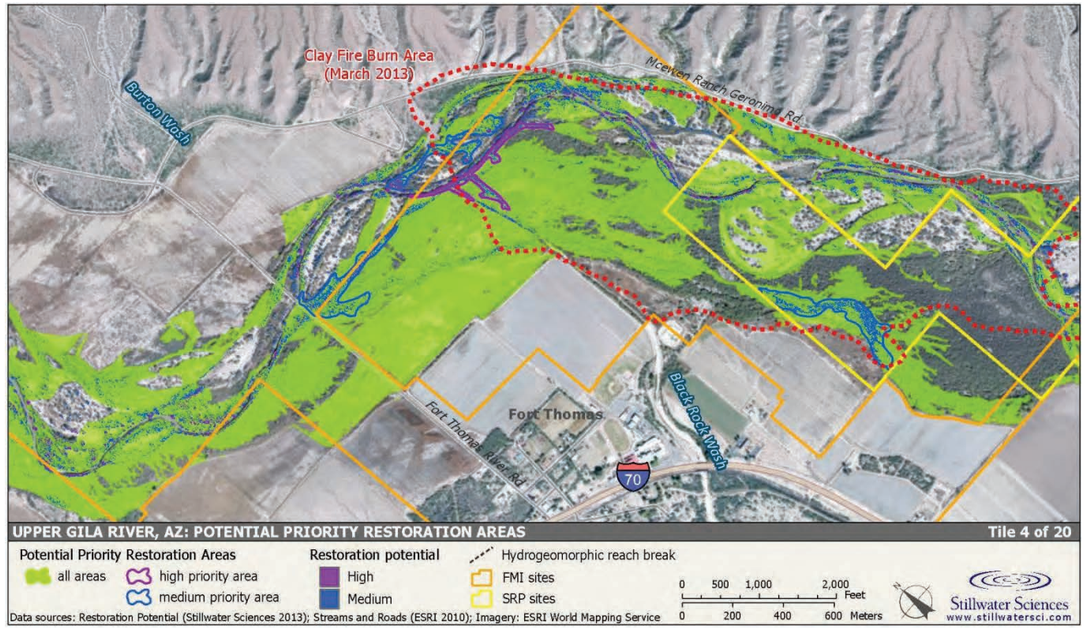
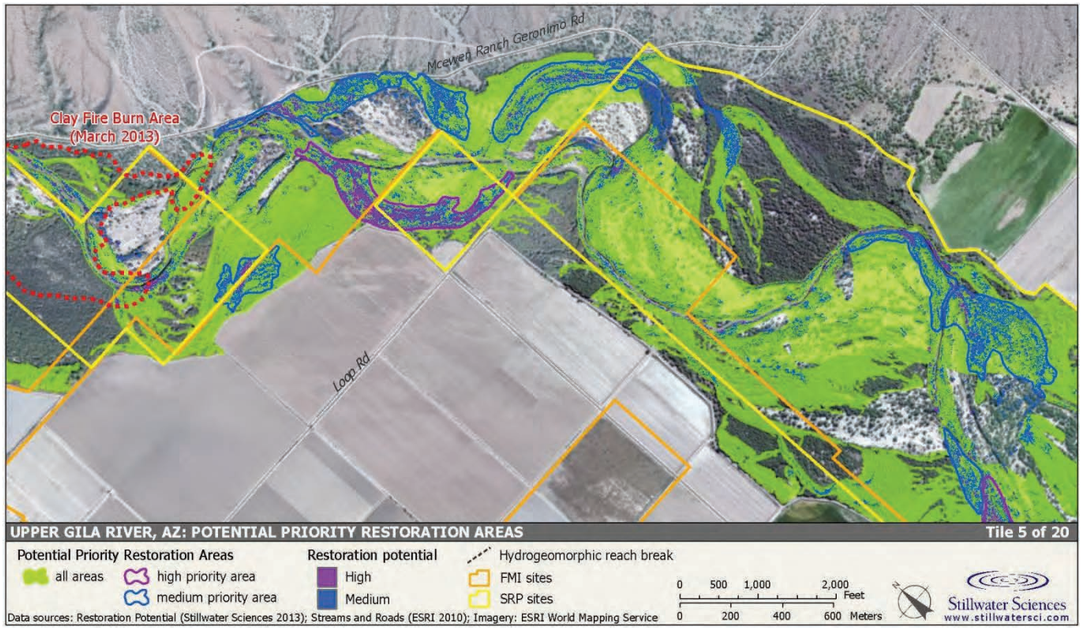
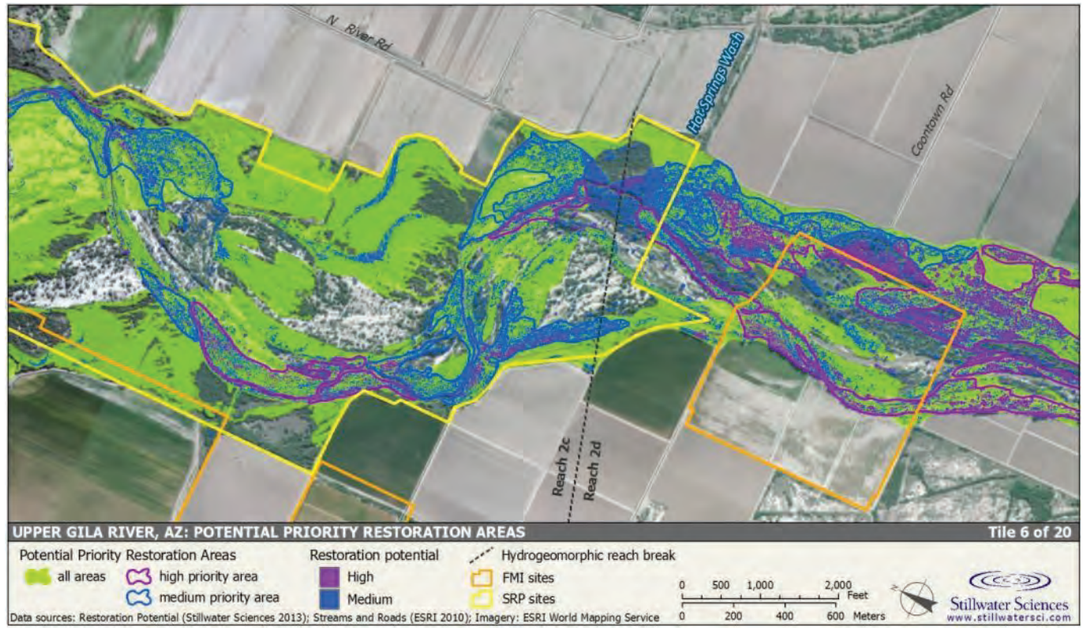


Figure 2-12.1. Upper Gila River Potentially Suitable Vegetation Restoration Areas for lower Reach 2c. See map-tile index in Figure B-1 in Appendix B.

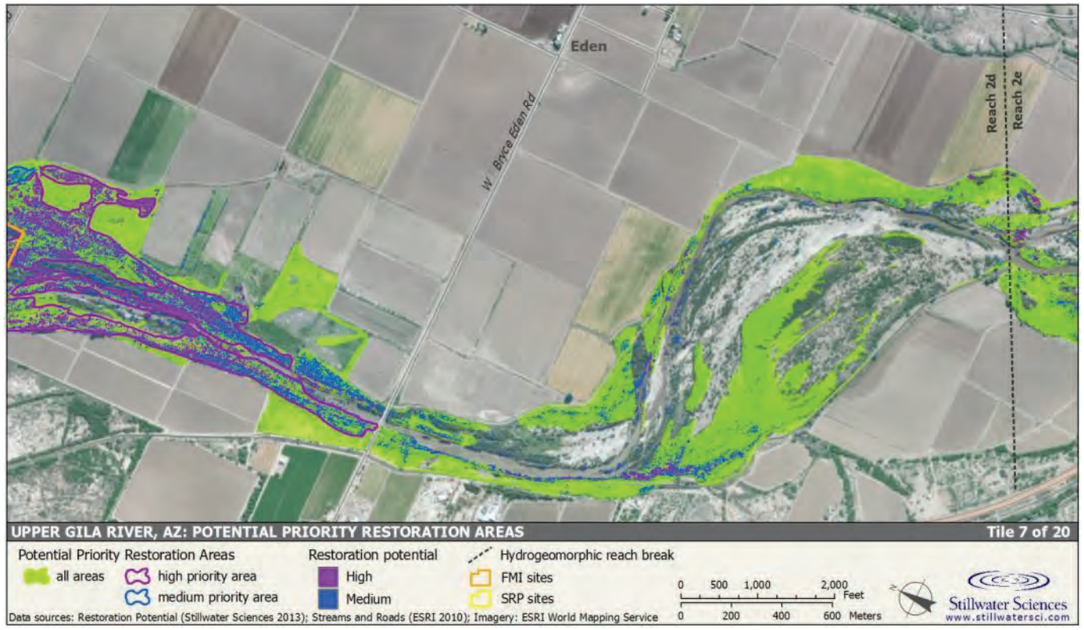
a)



b)



c)



d)

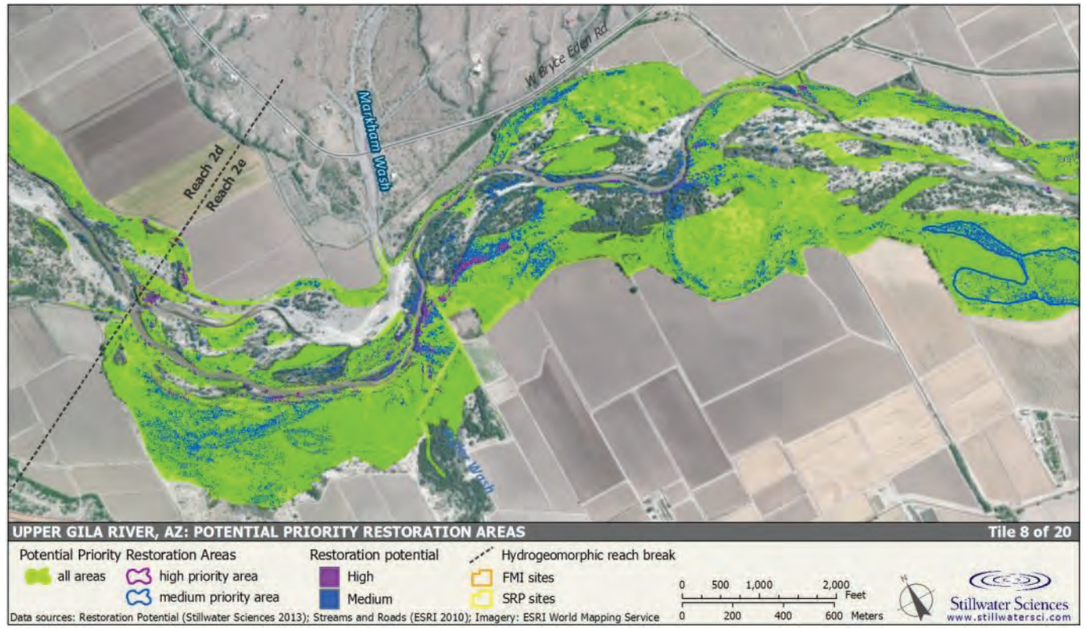
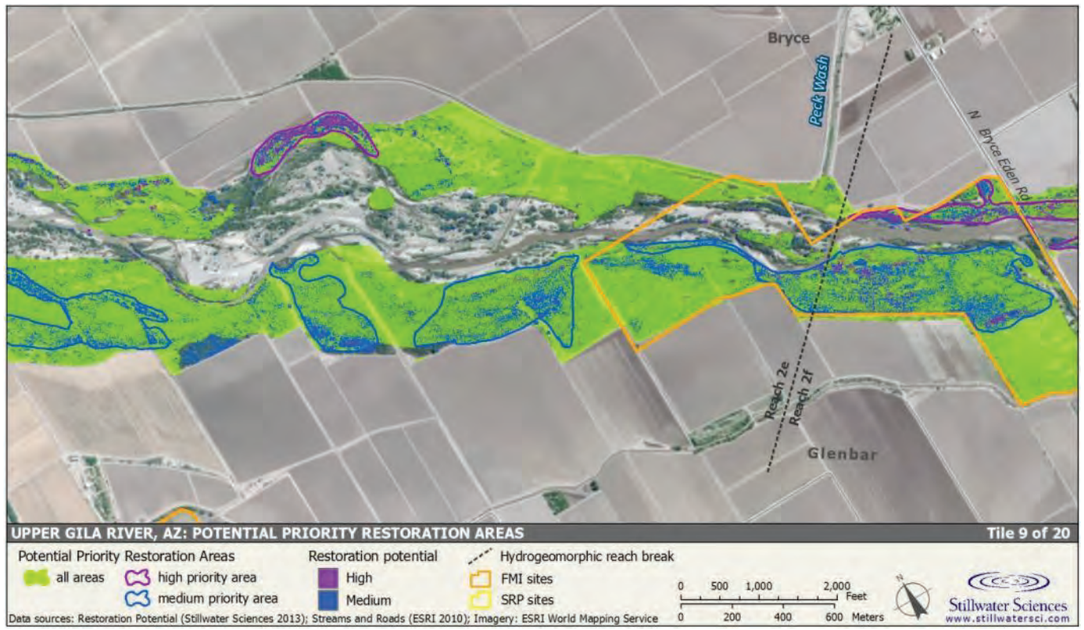
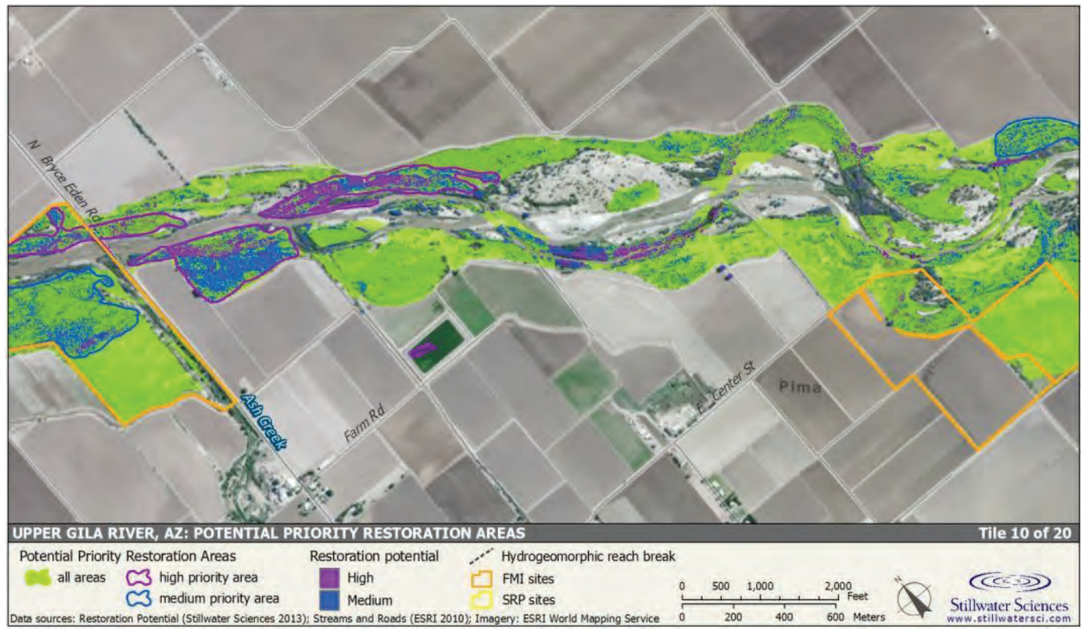


Figure 2-12.2. Upper Gila River Potentially Suitable Vegetation Restoration Areas for upper Reach 2c upstream to lower Reach 2e. See map-tile index in Figure B-1 in Appendix B.

a)



b)



c)



d)

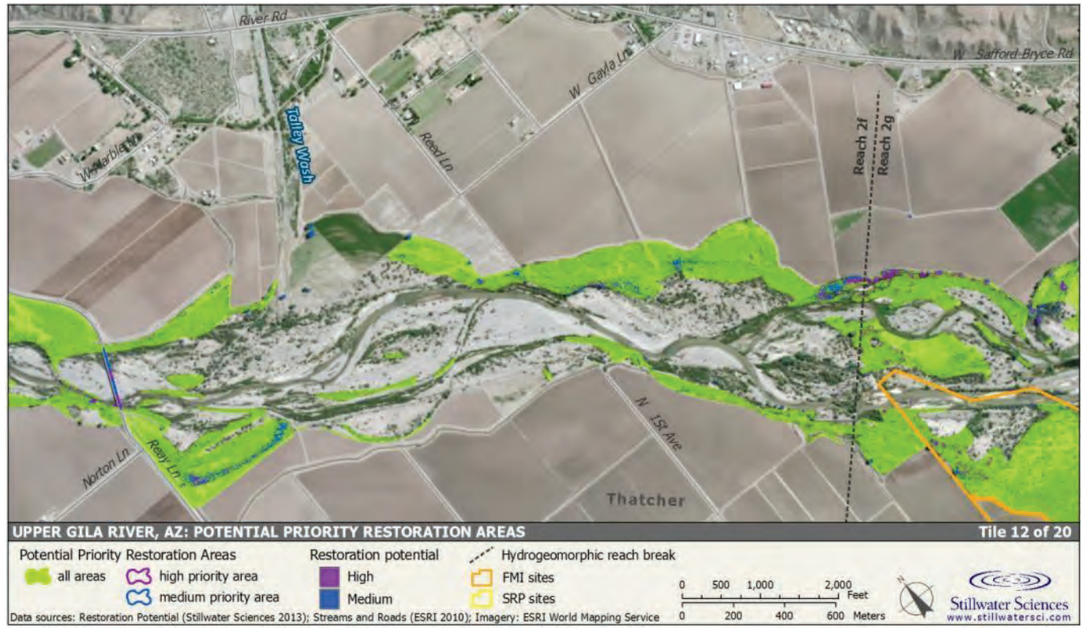
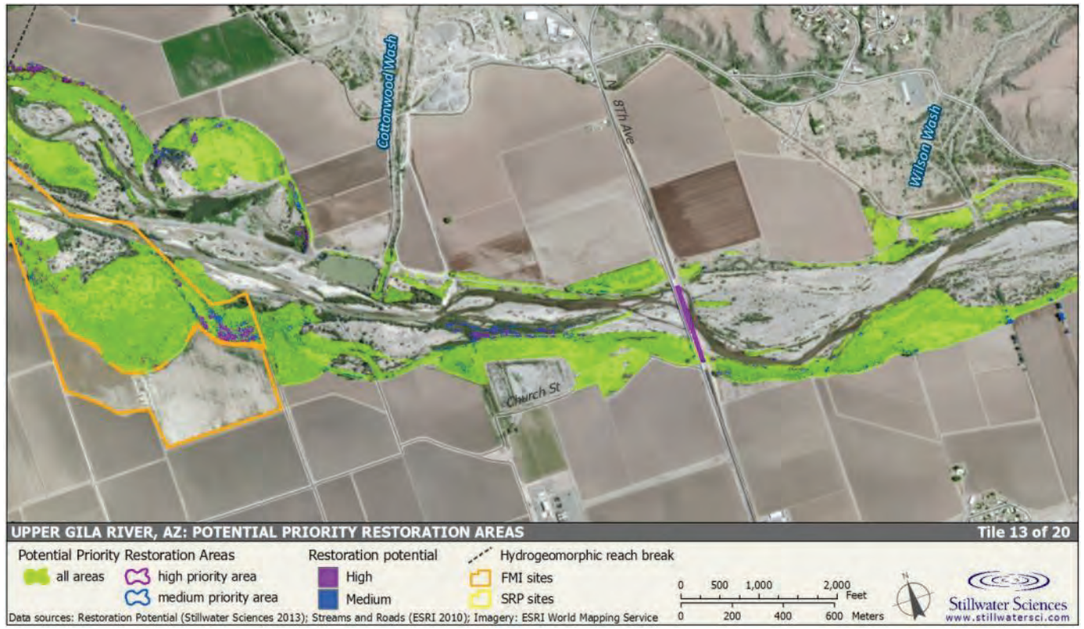
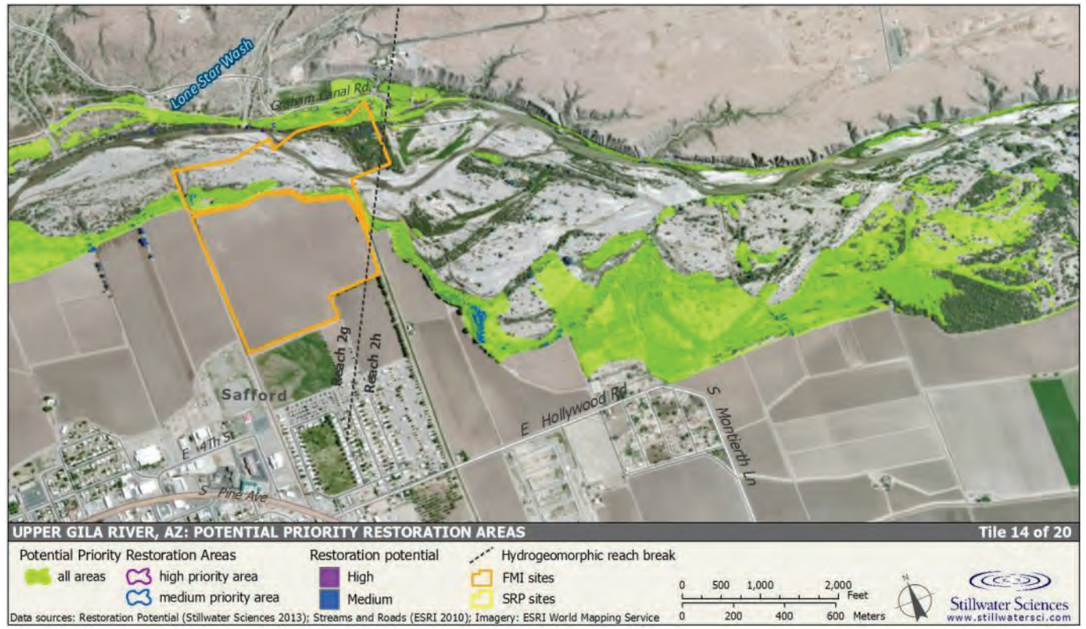


Figure 2-12.3. Upper Gila River Potentially Suitable Vegetation Restoration Areas for upper Reach 2e upstream to lower Reach 2g. See map-tile index in Figure B-1 in Appendix B.

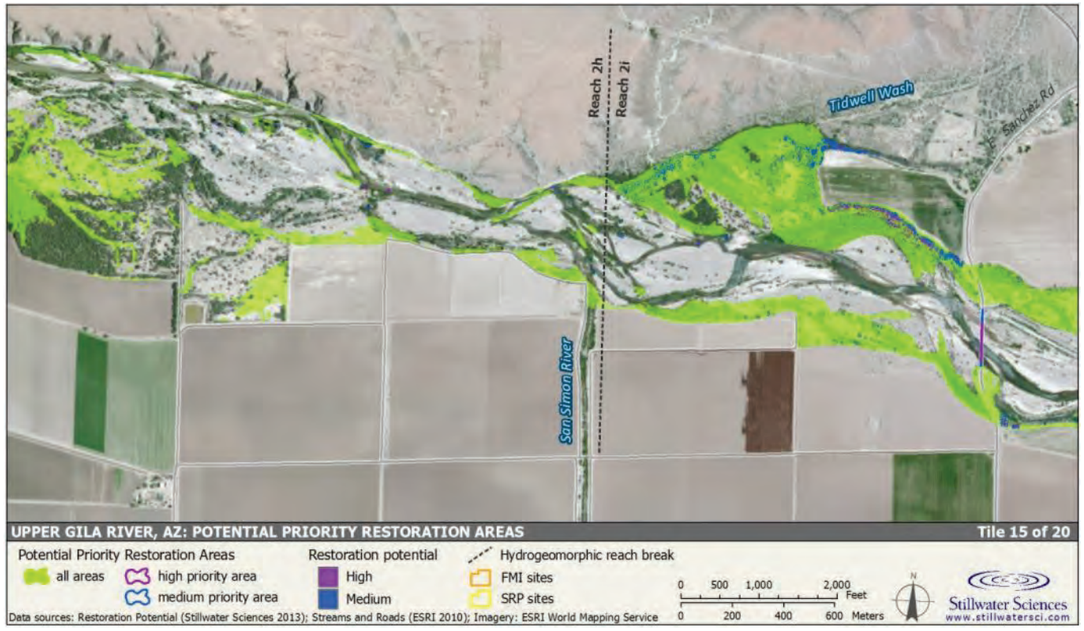
a)



b)



c)



d)

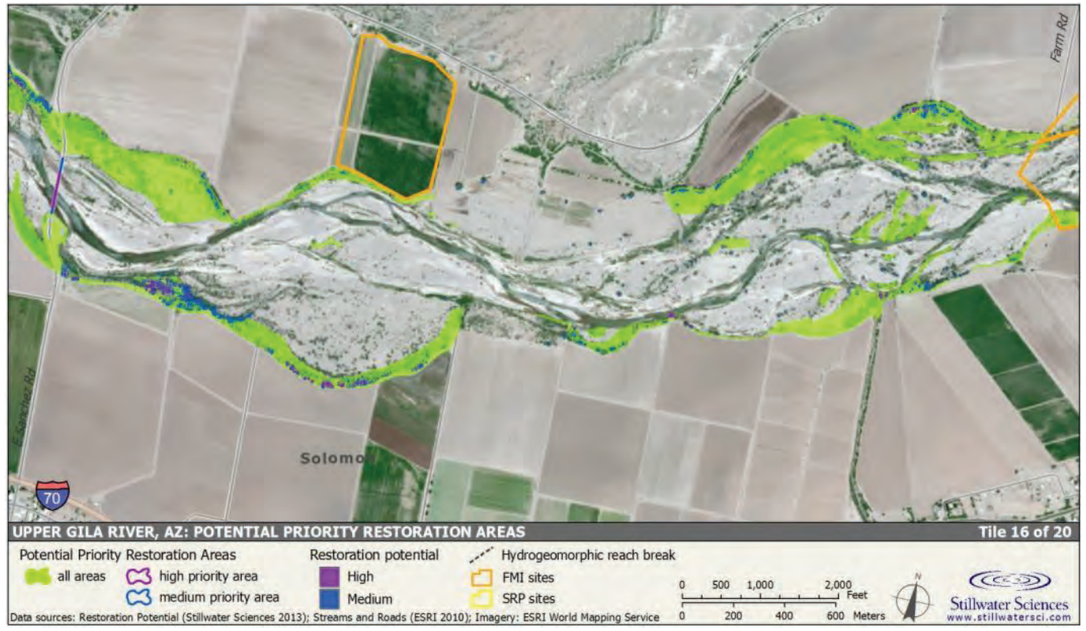
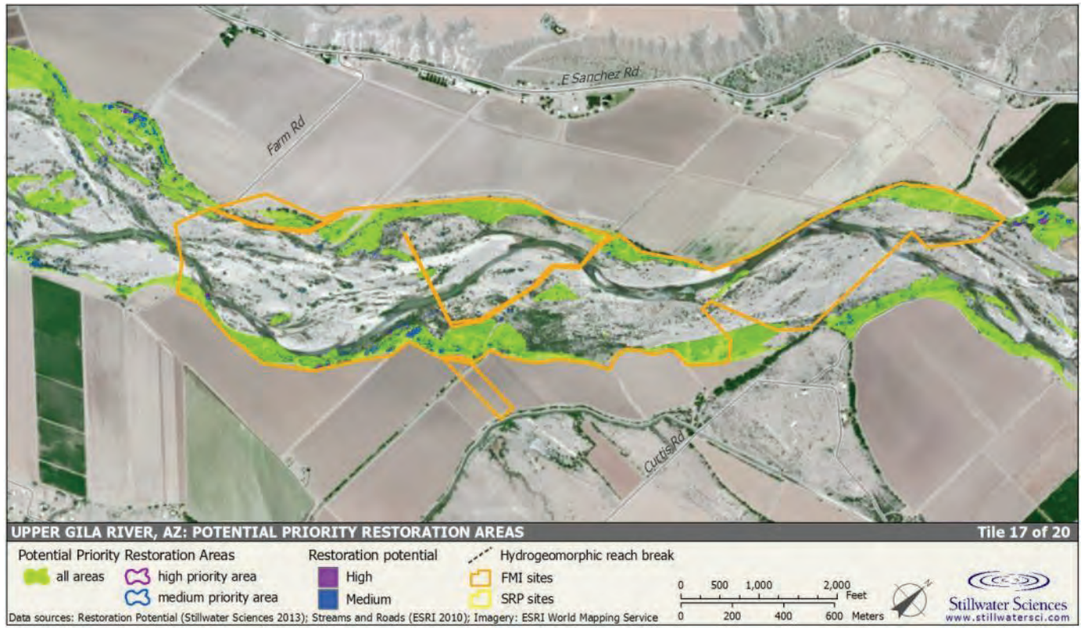
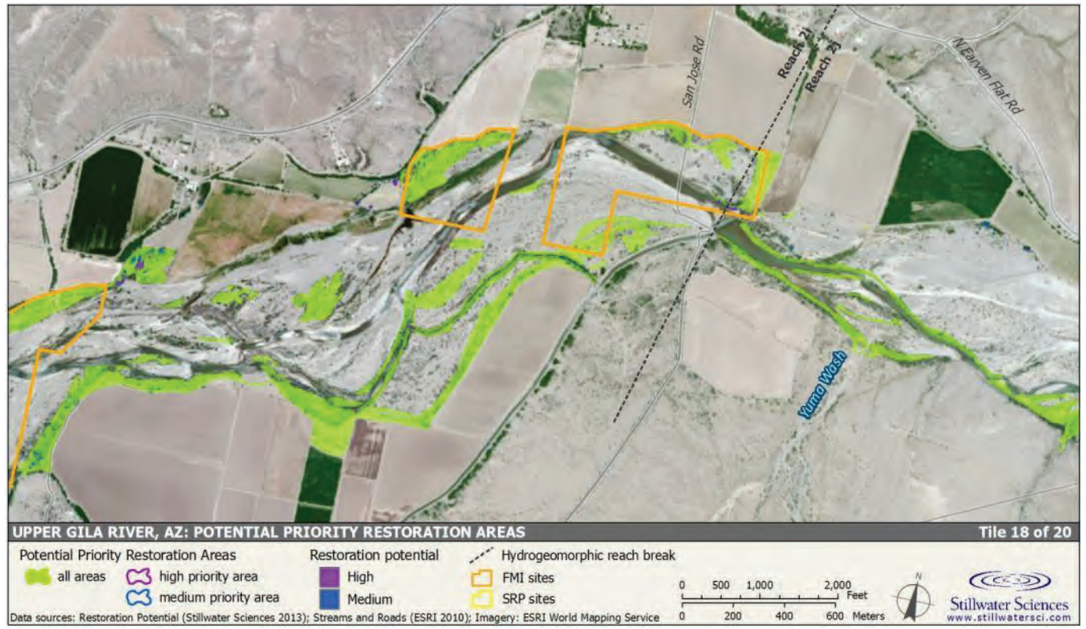


Figure 2-12.4. Upper Gila River Potentially Suitable Vegetation Restoration Areas for Reach 2g upstream to lower Reach 2i. See map-tile index in Figure B-1 in Appendix B.

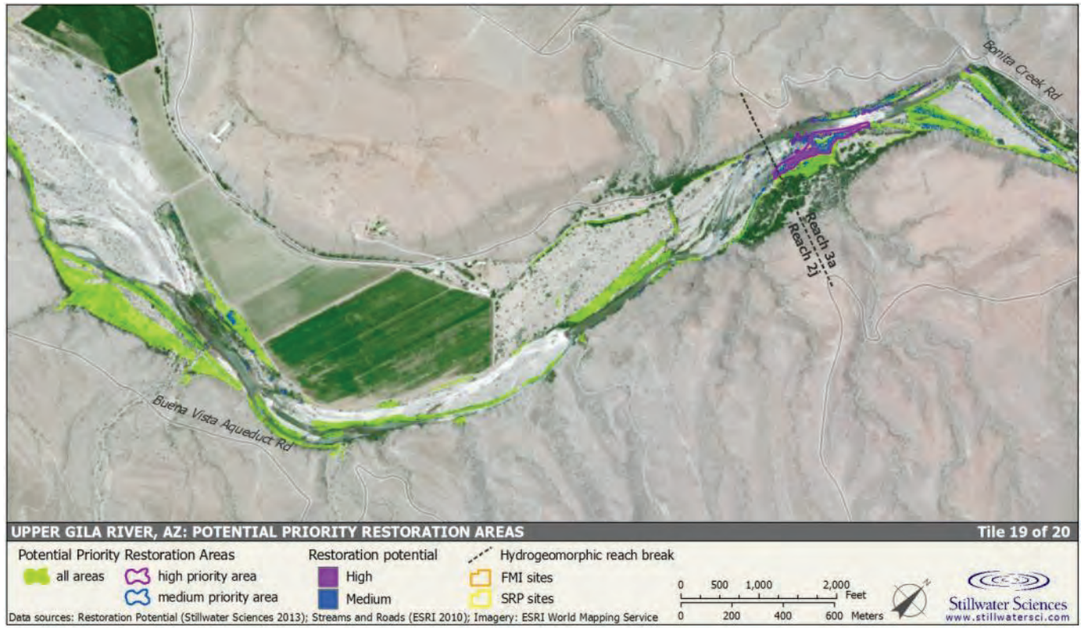
a)



b)



c)



d)



Figure 2-12.5. Upper Gila River Potentially Suitable Vegetation Restoration Areas for upper Reach 2i upstream to Reach 3a. See map-tile index in Figure B-1 in Appendix B.

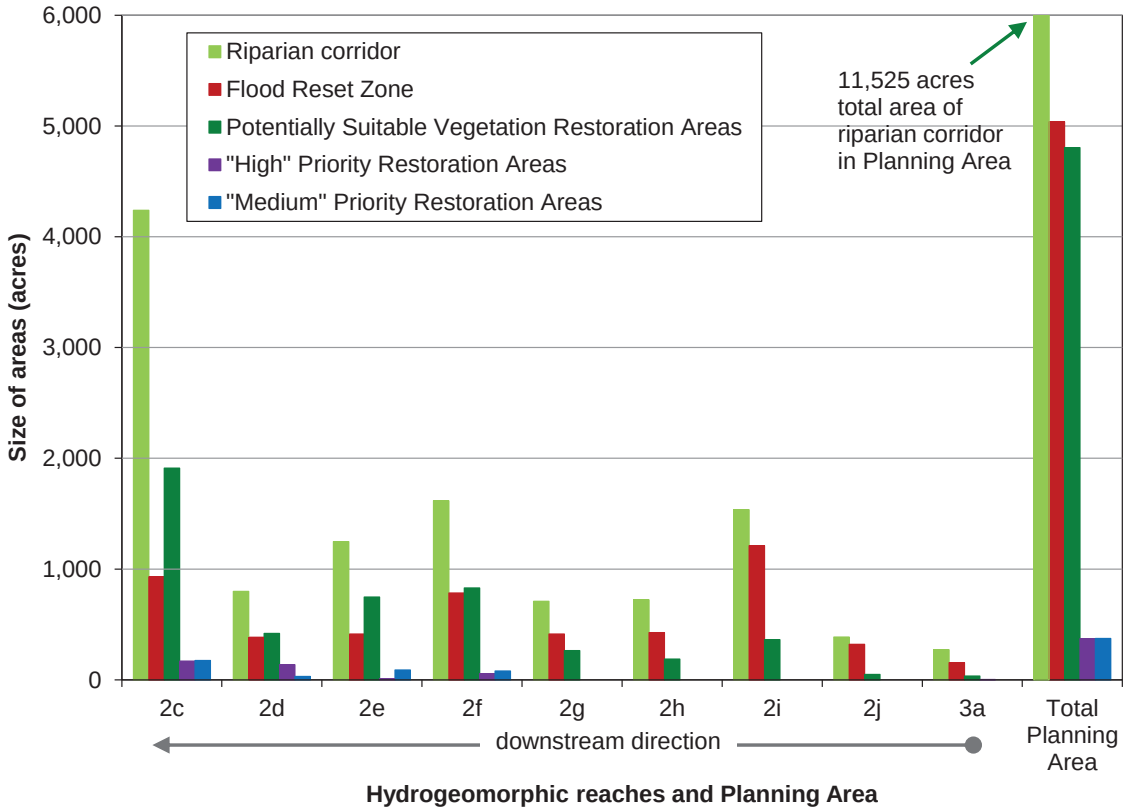


Figure 2-13. Histogram of sizes of the riparian corridor, Flood Reset Zone, and Potentially Suitable Vegetation Restoration Areas within the Planning Area and each of the hydrogeomorphic reaches.

3 SUMMARY OF FINDINGS AND RECOMMENDATIONS

This chapter presents a synthesis of the results of our ecohydrological assessment and supporting studies conducted as part of the Restoration Framework. The results have been integrated to identify restoration opportunities and constraints that, together, inform recommendations to be incorporated into the Restoration Implementation Plan to be authored by the Gila Watershed Partnership.

3.1 Summary of Ecohydrological Assessment and Other Information

Planning for any manner of riparian restoration in the tamarisk-dominated Gila Valley will require consideration of the following environmental factors:

Hydrogeomorphic conditions

- The upper Gila River naturally experiences a wide variation of flows, punctuated episodically by short-duration ("flashy") but intensive flood events most frequently experienced in March (winter storms) and August (summer monsoons).
- Three distinct hydrologic periods have been recorded over the past hundred years, beginning with a flood period in the early 20th century, followed by a relatively quiescent ~50-year period between about 1918 and 1965, and a ~40-year period of larger, more frequent flood events through at least 2005.
- The potential for channel-scouring floods to occur in any given year remains high despite an apparent lessening of large flood occurrence since the 1990s. Climate change predictions for the region estimate a likely increase in extreme events despite the expected increase in average temperatures and decrease in annual precipitation.
- Three dominant hydrogeomorphic reach characteristics are observed in the river corridor as it courses downstream through the Planning Area: a canyon-confined, coarse-grained channel with limited floodplain and some native riparian forest at the mouth of the Gila Box (reach 3a); a wide, drier, braided channel with sparse or disconnected riparian forest bordered by a broad, cultivated and developed floodplain (reaches 2f–2j); and a moister, fine-grained, braided channel dominated by a narrow, single-thread channel during lower flows that is encroached upon by dense riparian forest (mostly tamarisk), which is in turn bordered by a broad, cultivated floodplain with few developments downstream of Pima (reaches 2c–2e).
- River hydrology and geomorphic character are strongly influenced by the 6 irrigation canal diversion dams, 6 bridge crossings, and network of earthen levees which together modify the natural flow regime and potential for geomorphic change.

Flood-scour dynamics and risks

- Position of the low-flow channel(s) changes rapidly and completely during flood events, while the boundary of the broader active-channel changes less frequently.
- Flood-scour extent has generally been greater upstream of Pima, with an overall decreasing trend in the extent of the "high" (>66%) frequency flood-scour area in the downstream direction.
- Similarly, the areal extent of the Flood Reset Zone experiences a decreasing trend in the downstream direction below the Gila Box (i.e., reaches 2c–2j), where the Flood Reset

Zone accounts for over 80% of the riparian corridor near the upstream end of the Planning Area (reach 2j) and only about 20% near the downstream end (reach 2c).

- Restoration opportunities outside of the Flood Reset Zone are greater downstream of Pima (reaches 2c–2e) (i.e., more than half of the riparian corridor is available).

Vegetation conditions

- The riparian corridor currently supports mostly tamarisk-dominated shrublands, although several other vegetation types are present, including Fremont cottonwood-Goodding's willow woodland and narrowleaf willow-mulefat shrubland.
- There are pronounced variations in vegetation composition and distribution along the length of the riparian corridor in the Planning Area:
  - The upstream end of the Planning Area (reaches 2j and 3a above the San Jose Diversion Dam) hosts a higher proportion of native species and greater potential for natural recruitment, which appears to be correlated with a minimal presence of adjacent agriculture and little consumptive water use.
  - The middle of the Planning Area (reaches 2f–2i between the San Jose Diversion Dam and Pima) is sparsely vegetated, likely due to a greater influence of water diversion and larger extent of flood-scour activity.
  - The downstream end of the Planning Area (reaches 2c–2e below Pima) supports a much denser riparian cover, albeit mostly tamarisk, benefiting from more abundant agricultural return flow and less pronounced flood-scour activity.
- The general pattern of vegetation composition and distribution across the riparian corridor is: mixed riparian shrubland/narrowleaf willow-mulefat shrubland in a narrow band closest to the wetted channel; tamarisk semi-natural shrubland/tamarisk-mixed riparian shrubland next out from the channel within low-lying areas; burrobrush wash/tamarisk wash sparsely distributed upon slightly higher surfaces; and mesquite bosque sparsely distributed upon the highest surfaces (see Figure 2-9).
- The two main native vegetation types, narrowleaf willow-mulefat and Fremont cottonwood-Goodding's willow, were observed to be most commonly present upon low-lying surfaces being within 3 m (10 ft) and 4 m (13 ft) relative elevation, respectively, above the low-flow channel water surface.
- Natural recruitment of native riparian tree and shrub species appears to be limited by high density of tamarisk coverage and water availability; much of the observed native tree and shrub stands appear to have been recruited in association with the 1993 flood event.
- Because revegetation success is strongly influenced by water availability and avoidance of flood-scour activity, restoration opportunities appear greatest downstream of Pima (reaches 2c–2e) where a greater variety of vegetation types could be successfully restored with minimal or no long-term irrigation.

SWFL conditions and model-predicted high-quality areas

- SWFLs continue to inhabit portions of the Planning Area during the breeding season (spring/summer), and are most commonly present in the more densely vegetated riparian areas (mostly consisting of tamarisk) downstream of Pima.
- Nests are typically placed in trees where plant growth is most dense, where trees and shrubs have vegetation near ground level, and where there is a tall but low-density canopy. SWFL are generally not found in areas without willows, tamarisk, or both.

- SWFL metapopultions are considered most stable where many connected sites or large populations exist and, thus, are more likely to improve by restoring/creating twice the amount of suitable breeding sites to distribute birds across a greater geographical range, minimize risk of simultaneous catastrophic population loss, and avoid genetic isolation.
- Similarly, it is necessary to restore/create additional breeding habitat given that its suitability is quite sensitive to hydrological and structural changes, such as water availability, human developments, flood and wildfire disturbance, and tamarisk leaf beetle induced defoliation.
- Based on the "SWFL Satellite Model," the predicted highest quality areas are concentrated downstream of Thatcher (reaches 2c–2f), which generally correspond with those areas densely vegetated and outside of the Flood Reset Zone.

Soils and groundwater conditions

- Surficial soils sampled near the Ft. Thomas area and mapped throughout the Planning Area by NRCS are primarily composed of medium-sized sands with variable proportions of finer-grained silts and sands and coarser-grained sands and gravels. Soil salinity is generally low and pH is slightly alkaline.
- Measured soil sampling results and published reach-scale NRCS soils maps indicate soil texture, salinity, alkalinity are within the range of tolerance for most native riparian plant species. Shallow soils should generally be able to support plantings of cottonwood, narrowleaf and Goodding's willow, and other native woody riparian (e.g., *Baccharis* spp.) and upland species (e.g., *Atriplex* spp.), but may be too saline and/or alkaline to in a few areas to support plantings of native cottonwoods and willows.
- Groundwater measurements made throughout the Planning Area reveal generally shallow depths to the water table (6–16 ft bgs), which remain fairly static across the width of the riparian corridor regardless of proximity to the wetted channel.
- Comparisons between the groundwater measurements and the corresponding relative-elevation values at all but two of the piezometer locations reveal close agreement ($\leq$1 ft difference), indicating that use of the relative elevation surface to estimate depths to groundwater is an appropriate method for restoration planning in the Gila Valley.

Restoration Area Suitability

- From the ecohydrological assessment, nearly half of the riparian corridor of the Planning Area was predicted to be suitable—"Potentially Suitable Vegetation Restoration Area"—for supporting active riparian restoration, amounting to about 4,800 acres.
- The "High" and "Medium" Priority Areas each account for nearly 400 acres (750 acres in total), which is a more manageable size for rapid and effective active restoration involving some level of tamarisk removal and native re-planting beginning in 2014.
- The Potentially Suitable Vegetation Restoration Areas are concentrated more downstream of Thatcher where flood-scour risks are lower, vegetation-growth potential is greater, SWFL habitat quality is greater, soil salinity and alkalinity are reasonably low, and lower-lying areas potentially supporting wetter soils are readily available.

3.2 Synthesis of Findings

Our recommendations for restoration site selection and strategies are as follows:

- Based on consideration of our ecohydrological assessment and supporting studies, highest priority for active tamarisk treatment and native plantings should be focused downstream of Thatcher within reaches 2c–2f.
- The property parcels predicted to contain the greatest amount of "High" and "Medium" Priority Restoration Areas (from the ecohydrological assessment) are listed in Table 3-1. Also listed is the acreage of the highest predicted SWFL-breeding habitat suitability (from the "SWFL Satellite Model") for each identified parcel. (It should be noted again that land-ownership and/or land-use conflicts may exist at any of these parcels which may limit or prevent any alteration of existing vegetation coverage.)
- More immediate restoration prioritization should be given to the most suitable locations within those parcels burned during the "Clay Fire" near Ft. Thomas in early 2013 (see bottom of Table 3-1) and more recently (e.g., the smaller burn area near Bylas). The riparian vegetation, mostly tamarisk, was highly impacted during the fire, thus priming it for rapid, cost-effective restoration action specifically involving herbicide treatment of the re-sprouting tamarisk and then replanting with native species.
- More intensive active riparian restoration should involve a phased, patch-work ("Propagule Islands") approach to: preserve much of the existing taller SWFL-suitable tamarisk structure (to minimize disturbances to existing viable SWFL-nesting habitat); remove/treat lower tamarisk structure (in patches) and replace with native plantings well suited to site conditions; and gradually expand treatment and revegetation footprint before and following beetle colonization.
- Lower effort restoration strategies should also be considered throughout the remainder of the Planning Area following disturbance from fires or floods that have removed much of the tamarisk biomass. Fire-contingent restoration actions such as herbicide applications on re-sprouting tamarisk and/or active planting of native species should be planned for Priority Areas downstream of Thatcher (reaches 2c–2f). Post-flood-scour restoration actions can follow a similar approach taking advantage of newly cleared areas to treat remaining tamarisk and/or revegetate with native species.
- Given the greater occurrences of native trees and shrubs, as well as nearly all occurrences of floodplain wetland, that appear to be highly influenced by channelized tributary and/or agricultural return flows, active restoration actions should attempt to take advantage of such conditions through selection of sites with a known steady runoff supply or coordination with land managers to negotiate a viable water supply where natural sources are insufficient. Such sites should have higher success rates for both revegetation of native riparian species (i.e., higher survival and growth rates for planted trees and shrubs) and for creating or enhancing SWFL habitat (i.e., presence of surface water or saturated soils during the breeding season).
- Prior to any treatment/removal activity, coordination with the Phoenix office of the USFWS will be necessary to first secure the prerequisite permits for carrying out such work that could potentially be considered an unauthorized "take" of SWFL or other federally listed fish or wildlife in the implementation area, or determines activities can safely be undertaken without risking take. GWP has already initiated discussions with USFWS regarding the least impactful restoration strategies in the Planning Area, and will commence with preparation of a Biological Assessment and Section 10(A)(1)(a) Recovery Permit in summer 2014.

- Creation of suitable SWFL habitat elsewhere in the Gila Valley, such as upstream of Thatcher, is also recommended as it would expand the existing areal extent of viable habitat and provide additional resiliency to the system following beetle colonization. However, it is recognized that such an effort would require some combination of earthmoving, soil conditioning, and/or irrigation to support active plantings and creation of suitable breeding habitat, thus necessitating more detailed site designs, grading plans, and environmental permits (e.g., USACE Section 404).
- Finally, pre- and post-implementation monitoring is recommended to evaluate restoration success (see Appendix G). Restoration site monitoring plans should focus on factors such as: vegetation composition, density, and structure; physical and chemical soil properties; soil moisture/depth to groundwater; and avian/wildlife occupation and re-occupation.

Table 3-1. Top 20 parcels in the Planning Area having the most predicted "High" and "Medium" Priority Restoration Areas.

Parcel number [a]	Hydro-geomorphic reach	Ownership type	Area of overlap (acres)		Proximity to SRP and FMI restoration sites
			"High" + "Medium" Potential Priority Restoration Areas [b]	Highest predicted SWFL-breeding habitat suitability [c]	
105-10-006B	2f	FMI	56	63	Overlaps FMI site RRSA4
109-40-002	2d	Private	30	21	Adjacent to south side of FMI site RRSA3
109-32-008B	2c	BOR	27	75	Overlaps SRP site BR/Hancock
109-39-003	2d	Private	26	41	Adjacent to southeast corner of FMI site RRSA3
109-32-006A	2c	BOR	25	69	Overlaps SRP site BR/Bellman
105-10-009	2f	Private	23	32	Adjacent to east side of FMI site RRSA4
109-33-006A	2d	Private	19	27	Adjacent to SRP sites BR/Bellman and BR/Hancock and to FMI site RRSA3
109-11-003	2c	Private	19	46	Overlaps SRP sites SRPCE1 and SRPCE2 and adjacent to south side of FMI site RRSA1 and north side of FMI site RRSA2
109-33-005B	2d	FMI	19	24	Overlaps FMI site RRSA3 and adjacent to south side of SRP site BR/Bellman
109-33-001D	2c	BOR	14	42	Overlaps SRP site BR/Bellman and adjacent to north side of FMI site RRSA3
105-27-002	2f	Private	14	0.4	Adjacent to FMI's Pima Habitat Mitigation Site
109-63-006	2e	Private	14	17	Adjacent to west side of

Parcel number [a]	Hydro-geomorphic reach	Ownership type	Area of overlap (acres)		Proximity to SRP and FMI restoration sites
			"High" + "Medium" Potential Priority Restoration Areas [b]	Highest predicted SWFL-breeding habitat suitability [c]	
					FMI site RRSA4
109-34-005A	2d	Private	14	23	Adjacent to east side of FMI site RRSA3
109-39-001C	2d	Private	13	16	Adjacent to southeast corner of FMI site RRSA3
108-19-002	2c	Private	13	44	Adjacent to east side of FMI's Habitat Mitigation Site
105-09-002	2f	Private	12	34	--
108-15-001	2c	Private	11	45	--
108-13-002	2c	Private	11	42	--
108-11-001	2c	Private	11	21	--
109-34-006A	2d	Private	11	21	Adjacent to east side of FMI site RRSA3
Parcels burned during March 2013 Clay Fire near Ft. Thomas (Fire Contingent Restoration Sites)					
108-25-008	2c	FMI	10	0.2	Overlaps SRP site SRPCE4 and FMI site RRSA1
109-12-005B	2c	FMI	5	0	Overlaps SRP site SRPCE4 and FMI site RRSA1
109-11-001	2c	FMI	0	6	Overlaps SRP site SRPCE1 and FMI site RRSA1
109-11-004	2c	FMI	0	0	Overlaps SRP site SRPCE4 and FMI site RRSA1

a. Source: Graham County Assessor's Office
b. Derived from Potentially Suitable Vegetation Restoration Areas from the ecohydrological assessment (see Figure 2-12)
c. Derived from the "SWFL Satellite Model's" highest quality classes (classes 4 and 5) (see Figure F-2 in Appendix F).

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Appendix A

Technical Documentation for Remote-Sensing Data Collection
– *USU RS/GIS*

Document will be submitted separately by USU RS/GIS

Appendix B

Flood-Scour Analysis Supporting Information and Maps – *Stillwater Sciences*

B1 INTRODUCTION

This appendix presents supplemental information on the methods and results of the flood-scour analysis performed for the ecohydrological assessment described in the main report (see Section 2.1: Flood-Scour Analysis).

B1.1 Remote-sensing Analysis Methods

Historical aerial imagery was utilized in a geographic information system (GIS) to delineate areas of flood disturbance for selected historical floods along the upper Gila River in the Planning Area. Three of the most recent, large flood events were selected: 1983, 1993, and 2005 (see Figure 2-3 in the main report). Also utilized, although not mapped here, were the remote-sensing products generated in support of this project by USU RS/GIS based on a flight made in October 2012 of the entire Upper Gila River Project Area (see Section 2.1: Remote-Sensing Data Collection above and Appendix A). Many aspects of our flood-scour analysis were modeled on similar work done by Graf (2000), Tiegs et al. (2005), and Tiegs and Pohl (2005).

B1.1.1 Photo acquisition

Historical aerial photography immediately following the first two flood events (1983 and 1993) was generously provided by the Bureau of Reclamation (BOR) from their imagery collection originally compiled for their *Fluvial Geomorphology Study* conducted on the upper Gila River in the early 2000s (e.g., BOR 2004). This photography was shared as non-georeferenced, hard-copy prints, which were subsequent scanned by a third-party vendor at resolutions ranging from 600 dots per square inch (dpi) to 1200 dpi. Aerial photography following the most recent flood event (2005) was obtained from the U.S. Department of Agriculture. This photography was downloaded as orthorectified digital imagery[1]. Table B-1 summarizes these three photosets.

[1] Georeferencing refers to the process of "rubber-sheeting" or matching features in an image to a "real-world" coordinate system. Georeferencing typically only considers horizontal referencing, whereas an orthorectified image will be referenced using both horizontal and vertical components, resulting in a more accurate representation of earth's surface.

Table B-1. Aerial photography sets used in the upper Gila River ecohydrological flood-scour analyses.

Flood date	Peak discharge (cfs)					Closest imagery year(s)	Imagery type [A]	Scale / Resolution	Photo source [B]
	Gila River near Virden, NM	Gila River near Clifton, AZ	SF River at Clifton, AZ	Gila River near Solomon, AZ	Gila River at Calva, AZ				
	Upstream to downstream								
Oct 2–3, 1983	15,500	15,300	90,900	132,000	150,000	Oct 7, 1983	B&W non-rectified	1:20,000	Cooper Aerial
Jan 11–20, 1993	30,000	35,500	42,900	86,200	109,000	Mar 11–12, 1993	B&W non-rectified	1:6,000	USDA NRCS
Feb 12–14, 2005	32,700	30,700	21,800	39,000	40,100	Jul 2–Sep 17, 2005 (county-wide)	Color DOQs	1 meter	USDA NAIP

[A] B&W = black and white image; DOQs = Digital Orthophoto Quadrangle image
[B] USDA NRCS = U.S. Dept. of Agriculture Natural Resources Conservation Service; USDA NAIP = U.S. Dept. of Agriculture National Agriculture Imagery Program

B1.1.2 Georeferencing

In order to extract and accurately compare river planform data from the acquired aerial photography, a common spatial context was necessary. Using a GIS, the 1983 and 1993 imagery were georeferenced to a single spatial projection (UTM Zone 12S; NAD 83). The ESRI® ArcGIS georeferencing toolset was utilized to georeference the scanned hardcopy contact prints and digital imagery to the high-resolution 2005 and 2012 orthophotography, the latter of which was rectified by USU RS/GIS with the high-resolution LiDAR topography, thus providing a highly accurate standard control point source for the entire photographic record. Control points were typically located using old buildings, bridges, intersections, and other features that appeared unchanged between photos sets. Georeferencing methods utilized at least 10 control points per photograph; thin plate splines were used to produce a smooth (continuous and differentiable) surface. Orthorectified imagery was acquired at pixel resolutions ranging from about 0.25 to 1 m.

Spatial error in certain portions of photo sets due to imagery registration errors were occasionally significant, as high as 60 ft (~20 m). These errors were typically associated with image distortion at the outer edges of older photos, due to sub-standard aerial photography techniques, standard lens distortion, or oblique camera angles. However, spatial errors between most photo sets generally ranged between 10 and 50 ft (3 and 15 m), and sometimes were as low as 3 ft (1 m).

B1.1.3 Flood-scour digitizing

Each set of spatially referenced photography (each representing a particular flood) was used in a GIS to interpret two levels of flood-caused disturbance in the channel and floodplain areas. In addition, areas of low-disturbance or areas apparently retaining natural riparian vegetation coverage[2] within the floodplain after the flood were also mapped. Continuous examination of the high-resolution 2012 LiDAR topographic surface alongside the aerial imagery in a GIS provided an excellent means to delineate the static floodplain boundaries.

For purposes of photographic interpretation, the flood-scour areas were defined as follows:

High disturbance: These areas are characterized by distinct channel and floodplain areas severely disturbed by flow (i.e., scoured to bare substrate), typically with 10% or less apparent remaining riparian vegetative cover. This category may include agricultural or developed lands with a high level of apparent disturbance by flood flows, thus identification of this type is not always based upon vegetative cover, sometimes relying on patterns of obvious scour or deposition. Additionally, certain channel-adjacent areas surrounded by scour were classified as high disturbance, despite having high coverage of herbaceous or nascent vegetation; this characterization was assigned when vegetation appeared to have grown post-flood and prior to the aerial photograph date.

Medium disturbance: This class is characterized by distinct areas of low to moderate apparent disturbance by flow, typically defined as areas with more than 10% but less than 80% apparent riparian vegetative cover. This type includes agricultural or developed lands with low to moderate apparent disturbance by flood flows, thus, as with the high disturbance class, identification of this type is not always based upon vegetative cover.

Low disturbance (riparian vegetation): These areas were characterized by distinct zones of apparently natural riparian vegetation with little to no apparent disturbance by flood, typically containing more than 80% riparian vegetation. Areas in this class may have been inundated by floodwaters, but did not show significant signs of scouring or other disturbance that removed vegetation.

In addition to flood disturbance level, all polygons were classified as being either within or outside of the "active channel." Polygons within the active channel were those that appeared to have been directly affected by the river during the prior flood event and/or subsequent flows—areas of medium to high disturbance. Areas of riparian or non-riparian vegetation with no apparent disturbance were excluded. Areas of medium to high disturbance affected by flows from tributaries at their confluence with the river.

To record these areas, polygons were delineated around features within each flood year photo set using heads-up digitizing at a scale of 1:3000 in the GIS; in certain areas, shadow or dense vegetation made it necessary to sometimes digitize at scales of 1:2000 or, in cases of extremely low visibility, 1:1000. While methods for digitizing generally followed those described by Tiegs and Pohl (2005), the data generated in this study were not converted to a raster format for

[2] In the context of the floodplain vegetation communities of the upper Gila River, "riparian vegetation" includes all visible plant species, which may include a mixture of native and non-native species. It may also include vegetation types more typical of upland communities. Agricultural lands within the river's floodplain were also included as Low Disturbance, but were excluded from the active channel area in the absence of recent flood-scour.

analysis, but rather kept as polygons in an ESRI shapefile format (.shp), as originally digitized. All subsequent analyses were conducted using the polygon representation, which allowed for a finer scale of resolution in analysis output.

In addition to spatial error related to georeferencing, polygon delineation likely resulted in unknown spatial errors due to difficulties in interpreting features of interest. These types of error are most likely to occur with older images (e.g., 1983) used in this study. Older photographic film typically had a coarser grain than more modern films resulting in lower feature resolution once the image was scanned and georeferenced, making interpretation of riparian vegetation and other floodplain features more difficult.

B1.1.4 Quality control

Each flood-year polygon dataset was checked extensively for spatial and interpretive accuracy by a GIS supervisor and a senior geomorphologist who were not associated with the digitization process. This process ensured that the datasets were consistent and accurate within and across years. Assessments of spatial error were conducted by a GIS analyst who was not directly involved in the georeferencing or digitization processes.

B1.1.5 GIS analyses

The planform data digitized from the aerial photography sets were used to conduct two distinct spatial analyses to support understanding of fluvial dynamics in the mainstem river. These analyses included display of active channel area per flood event and calculation of historical flood disturbance probability.

B1.1.1.1 Width of active channel bed in successive floods

Knowledge of the last known flood disturbance for any particular area of the floodplain is critical to understanding the age of geomorphic surfaces and thus the approximate age of riparian vegetation growing there. All active channel layers were thus overlain in order of oldest to most recent event to produce a map displaying the active channel width (or extent) per event (see Figures B-2.1 through B-2.10 below). Additionally, the Low Disturbance areas from each flood-year layer were merged to represent the cumulative floodplain extent, an equally valuable component of the active channel maps for restoration planners seeking to identify potential sites safely outside the flood-disturbance areas but within the floodplain boundaries.

B1.1.1.2 Locational probability model

The methods and nomenclature discussed below have been generally based on those of Graf (2000) and Tiegs et al. (2005). For this analysis, we define a locational probability model as a graphical representation of the historical probability that any particular area within the floodplain and channel of the river was scoured (i.e., the High Disturbance and Medium Disturbance categories described above) by a major flood. As discussed above, aerial photographs chosen for use in this study were taken after major floods (see Table B-1) and thus represent the post-flood channel configuration for a particular flood.

Because the Virgin River is a flood-event dominated system and each set of photography was taken shortly after a major flood event, it can be assumed that each photo set represents the dominant planform configuration of the channel until the next large flood documented by aerial photography. This approach differs from that of Graf (2000), Tiegs et al. (2005), and Tiegs and

Pohl (2005), who assume that each photo set is representative of general channel conditions for a period of time from one photo set to the previous photo set. Thus, their approach does not appear to explicitly consider whether the photo is representative of the effects of particular floods, but rather describes general channel conditions over time.

There are numerous caveats to our assumption discussed above, the most important being that smaller floods occur between the photograph sets and likely result in at least some reworking of the channel; however, it remains that major changes to the channel and floodplain of the river are accomplished by large floods.

To derive a disturbance probability model, the photo sets needed to be weighted based on the amount of time each represented in the overall study period. The weighting values were calculated for each flood year using the following equation:

$$Weighting\ value\ (W_n) = \frac{years\ represented\ by\ given\ photograph\ (t_n)}{total\ number\ of\ years\ in\ photographic\ record\ (m)}$$

The value of t_n is the number of years between the documented flood of interest and the next photo documented flood. The value of *m* is the total number of years documented by aerial photography, from earliest photography set to most recent. Working through the equation for each flood year gave the results displayed in Tables B-2 and B-3.

Weighting values were assigned to flood year polygon layers in the GIS. All of the flood year layers for each analysis were then combined in the GIS (using the "union" function), resulting in numerous smaller polygons, all of which retained their original assigned probability for each year. For each individual polygon, all the years weighting values were summed, resulting in a probability of scour for each. The probability field was then used to illustrate locational probability in a map (see Figures B-2.1 through B-2.10 below).

Table B-2. Years represented by individual flood photography and total number of years in the photographic record for the upper Gila River.

Reach	Years of photography	Number of years represented by given flood photography (t_n)			Number of years in photographic record through 2013 (*m*)
		1983	1993	2005	
All Reaches	1983, 1993, 2005	10	12	8	30

Table B-3. Weighting values for individual floods photography and reaches of the upper Gila River.

Reach	Years of photography	Weighting value (W_n)		
		1983	1993	2005
All Reaches	1983, 1993, 2005	0.33	0.40	0.27

B2.1 Results of Flood-Scour Analysis

As a predominantly braided but dryland river, the mainstem channel of the upper Gila River largely comprises a primary low-flow channel and various short-lived secondary channels. The flood-scour analysis performed here reveals that the low-flow channel boundary changes rapidly and completely during flood events according to the magnitude of the event and other factors, whereas the boundary of the larger mainstem channel changes less frequently.

The results of our flood-scour analysis are presented graphically in two sets of maps: "Areal extent of active channel in successive floods" and "Frequency of active channel position." As described above, the former category presents the active-channel areas per mapped flood event. The latter category maps highlight those channel areas most frequently disturbed by repeat flood events. The Flood Reset Zone therefore depends on those more active areas, and are considered henceforth to include those areas found to have both >66% flood-scour frequency (i.e., scoured in 3 out of the 3 mapped events [1983, 1993, and 2005]) and "high" flood-disturbance activity—areas severely disturbed by flow, typically scoured to bare substrate retaining <10% apparent riparian vegetative cover—during the most recent flood of 2005. The size of the Flood Reset Zone progressively decreases in the downstream direction below the Gila Box (i.e., reaches 2c–2j), where it accounts for over 80% of the riparian corridor near the upstream end of the Planning Area (reach 2j) and only about 20% near the downstream end (reach 2c).

Figure B-1 presents an index map to the numerous flood-scour maps that are presented in Figures B-2.1 through B-2.10. The individual flood-scour maps are grouped by location, and presented in downstream to upstream order beginning in Reach 2c near Geronimo.

These maps are meant to guide restoration planning and implementation at multiple scales, ranging from restoration strategy development at the full river corridor and reach levels to site-specific restoration design and implementation. However, the maps are only one tool and need to be combined with a variety of other information to develop the most effective and efficient strategies and designs for riparian restoration, such as riparian vegetation classification (see Section 3: Riparian Vegetation Characterization in the main report). In particular, more detailed field-based information and geomorphic interpretation may be warranted to refine the fine-scale delineation of the Flood Reset Zone and predictions of likely future flood paths when designing and implementing site-specific plans for invasive species removal and revegetation of native riparian species.

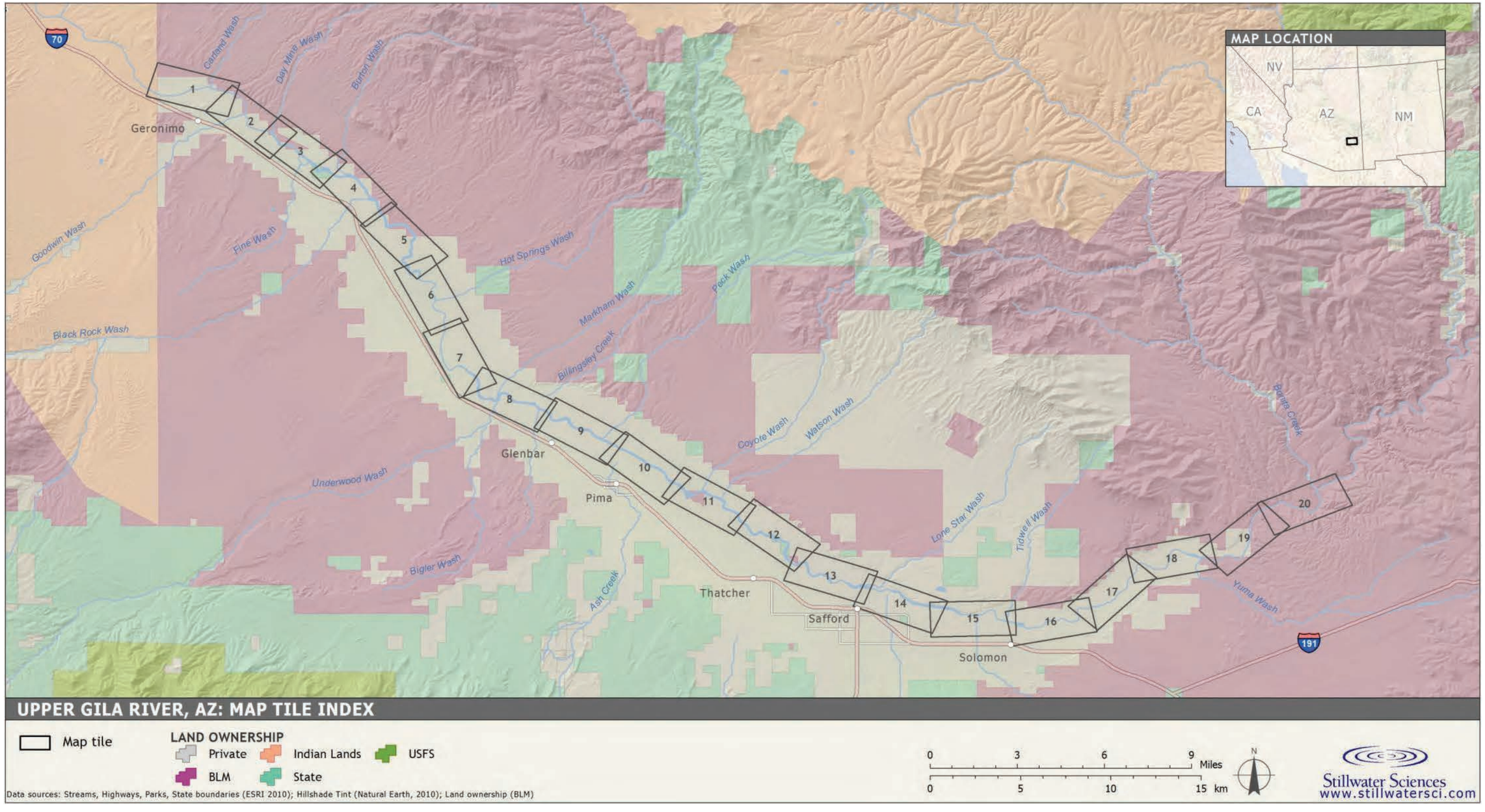
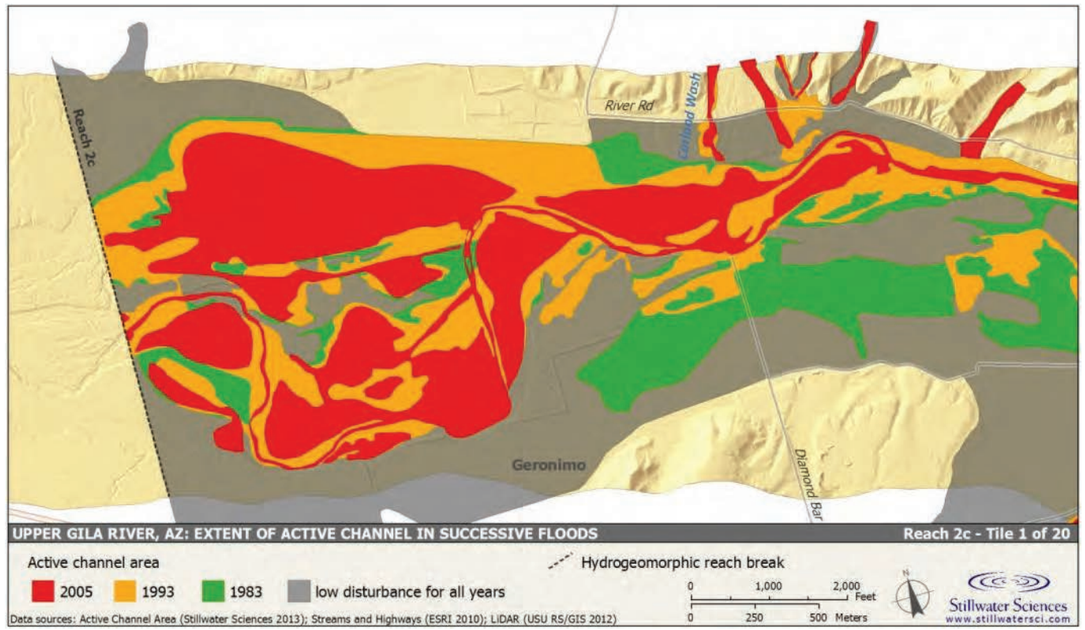
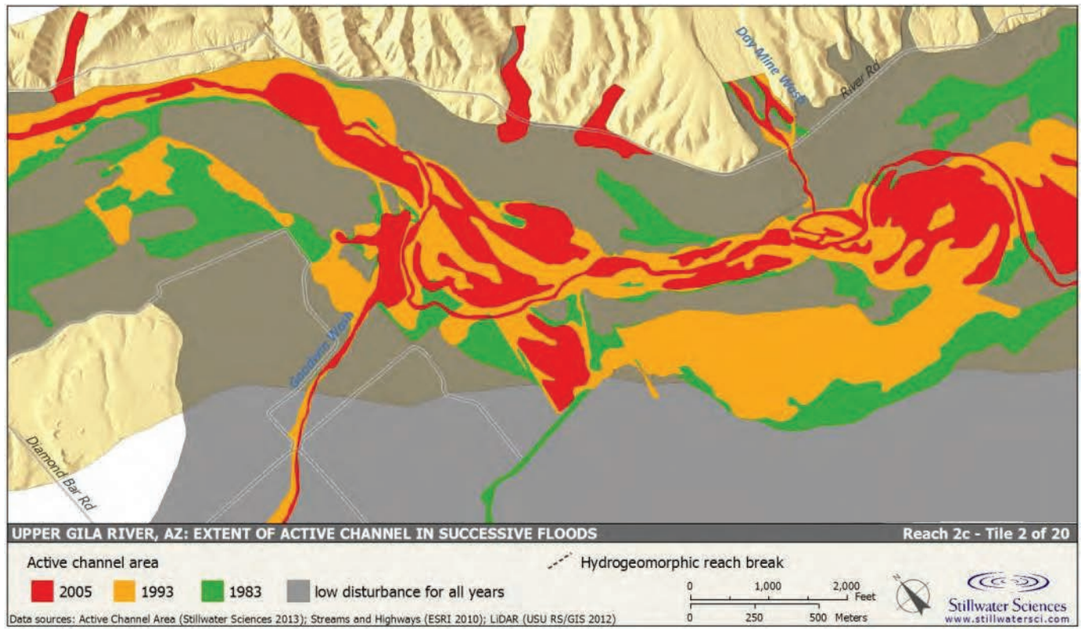


Figure B-1. Index map for flood-scour and priority restoration area map tiles along the upper Gila River within the Restoration Planning Area. See Figure B-2.1 through B-2.10 for individual map tiles.

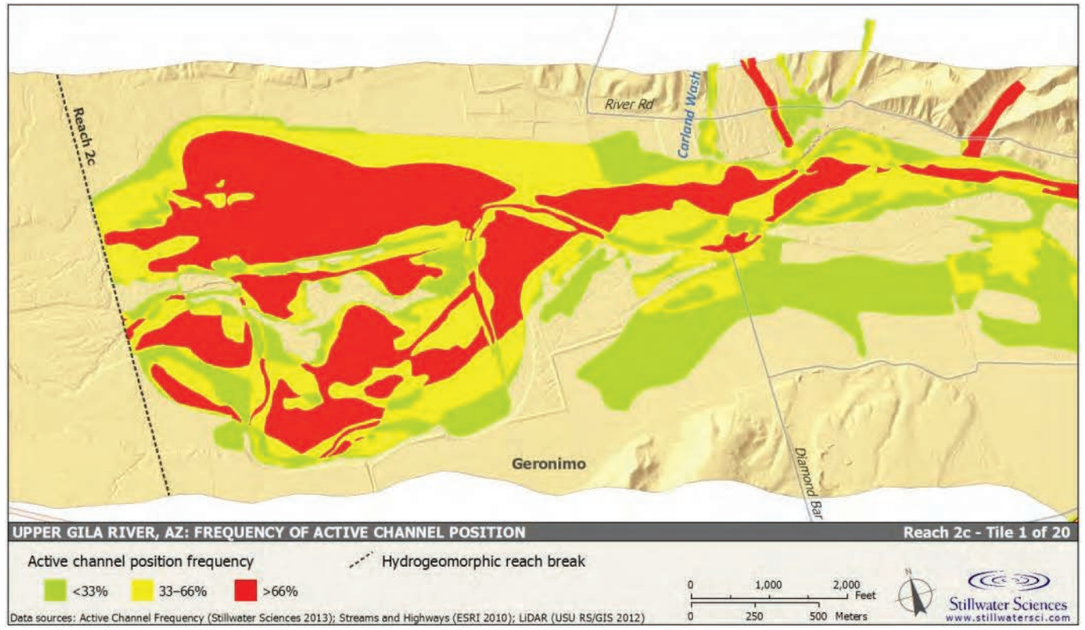
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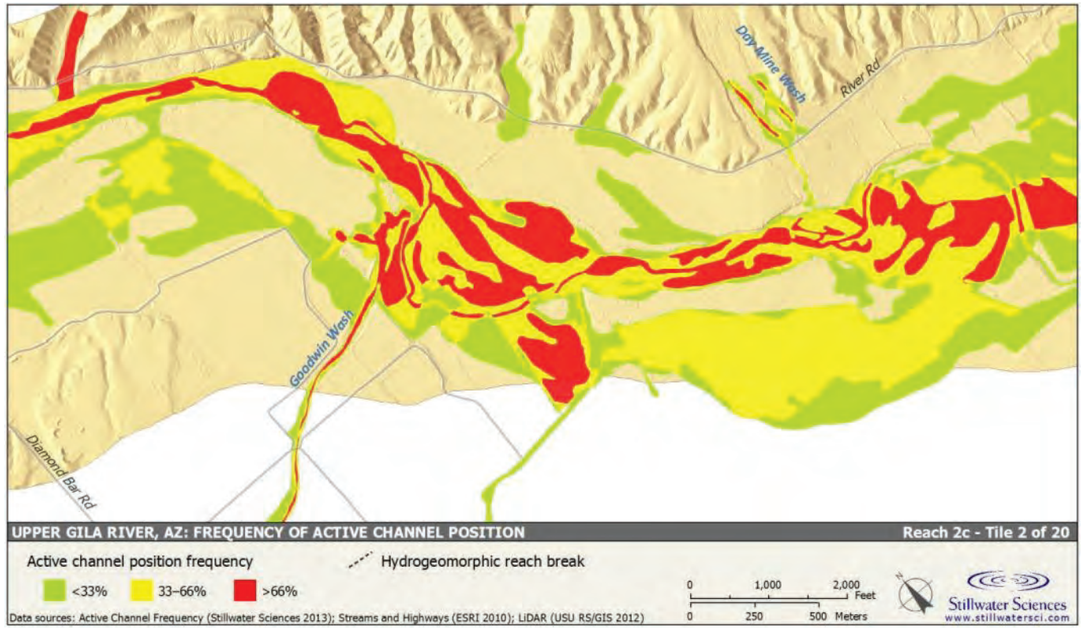
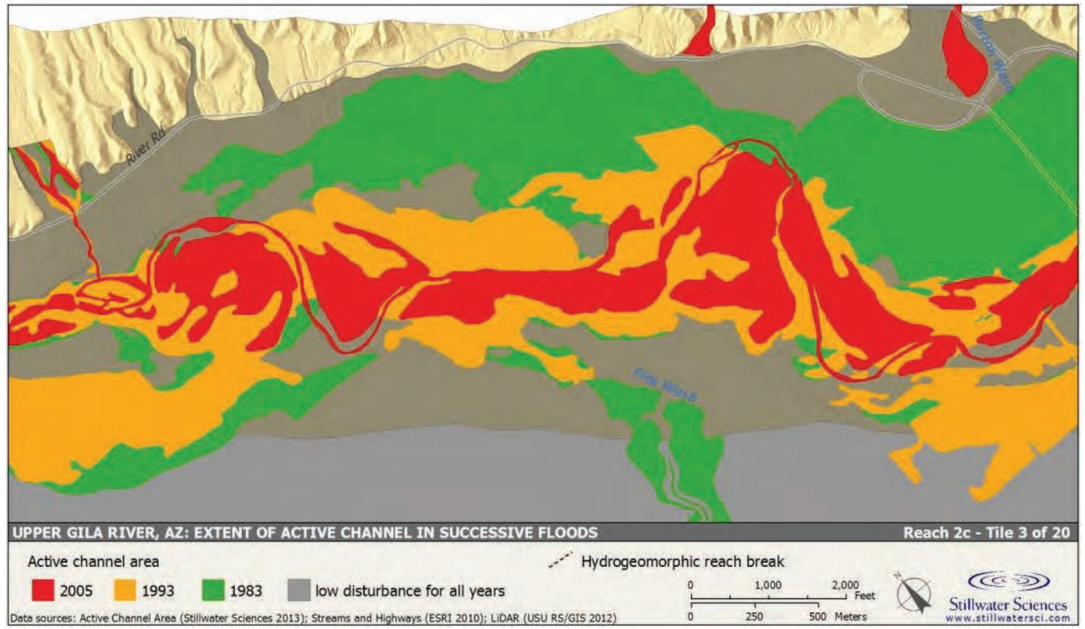
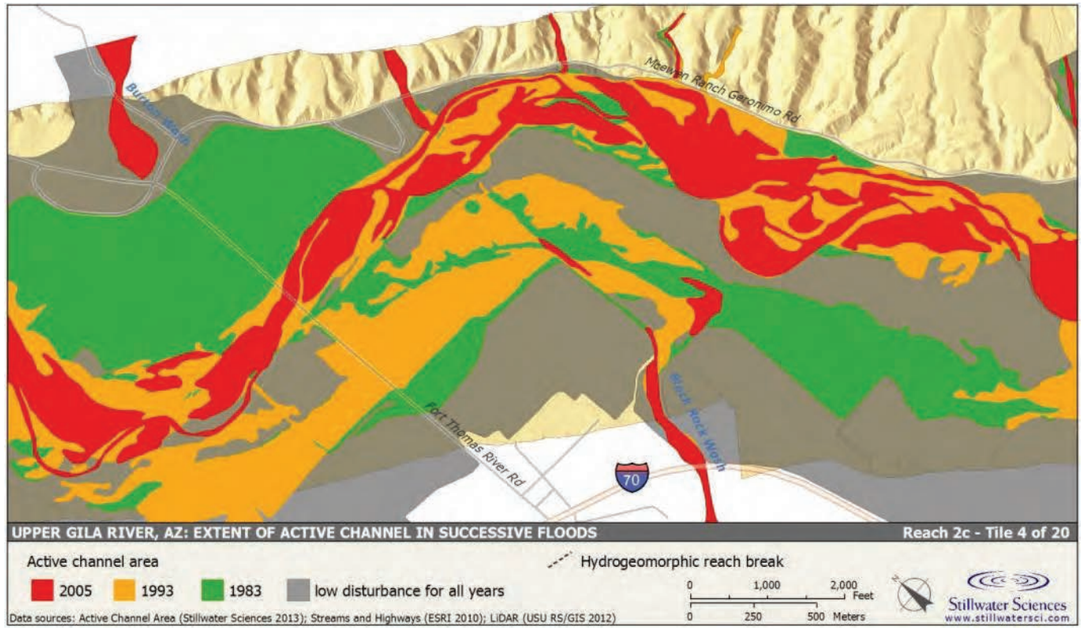


Figure B-2.1. Upper Gila River flood-scour analysis results for lower Reach 2c: areal extent of active channel in successive floods (a, b), with more recent floods displayed on top; and frequency of active channel position (c, d) showing proportion of time that the active channel has occupied a given location.

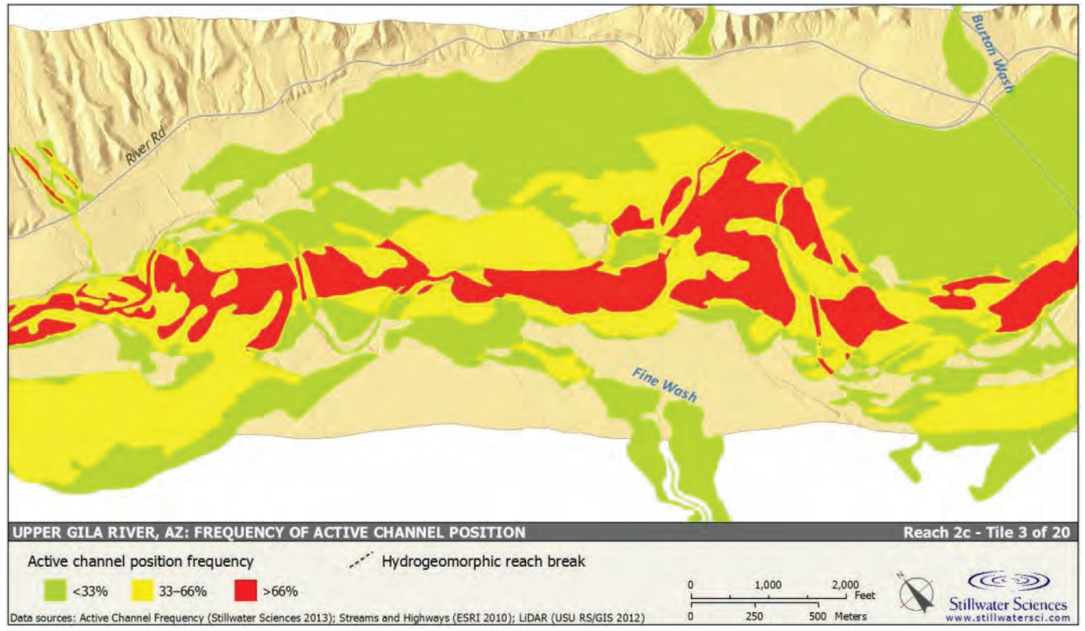
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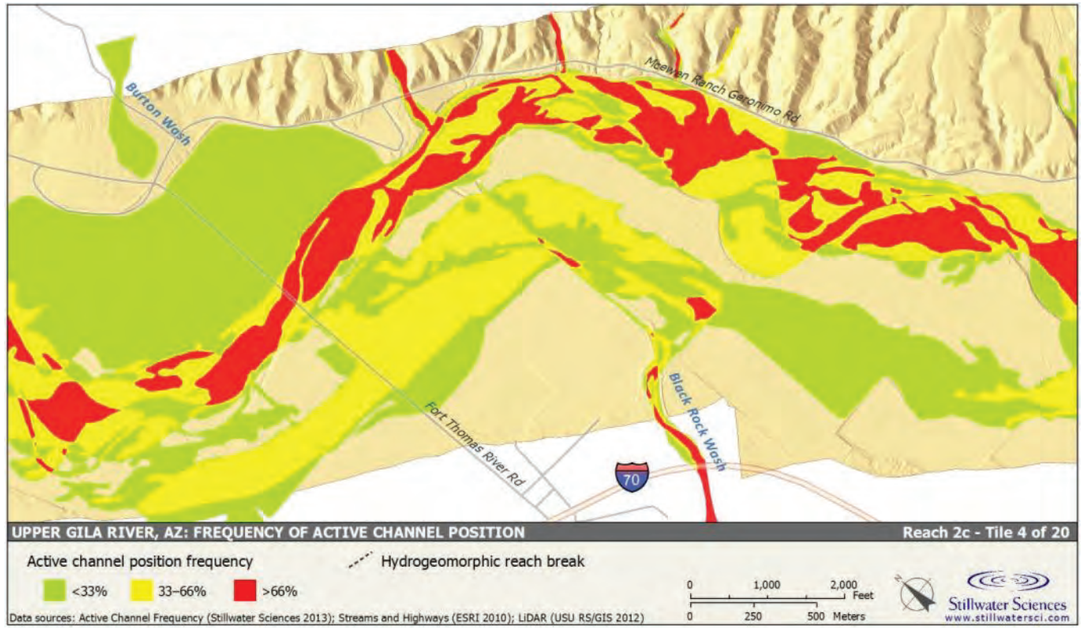
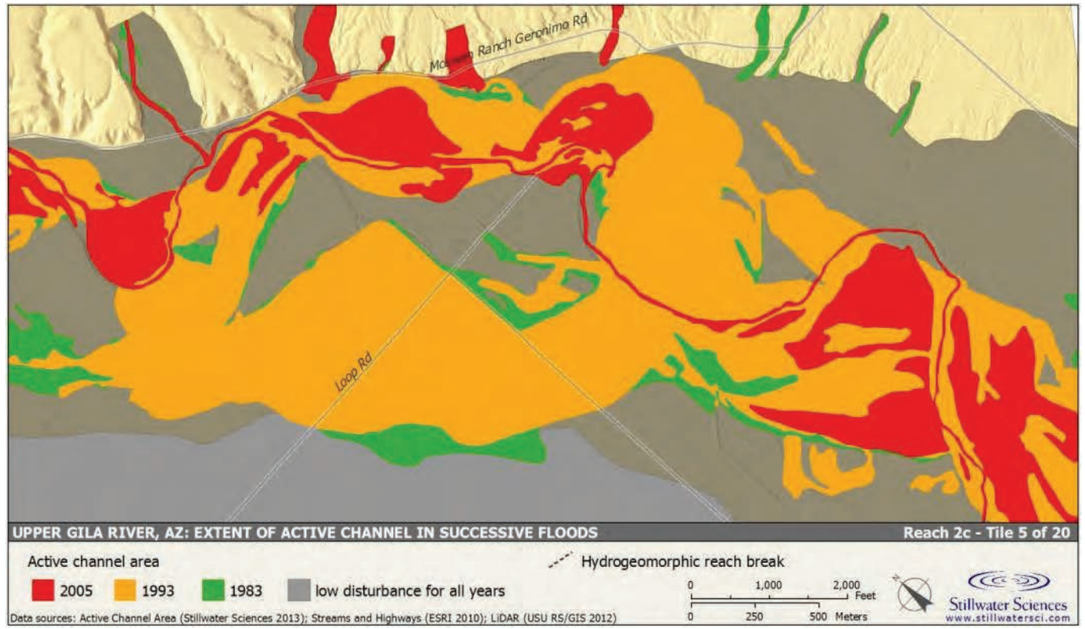
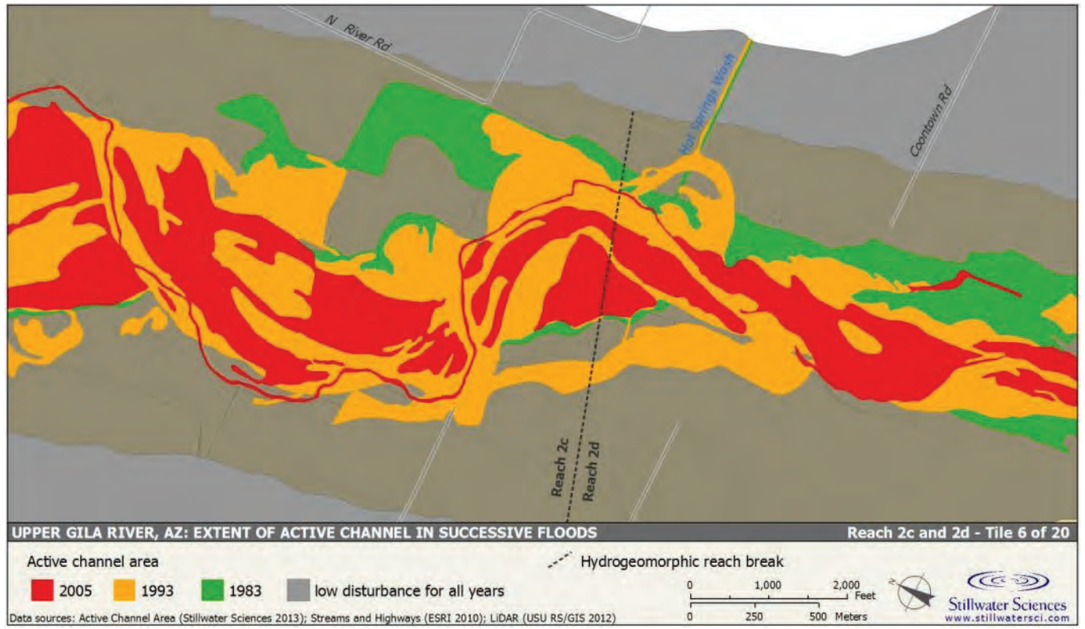


Figure B-2.2. Upper Gila River flood-scour analysis results for middle Reach 2c: areal extent of active channel in successive floods (a, b), with more recent floods displayed on top; and frequency of active channel position (c, d) showing proportion of time that the active channel has occupied a given location.

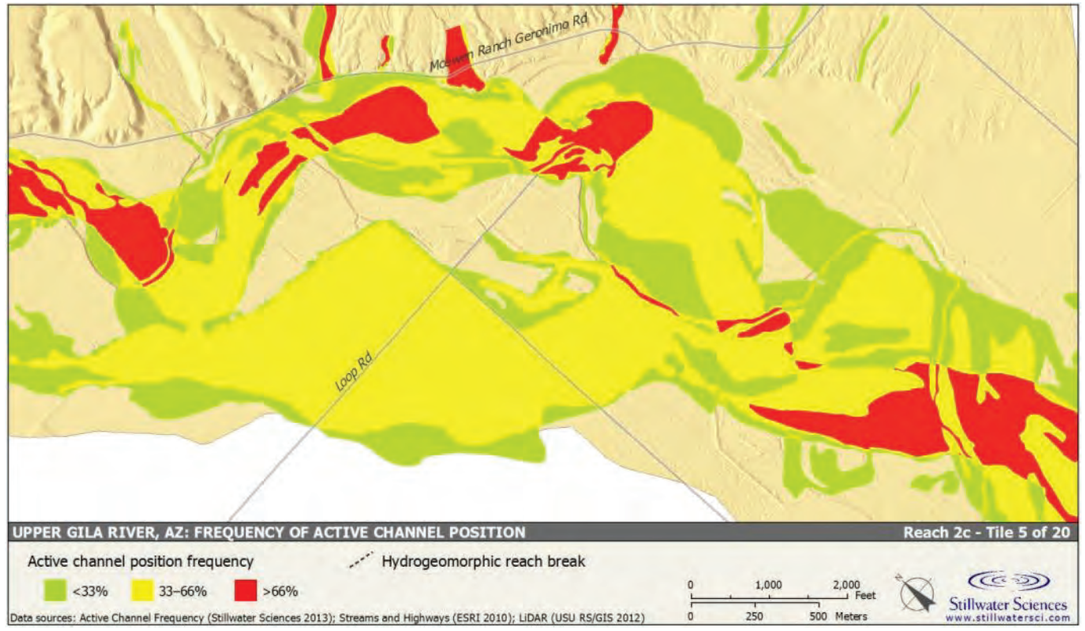
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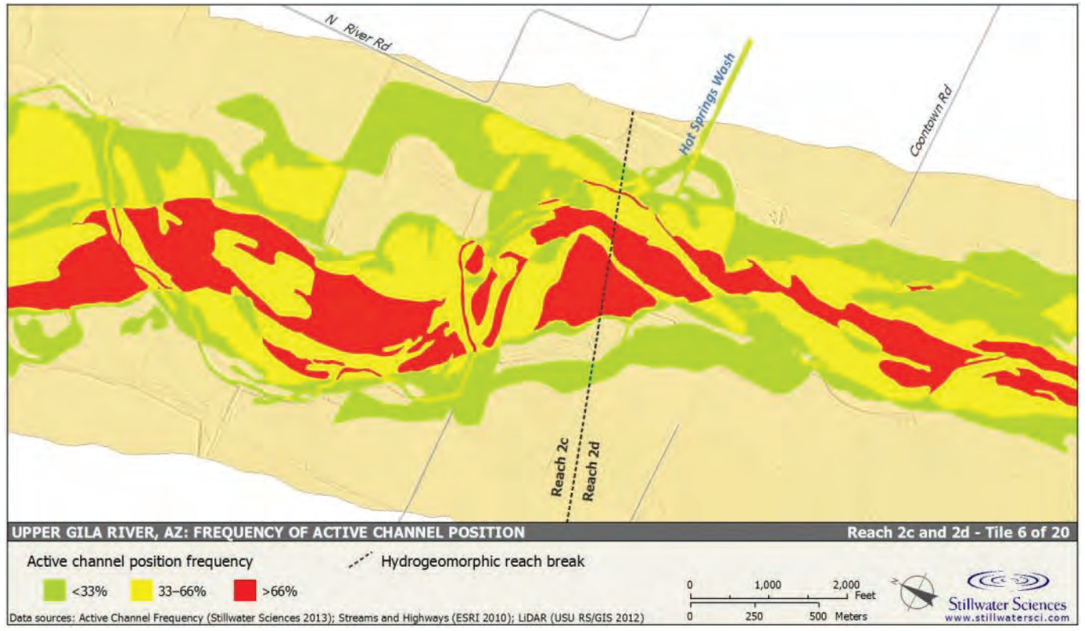
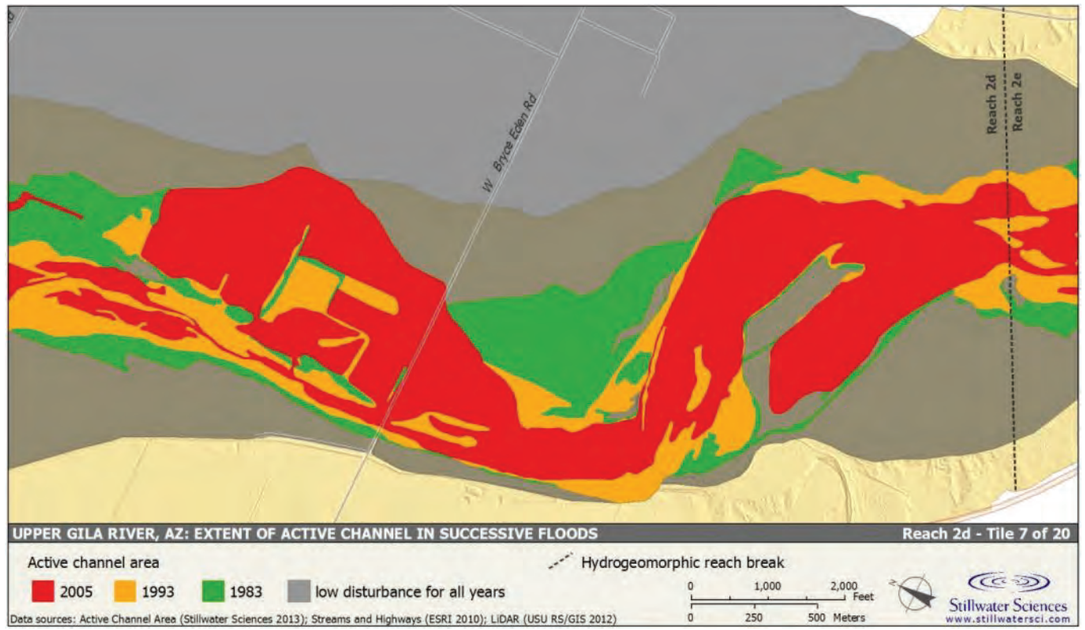
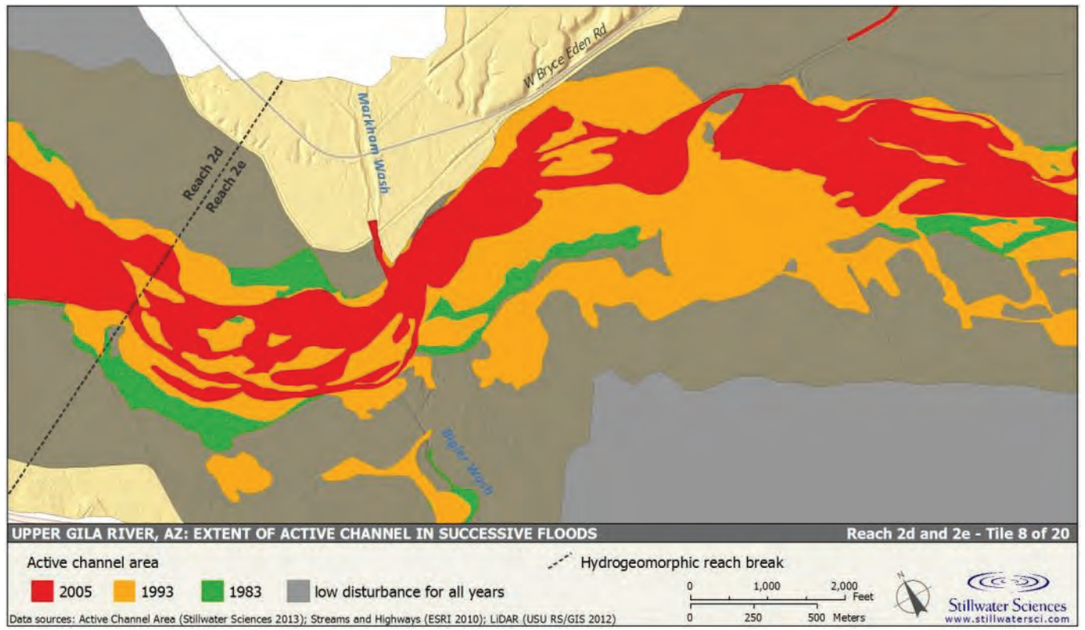


Figure B-2.3. Upper Gila River flood-scour analysis results for upper Reach 2c and lower Reach 2d: areal extent of active channel in successive floods (a, b), with more recent floods displayed on top; and frequency of active channel position (c, d) showing proportion of time that the active channel has occupied a given location.

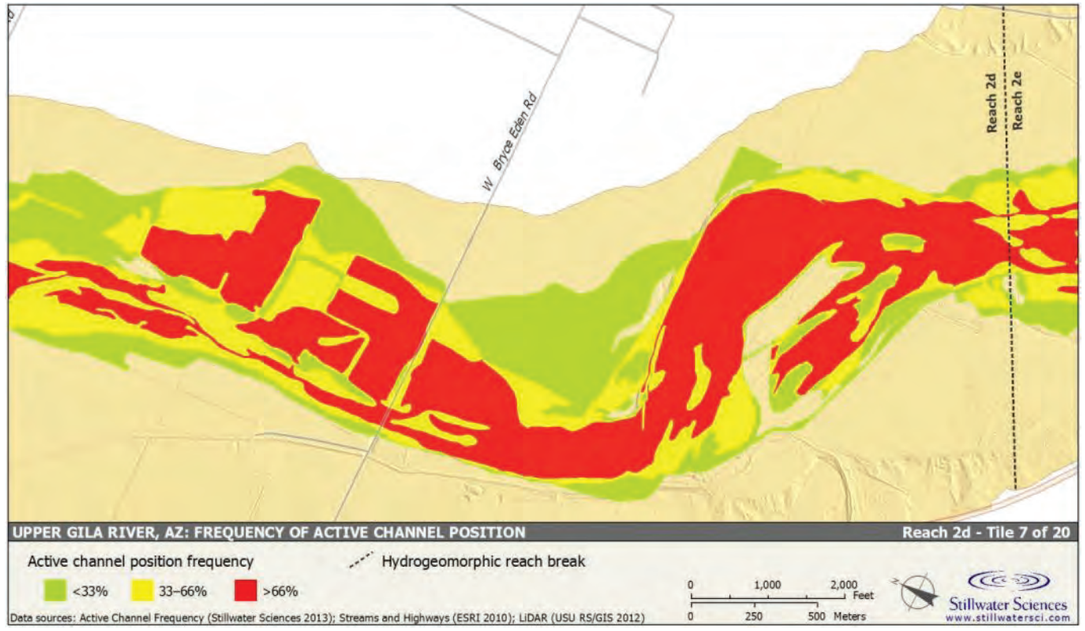
a)



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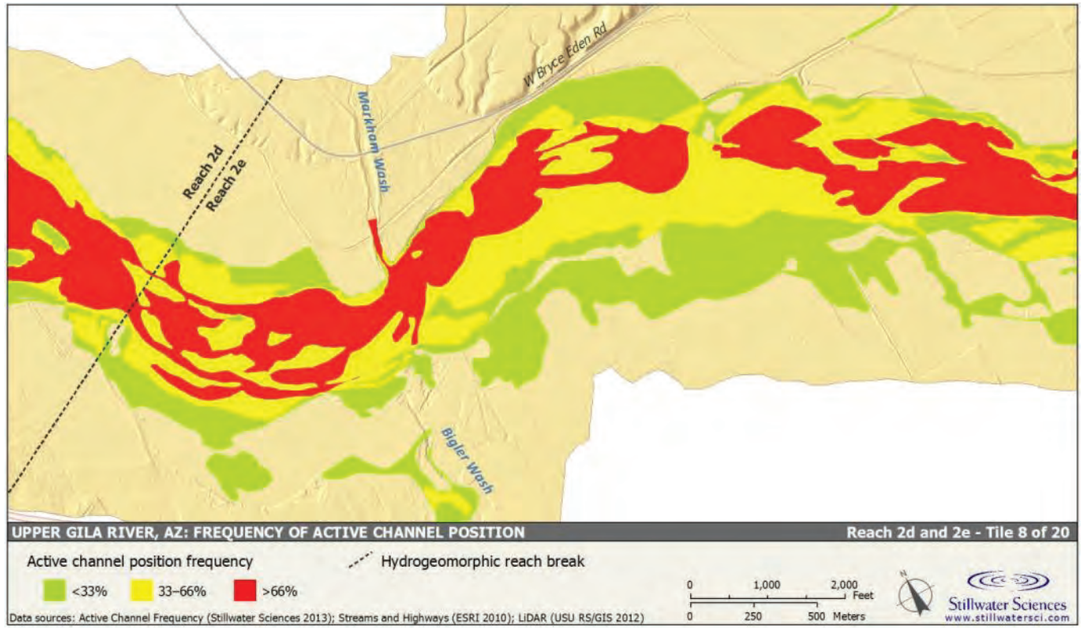
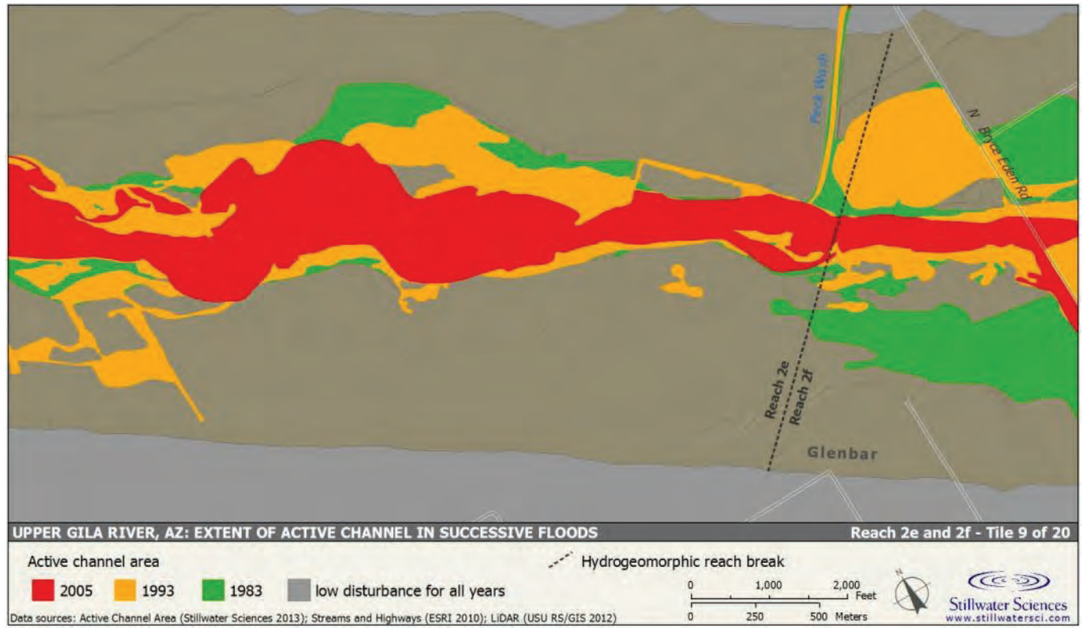
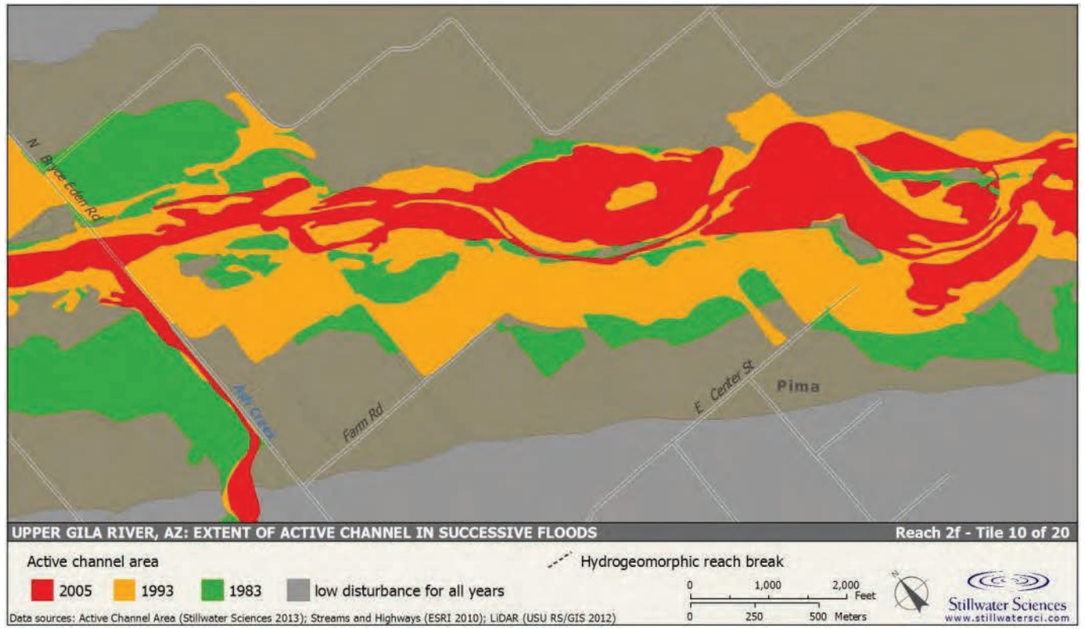


Figure B-2.4. Upper Gila River flood-scour analysis results for upper Reach 2d and lower Reach 2e: areal extent of active channel in successive floods (a, b), with more recent floods displayed on top; and frequency of active channel position (c, d) showing proportion of time that the active channel has occupied a given location.

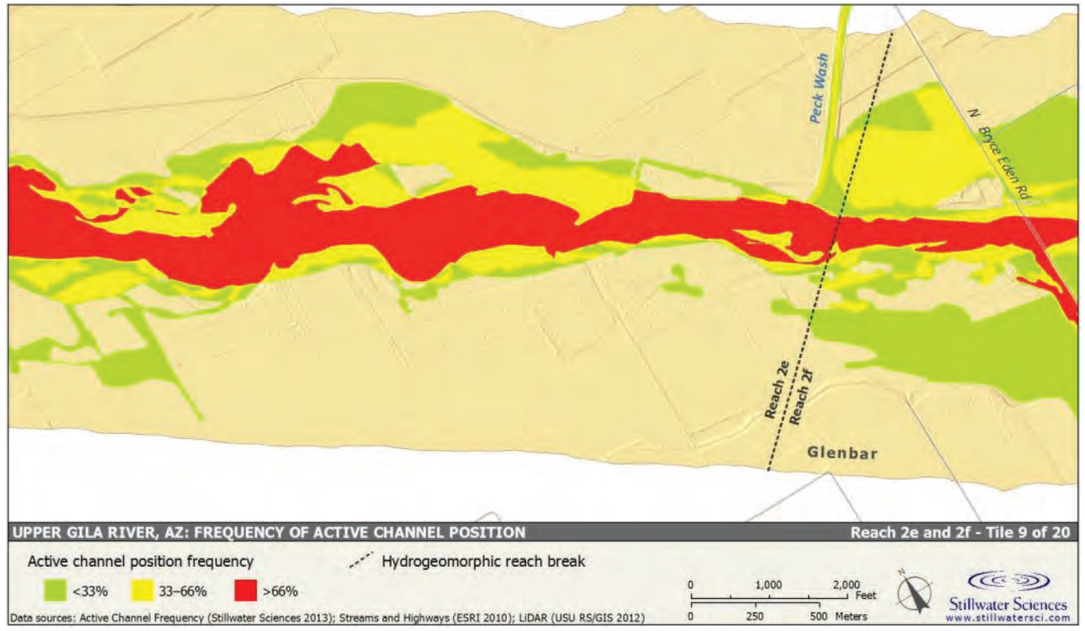
a)



b)



c)



d)

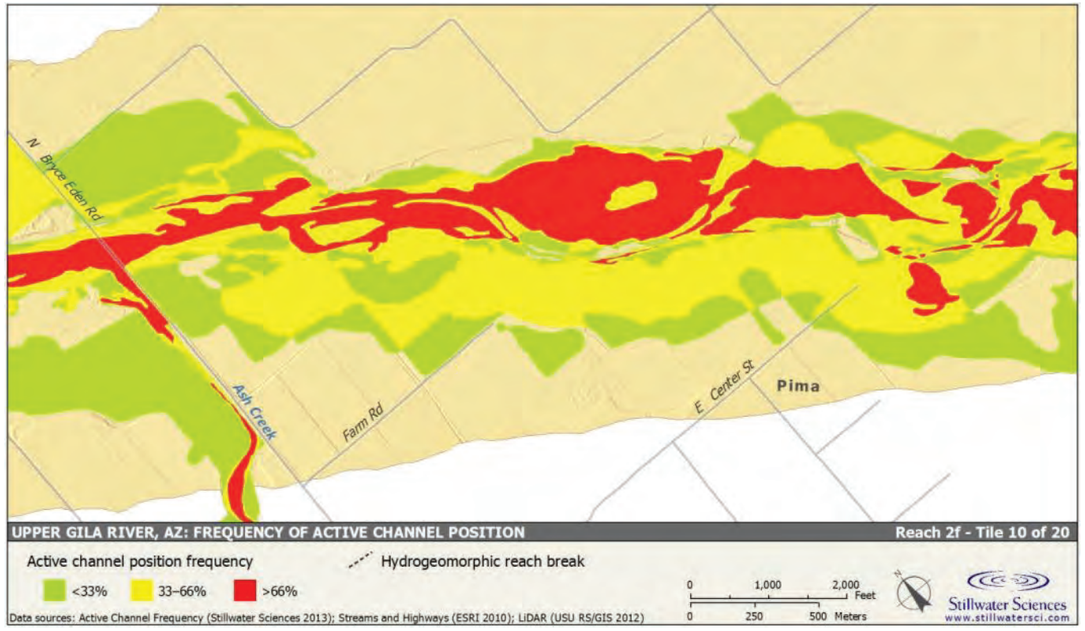
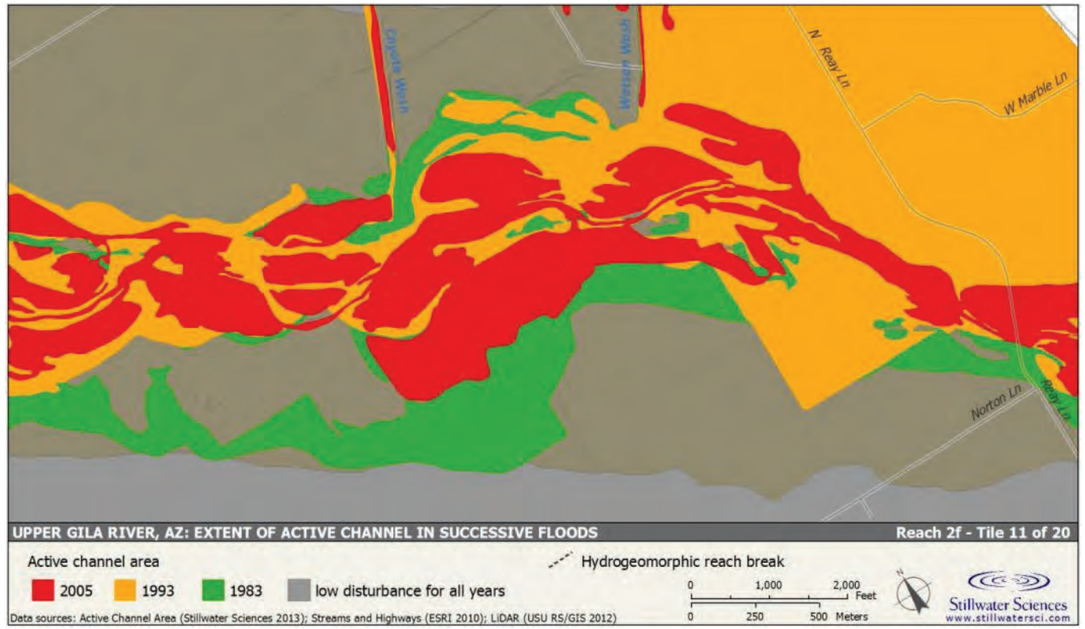
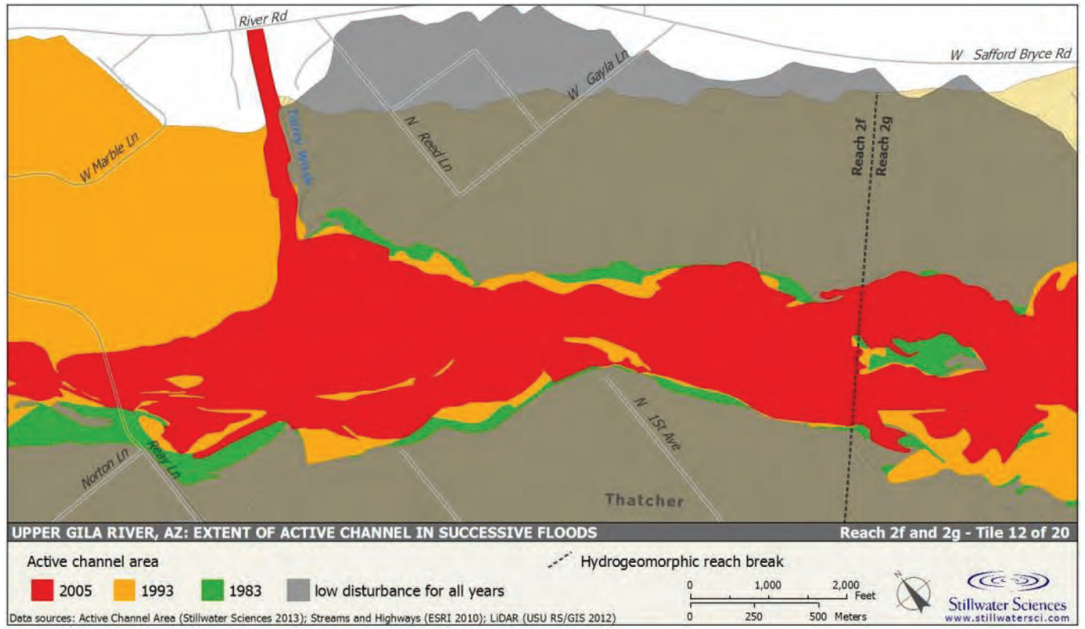


Figure B-2.5. Upper Gila River flood-scour analysis results for upper Reach 2e and lower Reach 2f: areal extent of active channel in successive floods (a, b), with more recent floods displayed on top; and frequency of active channel position (c, d) showing proportion of time that the active channel has occupied a given location.

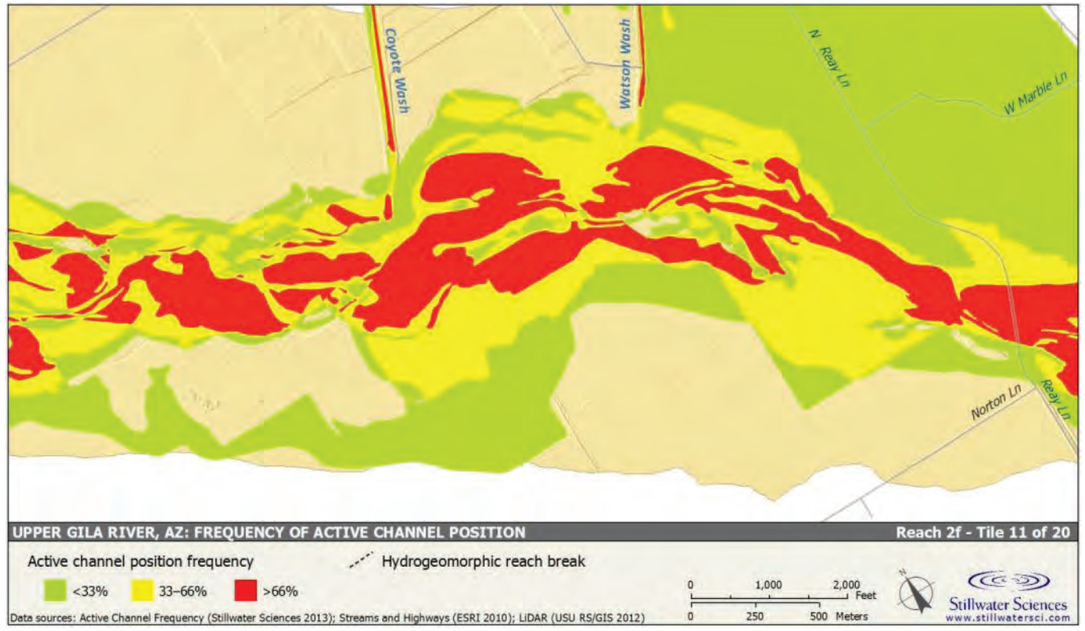
a)



b)



c)



d)

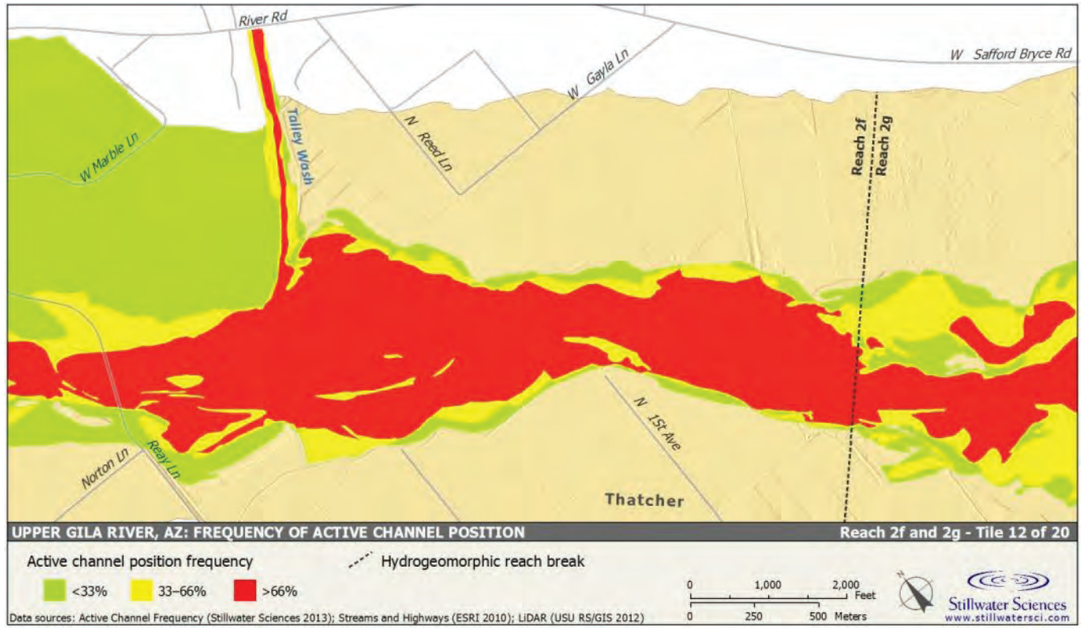
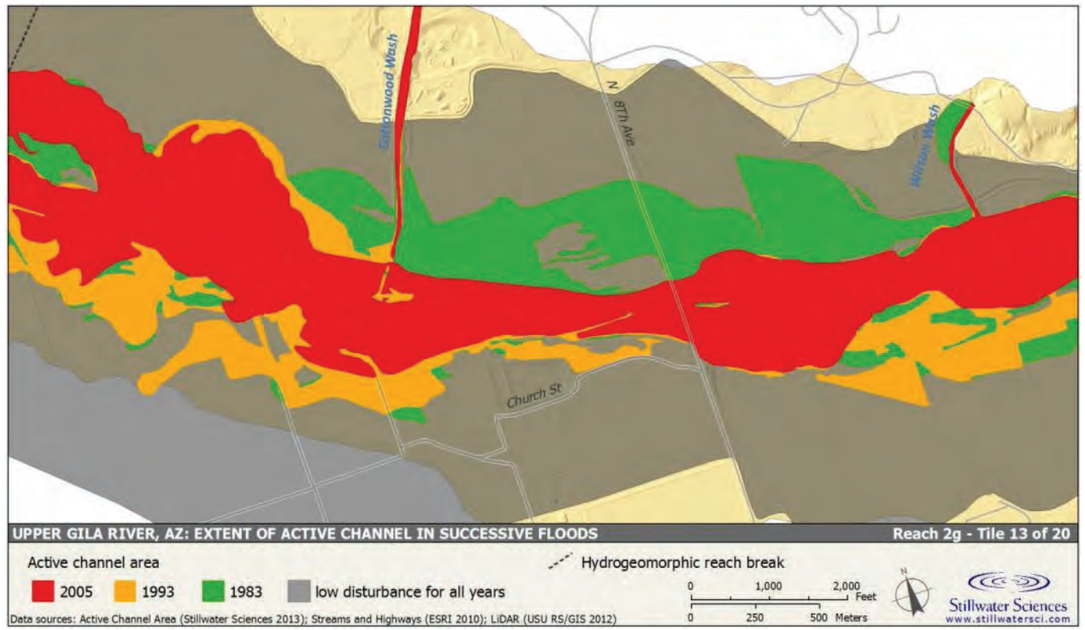
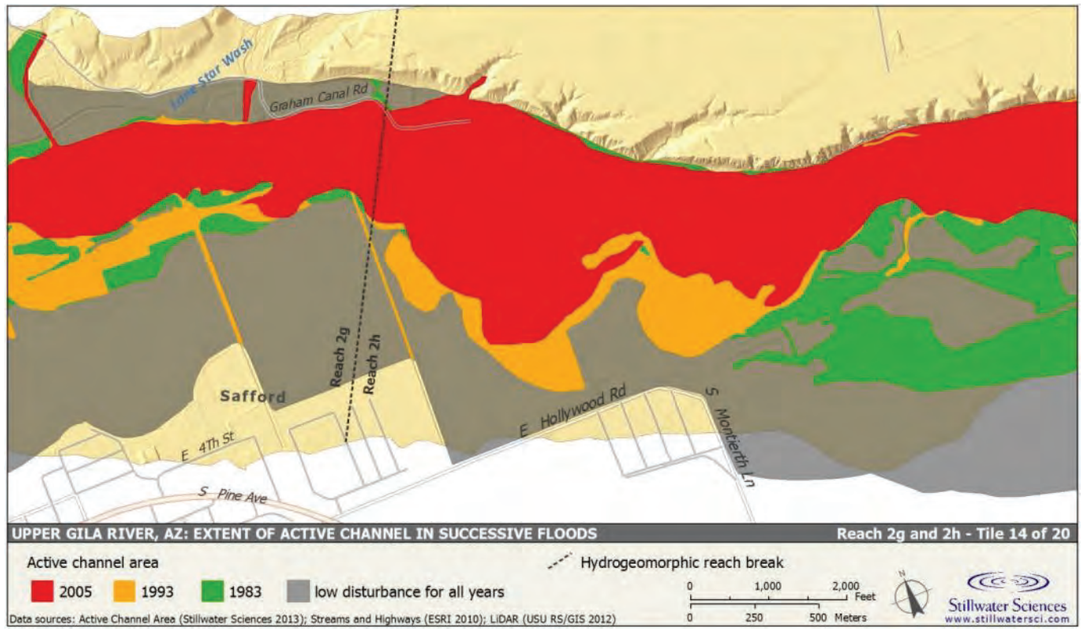


Figure B-2.6. Upper Gila River flood-scour analysis results for upper Reach 2f and lower Reach 2g: areal extent of active channel in successive floods (a, b), with more recent floods displayed on top; and frequency of active channel position (c, d) showing proportion of time that the active channel has occupied a given location.

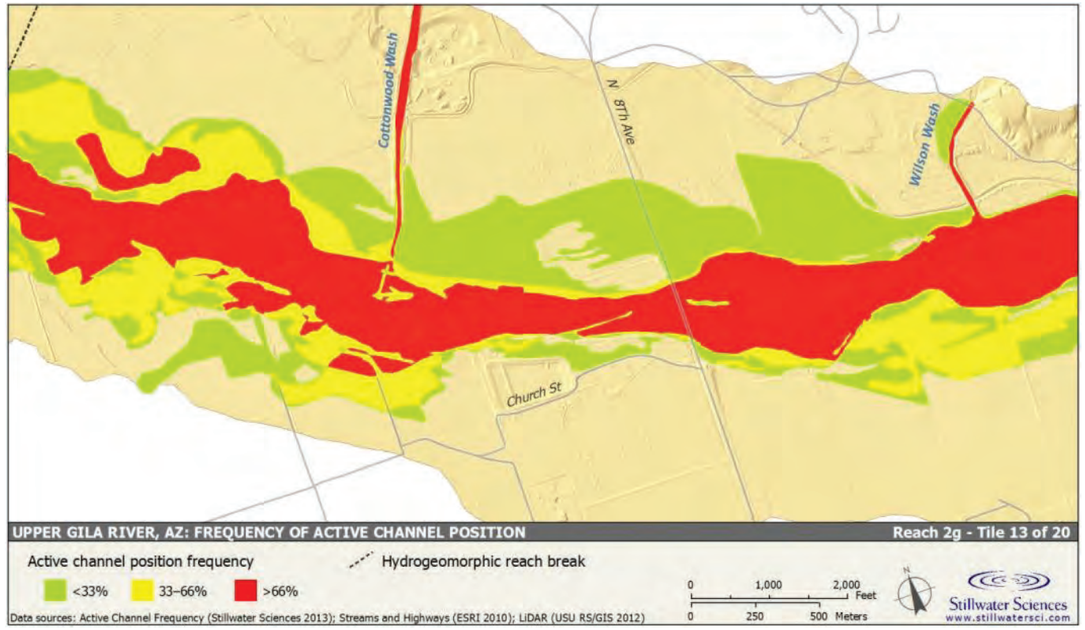
a)



b)



c)



d)

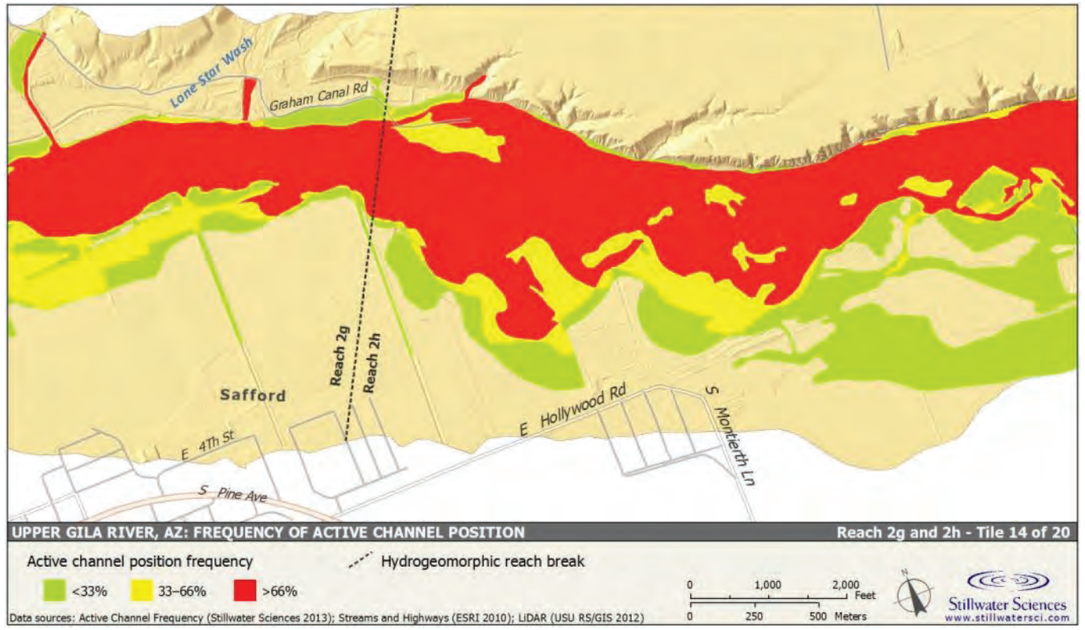
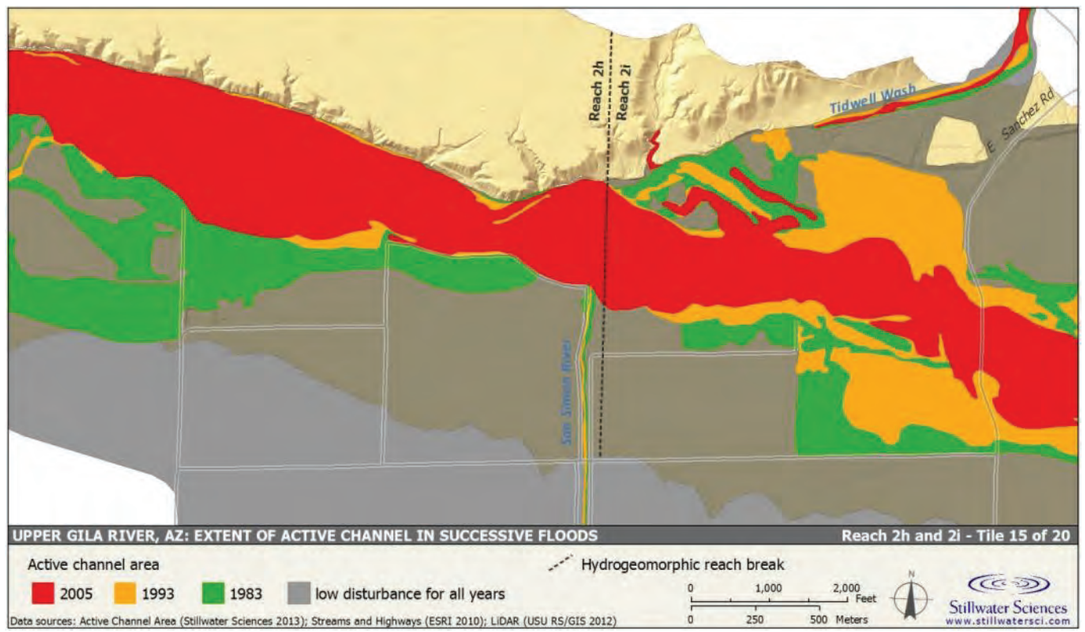
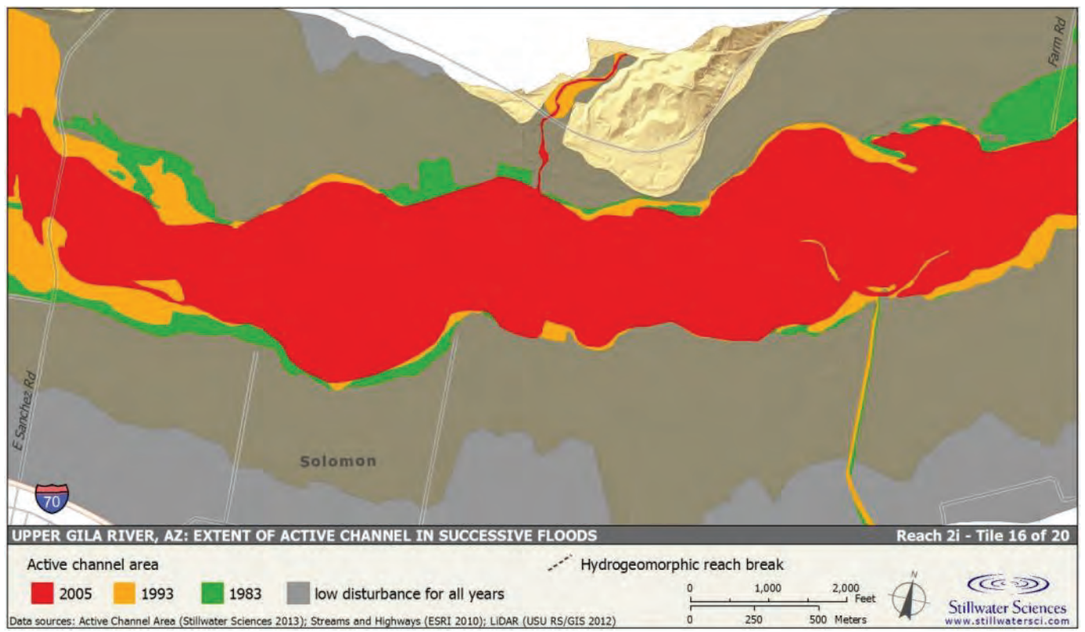


Figure B-2.7. Upper Gila River flood-scour analysis results for Reach 2g and lower Reach 2h: areal extent of active channel in successive floods (a, b), with more recent floods displayed on top; and frequency of active channel position (c, d) showing proportion of time that the active channel has occupied a given location.

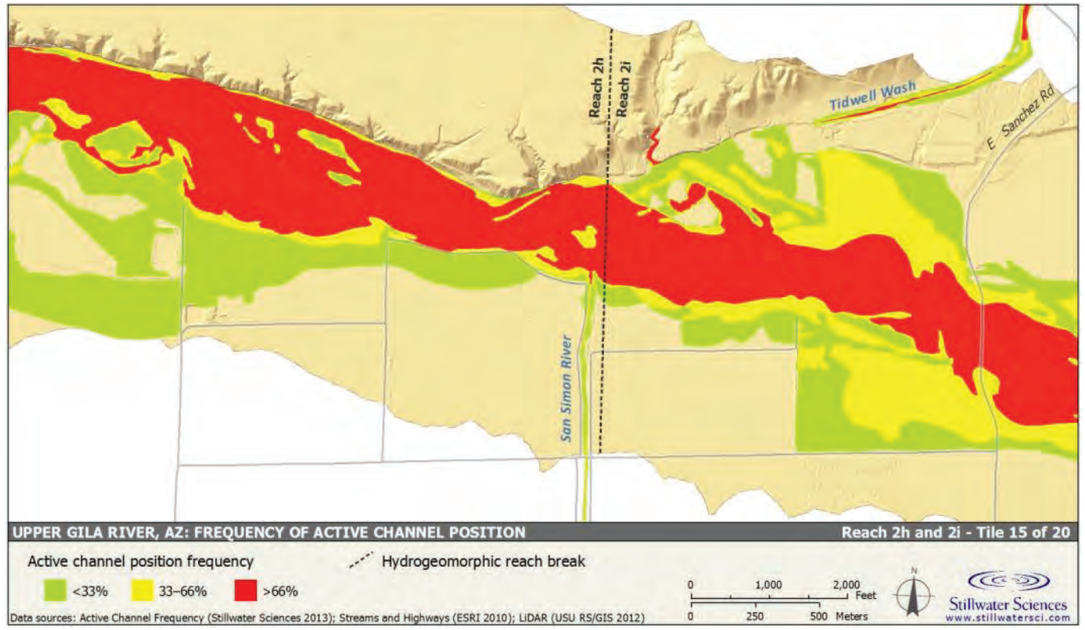
a)



b)



c)



d)

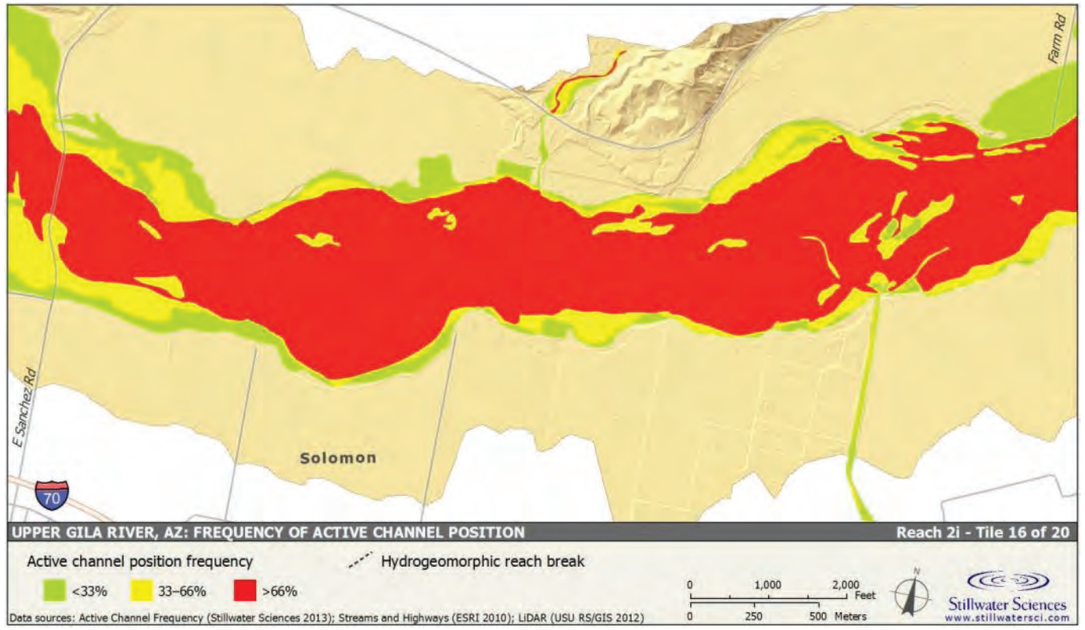
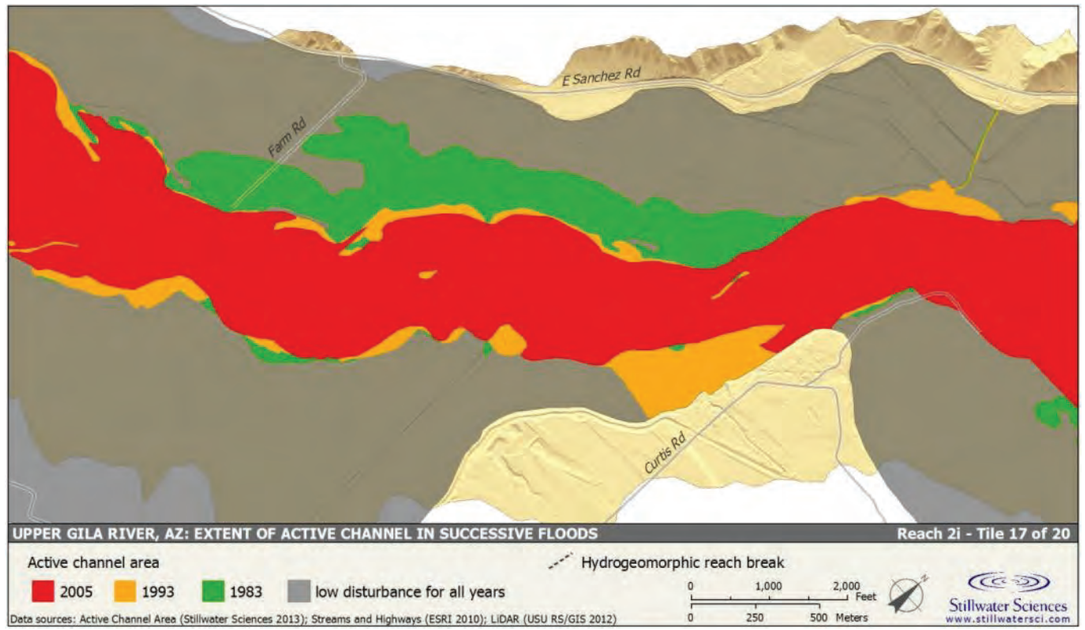
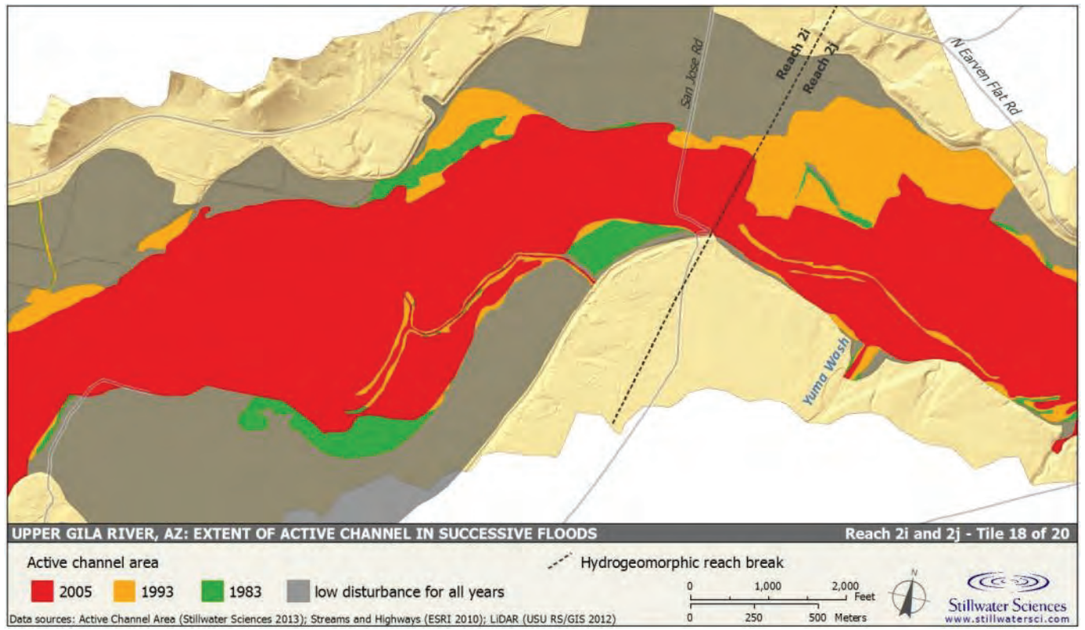


Figure B-2.8. Upper Gila River flood-scour analysis results for upper Reach 2h and lower Reach 2i: areal extent of active channel in successive floods (a, b), with more recent floods displayed on top; and frequency of active channel position (c, d) showing proportion of time that the active channel has occupied a given location.

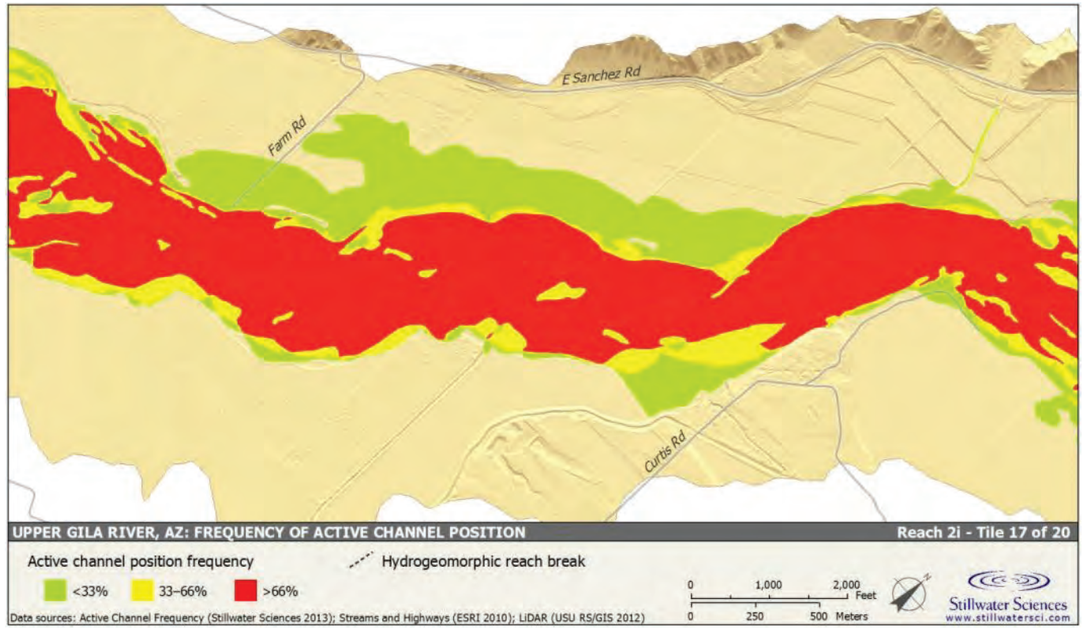
a)



b)



c)



d)

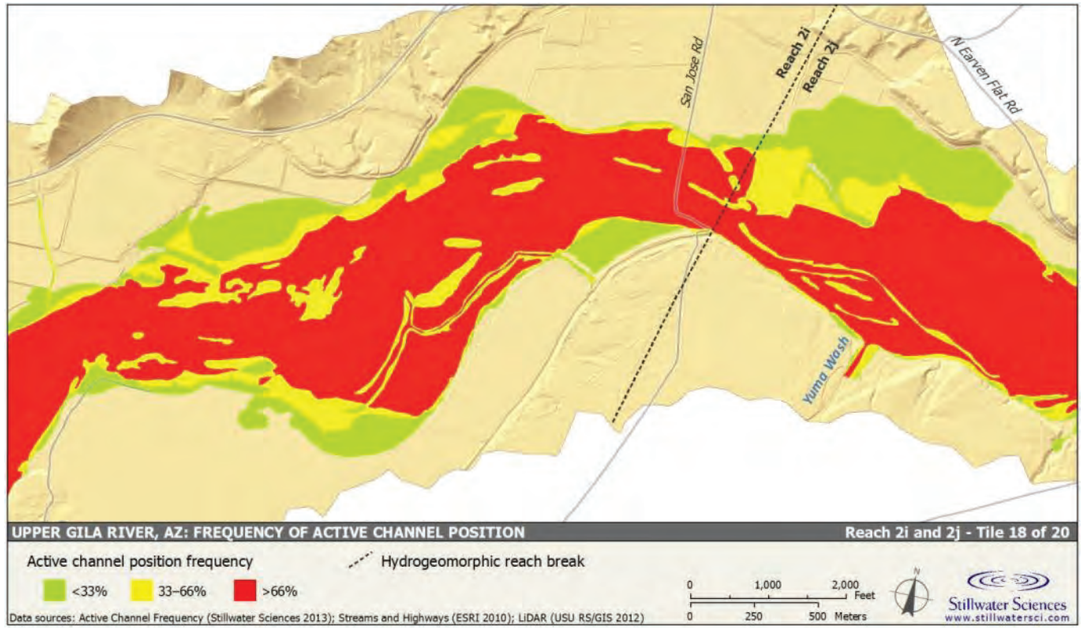
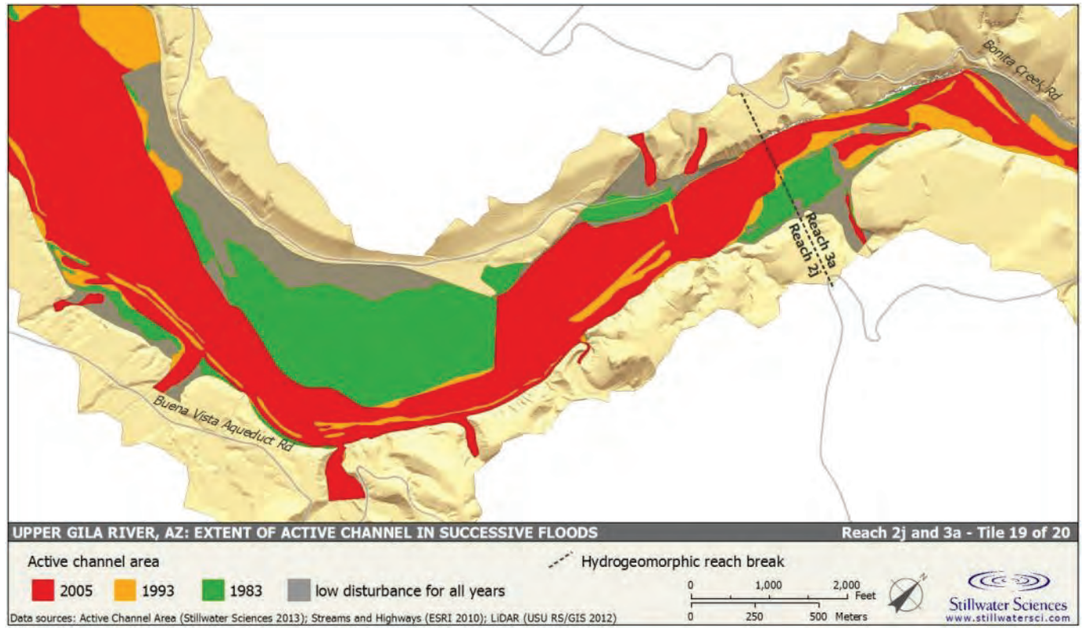
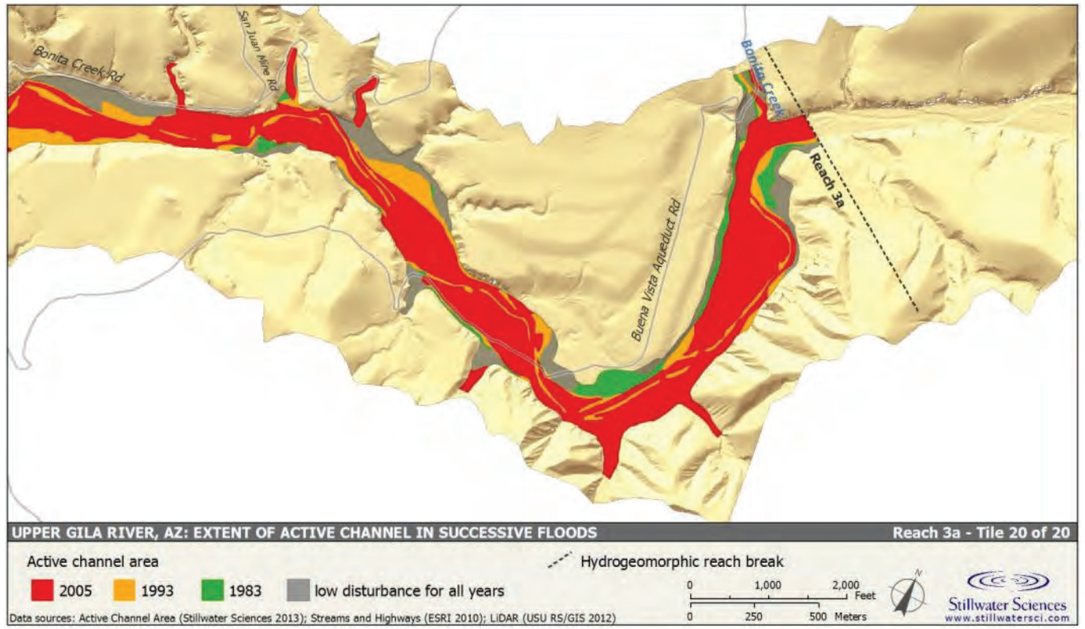


Figure B-2.9. Upper Gila River flood-scour analysis results for upper Reach 2i and lower Reach 2j: areal extent of active channel in successive floods (a, b), with more recent floods displayed on top; and frequency of active channel position (c, d) showing proportion of time that the active channel has occupied a given location.

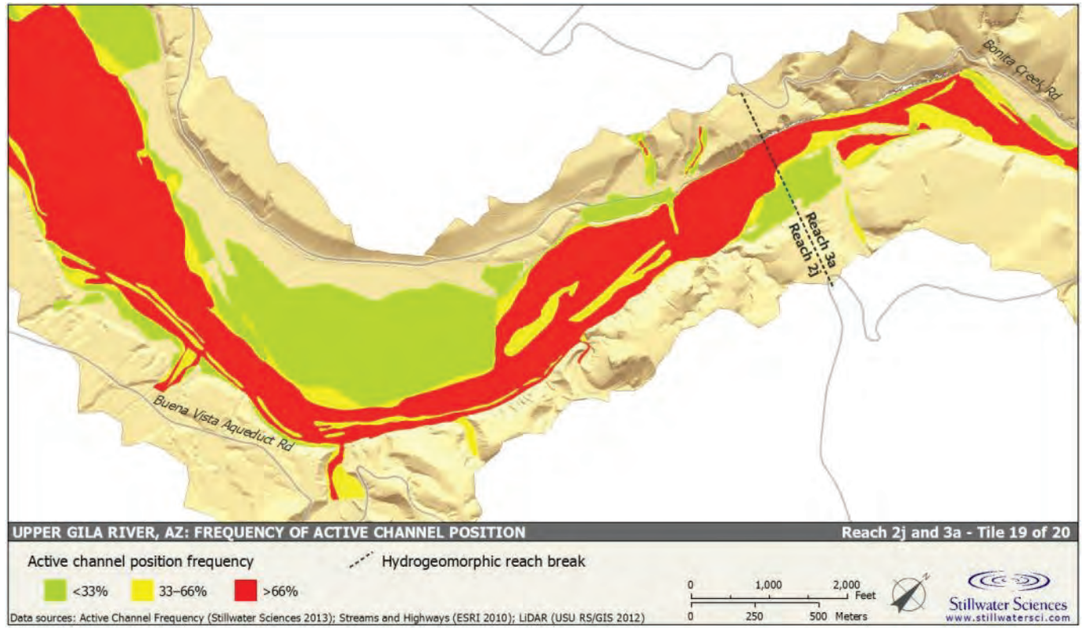
a)



b)



c)



d)

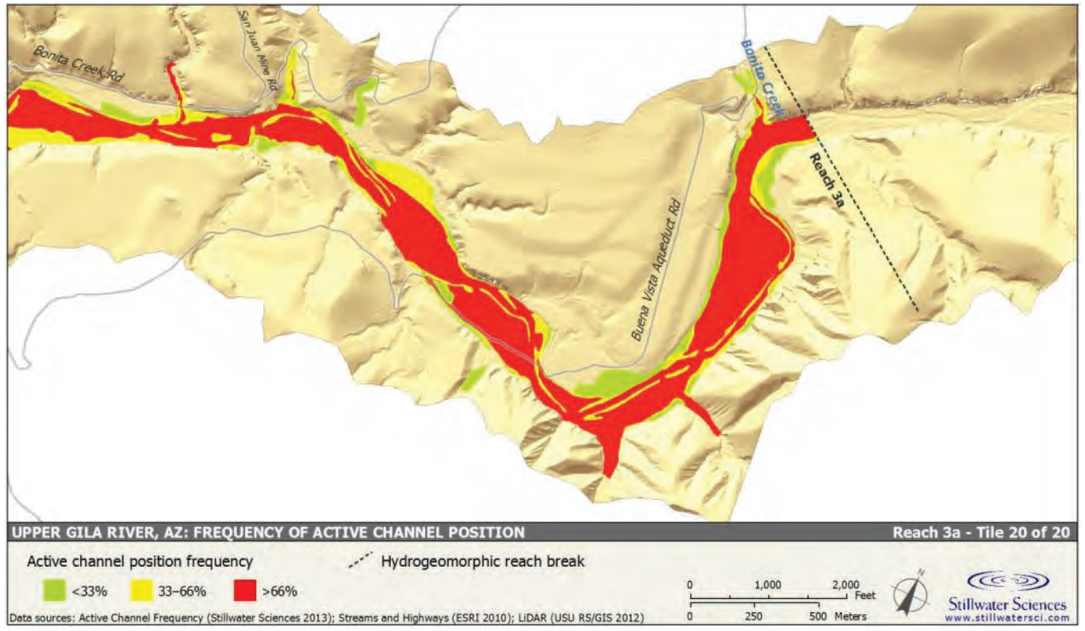


Figure B-2.10. Upper Gila River flood-scour analysis results for upper Reach 2j and Reach 3a: areal extent of active channel in successive floods (a, b), with more recent floods displayed on top; and frequency of active channel position (c, d) showing proportion of time that the active channel has occupied a given location.

B2 REFERENCES

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Graf, W. L. 2000. Locational probability for a dammed, urbanizing stream: Salt River, Arizona, USA. Environmental Management 25: 321–335.

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Appendix C

Riparian Vegetation Transect-Plot Data – *Stillwater Sciences*

Hydro-geomorphic reach (upstream to downstream order)	Transect	Plot number	Plot dimensions (m)			Topography		Soil Conditions				Hydrology				Fire evidence (Y/N)	Disturbance & Intensity Type						% Cover						Vegetation Cover Types													
			Width (m)	Length (m)	Radius (m)	Local form	Relative elevation [from 2012 LiDAR] (m)	Texture	Moisture (Y/N)	Moisture source	NRCS soil texture	Years since last flooded	Flood evidence	Flood frequency [from flood-scour analysis]	Ag return-flow influence (Y/N)		Disturbance type 1	Intensity of type 1	Disturbance type 2	Intensity of type 2	Disturbance type 3	Intensity of type 3	boulder / cobble	gravel	fines	water	vegetation	organic debris	Dominance	Herb phenology	Shrub phenology	Tree phenology	Species 1 (Age, %)	Species 2 (Age, % Cover)	Species 3 (Age, % Cover)	Species 4 (Age, % Cover)	Species 5 (Age, % Cover)	Species 6 (Age, % Cover)	Species 7 (Age, % Cover)	Species 8 (Age, % Cover)	Vegetation type	Adjacent veg type	Utah State University vegetation class	Canopy height [from 2012 LiDAR] (m)
3a	1	1	20	20		undulating	6.604004	Sand	no			>10		medium	no								0	0	15	0	75	10	Trees	Late	Late	Late	Prosopis glandulosa (mature; 25)	Chilopsis linearis (mature; 1)	Parkinsonia aculeatae (mature; 3)	Larrea tridentata (mature; 1)	Annual grasses (<0.3 m; 35)	Salsola spp. (>0.3 m; 10)			Mesquite bosque		Salt Cedar	-0.001038
		2	5	20		flat	6.971985	Silt	no			1 to 2	Debris deposits	medium	no								1	0	60	0	39	0	Shrubs	Late	Peak	n/a	Hymenoclea monogyra (mature; 15)	Baccharis sarothroides (mature; 10)	Prosopis glandulosa (mature; 10)	Tamarix spp. (mature; 2)	Annual grasses (<0.3 m; 20)				Burrobrush wash		Sand and Rock	-0.005981
		3	5	20		convex	0.055969	Sand	yes	River		<1	Drift lines	high	no								0	0	10	0	90	0	Trees	Late	Late	Peak	Populus fremontii (mature; 5)	Salix gooddingii (mature; 20)	Salix exigua (mature; 10)	Baccharis salicifolia (decadent; 15)	Prosopis glandulosa (mature; 5)	Tamarix spp. (mature; 5)	Cynodon dactylon (<0.3 m; 20)		Fremont cottonwood-Goodding's willow woodland		Sand and Rock (Water)	0
		4	5	20		flat	3.145996	Sand	yes	River		<1	Drift lines	high	no								10	10	20		60		Trees	Late	Peak	Peak	Salix exigua (mature; 20)	Salix gooddingii (pole; 40)	Cynodon dactylon (<0.3 m; 10)						Fremont cottonwood-Goodding's willow woodland		Salt Cedar (Bare soil and dry vegetation)	0.283997
		5	10	40		convex	0.036011	Silt	yes	River		1 to 2	Sediment deposit	medium	no		Competition from exotics	Low							25		75		Trees	Late	Peak	Peak	Populus fremontii (mature; 40)	Salix gooddingii (mature; 20)	Tamarix spp. (mature; 20)	Salix exigua (mature; 10)	Prosopis glandulosa (mature; 15)				Fremont cottonwood-Goodding's willow woodland	Mesquite bosque	Water (Bare soil and dry vegetation)	0
2j	3	1	20	20		flat	5.314026	Silt	no		coarse-loamy	6 to 10		low	no										10		80	10	Trees	n/a	n/a	Late	Populus fremontii (mature; 30)	Prosopis glandulosa (mature; 50)							Mesquite bosque		Cottonwood/ Goodding Willow	10.852966
		2	20	20		undulating	3.472046	Silt	no		coarse-loamy	<1		high	no		Competition from exotics	High							20		60	20	Shrubs	n/a	Late	Late	Populus fremontii (mature; 10)	Tamarix spp. (mature; 50)	Prosopis glandulosa (mature; 5)	Baccharis sarothroides (mature; 5)	Baccharis salicifolia (mature; 5)				Tamarisk-mixed riparian shrubland		Defoliated Salt Cedar	0
		3				flat	2.588013	Gravel	no		sandy	<1		high	no		Competition from exotics	Low						80	5		15		Shrubs	n/a	Late	n/a	Tamarix spp (mature; 5)	Hymenoclea monogyra (mature; 15)							Burrobrush wash		Sand and Rock	0
		4				convex	0.748962	Silt	yes		sandy	<1		high	no		Competition from exotics	Low							30	30	30		Shrubs	n/a	Late	n/a	Salix exigua (mature; 25)	Tamarix spp. (mature; 5)							Narrowleaf willow-mulefat shrubland		Willow	1.414001
	4	1	20	20		undulating	1.174011	Silt	yes		coarse-loamy	<1	Drift lines, soil cracks	high	no		Competition from exotics	High	ORV activity	Low			0	0	80	0	20	0	Shrubs	Peak	n/a	n/a	Tamarix spp. (mature; 15)	Baccharis salicifolia (mature; 5)	Salix exigua (mature; 2)						Tamarisk shrubland (low density)		Salt Cedar	1.197021
		2	10	20		undulating	3.291016	Gravel	no		n/a	6 to 10	Debris, drift lines	high	no		Competition from exotics	Low	Earth moving	High			10	10	20	0	60	10	Shrubs	n/a	n/a	n/a	Hymenoclea monogyra (decadent; 25)	Tamarix spp. (mature; 2)	Salsola spp. (>0.3 m; 5)	Portulaca oleracea (<0.3 m; 25)	Annual grasses (<0.3 m; 25)				Burrobrush wash		Salt Cedar	0.01001
		3	5	20		flat	0.619019	Gravel	no		sandy-skeletal	<1	Drift lines, bent veg	high	no		Competition from exotics	High					10	10	20	0	50	10	Shrubs	Peak	Peak	n/a	Tamarix spp. (mature; 20)	Baccharis salicifolia (mature; 20)	Cynodon dactylon (<0.3 m; 10)						Tamarisk-mixed riparian shrubland		Bare soil and dry vegetation	0.036011
		4	20	40		undulating	2.083008	Silt	yes	River	sandy-skeletal	1 to 2	Drift lines, debris	medium	no		Competition from exotics	Medium						0	10	20	70	0	Shrubs	Late	Late	n/a	Tamarix spp. (mature; 20)	Baccharis salicifolia (mature; 5)	Salix exigua (mature; 45)						Narrowleaf willow-mulefat shrubland	Burrobrush wash, Mequite bosque	Defoliated Salt Cedar (Salt Cedar)	0.003967
		5	10	40		concave	1.528992	Silt	yes	Ag runoff	coarse-loamy	>10		high	yes		Competition from exotics	High					10	10	3	0	95	2	Shrubs	Peak	Late	Peak	Tamarix spp. (mature; 50)	Baccharis salicifolia (mature; 5)	Populus fremontii (mature; 10)	Salix exigua (mature; 10)	Atriplex canescens (mature; 5)				Tamarisk-mixed riparian shrubland		Cottonwood/ Goodding Willow	0.938965
2i	6	1	25	40		convex	0.666992	Silt	yes	River	sandy-skeletal	<1	Drift lines, debris	high	uncertain								0	0	5	30	60	5	Shrubs	Late	Late	n/a	Salix exigua (mature; 35)	Tamarix spp. (mature; 25)	Baccharis salicifolia (mature; 5)	Salix gooddingii (mature; 5)	Sorghum halepense (>0.3 m; 5)	Cynodon dactylon (<0.3 m; 10)			Narrowleaf willow-mulefat shrubland		Willow	0.004028
		2	40	40		flat	1.473022	Silt	no		coarse-loamy	<1	Drift lines	high	no		Competition from exotics	High					10		65	0	15	10	Shrubs	Late	Late	n/a	Tamarix spp. (mature; 10)	Sorghum halepense (>0.3 m ; 5)							Tamarisk wash		Sand and Rock	0.003967
		3	20	20		undulating	2.655029	Silt	yes	Swale	sandy-skeletal	3 to 5	Debris	medium	no								0	0	15	0	35	50	Trees	Late	Peak	n/a	Tamarix spp. (mature; 20)	Heliomeris longifolia var. annua (<0.3 m ; 15)							Tamarisk shrubland		Defoliated Salt Cedar	0.435974
		4	10	30		convex	4.042969	Silt	yes	Ag runoff	coarse-loamy	>10		n/a	yes		Agriculture	Low					0	0	5	0	85	10	Trees	Late	Peak	Late	Populus fremontii (mature; 90)	Salix gooddingii (mature; 18)	Prosopis glandulosa (mature; 10)	Baccharis salicifolia (mature; 5)	Sarcostemma cynanchoides (mature; 1)	Sorghum halepense (>0.3 m; 10)			Fremont cottonwood-Goodding's willow woodland	Tamarisk shrubland	Cottonwood/ Goodding Willow	3.637024
	7	1	20	30		convex	2.491028	Silt	yes		coarse-loamy	<1	Debris	high	uncertain		Competition from exotics	Medium					10	0	10	40	40	10	Shrubs	Late	Late	Late	Tamarix spp. (mature; 25)	Salix exigua (mature; 10)	Salix gooddingii (seedling; 2)	Sorghum halepense (>0.3 m ; 2)	Cynodon dactylon (<0.3 m; 5)				Tamarisk-mixed riparian shrubland	Tamarisk wash	Salt Cedar (Defoliated Salt Cedar)	1.130981
		2	5	20		undulating	2.757019	Silt	no		coarse-loamy	3 to 5	Debris,water cracks	n/a	uncertain		Competition from exotics	Low					0	0	10	0	80	10	Trees	Late	Late	Late	Populus fremontii (decadent; 50)	Bassia scoparia (>0.3 m ; 10)	Datura wrightii (>0.3 m; 2)	Tamarix spp. (mature; 15)					Fremont cottonwood-Goodding's willow woodland	Tamarisk wash, Tamarisk shrubland	Cottonwood/ Goodding Willow	0
		3	20	20		flat	0.982971	Silt	no		coarse-loamy over sandy or sandy-skeletal	>10		high	no		ORV activity	Low	Competition from exotics	Low			0	0	50	0	30	20	Trees	Late	Late	n/a	Baccharis sarothroides (decadent; 15)	Atriplex canescens (mature; 10)	Lycium torreyi (mature; 1)	Tamarix spp. (mature; 5)	Acacia greggii (seedling; 2)	Salsola spp. (>0.3 m; 2)	Amaranth spp. (>0.3 m; 5)		Mixed shrubland	Tamarisk wash	Sand and Rock	0
	8	1	20	20		flat	0.45697	Silt	yes	River	coarse-loamy	<1	Matted grass	high	no		ORV activity	Low	Competition from exotics	Medium				30	50		15	5	Shrubs	Late	Late	n/a	Tamarix spp. (mature; 10)	Hymenoclea monogyra (mature; 5)	Sorghum halepense (>0.3 m; 3)	Cynodon dactylon (<0.3 m; 1)					Tamarisk wash		Salt Cedar	2.10199
		2	10	20		convex	0.541992	Sand	yes	River	coarse-loamy over sandy or sandy-skeletal	<1	Bent veg	high	no		Recreational use (non-ORV)	Low	Competition from exotics	Low	ORV activity	Low			5		95		Shrubs	Late	Peak	n/a	Tamarix spp. (mature; 15)	Baccharis salicifolia (mature; 30)	Salix exigua (mature; 20)	Sorghum halepense (>0.3 m ; 60)					Mixed riparian shrubland		Sand and Rock	-0.001038
		3	10	10		flat	3.454041	Silt	no		sandy-skeletal	6 to 10		medium	no		Competition from exotics	High							10		15	75	Shrubs	n/a	Late	n/a	Tamarix spp. (mature; 12)	Datura wrightii (>0.3 m ; 1)	Salsola spp. (>0.3 m; 2)						Tamarisk shrubland		Defoliated Salt Cedar	0
		4	20	20		flat	3.30603	Silt	yes	Swale	coarse-loamy over sandy or sandy-skeletal	6 to 10		high	no		Competition from exotics	High							40		50	10	Shrubs	Late	Late	n/a	Tamarix spp. (mature; 20)	Heliomeris longifolia var. annua (<0.3 m ; 15)	Triantherna portulacastrum (<0.3 m; 15)	Chameasyce sp. (<0.3 m; 15)	Baccharis sarothroides (mature; 2)	Salsola spp. (>0.3 m; 10)			Tamarisk shrubland		Defoliated Salt Cedar	-0.005005
		5	5	20		flat	1.325989	Silt	yes	River	coarse-loamy	<1	Debris, bent veg	high	no		Competition from exotics	Medium							15		70	15	Shrubs	Late	Late	n/a	Tamarix spp. (mature; 15)	Sorghum halepense (>0.3 m ; 40)	Cynodon dactylon (<0.3 m; 30)	Salix exigua (mature; 2)	Baccharis salicifolia (mature; 2)				Tamarisk wash		Willow	0.04303

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Appendix D

Riparian Plant Species Requirements – *Stillwater Sciences*

D1 INTRODUCTION

This appendix presents supplemental information on growing requirements for many of the native plant species that may be appropriate to restore in the Planning Area.

D1.1 Background Information and Data Definitions

Wetland and riparian vegetation dynamics are tightly coupled with hydrogeomorphic processes. Inputs of water, sediment, nutrients, and other ecological factors provide the raw materials that are shaped by physical forces such as groundwater-surface water interactions, flooding, tidal forces, erosion, sediment deposition, and chemical exchanges to develop wetland, channel and floodplain habitats. These inputs strongly influence plant species composition, distribution, and physical structure. Vegetation structure and composition, in turn, provide habitat, shade, cover, food, energy, and organic matter inputs for wildlife and aquatic communities and influence their population and food web dynamics.

Plant species are distributed along gradients of resource availability (e.g., light, water, nutrients), chronic environmental stress (e.g., salinity, inundation duration), and episodic physical disturbance (e.g., fire, flood, scour). Each plant species has evolved a unique suite of life history traits to cope with its environmental conditions, and its distribution across the landscape reflects the tradeoffs of its particular stress-tolerance and resource-capture strategies.

Riparian and wetland plants can be classified by their tolerances to drought, inundation, shade, salt, and herbivory. Other factors such as soil texture, rooting depth, and water use efficiency affect the ways plant species use below-ground resources and thus influence their distributions among suitable sites.

A list of native riparian trees, shrubs, forbs, and herbs found in the Gila Valley Planning Area was developed (Table D-1), and information on water availability/use factors, soil conditions, and other environmental characteristics (shade tolerance, tolerance to hedging, minimum temperature) necessary for growth and survival of each species were identified from the USDA PLANTS Database (NRCS 2002). The contents of Table D-1 are defined in the following sections. This information can be used to identify and prioritize potential riparian vegetation restoration areas within the Planning Area based on physical and other biological factors.

Table D-1. Riparian plant species requirements.

Species	Common name	Wetland indicator status	Anaerobic tolerance	Drought tolerance	Moisture use	Root depth, minimum (inches)	Precipitation (min)	Precipitation (max)	Adapted to fine textured soils?	Adapted to medium textured soils?	Adapted to coarse textured soils?	Nitrogen fixation	Fertility requirement	CaCO3 tolerance	pH (min)	pH (max)	Salinity tolerance	Hedge tolerance	Shade tolerance	Temperature minimum (°F)
Acacia greggii	catclaw acacia	Not listed	None	High	Low	12	3	20	Yes	Yes	Yes	None	Low	High	6.5	8.5	None	High	Intolerant	-13
Acer negundo	boxelder	FACW	Medium	High	Medium	40	15	75	Yes	Yes	Yes	None	Medium	High	5	7.8	Medium	None	Tolerant	-46
Atriplex canescens	fourwing saltbush	Not listed	None	High	Medium	20	5	18	Yes	Yes	Yes	None	Low	High	6.5	9.5	High	Medium	Intolerant	-43
Atriplex lentiformis[1]	big saltbush	FAC	High	High	Low	20	4	20	No	Yes	No	None	Medium	High	7	10	High	High	Intolerant	7
Baccharis salicifolia	mule-fat	FAC	Low	Low	Medium	12	10	18	Yes	Yes	Yes	None	Low	High	7	8.5	High	Low	Intolerant	-3
Baccharis sarothroides	desertbroom	FACU	Low	High	Low	12	2	10	Yes	Yes	Yes	None	Low	High	7	8.5	Medium	Low	Intolerant	28
Bouteloua gracilis	blue grama	Not listed	None	High	Medium	16	8	22	Yes	Yes	Yes	None	Low	Medium	6.6	8.4	Medium	None	Intolerant	-43
Celtis laevigata	sugarberry	FAC	Medium	Low	High	24	20	80	Yes	Yes	No	None	Medium	Medium	4.4	7.7	Low	Low	Tolerant	-21
Chilopsis linearis	desert willow	FACU	Low	High	Low	12	4	37	No	No	Yes	None	Low	Medium	6.6	10	Low	High	Intermediate	-23
Chilopsis linearis	desert willow	FACU	Low	High	Low	12	4	37	No	No	Yes	None	Low	Medium	6.6	10	Low	High	Intermediate	-23
Distichlis spicata	saltgrass	FAC	High	Medium	Medium	2	5	70	Yes	Yes	No	None	Medium	High	6.4	10	High	None	Intolerant	-35
Fraxinus velutina	velvet ash	FAC	Low	Medium	Low	24	12	20	Yes	No	No	None	Low	None	5.8	7.5	None	Medium	Intolerant	-13
Hymenoclea monogyra	singlewhorl burrobrush	Not listed	Medium	High	n/a	12	4	80	No	Yes	Yes	None	0	0	6.1	7.9	0	0	0	27
Juncus mexicanus[2]	Mexican rush	FACW	High	Low	Medium	8	8	20	Yes	Yes	No	None	Medium	Medium	6.2	8.2	High	None	Intolerant	-18
Muhlenbergia asperifolia	scratchgrass	FACW	Medium	Low	High	8	12	40	Yes	Yes	No	None	Low	High	6	8.4	High	None	Tolerant	-18
Populus fremontii[3]	Fremont cottonwood	Not listed	Medium	Medium	High	32	20	26	Yes	Yes	Yes	None	Medium	Medium	6	8	Low	None	Intolerant	-13
Salix exigua	narrowleaf willow	FACW	High	Medium	High	20	20	30	No	Yes	Yes	None	Low	High	6	8.5	Low	Medium	Intermediate	-38
Salix gooddingii	Goodding's willow	FACW	High	Medium	High	28	12	55	No	Yes	Yes	None	Medium	Low	5.7	7.4	None	None	Intolerant	-23
Sambucus nigra (mexicana)	blue elderberry	FACU	Medium	High	Low	12	10	60	No	Yes	Yes	None	Low	Medium	4.9	7.5	None	Low	Intermediate	-38
Schoenoplectus californicus	California bulrush	OBL	High	Low	High	14	40	60	Yes	Yes	No	None	Medium	Medium	5	9	Low	None	Intolerant	17
Schoenoplectus maritimus	cosmopolitan bulrush	OBL	High	Low	Medium	12	40	60	Yes	Yes	Yes	None	Low	Medium	4	7	High	None	Intolerant	-23
Sporobolus airoides	alkali sacaton	FAC	Medium	High	Low	16	5	13	Yes	Yes	Yes	None	Medium	High	6.6	9	High	None	Intolerant	-38
Sporobolus wrightii	big sacaton	FAC	None	Medium	Medium	20	5	20	No	Yes	Yes	None	Low	High	5.6	8	Low	None	Intolerant	-13
Typha latifolia	broadleaf cattail	OBL	High	None	High	14	14	180	Yes	Yes	Yes	None	Medium	Medium	5.5	8.7	Low	None	Intermediate	-36

Notes:
[1] The "Casa" cultivar has no anaerobic tolerance, medium moisture use, min precip of 6, and temp min of -8 (F).
[2] Other *Juncus* species that may occur in the Gila Valley Planning Area are likely to have fairly similar requirements.
[3] *P. fremontii* is not listed in the 2013 wetland indicator status list, but the related *P. deltoides* is listed as FAC.

D2.1 Environmental Factors

D2.1.1 Wetland indicators status

The U.S. Fish and Wildlife Service has prepared a National List of Plant Species That Occur in Wetlands: 1988 National Summary (USFWS 1988) and the 2103 Updated List (Lichvar 2013). Indicator categories are:

- Obligate Wetland (OBL). Occur almost always (estimated probability >99%) under natural conditions in wetlands.
- Facultative Wetland (FACW). Usually occur in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
- Facultative (FAC). Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
- Facultative Upland (FACU). Usually occur in non-wetlands (estimated probability 67%-99%), but occasionally found in wetlands (estimated probability 1%-33%).
- Obligate Upland (UPL). Occur in wetlands in another region, but occur almost always (estimated probability >99%) under natural conditions in non-wetlands in the region specified.

The wetland indicator categories should not be equated to degrees of wetness. Many Obligate Wetland species occur in permanently or semi-permanently flooded wetlands, but a number also occur and some are restricted to wetlands that are only temporarily or seasonally flooded. The Facultative Upland species include a diverse collection of plants that range from weedy species adapted to a number of environmentally stressful or disturbed sites (including wetlands) to species in which a portion of the gene pool (an ecotype) always occur in wetlands. Both the weedy and ecotype representatives of the facultative upland category occur in a variety of wetland habitats, ranging from the driest wetlands to semi-permanently flooded wetlands. Species not included in the 1988 or 2013 lists are typically considered non-wetland species.

D2.1.2 Water availability/use factors

Anaerobic Tolerance: What is the plant's tolerance of anaerobic conditions of the growth medium, relative to other species? (Low, Medium, High, None)

Drought Tolerance: What is the tolerance of the plant to drought conditions relative to other species in the same plant type and same geographical region? (Low, Medium, High, None)

Moisture Use: What is the degree to which this plant uses available soil moisture, relative to other species in the plant type? (Low, Medium, High)

Minimum Precipitation: The 2 in 10 year average minimum precipitation (inches) across years, of the driest climate station within the known geographical range of the plant. For cultivars, the geographical range is defined as the area to which the cultivar is well adapted rather than marginally adapted.

Maximum Precipitation: The annual average precipitation (inches) of the wettest climate station within the known geographical range of the plant. For cultivars, the geographical range is defined as the area to which the cultivar is well adapted rather than marginally adapted.

D2.1.3 Soil-related factors

Minimum Root Depth: The minimum depth of soil required for good growth in inches. Plants that do not have roots such as rootless aquatic plants (floating or submerged) and epiphytes are assigned a minimum root depth value of zero.

Adapted To Fine/Medium/Coarse Textured Soils: Can this plant establish and grow in soil with a fine/medium/coarse textured surface layer? (Yes, No) Refer to Table D-2.

Table D-2. VegSpec soil texture groups and corresponding soil texture classes.

VegSpec soil texture group [1]	Corresponding soil texture classes from the Soil Texture Triangle [2]		
Coarse	Sand	Coarse sand	Fine sand
	Loamy course sand	Loamy fine sand	Loamy very fine sand
	Very fine sand	Loamy sand	
Medium	Silt	Sandy clay loam	Very find sandy loam
	Silty clay loam	Silt loam	Loam
	Fine sandy loam	Sandy loam	Coarse sandy loam
	Clay loam		
Fine	Sandy clay	Silty clay	Clay

Notes:
[1] Source: The soil texture classes are from the Soil Science Society of America, http://www.soils.org/. An NRCS team partitioned the soil textures into the 3 groups.
[2] The United States Department of Agriculture (USDA) defines particle sizes as: sand 2.0–0.05 mm; silt 0.05–0.002 mm; and clay <0.002 mm in diameter.

Nitrogen Fixation: What is the amount of nitrogen fixed by this plant relative to other species? (None, Low, Moderate, High, Unknown (blank))

Fertility Requirement: What is the level of nutrients (N, P, K) required for normal growth and development relative to other species? (Low, Medium, High)

CaCO3 Tolerance: Want is the plant's tolerance to calcareous soil relative to other species. We define calcareous soil as soil containing sufficient free $CaCO_3$ and other carbonates to effervesce visibly or audibly when treated with cold 0.1M HCl. These soils usually contain from 10 to almost 1000g/kg $CaCO_3$ equivalent. (Low, Medium, High, None, Unknown (blank))

Minimum/Maximum pH: The minimum/maximum soil pH within the plant's known geographical range. For cultivars, the geographical range is defined as the area to which the cultivar is well adapted rather than marginally adapted.

Salinity Tolerance: What is the plant's tolerance to soil salinity? Tolerance to a soil salinity level is defined as only a slight reduction (not greater than 10%) in plant growth. None = tolerant to a soil salinity of 0–2 mmhos/cm; Low = tolerant to a soil salinity of 2.1-4.0 mmho/cm; Medium = tolerant to a soil salinity of 4.1–8.0 mmhos/cm; High = tolerant to a soil salinity greater than 8.0 mmhos/cm.

D2.1.4 Other environmental factors

Shade Tolerance: What is the tolerance for this plant, relative to other species, to grow in shade conditions? Refer to Table D-3. (Intolerant, Intermediate, Tolerant)

Table D-3. Comparison of shade tolerance classes.

Silvics of North America classes	Corresponding VegSpec classes
Very Intolerant and Intolerant	Intolerant
Intermediate	Intermediate
Very Tolerant and Tolerant	Tolerant

Hedge Tolerance: What is the tolerance of the woody perennial to hedging (close cropping) by livestock or wildlife. Forbs, grasses and non-woody vines are classified as "None."
(Low, Medium, High, None, Unknown (blank))

Minimum Temperature: The 2 in 10 year average minimum temperature (F°) across years, of the coldest climate station within the known geographical range of the plant. For cultivars, the geographical range is defined as the area to which the cultivar is well adapted rather than marginally adapted.

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Appendix E

SWFL Existing Conditions Summary
– *Matthew P Johnson*

E1 INTRODUCTION

The following descriptions and evaluation of Southwestern Willow Flycatcher (*Empidonax traillii extimus*) (SWFL) habitat occurred in 2013 within the Gila Valley Restoration Planning Area (see Figure 1-1 in the main report). This evaluation is based on direct habitat observations of each site using the NRCS southwestern willow flycatcher habitat methods established in 2012. This method was developed for riparian habitats within the state of Utah and was modified for conditions along the Gila River within the proposed Planning Area. The following habitat evaluations are only a portion of the proposed sites currently being considered in the Planning Area. In spring/summer 2014, we will survey and evaluate habitat for willow flycatcher at all proposed Planning Area sites.

Because of the sensitive nature of publically distributing locational information on endangered species, like the flycatcher, results of our habitat evaluation are not presented below. These data may be provided by request through the U.S. Fish and Wildlife Service office in Phoenix, Arizona (http://www.fws.gov/southwest/es/arizona/).

E1.1 Range Wide Southwestern Willow Flycatcher Breeding Population Sustainability, Habitat, Water and Food Background

Twice the amount of suitable habitat is needed to support the numerical territory goals because the long-term persistence of flycatcher populations cannot be assured by protecting only those habitats in which flycatchers currently breed (USFWS 2002). It is important to recognize that most flycatcher breeding habitats are susceptible to future changes in site hydrology (natural or human-related), human impacts such as development or fire, and natural catastrophic events such as flood or drought (USFWS 2002). Furthermore, as the vegetation at sites matures, it can lose the structural characteristics that make it suitable for breeding flycatchers (USFWS 2002). These and other factors can destroy or degrade breeding sites, such that one cannot expect any given breeding site to remain suitable in perpetuity (USFWS 2002). Thus, it is necessary to have additional suitable habitat available to which flycatchers can readily move if displaced by such habitat loss or change (USFWS 2002).

E1.1.1 Habitat criteria

The flycatcher currently breeds in areas from near sea level to over 2,600 meters (m) (8,500 feet (ft) (Durst et al. 2008) in vegetation alongside rivers, streams, or other wetlands (riparian habitat). It establishes nesting territories, builds nests, and forages where mosaics of relatively dense and expansive growths of trees and shrubs are established, near or adjacent to surface water or underlain by saturated soil (Sogge et al. 2010). Habitat characteristics such as dominant plant species, size and shape of habitat patch, tree canopy structure, vegetation height, and vegetation density vary widely among breeding sites. Nests are typically placed in trees where the plant growth is most dense, where trees and shrubs have vegetation near ground level, and where there is a low-density canopy. Some of the more common tree and shrub species currently known to comprise nesting habitat include Gooddings willow (*Salix gooddingii*), coyote willow (*Salix exigua*), Geyer's willow (*Salix geyeriana*), arroyo willow (*Salix lasiolepis*), red willow (*Salix laevigata*), yewleaf willow (*Salix taxifolia*), boxelder (*Acer negundo*), tamarisk (also known as saltcedar, *Tamarix ramosissima*), and Russian olive (*Elaeagnus angustifolia*) (USFWS 2002). While there are exceptions, generally flycatchers are not found nesting in areas without willows, tamarisk, or both.

E1.1.2 Water criteria

Southwestern willow flycatcher nesting habitat is associated with perennial stream flow that can support the vegetation characteristics needed by breeding flycatchers. Flycatcher nesting habitat can also persist on intermittent (ephemeral) streams that retain local conditions favorable to riparian vegetation (USFWS 2002). The range and variety of stream flow conditions (frequency, magnitude, duration, and timing) (Poff et al. 1997) that will establish and maintain flycatcher habitat can arise in different types of both regulated and unregulated flow regimes throughout its range (USFWS 2002). Also, flow conditions that will establish and maintain flycatcher habitat can be achieved in regulated streams, depending on scale of operation and the interaction of the primary physical characteristics of the landscape (USFWS 2002). Flowing streams with a wide range of stream flow conditions that support expansive riparian vegetation are also an essential physical feature of flycatcher habitat. The most common stream flow conditions are largely perennial (persistent) stream flow with a natural hydrologic regime (frequency, magnitude, duration, and timing). However, in the Southwest, hydrological conditions can vary, causing some flows to be intermittent, but the floodplain can retain surface moisture conditions favorable to expansive and flourishing riparian vegetation. These appropriate conditions can be supported by managed water sources and hydrological cycles that mimic key components of the natural hydrologic cycle.

E1.1.3 Food criteria

The southwestern willow flycatcher is somewhat of an insect generalist (USFWS 2002), taking a wide range of invertebrate prey including flying, ground and vegetation-dwelling species of terrestrial and aquatic origins (Drost et al. 2003). Flycatchers employ a “sit and wait” foraging tactic, with foraging bouts interspersed with longer periods of perching (Prescott and Middleton 1988).

Flycatcher food availability may be largely influenced by the density and species of vegetation, proximity to and presence of water, saturated soil levels, and microclimate features such as temperature and humidity (USFWS 2002). Flycatchers forage within and above the tree canopy, along the patch edge, in openings within the territory, over water, and from tall trees as well as herbaceous ground cover (Bent 1960, McCabe 1991).

E1.2 SWFL Evaluation Guide

The following is a re-presentation of the Natural Resources Conservation Service’s (NRCS) Wildlife Habitat Evaluation Guide for southwestern willow flycatcher (May 2013 version: http://efotg.sc.egov.usda.gov/references/public/NM/Rangewide_SWFL_WHEG(5-15-2013).xlsx).

A SWFL evaluation area is a discrete area of vegetation and hydrology. Plant species and composition, age, and height are considered in the evaluation area. Due to the wide variety of habitat used by the species across its range, the evaluator will need to interpret the questions to their situation.

E1.2.1 Habitat configuration

- Two or more large patches consisting of dense (difficult to walk through) woody riparian vegetation. Patches are mostly > 33 feet wide and > 20 acres in size.
- Two or more large patches consisting of dense (difficult to walk through) woody riparian vegetation. Patches are mostly > 33 feet wide and are >10 acres but < 20 acres in size.
- A multiple patch complex with one large patch consisting of dense (difficult to walk through) woody riparian vegetation. Large patch is mostly > 33 feet wide and least 10 acres in size. Additional patches are > 2.5 acres but < 10 acres.
- Multiple patches consisting of dense (difficult to walk through) woody riparian vegetation. Patches are at least 33 feet wide and > 2.5 acres and < 4.5 acres in size.
- A single patch of dense riparian vegetation at least 33 feet wide and > 2.5 acres, but < 4.5 acres in size, or is < 2.5 ac but is connected to other patches.
- A single, narrow strip of riparian vegetation that does not extend from or connect to a larger patch and AVERAGE WIDTH is less than 33 feet wide and is <2.5 acres and is not connected to another patch.

E1.2.2 Habitat structure

- Mature multi-storied riparian vegetation with canopy heights ranging from approximately 35 to 65 feet tall, with mosaics of densely vegetated understory's of shorter trees (greater than 15 feet tall that are difficult to walk through).
- Young stands of regenerating riparian vegetation with similar heights of vegetation approximately 15 feet in height (that are difficult to walk through).
- Mature woody riparian vegetation with canopies greater than 15 feet with multiple canopy gaps containing younger trees less than 15 feet in height.
- Young stands of regenerating vegetation with varying heights, most <15 feet in height.
- Canopy height for entire patch is less than 15 feet in height, consisting of mature, somewhat interconnected trees and with little to no regeneration.
- No connected trees; little to no regeneration. Trees are not capable of reaching above 15' in height.

E1.2.3 Habitat composition—woody

- Woody riparian vegetation composed of native species (i.e., typically woody species such as willow, cottonwood) and no exotic vegetation (such as tamarisk, and Russian olive).
- Woody riparian vegetation dominated by >75% native vegetation (i.e. typically woody species such as willow, cottonwood) with a smaller component of exotic vegetation (most likely tamarisk, and possibly Russian olive).
- Woody riparian vegetation dominated >50% native vegetation (i.e. typically woody species such as willow, cottonwood) with a smaller component of exotic woody species (most likely tamarisk, and possibly Russian olive).
- Woody riparian vegetation composed of >50% exotic vegetation (mostly likely tamarisk, and possibly Russian olive).
- Little to no woody riparian vegetation flycatcher's use for nesting; or site potential is for herbaceous only. Abundant wetland vegetation like cattails or arundo do not comprise flycatcher habitat.

E1.2.4 Habitat composition—herbaceous (grass, forb, sedge)

- Native understory > 2 ft tall.
- Native with some non-native understory > 2 ft tall.
- Native with some non-native understory 6 in – 2 ft tall.
- Understory dominated by non-natives or is < 6 inches tall.
- Little to no understory of grasses, forbs, or sedges.

E1.2.5 Water depletions

- No river diversion or groundwater pumping.
- Limited river diversion or groundwater pumping that does not reduce the water available for riparian or lake bottom habitat regeneration, growth, maintenance, distribution, or abundance.
- River diversion or groundwater pumping that reduces the water available for riparian or lake bottom habitat regeneration, growth, maintenance, distribution, or abundance; minimum suitable habitat maintained in most years.
- River diversion or groundwater pumping that reduces the water available for riparian habitat regeneration, growth, maintenance, distribution, or abundance: minimum suitable habitat only available in wettest years.
- River diversion or groundwater pumping to the extent that water is not available for riparian habitat regeneration, growth, maintenance, distribution, or abundance.

E1.2.6 General hydrology (especially May 15-Aug 1)

- Perennial surface flow with elevated groundwater within or adjacent to assessment area.
- Intermittent streams that provide surface water during the breeding season.
- Mostly perennial surface flow, with some intermittent sections or short durations of intermittent flow and elevated groundwater maintains moist soils
- Intermittent or perennial surface flows during the breeding season with elevated groundwater.
- No surface flow or rare occurrence of surface flow; breeding season in most years without moist soils and elevated groundwater.

E1.2.7 Flood frequency

- Regular flooding every 1.5–2 years. Flood plain wetlands (oxbows, backwater wetlands) are still hydrologically connected to the river. High flows in the river channel result in surface water saturation of these floodplain features.
- Overbank flooding occurs every 3–4 years. Channel is slightly incised. Flood plain wetlands (oxbows, backwater wetlands) are still hydrologically connected to the river. High flows in the river channel result in surface water saturation of these floodplain features.
- Flooding every 5-6 years. Most floodplain wetlands are wetted when river levels rise.

- Flooding every 7–10 years. Only the deepest floodplain wetlands are wetted when river levels rise. Some runoff water available to help establish woody vegetation.
- No flooding. The channel is deeply incised or confined by structures such as levees. Floodplain wetlands are no longer hydrologically connected to the river. Runoff cannot provide enough water to establish dense woody vegetation.

E1.2.8 Site disturbance

- No human disturbance occurs in the assessment area.
- SWFL Habitat quality factors are maintained with minimal disturbance. Access is limited to the non-breeding/brood rearing season. Land management, such as livestock grazing and fire wood harvest are conducted so that the timing and intensity avoids or minimizes disturbance. No vehicular recreational activities within or adjacent to assessment area. All disturbance activities occurs outside the breeding season: all grazing will be consistent with NRCS grazing plans specific to SWFL management.
- SWFL habitat quality factors are maintained with noticeable, short term impacts to habitat quality from land management such as livestock grazing, and fire wood harvest, and other land management. No vehicular recreational activities within or adjacent to patch: grazing will follow NRCS approved grazing plan specific to SWFL management. Grazing plan may include part of the growing season (but not nesting season) some years.
- SWFL habitat quality factors are present but long term impacts to habitat quality are apparent. Land management decisions are applied without regard for the SWFL nesting season. Livestock grazing is conducted without an NRCS plan. No vehicular recreational activities within or adjacent to assessment area.
- Low-quality SWFL habitat due to human activities and land management. Physical and auditory disturbances during the nesting season are common. Vehicular recreational activities within or adjacent to assessment area.

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Appendix F

SWFL Breeding Habitat Prediction Modeling – *James R. Hatten and Matthew P. Johnson*

F1 INTRODUCTION

The Southwestern Willow Flycatcher (*Empidonax traillii extimus*) (SWFL) is a federally endangered bird (USFWS 1995) that breeds in riparian areas in portions of New Mexico, Arizona, southwestern Colorado, extreme southern Utah and Nevada, and southern California (USFWS 2002). Across this range, it uses a variety of plant species as nesting/breeding habitat, but in all cases prefers sites with dense vegetation, high canopy, and proximity to surface water or saturated soils (Sogge et. al 2010).

A key challenge facing the management and conservation of willow flycatchers is that riparian areas are dynamic, with individual habitat patches subject to cycles of creation, growth, and loss due to drought, flooding, fire, and other disturbances (Hatten and Sogge 2007, Paxton et al. 2007). The recent establishment of the tamarisk leaf beetle introduces a new dynamic factor affecting habitat suitability (Paxton et al. 2011). Measuring and predicting SWFL habitat—either to identify areas that may develop into appropriate habitat for SWFLs or that, with intervention by active restoration could support future flycatcher nesting—requires knowledge of recent/current/future habitat conditions and an understanding of the dynamic processes and ecological factors that determine willow flycatchers' use of riparian breeding sites.

Breeding site assessment has typically been based on qualitative criteria (e.g., "dense vegetation" or "large patches") that require on-the-ground field evaluations by local or regional flycatcher experts. While this has proven valuable in locating many of the currently known breeding sites, it is nearly impossible to apply this approach effectively over large geographic areas (e.g., the Gila River). The SWFL Recovery Plan (USFWS 2002) recognizes the importance of developing new approaches to habitat identification, and recommends the development of drainage-scale, quantitative habitat models. In particular, the plan suggests using models based on remote sensing and GIS technology that can capture the relatively dynamic habitat changes that occur in southwestern riparian systems.

Southwestern willow flycatchers are present in the Gila Valley Restoration Planning Area (hereafter "Planning Area"), an 85-km section of the upper Gila River in Arizona (see Figure 1-1 in the main report), which has been designated as critical habitat for the species by the USFWS. They typically establish nesting territories, build nests, and forage where mosaics of relatively dense and expansive growths of trees and shrubs are established near or adjacent to surface water and/or underlain by saturated soil (Sogge et al. 2010). SWFLs exist and interact as groups of metapopulations—a group of geographically separate breeding populations connected to each other by immigration and emigration—and are considered most stable where many connected sites or large populations exist. Metapopulation persistence or stability is more likely to improve by adding more breeding sites rather than expanding existing sites, which would distribute birds across a greater geographical range, minimize risk of simultaneous catastrophic population loss, and avoid genetic isolation. Approximately twice the amount of suitable habitat is therefore needed to support the numerical territory goals because the long-term persistence of SWFL populations cannot be assured by protecting only those habitats in which the species currently breeds (USFWS 2002).

It is also important to recognize that most breeding habitats are susceptible to future changes in site hydrology (natural or human-related), human impacts such as development or fire, and natural catastrophic events such as flood or drought (Hatten and Sogge 2007). Furthermore, as the vegetation at sites mature, it can lose the structural characteristics that make it suitable for breeding individuals. These and other factors can destroy or degrade breeding sites making their

suitability ultimately ephemeral. Thus, it is necessary to have additional suitable habitat available to which SWFLs can readily move if displaced by such habitat loss or change.

Information on reach-scale SWFL conditions supported by habitat-prediction modeling performed specifically for the Planning Area is presented here. Field surveys were conducted in 2013 to characterize existing and potential SWFL-habitat quality throughout the Planning Area. The findings of these field surveys, in additional to supporting information on general species conditions, are presented in Appendix E, as authored by Matt Johnson of Northern Arizona University. In spring/summer 2014, additional willow flycatcher surveys and habitat evaluations will be conducted in proposed restoration sites in order to validate the model results discussed in this report and continue to better characterize the potential SWFL habitat quality within the Planning Area.

There are six objectives of the SWFL existing-conditions review and habitat prediction modeling:

1. Develop a conceptual model of SWFL breeding requirements (Figure F-1), which include physiological and other environmental processes that were identified by previous research as important determinants of species survival and reproduction, and are conceptual links to the spatially and temporally comprehensive variables that were available for us to use in our statistical modeling.
2. Gather and synthesize historical SWFL presence/absence and breeding data along the upper Gila River (Arizona/New Mexico boundary–Gila River/San Pedro Confluence).
3. Estimate potential breeding habitat for SWFL in the Planning Area by characterizing existing habitat conditions through field surveys.
4. Apply two sets of models to estimate SWFL habitat within the Planning Area: (a) satellite models, which characterize vegetation from Landsat Thematic Mapper (TM) imagery; and (b) aerial models, which use fine-scale data to characterize vegetation from orthorectified digital aerial photography and LiDAR collected in October 2012.
5. Incorporate the effects that tamarisk biocontrol will have on SWFL habitat over a period of three to five years following expansion of the beetle into the Gila Valley area. The modeling effort can potentially map likely defoliated areas under future scenarios and help detect trends in SWFL habitat suitability caused by changes in vegetation over time.
6. Communicate the progress of model development and results with Gila Watershed Partnership, U.S. Fish and Wildlife Service, Bureau of Reclamation, Arizona Game and Fish, and Salt River Project.

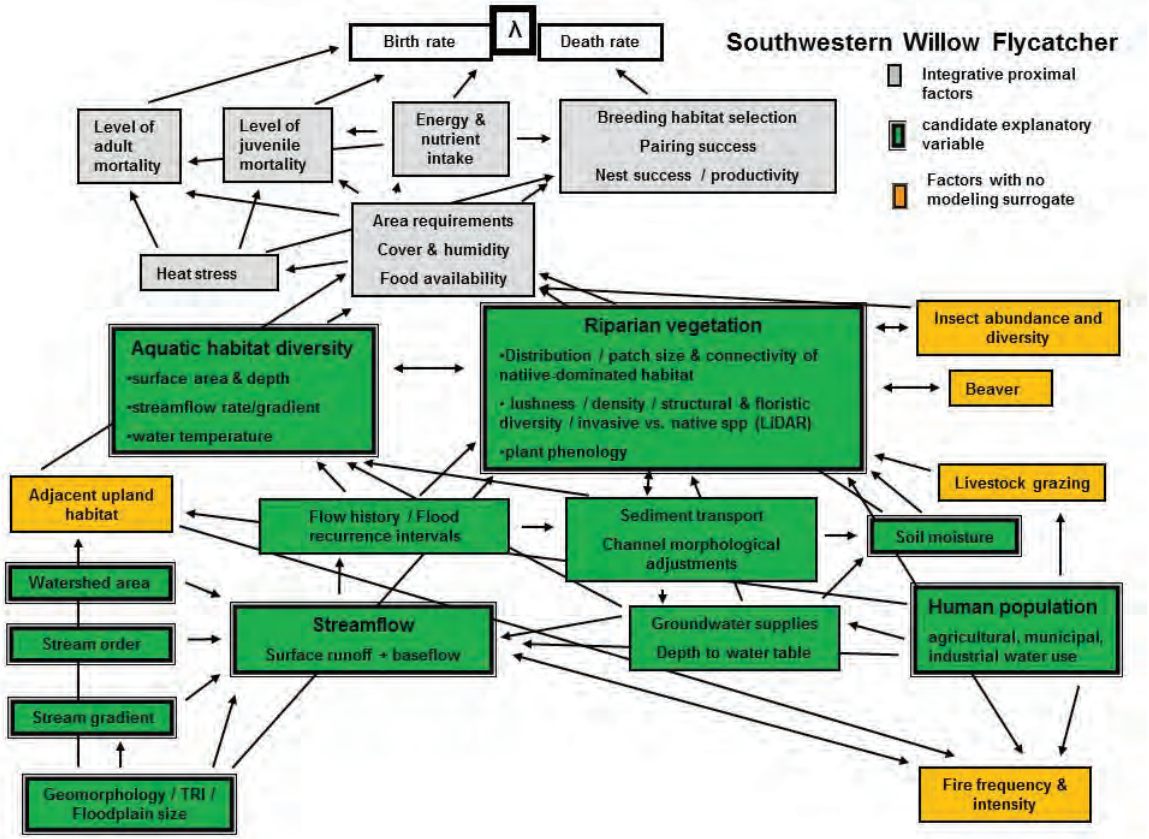


Figure F-1. Southwestern willow flycatcher conceptual model of factors that might possibly affect flycatcher and population dynamics that includes changing physiological and environmental integrative proximal factors (gray), candidate explanatory variables (green) and factors with no modeling surrogate (orange) that may affect flycatcher productivity but have no direct data to support it.

F2 METHODS

F2.1 SWFL Satellite Model

In 1999 the Arizona Game and Fish Department (AGFD) developed a GIS-based model (Hatten and Paradzick 2003) to identify willow flycatcher breeding habitat from Landsat Thematic Mapper (TM) imagery and a 30-m resolution digital elevation model (DEM). The GIS-based model (hereafter called "satellite model") was developed with presence/absence survey data acquired along the San Pedro and Gila rivers, and from the Salt River and Tonto Creek inlets to Roosevelt Lake in southern Arizona. The satellite model has been tested by predicting SWFL breeding habitat at multiple locations around Arizona and New Mexico, performing as expected by identifying riparian areas with the highest flycatcher nest densities (Hatten and Sogge 2007, Hatten et al. 2010). Thus, our first modeling objective was to assist with site restoration and planning through application of the satellite model in the Planning Area.

We applied the satellite model to identify and map potential SWFL breeding habitat in 2013 along the entire Planning Area. For modeling purposes, we developed four spatially explicit predictor variables (grids) extracted off of Landsat imagery and a 30-m resolution DEM (Table F-1). We used binary logistic regression (Hosmer and Lemeshow 1989) and Arc/Info® GRID (ESRI, 1992) to calculate and map the relative quality of breeding habitat within 0.09-ha (30m×30m) cells. We calculated the relative quality of breeding habitat (P) with the following equation:

$$P \quad \frac{e^{g\ x}}{1+e^{g\ x}} \qquad \text{(Eq. 1)}$$

where g(x) is the linear combination of parameter estimates obtained from the logistic regression (Hosmer and Lemeshow 1989, Keating and Cherry 2004). In Eq. (1), the relative quality of flycatcher breeding habitat is linked to the probability of a flycatcher territory occurring. The satellite model assigns cells a probability between 1 and 99%, which we reclassified into 1 of 5 probability classes: (1) 1–20%, (2) 21–40%, (3) 41–60%, (4) 61–80%, and (5) 81–99%. Larger probability classes (classes 4 and 5) have been found to contain higher densities of breeding flycatchers in Arizona and New Mexico (Paxton et al. 2007, Hatten and Sogge 2007).

Table F-1. Four predictor variables the satellite model uses to identify and map potential SWFL habitat in the Planning Area.

Variable	Description
ND_BEST4	Amount (i.e., number) of cells with NDVI values >0.41 within a 120-m radius
ND_TOP3	Binary (cells with NDVI > 0.33 = 1; NDVI < 0.33 = 0)
ND_SD4	Variability (SD) in NDVI within a 120-m radius
FLOOD30	Amount of floodplain or flat area within a 360-m radius from a 30-m DEM)

NVDI=Normalized Difference Vegetation Index

F2.2 Habitat Time Series

One of the great advantages of the satellite model is its utility for change detection and habitat time-series analysis since it reimages the same location every 16 days (Aronoff 1989). Thus, we created a habitat time series for the Planning Area by populating the SWFL satellite model with 27 Landsat scenes from 1986–2013. The habitat time series served two purposes: (1) it allowed us to create a bar graph that depicts how much potential SWFL breeding habitat was in the Planning Area between 1986 and 2013; and (2) it enabled us to create a time-lapse video that depicts how SWFL habitat changes year to year between 1986 and 2013 over the entire Planning Area. The habitat time series also will provide a baseline of predicted SWFL habitat that can be compared to future conditions.

F2.3 SWFL LiDAR Model

Identification of functional relationships between birds and the structure and composition of vegetation is a key step toward predicting how changes in specific land-cover types may affect various taxonomic assemblages. Most habitat suitability models are based on digital maps that very often describe the environment at a human scale and, hence miss ecological features such as structure that are important for wildlife. LiDAR (Light Detection And Ranging) data, laser scanning acquired by remote sensing, can fill this gap by providing useful information not only on the spatial extent of habitat types but also information on the vertical height. The advantage of LiDAR derived variables lays also in the availability at a large scale, instead of just in the survey sites. LiDAR data are beginning to be used in wildlife modelling and ecological studies with interesting results, especially for woodland species, where vegetation structure plays an important role in occupying a site and successfully breeding (Vierling et al. 2008, Martinuzzi et al. 2010, Müller and Brandl 2009, Flaspohler et al. 2010).

The LiDAR data are acquired by active remote sensing utilizing a laser scanning technique. The LiDAR sensor, usually mounted on an airplane, is a device that sends an infrared signal and registers the type and number of echoes of that signal received from the ground and from objects located above the ground such as trees and shrubs (Lefsky 2002). Standard processing of LiDAR data provides high resolution Digital Surface Models (DSMs) and Digital Terrain Models (DTMs) from which it is possible to derive useful information not only on the spatial extent of habitat types but also on the vertical height and structure of vegetation such as canopy height, stem diameter, canopy cover, and biomass (Goetz et al. 2007, Kaartinen and Hyyppä 2008, Lefsky 2002). Already, the benefits of LiDAR imagery are substantial enough that some authors have suggested that these measurements may begin to replace field measurements of vegetation structure traditionally used to describe wildlife habitat (Vierling et al. 2008).

Here we investigate LiDAR measurements of canopy height and heterogeneity to describe habitat associations for southwestern willow flycatcher in the Planning Area. Specifically, we use these measurements to conduct a multiscale analysis that compares the predictive power of models using variables (measurements) of canopy height and heterogeneity at a spatial resolution of 0.2 to 50 ha as predictor variables. Specifically, our objectives are to: (1) evaluate the utility of LiDAR measurements to provide information about habitat associations of riparian vegetation for southwestern willow flycatcher, and projected restoration sites along the Gila River; (2) evaluate the predictive performance of fine-scale vegetation measurements (canopy height, stem diameter, canopy cover) at 1-4 meter resolution to habitat measurements obtained at a coarser scale (30 m); and (3) compare the classification accuracies of the LiDAR habitat model to the satellite habitat model.

F2.4 Model Fit and Accuracy Assessment

We assessed the fit of the satellite model with nest and territory locations collected at Fort Thomas, by Salt River Project (SRP) personnel (SRP 2004–2012). Nest density is calculated by dividing territory numbers within each probability class by the area (hectares, ha) found within each probability class (Hatten and Paradzick 2003). The satellite model works as expected when territory/nest densities increase in higher probability classes. Conversely, we assessed model accuracy with omission (sensitivity) and commission (specificity) errors. An omission error occurs when a territory location falls outside of predicted habitat, thus omission errors change according to what probability cut point is selected (Hatten and Paradzick 2003). If the model is working correctly, omission errors should increase as the cut point is raised because less riparian vegetation is predicted as suitable for breeding.

F3 RESULTS

F3.1 SWFL Satellite Model

We successfully applied the SWFL satellite model (30-m resolution) to the Planning Area using Landsat 5 and 8 imagery (Landsat 5 prior to 2012, Landsat 8 afterwards). Satellite-model output included a continuous probability grid, a five-class probability grid, and a binary habitat grid, with higher cell values in each case indicating relatively better SWFL habitat. Figure F-2 displays the results of the five-class probability grid, with green areas representing the greatest breeding habitat suitability and red areas representing the lowest suitability. The satellite model identified the largest amounts of high-probability breeding habitat in planning Reaches 2c–2f, which is the downstream portion of the Planning Area. Reaches 2g–2j, and 3f, contained very little high-probability breeding habitat and are in the upstream portion of the Planning Area.

The habitat time series (Figure F-3) revealed that predicted SWFL habitat, as determined from the satellite model, fluctuates year to year, with a low of 589 ha (2002) and a high of 1,762 ha (2008). The yearly mean of predicted habitat was 1,112 ha, with a standard deviation (SD) of 288 and a coefficient of variation of 25.9%.

We assessed the accuracy of the satellite model with 2009 data since surveyors georeferenced 63 nest locations near Fort Thomas that summer. According to the satellite model, 63 nests occurred inside class-5 habitat while 6 were in class-4 habitat (Figure F-4). There were no omission errors (i.e., all nests fell within high-probability habitat), as determined from the satellite model. Furthermore, no nest locations occurred in lower-probability classes (1–3), demonstrating the excellent performance of the satellite model.

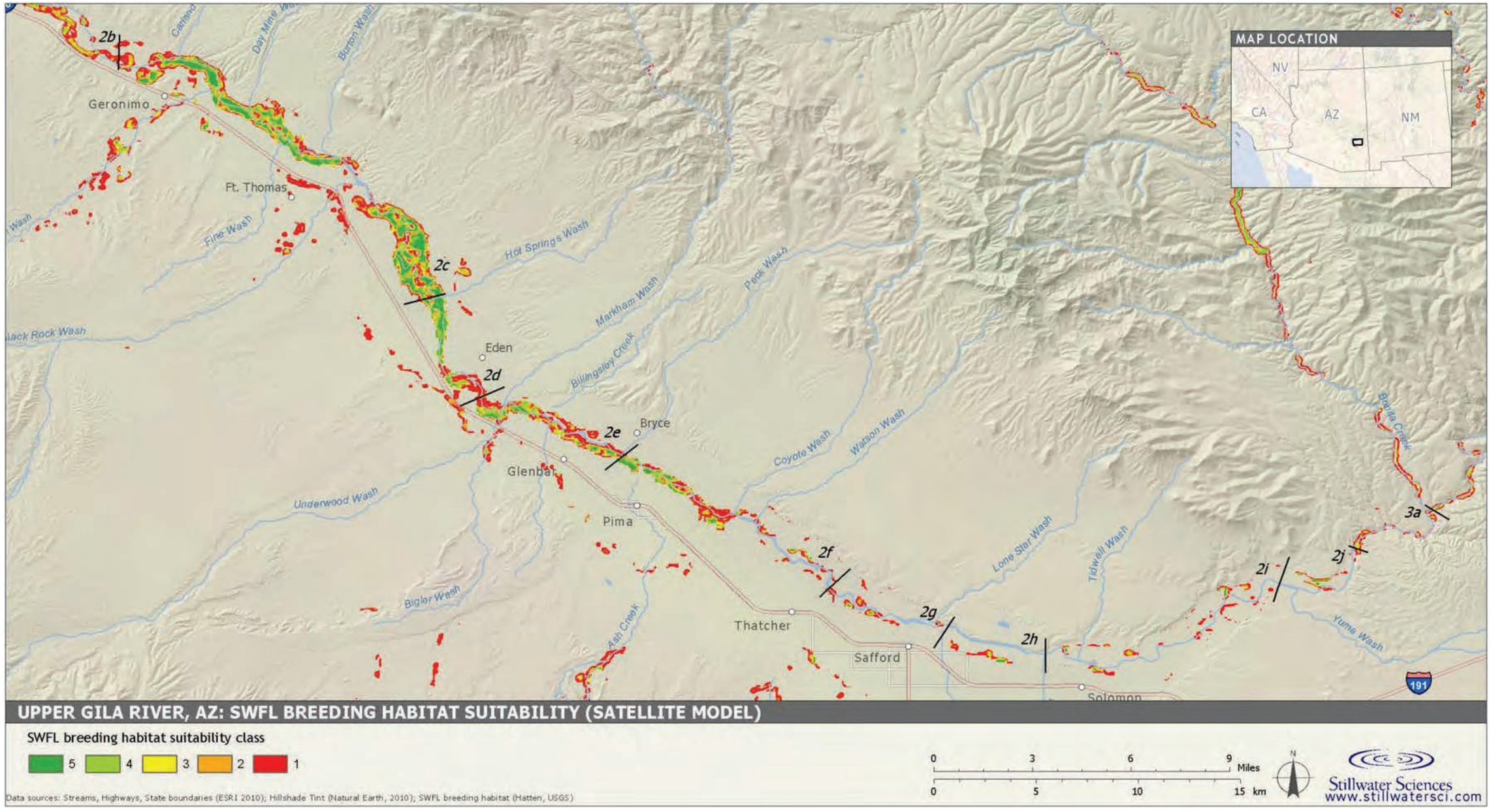


Figure F-2. Map of predicted SWFL breeding habitat suitability using the SWFL satellite model in the Planning Area (in reaches 2b–3a). Suitability value grades from green (greatest) to red (least).

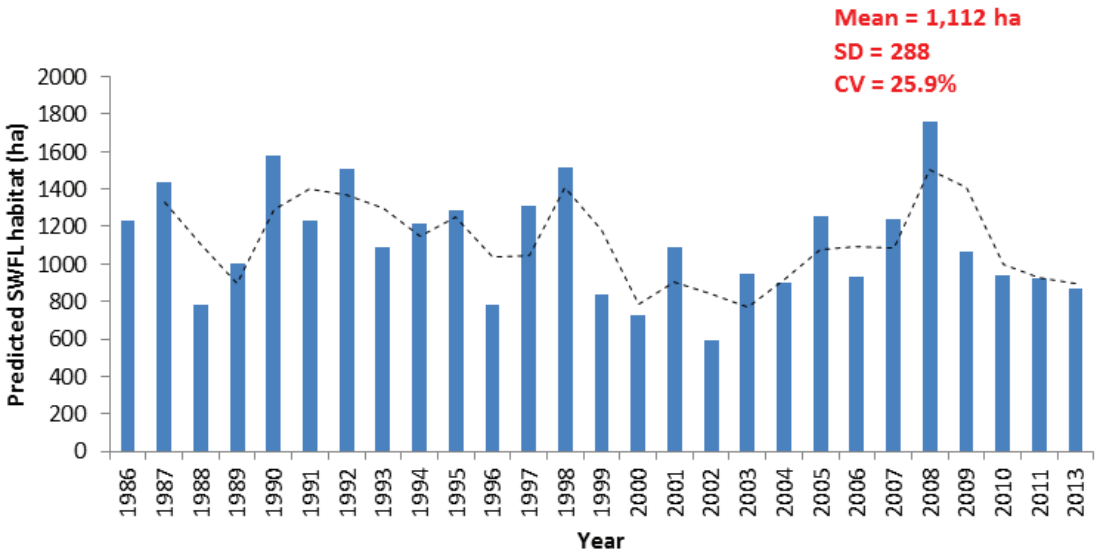


Figure F-3. Amount of predicted SWFL breeding habitat in the Planning Area (Bonita Creek to reservation boundary), obtained with the SWFL satellite model. The dashed line is a two-year running average. The year 2012 was unavailable due to a lapse in Landsat coverage.

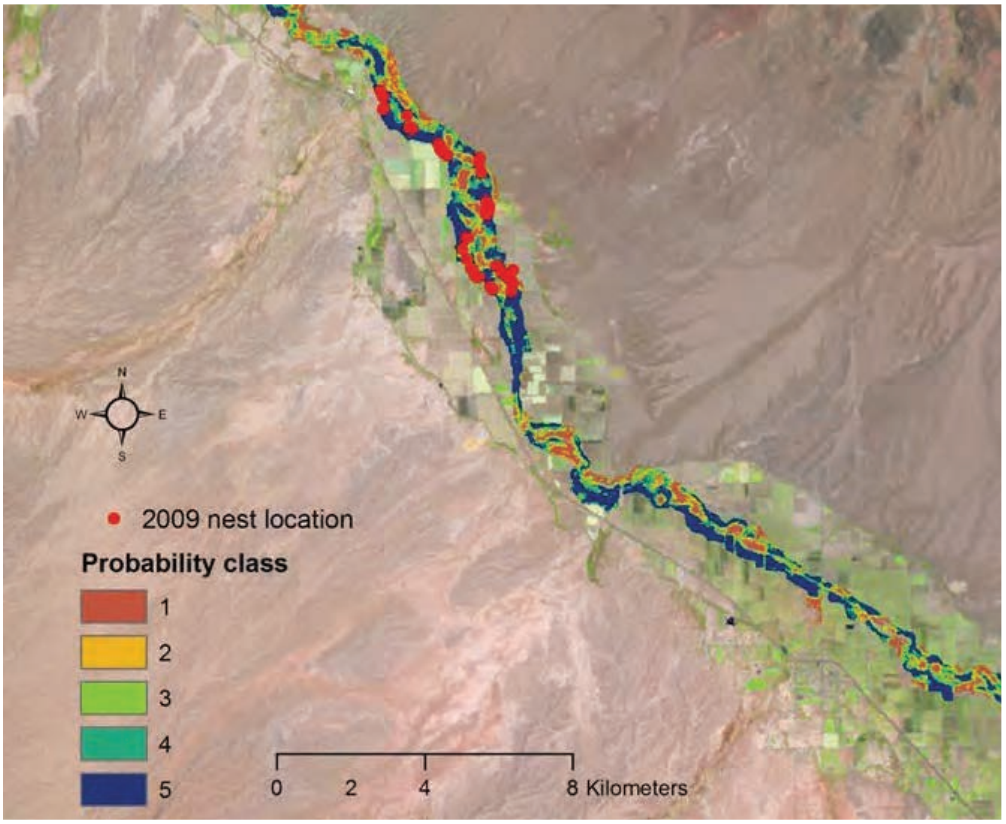


Figure F-4. Southwestern willow flycatcher nest locations in 2009 inside the Planning Area, near Fort Thomas (reaches 2c–2f), overlaid on five probability classes output by the satellite model. Larger probability classes are more suitable than smaller probability classes. A Landsat image is displayed in the background.

F3.2 SWFL LiDAR Model

The results of the LiDAR SWFL habitat modeling will be concluded after the 2014 spring/summer field season when we have a larger set of observed SWFL territories to build a more robust model. This larger set will be obtained from the 2014 SWFL surveys conducted at Fort Thomas and the proposed restoration Planning Area.

F4 DISCUSSION

The satellite model identified the largest amounts of high-probability breeding habitat in planning Reaches 2c–2f, which were wetter and lusher than upstream reaches (Figure F-2). The habitat time series (Figure F-3) revealed that predicted SWFL habitat in the Planning Area fluctuated ~25% year to year, between 589 ha (2002) and 1,762 ha (2008). The habitat time series dates back to 1986 and provides us with an excellent baseline to compare future conditions. For instance, when the tamarisk beetle invades the Planning Area, we will be able to determine if SWFL breeding habitat significantly deviates from the 2-yr running average. Most of the fluctuations are likely due to changes in leaf moisture and surface area, which NDVI is highly sensitive to (Avery and Berlin 1992). In addition, drought and fire negatively affect the amount of predicted SWFL breeding habitat on an annual or decadal cycle, while wet conditions increase NDVI and habitat estimates (Paxton et al. 2007, Hatten et al. 2010). For example, the satellite model found years 2000 and 2002 had the lowest amounts of predicted SWFL breeding habitat between 1986 and 2013, which coincided with severe drought conditions that affected vegetation vigor in the Planning Area.

The satellite model allows managers to track changes in riparian vegetation and SWFL habitat on a bi-weekly basis since Landsat 8 reimages the same location every 16 days. This will enable us to establish how vegetation vigor and predicted flycatcher habitat respond to environmental factors at different times of the breeding season, as well as among years. The time-lapse videos we produced from the satellite model's habitat time series shows an environment changing annually in response to environmental conditions. Flood, fire, and drought are currently the stressors that appear to affect the SWFL habitat predictions most, but we will soon be able to add insect infestation to the list when tamarisk beetle begins to defoliate the tamarisk favored by southwestern willow flycatchers (Paxton et al. 2011). The satellite model provides a baseline that will enable us to carefully implement riparian restoration activities along the Gila River within the proposed Planning Area as well as assess environmental stressors on SWFL habitat.

F5 ACKNOWLEDGEMENTS

We thank Ruth Valencia (Salt River Project) for providing territory/nest data so that we could evaluate the satellite model. We are grateful to Ken Tiffan and Deborah Reusser, U.S. Geological Survey, for their constructive comments that improved this report. We appreciate Jan Holder, Executive Director, Gila Watershed Partnership, for providing project oversight and coordination. Lastly, we thank the Walton Family Foundation for providing the funding for this project. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement of the U.S. Government.

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Appendix G

Restoration Site Monitoring: Vegetation, Soils, and Groundwater

– *Tom L. Dudley, Kevin R. Hultine, and Devyn A. Orr*

G1 INTRODUCTION

This appendix describes the initiation of a monitoring program in the Gila Valley Restoration Planning Area (Planning Area) developed and implemented by Drs. Tom Dudley and Kevin Hultine, with technical support from Devyn Orr, and additional field support from Dan Koepke.

G1.1 Background

As described in the main report, the Gila Watershed Partnership is developing plans for riparian restoration of upper Gila River riparian habitats for multiple objectives, particularly to reduce the negative impacts of invasive tamarisk and promote the establishment of native Cottonwood-Willow gallery woodlands within this high-value riparian ecosystem.

In the Gila Valley, invasion by tamarisk (*Tamarix ramosissima* and *T. parviflora*; salt cedar) is particularly intense as it has become the dominant woody plant species in the riparian corridor. Tamarisk competes with native vegetation and provides poor quality habitat to wildlife, is avoided by plant-feeding wildlife species and livestock, wastes critical water resources through its excessive evapotranspiration, exacerbates erosion and sedimentation issues in the river channel, and has become an increasingly threatening concern because it readily burns, even when healthy and green, turning riparian areas from barriers against fire into "wicks" that facilitate wildfire spread.



Repeat views of a tamarisk-infested floodplain along the Virgin River near Littlefield, AZ showing the green, foliated tamarisk (top) becoming browned and defoliated (bottom) over a 4-week period in 2010

The anticipated decline in tamarisk coverage within the Planning Area also brings concerns over how to manage riparian areas, including how to promote native vegetation for wildlife, particularly the federally endangered southwestern willow flycatcher (*Empidonax traillii extimus*; SWFL) and proposed threatened western population of yellow-billed cuckoo (*Coccyzus americanus*; YBCU). The Gila Valley supports one of the largest remaining populations of flycatchers and most build their nests in tamarisk, so defoliation by biocontrol will reduce the value of this non-native plant for wildlife. Natural recovery is expected over the long term, but can be accelerated by "helping" nature through restoration of native riparian trees that will provide habitat to fauna as well as improving overall environmental conditions, including reducing the risk of wildfire.

The objective of the Restoration Framework was to identify locations with environmental conditions appropriate for restoration of native cottonwood-willow vegetation for SWFL, YBCU and other wildlife, and that can also serve as a source population for natural recruitment of native vegetation. The approach uses a combination of remote sensing, hydrological evaluation and field topographic and vegetation assessment to identify sites where plants can be self-sustaining, but

also at low risk of flood scouring. Combined with documentation of historic and current SWFL habitat use, restoration sites are intended to also have high potential for colonization by the bird.

In some restoration sites, tamarisk may require moderate control measure to open up space and facilitate establishment of native plants. But because biocontrol will eventually reduce plant volume and the remaining plants provide structural benefits for wildlife, the intent is to minimize weed treatments, in part because prior analyses have shown that physical disturbance promotes secondary invasion of other noxious weeds such as Russian thistle, knapweeds, or perennial pepperweed that interfere with riparian recovery. On the other hand, the impacts of increasingly frequent wildfire on the Gila River, fueled by abundant tamarisk vegetation and often within SWFL nesting territories, can be turned into an asset if we can implement restoration efforts where fire has reduced weed biomass. This requires rapid herbicide treatment, however, because tamarisk readily re-sprouts and can regain high vegetative cover within a single growth season. All these elements are brought together in planning for successful and cost-effective riparian restoration, what we term "Integrative Ecosystem Pest Management."

G1.2 Purpose of Monitoring Program

In support of the Restoration Framework we initiated a pre-biocontrol monitoring program from which future efforts to monitor environmental conditions in the Planning Area may reasonably follow and to compare results as conditions respond to beetle colonization. Specifically, the monitoring program is intended to provide a quantitative system for evaluating the conditions of vegetation and associated ecosystem variables as they relate to current and future suitability for occupation by SWFL. It is also meant to build the capacity to evaluate the effectiveness of restoration actions in meeting the primary objective of enhancing habitat for SWFL in the face of future tamarisk defoliation by the leaf beetle. The program also provides an environmental framework for assessing future impacts of tamarisk biocontrol, involving the documentation of tamarisk distribution, abundance, health and genetic make-up.

The monitoring program was employed at several sites identified during the ecohydrological assessment and SWFL habitat modeling as exhibiting relatively high suitability for active tamarisk treatment and/or native vegetation plantings.

G2 MATERIALS AND METHODS

G2.1 Vegetation Monitoring

The objectives of the vegetation monitoring task was to: (1) document vegetation status (plant species composition and condition, stem densities, canopy structure, biocontrol impacts, non-native plant abundance, etc.) prior to and during the course of restoration actions at current and proposed restoration sites for SWFL habitat enhancement; and (2) assess SWFL reproductive needs by applying monitoring protocol to existing nesting sites in order to describe reference conditions as a target for designing restoration treatments. Monitoring was initiated in the spring of 2013, targeting potentially suitable restoration sites and a representative subset of currently occupied sites to provide reference conditions for SWFL nest site choice. The monitoring protocol was applied immediately prior to anticipated SWFL return from over-wintering regions to document vegetation conditions as closely as possible to the nesting period without interfering with reproductive activity. Monitoring stations were established to provide two general types of information: (1) to document vegetation and soils conditions at sites currently or recently known to be occupied by SWFL, as a guide to the target ecosystem conditions to be replicated in restoration efforts; and (2) to characterize potential restoration locations in order to provide baseline, pre-treatment conditions to be used both for determining best management practices suited for ecosystem conditions currently at those sites, and for evaluating the effectiveness of treatments and anticipated recovery responses once projects are implemented.

G2.1.1 Vegetation survey overview

Survey teams consisted of a minimum of three technicians, with one team leader designated for the full course of site monitoring to maintain sampling consistency throughout the exercise. Owing to the objective of characterizing riparian habitat for SWFL usage, the team leader was also qualified for surveying of riparian bird species and habitat, and specifically certified for SWFL monitoring.

Sites considered to be "Occupied" were chosen based on prior avian surveys conducted by SRP wildlife biologists (SRP 2013). However, because we were monitoring site conditions prior to return from over-wintering grounds, it was not possible to verify whether conditions at these locations were still suitable for breeding. Only one pre-nesting sampling exercise was implemented—during April and May (once vegetation had fully leafed out)—to avoid potential habitat disturbance if sensitive bird species were present. There was furthermore not a substantial enough change in site conditions between pre- and post-breeding season dates to merit a second round of monitoring.

G2.1.2 Spatial allocation of vegetation sampling units

Vegetation was monitored at the 7 sites selected within the Planning Area with the highest number of confirmed SWFL detections in previous years, based on data collected by SRP (2013). These sites were located between the towns of Pima and Fort Thomas on properties owned and/or managed by Freeport-McMoRan Copper & Gold (FMI), Salt River Project (SRP), Bureau of Land Management (BLM), and Bureau of Reclamation (BOR). The sites, which are shown in their respective maps in the results section below, are as follows (listed in upstream order):

1. FMI's Riparian Restoration Study Area site #1 (**FMI-RRSA-1**) and SRP's Conservation Easement site #4 (**SRPCE-4**), which overlay the "Clay Fire (2013)" burn area
2. FMI-owned **SRPCE-1** (immediately south of FMI-RRSA-1)

3. **FMI-RRSA-2** and **SRPCE-2**
4. BLM-owned SRP mitigation site #1 (**SRP-1**) (east of FMI-RRSA-2)
5. SRP-owned SRP mitigation site #2 (**SRP-2**) (east of FMI-RRSA-2)
6. BOR-owned SRP mitigation site "BR/Bellman" (**SRP-BR/Bellman**) (south of FMI-RRSA-2)
7. **FMI-RRSA-3**

At each of these sites, 8 plots were established along two independent transects, for a total of 16 plots per site. The zone of suitable SWFL habitat at prior occupied sites tended to be narrow, leading us to establish survey plots in a general linear array following contours of the stream channel. All plots were located within 200 meters (m) of the active channel except for SRPCE-1, where SWFL have nested up to 350 m from the river; most were within 100 m.

The 16 plots were arranged on a transect grid overlaying the general target area. The length of transects was determined by the habitat patch dimensions, with a minimum length of 20 m if habitat was narrow in breadth, while up to 100 m length where the habitat zone was broad. Each plot had an area of approximately 50 square meters (m^2), with each center point arranged along a transect at a minimum distance of 10 m between each plot (Figure G-1). Plots formed a diamond shape, extending 5 m in both directions along the transect and 5-m perpendicular from the center point; 5-m ropes or measuring tapes formed each radial, with a longer rope or tape connecting each end-point to form a series of 4 triangular sectors. Vegetation traits were assessed as described below for stem densities and other variables. Associated with each plot, three 1 x 1-m quadrats for understory species composition and primary cover analysis were set at 0, 5, and 10 m (beginning, middle, and end of plot), while vertical structure was estimated at 1-m intervals along the diagonal transect (10 points).

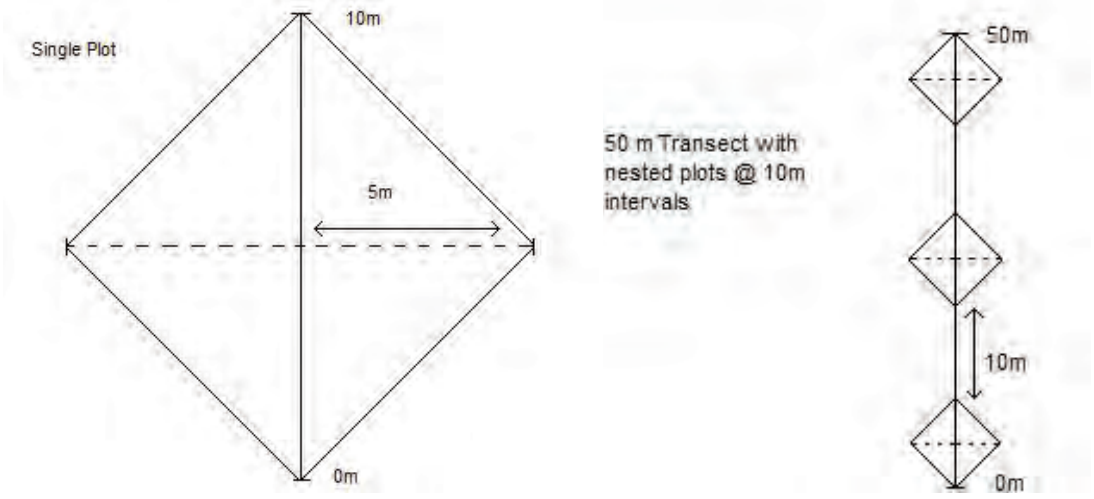


Figure G-1. Diagram of one vegetation survey plot (left) and typical plot arrangement along each transect (right)

G2.1.3 Total plot measurements

Density, percent cover, and species identity of all woody perennial plants (shrubs, trees, etc.) and non-woody plants over 1.5 m in height were counted within each 50 m^2 plot. Stem counts were taken on a plane 10 centimeter (cm) above the ground for all woody plants present on site. To be counted, a stem needed to originate from a woody plant exceeding 1.5 m in height, and the base of the stem had to be entirely within the plot. Stem diameters exceeding 8 cm (at 10 cm height) were measured with a sliding caliper and recorded; stems with a diameter <2 cm (at 10 cm height) were excluded from the count.

To characterize plot surface traits, we estimated the percent of the plot occupied by bare substrate. Qualitative notes were taken to indicate attributes of relevant substrate (i.e., moist, wet, dry, sandy, silty, loam, clay). In addition, we estimated the total percent of the plot occupied by leaf litter (*Tamarix* spp. or non-*Tamarix* source), dead wood, cobble, and standing water coverage (for which an average depth was also estimated).

G2.1.4 Quadrant measurements

Density, primary cover and species identity of all woody and herbaceous plants were counted within each 1 m^2 quadrat. For each species, total number of stems and condition (alive or dead) were recorded, as well as an estimate of percent cover. Percent cover of leaf litter, woody debris, and exposed substrate were estimated, along with average litter depth and species composition of leaf litter (*Tamarix* spp. or non-*Tamarix* source). A qualitative assessment of substrate type (sand, gravel, cobble, etc.) was made. A densitometer reading was taken at each quadrat to determine percent foliar cover. Signs of any animal activity (tracks, bite marks, fecal material, etc.) was also noted.

G2.1.5 Vertical point / canopy cover measurements

Vertical intercepts of vegetation within each plot were measured using the "hits to a pole" method of Mills et al. (1991). From ground level to maximum shrub/tree height, the number of hits per meter layer were counted by species. For this project, both dead and live material were included, but recorded separately. A "hit" occurred when plant material was within a 10 cm radius of the center of the pole. All woody and herbaceous plants were recorded.

G2.2 Soils Monitoring

Soil samples were collected at the 7 vegetation-monitoring sites along the established site transects. At each transect, soil samples were collected every 10–20 m at two depths: 0–10 cm and 20–30 cm. Each soil sample was placed in a paper bag and allowed to air-dry before processing soil texture (i.e., percent, sand, silt, and clay), electrical conductivity (EC), and pH. Texture was determined by separating and dry-weighing incremental grain size material using a nested sieve set of standard mesh openings. Coarse sand ranged from #4–10 sieve mesh size, medium sand ranged from #10–40 mesh size, and fine sand was from #40–200 mesh size. Silt and clay content were determined using a #200 and #230 mesh size. Proportions of total weight in each size fraction yielded a measure of percent "fines"—an indicator of water holding and infiltration capacity. The number of transects per site ranged from 1 to 6, and the number of sample locations ranged from 8 to 40 per site. The coordinates of the soil sample locations are given in Table G-2.

G2.3 Groundwater Monitoring

Shallow groundwater levels were monitored close to the active river channel at 6 locations in the Planning Area. Some, but not all, of the groundwater monitoring locations were generally near the vegetation and soil monitoring sites. Two well piezometers were installed at each location to monitor groundwater depth throughout the season. The paired wells (i.e., nest) were aligned perpendicular to the primary river channel with one well located near the edge of the channel and the second well located near the outer edge of the riparian vegetation corridor. One site (Site 2) has three wells: two are along a single transect, and a third placed approximately one mile upstream from the other two installations. Site 4 only has one well because access to the second location was not feasible. The coordinates of each piezometer are given in Table G-3.

G3 Monitoring Results

G3.1 Vegetation Monitoring Results

G3.1.1 Vegetation composition and structure at all monitoring sites

Occupied sites varied from monotypic, single strata stands to habitat patches with multiple species and more complex canopy and subcanopy structure. Tamarisk formed a nearly continuous, closed canopy (with no distinct overstory layer). Canopy height generally averaged from 5 to 10 m, with canopy density uniformly high. Live foliage density was relatively low from 0 to 2 m above the ground, typical of the interior of tamarisk stands, but increased higher in the canopy. Within the patches, there are numerous small openings in the canopy and understory. The numerous dead branches and twigs provided for most of the structural density in the lower 2 to 3 m strata. In normal or wet precipitation years, surface water is adjacent to or within tamarisk habitat patches, as evidenced by the desiccated remains of wetland species in the understory of some plots; however due to the ongoing drought in this region, all consistent water at our monitoring sites was constrained to the main channel and agricultural runoff ditches. Compiled results from the vegetation monitoring effort are briefly summarized in Table G-1 and Figures G-2, G-3, and G-4.

SWFL nesting sites were characterized by fairly monotypic tamarisk stands, with very low density of natives. Only four native species were present within our survey plots: Fremont cottonwood (*Populus fremontii*), Goodding's willow (*Salix gooddingii*), coyote willow (*Salix exigua*), and mulefat (*Baccharis salicifolia*). The herbaceous layer at all locations was sparse and not a significant habitat component; typically no more than one or two herbaceous species were detected—bermuda grass (*Cynodon dactylon*) and johnsongrass (*Sorghum halepense*)—and total ground cover was well below 10%. Dead material at all sites accounted for a significant proportion of the vegetation structure. Elsewhere on the monitoring sites, desert broom (*B. sarothroides*), Emory's baccharis (*B. emoryi*), and/or mesquite (*Prosopis glandulosa* and/or *P. velutina*) occasionally occurred at very low cover. Vegetation density of all species across sites was highly variable. Substrates were composed predominantly of silt and clay, with sand occurring along both old and current channels. These tamarisk-dominated shrublands and tamarisk-willow woodlands typically occur on silty substrates. Soil moisture conditions varied from wet to dry, depending on the proximity to the river, relative elevation from the low-flow channel, time since last rain or flood, and agricultural return flows; however, beyond 2 m of an active channel, our plots all exhibited dry soils. Results of the sampled soils are presented below.

Due to the within-site patchiness of vegetation in the monitoring area, vertical foliar density was determined to be a more meaningful measurement of site suitability than average stem density. Tree stem density varied greatly depending on stand age; at SRP 1, stem density was high and fairly uniform, while at SRP-BR/Bellman and SRPCE-1, trees were older, taller, and larger in diameter, resulting in lower near-ground stem cover. However, this variation had less effect on canopy density and vertical stem structure above 1–2 m. Looking at vertical foliar density at each site, there is a significant increase in density from 1–3 m.

Typically, plots have a well-defined litter layer, and an uneven distribution of fallen woody debris, (ranging from 0-90% quadrat ground cover with an average of 10% cover). Herbaceous ground cover was sparse to absent across all sites. Due to the particularly dry season during our surveys, no plots contained standing water. Canopy height varied from site to site (typically 5–10 m), but FMI-RSSA-3 had an uncharacteristically high canopy of 15 m due to the presence of cottonwoods at this site.

Table G-1. Dominant vegetation characteristics averaged across all vegetation survey plots.

Average ground cover (%)	97%
Average canopy height (%)	7%
Standing water (%)	0%
Woody debris (%)	10%
Herbaceous cover (%)	0.1%

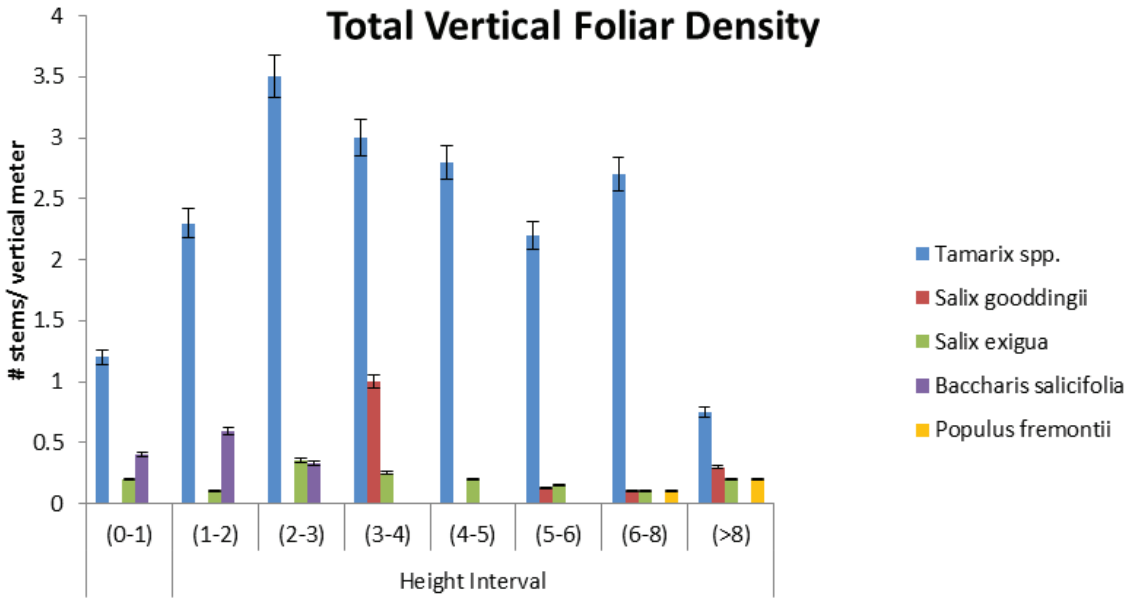


Figure G-2. Vertical foliar density by dominant plant species averaged across all vegetation-survey plots. Tamarisk dominates all height classes. *Baccharis salicifolia* and *Salix exigua* are present at low densities in the understory, *Salix gooddingii* and *Salix exigua* occur occasionally in the mid-story and canopy, and *Populus fremontii* occurs at very low densities in the canopy.

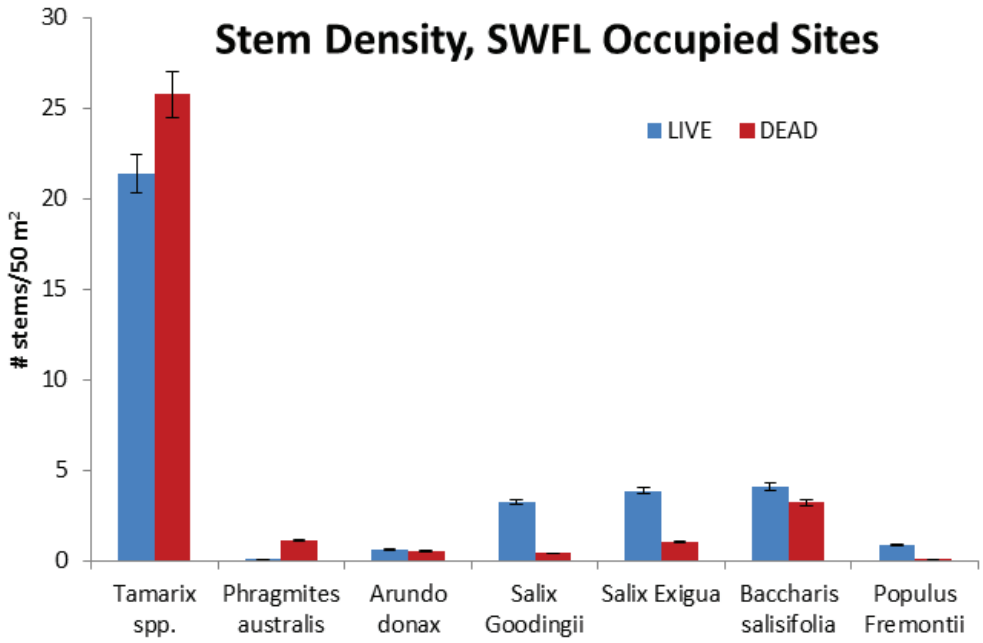


Figure G-3. Stem density by dominant plant species averaged across all vegetation-survey plots. Tamarisk snag currently accounts for over 50% of tamarisk density at sites utilized by SWFL.

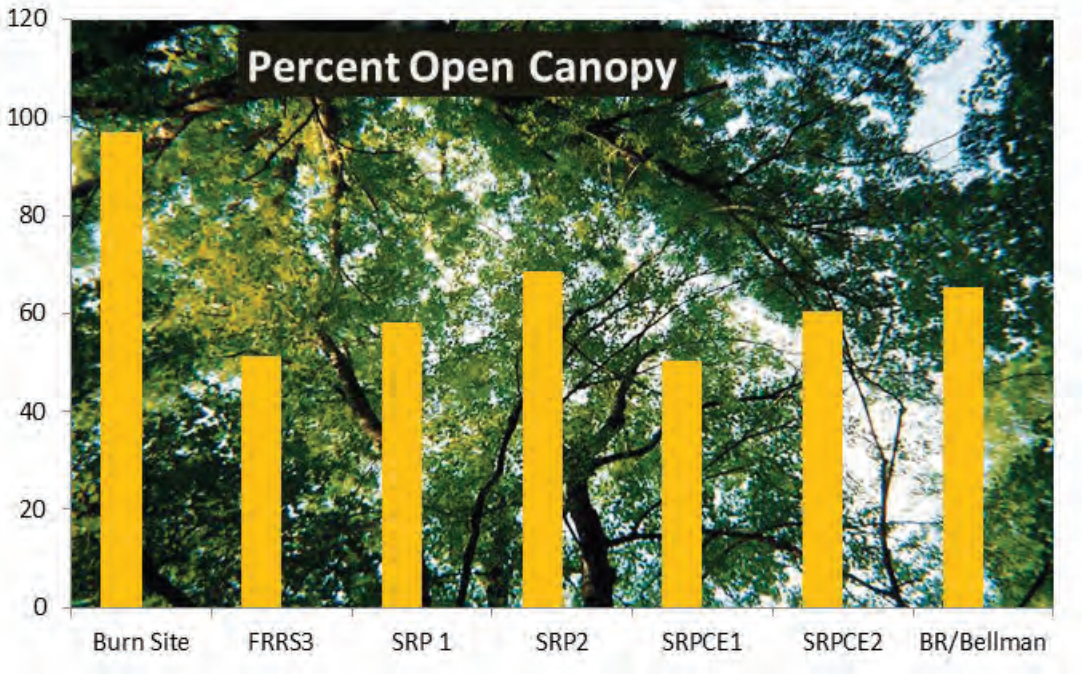


Figure G-4. Percent open canopy cover at each of the vegetation-survey sites. Canopy cover varied from 4–50% across sites; excluding the burn site, all sites fell between 45–50% cover.

G3.1.2 Site-specific vegetation conditions

FMI-RRSA-1 / SRPCE-4

The increased fire susceptibility of tamarisk relative to native vegetation types is a notable threat to the persistence of suitable habitat along this portion of the river. In March 2013 near Fort Thomas, nearly all of the tamarisk and willow biomass was burned on the upstream section of FMI-RRSA-1 during the Clay Fire. In previous years, this site hosted a number of SWFL breeding pairs. During our April surveys, one willow flycatcher individual was observed singing from a dead tamarisk branch overhanging the main river channel. Although this was prior to the breeding season and the individual did not remain at the site, its presence suggests there is still a good possibility of re-colonization of this site once the vegetation has recovered, either through tamarisk growth or restoration of native species.

Overall, the site is characterized by bare, dry and silty substrates, with sand and gravel present in the scour zone, and with little organic or litter component remaining owing to fire intensity (Figures G-5 and G-6). During our April survey, no live biomass was present, except for a 1–2 m strand immediately adjacent to the main channel in some reaches, where presumably conditions were moist enough to protect vegetation from mortality during the fire. Cover of all species was low (<15%). However, by the beginning of May, nearly all burnt tamarisk trees were observed to be re-sprouting vigorously from the base, indicating there is only a limited window of opportunity to establish native species before tamarisk biomass once again dominates the site. The channel is only moderately incised, with approximately 3 m difference between surface water and the surrounding terrace, indicating that groundwater should be sufficiently close to the surface to support restoration plant materials; however, preliminary assessment indicates that depth to groundwater is progressively deeper at distance from the stream, as expected in a “losing reach” (sub-surface flows generally downward). One piezometer is now installed, and an array at different distances from the stream channel is needed to describe seasonal water available dynamics for planning location-specific restoration methods and target species (see groundwater monitoring results presented below).

The area potentially suitable for active restoration of SWFL habitat is approximately 30 hectares (ha). Some portions would potentially benefit habitat for other species such as yellow-billed cuckoo, as well as to provide a fire-resistant, native vegetation buffer zone to inhibit future penetration of fire into the riparian area.

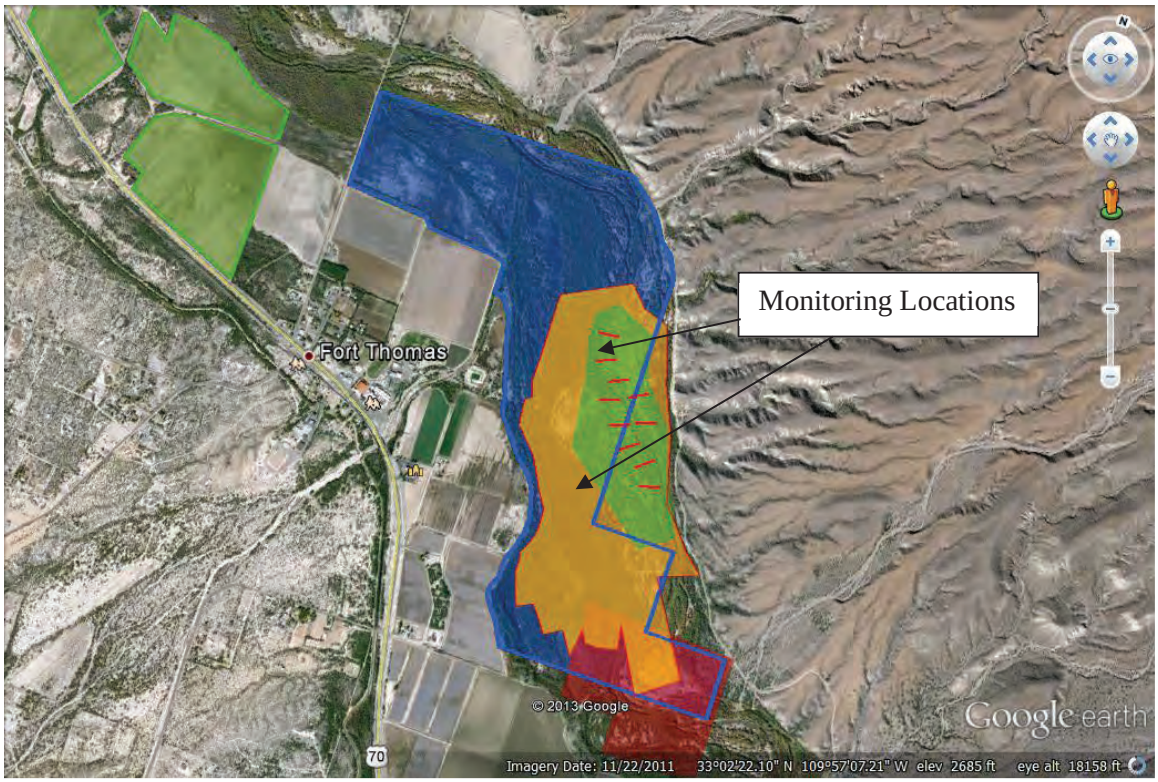


Figure G-5. Map of the FMI-RRSA-1 / SRPCE-4 site showing vegetation monitoring locations. The approximate burned area boundary is shown in orange within which the target restoration zone is indicated by the green polygon. Red lines indicated vegetation transects completed in June 2013 across primary. Blue boundary is property line of FMI land, with BLM-managed federal land on the eastern portion.

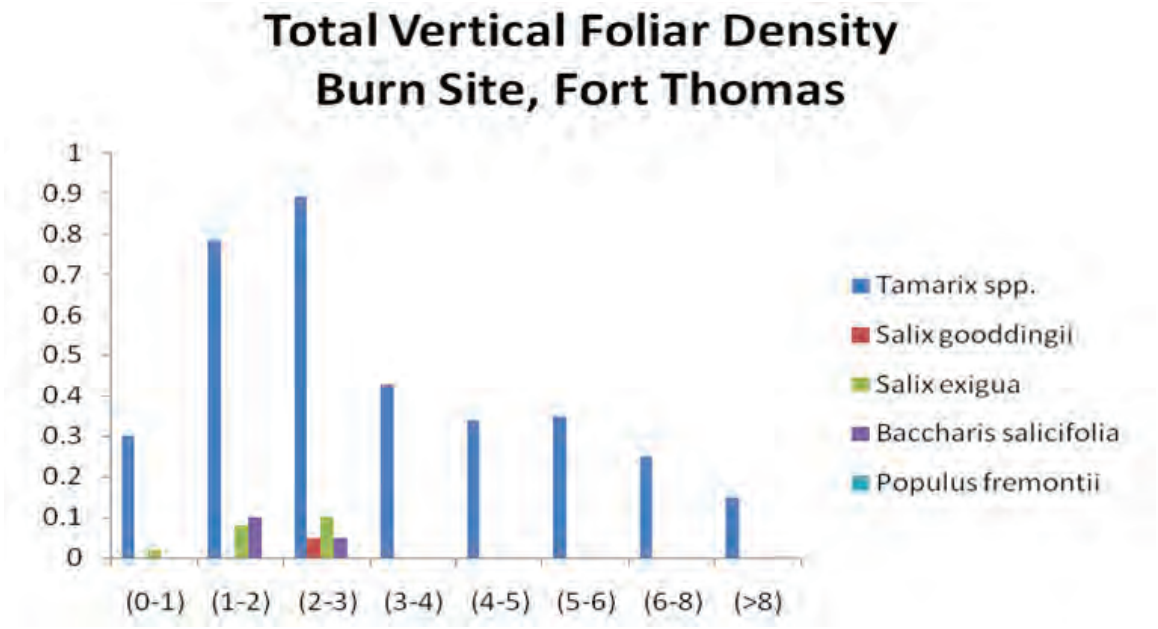


Figure G-6. Vertical foliar density at the FMI-RRSA-1 / SRPCE-4 site. Most of the tamarisk biomass is dead material in the wake of the Clay Fire, except under 3 m where re-sprouting has occurred. Natives are a very minor habitat component.

SRPCE-1

Vegetation at this site is characterized by monotypic tamarisk (Figures G-7 and G-8). Density is variable, with percent cover ranging from 20–90%. Most individuals are under 10 m in height. Substrates are silt and clay, with moisture ranging from dry to very moist (see additional soils results below).

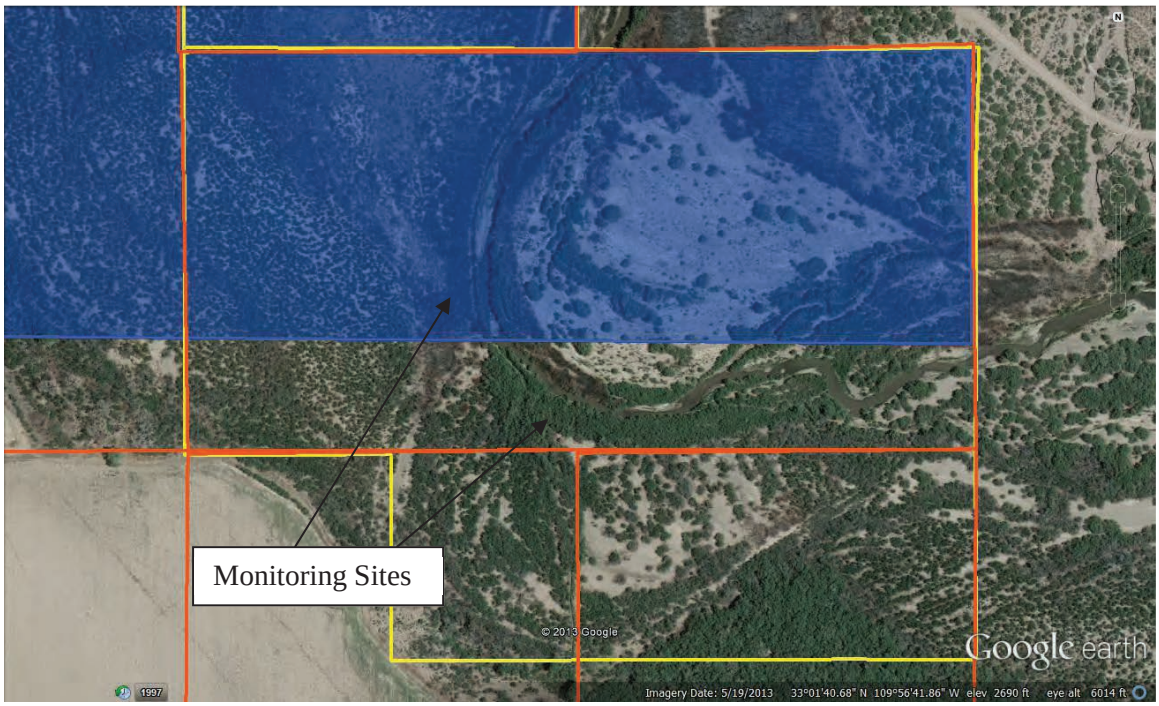


Figure G-7. Map of the SRPCE-1 site showing vegetation monitoring locations.

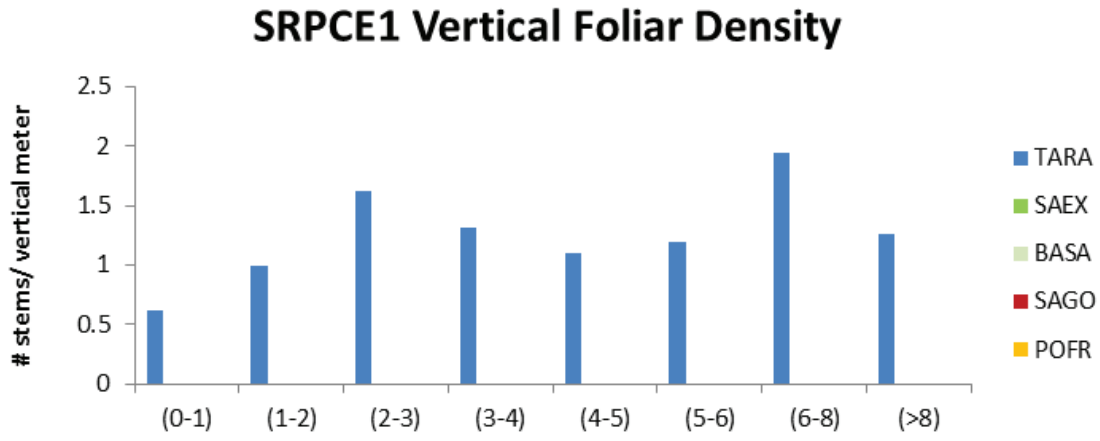


Figure G-8. Vertical foliar density at the SRPCE-1 site. Tamarisk dominates all height categories, with greatest densities from 2–3 m and 6–8 m.

FMI-RRSA-2 / SRPCE-2

This site had the highest proportion of coyote willow, with an almost equal proportion of tamarisk and willow below 4 m (Figures G-9 and G-10). Density is variable, with total percent cover ranging from 10–80%. Soils are a mix of silt and clay, and range from dry to moist (see additional soils results below).

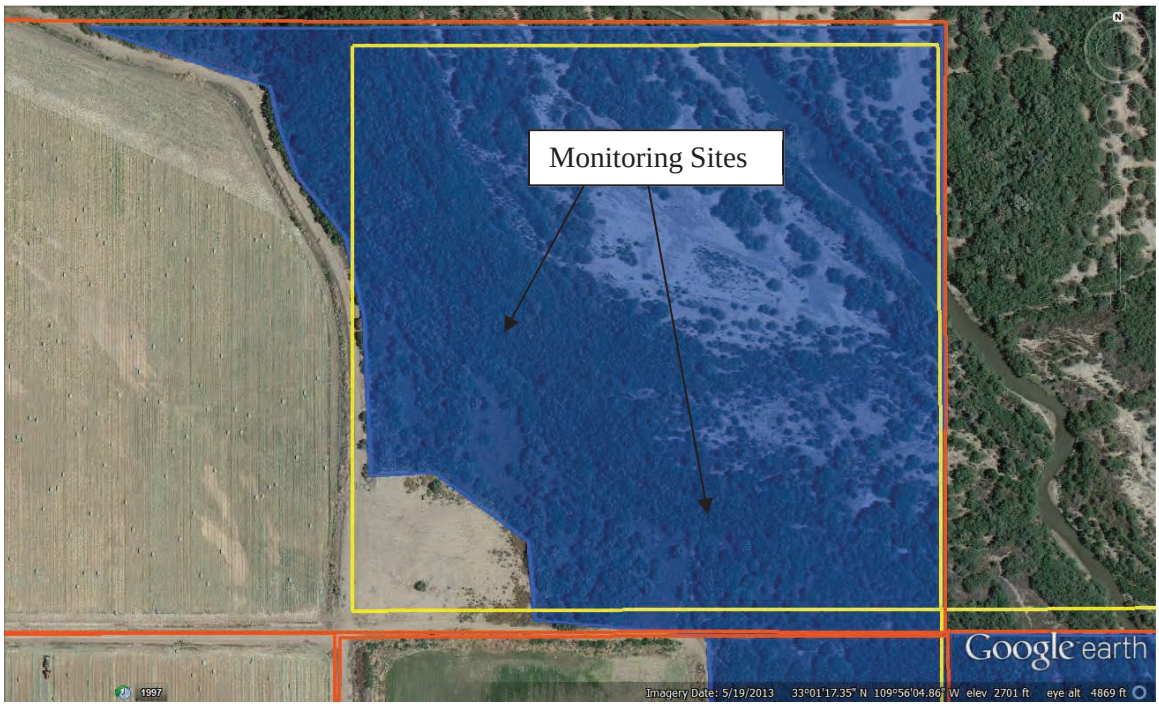


Figure G-9. Map of the FMI-RRSA-2 / SRPCE-2 site showing vegetation monitoring locations.

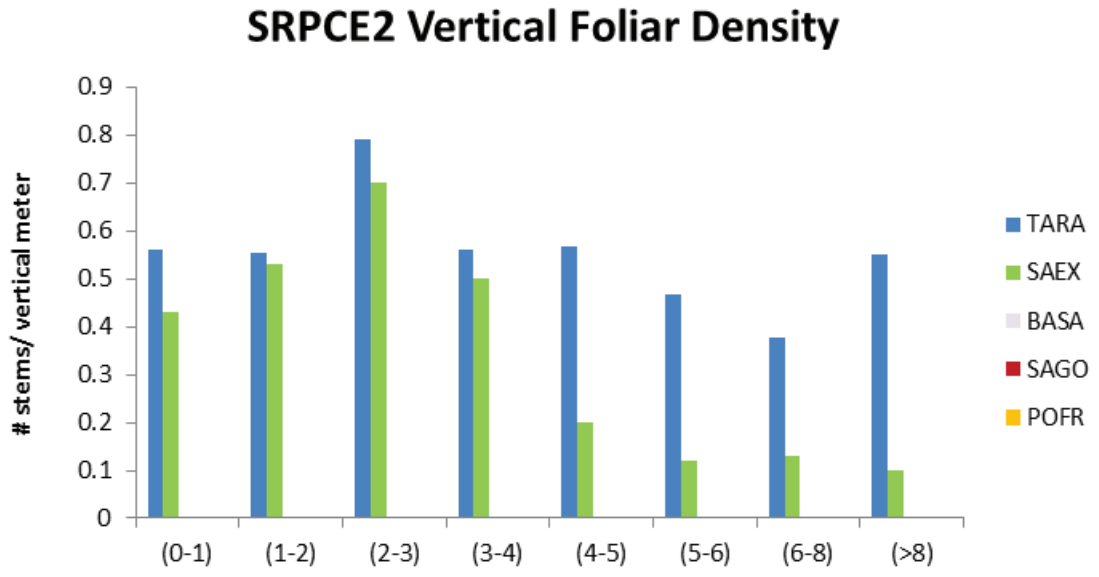


Figure G-10. Vertical foliar density at the FMI-RRSA-2 / SRPCE-2 site. Foliar density is greatest from 2–3 m.

SRP-1 and SRP-2

Vegetation at both sites is characterized by monotypic tamarisk (Figures G-11, G-12, G-13, and G-14). Density is variable, with percent cover ranging from 10–90%. Individual height and trunk diameter also varied greatly, with some trees well over 10 m tall. Substrates are silt and clay, with moisture ranging from dry to very moist (see additional soils results below).

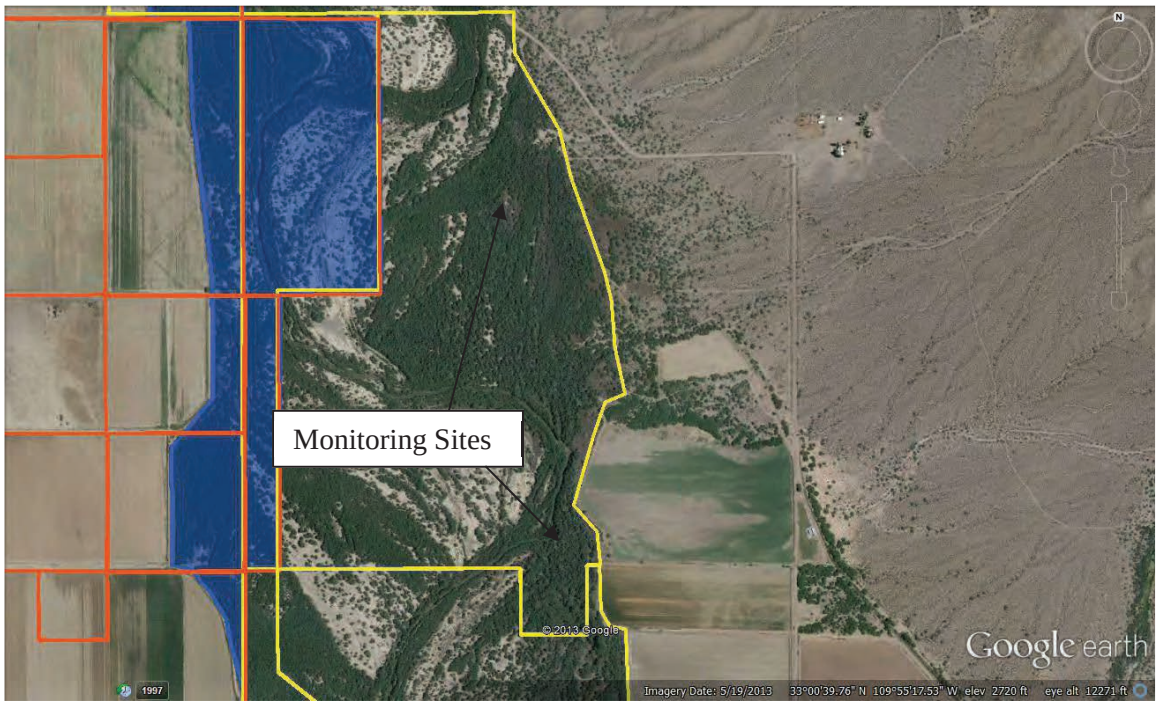


Figure G-11. Map of the SRP-1 site showing vegetation monitoring locations.

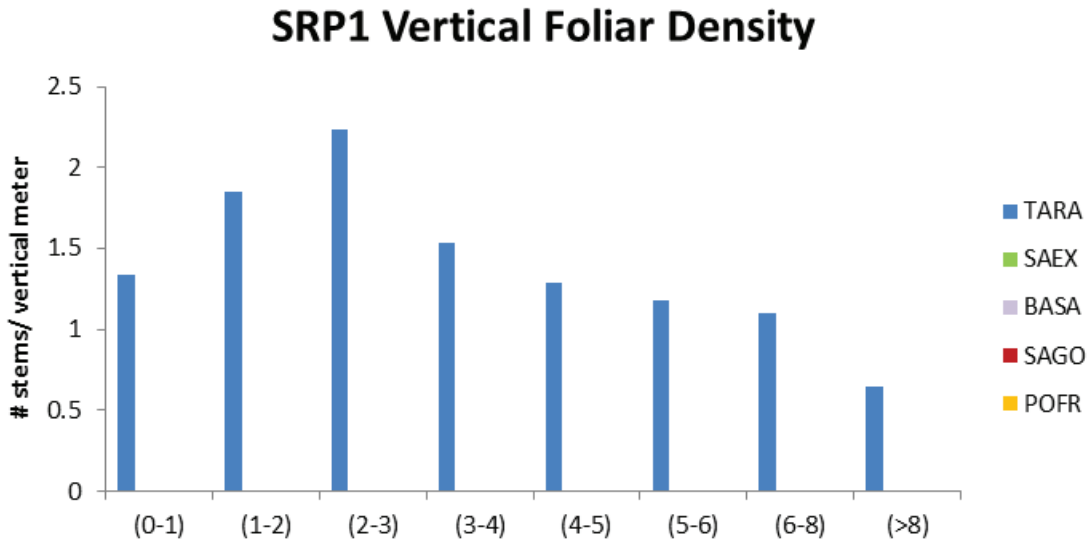


Figure G-12. Vertical foliar density at the SRP-1 site. Foliar density is greatest from 2–3 m.



Figure G-13. Map of the SRP-2 site showing vegetation monitoring locations.

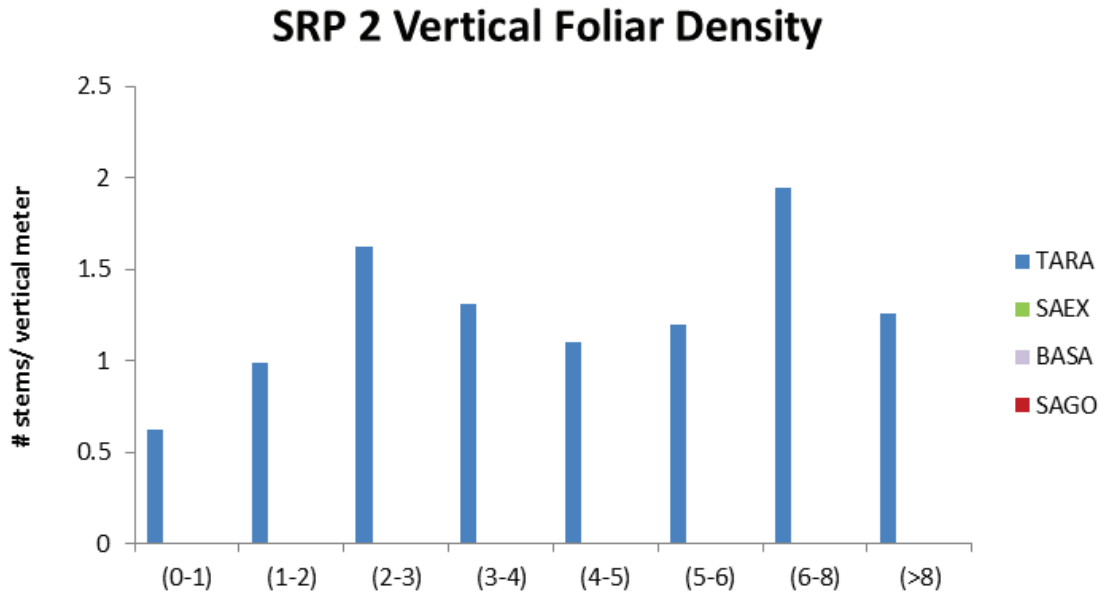


Figure G-14. Vertical foliar density at the SRP-2 site. Tamarisk dominates all layers, with greatest densities from 2–3 m and 6–8 m.

SRP-BR/Bellman

Mulefat and coyote willow are significant habitat components at this site (Figures G-15 and G-16). Mulefat accounts for the greatest proportion of the vegetation density below 3 m. Soils are a mosaic of silt and clay, and dry across most of the site (see additional soils results below).



Figure G-15. Map of the SRP-BR/Bellman site showing vegetation monitoring locations.

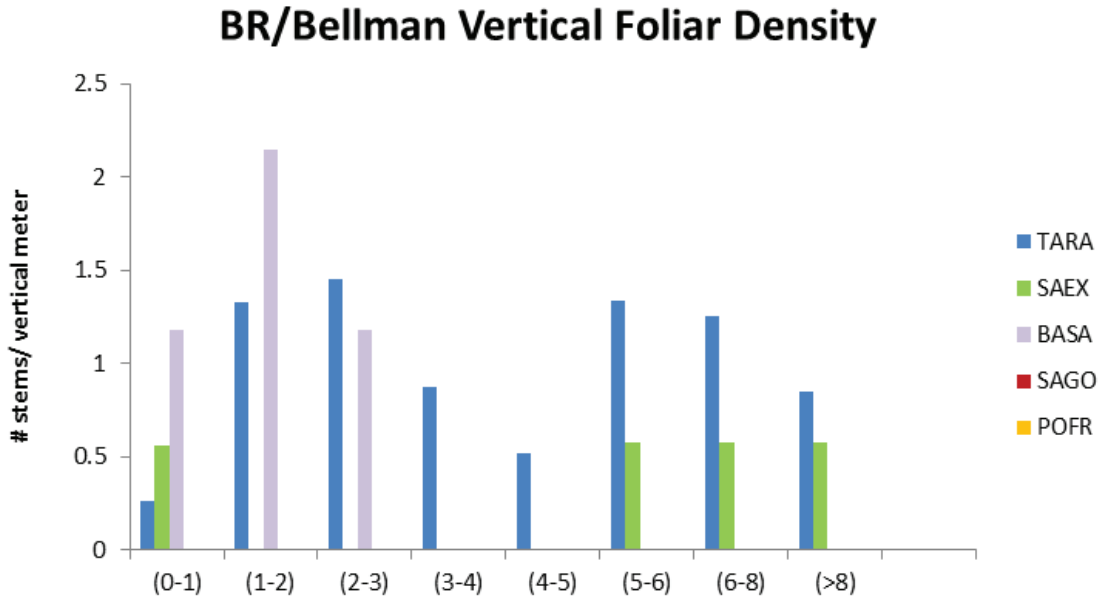


Figure G-16. Vertical foliar density at the SRP-BR/Bellman site. Vegetation reaches the great densities from 1–3 m and 5–8 m.

FMI-RRSA-3

This is the only site we monitored having a significant Fremont cottonwood-Goodding's willow woodland, although monotypic tamarisk still covers over half the property (Figures G-17 and G-18). Here, the cottonwood stand occurs between the edge of the agricultural fields and the outer margin of the riparian corridor, on the bank of a high-flow channel. Cottonwood and Goodding's willow are present at 20–60% cover, and form a dense, high canopy (8–14 m). Trees are mature or decadent, with low levels of recruitment. The shrub layer is composed of *Baccaris* spp. and tamarisk at 10% cover. There is a thick leaf litter layer, and much of the ground is covered by downed wood; soils are a mosaic of sand, silt, and clay with varying moisture levels (see additional soils results below). Common reed (*Phragmites australis*), arundo (*Arundo donax*), and bermudagrass occur at lower densities at this site, adjacent to the river channel. The rest of the site is a tamarisk-Goodding's willow mixed type, where Goodding's willow is present at 10–30% cover near the channel and then drops out at higher elevations of the floodplain where soils are drier. One yellow-billed cuckoo pair was incidentally detected on this property in the cottonwood canopy late in the season.

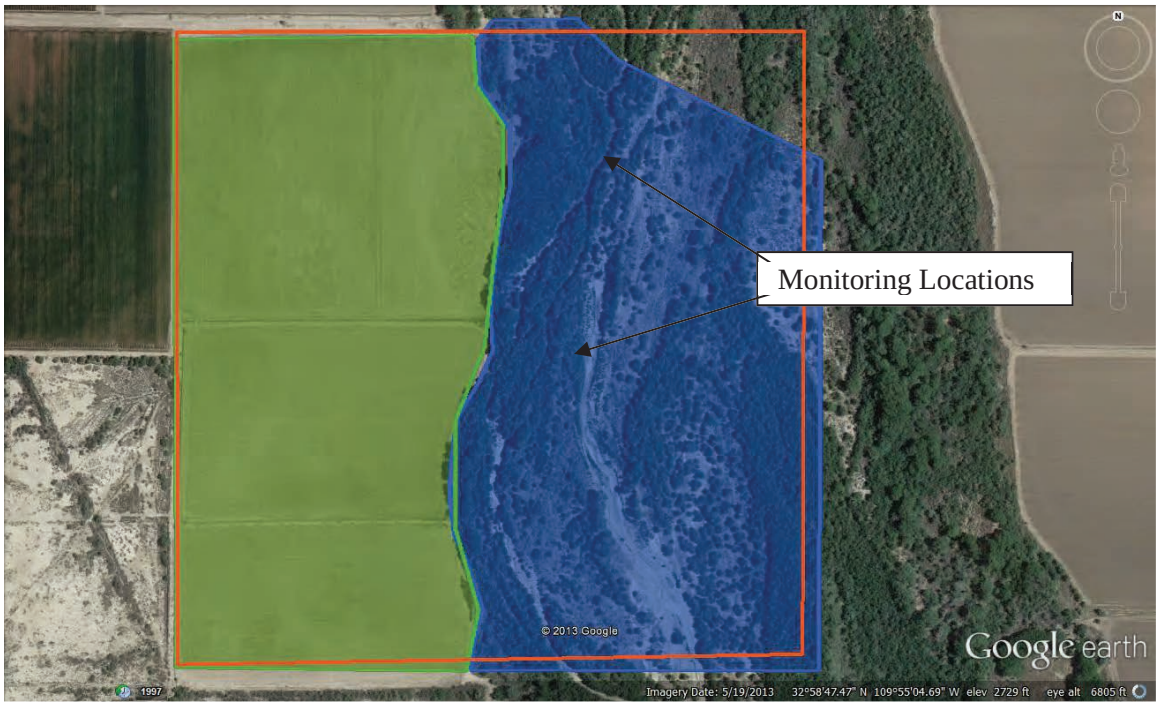


Figure G-17. Map of the FMI-RRSA-3 site showing vegetation monitoring locations.

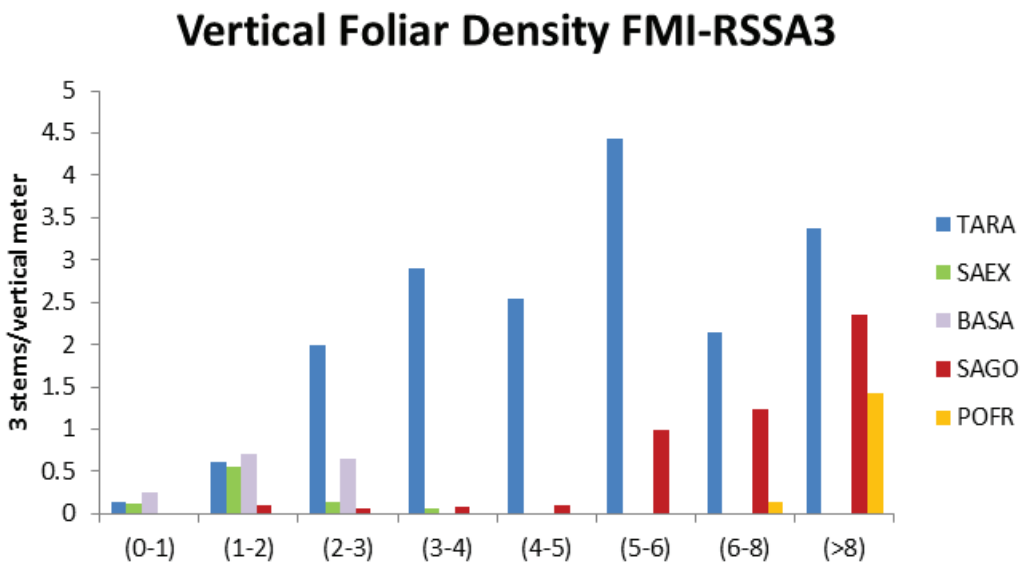


Figure G-18. Vertical foliar density at the FMA-RRSA-3 site. Mulefat and coyote willow occur at low densities in the understory. Goodding's willow and cottonwood make up 30-60% of the canopy.

G3.2 Soils Monitoring Results

Overall, the sampled soils (Table G-2) were generally composed of fine sand (Figure G-19). Soil EC was generally higher in the upper 0–10 cm layer (Figure G-20), while soil pH was generally the same at the two depths (Figure G-21). More detailed results are described below for each of the sampled sites.

Table G-2. Soil sample site names, location, number of transects per site, and total number of soil samples per site.

Monitoring site	Soil sampling site ID	Longitude, Latitude (NAD83)	Number of transects	Total number of soils samples
FMI-RRSA-1 / SRPCE-4	"Burn North"	33.04016, -109.95011	5	31
	"Burn South"	33.0371, -109.94686	5	40
SRPCE-1	"SRPCE 1-2"	33.02741, -109.94540	1	8
	"SRPCE 1-1"	33.02633, -109.94506	1	8
FMI-RRSA-2 / SRPCE-2	"SRPCE 2-1, 2-2"	33.02107, -109.93491	2	16
SRP-1	"SRP 1-1"	33.02033, -109.92565	1	8
	"SRP 1-2"	33.00703, -109.92205	1	8
SRP-BR/Bellman	"BR/Bellman"	32.9936, -109.93725	2	16
FMI-RRSA-3	"FMI 3"	32.98131, -109.91800	6	31
	"FRRS 3-1, 3-2"	32.98062, -109.91875	2	16

FMI-RRSA-1 / SRPCE-4

Soil texture of the samples collected at the "Burn North" and "Burn South" locations was composed primarily of fine to medium-sized sand (Figure G-19). For each of the five transects sampled at the two sites (n=10 sites), the upper soil layer (0–10 cm) had a consistently higher EC than the lower layer (20–30 cm) (Figure G-20). However, only two of the five "Burn North" samples were significantly different ($P < 0.05$), and no significant differences were detected at the "Burn South" sites. The range of mean EC for 0–10 cm was 372 to 1200 micro-siemens per centimeter (uS/cm), and 124 to 482 uS/cm for the 20–30 cm depths. Measured pH in soil samples collected at the "Burn North" site were consistently lower in the upper soil layer (0–10 cm) (Figure G-21). Mean pH values in the upper layer ranged between 8.0 to 8.6, while mean values in the lower layer (20–30 cm) ranged between 8.3 and 8.6.

SRPCE-1 and FMI-RRSA-2/SRPCE-2

The soil texture of samples collected at the "SRPCE 1-1" and "SRPCE 1-2" sites were fairly evenly distributed. Soils sampled from the "SRPCE 2-1" and "SRPCE 2-2" sites contained a greater proportion of course-textured sand. The measured EC values were generally greater in the upper soil layer (0–10 cm). The range of mean EC for 0–10 cm was 1075 to 2047 uS/cm, and 603 to 1365 uS/cm for 20–30cm. The mean pH ranged from 8.0 to 8.4, with the lower pH values measured in the upper soil profile, but no significant differences occurred.

SRP-1

The soil texture of samples collected at the "SRP 1-1" and "SRP 1-2" sites were composed mostly of course-textured sand intermixed with medium textured sand. The measured EC values were inconsistent between the two sampling sites. Mean values were greater in the lower soil layer (20–30 cm) at the "SRP 1-1" site, but greater in the upper soil layer (0–10 cm) at the "SRP 1-2" site. The range of mean EC for 0–10 cm was 1441 to 1695 uS/cm, and 908 to 2557 uS/cm for 20–30cm. The mean pH ranged from 7.9 to 8.6 and was consistently lower in the upper soil layers.

SRP-BR/Bellman

The soil texture of samples collected at the "BR/Bellman" site was composed mostly of coarse to medium sands. The measured EC values were greater for the lower soil layer (20–30 cm) for both transects; it was significantly greater for one and almost significantly higher for the other ($P=0.014$ and $P=0.064$, respectively). The range of mean EC was 581 to 1000 uS/cm for the 0–10 cm layer, and 316 to 457 uS/cm for the 20–30 cm layer. The mean pH values were greater but not significantly so for the two transects of the 20–30 cm layer compared to the 0–10 cm profiles. The range of pH for the 0–10 cm layer was 7.9 to 8.2, and 8.2 to 8.4 for the 20–30 cm layer.

FMI-RRSA-3

The soil texture of samples collected at the "FMI-3" site for the upper soil layer (0–10 cm) were slightly skewed toward course sand, but texture at the lower soil layer (20–30 cm) were widely distributed from course sand to finer silts and clays. Soil texture of samples collected at the "FRRS 3-1" and "FRRS 3-2" sites mostly ranged from medium sand to silt. At the "FMI-3" site there were no significant differences detected in mean EC values between soil profile depths, but all 6 transects had greater EC values at the 0–10 compared to 20–30 cm profile. The range of mean EC values was 189 to 571 uS/cm for the 0–10 cm layer, and 175 to 280 uS/cm for the 20–30 cm layer. All transects had a higher pH for the 20–30 cm profile, but no statistical differences between this lower layer with the upper layer were detected. The range of mean pH values was 7.8 to 8.3 for the 0–10 cm layer, and 8.0 to 8.4 for the 20–30 cm layer.

Both transects at the "FRRS 3-1" and "FRRS 3-2" sites had greater EC values in the upper soil layer, but only one was statistically greater (P=0.0071). The range of EC values was 348 to 483 uS/cm for the 0–10 cm layer, and 173 to 206 uS/cm for the 20–30 cm layer. The mean pH values were greater in the lower soil layer, with one transect yielding a significant difference (P = 0.0134). The range of mean pH was 8.3 to 8.4 for the 0–10 cm layer, and 8.5 to 8.6 for the 20–30 cm layer.

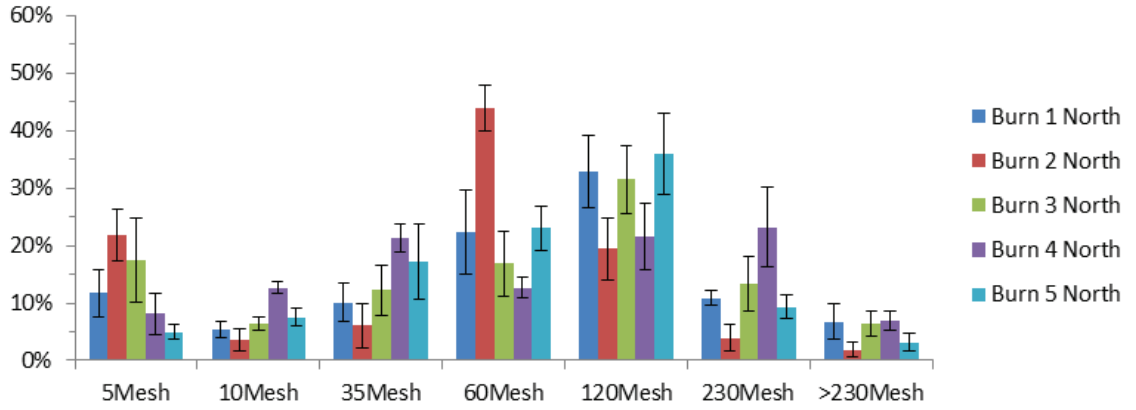


Figure G-19. The mean (se; n=6) soil texture sieve or mesh sizes of the 0-10 cm soil profile for each of the five transects of "Burn North" sample location at the FMI-RRSA-1 / SRPCE-4 site.

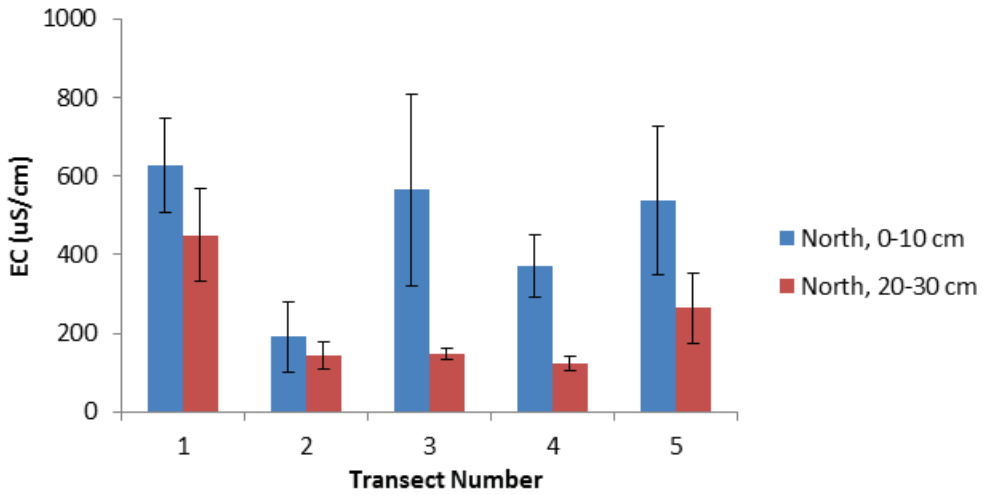


Figure G-20. The mean (se; n=6) soil electrical conductivity (EC) of the 0-10 cm and 20-30 cm soil profiles for each of the five transects of "Burn North" sample location at the FMI-RRSA-1 / SRPCE-4 site.

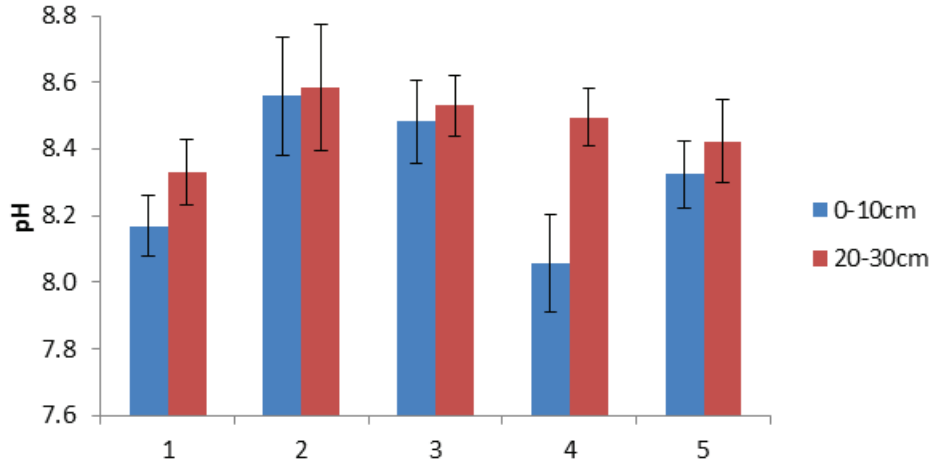


Figure G-21. The mean (se; n=6) soil pH of the 0-10 cm and 20-30 cm soil profiles for each of the five transects of "Burn North" sample location at the FMI-RRSA-1 / SRPCE-4 site. Only Site 4 was significant.

G3.3 Groundwater Monitoring Results

The initial results of our groundwater monitoring efforts are summarized in Table G-3 and Figure G-22 below.

We anticipate that the well nests and overall well network will serve several important functions for guiding restoration efforts. The well nests will allow managers to assess groundwater patterns across the width of the riparian area. Where the reach is "loosing," or where there is significant channel down-cutting, we would expect greater depth to groundwater on the outer edge of the riparian area. However, our initial measurements conducted in January 2014 generally suggest that depth to groundwater remains fairly static across the width of the riparian area and is not wholly dependent on proximity to the wetted river channel. Future measurements during periods of low flow will provide a greater detail of groundwater patterns. A second important function of the well nests is that combined, the wells will provide a more detailed view of groundwater depth over a fairly large reach of the Gila River that will improve groundwater mapping and future ecohydrological assessment of this section of river targeted for near-future restoration.

As part of the ecohydrological assessment, the initial groundwater measurements were compared to relative elevations estimated at each of the piezometer locations (see related sections in the main report). The relative-elevation surface was produced from the 2012 LiDAR data collected for this project. The relative elevations values represent the land surface height above the low-flow channel, which is intended to serve as a proxy for depth to groundwater. Comparisons between the initial groundwater measurements and the corresponding relative-elevation values at all but two of the piezometer locations reveal close agreement ($\leq$1 ft difference), suggesting that use of the relative elevation surface to estimate depths to groundwater is a suitable method for restoration planning in the Gila Valley. The two piezometer locations with greater differences (>1 ft) are at 5a and 6a. We suspect that the differences are due to recording error with the GPS coordinates and, thus, recommend their coordinates be re-recorded during subsequent monitoring.

Table G-3. Summary of piezometer locations, piezometer depths, and depths to the saturated zone from initial measurements taken in January 2014.

Site number	Longitude, Latitude (NAD83)	Piezometer casing depth below ground surface (ft)	Groundwater depth measured below ground surface (ft)	Distance From Center of Wetted Channel (ft)
1a	33.05986, -109.98505	16.4	12.1	57
1b	33.05879, -109.98607	15.8	12.3	549
2a	33.04366, -109.95708	16.4	12.6	1532
2b	33.04742, -109.95379	15.6	8.5	132
2c	33.03919, -109.94943	10.5	6.7	43
3a	33.01871, -109.92972	21.6	15.7	69
3b	33.01872, -109.93113	16.4	13.9	351
4a	32.97842, -109.91920	10.2	6.5	456
5a	32.92118, -109.84073	10.3	5.9	57
5b	32.92012, -109.84137	16.3	11.3	485
6a	32.85271, -109.73497	15.3	8.5	722
6b	32.85540, -109.73623	14.9	11.3	186

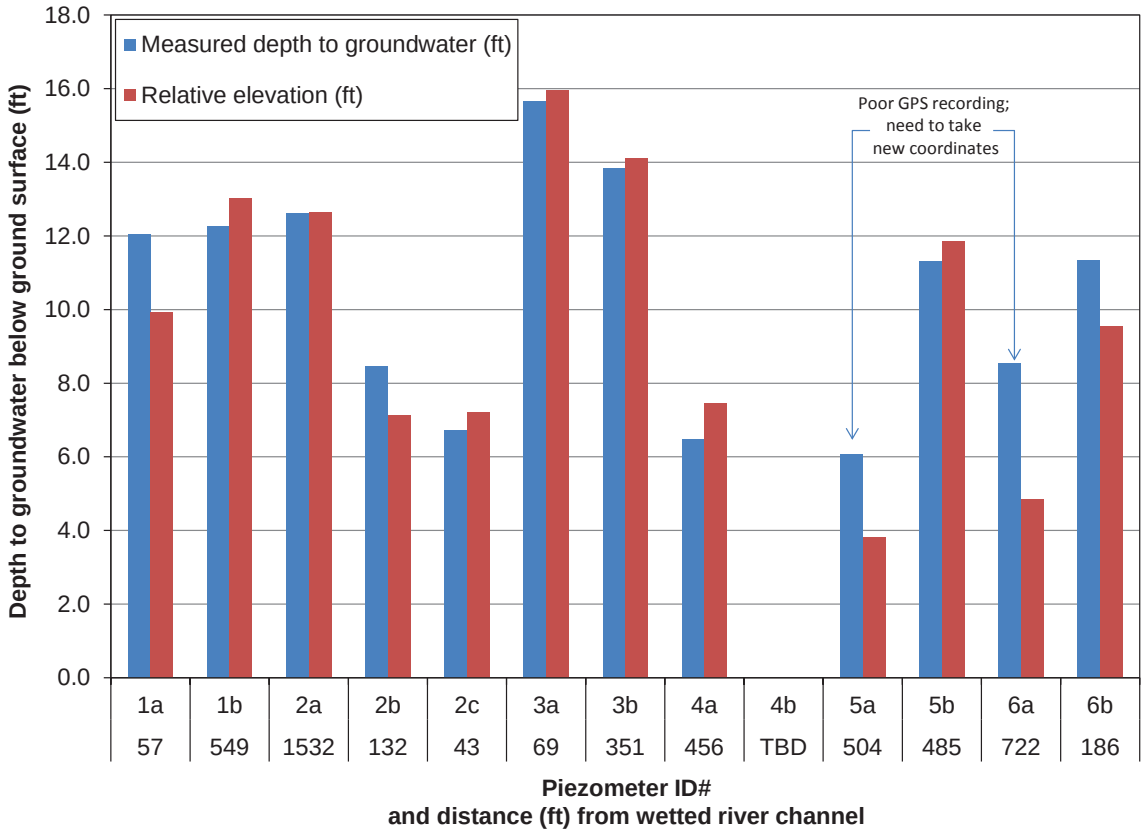


Figure G-22. Plot of measured groundwater depths in the Planning Area taken in January 2014. Measurements are compared to relative ground-surface elevations above the low-flow river channel elevation.

G4 RECOMMENDATIONS FOR RIPARIAN HABITAT RESTORATION

G4.1 Tasks and Workplan

Because flycatchers breed in a variety of riparian habitat types (including tamarisk and a variety of natives), there are more habitat restoration options available than would be the case if flycatcher habitat use was restricted to a single association. The fact that flycatchers will occupy small habitat patches (e.g., 10 ha) means that even small-scale riparian protection and/or restoration programs could be beneficial, though larger projects would yield the greatest chance for breeding site longevity.

Habitat restoration in the Planning Area should be a staged program, proceeding from detailed site assessment and project planning and design, through implementation of invasive plant control treatments and re-vegetation, with monitoring and an adaptive management oversight process to verify objectives are being met in a timely fashion and that the project will successfully achieve the goals. The steps involved are as follows:

1. Initial project concept development and general description of approach (this entire document)
2. Site assessment to accurately assess environmental parameters relevant to treatment methods, including:
    a. Existing vegetation surveys and trends, including post-fire plant response, for evaluating treatment methods and site potential and as a baseline for measuring project success (completed, June–July 2013)
    b. Soil sampling for salinity, pH, texture, moisture availability, and major ion and nutrient status (completed, May–July 2013)
    c. Surface moisture and groundwater depth assessment for design of plant composition and restoration methods based on water availability across all seasons, including evaluation of possible irrigation needs to facilitate vegetation establishment (completed, January 2014)
    d. Avian surveys to determine presence and site preference for native wildlife, particularly SWFL and YBCU which require special effort to avoid disturbance during restoration implementation (ongoing surveys by SRP on their mitigation parcels; initial surveys completed May–July 2013 and repeat surveys planned for May–July 2014 [see Appendix E])
3. Native plant source selection and production/propagation (plant list and source evaluation underway by GWP; greenhouse completed by GWP for plant materials preparation)
4. Tamarix treatments, including localized removal and/or herbicide applications where needed to maintain open space and reduce invasive plant biomass and follow-up spot treatments; plans should also be in place to enable rapid action in the event of flood or wildfire, to take advantage of the opportunity provided by this window of low-tamarix biomass prior to re-sprouting
5. Re-vegetation implementation:
    e. Stage 1—installation of pole cuttings, size based on site conditions, where perennial water availability will support establishment even under drought conditions of summer/fall, and where no interference from herbicide applications
    f. Stage 2—installation of poles, rooted material, container plants, etc. (including vines for climbing on standing dead Tamarix), in adjacent and/or higher terrace

sites when seasonal precipitation will support growth, as well as where irrigation would facilitate establishment in higher stress sites

g. Stage 3—propagated understory and other plant species installed to enhance species and habitat diversity at multiple canopy layers

6. Monitoring and adaptive management:

h. Survival and growth rates of restoration planting censused to evaluate most successful methods

i. Site environmental conditions and vegetation assessment continues for comparison with baseline conditions

j. Avian surveys continue to determine if and when SWFL and other species of interest re-colonized restoration sites

k. All data and other information, including climate and hydrology/geomorphology trends, evaluated to change management actions to enhance survival and self-sustaining recruitment of native vegetation

G4.2 Tamarisk Re-Sprout Treatment at Burned Sites

Immediate tamarisk treatment is recommended at the recently burned FMI-RRSA-1 / SRPCE-4 site to take advantage of the cleared vegetation biomass with minimal impacts to avian wildlife. Biomass removal by the fire was greater than 90% with few plants undamaged (mostly isolated plants with little value to SWFL). Thus, no mechanical treatments were thought necessary at the time of the vegetation surveys in summer 2013. Survival of burned plants, however, has been revealed to be high, with over 94% showing basal re-growth of foliage within 2 months of the fire, and we recommend immediate treatment of these sprouts with herbicide to enable re-vegetation of native plants within this growing season. A triclopyr compound (commonly Garlon-4) can safely be used adjacent to aquatic habitats and is effective on tamarisk, with appropriate surfactant, as a foliar application. Back-pack hand-sprayers are likely appropriate at this scale of operation, by qualified applicators. As the site is no longer suitable for SWFL nesting (documented by D. Orr, June 2013), herbicide-use would presumably be applied without concern for listed avian species. Potential effects to other sensitive wildlife (e.g., listed fisheries) should be evaluated despite that the EPA assessment states that triclopyr has no significant impacts to aquatic vertebrates. Herbicides should be applied prior to any re-vegetation with native plant materials to avoid drift and over-spray impacts, although spot re-treatments may be suitable at a later date with proper precautions.

While the immediate focus of restoration is on potential SWFL habitat, it would be important to treat all Tamarix re-sprouts within the burn area while biomass is low and enabling rapid restoration across the burned area as is feasible and meets overall resource management objectives. Treatments should be as soon as is possible for all sites, ideally to yield mortality (although greatest impact is achieved during Fall when plants are translocating metabolites into roots prior to winter senescence of foliage) The total burn area requiring herbicide treatment, including both moist areas and higher terraces, is approximately 40 ha (100 ac), still feasible using hand methods but potentially mechanical weed sprayers for lower-sensitivity areas would provide greater cost-effectiveness.

Figures G-23 and G-24 present predicted vegetation responses under two post-biocontrol treatment scenarios for the recently burned FMI-RRSA-1 / SRPCE-4 site. Scenario 1 assumes that no active tamarisk biomass removal would occur following beetle-induced mortality (Figure G-23), whereas Scenario 2 assumes that roughly two-thirds of the standing tamarisk biomass

would be removed and the four dominant native plant species would be actively planted in areas where soil conditions are suitable for establishment (Figure G-24).

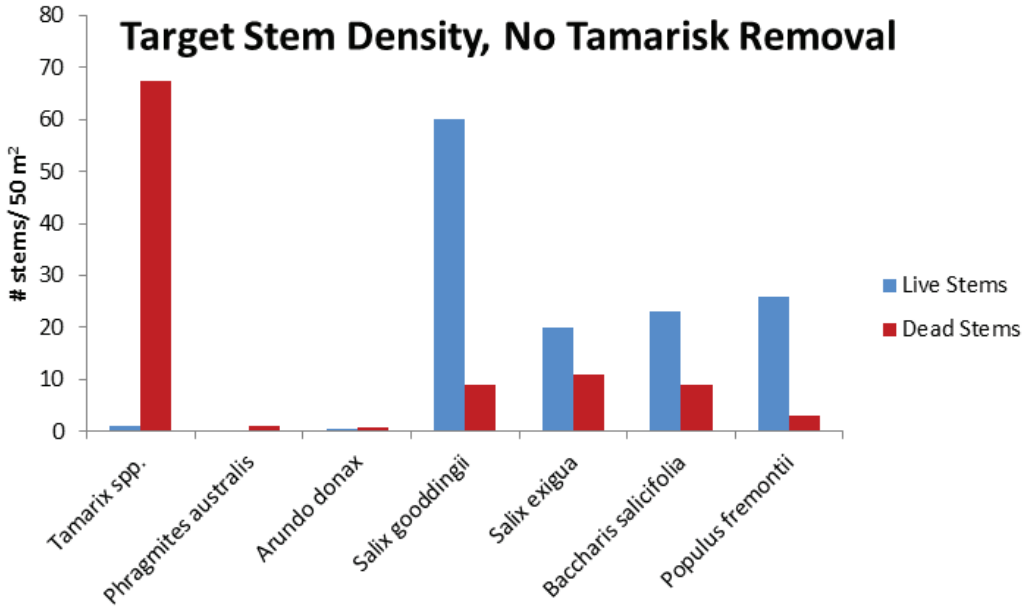


Figure G-23. Vegetation stem density predicted under Post-Biocontrol Treatment Scenario 1: after beetle-induced tamarisk mortality with no active tamarisk biomass removal is done. Dead tamarisk continues to play a structural role in the riparian zone, as the few natives present are released from competition pressures and begin to increase in density and cover.

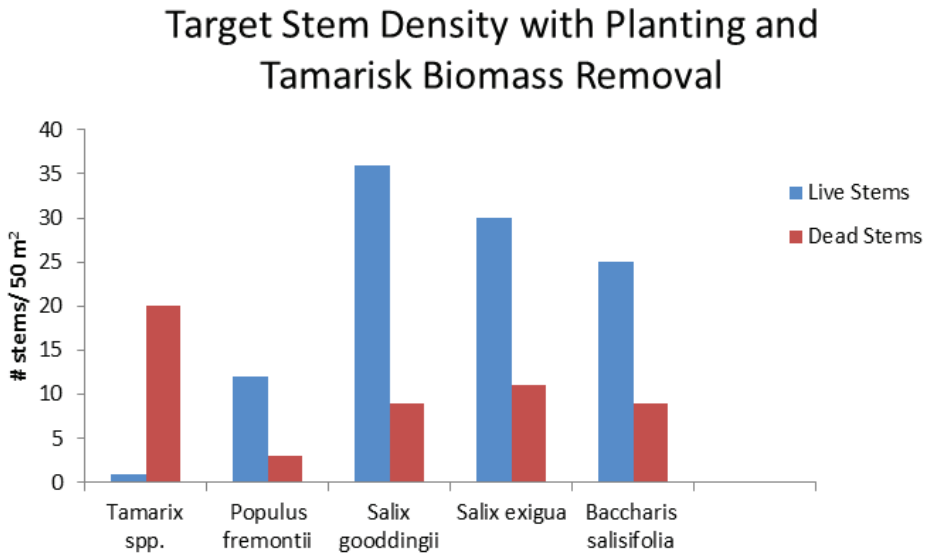


Figure G-24. Vegetation stem density predicted under Post-Biocontrol Treatment Scenario 2: after beetle-induced tamarisk mortality with some active tamarisk biomass removal and native plantings. The scenario assumes that roughly two-thirds of standing tamarisk biomass is removed and the four dominant native species are actively planted in areas where soil conditions are suitable for establishment. Removal of biomass also allows for better native recruitment.

G4.3 Plant Propagation, Installation, and Monitoring

G4.3.1 Plant materials

The primary restoration species will be willows, including narrow-leafed willow (*Salix exigua*) and black or Goodding's willow (*S. gooddingii*), and other less common willow. These are fast-growing species anticipated to achieve sufficient size to be suitable for SWFL nesting within 3–4 years. The latter is an arboreal species while *S. exigua* is shrubby and produces new shoots from lateral roots, creating the dense, multi-layer canopy structure favored by the flycatcher. Additional higher level canopy structure would be provided by cottonwood (*Populus fremontii*) that is a high-value habitat element for yellow-billed cuckoo, another species of conservation concern in Arizona (and soon to be federally listed as threatened).

To provide greater understory structure and promote faster habitat renewal at this site, we recommend propagated various forbs, vines, and shrubs in the project greenhouse for outplanting. Several species can be to both fill in gaps between planted woody species, as well as to stabilize soils and resist secondary invasion by noxious weeds. Native vines such as canyon grape (*Vitus arizonica*), woodbine (*Parthenocissus vitacea*), virgin's bower (*Clematis* spp.), and others could be grown within residual tamarisk biomass, or "skeletons" (i.e., dead stems remaining post-fire), to rapidly provide habitat and shading for wildlife and insects that are food for birds, lizards, and other vertebrates.

G4.3.2 Re-vegetation methods

Methods for implementing restoration will vary based on site conditions and timing, particularly whether near-surface water is sufficient to support growth without irrigation. SWFL nest sites are restricted to locations where surface water or high humidity are found, thus there would be no need to irrigate in sites intended specifically for enhancing their habitat. At these "wet" sites pole cuttings can be cut nearby, treated with rooting hormone, and installed directly into the soils. Planting depth of 1 meter or more is desirable for promoting adequate root development, and can be attained by driving in solid stake and removing to subsequently insert tree poles. Alternatively, a high pressure water drilling unit, or "stinger," can be used to prepare a hole for stem insertion, with the advantage of immediately bathing the site with water. For those taxa that do not grow readily from pole cuttings, plants will be grown from seed or cuttings in the greenhouse, and again inserted into moist soils with bare roots or root/soil intact, depending on conditions.

At greater distance from surface water or where groundwater depth is greater than about 1 meter, alternative methods and/or timing of re-vegetation will be used. Once depth to water is determined, larger poles of native trees can be cut and inserted to greater depth to ensure direct and perennial access to water. Such methods have been used successfully for cottonwoods and other plants with very large pole cuttings such as stems 4 or 5 meters long and correspondingly large diameter so that the majority of the stem is buried, with only a portion a meter or so in length remains aboveground. This method can be used to establish relatively large plants or trees in a short period of time, but require heavier machinery, such as gas-powered auger, to attain sufficient depth for the planting hole.

According to the minimum standards that members of the Restoration Science Team and the SWFL Technical Advisory Committee have developed for application to SWFL habitat enhancement, a minimum of about 4 ha (10 ac) is desired in SWFL site restoration. Vegetated patches can be relatively narrow but based on pre-treatment assessment of occupied sites we consider about a 30-m wide patch as a practical minimum while 100-m wide patches are excellent, particularly with the stream or permanently moist element within the patch. Thus, we

propose implementing restoration for about 1 km of stream length with an average width of 50 m. The actual project plans will likely be more detailed, based on site surveys and soil moisture and groundwater assessment. At a later stage, or if resources become available, a larger area would be targeted for SWFL enhancement within the burned area of site FMI-RRSA-1 / SRPCE-4, ideally for all suitable micro-habitat within the river segment.

Restoration should also be targeted at higher surfaces on the floodplain where tamarisk has burned in order to provide a buffer to the core SWFL habitat, to reduce the potential for tamarisk re-growth to promote future destructive wildfire, and serve as habitat for other sensitive but less restricted riparian wildlife species. On these higher and drier terraces, moisture is less dependable and unless deep planting techniques (4+ m poles extended to groundwater depth) can be used, it would be better to wait until the fall/winter seasons when water availability would be greater and water demands by vegetation lower. In the interim it may be necessary to apply herbicide treatment to tamarix re-growth to prevent re- accumulation of weed biomass.

G4.3.3 Implementation timing

Re-vegetation should be staged, based on pre-planting treatments, substrate conditions, plant phenology, and availability of propagation material. For permanently moist/saturated sites willows and some other taxa can be installed at any season, and could be planted as early as summer 2014 after SWFL nesting has ended, and once materials and labor are available. Initial focus during this time period should be near known SWFL nesting areas to maximize plant-establishment times before the 2015 nesting season. The remaining SWFL-suitable areas, as well as higher terrace sites, could be planted in late fall 2014/winter 2015 based on availability of moisture from seasonal precipitation, once tamarisk treatments are to a stage where planting is feasible. In these zones temporary irrigation may be appropriate to facilitate initial establishment, but site conditions and planting method will be determined so that cost- and labor-intensive irrigation needs are minimized, and intended for removal within one or two years of planting. Plant materials propagated in the EAC greenhouse from seed or stem material will be installed when winter moisture is available to create diversity of species composition and vegetation structure.

G4.3.4 Monitoring

Several elements of site monitoring needed to design restoration treatments, and to evaluate effectiveness, include:

1. Pre-treatment site monitoring for environmental conditions:
    a. Vegetation monitoring—vegetation surveys consisting of ten 100-m transects starting from water's edge across lower surface for species composition and density of canopy and understory plant species, vertical vegetative structure, canopy density/light penetration and substrate condition including litter/organic debris (soil collections from 20-m intervals along each transect)
    b. Soil characterization—soil texture, salinity/conductivity, pH, carbon (C) and nitrogen (N) content and major cations analyses from sampled from hand-augered soil cores collected at 0–10 and 20–30 cm depths
    c. Soil moisture/depth to groundwater monitoring—installation of a series of digital piezometers to document soil moisture/shallow groundwater status, both prior to implementation and continuously over course of season to track depth to groundwater; installations should consist of at least 2 piezometers set

perpendicular to the stream channel from near stream margin (but high enough that washout risk is minor) and extending to upper floodplain terrace

d. Avian monitoring—SWFL and riparian bird censuses pre-treatment and during treatment by qualified and permitted avian specialist, including arthropod sampling to evaluate wildlife food resource availability as well as to detect potential presence of tamarisk leaf beetle (biocontrol agent)

2. Post-treatment site monitoring:

e. Vegetation monitoring— maintain vegetation transects to monitor growth and survival of re-vegetated plants, with advisory for adaptive management to promote successful establishment of native vegetation

f. Soil characterization—soil samples collected annually to assess change in soil productivity and anticipated decline in salinity with reduction in tamarisk dominance

g. Soil moisture/depth to groundwater monitoring—continue quarterly (or more frequent) groundwater monitoring to assess change in shallow groundwater levels in association with reduction in tamarisk dominance

h. Avian monitoring—continue seasonal SWFL and avian/wildlife surveys to detect re-occupation of sites following treatment activities and/or beetle-induced reduction in tamarisk dominance

G5 REFERENCES

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DRAFT REPORT ◦ SEPTEMBER 2018

Upper Gila River Watershed Assessment









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GWP Watershed Assessment

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PAST AND PRESENT PARTNERS

Arizona Game and Fish Department
Arizona Department of Environmental Quality
Arizona Department of Agriculture
Arizona Department of Transportation
Arizona Department of Forestry and Fire Management
Arizona State Land Department
Arizona Conservation Corps
Borderlands Restoration, L3C
Boulder Creek Construction
City of Safford
Conservation Legacy
Coronado RC&D
E-Quality Inc.
U.S. Natural Resource Conservation Service
U.S. Fish and Wildlife Service
U.S. Bureau of Land Management
U.S. Forest Service
U.S. Bureau of Reclamation
Graham County
Greenlee County
Southeast Arizona Clean and Beautiful
Sky Island Alliance
Sky Island Restoration Cooperative
Stillwater Sciences
Southwest Decision Resources
Town of Thatcher
Town of Pima
Town of Duncan
Town of Clifton
Tamarisk Coalition
Freeport-McMoRan, Inc.
Graham County Chamber of Commerce
Greenlee county Chamber of Commerce
Rivers Edge West
United Way of Graham & Greenlee Counties
University of Arizona – Cooperative Extension
University of Arizona – Water Resource Research Center
Walton Family Foundation
Numerous Private Citizens

LIST OF ACRONYMS

ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
AMA	Active Management Area
ANSAC	Arizona Navigable Stream Adjudication Commission
BLM	Bureau of Land Management
CES	Cooperative Extension Services
CWA	Clean Water Act
EA	Environmental Assessment
EIS	Environmental Impact Statement
ESP	Enhancement of Survival Permit
EQIP	Environmental Quality Incentives Program
ESA	Endangered Species Act
GPM	Gallon per minute
GWP	Gila Watershed Partnership
GVID	Gila Valley Irrigation District
ITP	Incidental Take Permit
NEPA	National Environmental Policy Act
NOI	Notice of Intent
NRCS	Natural Resources Conservation Service
UA	University of Arizona
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USFS	United States Forest Service
WIP	Watershed Improvement Program
WOTUS	Waters of the United States
WRRC	Water Resources Research Center

EXECUTIVE SUMMARY

The Gila Watershed Partnership's (GWP) Watershed Assessment provides a summary of the primary resources and issues in the watershed, with specific and general recommendations for the Upper Gila River Watershed in Arizona. This document was compiled through a process involving the following tasks:

- Review the five-year watershed planning initiative, led by the University of Arizona Water Resources Research Center.
- Compile and synthesize relevant feedback from stakeholders.
- Assess current status of natural resources since completion of the *2014 Atlas of the Upper Gila River Watershed* (WRRC 2014).
- Provide updated maps of the watershed depicting resources and key analysis results.
- Conduct public presentations and review of plan with stakeholders.
- Develop recommendations to achieve the GWP's short-term and long-term goals.

The goals, data, and recommendations in this report are built upon a strong foundation of experiences and expertise of GWP's Board of Directors, staff, and stakeholders, supported by collaboration with Stillwater Sciences and the University of Arizona Water Resources Research Center (WRRC). This plan was developed as part of a project funded by the Walton Family Foundation.

General Management Recommendations include:

1. **Convene decision-makers around watershed issues.** Watershed management is strengthened with the participation of local decision-makers, experts, and community members. The GWP is best positioned to convene disparate groups and host critical dialogues about the health of the region in order to build common understanding of the issues and develop solutions.
2. **Prioritize areas most vulnerable to fire.** The Upper Gila River Watershed's patchwork of property ownership and land management create potential hazards for property and wildlife in the region. GWP will work with landowners and agencies to standardize management practices and develop a multi-jurisdictional plan for fire risk reduction.
3. **Identify infrastructure at risk from natural disasters.** Aged erosion control structures and outdated engineering over the last century has left the Upper Gila River Watershed at risk for flooding and other natural disasters. A concerted effort is necessary to identify and target compromised structures that pose the greatest threat to people, property, and the natural system.
4. **Cultivate next generation of watershed stewards.** Youth engagement, which has been found to be highly effective, will serve as a primary method for outreach and education in the communities in the Upper Gila River Watershed.
5. **Support conservation practices and policies.** Boost initiatives to install more efficient water-related infrastructure in homes, fix leaks, provide education on money savings, and get people to buy-in to conserving water. These types of programs could play a continuing role into the future, particularly in areas where new residential and commercial growth would create increased water demand. These programs may be

particularly important in areas where proposed conservation measures and programs have not yet been adopted.

6. **Establish Best Management Practices for Uplands.** Using resources from the Bureau of Land Management and other federal agencies, develop a set of practices customized for the region and reflective of the major stressors that impact upland health and, in turn, influence riparian and watershed health.
7. **Delineate River Management Segments.** Based on land ownership and aligned management objectives, delineate the management network and segments of the river corridor to prioritize management actions and the responsible entities.

SECTION 1: INTRODUCTION

The communities of the Upper Gila River Watershed have witnessed threshold moments in which decision-making at particular points in time resulted in substantial shifts in the future development and land use of the Valley. These threshold moments demonstrate how a collective choice or series of choices can result in long-term effects for residents and resources throughout the watershed. Land surveys and ownership arrangements established in the late 19th century impacted access to important resources like surface water and mineral rights. Site selections for new roadways and railways have had spillover effects for those communities included or excluded from such projects. In other cases, when expensive public projects were constrained by limited budgets, decisions were required to weigh community support. An early 20th century referendum led to the construction of a highway from Safford to Duncan instead of a dam in the area of the Gila Box. A long-term, anti-wildfire policy on federal forest lands has been shown to have counterproductive results, as the reduction in frequent, small-intensity fires is replaced by infrequent but tremendously destructive high-intensity blazes like the Wallow Fire in 2011. New plant species were introduced into the landscape during these waves of settlement; most notably contributing to the colonization of the Upper Gila River riparian zone by the invasive tamarisk tree. Decisions and policies regarding land use and resource management can have lasting, long-term cumulative impacts on the watershed.

From historical examples to the present, the sustainability of water supplies in the face of fluctuating precipitation levels has remained a constant theme in the life of residents of the Upper Gila River Watershed. This variability requires innovative and collaborative approaches to management of the land and water resources. The Gila Watershed Partnership (GWP) has taken on these challenges for the last three decades and persists in creating an ever more robust framework for future management decisions.

WATERSHED ASSESSMENT GOALS AND OBJECTIVES

This document is intended to draw together past and current watershed-focused planning efforts with stakeholder feedback in order to identify priority activities that will best address the major watershed challenges. It will provide guidance for future GWP projects and actions which support the efforts of partnering land and resource managers.

Objectives

The main objectives of the Watershed Assessment are to:

- Characterize the existing resource conditions in the river-riparian corridor and upland areas throughout the watershed.
- Identify the greatest stressors affecting resources and functions of the physical, hydrological, and ecological systems in the watershed.
- Integrate the information on resource conditions and stressors to develop one or more watershed condition indicators.
- Identify data gaps and areas of greatest uncertainty.
- Provide recommendations for actions to improve watershed conditions and beneficial human uses.
- Identify metrics with which to measure progress toward GWP's goals and objectives.

Watershed Condition

The greater the departure from the natural "pristine" state, the more impaired the watershed conditions are likely to be. Watershed condition refers to the physical and biological processes that impact the soil and hydrologic functions supporting ecosystems and a healthy environment. These conditions can reflect a range of variability from "natural pristine" (functioning properly) to "degraded" (severely altered state or impaired) (U.S. Forest Service 2011). Watersheds that are functioning properly have ecosystems that capture, store, and release water, sediment, wood, and nutrients within a natural range. This proper functioning can create and sustain functional habitats that are capable of supporting diverse populations of native aquatic- and riparian-dependent species, providing substantial economic, recreational, aesthetic, and other benefits.

In sum, a well-functioning watershed is a healthy watershed. While the Upper Gila River Watershed is sparsely populated and not heavily developed, certain activities such as agriculture, ranching, recreation, and mining can alter natural functioning of the watershed. This Watershed Assessment describes various indicators and variables that may impact watershed function. A framework for evaluating watershed condition is depicted in Figure 1. The example depicted here uses a suite of "indicators" and corresponding attributes related to watershed processes to determine watershed condition (U.S. Forest Service 2011). This and similar watershed condition frameworks typically are best suited for evaluating watershed condition relative to other watersheds within a region or state, to help resource managers plan and prioritize watershed protection and restoration efforts (EPA 2017).

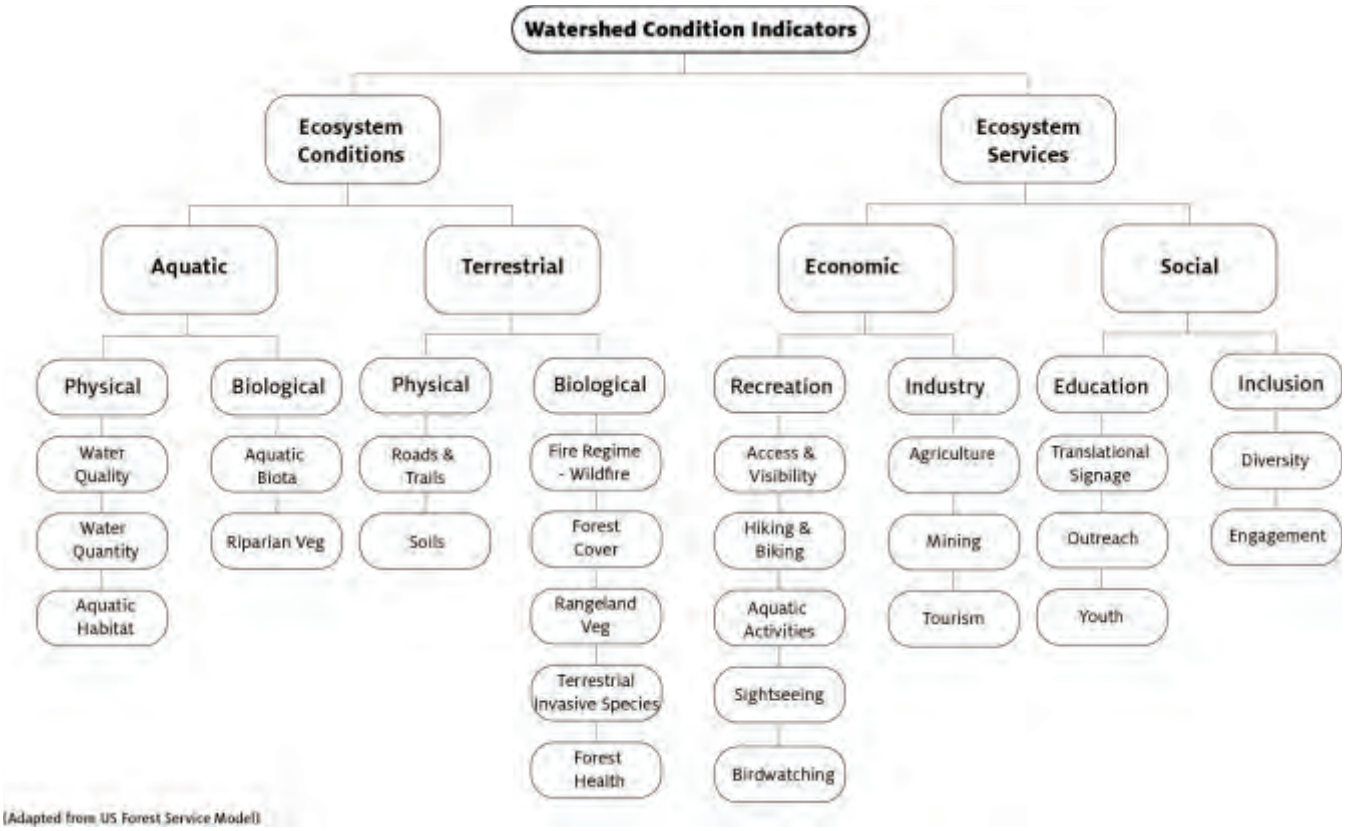


Figure 1. Watershed Condition Indicators Model, adapted from the U.S. Forest Service Watershed Condition Classification Technical Guide (2011).

To gain a better understanding of which watershed indicators are being evaluated or have been evaluated in the past, GWP is soliciting input from stakeholders using the Watershed Condition Indicators Worksheet included herein as Appendix A. The information obtained by those working in the watershed will provide helpful context for deciding which watershed indicators should be addressed by GWP, which are already being addressed by partners, and which could be addressed by GWP supporting partners.

CONSISTENCY WITH PREVIOUS PLANNING EFFORTS

This Watershed Assessment is intended for use alongside the GWP *Watershed Conservation Plan*, *Riparian Restoration Plan*, and *Restoration Framework Report*, along with other technical reports that were assessed for the development of this document.

This report is also aligned with local planning considerations of Towns, Cities, Counties, and Federal Agencies (Table 1).

Table 1. Aligned planning and resources management reports.

Source	Related Sections or Documents
Graham County Multi-Jurisdictional Hazard Mitigation Plan (2010)	• 5.3. Hazard Risk Profiles (5.3.1-7: Dam Failure, Drought, Fissure, Flood/Flash Flood, Severe Wind, Wildfire)
Graham County Comprehensive Plan (1996)	• All goal statements, especially 1 and 2: 1.) To allow and provide for growth which has positive benefits to county residents and that is compatible with the natural environment and to insure economic security; 2.) To conserve natural resources, preserve scenic beauty and to promote recreational opportunities • 2.4.3 Environmental Impact Review (EIR)
Greenlee County Comprehensive Plan (2003)	• Vision Statement • Plan Element C. Environmental
U.S. Forest Service	• Watershed Condition Assessment Criteria • Land management Plan for the Apache-Sitgreaves National Forests (2016)
U.S. Bureau of Land Management	• Resource Management Plan • BMPs that address uplands
Arizona Department of Environmental Quality	• Five Year Non-point Source Management Plan (2015-2019): Identify impairments to surface and groundwater quality; Prevent and reduce NPS pollution discharges to protect and restore surface or groundwater resources; Coordinate efforts of various programs within ADEQ and with other agencies and partners to prevent and reduce NPS impacts to surface and groundwater
City of Safford General Plan (2016)	• Environmental Planning and Water Resources Element • Parks, Recreation, Trails, and Open Space
Town of Thatcher General Plan (2008)	• II.A.3. The General Plan recognizes the need for parks, recreational areas and open areas, which add to the attractiveness of the community, the quality of life of the residents and the expectation that park sites will be reserved and developed within new development projects." • II.A.4. Land use Considerations • II.A.5. Goals and Objectives – Goal 1: Proactively manage and direct growth to suitable areas for residential, commercial, and industrial uses
Town of Clifton (1985)	• Community Development Objectives and Policies – Provide the environment and improve the quality of life in the community
Town of Pima (2016)	• Future Changes in Land Use: Development Goal: Encourage the character of development in Town to be consistent with Pima's vision; associated Policy: Promote the use of landscaping that is appropriate for Pima, its natural setting and climate. • Future Changes in Public Services: all Water Goals

WATERSHED ASSESSMENT DEVELOPMENT AND ADAPTATION

This Watershed Assessment is intended to be a "living" document that is updated as environmental and land use conditions change, and/or GWP mission and goals adapt. The purpose of this document is to present a holistic view of the watershed conditions in order to assess the most effective and pragmatic ways to address those conditions under current and potential circumstances.

The Watershed Assessment will be periodically reviewed and revised in order to re-assess the watershed condition and respond to opportunities and challenges in a timely manner. The GWP Science and Technical Advisory Committee will review the Watershed Assessment once every 3 years from the time of completion. In cases where there are relevant changes in the plans of partnering organizations or dramatic changes in watershed conditions, review and revisions may occur on a more frequent basis.

PAST AND PRESENT GWP PROJECTS

Riparian Restoration Projects

The GWP has identified and begun riparian restoration at five discrete sites along the Upper Gila River in the Safford Valley, near the communities of Pima and Fort Thomas (Figure 2). The purpose of the riparian restoration projects is to re-establish native habitat for the Southwestern Willow Flycatcher (SWFL) and to control ecological, social, and economic threats from invasive tamarisk and other associated invasive species. The restoration sites were identified by GWP and their restoration-planning science team as part of a comprehensive ecohydrological assessment that evaluated restoration suitability throughout the river corridor in the Safford and Duncan valleys (Orr et al. 2014). This process entailed consideration of numerous environmental factors, each influencing suitability of SWFL-focused restoration in light of the imminent arrival of the tamarisk leaf beetle. Environmental factors included flood-scour risk, vegetation character, water and soil-moisture availability, soil salinity, and SWFL-nesting habitat suitability. The five restoration sites range in size from 2.9 to 24.6 acres, and total approximately 54.3 acres. Additional restoration is being planned at sites in the river-riparian corridor of the mainstem Gila River in and near the Safford Valley.

Other Ongoing GWP Projects

- Eastern Arizona College Discovery Park Campus Pollinator Garden
- Upper Gila River Watershed Riparian Restoration
- San Francisco and Blue River *E.coli* Reduction
- Upper Gila River Fuels Reduction
- Point of Pines Restoration

Past GWP Projects

Over 25 years, the GWP and partners have undertaken a variety of watershed projects, spanning from restoration to water quality improvement in the San Francisco River sub-basin and the removal of abandoned automobiles.

Tamarisk Removal and Restoration

- Zorilla Street Bridge Restoration
- Gila River Restoration at Apache Grove
- Point of Pines Restoration

Water Quality

- Central Retention Dam Rehabilitation
- Gila River Clean Up

- Abandoned Vehicle Removal Project – Crushed Vehicles Loaded for Removal
- Kaler Ranch Erosion Control Project, Phase I
- *E.coli* Reduction through Alternative Livestock Water on Kaler Ranch, Phases I, II, and III
- Buzzard Roost Clean Up
- Peterson Wash Stabilization
- Syfert Wildlife Watering Facility – Wildlife Watering Hole at Ten Ranch
- Ely Fence Replacement Project
- Salt Water Wells Closures
- Bellman Well Closure
- Thatcher Well Closure
- Groundwater Quality Project with ADEQ

Education

- Gila River Water Conservation Education Project
- Dzil Nchaa Si'An/Mt. Graham Youth Practicum Education Project Grant
- Upper Gila River Watershed Master Watershed Steward Class
- San Francisco River Master Watershed Steward Class
- Apache Grove Program
- GWP Monthly Speaker Series
- Discovery Park Earth Day

Water Conservation

- Graham County Fairgrounds Project
- Water Counts Program

Research

- Upper Gila River Fluvial Geomorphology Study
- San Simon Legacy Database
- Measuring the Flow of the San Francisco River

Economic Development & Tourism

- Growing Greenlee County as a Birding Destination
- The Buildings on Chase Creek in Clifton - Facade Improvement

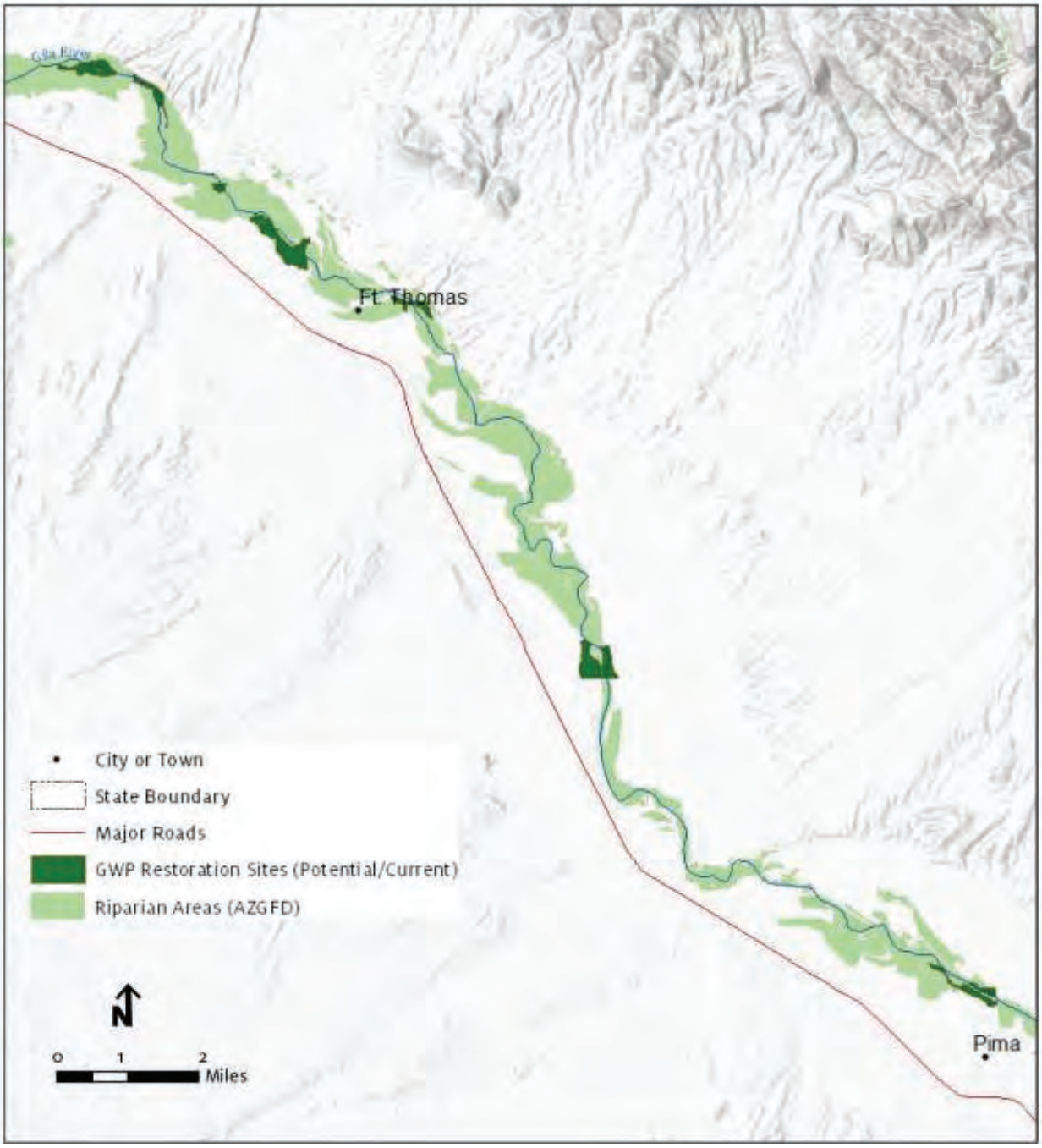


Figure 2. Locations of completed and ongoing GWP riparian restoration.

GEOGRAPHIC EXTENT OF THE WATERSHED ASSESSMENT

This Watershed Assessment is focused on the large expanse of southeastern Arizona within the Upper Gila River Watershed upstream of San Carlos Dam (Figure 3). The Watershed Assessment describes resources, uses, and stressors occurring in the mainstem Upper Gila River corridor from the Arizona-New Mexico border downstream to San Carlos Reservoir, and in the tributaries and upslope areas of the watershed. Because the inputs and processes acting throughout the watershed naturally propagate downstream to the drainage network, historical and current water and land management throughout the watershed shape the structure, function, and stressors acting on the river-riparian system. Understanding the resource conditions and relative magnitude of these influences will help define and prioritize future watershed management opportunities and constraints.

Reaches and Sub-basins

Between San Carlos Dam and the Arizona-New Mexico border, the Gila River flows through two broad alluvial valleys (the Duncan-Virden Valley and the Safford Valley) separated by the Gila Box, a much narrower, bedrock- confined system. Between York and the Duncan Valley, the Gila River is semi-confined with valley width ranging from 500-700 ft, until the valley widens significantly just downstream of Duncan.

Previous studies have delineated reaches and sub-basins for purposes of analysis and management. Orr et al. (2014) sub-divided the Gila River between Coolidge Dam and the lower Gila Box into three hydrogeomorphic reaches (the Reservoir-influenced Reach, The Gila (Safford) Valley, and the lower Gila Box. The U.S. Bureau of Reclamation (2003) identified 14 discontinuous reaches in the Duncan and Safford Valleys as part of an erosion study. The Safford Valley was further subdivided into 10 reaches based on floodplain width, vegetation, degree of braiding, land use, and tributary confluences.

Because this Watershed Assessment has a much larger study area than Orr et al. (2014) and the Reclamation (2003) erosion study, we have divided the Gila River into six reaches and include six large tributaries as separate sub-basins. The reaches and sub-basins are indicated by number in Figures 3, 4, and 5.

Gila River Mainstem Reaches

1. The Duncan Valley Reach from the New Mexico Border to Highway 191 (about 18 river miles)
2. The Gila Box Reach from Highway 191 to Bonita Creek (about 33 river miles)
3. The Upper Safford Valley Reach from Bonita Creek to the Smithville Diversion Dam (about 18 river miles)
4. The Lower Safford Valley Reach from Smithville Diversion Dam to the east boundary of the San Carlos Apache Reservation (about 34 river miles)
5. The Bylas Reach from the east boundary of the San Carlos Apache Reservation to the upstream limit of the reservoir backwater (defined by Orr et al. (2014) as the confluence with Bone Spring Canyon) (15.6 river miles)

6. San Carlos Reservoir and Backwater Reach from Bone Spring Canyon to Coolidge Dam (about 24 river miles).

Tributary Sub Basins

1. San Francisco River
2. Blue River
3. Eagle Creek
4. Bonita Creek
5. San Simon River
6. San Carlos River

Upland Zones

In mountain upland areas, there are unique blends of climate, geology, hydrology, soils, and vegetation shaping the landscape, with waterways often cutting down steep slopes to lower elevations and major drainages (washes, ephemeral streams, the mainstem Gila River). These factors, and more, influence the overall health of water resources: chemicals from the mineral weathering of rocks, from the decay of vegetation, and groundwater.

Delineating zones for the uplands would help with their management and aid in wrapping in the upland Best Management Practices from the Arizona Department of Environmental Quality (ADEQ) and the Bureau of Land Management (BLM). For instance, it would be important to identify material contribution areas, or small headwater catchments in the uppermost reaches of the watershed, as well as upland areas immediately adjacent to streams and rivers that are not floodplain, terrace, or riparian area. Material contribution areas provide food and energy (e.g., falling leaves) to aquatic organisms that is then transported downstream through ecological processes. The results of a proper functioning condition (PFC) analysis, such as those conducted by BLM for streams and rivers in the Upper Gila River Watershed, can be combined with other types of watershed assessments for a better understanding of how the riparian and upland areas interact. A PFC analysis is also often used as a screening level assessment to determine whether or not more intensive, quantitative analyses are necessary.

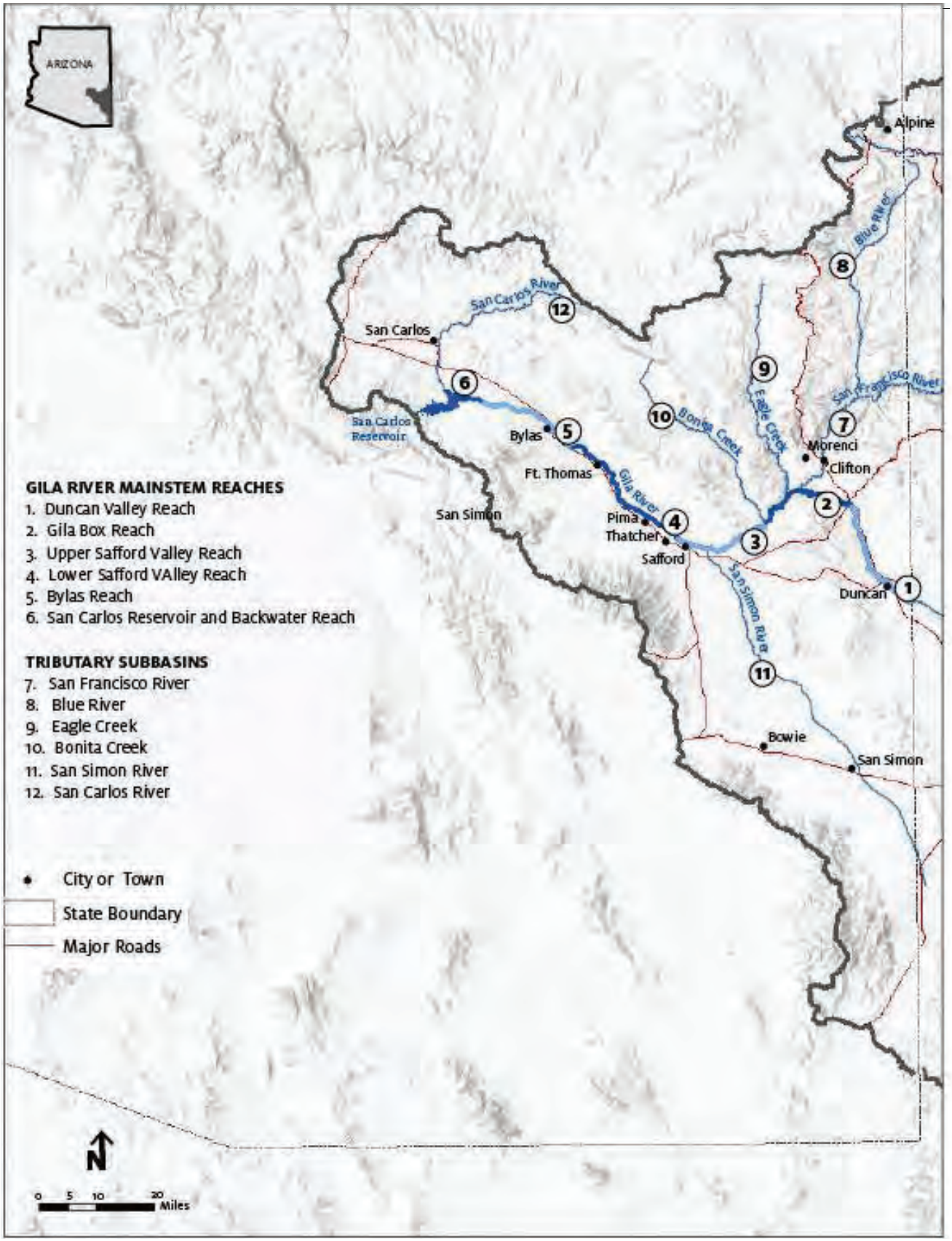


Figure 3. Geographic extent of the Watershed Assessment Plan with reaches.

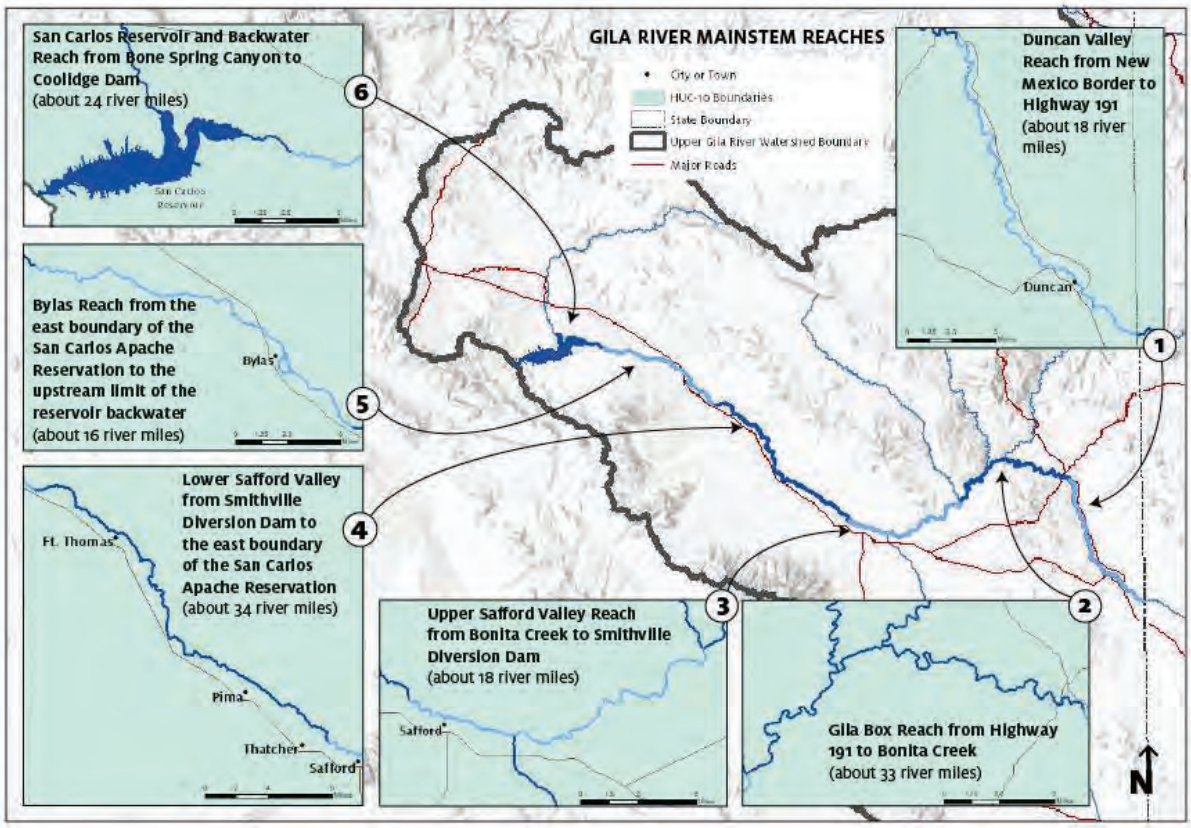


Figure 4. Mainstem reaches with description.

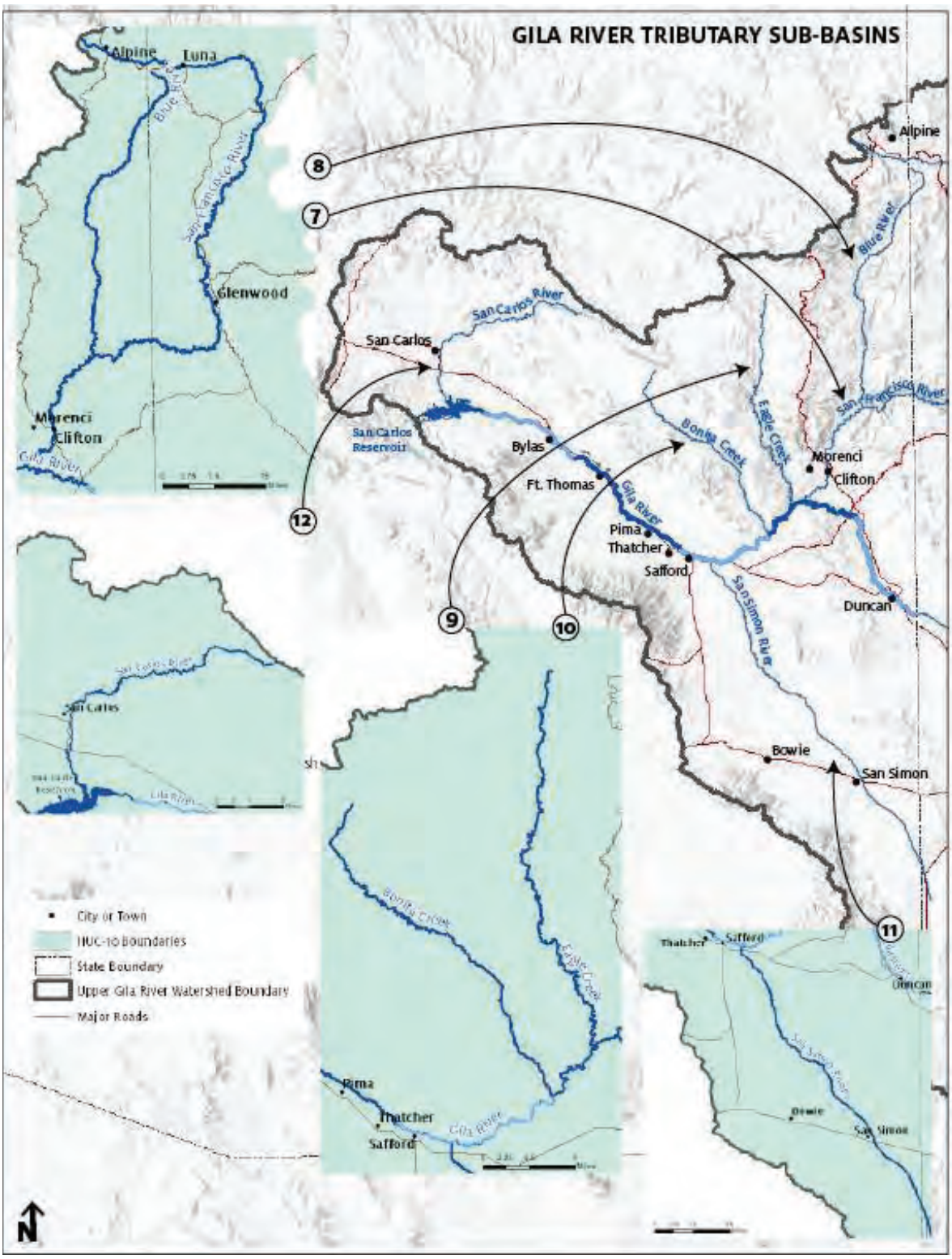


Figure 5. Upper Gila River Tributary Sub-basins.

SECTION 2: RECOMMENDATIONS

This section was developed with the participation of the GWP in order to identify and prioritize recommendations that are consistent with the mission, goals, and outlook of the organization, with specific recommendations pertaining to these priorities. These recommendations can be further refined and prioritized by means of prioritization exercises conducted by GWP with stakeholders. This section also describes data gaps and uncertainties that should be prioritized and developed into recommended actions.

1. Relationship Building - Engagement

Community engagement, recreation, and economy

- Seek opportunities to work with municipalities on the restoration/water quality/education portions of recreation and economic development initiatives.
- Seek available opportunities to purchase goods and services locally and hire local labor.
- Seek to improve workforce and education opportunities.

Farmer engagement and upland management

- Work with landowners to find mutually beneficial opportunities and projects.
- Work with land owners and aid agencies in decreasing erosion and *E.coli* through restoration and incentive programs.
- Work with land owners and agencies to identify and grow plants needed to restore damaged rangeland.

2. Recommended Actions

Infrastructure and fire/flood management

- Develop a fire management plan in cooperation with rural fire management districts.
- Prioritize vegetation management in fire prone areas of the watershed, including riparian corridors and in proximity to habitation, to reduce risk of wildfire and loss of life and property.
- In riparian corridors prioritize removal of tamarisk, which is extremely flammable, and revegetation with native species.
- Evaluate the degree to which sediment derived from fires impacts infrastructure, water quality, and aquatic and riparian habitat.
- Evaluate sediment control structures (check dams) to identify those which may be failing or full and unable to store additional sediment.
- Identify and prioritize sediment control structures to be maintained or abandoned.

Water quality, water supply, and water demand

- Seek opportunities to improve water quality through outreach and education to landowners and recreational users, especially in heavily trafficked areas such as the Gila Box and private lands.
- Partner with irrigators and other water users, including municipalities and mining interests, to reduce water demand by improving use of gray/recycled water, improving infrastructure efficiency, and implementing conservation efforts.

- Continue to monitor and update water supply and demand figures, provided by ADWR, every five years.
- Continue to work toward improving water quality and removing rivers from the 303d list.
- Reduce surface runoff and improve groundwater recharge by promoting low impact design (LID) practices that reduce impermeable area (roofs and pavement), dissipate runoff, and collect storm runoff in small impoundments (retention basins) for purposes of groundwater recharge, where appropriate.
- Quantify the sediment load from abandoned erosion control structures.

Geology, hydrology, and geomorphology

Although there have been studies of individual watersheds, few quantitative data of sediment sources and sinks are available for the Upper Gila. A geomorphological study of the Upper Gila Watershed including the tributaries would greatly help to prioritize restoration actions for riparian and aquatic species and assess the potential for aggradationally-induced flooding.

This study would include:

- updating maps of levees, potentially identifying levees with limited functionality;
- identifying levees that exacerbate rather than mitigate flooding in developed areas;
- assessing the potential for sediment delivery from failing sediment control structures in the San Simon watershed and other locations draining gullied Quaternary sediment deposits;
- assessing channel impacts from wildfire; and
- developing a sediment budget for the watershed to identify problem sediment sources and quantify current and potential sediment inputs throughout the watershed.

These studies can then be used to focus management actions. For example, the San Simon River has historically been a large sediment source to the Gila River and is a candidate for further evaluation and actions to control sediment.

Stream and riparian ecosystem health

- Fence or otherwise control livestock from accessing streams and streambanks, to help improve water quality, reduce erosion, and reduce impacts to native aquatic and riparian species. Consult state and federal resource agencies for best management practices (BMPs) and guidelines, and to identify potential sources of funding assistance.
- Encourage landowners to plant native riparian vegetation along perennial and ephemeral streams where vegetation removal, grazing, recreation, or other uses have caused erosion and compromised riparian functions. Consult state and federal resource agencies for best management practices (BMPs) and guidelines, and to identify potential sources of funding assistance.
- Continue establishing and maintaining exclusion fencing or otherwise manage livestock to prevent access to streams and streambanks, to help improve water quality, reduce erosion, and reduce impacts to native aquatic and riparian species. Consult state and

federal resource agencies for best management practices (BMPs) and guidelines, and to identify potential sources of funding assistance.

- Seek opportunities for private landowners to partner with state and federal resource agencies, conservation groups, volunteer organizations, and other entities to conduct aquatic habitat inventory, restoration, and monitoring efforts. Information obtained from baseline inventory and monitoring will help identify and prioritize the most suitable areas for conservation and possibly reintroduction of native fishes and other aquatic/riparian species.
- Recognizing that alterations to watershed hydrology (e.g., increased peak flow frequency and magnitude; lower baseflows) adversely affect native species, minimize existing and future hydrologic modification by promoting low impact design (LID) practices that reduce impermeable area (roofs and pavement) and dissipate runoff, by implementing modern stormwater and erosion control measures, and by encouraging native-species revegetation of bare soil caused by all types of land use.
- In cooperation with land owners, continue to conduct riparian restoration in the potentially suitable areas identified by Orr et al. (2014) and other areas, particularly burned areas, to pre-emptively maintain and enhance SWFL habitat prior to defoliation of tamarisk by the tamarisk beetle. Riparian restoration will also maintain and enhance ecosystem services and human uses, including recreation and aesthetic enjoyment, and may also increase water quantity in the river.
- Expand the ecohydrological assessment used by Orr et al. (2014) to other riparian corridors in the watershed, to identify additional areas with the greatest potential for effective and successful native vegetation restoration. Absent more detailed information, suitable areas for active restoration included those lying within the 0–4 m elevation range above the low-flow channel.
- More immediate restoration prioritization should be given to the most suitable locations within recently burned riparian parcels (e.g., following the Clay Fire and the Bee Town burn area near Bylas). The riparian vegetation, mostly tamarisk, was highly impacted during the fire, thus priming it for rapid, cost-effective restoration action specifically involving herbicide treatment of the re-sprouting tamarisk and then replanting with native species.
- More intensive active riparian restoration should involve a phased, patch-work ("Propagule Islands") approach to: preserve much of the existing taller SWFL-suitable tamarisk structure (to minimize disturbances to existing viable SWFL-nesting habitat); remove/treat lower tamarisk structure (in patches) and replace with native plantings well suited to site conditions; and gradually expand treatment and revegetation footprint before and following beetle colonization.
- Lower effort restoration strategies should also be considered throughout the remainder of the Planning Area following disturbance from fires or floods that have removed much of the tamarisk biomass. Mechanical removal and fire-contingent restoration actions such as herbicide applications on re-sprouting tamarisk and/or active planting of native species should be planned for Priority Areas downstream of Thatcher. Post-flood-scour

restoration actions can follow a similar approach taking advantage of newly cleared areas to treat remaining tamarisk and/or revegetate with native species.

- Given the greater occurrences of native trees and shrubs, as well as nearly all occurrences of floodplain wetland, that appear to be highly influenced by channelized tributary and/or agricultural return flows, active restoration actions should attempt to take advantage of such conditions through selection of sites with a known steady runoff supply or coordination with land managers to negotiate a viable water supply where natural sources are insufficient. Such sites should have higher success rates for both revegetation of native riparian species (i.e., higher survival and growth rates for planted trees and shrubs) and for creating or enhancing SWFL habitat (i.e., presence of surface water or saturated soils during the breeding season).
- In future riparian restoration planning and prioritization efforts, consider other factors including landowner willingness, existing conservation easements or related land use requirements, presence of key infrastructure, water rights, and initial and long-term costs and maintenance requirements.
- Prior to any treatment/removal activity, coordination with the Phoenix office of the USFWS will be necessary to first secure the prerequisite permits for carrying out such work that could potentially be considered an unauthorized "take" of SWFL or other federally listed fish or wildlife in the implementation area, or to determine that activities can safely be undertaken without risking take.
- Pre- and post-implementation monitoring is recommended to evaluate restoration success (see Appendix G in Orr et al. 2014). Restoration site monitoring plans should focus on factors such as: vegetation composition, density, and structure; physical and chemical soil properties; soil moisture/depth to groundwater; and avian/wildlife occupation and re-occupation.

3. Data Gaps and Uncertainties

Topics for which little or no information is available or those for which the availability or status of information is uncertain include:

- Effects of water diversion structures on sediment dynamics and channel morphology in the mainstem Gila River to address gaps in previous research.
- Quantification of sediment sources to the Upper Gila Watershed.
- Sediment supply from failed or filled sediment retention basins in the San Simon watershed and other watersheds with sediment retention structures.
- Amount of groundwater pumping by domestic wells.
- Impacts (positive and negative) of managed grazing on riparian areas.
- Uplands management practices customized for the conditions and context of the Upper Gila Watershed.
- Engage with land owners on cooperative projects and quantify benefits to land owners.
- Establishment of a Community Fire Protection and Response District to provide coordinated wildland fire prevention and post-fire planning, monitoring, and restoration support.

SECTION 3: METRICS FOR MEASURING PROGRESS

This section describes some of the metrics that can be used to measure success of priority actions (i.e., "Are the actions resulting in watershed improvement?") and progress toward achievement of GWP's short-term and long-term goals. Priority actions may include those intended to improve watershed conditions such as the aquatic and terrestrial indicators included in the Watershed Condition Indicators framework (see Section 1, Figure 1).

Geomorphology and hydrology metrics

Geomorphology and hydrology set physical structure that provides aquatic and riparian habitats. Metrics used in wetter watersheds such as wood loading are not as important in the Upper Gila River Watershed. Fluvial geomorphic metrics used elsewhere (e.g., US Forest Service 2011) include LWD loading, width-to-depth ratio, bed elevation changes, and floodplain connectivity. Because much of the watershed is sparsely vegetated, LWD should naturally be rare in those areas but in confined reaches of the Gila River and tributaries it may provide important functions including aquatic habitat complexity and flood energy attenuation. Additionally, the widespread braided morphology in the alluvial valleys means that while width-depth ratio is a useful metric to track, high width-depth ratios do not necessarily reflect impairment. Moreover, width-depth ratio in braided rivers is less stable from year to year than in single-thread rivers because width-depth ratio is often tied to the magnitude and duration of the last high flow and because bankfull depth is difficult to assess in braided rivers. Similarly, even in a pristine reach of the Upper Gila River, low wood loading levels relative to the Pacific Northwest might also be expected because forest density and wood recruitment dynamics are much different in arid watersheds such as the Upper Gila River. Width-depth ratio might also be expected to increase as tamarisk (which limits bank erosion) is replaced by native willows and cottonwoods as the dominant riparian vegetation. Metrics of the success of management actions include quantitative measures of channel characteristics such as bed elevation changes, channel width, valley, width, sediment transport, and sediment supply. Management targeted at geomorphology is likely most relevant in terms of changes to habitat, including habitat maintenance for native fish and riparian species once the tamarisk beetle reaches the Upper Gila. This can be quantified using changes to bed elevation. Metrics to consider for the Upper Gila River Watershed include:

- Bed elevation of the mainstem and tributary streams to track aggradation and incision
- Width-depth ratio/Width changes
- Levee extent and condition
- Spatial variations in sediment supply

Care must be taken in assessing the degree to which the metrics reflect the natural state of the channel rather than impairment.

Water quantity metrics

Groundwater levels:

- Relative change over time, as determined by groundwater well monitoring (refer to ADWR's data: https://new.azwater.gov/sites/default/files/WL_Change_Report_Final.pdf

Stream discharge:

- Achievement (% of time) of continuous flow target at selected locations, based on historical hydrograph analysis
- Index of Hydrologic Alteration (IHA; The Nature Conservancy 2009)

Wildfire metrics

- Change over time (in acres and fuel type) to the arrangement of the fuel, taking it from a vertical arrangement to a horizontal arrangement while also reducing fuel loading.
- Identified breaks in uniform continuity of fuel, aiming for a patchy dispersal.
- Potential wildfire fuel is reduced and structure of remaining fuel is horizontal rather than vertical.

Water quality

- Percentage of the surface water (e.g., acres or stream miles) in the watershed listed as water quality impaired (303d-listed).
- Annual number or frequency of water quality exceedances, as determined by long-term or event-specific water quality monitoring/testing

Terrestrial vegetation and wildlife metrics

- Terrestrial habitat fragmentation (edge/area ratio, road density, or other measure); metrics may be derived or modified from criteria used in BLM's Proper Functioning Condition assessments.
- Land use patterns, land cover changes; metrics may be derived or modified from criteria used in BLM's Proper Functioning Condition assessments.
- Relative abundance (% of total species or other measure) of native wildlife species
- Relative number of listed and sensitive species, by taxonomic group (e.g., birds)
- Area (e.g., acres) of replaced or created suitable SWFL habitat elsewhere in the Safford Valley, such as upstream of Thatcher. This metric would help quantify and track the trend in the existing areal extent of viable SWFL habitat and provide additional resiliency to the system following beetle colonization (Orr et al. 2014). However, it is recognized that such an effort would require some combination of earthmoving, soil conditioning, and/or irrigation to support active plantings and creation of suitable breeding habitat, thus necessitating more detailed site designs, grading plans, and environmental permits (e.g., USACE Section 404).

Aquatic and riparian metrics

- Index of Biotic Integrity (IBI) for fish and/or macroinvertebrates (a multi-metric index, e.g., Karr and Chu 1997).
- Relative abundance or canopy coverage (stem density, % cover, or other measure) of native riparian vegetation (by reach and sub-basin); data for the Gila Box and elsewhere may be available from BLM's Proper Functioning Condition assessments.
- Increasing trend in the number of reaches and extent of stream monitoring.
- Evidence of natural recruitment of native riparian vegetation; site- or reach-based, as indicated by presence of seedlings/saplings of a specified height (e.g., 1 meter); data for

the Gila Box and elsewhere may be available from BLM's Proper Functioning Condition assessments.

- Floodplain presence and function (e.g., % of channel length, by reach, with hydrologically connected floodplain; area of floodplain and degree of hydrologic connectivity); data for the Gila Box and elsewhere may be available from BLM's Proper Functioning Condition assessments.
- Relative abundance (% of total species or other measure) of native aquatic species; data for the Gila Box and elsewhere may be available from BLM's Proper Functioning Condition assessments.
- Relative number of listed and sensitive species, by taxonomic group (e.g., fish); data for the Gila Box and elsewhere may be available from BLM's Proper Functioning Condition assessments.
- Hydrologic alteration/hydrologic connectivity (fish barriers/mile of stream length, other measures); data for the Gila Box and elsewhere may be available from BLM's Proper Functioning Condition assessments.

Diversity and engagement metrics

- Jobs created performing riparian restoration or other activities (type and number of jobs; average length of employment):
    - Jobs performed by at-risk and underserved individuals
    - Internships
    - Monitoring
    - Local hires
    - Number of staff continuing education in relevant social or physical sciences
- Youth communication and engagement activities
    - Number of events
    - Attendance
- Working group activities
    - Number and type of working groups
    - Milestones
    - Membership (attendance, diversity of affiliations)
- Public meetings
    - Number and type of meetings
    - Attendance (number, diversity of affiliations)
- Engagement of private land owners
- Online presence (measured by analytics tools)
    - Social media (followers, post engagement)
    - Website traffic

PROGRESS TOWARD GWP GOALS

Metrics to evaluate progress in achieving GWP's short-term and long-term goals are described in Table 2. It is expected that metrics will be modified in coordination with GWP (e.g., the Science Advisory Committee) as goals are revised, to select those that provide the best and most feasible measure of progress.

The GWP's short-term goals are those intended to be achieved within 5 years. Short-term goals are focused on riparian restoration at discrete sites, which includes removal of tamarisk and other invasive riparian vegetation and restoration through revegetation with native species. These actions will provide and enhance habitat for native wildlife, especially in areas dominated by tamarisk where existing habitat provided by tamarisk is expected to be reduced with the arrival of the tamarisk beetle and subsequent defoliation and mortality of tamarisk.

Long-term GWP goals are to be achieved within 10–30 years, and include larger-scale removal of tamarisk and other non-native invasive riparian plant species and revegetation through natural (passive) recruitment. Sites at which long-term riparian restoration will be focused include the following:

- High priority sites that normal river flooding processes are unlikely to naturally remove tamarisk as identified in the ecohydrologic assessment (Orr et al. 2014),
- Sites where private property and high-value vegetation (e.g., cottonwood groves) could be damaged by wildfire,
- Sites with willing landowners who are in agreement with approaches to re-establish native vegetation, and/or
- Sites where the tamarisk leaf beetle, when established, would not be an effective approach.

Long-term goals also include addressing other high-priority stressors in the watershed such as water quality impairment and adverse impacts resulting from intensive livestock grazing. A future iteration of this report and recommended next step is to broaden goals and metrics to include upland management.

Table 2. GWP goals and metrics to measure attainment of goals.

Goal	Metric	Comments
Short-term (5 yrs)		
Through active tamarisk control and re-vegetation projects, establish a minimum of 20 sites composed of willow/cottonwood plant communities of a minimum of 6 acres each for a total area not less than 200 acres.	Number of treatment sites ≥ 6 acres composed of willow/cottonwood Combined total acreage of treatment sites composed of willow/cottonwood, relative to 200 acre short-term target and long-term targets, expressed as a percentage Post-treatment survey results documenting SWFL nests or nesting potential (habitat suitability) Post-treatment survey results	These sites, identified through the eco-hydrologic study and other science-based activities, will provide potential nesting sites (refuge) for the SWFL as probable defoliation from the tamarisk leaf beetle occurs. These sites, known as propagule islands, will also provide native seed sources that are critical for re-establishing riparian plants throughout the watershed during flooding events. Also consider revegetation with giant sacaton (*Sporobolus wrightii*), a native grass which may have been a historically important

Goal	Metric	Comments
	documenting seed production by native riparian species (willow, cottonwood, others)	component of the riparian vegetation community.
Provide plant materials suitable for the Upper Gila River Watershed by developing a native plant nursery composed of a greenhouse, shade structure, plantation fields, and coppice fields.	Number of plants of each species produced and used for restoration/revegetation in the watershed	Consider propagating giant sacaton for use in riparian revegetation.
Assess and track success of restoration actions through the development and implementation of rapid and long-term monitoring protocols.	Allocation of funding for development of rapid and long-term monitoring protocols Completion of monitoring manual that includes final rapid and long-term monitoring protocols	Final monitoring manual should incorporate review comments by GWP Science Advisory Committee, funding entity, and other appropriate expert reviewers
Long-term (10–30 yrs)		
Reduce the relative canopy cover of tamarisk to less than 10% through active control measures and through the expected establishment of the tamarisk leaf beetle.	Relative canopy cover (%) of tamarisk, relative to 10% goal	Based on annual monitoring and mapping results Consider reporting on a reach-or site-specific basis
Reduce the relative canopy cover of other invasive species to less than 15%.	Relative canopy cover (%) of invasive riparian plant species other than tamarisk, relative to 15% goal	
Through primarily passive revegetation, increase native and desirable vegetation to levels that provide a riparian plant community composed of overstory and understory vegetation. Native species will be dominant and resilient through natural processes.	Riparian vegetation species and structural composition	Based on annual monitoring and mapping results Consider reporting on a reach-or site-specific basis Consider adding giant sacaton to the list of desirable native riparian vegetation included in revegetation goals.
Where possible, reduce stressors beyond invasive species to the river system – namely water quality and grazing pressures.	Water quality metrics: - Percentage of the watershed listed as water quality impaired (303d-listed). - Annual number or frequency of water quality exceedances, as determined by long-term or event-specific water quality monitoring/testing Metrics for grazing pressure and other stressors TBD, with input from GWP and stakeholders	If other high-priority stressors are identified, other metrics can be developed or added as appropriate

SECTION 4: WATERSHED CHARACTERIZATION

River-riparian ecosystems are interactive and deeply linked products of their landscape context (Figure 6). At broad scales in the landscape, there are several key factors that affect the fluvial and geomorphic processes and attributes that shape the structure and composition of riparian zones in alluvial river systems. These factors include climate (precipitation and temperature patterns), parent material (lithology), topography (slope, aspect, upslope drainage patterns), and input rates of water, sediment, nutrients, energy, woody debris, and chemical constituents from the watershed into the river. At finer scales within the watershed, key fluvial and geomorphic processes and attributes then shape riverine and riparian habitats, which in turn affect the biotic responses of aquatic and terrestrial populations and communities (Figure 6). Natural and anthropogenic disturbances (e.g., floods, fire, landslides, human land and water use, climate change) influence the system at all levels, from climate, watershed inputs, fluvial and geomorphic attributes and processes, to habitat (structure, complexity, connectivity), and biotic responses (Downs et al. 2011). Recognizing how broad-scale process differences interact with drivers and stressors (such as natural disturbance and human land use and flow regulation) is an important first step in assessing riparian condition and planning trajectories for functional recovery or enhancement of resilient riparian ecosystems.

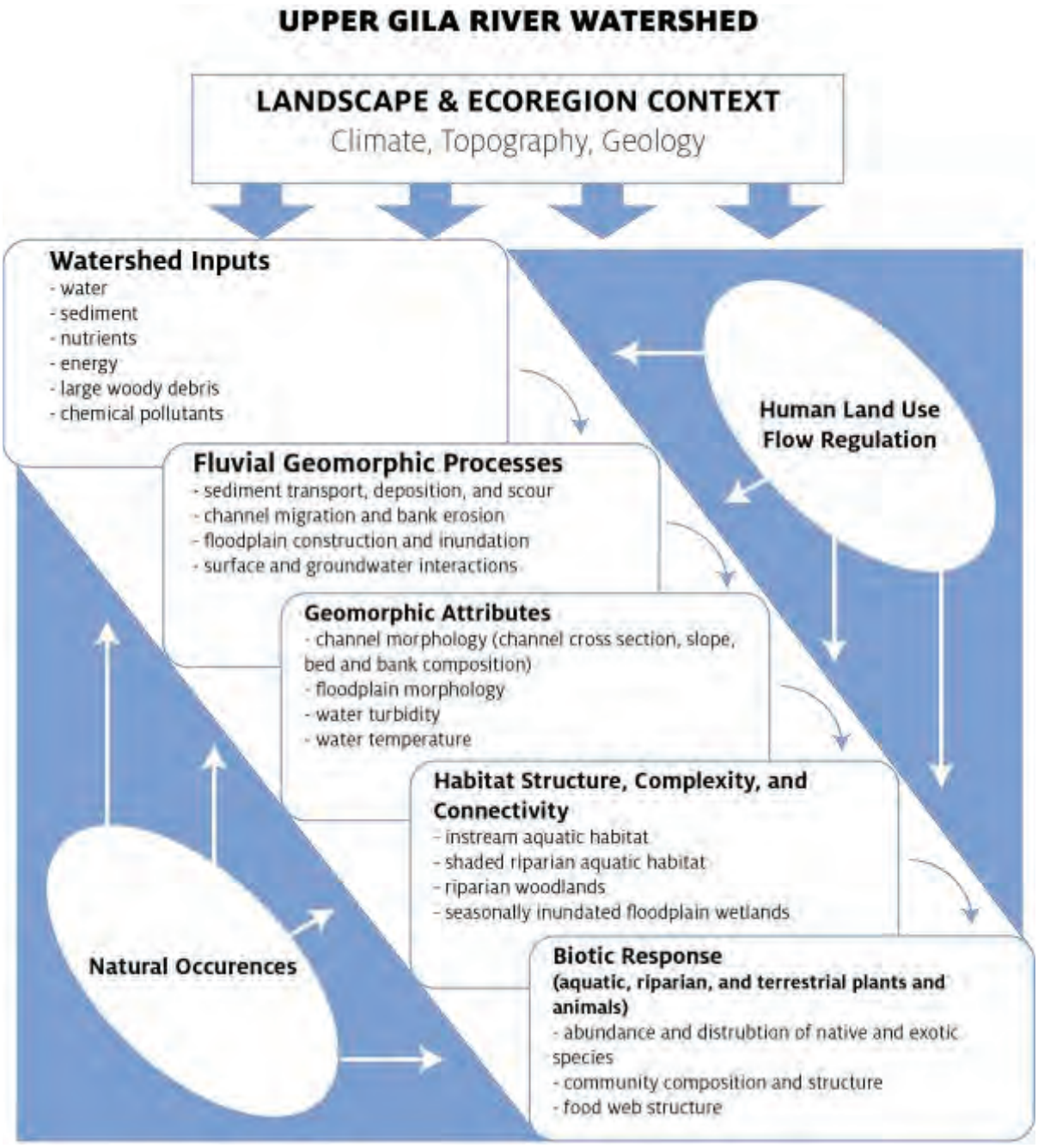


Figure 6. Ecosystem process linkages that influence habitat and biotic response (adapted from Stillwater Sciences conceptual diagram).

LOCATION OF THE UPPER GILA WATERSHED

Watersheds have physical boundaries that do not always align with political boundaries. The Upper Gila River Watershed has an area of approximately 9.7 million acres (15,193 mi^2) that straddles the Arizona-New Mexico border, with 48.4% of that total area located in Arizona, and the remaining 51.6% in New Mexico (Figure 7). The Arizona portion of the Upper Gila Watershed is approximately 7,354 square miles.

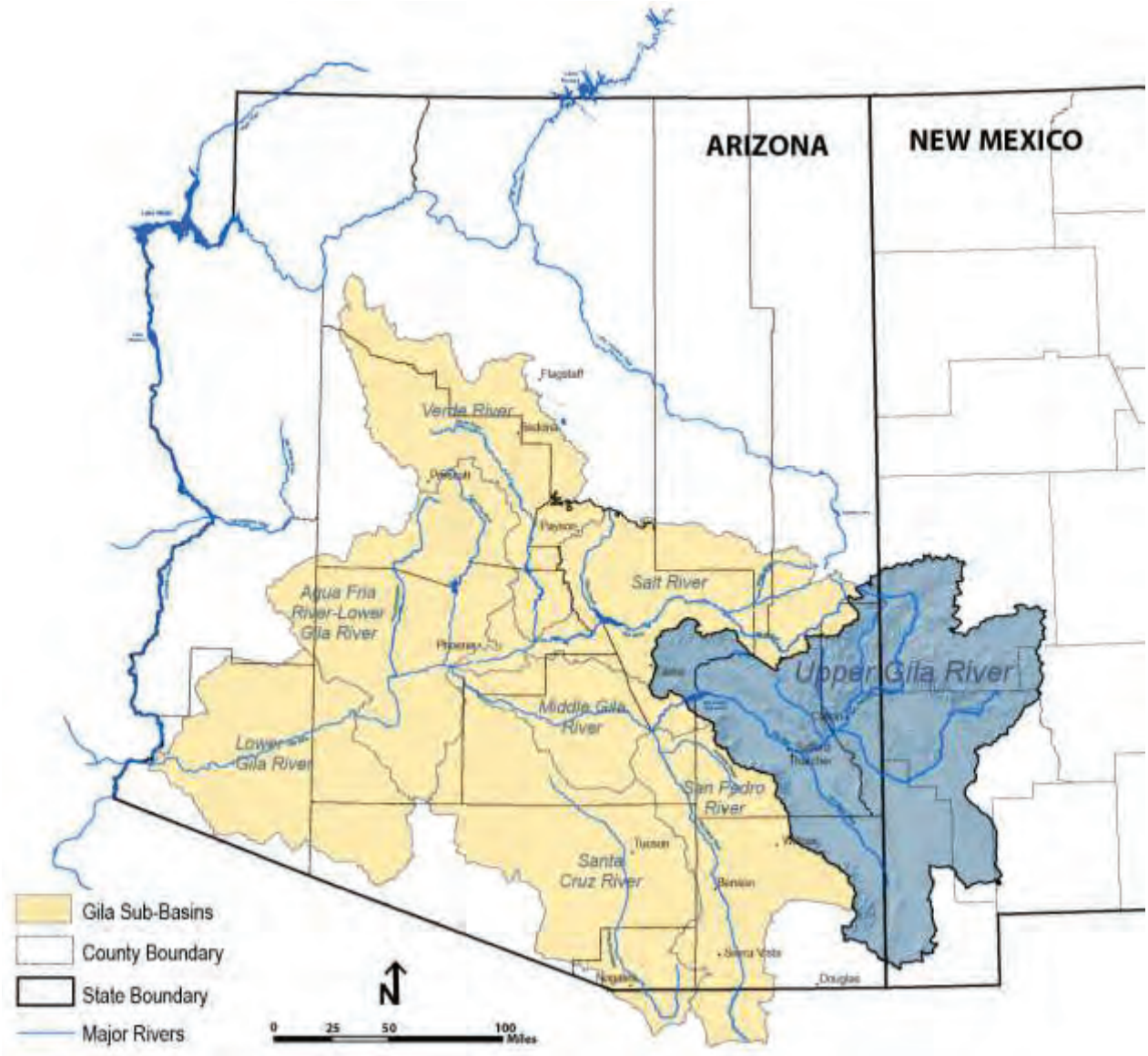


Figure 7. Upper Gila River Watershed in context of the entire Gila River watershed.

CLIMATE AND WILDFIRE

Arizona and the southwestern United States are built for drought. However, as temperatures are consistently warmer in recent years, the effects of longer-term warming are compounded. If observing rain gauge data (SPI) and historical averages, short-term predictions can be favorable or average, but when combined with warmer temperatures, we lose temporary gains in precipitation and drought creeps back in (Figures 8 and 9). The most high-risk areas must be considered with constant stress on trees, soil water balance, and variability or declining snowpack in upper elevation areas, while lower elevation areas may be more adapted to water stress as long as the timing of precipitation persists.

KEY TAKEAWAYS

- Rainfall in the Upper Gila Watershed is strongly tied to elevation with higher precipitation in the mountains (up to 40 inches per year) and the lowest precipitation in the valleys (about 8-10 inches per year).
- Rain occurs primarily during winter storms and summer monsoons; however drought has negatively affected the amount of long soaking rain in the winter, and it is predicted that the area will receive less, but more intense monsoon events.
- The Upper Gila River Watershed has experienced several large fires since 2011, including the largest fires on record in Arizona and New Mexico.
- These fires can result in direct mortality for fish and wildlife.
- The fires also increased runoff and sediment supply to the Upper Gila Watershed.
- The largest fires tend to be in the uplands, where vegetation is the densest. Effects of fire subsequently propagate downstream and can severely impact habitat for fish and other native species.
- The high flammability of tamarisk has contributed to the severity of fires in the riparian corridor of the lower Safford Valley.
- Major disasters, such as floods, can seriously degrade or destroy much of the infrastructure in relation to the river.
- Federal disaster relief programs made some funds available for the repair or reconstruction of flood-affected areas. These federal programs often added restrictions regarding the type of construction that could be funded, with the result that some potential upgrades to infrastructure may not be permitted.

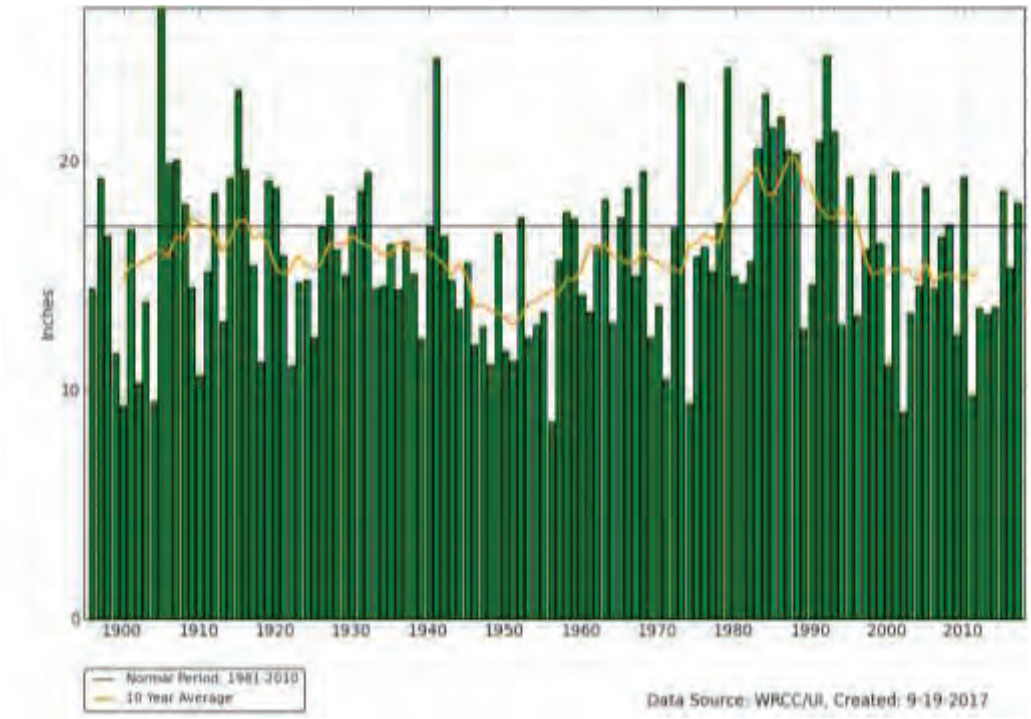


Figure 8. Precipitation patterns in the Upper Gila River Watershed, by decade ending in August, over the last 100 years.

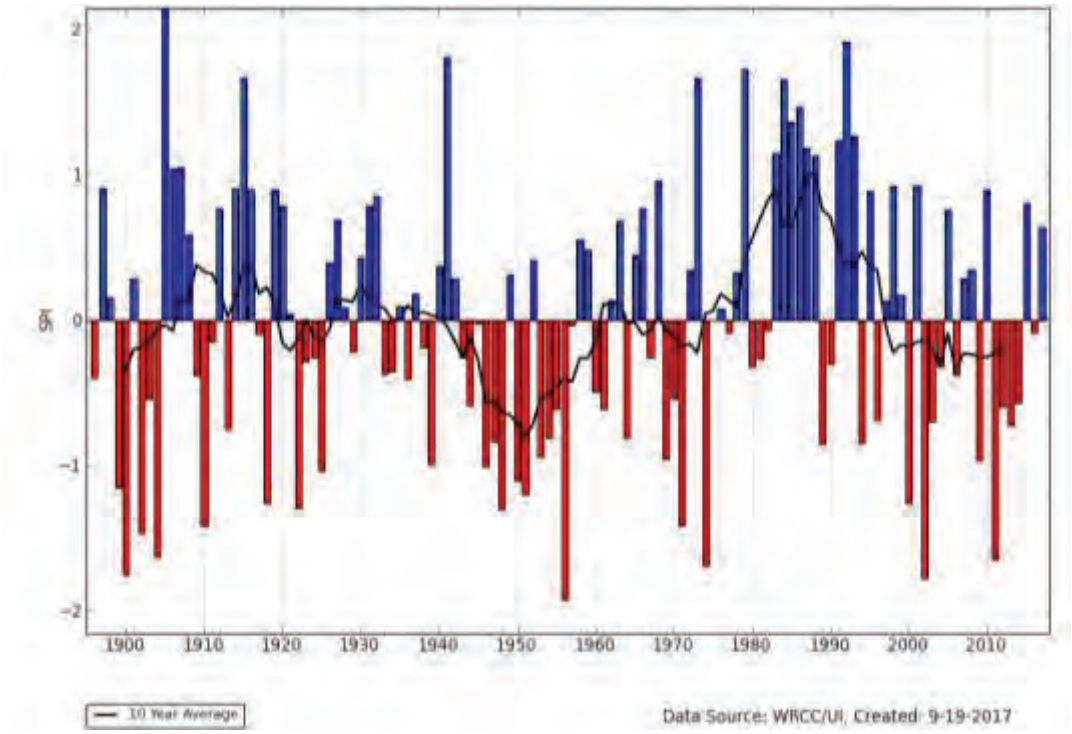


Figure 9. Standardized Precipitation Index for the Upper Gila River Watershed by decade, ending in August; blue bars indicate "above average" rainfall, while the red bars "below average" or "drought" patterns.

Precipitation and drought

Observing the last 100 years of precipitation patterns in the Upper Gila River Watershed, patterns of extended drought or "below average" precipitation (Figure 8) can put stress on both biological communities and the economic reliance on farming and ranching in the region. As shown in Figure 8, the majority of average precipitation (depicted with the yellow line) has fallen below the established "normal" period set defined between 1981 and 2010 (depicted with the black line). Climate Assessment for the Southwest (CLIMAS) predicts an overall drier and warmer future, which requires decision making at local, national, and global levels (Trenberth et al 2013). Southeastern Arizona is predicted to receive less precipitation in fewer, more extreme events in the future as the overall precipitation average continues to decrease in this region (Figure 9). The degree of wet and dry years contributes to a high degree of uncertainty and affects how communities, watershed practitioners, agriculturists, and others can plan for extreme events.

A 30-year record of annual rainfall measurements from precipitation stations were averaged and spatially-extrapolated by the PRISM Climate Group at Oregon State University to create a precipitation map (Figure 10). More precipitation falls at higher elevation in the 'sky island' region of Southeastern Arizona, creating wetter and more vegetated ecosystems separated by desert 'seas'. The regional topography of these isolated mountain systems, known more generally as the Basin and Range Province, include deep sediment-filled valleys between mountain ranges. The mountains in Southeast Arizona receive precipitation flows via regional flow paths to recharge groundwater in the basin sediment.

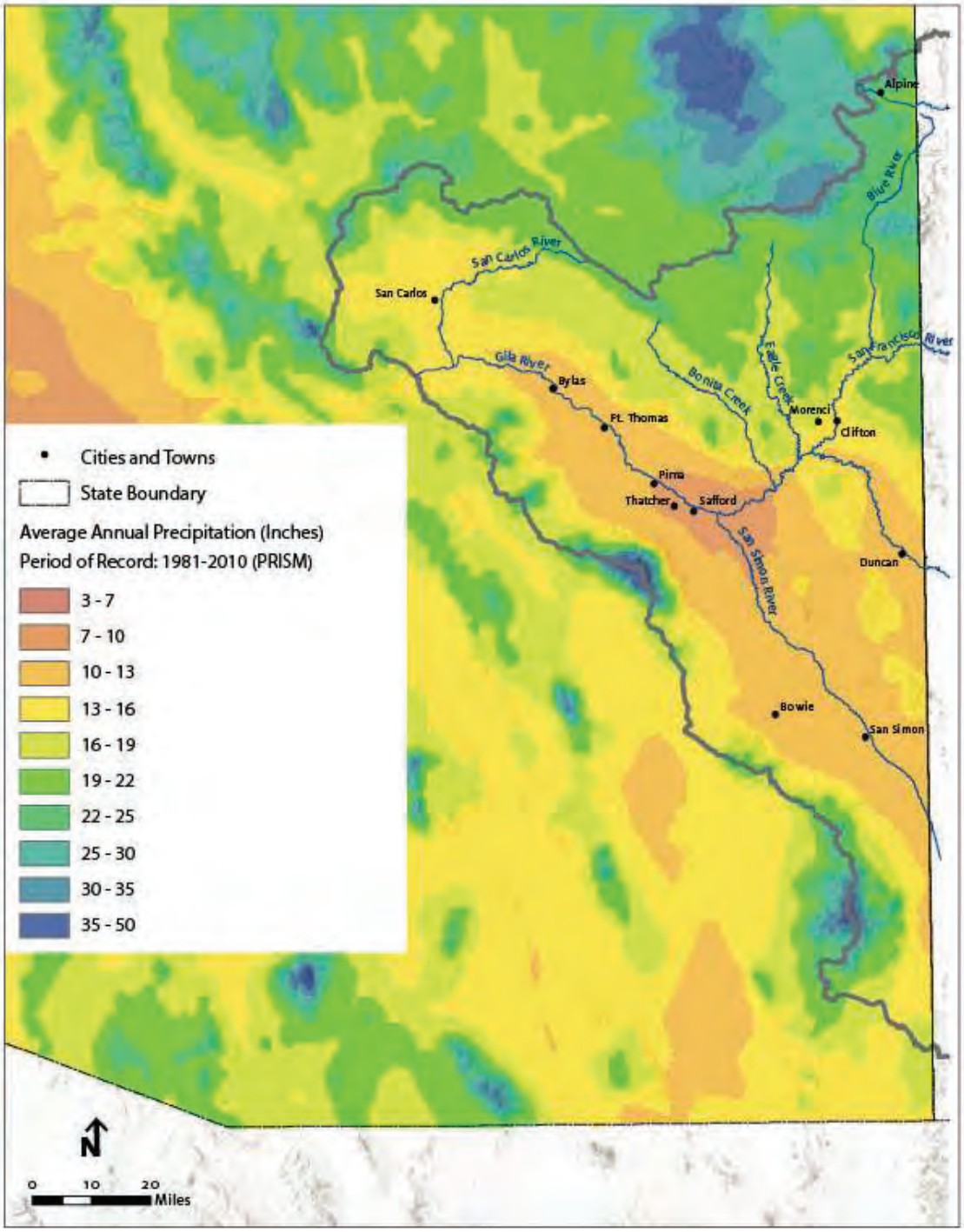


Figure 10. Regional map of average annual precipitation between 1981 and 2010 (PRISM 2017).

Lower elevation areas in the Upper Gila River Watershed, such as the Safford Valley and the San Simon Valley, receive the least rainfall, generally between 8 and 10 inches. The highest peaks in the Pinaleño and Chiricahua mountains receive more than 40 inches.

Recent fires (in the Chiricahuas, on Mount Graham, the Wallow, and Whitewater-Baldy Complex Fire), particularly those with high burn severity, will impact soils and may result in less infiltration of precipitation. This would increase surface flow and decrease the amount of mountain front recharge. The recent history and effects of wildfire in the Upper Gila River Watershed are described in the following section.

Global climate models predict the region will receive precipitation in fewer, larger events. Winter precipitation tends to arrive in blankets of clouds lingering over states for days, delivering moisture in drizzles. This gentle rain is more likely than the pounding summer storms to soak into the ground. As a result, winter precipitation tends to influence regional water supplies more than summer rains.

Winter precipitation also plays an important role in forest health. The growth rings of high-elevation southwestern trees typically reflect cool-season precipitation, with more growth occurring in years of abundant snow and rain. Because of this, researchers can use tree rings to reconstruct winter precipitation patterns far beyond the instrumental record, which goes back only about 100 years in the West. Winter and spring precipitation also exerts a large influence on when the wildfire season starts and whether grasslands or forests are more susceptible to ignition. A lack of cool-season precipitation can make forests more vulnerable to wildfires. Meanwhile, wet winters actually can spur fires in grasslands made lush by cool rains and then cured into kindling during a subsequent dry heat.

The monsoon season arrives in the summer, often around mid- to late June. Roughly half of the annual rainfall comes during the summer monsoon in southern Arizona and New Mexico. Monsoon rainfall events tend to be short and spotty, with intense, local storms drenching some areas and neighborhoods but not others. The water from these storms quickly flows off the landscape into streets and rivers, with most remnant moisture soon evaporating in the summer sun. In recent decades, the observed trend has leaned toward more extreme weather events that can damage property and lives. During the “wet period” of the 1980s and early 1990s, a series of floods caused tremendous amounts of damage to infrastructure in the valley.

Wildfire

The accumulation of combustible materials, such as leaf litter and dead vegetation following a major disturbance such as disease or insect infestation, combined with low water levels and hot, dry conditions can result in substantial fires. While vegetation removal can lead to temporarily increased surface flows due to less transpiration, evaporation rates can increase from the loss of shade-cover. New plants, sometimes not the same species as those removed by the fire, will establish as part of the post-fire recovery process. A fire-denuded riparian buffer is also typically subject to greater erosion.

Fire risk can be exacerbated by the interplay of other drivers in the watershed. Extended drought will result in critical water stress on plants, leading to large areas of dead or dying vegetation. Land management practices, such as forest thinning, can lessen the risk of large fires. Such efforts are particularly resource- and time-intensive, however, and these efforts are

complicated by a patchwork of public and private land ownership as well as the often-challenging terrain in the watershed.

There have been five significant fires within the Upper Gila River Watershed since 2001: the Nuttall Complex, Horseshoe I, Horseshoe II, Wallow, and the Whitewater-Baldy Complex (Figure 11). These fires occurred where fuel was available at higher elevations within the watershed, and therefore near the watershed boundary. Of these, only the smaller Horseshoe I and the Whitewater- Baldy Complex were entirely contained within the Upper Gila River Watershed. The statistics shown in Figure 11 represent the severity of the burn area in the Upper Gila River Watershed only. Other than the Horseshoe I fire, which was almost entirely a low-severity fire, the four other major fires had severe burn intensities in 9–13% of their area in the Upper Gila River Watershed. The 2012 Whitewater-Baldy Complex fire burned over 292,000 acres in the San Francisco River watershed and was the largest wildfire recorded in New Mexico. Both the Wallow Fire and the Horseshoe II fire occurred in 2011, and were two of the five largest fires in Arizona history. The Wallow fire was the largest fire on record in Arizona (Meyer 2011), burning over 500,000 acres, 156,678 acres of which were in the Blue River watershed (Banister et al. 2014). The Wallow Fire dramatically increased stream discharge relative to rainfall (Wagenbrenner 2013) and also increased bedload supply to channels (Wagenbrenner and Robichaud 2014). Approximately 196 miles of perennial streams in the San Francisco and Blue River watersheds and 38 miles of perennial stream in the Gila River watershed were impacted by the Wallow Fire (Meyer 2011). The Wallow fire resulted in widespread fish mortality (AGFD 2012a), likely due to contamination of the water by ash. The high sediment supply from post-fire erosion degrades stream habitat by filling pools and simplifying and aggrading the stream bed.

Wildfire is an increasingly common disturbance in western river corridors owing, in part, to infestation by tamarisk. For example, two fires burned the Gila River floodplain in the Lower Safford Valley in 2013: the Clay Fire near Ft. Thomas and the Bee Town fire near Bylas. The Bee Town fire burned 1200 acres. A third fire burned about 230 acres in March 2018 near two GWP restoration sites near Ft. Thomas.



Comparison of the effects of the 2018 fire in areas dominated by native vegetation (left) and areas dominated by tamarisk (right). *Photo credit: Daniel Bove*

Riparian areas are considered to be barriers to wildfire spread due to the typical dominance by fire-resistant native vegetation with relatively high moisture content (e.g., willows and cottonwoods), but the replacement of the fire-resistant native vegetation by the more flammable tamarisk has reversed this relationship, with tamarisk-dominated areas burning approximately 10 times more frequently than native-dominated counterparts (Busch 1995). A site visit after the 2018 fire revealed that areas where tamarisk had been cleared or native

vegetation dominated the fire burned with a lower intensity than in reaches dominated by tamarisk (see photos above, D. Bove, personal communication). Defoliation by the leaf beetle would appear to exacerbate this situation, but studies in Nevada show that tamarisk is highly flammable regardless of whether it is “browned-out” by defoliation or in a “healthy green” state (Dudley and Brooks 2011). Escaped fire from land-clearing on adjacent agricultural areas has become a serious concern for land managers in the Lower Safford Valley, particularly where weedy forbs next to fields carry fire into the arid, tamarisk-dominated riparian edges, and then into the mixed native/tamarisk vegetation along the river. This establishes a feedback loop in which fire promotes tamarisk, which recovers readily from burning by resprouting to become even more abundant, eventually displacing native elements in the stand. Biocontrol by the tamarisk beetle eventually reduces tamarisk volume, and after 3+ years of repeat defoliation can lead to mortality (Bean et al. 2013), thereby gradually reducing fire risk over the long term, although active restoration efforts are needed to speed up the process of reducing riparian fire risk in critical areas.

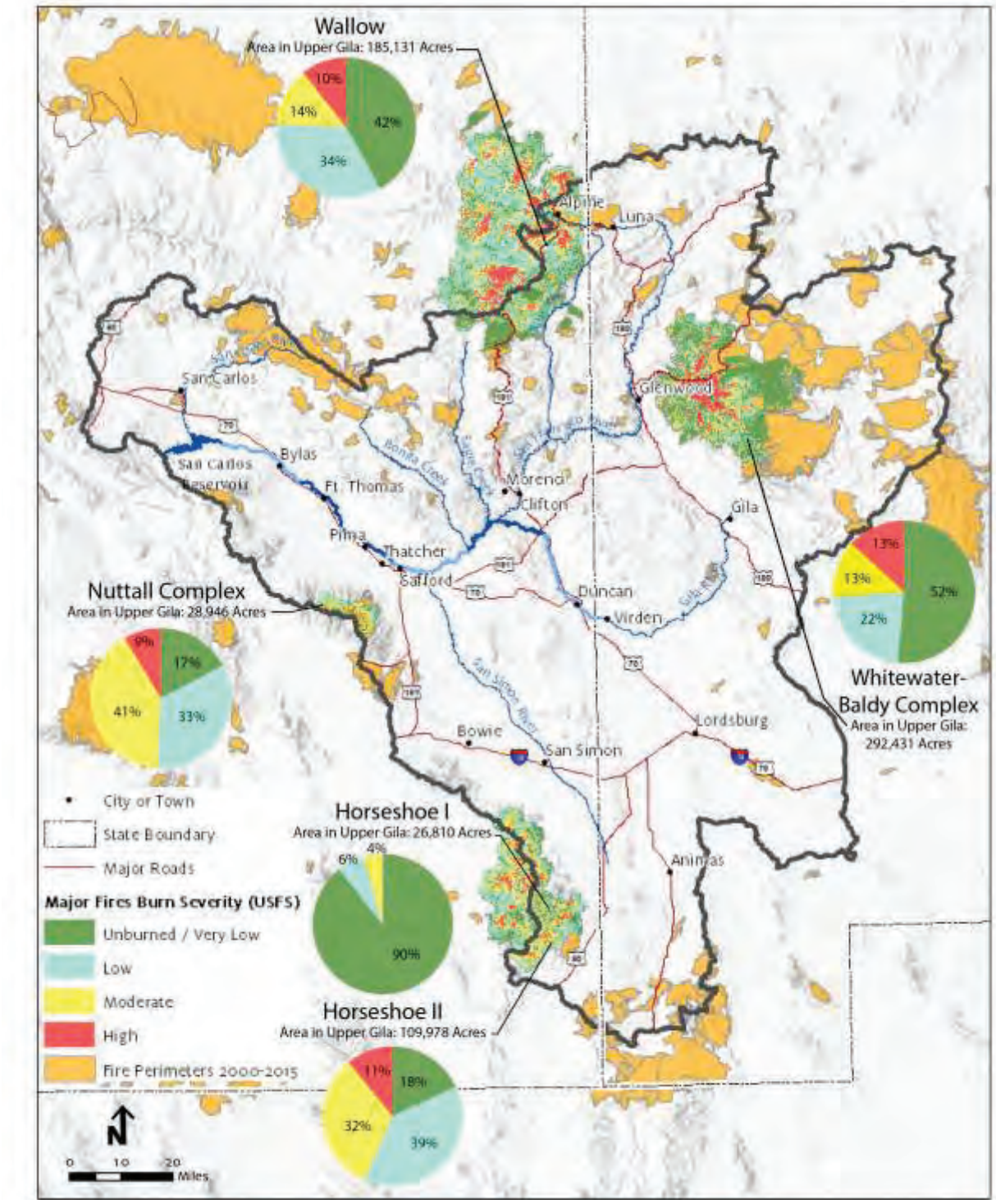


Figure 11. Significant fires in the Upper Gila River Watershed in both Arizona and New Mexico portions of the watershed (2000–2015).

In sum, the primary concern of water and land managers related to the fire regime within the Gila River Watershed concerns actions that might change a historic trend of fast-moving, high-intensity fires. Primary considerations include:

a. Fuel loading caused by tamarisk and how much of this fuel is present (measured in tons per acre)
b. Availability of this fuel to burn, based on time of year, time of day, and atmospheric conditions (directly affecting fuel moisture content and fuel temperature).
c. Vertical arrangement of fuel, which allows fires to get from the surface to the canopy causing dependent crown fires
d. Uniformity across the landscape, which allows fires to continue to burn with no breaks.

Working with partners, the emphasis must revolve around answering the question: What does it mean to change the way that fires respond to environmental factors and human intervention? How do we accomplish changing the fire regime in a patchwork of land ownerships and in the face of the challenges listed above?

GEOLOGY, HYDROLOGY, & GEOMORPHOLOGY

Watershed management is most effective when it considers the physical characteristics of the watershed. Below we describe the geology, hydrology, and geomorphology of the Upper Gila River Watershed.

KEY TAKEAWAYS

- The Gila River and its tributaries are subjected to very large floods that reset the morphology of the channel and floodplain. The width of the river expanded dramatically in 1915 and again in 1983 after large floods.
- Tamarisk has likely constrained the channel and floodplain in the mainstem Gila River since the early 20th century.
- Levees in the Safford and Duncan valleys constrain the flooded width and may exacerbate erosion and deposition during large floods.
- Channel incision and wildfire supply very high sediment loads to the Gila River and its tributaries, but the effects of the supply on the morphology of the river channel and floodplain have not been systematically evaluated.
- Removal of tamarisk either as part of stream restoration or due to the arrival of the tamarisk beetle is likely to lead to increased bank mobility and lateral channel erosion, primarily during smaller floods.
- There are many erosion control structures in the tributaries to the Gila River that have exceeded their design life and are failing, potentially increasing the supply to downstream reaches as eroded sediment from the retention basins is added to other sediment from the uplands. These retention basins could cause particular problems during large floods.
- Large sediment sources to the Gila River likely include the Blue River, San Simon River, and other smaller tributaries where the valleys are filled with thick deposits of relatively recent river and lake sediments.
- The effects of sediment supply on the mainstem Gila River have not been thoroughly investigated.

Geology

With the exception of the San Francisco River watershed, the Upper Gila River watershed is primarily located in the Mexican Highland section of the Basin and Range Province; a geographic region with a unique topography created by a period of tectonic extension (stretching) during the Miocene Epoch (17 million years ago). This region is generally characterized by a series of roughly parallel mountain ranges that trend northeast-southwest and are separated by broad flat valleys (Nations and Stump 1996). The San Francisco River watershed primarily lies within the Central Highlands Transition Zone between the Basin and Range Province and the Colorado Plateau.

The Gila River originates in the Mogollon Mountains of New Mexico. The mountain ranges bordering the valleys are made of consolidated volcanic, metamorphic, and sedimentary rocks (Figure 12). The Gila, Peloncillo and Chiricahua Mountains are made of rocks from mostly volcanic origin. The Piñaleno Mountains, to the south of the Safford Valley, are formed by Precambrian metamorphic rocks, while the Santa Teresa Mountains are comprised of granitic rocks. The uplands of the Duncan Valley are primarily comprised of Tertiary conglomerates and sandstones. The upper portions of the San Carlos River Watershed are comprised of Proterozoic granitic and sedimentary rocks.

Several drainages (e.g., the lower San Carlos River, San Simon River, Goodwin Wash, Tripp Wash, and Underwood Wash) are composed of Quaternary lake and river sediments (sand and gravel). These drainages are often lined by river terraces and are often large sediment sources.

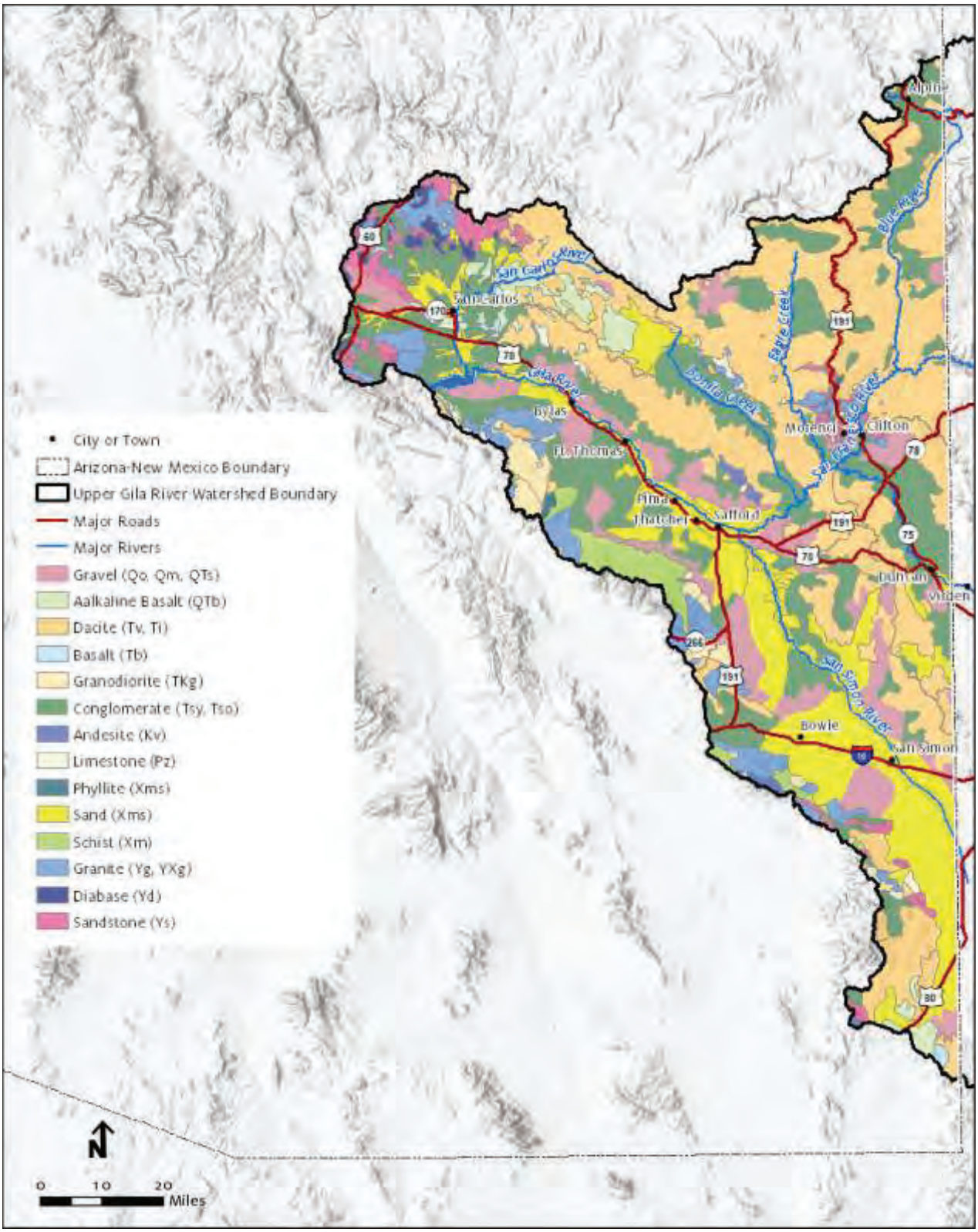


Figure 12. Geology of the Upper Gila River Watershed. Source: Atlas of the Upper Gila River Watershed (Banister et al. 2014).

Hydrology

The Upper Gila River Watershed experiences a warm, high desert climate with air temperatures varying seasonally. The average monthly maximum temperature occurs in June (99 °F) and minimum temperature occurs in December (29 °F), as recorded at the Safford Agricultural Center from 1981–2010 (NCDC 2013). Annual precipitation is generally bi-seasonal, with cold, winter frontal storms arriving between December through March and tropical monsoons arriving in July through October. The wettest month is typically August (1.9 inches) while the driest month is May (0.25 inches), based on rainfall measurements in Safford from 1981–2010 (NCDC 2013).

The arid climate in eastern Arizona is interrupted by periods of intense winter and late-summer storms that often flood the rivers and streams. Streamflow data from seven long-term gaging stations along the mainstem upper Gila River, San Francisco River, Blue River, and San Simon River were obtained from the USGS's National Water Information System website: http://waterdata.usgs.gov/nwis. These spatially distributed stations provide a reliable characterization of the average daily river flows in the watershed, as well as the episodic hydrologic regime responsible for driving the flood-scour processes and geomorphic expression. Basic information for the gages is summarized in Table 3.

Table 3 also shows the normalized mean discharge (the mean daily discharge divided by the drainage area). The normalized mean discharge is a useful metric for comparing the mean stream flows among gages with differing drainage areas. There are many differences between the gages, with normalized discharge in the Gila River generally decreasing downstream due to losses from diversions and groundwater. The mean discharge in the mainstem Gila River does increase downstream of the junctions with the San Francisco River, Eagle Creek, and Bonita Creek (the Gila River near Clifton gage is upstream of the San Francisco River junction). The San Francisco River watershed, and in particular the Blue River gage, has a higher mean discharge than all of the Gila gages reported here, reflecting the high elevation of the San Francisco basin, relative to the average elevation of the Gila River watershed. The mean normalized discharge at the San Simon gage is about 10% of the normalized discharge of the Gila River at the head of Safford Valley (USGS Gage 099448500). This reflects the lower elevation and hence much lower precipitation in the San Simon watershed.

Table 3. USGS discharge gaging stations in the Upper Gila River Watershed.

USGS gaging station [a] [upstream to downstream]	Total period of record in water years [b, c]	Drainage Area (mi^2)	Maximum peak discharge (cfs)	Mean daily discharge (cfs)	Mean daily discharge (inch/year)[d]	Reach/ Sub-basin
09432000 Gila River below Blue Creek, near Virden, NM	1927–2013	3,203	52,700 [Dec 19,1978]	210	0.89	Gila River upstream of the AZ/NM border
09442000 Gila River near Clifton, AZ	1911–1917, 1928–1946, 1948–2013	4,010	57,000 [Dec 19, 1978]	194	0.66	Gila Box
09444200 Blue River Near Clifton, AZ	1967 - 1980, 1998 - 2018	506	30,000 [Oct 20, 1972]	60	1.61	Blue River
09444500 San Francisco River at Clifton, AZ	1891, 1905–1907, 1911–2013	2,763	90,900 [Oct 2, 1983]	215	1.06	San Francisco River
09447800 Bonita Creek near Morenci	1981-2018	302	19,500 [Oct 2, 1983]	7.3	0.33	Bonita Creek
099448500 Gila River at head of Safford Valley, near Solomon, AZ	1914–2013	7,896	132,000 [Oct 2, 1983]	453	0.78	Gila Upper Safford Valley
09457000 San Simon Near Solomon, AZ	1931-1932, 1935-1982	2,192	27,500 [Aug 9, 1931]	13	0.08	San Simon River
09466500 Gila River at Calva, AZ	1916, 1930–2013	11,470	150,000 [Oct 3, 1983]	363	0.43	Gila River Bylas Reach
09468500 San Carlos River Near Peridot, AZ	1914-present	1,026	54,800 [Jan 8, 1993]	56	0.74	San Carlos River

[a] Weblinks to source data:
[1] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09432000
[2] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09442000
[3] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09444200
[4] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09444500
[5] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09448500
[6] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09447800
[7] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09466500
[8] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09457000
[9] http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=09468500

[b] Water year (WY) is the 12-month period from October 1 through September 30.

[c] Period of records utilized in the flood-frequency and daily-duration analyses slightly differ from the total period of record due to data gaps and/or unreliable historical data:

[1] Flood-frequency analysis: Virden=WY 1927–2013; Clifton=WY 1911–1917, 1928–1946, 1948–2013; SF at Clifton=WY 1911–2013; Solomon=1914–2013; and Calva=1930–2013.

[2] Daily-duration analysis: Virden=July 1, 1927–Sept 30, 2013; Clifton=Nov 1, 1910–Sept 30, 2013; SF at Clifton=Oct 23, 1910–Sept 30, 2013-09-30; Solomon=Oct 1, 1920–Sept 30, 2013; and Calva=Oct 1, 1929–Sept 30, 2013.

[d] Calculated as mean annual discharge divided by the drainage area.

The mainstem Gila River has flashy peak flows that dwarf the mean daily flows (e.g., 132,000 cfs peak flow versus 453 cfs mean daily flow in the Safford Valley) but usually span only a few hours to days. The 10 largest floods recorded to date in the valley occurred in water years (WY) 1915, 1916, 1917, 1973, 1979, 1984, 1985, 1993, 1995, and 2005, based on gage data from the Solomon and Calva stations (Figure 13). These records highlight the flood period initially observed in the early 20th century, a relatively quiescent 50-year period up through the mid-1960s, and a 40-year period of larger, more frequent flood events since the late 1960s.

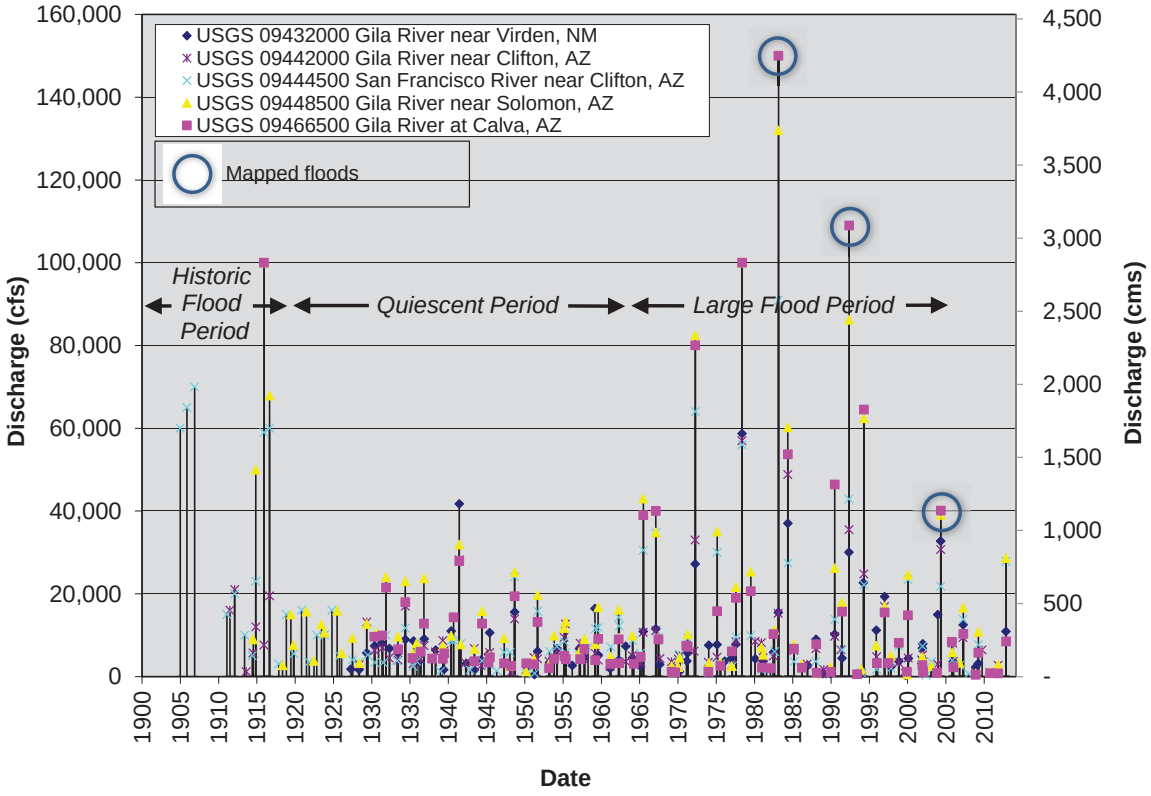


Figure 13. Historical flood peaks through water year 2013 at five long-term streamflow gages on the mainstem upper Gila River and lower San Francisco River. Flood-scour mapping by Orr et al. (2014) focused on three of the most recent large flood peaks, as indicated with blue circles.

While the data shown in Figure 13 suggest that the recent large-flood period has been waning since the 1990s, it should be cautioned that the potential for channel-scouring floods to occur in the near-future remains high.

In summary, the upper Gila River naturally experiences a wide variation of flows, punctuated episodically by short-duration but intensive high-flow events. These flashy discharge dynamics, which are common to large, dryland riverine systems, periodically result in dramatic geomorphic change (Graf 1978). The hydrology of the Gila River is likely to adjust due to climate change. And while climate models predict less total precipitation for the southwest region, increased frequency of intense storms and more precipitation falling as rain versus snow are expected to make southwest rivers more susceptible to flooding (USGCRP 2009). Thus, any restoration planning effort on the upper Gila River demands consideration of flood dynamics to best ensure long-term success.

Groundwater

Understanding basin-wide groundwater trends requires a general knowledge of the morphology of the basin as well as an understanding of the subsurface geology that underlies the aquifer units. The Upper Gila River Watershed is composed of five groundwater basins; Bonita Creek, Morenci, Duncan Valley, San Simon, and Safford. The Bonita Creek groundwater basin is entirely contained within the Upper Gila River Watershed and drains to Bonita Creek. The Bonita Creek aquifers include recent stream alluvium, basin fill, and volcanic bedrock (ADWR 2009) Aquifers in the Morenci groundwater basin consist of recent stream alluvium and volcanic rocks. The Morenci groundwater basin contains the drainage area of Eagle Creek, Blue River, and the San Francisco River. The Duncan Valley groundwater basin follows the Gila River from the New Mexico Border to just upstream of the confluence with the San Francisco River. The primary groundwater source in the Duncan Valley groundwater basin is recent stream alluvium, and additional groundwater is stored in Gila Formation sedimentary rocks (ADWR 2009). Groundwater elevations at two example wells evaluated by ADWR in the Duncan Valley were quasi-steady since 1975 (ADWR 2009). The Morenci and Duncan Valley groundwater basins are bounded by the New Mexico border, though the physical boundary contributing to the headwaters of these watersheds extends into New Mexico. The Safford groundwater basin is comprised of three smaller sub-basins: the San Simon sub-basin, Gila Valley sub-basin, and the San Carlos sub-basin.

Groundwater in the San Simon Valley has been primarily pumped from a deep confined aquifer, rather than the shallow aquifer that occurs there. The two aquifers are separated by a relatively impermeable Blue Clay layer (aquitard) whose depth varies across the basin. Groundwater pumping in the San Simon watershed increased from 1951-1983, then experienced a sharp decline as demand decreased, and the groundwater level has been declining at an average rate of 1.7 ft/yr from 2007 to 2015 (ADWR 2015). The principle aquifer for the San Carlos and Safford sub-basins is the younger basin fill (ADWR 2009).

The Groundwater conditions map (Figure 14) shows water levels of 309 shallow groundwater wells. Depth to water and well elevation were measured initially between 1987 and 1992, and then again in 2007 during the winter and early spring (December through March) for all measurements. The initial (1987–1992) water level was subtracted from the newer (2007) water level to calculate the change at each well. Positive change values indicate a rise in groundwater level, and negative values indicated a drop in water level. The overall range of the

water level change is -91.2 to +76.8 feet, which indicates localized withdrawal and recharge effects. During this period, groundwater elevations decreased the most along the San Simon River, just south of Interstate Highway 10, which is surprising given that the lower aquifer is the primary groundwater source (ADWR 2015). Groundwater elevations increased the most in wells north of the confluence of the Gila and the San Simon rivers.

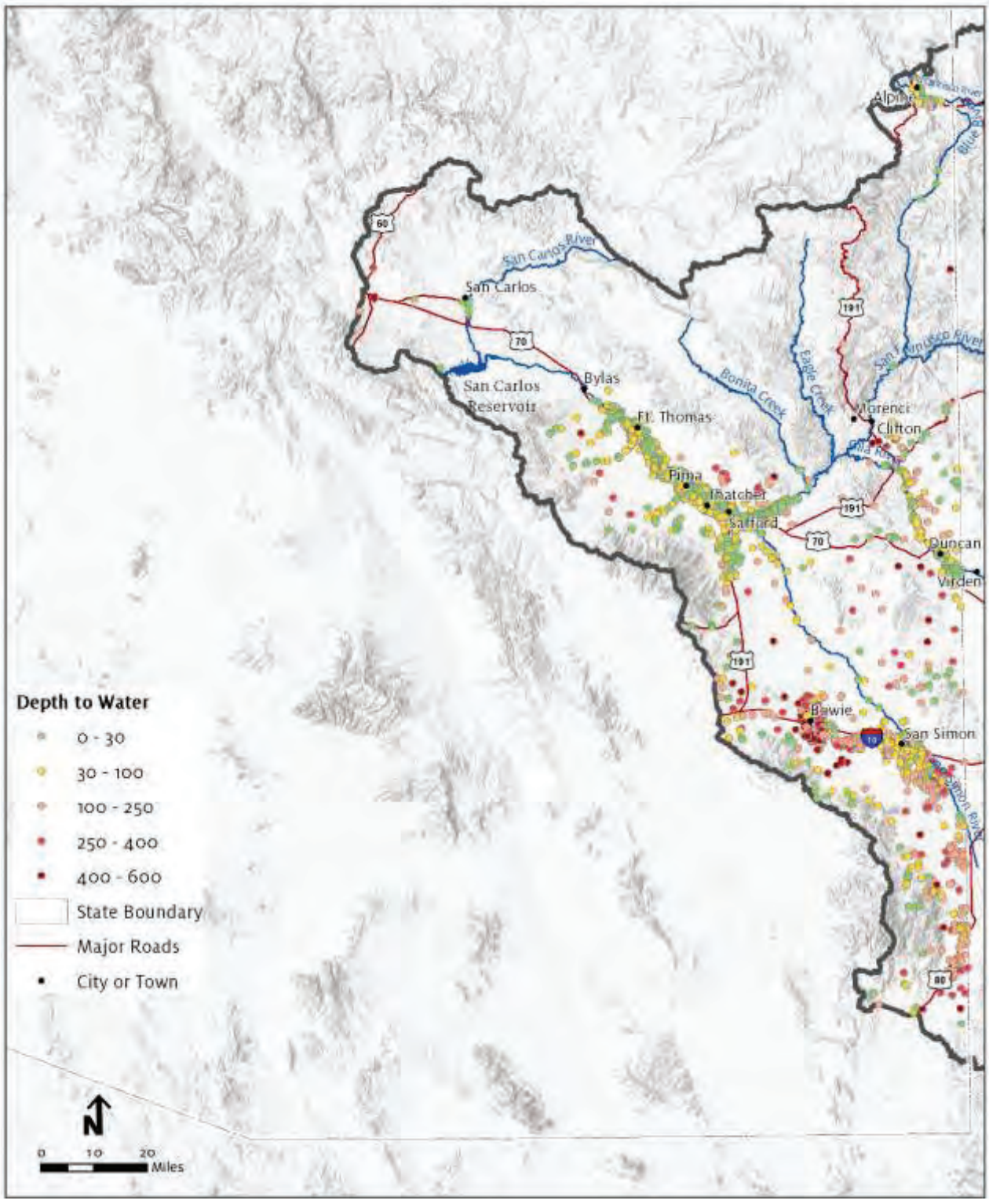


Figure 14. Groundwater level change between initial measurements in 1987–1992 and 2007. Source: Atlas of the Upper Gila River Watershed (Banister et al. 2014).

Geomorphology

The Upper Gila River

The upper Gila River between San Carlos Reservoir and the Arizona-New Mexico Border alternates between a multi-thread morphology (often single-threaded at low flow) with a wide floodplain confined by levees in the Safford and Duncan valleys, to a single-thread channel in a valley confined between high bedrock cliffs in the Gila Box. The slope is typically about 0.002 (0.2%) and relatively uniform. The bed is predominantly sand with lesser amounts of gravel, although the grain size distribution of the bed has not been systematically explored. The river has been altered by encroachment of tamarisk on the floodplain, which began in the early 20th century (Burkham 1972). A series of diversion dams in the Safford Valley divert water and trap sediment in the reaches immediately upstream of the diversion, leading to local aggradation and in places, long-term sediment management operations. Tributaries with high sediment loads tend to be those with easily erodible soils (Figure 15) (i.e., San Simon watershed, Blue River watershed, Rainville Wash, and the North Slope of Mt. Graham), rather than the steepest watersheds, which tend to have greater rock strength.

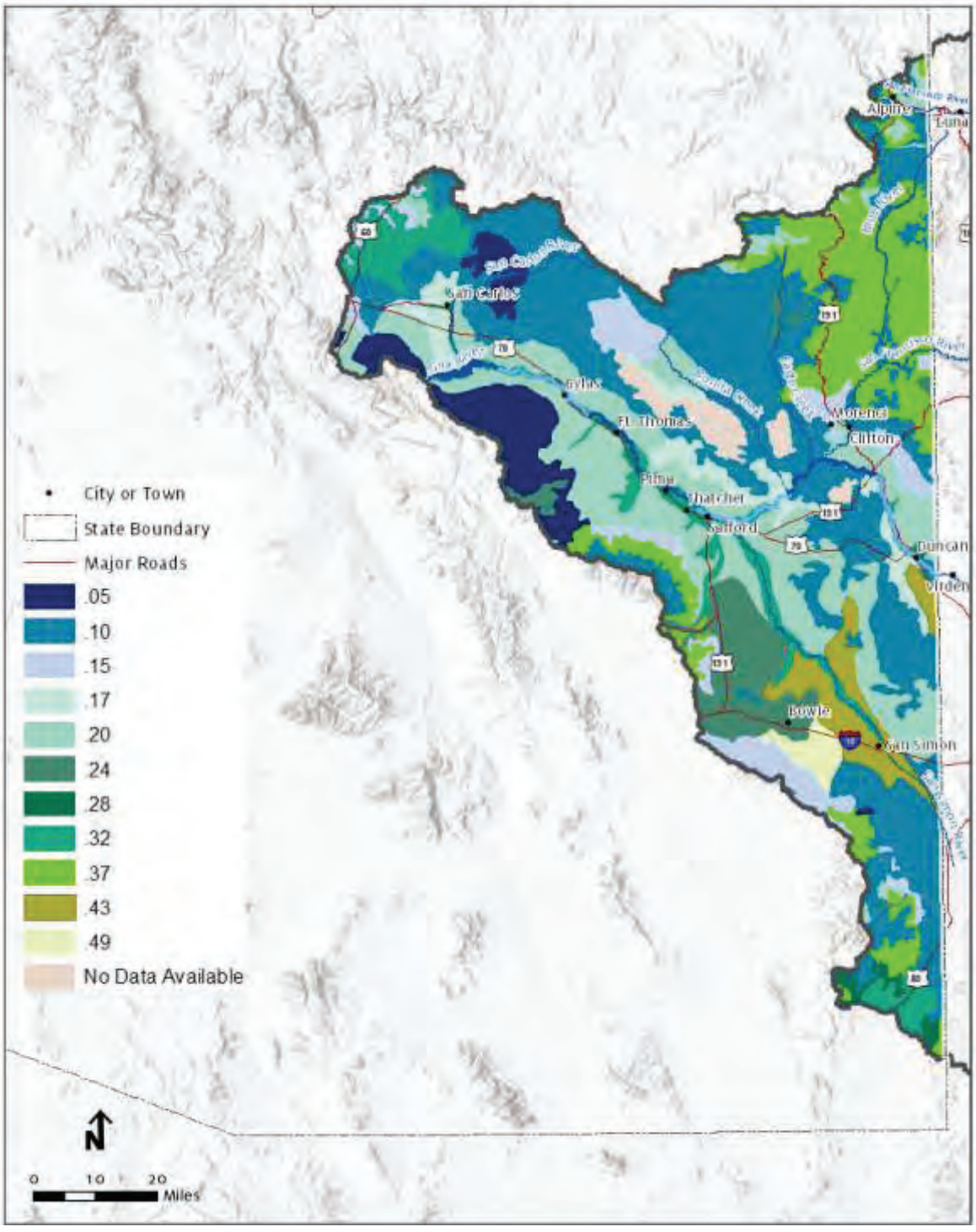


Figure 15. Soil erodibility (NRCS 2011).

Downstream of Pima, the valley narrows somewhat and the channel transitions to a wetter, fine-grained, braided/ meandering channel system composed of a narrow single-thread channel during lower flows that is encroached upon by dense riparian vegetation (mostly tamarisk), which is in turn bordered by a broad, cultivated floodplain with few developments. During high-

flow events, side-channels also convey flow giving a more pronounced braided appearance to the river corridor. The entire corridor and some portion of its floodplain become inundated during the largest floods.

The natural flow and sediment-transport regime in the Safford Valley is altered by the presence of in-channel irrigation diversions, bridge crossings, and agricultural levees. A total of six irrigation canal diversion dams span at least part of the river corridor downstream of the Gila Box (listed from upstream to downstream): the Brown, San Jose, Graham, Smithville, Curtis, and Ft. Thomas diversion dams. The BOR (2004) mapped numerous occurrences of historical and existing levees and pilot channels, all of which appear to have been constructed in response to flooding, many of which are poorly managed and failing. Sediments accumulate upstream of the diversion structures, and some have historically been dredged (BOR 2004) to maintain functionality of the structures. The amount of sediment removed from the structures is not known, and the effect of the structures on sediment supply to downstream reaches has not been investigated.

The Gila River is subjected to large flood-scouring flows (Orr et al. 2014, BOR 2004), which tend to fill the entire valley and scour much of the floodplain. During these events, the low-flow channel position can change rapidly as the main thread of the channel migrates and switches position While the low flow channel boundary shifts during these floods, the boundary of the broader active-valley area changes less frequently. The flood-scour width is generally greater above Pima, and lower below. Levees likely exacerbate lateral erosion and land loss outside of the channel corridor (BOR 2004). Comparison of early maps and aerial photographs suggest that the channel widened significantly following the 1905 flood and that width has been subsequently maintained, and that many of the tributaries began incising while the Gila River widened, but the causal mechanism is unknown (Burkham 1972). It is possible that historical grazing destabilized the mainstem Gila and its tributaries and increased the sediment load.

Dense stands of tamarisk along the mainstem Gila River provide greater stability to the river and floodplain substrates than do native vegetation (e.g., willows and cottonwoods) and, as an unintended consequence, progressively narrow the active channel thereby increasing the frequency of floodplain inundation (Graf 1978). Bank erosion may increase following the removal of tamarisk either as part of stream restoration or due to the arrival of the tamarisk beetle.

Orr et al. (2014) identified a “Flood Reset Zone” downstream of the Gila Box as a flood risk assessment tool to inform restoration area prioritization and strategy selection (i.e., passive versus active revegetation) as part of the ecohydrological assessment. This zone includes areas having both 100% flood-scour frequency (i.e., scoured in 3 out of the 3 mapped events [1983, 1993, and 2005]) *and* “high” flood-disturbance activity—areas severely disturbed by flow, typically scoured to bare substrate retaining <10% apparent riparian vegetative cover—during the most recent flood of 2005. The size of the Flood Reset Zone progressively decreases in the downstream direction in the Safford Valley. The mapped flood reset accounts for over 80% of the riparian corridor near the upstream end of the Valley and only about 20% near the

downstream end. The BOR (2004) documented widespread levee failure throughout the reach during these large floods, due to lateral erosion enhanced by overly confining flow with levees. The morphology of reaches of the Upper Gila River from upstream to downstream is described below, followed by the major tributaries.

Gila River upstream of the New Mexico State Line

Although it is outside of the plan area, the Gila River upstream of the New Mexico border acts as a source of water and sediment to the Gila River in Arizona and stressors upstream of the New Mexico border are among the important considerations for conservation and management of the Gila River in the plan area. The Gila River in New Mexico is mostly confined by bedrock on both banks, with some wider valleys (i.e., near Gila, NM). The lowermost seven miles of this reach is part of the Duncan Valley, but is outside of the plan area. The Upper Gila Total Maximum Daily Load (TMDL) (ADEQ 2011) identified the reach of the Gila from the Arizona border downstream to Bitter Creek as impaired for sediment. This impairment was for low flows only (when sediment transport is comparatively small) but suggests that sediment supply could be high from the Gila River upstream of the New Mexico border. Extensive sparsely vegetated desert areas coupled with easily erodible soils lead to relatively high background levels of sediment loading (ADEQ 2011). A water diversion project, to divert water from the Gila and San Francisco rivers in New Mexico, is proposed as part of the Arizona Water Settlements Act. The proposed project involves water diversions and groundwater wells on the Gila River near Cliff, New Mexico and water storage ponds near Virden, New Mexico at the upstream end of the Duncan Valley. Three diversion structures and a reservoir are proposed on the San Francisco River between Pleasanton, New Mexico (~11 miles upstream of the Arizona-New Mexico Border) upstream to about 0.4 miles upstream of the confluence with Pueblo Creek (~26 miles upstream of the border). The project is currently under deliberation and may affect hydrology and channel morphology downstream of the diversion depending on the design and implementation.

Duncan Valley Reach (New Mexico Border to Highway 191)

The Duncan Valley Reach extends downstream about 18 miles from the New Mexico Border to Highway 191. The upper 6 miles of the reach flows through the Duncan Valley. The Duncan Valley ranges from 3,600–4,000 feet wide and is dominated by agriculture on the floodplain and is morphologically similar to the Safford Valley. The slope in this reach is approximately 0.002 (0.2%). Confined reaches (~ 500 ft valley width) are interspersed with wider valleys up to 2000 ft wide (e.g., the York Valley) in the lower 18 miles of the reach.

Brandau et al. (2013) identified the Rainville/Railroad Wash as a large potential source of sediment to the Gila River in the Duncan Valley. Rainville Wash enters the Gila River immediately upstream of Duncan. The surficial geology of the watershed is dominated by Quaternary terraces and fans deposited over former lakebed sediments (Brandau et al. 2013). This geologic type often has very high soil erodibility and high sediment loads in the Upper Gila Watershed. The channels are highly incised and 32 sediment retention structures in the tributaries are designed to trap sediment from channel incision (Brandau et al. 2013). The

contribution of sediment from Rainville Wash to the upper Gila has not been quantified. Brandau et al. (2013) identified several other retention basins in tributaries draining to the Duncan Valley. These structures are in various states of disrepair and may be acting as a sediment source to the upstream portion of the Duncan Valley. In addition, Goat Camp Canyon has one sediment retention structure that failed in the early 2000s and sediment from the retention basin is moving downstream into the Gila River (Brandau et al. 2013). Levee breaches along the Gila River near Railroad Wash led to extensive property loss between 1978 and 2000 within the former active flood zone (BOR 2004).

Gila Box Reach (Highway 191 to Bonita Creek)

The Gila Box Reach extends from Highway 191 about 33 miles downstream to the confluence with Bonita Creek through the Gila Box National Riparian Conservation Area. Within the Gila Box National Riparian Conservation Area, three major tributaries join the Gila River including the San Francisco River, Eagle Creek, and Bonita Creek. Cliffs composed of the Miocene to Pliocene-age Gila Conglomerate confine the channel and extend up to 1,000 ft above the valley floor. The BLM has conducted two desktop analyses of the Gila Box (Cockman and Sexton 2016, Cockman and Caldwell 2016) and completed several Proper Functioning Condition evaluations in the Gila Box. A recent Properly Functioning Condition report for 3.9 miles of the Gila Box upstream of the confluence of the San Francisco and Gila Rivers (Martin et al. 2017a) noted that while the outside banks were stabilized by vegetation, vegetation could be sparse on bars. In addition, they observed widespread sediment deposition in their 3.9-mile long study reach and that the floodplain had occasional boulders and overflow channels. In the downstream end of the Gila Box, Orr et al. (2014) described the channel as confined and gravel bedded with willow-cottonwood riparian forests.



Downstream views of the Gila River: mouth of Gila Box *(top)*; in the upper Safford Valley *(middle)*; and the lower Safford Valley *(bottom)* (Photos by Stillwater Sciences).

Upper Safford Valley (Bonita Creek to Smithville Diversion Dam)

In the Upper Safford Valley Reach, the Gila River is generally a vegetated, low-gradient (Slope = 0.0018), braided river corridor bordered by a broad floodplain. The character of the channel changes from upstream to downstream in this reach. Downstream of the Gila Box, the valley gradually widens to the San Jose Diversion Dam. Downstream of the San Jose Diversion Dam,

the Gila River is a wide, braided/meandering channel with sparse to moderately dense riparian vegetation (mostly tamarisk) bordered by a broad, cultivated and developed floodplain. The floodplain supports agriculture and some urban developments. The Brown Canal Diversion Dam is 3.5 miles downstream of Bonita Creek, and is currently damaged (L. Opall, personal communication). Disconnected levees along towns and agricultural lands constrain the active floodplain width. The braided corridor generally ranges in width from 1,000 to 4,600 ft.

Lower Safford Valley (Smithville Diversion Dam to San Carlos Apache Reservation boundary)

The Gila River in the lower Safford Valley has valley widths that range from about 900 ft to 4,000 ft. The valley is generally narrower downstream of the town of Ft. Thomas, with narrow points often corresponding to bajadas[1]. For most of the reach length, agriculture occurs on both banks, but is limited to the southwest bank downstream of the town of Ft. Thomas. The river valley is braided, with a single-thread low flow channel confined by tamarisk. In some places the river corridor is confined by levees.

Several tributaries that enter the Gila from the south between Stockton Wash to Goodwin Wash historically have been large sources of sediment. Structures were built in the 1950s in this reach, many of which are currently failing (Brandau et al. 2013). The surficial geology is typical of rapidly eroding areas in the Upper Gila River watershed, with surficial Quaternary sediments including river deposits, former lake sediments, and fluvial terraces. The Sinuosity in this reach is generally 1.1-1.2 (Hooke 2000).

Bylas Reach (San Carlos Apache Reservation boundary to Bone Spring Canyon)

The Bylas Reach is the narrowest reach of the Gila River Valley downstream of the Gila Box. The valley in this reach is typically about 2,500 ft wide. The river in this reach is densely vegetated with tamarisk, with a braided pattern through the valley, although at low flows the channel is confined to a single thread. Levees have not been mapped in this reach, but aerial photographic inspection suggests that they may occur near the town of Bylas.

San Carlos Reservoir Reach (Bone Spring Canyon to Coolidge Dam)

This reach contains San Carlos Reservoir and the backwater reach of the Gila River. The backwater reach has dense tamaraisk stands that line a single-thread channel with a sinuosity of about 1.3. The San Carlos River enters the Gila just upstream of the reservoir within this reach. The valley width ranges from 1,600 ft to 4,800 ft in the backwater reach.

Tributaries

San Francisco River

The San Francisco River is the largest tributary to the upper Gila River, with a drainage area of 2,800 mi^2, and joins the Gila River from the north 2.6 mi upstream of Eagle Creek in the Gila Box National Riparian Area. The watershed contains the San Francisco and Blue Rivers in Arizona and New Mexico. The Blue River watershed is described separately below. The San Francisco

[1] A bajada is an alluvial plain formed at the base of a mountain by the coalescing of several alluvial fans.

River is confined within a bedrock canyon for most of its length, with bedrock hillslopes abutting the channel in several places. Within the canyon, floodplain deposits supporting riparian vegetation occur throughout the river. Riparian areas are dominated by cottonwoods, native willows, sedges and grasses (Gila Watershed Partnership 2012).

Downstream of the confluence with the Blue River, the valley width is 300–600 ft, and generally decreases downstream. The San Francisco River was identified as impaired for suspended sediment in the Gila River TMDL (ADEQ 2011). Similar to the Duncan Valley reach sediment impairment is identified only at low flows, and available information is insufficient to characterize the sediment supply during high flows. The Gila Watershed Partnership has identified vegetation changes associated with grazing in riparian areas, particularly near Clifton, and grazing impacts are a major sediment source in the San Francisco watershed (Gila Watershed Partnership 2012). Other sources of sediment to the channel include recreation, off-road vehicles, and recent fires. Additionally, there is concern about sediment loads associated with lateral erosion of river terraces in the upper San Francisco River (NRCS, no date). The Morenci Mine, a copper mine located upstream of the towns of Clifton and Morenci, is operated under federal and state laws, which require that no water leaves the mine property and include strict measures to control sediment production. There are at least seven dams in the San Francisco River watershed (NRCS, no date) but, to our knowledge, their impact on water and sediment supply have not been quantified.

Martin et al. (2017b) completed a Proper Functioning Condition Study in the downstream-most 6 miles of the San Francisco River. They found that the reach had a slope of 0.004, with an average depth of 3.4 ft and average channel width of 72 ft (Martin et al. 2017b). They also observed that vegetation was absent on some point bars and observed some large wood on the channel banks and floodplain. Mid-channel bars and lateral point bars were observed in this lowest reach of the San Francisco River. They also observed direct effects of off-road vehicle use on the channel banks and floodplain.

Blue River

The Blue River watershed has a drainage area of 618 mi^2 and joins the San Francisco River approximately 18 miles upstream of Clifton. The Blue River drains mountainous terrain and the river valley is confined by bedrock cliffs. The soil characteristics of the Blue River watershed (Figure 15) lead to relatively high sediment loads, much of it from landslides (ADEQ 2011). Sediment loads were also very high following the Wallow Fire (Gila Watershed Partnership 2012).

Eagle Creek

Eagle Creek is a perennial stream that joins the Gila River 9.4 miles upstream of Bonita Creek in the Gila Box National Riparian Area. Eagle Creek has a drainage area of 654 mi^2 and primarily drains Miocene-Oligocene volcanic rocks. The sinuous creek is confined by bedrock and has a valley width of 350–500 ft. The Morenci Mine is along the eastern end of the drainage between Eagle Creek and the San Francisco River. Eagle Creek has not been identified as a significant

sediment source to the Gila River. Since 1944 water has been diverted from the Black River (a Tributary to the Salt River) to Eagle Creek for use by the Morenci Mine.

Bonita Creek

Bonita Creek joins the Gila River from the north near the downstream end of the Gila Box. Bonita Creek is a perennial river with a drainage area of 312 mi^2 (808 km^2). Bonita Creek drains primarily resistant Miocene Conglomerate and Miocene-Oligocene Volcanic Rocks. The Bonita Creek Basin drains the Gila Mountains to the south and the Nantac Rim to the north. The creek is confined between bedrock valley walls but has a 200–230 ft wide vegetated alluvial valley. An infiltration gallery located on Bonita Creek approximately 5-6 miles above the mouth collects water for the City of Safford's water supply pipeline.

San Simon River

The San Simon River is an ephemeral river that joins the Gila River from the south near the town of Solomon. The San Simon River has a drainage area of 1,606 mi^2 (4,159 km^2) and drains relatively erodible loamy soils (Banister et al. 2014). Unlike the other sub-basins described herein, the San Simon watershed is relatively flat. The San Simon Valley is wide and is composed of extensive Quaternary river and lake deposits on the valley floor with Quaternary terrace deposits, particularly downstream of the town of Rodeo, New Mexico (near the Arizona-New Mexico border). As a consequence of the basin geology, the San Simon watershed has the highest soil erodibility of any of the other reaches or sub-basins in the Upper Gila River Watershed (Figure 13). The river is incised in a single thread, with large sediment deposits upstream of many sediment retention dams (described below). There is little agriculture except near the towns of Bowie and San Simon. Vegetation cover is limited in the basin and soil erosion is common.

The best available evidence suggests that widespread arroyo formation in the San Simon Watershed began in the early 20th century, with more than 100 miles of gullies exceeding 10 feet in depth (Burkham 1972). Arroyos are entrenched ephemeral streams found in the southwest that undergo periodic erosion (gullying) and filling (Waters and Haynes 2001). The cause of the arroyo formation is not certain, but Olmstead (1919) reported that incision in the San Simon originated following excavation of a 4 ft deep and 20 ft wide drainage ditch near the confluence with the Gila in the 1880s. Gullying, however, occurred in many of the tributaries to the Gila River following several years of drought and a large storm in 1915 (Burkham 1972), suggesting that the drainage ditch may not be the sole cause of gullying. Arroyos formed throughout the Southwest in the early 20th Century (Waters and Haynes 2001). The degree to which the gullying and arroyo formation was exacerbated by grazing is unknown, but given the timing of surface erosion and evidence from other basins, a change in vegetation perhaps in combination with the ditch excavation were the likely driver of the transition from a quasi-stable landscape to one with widespread erosion. The gullying extends from the mainstem up into the tributaries. The large volumes of sediment from surface erosion are retained and partially mitigated by numerous check dams in the tributaries and mainstem San Simon. Due to incision in the early 20th century the BLM installed at least 19 major detention dams in the San

Simon watershed (Brandau et al. 2003). In a subsequent study, Brandau (2013) identified 931 sediment control structures of various sizes and design in the San Simon Watershed. Of the 931 structures, 283 appeared to be breached. These breached dams are likely providing high sediment loads to the San Simon River and the upper Gila River. The San Simon is likely the largest sediment source to the Gila River downstream of the Gila Box (Brandau et al. 2013).

San Carlos River

The San Carlos River enters the Gila River form the north and has a drainage area of 1,054 mi^2. The river primarily drains the San Carlos Reservation and the San Carlos River and its tributaries are primarily multi-threaded, braided streams. The Talkalai Lake Reservoir has partially regulated discharge since 1979 (Webb and Boyer 2001). The valley is up to 2,600 ft wide in the lower reaches of the watershed. The lower portions of the watershed have a broadly similar geology to the San Simon Watershed. To our knowledge, the amount of 20th century arroyo cutting and gullying in the San Carlos Watershed has not been quantified, but a brief aerial photographic survey suggests that the degree of gullying is much less than the San Simon River. We are not aware of a systematic study of sedimentation in the San Carlos Watershed.

LAND USE & PEOPLE

Healthy communities are part of a healthy watershed. Economic and cultural context in the watershed are an important consideration in the work of GWP and partners. Understanding how humans have made an impact on the landscape, going back thousands of years, and recent patterns of settlement and land use will help us understand changes in the watershed.

Residents of the watershed largely value this vast landscape for its scenery and sense of place. In many instances, stakeholders have communicated the desire to preserve this rural lifestyle that has disappeared from many other places in the West. The GWP has even incorporated this value into their mission statement. However, the dispersed nature of the population can be a challenge for a watershed partnership seeking to connect stakeholders with projects in their region. See Figure 16 for snapshots of population and economic indicators in Graham and Greenlee Counties.

KEY TAKEAWAYS

- Dispersed and small populations can make engaging stakeholders in water and land management decisions difficult. These population characteristics also have implications for how water is obtained, treated, regarded (i.e. well owners vs municipal water utilities)
- Increased aging populations can have economic impacts, both positive and negative. Retirement populations can provide economic stimulus to a region, but economic growth requires an active labor force.
- An estimated 70% of the population of the Upper Gila Watershed lives within five miles of the Upper Gila or the San Francisco rivers. Maintained infrastructure is especially important in proximity to waterways. If there is a decrease in the amount of funds made available by federal agencies to local government, an increasing amount of the burden of maintaining this infrastructure falls on county and city/town governments.
- While agriculture and mining remain important sectors in many rural economies including the Upper Gila Watershed, service and retail industries have accounted for most job growth in rural America over the past few decades. Job opportunities available to the rural labor force is a key consideration for education of the youth.
- Increasing the area covered by homes, businesses and roads increases stormwater runoff, which can lead to flooding and/or water quality concerns.

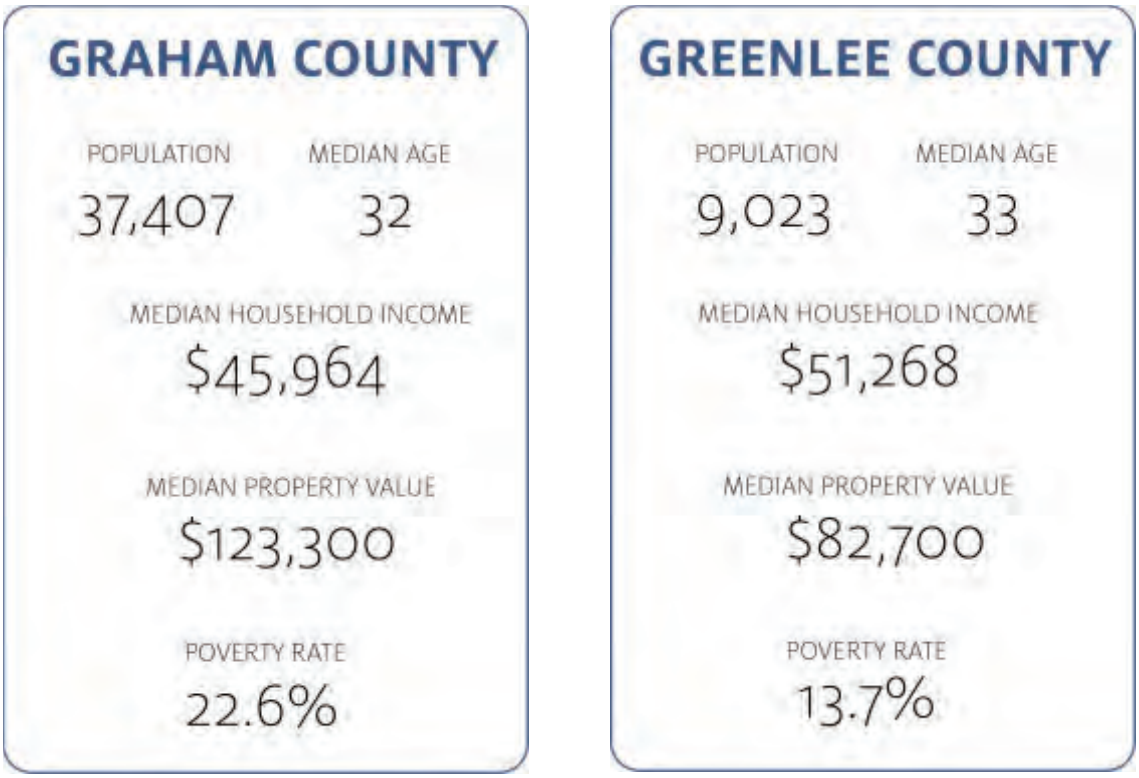


Figure 16. Snapshots of population and economic data for Graham and Greenlee Counties, AZ (U.S. Census Bureau 2015).

Population growth, age distribution, and demographics

Graham and Greenlee Counties make up most of the Upper Gila Watershed. This 7,354 square mile watershed is occupied by only 47,500 people (2015), mostly living in the Safford and Clifton areas. Within these counties, the population density is widely dispersed with approximately 8 people for every square mile in Graham County and 5 people for every square mile in Greenlee County (ACS 2015, 5-Year Estimates)—some of the lowest rates of population density in the state.

The population within the watershed has changed dramatically over the last thirty years and can experience dramatic shifts based on largely economic trends. The 2018 total population estimate of Graham County is 37,407 people, and 9,023 people in Greenlee County. Since 2000, the population in Graham County has increased 9% (from 33,997 people), while the population of Greenlee County has increased 5% (from 8,584 people) (U.S. Census Bureau 2017) (Figures 17 and 18). However, as Figures 17 and 18 indicate, the population can fluctuate dramatically according to different economic and environmental factors, both regionally and nationally.

An estimated 70% of the population of the Upper Gila Watershed lives within five miles of the Upper Gila or the San Francisco rivers. With the exception of Peridot and San Carlos, the largest municipalities are all located along these two rivers. The region's settlement from the mid-1800s onward was concentrated along these corridors to take advantage of the water for

human uses, particularly agriculture. Infrastructure similarly is closely associated with the river. Public and private actors are responsible for a variety of infrastructure in the region, from irrigation ditches and diversion dams to roads and bridges. Much of the costs associated with maintaining the public infrastructure is carried by local governments, with some assistance from state and federal entities. In recent years, there has been a marked decrease in the amount of funds made available by these levels of government. As a result, an increasing amount of the burden of maintaining this infrastructure falls on county and city/town governments. In addition, compliance costs regarding certain state or federal regulations (such as the National Historic Preservation Act, the National Environmental Planning Act, or the Endangered Species Act) increases the expenses born by governmental entities.

For Graham and Greenlee Counties, approximately 23–26% of the population is between the ages of 18 and 34 years old (Figure 16). The population of 65 years and over is 11–12% in these counties. A society is considered relatively old when the proportion of the population age 65 and over exceeds 8 to 10%. By this standard the proportion of elderly people in the United States was 12.6% in 2000, compared with only 4.1% in 1900. Elderly populations are projected nationwide to increase by 27% between 2012 and 2050 (Ortman et al 2014).

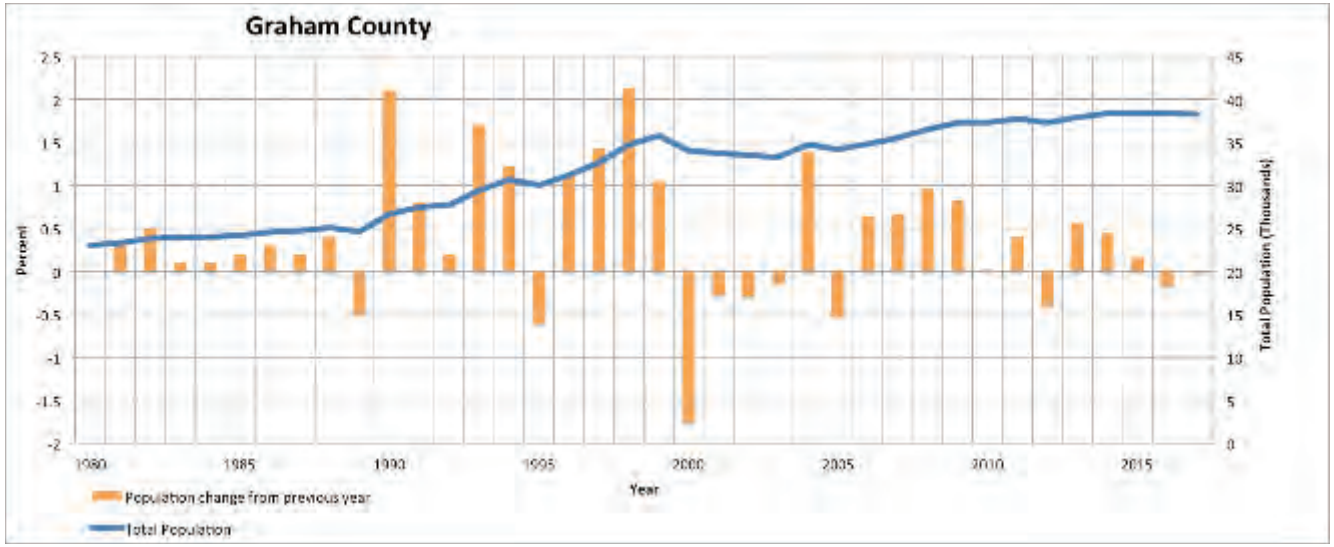


Figure 17. Graham County population between 1980 and 2017.

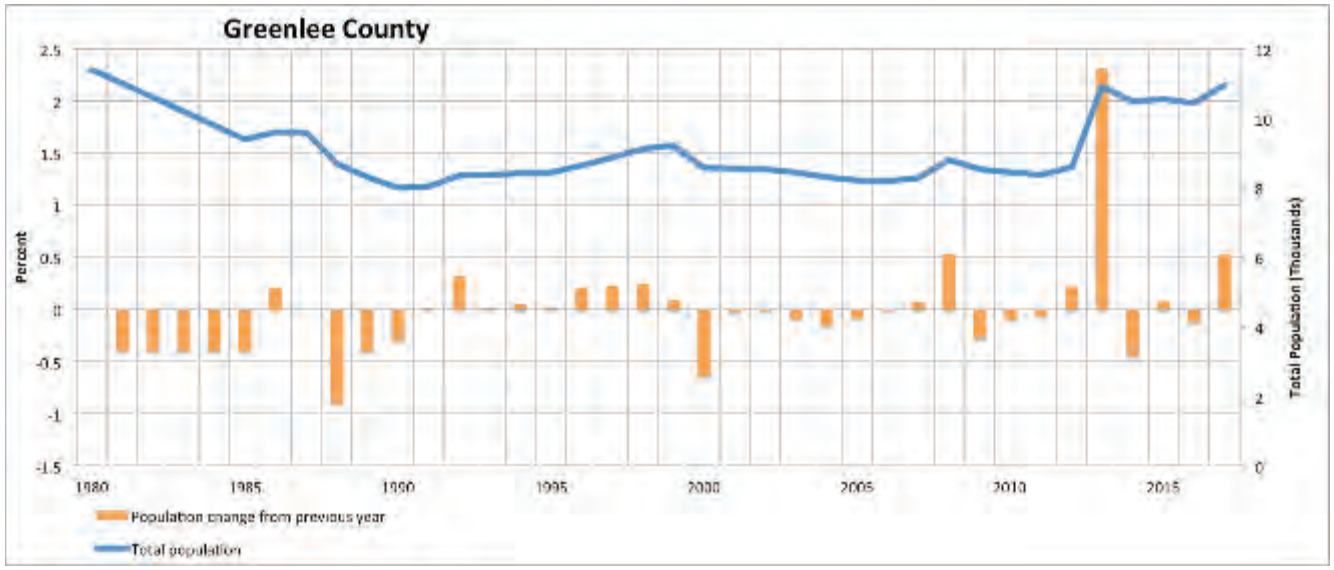


Figure 18. Greenlee County population between 1980 and 2017.

Economy and industry

Changes in technology have resulted in modifications to farming and land use patterns throughout the course of the Gila River's history of human occupation. From a market-driven perspective, the arrival of the railroad – and later, paved surface roads—led to the integration of the local farm economy into national and international markets. Instead of selling crops to the nearby towns, new sellers were suddenly available. Choice of crops by local farmers then became influenced by opportunities to participate in distant commodity markets. Cotton became popular among farmers in the Valley, and it remains a staple crop today.

Cotton is the primary crop grown in the Upper Gila Watershed, providing a strong cultural and economic base in Graham County communities, while ranching and livestock sales dominate in Greenlee County. According to the 2012 USDA Census of Agriculture, crop sales in Graham County accounted for $170 million (97% of all ag sales in the county) and livestock sales accounted for $414,000 (3% of all ag sales in the county). Meanwhile, crop sales in Greenlee County accounted for $2.4 million (25% of all ag sales in the county) and livestock sales accounted for $7.3 million (75% of all ag sales in the county) (USDA 2012). In 2012, 412 farms were located in Graham County (an increase from 343 farms in 2007) consisting of 1.25 million acres (USDA 2012)[2]. In the same year, 159 farms were located in Greenlee County (an increase from 127 farms in 2007), consisting of 52,000 acres[3]. There are also seven wheat farms in Graham County and zero in Greenlee, while there are six barley farms in Graham and zero in Greenlee (Kerna et al. 2016).

The economy of Graham County, AZ employs 11,954 people. The largest economic impacts are from Mining, Oil, Gas Extraction[4]; Management of Companies & Enterprises; and Public Administration, which employ respectively 18.64; 6.32; and 1.77 times more people than what would be expected in a location of this size. The largest industries in Graham County are Retail trade (1,605), Educational Services (1,596), and Healthcare & Social Assistance (1,391), and the highest paying industries are Utilities ($75,446), Mining, Quarrying, Oil, Gas Extraction ($61,453), and Professional, Scientific, Tech Services ($54,000).

The economy of Greenlee County, AZ employs 3,346 people. This area specializes in Mining, Quarrying, Oil, Gas Extraction; Management of Companies & Enterprises; and Agriculture, Forestry, Fishing, Hunting, which employ respectively 69.12; 6.77; and 2.37 times more people than what would be expected in a location of this size. The largest industries in Greenlee County, AZ are Mining, Quarrying, Oil, Gas Extraction (1,398), Construction (344), and Educational Services (270), and the highest paying industries are Mining, Quarrying, Oil, Gas Extraction ($59,116), Professional, Scientific, Tech Services ($55,043), and Transportation & Warehousing ($34,896).

[2] This figure accounts for both farming and ranching land, including federal rangeland.
[3] This figure accounts for both farming and ranching land, including federal rangeland.
[4] US Bureau of Reclamation defined category. There is no known oil or gas extraction in Graham or Greenlee Counties.

"Mining, Quarrying, Oil, Gas Extraction" is one of the most common employment sectors for those who live in both Greenlee County and Graham County. However it is important to remember that of these residents may live in either of those counties and work somewhere else. Census data is tagged to a residential address, not a work address.

Land use

Land under different ownership is managed in different ways. The San Carlos Apache are a sovereign nation with an independent system of land management and water rights reserved prior to most others in the watershed. The U.S. Forest Service, BLM, and Arizona State Land Department lease lands to private citizens for uses such as grazing, mining, recreation, and rights of way for transportation and utilities (Figure 19, Table 4). The harvest and collection of forest products is also permitted on U.S. Forest Service land. The State Trust Lands are often interspersed with federally managed land and privately owned land, and may be sold into private ownership in the future. Several small areas in the watershed are managed for wildlife and recreation by the Bureau of Reclamation, the Salt River Project, the National Park Service and the Arizona Department of Game and Fish. Private ownership on the remaining parts of the watershed is primarily used for farming, ranching, mining, and housing.

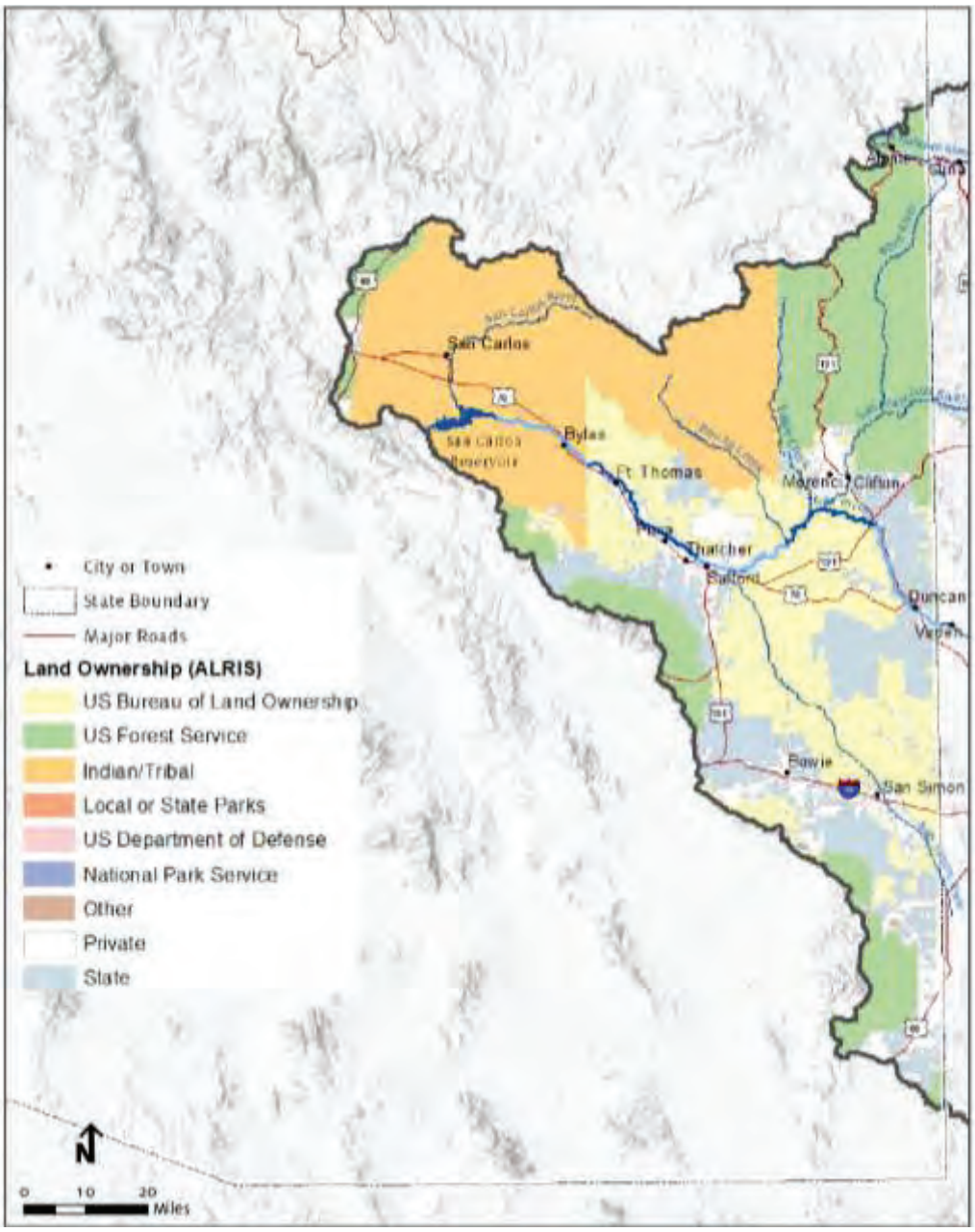


Figure 19. Land ownership in the Upper Gila Watershed (Source: ARLIS 2010).

Table 4. **Land ownership in the Watershed.**

Ownership	% Total Area
BLM	23%
Indian Lands	29%
Private	10%
State	14%
U.S. Forest Service	23%
Other (NPS, Military)	1%

Changes in land cover, such as the conversion of agricultural lands to houses and businesses, can impact the water quantity and quality. Figure 20 depicts a simplified land cover change analysis using information from the National Land Cover Database (NLCD). Datasets were developed for 1992, 2001, 2006, and 2011 using satellite imagery (Landsat TM/ETM+) with a spatial resolution of 30 meters. Though all four datasets were produced as part of the same program, changes in methodologies and input between the NLCD datasets makes it so that these datasets cannot all be directly compared to one another, although techniques have been created to correlate the datasets. Overall accuracy of the 1992 NLCD varied by region, but was 70% for the Southwest (Wickham et al. 2004). Overall accuracies for the entire 2001 and 2006 NLCD were 79% and 78%, respectively (Wickham et al. 2013).

To analyze land cover change, 1992 and 2006 land cover were compared (Table 5, Figure 20). The two original maps had different land classifications, so it was necessary to change both to more general categories that matched.

2006 Results: The differences in the original datasets make it difficult to examine change in specific areas, however it is possible to look at the landscape as a whole, and the relative proportion of each land cover class reveals interesting trends of land cover change in the watershed. For example, the percentage of land used for agriculture (2%) remained constant between 1992 and 2006 whereas the land for “urban” or houses, commercial use, and roads increased from 0.1% of the land area to 1%. While it is still a very small fraction of the total area this represents a 580% increase in land used for roads, homes, or businesses. Similarly, the area covered by “riparian” plants, which includes both native cottonwoods and willows as well as tamarisk, increased from 0.1% of the land to 0.5%. While riparian area remains only a tiny fraction of the land cover in the watershed, it increased 330% between 1992 and 2006. Finally, although it is notable that the area of forest land increased from 14% to 20%, the data represent conditions prior to several major forest fires and may not accurately reflect current conditions. It is also possible that the increase in forest land in particular is due, at least in part, to the different classification schemes from the original data.

Table 5. Land cover change in the Upper Gila River Watershed, 1992-2006.

Land cover	Area 1992	Area 2006
Agriculture	2%	2%
Barren	0.5%	0.3%
Forest	14%	20%
Open Water	0.3%	0.2%
Riparian	0.1%	0.5%
Shrubland and Grassland	83%	76%
Urban	0.1%	1%

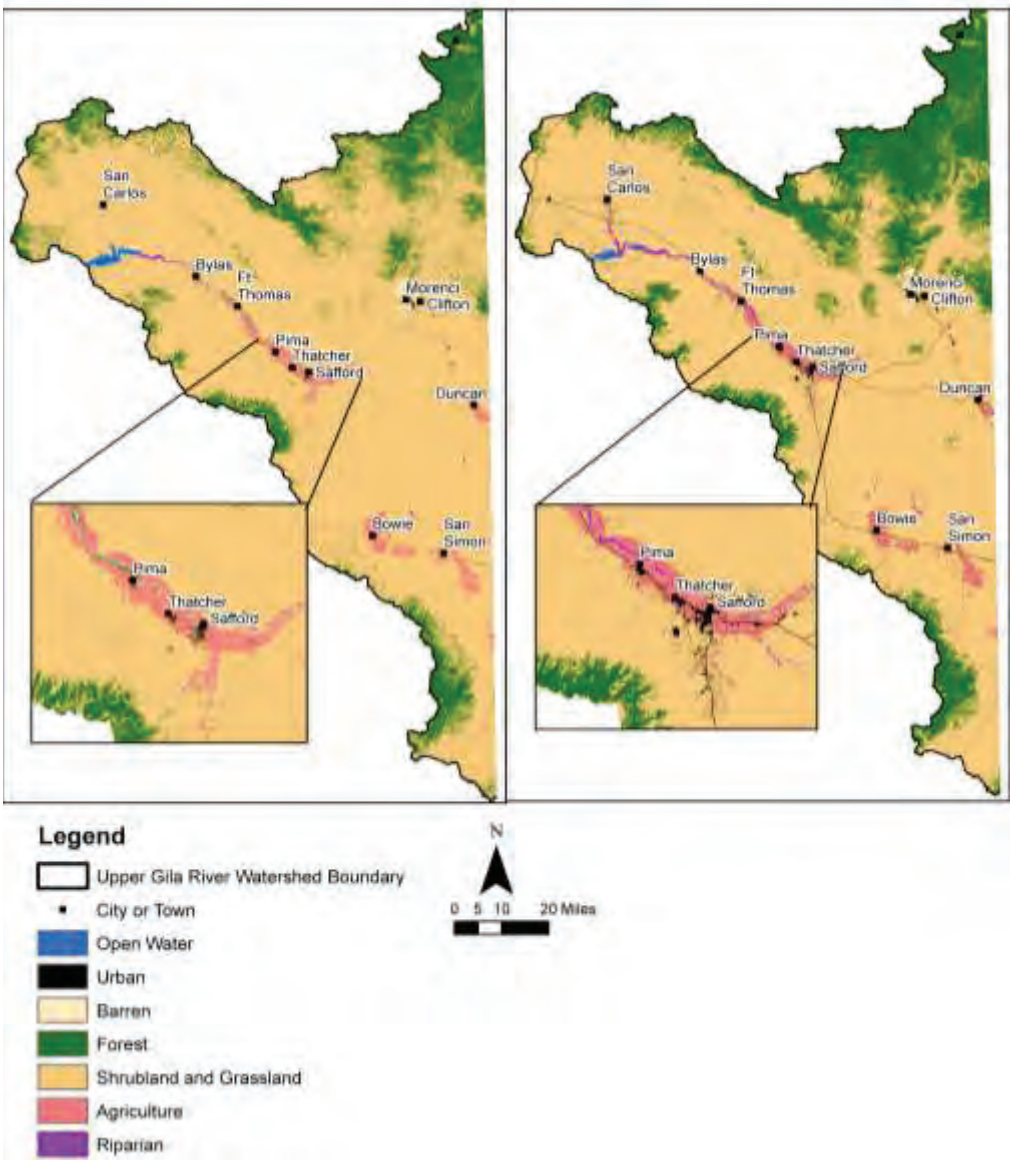


Figure 20. Land cover change (NRCS 1992-2006).

WATER USE AND SUPPLIES

In our water-scarce state, the Gila River has and will continue to be a valuable and highly sought after water source. Its surface water supplies and underlying groundwater allow the existence of robust farming, ranching, and mining, while providing a ribbon of green to the arid landscape. However, as much as these water resources have shaped the history of the watershed, a variety of legal uncertainties will influence future water supplies, potentially in a drastic way. The GWP can contribute to acquiring knowledge of the area's water limits and aiding in more efficiently managing water usage in order to cope with these uncertainties and maintain a secure water supply. These contributions are aligned with the GWP's long-term mission and goals to improve community health and preserve the rural lifestyle so central to the region.

Throughout Arizona, surface water rights are established by the doctrine of prior appropriation, commonly referred to as "first in time, first in right." Water that was first put to "beneficial use" is prioritized by state law as the imminent water right. During drought, whoever owns senior water rights are satisfied before those with more junior rights. Surface and groundwater use in the Upper Gila Watershed are also affected by a number of state and federal laws, court orders, and Congressionally-mandated settlements, namely the 1935 Globe Equity Decree No. 59, the San Carlos Apache Water Rights Settlements Act of 1992, Arizona Water Settlements Act of 2004, and the ongoing Gila River Stream Adjudication, which will adjudicate water rights not included in the aforementioned existing decrees or settlements (Mott Lacroix 2016)

Understanding water supplies in the region is difficult because of (1) lack of groundwater data and (2) complex regulations that do not apply uniformly across the watershed. Future water supplies are highly uncertain and affected by multiple variables (Figure 21). Most of the watershed could have either a deficit or surplus in their available water supplies, depending on the method used to calculate future supplies and demands. Through the study led by the University of Arizona Water Resources Research Center, stakeholders participated in the Water Supply and Demand Working Group, contributing data and expertise to the study in 2015. Participation in the Water Supply and Demand Working Group was open to all and included water users with expertise in municipal, farming, ranching, and mining water demand. This group did not, however, include representation from the San Simon region, making the figures presented for this region, particularly demand projections, speculative.

KEY TAKEAWAYS

- No feasible additional long-term supplies, except for *transfers between basins*; e.g., Morenci to Safford, however, there would not be a significant amount of extra water available through that avenue.
- Farming system is especially constrained, and the strict rules governing water use do not allow much room for flexibility or creative solutions. Of particular concern are the lack of return flow credits and the dis-incentives for water efficiency.
- Water use for many municipal, industrial, and irrigation wells in the watershed is capped based on the Arizona Water Rights Settlement Act. This limits the area's legally available water.
- Water use by domestic wells could be significant and is underreported.
- While water use by one does not necessarily mean the water is unavailable to another, affordable and high-quality water are increasingly questioned, considering uncertainty.
- Cooperation will be necessary in order to close the gap between water supplies and demands. The GWP is a well-placed and –equipped organization to play a crucial role.

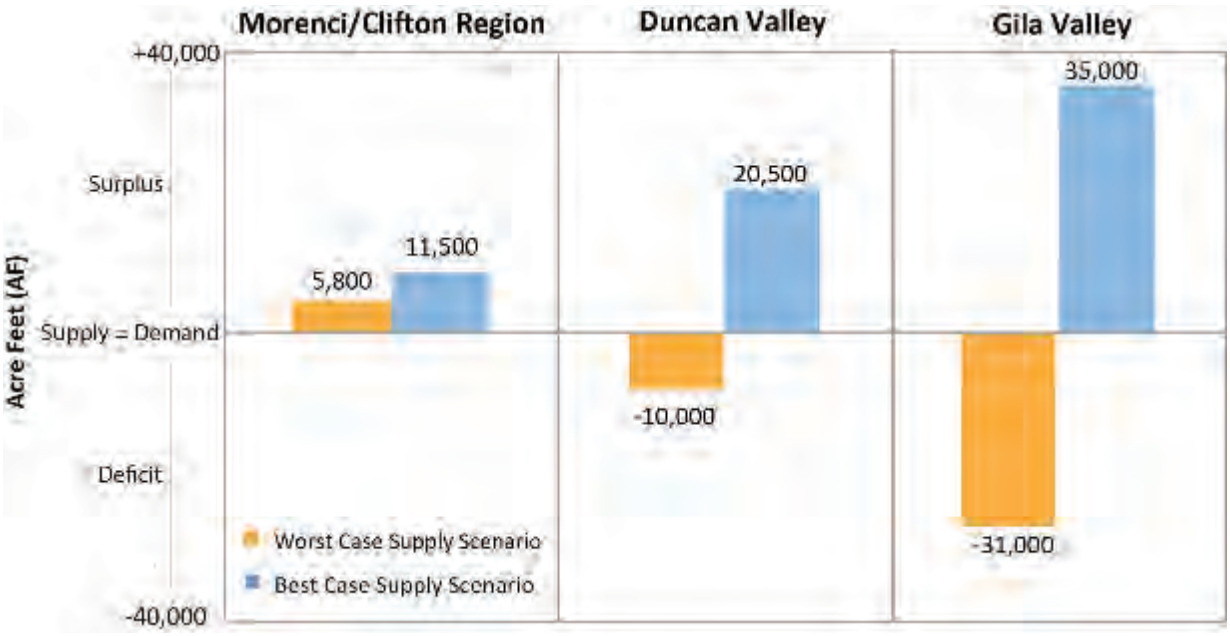


Figure 21. Water supply deficits looking 30 years into the future.

Water supplies

Quantifying the region's water supply proved to be a complex task requiring multiple strategies during the 2015 Water Supply and Demand Study led by the UA Water Resources Research Center. The approach used to calculate water supply can greatly impact the projected gap

between water supply and demand. The estimations were based on four approaches: (1) Physically available water supply, (2) Legally available water supply, (3) Recently available water supply, and (4) 20% decrease in water supply. An approach that focused on *Physically Available Water Supply* would be based on stream gages for the determination of surface water (available through publicly released information from the Gila Water Commissioner's office), and for the determination of ground water based on 2009–2013 average pumping reports.

An approach informed by the *Legally Available Water Supply* would hone in on key components like the Globe Equity Decree, Arizona Water Settlements Act of 2004, and any other existing restrictions on diversions. Consideration of *Recently Available Water Supply* would also be a complicating factor, given the impact of the long drought. The Arizona Water Resource Development Commission's report offers insight into this situation. Potential impacts of different events, like the operationalization of the New Mexico CAP Unit or the varied consequences of a catastrophic flood, have been anticipated through an assumption of a *20% Decrease in Water Supply* (based on the Recently Available Water Supply estimate as a baseline). These four Water Supply approaches were taken in order to provide detailed and differentiated perspectives on water availability.

However, there can be a difference between "paper water" and "wet water"; one may have a legal water right, but whether that resource is actually available in the river or stream, or accessible from a groundwater well, may be a different story. The water supply data produced by WRRC quantify the estimated surface water and groundwater available in the watershed, compared with water that is legally available for use after accounting for regional water rights and obligations to downstream users. In addition to physically and legally available water, the amount of water recently available in the watershed was considered to account for the drought conditions of the past 16 years, as was a 20% reduction in water supply to account for uncertain impacts to water availability, such as persistent or worsening drought.

Water demand

Water use in the Upper Gila River Watershed is dominated by agricultural activities, especially in the Gila Valley where cotton production is highly active (Figures 22 and 23). The overall distribution of water demand among municipal, industrial, and agricultural water users resembles statewide water demand trends, with agricultural demand being somewhat higher compared to the statewide average of 74% (ADWR 2016). Between 2001 and 2006, an average of 91% of the surface water diversions and groundwater pumping were to meet agricultural water needs (ADWR 2016). Depending on the irrigation method, much of this water can return to the river or infiltrate through the soil into the aquifer. The more efficient the irrigation method, the less water will return to the river or aquifer. Water demand for industrial purposes, predominantly mining, makes up 4.5% of the demand in the watershed, the remaining 4% is used for municipal demand (Figure 22). In contrast to agriculture, industrial and municipal water uses are generally considered consumptive, as they return less water to the river or aquifer. An acre-foot of water for mining uses may, however, be used many times over. The amount of demand from domestic wells are not reported and therefore their contribution

to overall water demand in the watershed is not well understood. The number of wells in the watershed have increased more than threefold over the last 60 years.

Overall, in the Upper Gila River Watershed water demand did not change significantly between 1991 and 2009, but there is year-to-year variability in the water demand by agricultural and mining users in particular (Bannister et al 2013). The proportion of groundwater versus surface water used in the watershed has fluctuated over time, with increased surface water use when it is more available and increased groundwater use when surface water is scarce.

Much of the watershed is subject to the provisions of the Arizona Water Right's Settlement Act. The full implications of this Act on water supply availability are too complex for this report. However, it is notable that most of the municipal, industrial and agricultural wells in the watershed are metered and the use of water from those wells is capped—e.g., no more than six acre-feet of water per acre for agricultural lands within the Act's decreed area.

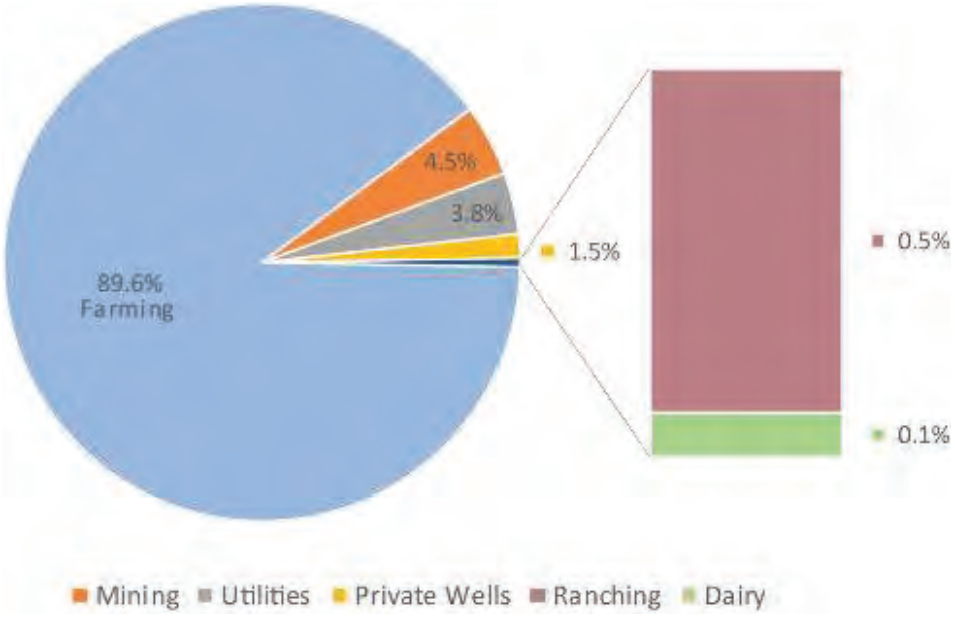


Figure 22. Water use defined by sector.

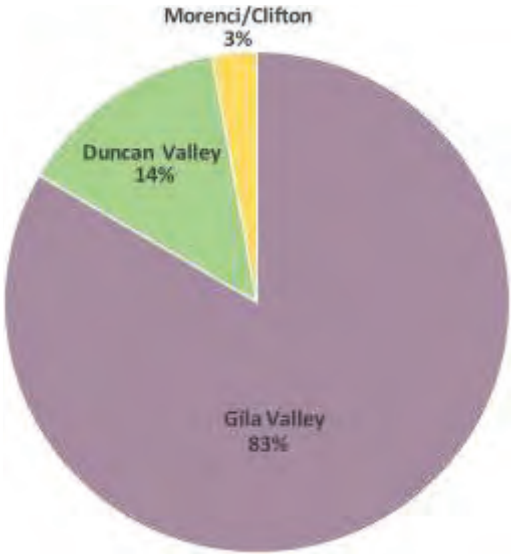


Figure 23. Water use defined by geographic areas.

WATER QUALITY

Access to reliable and reasonably clean supplies of water has been crucial to sustained human presence in the Upper Gila River Watershed for millennia. Particularly because of the arid climate and the long dry periods between the annual cycle of summer and winter rainfall, water has been a limiting factor on population growth and development. Modern technology has expanded the availability of water, with improved abilities to drill for water and transport it. As a result, certain areas have been settled and even irrigated when their former uses were more seasonal or transient in nature. Even so, the substantial cost of modern efforts to procure clean and reliable water supplies continues to influence land uses, underscoring the high value of water resources. The GWP has been successful in addressing water quality in the watershed with certain projects. This section will consider that success in context of the watershed-wide conditions.

KEY TAKEAWAYS

- The 2012 Watershed Improvement Plan for the San Francisco-Blue Rivers, produced by the GWP and partners, is an ongoing source of water quality information and instruction for the region.
- Fire continues to be an uncertain, but potentially devastating, threat to surface water quality in the region.
- While seeking to increase recreational opportunities, continued efforts must focus on waste disposal facilities at those sites.
- Public education must be ongoing to remind people that their water supplies are not completely self-cleaning, especially considering the level and types of activity around the river.
- Salinity continues to be an issue for farmers and residents of the area.
- More frequent and consistent testing of surface water chemical data is necessary to better characterize waters, particularly those designated 'inconclusive' by ADEQ in its 2016 report.
- The designation of impaired waters needs to be adjusted in order to remove stretches of the Gila River and its tributaries from the 303 list.

Surface Water

The ADEQ uses five categories to evaluate the status of a given water source, four of which have been observed in the Upper Gila River Watershed. These categories depend on the parameters tested and the frequency of testing. Attaining all uses (category 1) indicates that a full suite of parameters were tested a sufficient number of times with no exceedances reported at any time. Attaining some uses (category 2) is given for a water that recorded at least one exceedance, but in repeated sampling the exceedance was not consistent. Inconclusive (category 3) is given for a water which was not tested for enough parameters or frequently enough to determine water quality status. Impaired (category 5) is given for a waters that exceed criteria repeatedly. There were no waters with a Not Attaining Waters (category 4) status in the watershed. Surface water quality is designated impaired on the Gila in two places: just upstream of the confluence with the San Francisco and just downstream of the confluence

with Bonita Creek. Cave Creek, in the San Simon Watershed in the Chiricahua Mountains is also designated impaired for selenium.

The Gila, San Francisco, Blue and San Simon Rivers as well as Bonita and Eagle Creek waterways make up a good portion of the water supply for the watershed's municipalities, industries, ranchers, farmers, and its wildlife that rely on riparian areas. Many of these rivers have seen a drop in seasonal flow due to lower winter snowpack levels as well as an increase in water quality issues over the years. The Blue, San Francisco, and Gila Rivers are all listed on the federal 303(d) impaired waters list due to *E. coli* exceedances and some are listed for sediment and lead. Although recreation is a large economic driver for our communities, there is risk for people who swim, fish and boat due to the water impairments seen throughout the watershed. The watershed has third highest miles of *E. coli* impaired rivers in the State of Arizona with a total of 56.9 miles (ADEQ - Water Quality Program 2016).

Water quality problems may originate from both "point" and "nonpoint" sources. The Clean Water Act (CWA) defines "point source" pollution as "any discernable, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged" (33 U.S.C. § 1362(14)). In the past, the primary sources for nonpoint source pollutant concerns in the Upper Gila Watershed were identified as abandoned mine sites, new development and increased urbanization, and new road construction (Ajami et al 2005). Apache Creek-Upper Gila River, Yuma Wash-Upper Gila River, Centerfire Creek-San Francisco River, Mule Creek-San Francisco River, Chase Creek-San Francisco River, and Stockton Wash subwatersheds are prioritized as high-risk areas from nonpoint source pollutants (metals, sediment, or organic constituents) (Ajami et al 2005).

ADEQ placed river reaches of the San Francisco and Blue Rivers on the Clean Water Act 303(d) Impaired Waters List as impaired for the bacterium *Escherichia coli* (*E. coli*), based on testing results accumulated over years. Water quality monitoring professionals commonly use *E. coli* as an indicator for other waterborne pathogens that may pose more serious health risks to people (ADEQ 2012). Some members of the public are aware of waterborne pathogens and bacteria as well as parasites, amoebas and viruses. Salmonella is a well known for causing serious illness in humans; this bacteria is found in the intestinal tracts of animals and humans, as well as in contaminated water. Cryptosporidium and Giardia are parasites found in contaminated water that often cause gastro-intestinal and other illness (GWP 2012).

Typical sources of *E. coli* contamination:

- Recreation: Without toilet facilities or trash disposal, river stretches are vulnerable
- Livestock: Although widely restricted, cattle and sheep may frequent natural watering holes, which can affect some reaches
- Wildlife: Many kinds of wildlife visit the streams, accumulating in the uplands and washing into waterways during precipitation events
- Faulty or substandard septic systems: Most likely an issue during periods of heavy rainfall and resulting runoff

- Fire: For example, the 2011 Wallow Fire devastated 535,000 acres in Arizona and New Mexico, exacerbating later flooding and high loading of fine grasses and other sediments, also leading to higher levels of *E. coli*

The *E. coli* impairments along the San Francisco and Blue Rivers are attributed primarily to human and bovine fecal matter in the rivers (GWP 2012). These *E. coli* sources were confirmed by DNA testing completed in 2008 by the University of Arizona. A Watershed Improvement Plan (WIP) for the San Francisco and Blue Rivers was completed in 2012 with the guidance of the ADEQ and Watershed Improvement Council that included GWP (GWP 2012). As GWP finalizes two projects addressing human contributions of *E. coli* and other enteric pathogens, as were outlined in the WIP, we are looking ahead at the next steps in improving the water quality in this region. *E. coli* is identified by ADEQ as a pollutant for several reaches in the Upper Gila Watershed with primary sources identified by reach (Table 6). More testing is necessary to more accurately identify the primary source of contamination.

Table 6. Upper Gila Water Quality Monitoring (updated by ADEQ, 2017).

Reach	Pollutant(s)	Common Primary Sources	Status
Bonita Creek to Yuma Wash	E. coli, suspended sediment concentration (SSC)	agriculture, logging, septic systems, road crossings, permitted sources, grazing, others	E. coli and SSC TMDLs completed and approved by EPA in 2012 and 2013
New Mexico Border to Bitter Creek	E. coli and sediment	agriculture, logging, septic systems, road crossings, permitted sources, grazing, others	E. coli and SSC TMDLs completed and approved by EPA in 2012 and 2013
San Francisco River/Blue River	E. coli	recreation, livestock, wildlife, septic systems	WIP completed in 2012

Groundwater

The valleys of the Gila River and its tributaries are primarily made up of alluvial materials up to several thousand feet thick. A coarse, 100-foot thick, highly permeable aquifer lies under and along the main river channel (ADWR 2009). Beneath this younger alluvium is a finer grained material with locally concentrated salt (evaporite) deposits. Natural subsurface flow through the aquifer systems transmits salts to the Gila River, consequently increasing salinity in the water column; salinity levels are a major concern for water users in the Gila Watershed. Many statistically significant groundwater quality patterns were found between younger alluvium recharged by the Gila River and older alluvium and/or hard rock recharged by local precipitation. Total dissolved solids (TDS), major ions, nitrate, and boron concentrations were higher in younger alluvium than older alluvium and/or hard rock, while pH levels were lower in

the younger materials and higher in the older materials. There were no noteworthy patterns involving arsenic and fluoride, the two most frequent constituents in exceedance in the watershed (ADEQ 2009).

The quality of groundwater has been studied in the Upper Gila River Watershed by the Arizona Department of Water Resources (ADWR) and ADEQ. These reports are inconsistent regarding the source of high levels of TDS, which is the main threat to water quality in the basin. The sources of TDS in the Safford Basin could be weathered dissolved geologic materials (particularly evaporites present in the Lower Basin Fill and Upper Basin Fill) or water where the TDS has been concentrated via evaporation (reducing the volume of water while leaving behind the dissolved materials). Additional theories include a lower artesian aquifer has high TDS which flows upward through faults to concentrate TDS in the Lower Basin Fill and Upper Basin Fill as well as downward migration of high TDS waters from irrigation runoff (data, summarized by Gootee (2012), do not show any correlation between depth of well and TDS). While the scale of riparian fires is very different, such fires can have direct and immediate impacts on water quality of shallow aquifer systems.

Chemical parameters that have exceeded minimum quality criteria for groundwater in the basin are: TDS, arsenic, fluoride, lead and nitrite. Many of these exceedances are located near the Safford-Pima corridor, upstream along the Gila as well as south along Highway 191. Many wells have more than one parameter with an exceedance value. Two wells were closed due to these contaminants, including Belleman and Thatcher Wells in 2000. The Wallen water report displayed improvement in groundwater quality since the records in the 1950 Hemp report.

Groundwater sample results for the Upper Gila Watershed are compared with the Safe Drinking Water Act (SDWA) water quality standards. Public water systems must meet these enforceable, health-based, water quality standards, called Primary Maximum Contaminant Levels (MCLs), when supplying water to their customers. Primary MCLs are based on a daily lifetime (70 years) consumption of two liters of water (ADEQ 2009). While domestic well-owners are responsible for testing their own water, municipal and community supplies are tested regularly to comply with the SDWA. In the Upper Gila Watershed, targeted outreach and education efforts are best directed at private domestic well-owners so they are aware of risk factors and available information about their water.

TERRESTRIAL VEGETATION AND WILDLIFE

Vegetation in the Upper Gila River watershed influences and is influenced by a variety of biotic and abiotic factors. Vegetation provides habitat for terrestrial and riparian species, influences aquatic habitat quality, and helps control sediment delivery rates. Nine different biotic communities, or vegetation types classified according to Brown et al. (1979), have been mapped in the Arizona portion of the Upper Gila River Watershed (Banister et al. 2014; Table 7 and Figure 24). Slope, position, elevation, moisture, and temperature are the primary environmental factors affecting the distribution of these vegetation types within the watershed. The entire river-riparian corridor falls within the Sonoran Desert scrub and Chihuahuan Desert scrub communities, which occur on the river terraces and uplands. Riparian vegetation occurs along the river corridor and montane conifer forests are found in the higher-altitude mountain ranges (Orr et. al. 2014). Only 10% of the Arizona portion of the watershed is privately owned; large areas of the remaining land are managed by the U.S. Forest Service and BLM. Grazing is a major economic activity in the watershed, and in many areas wildlife shares the largely undeveloped land with cattle.

KEY TAKEAWAYS

- Special-status species protection may conflict with other land uses, including human water needs, development, agriculture, and recreation.
- Increased stressors on special-status species due to local extirpations in heavily developed areas outside the watershed may result in further restrictions on development in less developed portions of the watershed.
- Habitat destruction and fragmentation, non-native invasive species, and competing land uses restrict the movement and successful reproduction of wildlife species.
- Preserving habitat and wildlife corridors will maintain and improve dispersal, access to suitable habitat, population structure, and genetic diversity.
- Long term drought, land use conversion, non-native invasive species, wildfire, climate variability and increases in the number and severity of wildfires may affect habitat for plants and wildlife.

Table 7. Major vegetation types in the Upper Gila River Watershed in Arizona.[1]

Vegetation type	Percent of project area
Woodlands	
Great Basin Conifer Woodland	11.0%
Madrean Evergreen Woodland	13.5%
Petran Montane Conifer Forest	7.5%
Petran Subalpine Conifer Forest	0.1%
Shrublands	
Chihuahuan Desert Scrub	15.1%
Interior Chaparral	5.7%
Sonoran Desert Scrub	18.2%
Grasslands	
Plains and Great Basin Grassland	3.4%
Semidesert grassland	25.4%

[1] Source: Banister et al. 2014

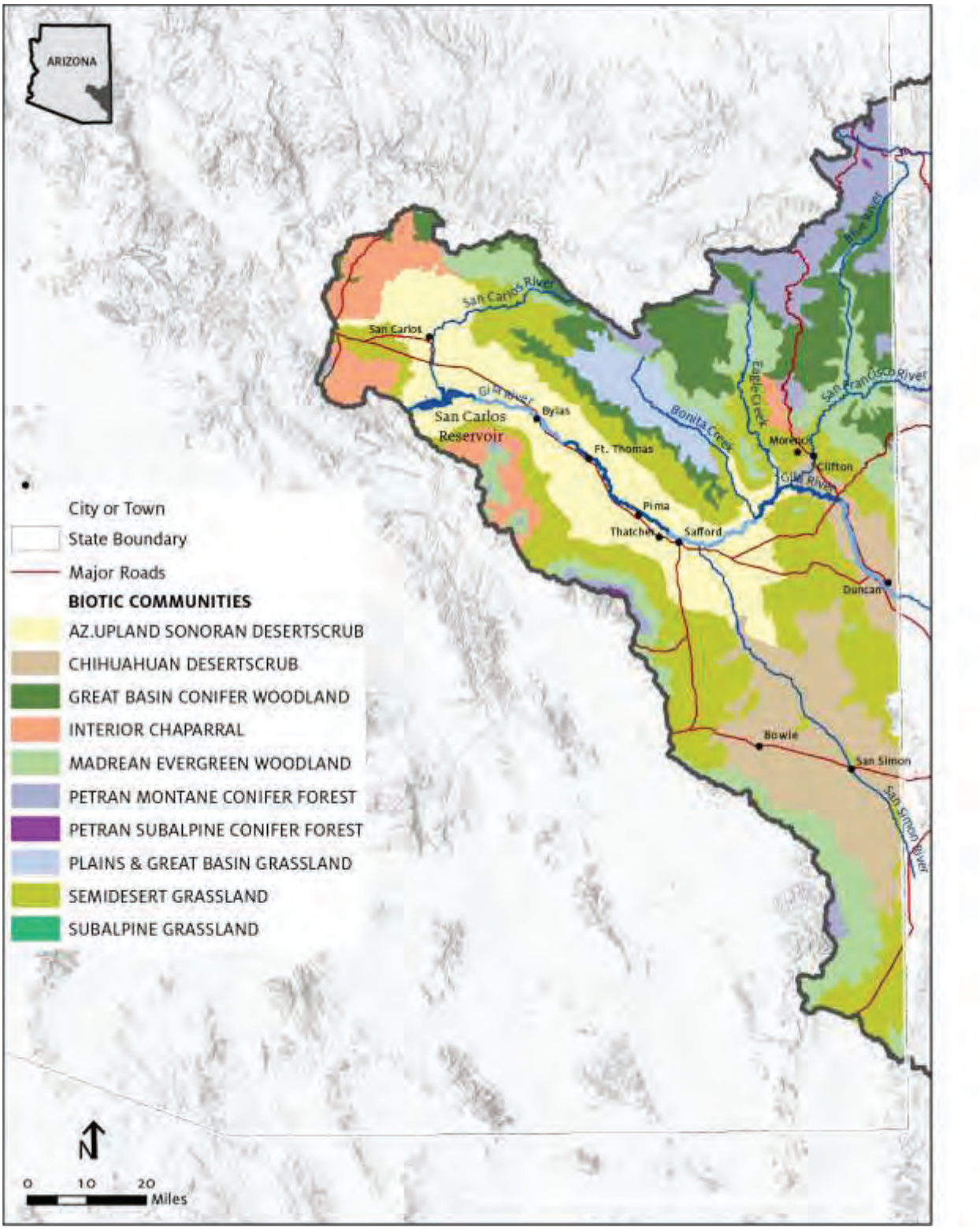


Figure 24. Biotic communities in the Upper Gila River Watershed in Arizona (Arizona Electronic Atlas 2009).

Each of the mapped vegetation types provides habitat for a rich assemblage of plants and wildlife, including native terrestrial and aquatic species listed as threatened or endangered under the Endangered Species Act. Twenty-one federally listed plant and wildlife species have the potential to occur in the Upper Gila River Watershed (Appendix B; USFWS 2018a). The U.S. Fish and Wildlife Service designates critical habitat (areas considered essential for survival) for each species listed as threatened or endangered; twelve species have designated critical habitat in the watershed: Gila chub, loach minnow, razorback sucker, spikedace, Chiricahua leopard frog, narrow-headed garter snake, northern Mexican garter snake, Mexican spotted owl, southwestern willow flycatcher, Mount Graham red squirrel, jaguar, and yellow-billed cuckoo. In addition, numerous plant and wildlife species are considered state-listed special-status species and have the potential to occur in the watershed; these species are listed in Appendix B (AGFD 2018). Descriptions of the vegetation types are provided in the following sections, including reference to any potentially associated federally-listed plant and wildlife species. Special-status species associated with riparian and aquatic habitats along the Upper Gila River mainstem are described in Appendix C.

Great Basin Conifer Woodland

Great Basin Conifer (pinyon-juniper) Woodlands cover large areas at elevations from about 5,000 to 7,500 feet (Arizona Department of Water Resources 2009) that receive about 12 to 20 inches of annual precipitation. Found mostly in northern Arizona and scattered parts of southeastern Arizona (McClaran and Brady 1994), the pinyon-juniper woodland zone is adjacent to and surrounds montane conifer forests in Arizona; in southern Arizona these woodlands merge with the chaparral zone (Arizona Department of Water Resources 2009). Dominant tree species include one-seed juniper (*Juniperus monosperma*), Utah juniper (*J. osteosperma*), and pinyon pine (*Pinus edulis*) (McClaran and Brady 1994); other pines and junipers may be present depending on geography. The understory may consist of grassland, chaparral, or desert scrub (Arizona Department of Water Resources 2009). This vegetation type provides habitat for the Mexican wolf which uses mid- to high-elevation woodlands of mixed conifers, oaks, and pinyon pines for foraging. Areas with perennial bunch grass in the understory and canyon topography may also support the Federally Threatened New Mexican ridge-nosed rattlesnake.

In the Upper Gila River Watershed, Great Basin Conifer Woodland covers 11% of land and is found north of the Gila River. The Federally Threatened Zuni fleabane (*Erigeron rhizomatus*) is found in Great Basin Conifer Woodlands at elevations from 7,300 to 8,000 feet on usually north-facing slopes (occasionally east- or west-facing) up to 40 degrees (USFWS 1988).

Madrean Evergreen Woodland

Madrean Evergreen Woodlands range widely from the mountains of southeastern Arizona (and northwest to Yavapai County), to southwestern New Mexico, the Trans-Pecos Texas, and southward into the Sierra Madre of Mexico. Species composition varies greatly depending on geography and elevation, but typically includes evergreen and deciduous oaks (*Quercus* spp.), alligatorbark (*Juniperus deppeanal*), one-seed juniper, and Mexican pinyon (*Pinus cembroides*). At higher elevations, other oak species as well as any of several Madrean pines (such as Apache

pine [*Pinus engelmannii*], Chihuahua pine [*P. leiophylla*], Arizona pine [*P. arizonica* var. *arizonica*], pino triste [*P. lumholtzii*], Durango pine [*P. duranensis*], and Cooper's pine [*P. cooperi*]) become co-dominant or replace those from lower elevations. The vegetation type supports the Federally Threatened Mexican spotted owl which is generally found in dense, multi storied forests of mixed conifers and evergreens. It also provides habitat for the Mexican wolf.

In the Upper Gila River Watershed, Madrean Evergreen Woodland covers 13.5% of land, generally at elevations from 4,200 to 8,000 feet. Oak species characteristic of this community in southeast Arizona include silverleaf oak (*Quercus hypoleucoides*) and netleaf oak (*Q. rugosa*) (Brown 1982). The Federally Endangered Arizona hedgehog cactus (*Echinocereus triglochidiatus* var. *arizonicus*) may be found in Madrean Evergreen Woodland where it is adjacent to Interior Chaparral, with a more open canopy. The hedgehog cactus is threatened by multiple human uses including road and utility construction, off-road vehicle use, and illegal collecting (Fletcher 1984).

Petran Montane Conifer Forest

Petran Montane (Rocky Mountain) Conifer Forests commonly occur between about 6,500 to 10,000 feet where moisture is relatively limited. At lower elevations, the forest may be exclusively ponderosa pine (*Pinus ponderosa*). At higher elevations, the forest contains a mix of conifers that may include Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), limber pine (*Pinus flexilis*), blue spruce (*Picea pungens*), and southwestern white pine (*Pinus strobiformis*), with ponderosa pine on warmer slopes. Aspen (*Populus tremuloides*) and Gambel oak (*Quercus gambelii*) are prominent in these forests following disturbances. (Brown 1982). Many stands of ponderosa pine are relatively open, with an understory of grasses, forbs, shrubs and broadleaf trees (Hendricks 1985). This vegetation type provides habitat for the Federally Endangered Mount Graham red squirrel which requires old-growth montane conifer forests and woodland.

In the Upper Gila River Watershed, Petran Montane Conifer Forest covers 7.5% of land and is most prevalent in the northeast portion, with small patches in the southern portion on the slopes surrounding Mt. Graham, Flys Peak, and Chiricahua Peak.

Petran Subalpine Conifer Forest

Petran Subalpine Conifer Forests are found at high elevations, from approximately 8,000 to 12,500 feet. These forests are typically composed of Engelmann spruce (*Picea engelmannii*), with subalpine/corkbark fir (*Abies lasiocarpa*) co-dominant. Aspen may be found in lower elevation areas following disturbance, and blue spruce is occasionally common in canyons and other lower-elevation locations. Limber pine and bristlecone pine (*Pinus aristata*) may be found on higher ridges, while wetter sites may contain Rocky Mountain maple (*Acer glabrum*), Bebb willow (*Salix bebbiana*), Scouler's willow (*Salix scouleriana*), blue elderberry (*Sambucus nigra* ssp. *cerulea*), thin-leaved alder (*Alnus incana* ssp. *tenuifolia*), or bitter cherry (*Prunus emarginata*) (Brown 1982). This vegetation type provides habitat for the Mexican wolf.

In the Upper Gila River Watershed, Petran Subalpine Conifer Forest accounts for just 0.1% of the area and is found in the mountains surrounding the community of Alpine in the northeast portion of the watershed, as well as in the southeast around Mt. Graham and between Flys Peak and Chiricahua Peak.

Chihuahuan Desert Scrub

The Chihuahuan Desert Scrub covers large expanses of land from southeast Arizona to southwest Texas and south to north-central Mexico. Generally found at elevations from 1,300 to 5,000 feet throughout its range (Brown 1982), but mostly above 3,500 feet in Arizona (Hendricks 1985), the most common species are creosote bush (*Larrea tridentata*), tarbush (*Flourensia cernua*), whitethorn acacia (*Acacia neovernicosa*) (Brown 1982), and sandpaperbush (*Mortonia scabrella*), often forming nearly pure stands of each (Hendricks 1985). Various agave (*Agave* spp.), beargrass (*Nolina* spp.), yucca (*Yucca* spp.), and a variety of woody shrubs may be present (Brown 1982), as well as a diverse assemblage of herbaceous perennials and small cacti (Hendricks 1985). This vegetation type provides habitat for northern aplomado falcon and the Federally Endangered jaguar which both hunt in the desert scrublands of southeastern Arizona. Ocelots, a Federally Endangered species, are also known to use this vegetation type in areas where stand density is high providing adequate cover for foraging.

In the Upper Gila River Watershed, Chihuahuan Desert Scrub is near its northwestern extent, and may occasionally grade into Sonoran Desert vegetation types. It is found throughout the upstream end of the Gila Box, as well as large expanses of the southern portion of the watershed, covering a total of 15.1% of the area.

Interior Chaparral

Interior Chaparral is found throughout Arizona to Texas and south into Mexico, growing at elevations ranging from 3,000 to 8,000 feet, below woodland or coniferous forest and above grassland or desert scrub. Interior Chaparral consists of deep-rooted evergreen shrubs and trees that have broad, sclerophyllous leaves. Of the over 50 shrub species in this community, the most common include shrub live oak (*Quercus turbinella*), sugar sumac (*Rhus ovata*), hollyleaf buckthorn (*Rhamnus crocea*), manzanitas (*Arctostaphylos* spp.), birchleaf mountain mahogany (*Cercocarpus breviflorus*), yellowleaf silktassel (*Garrya flavescens*), brickellbush (*Brickellia californica*), California flannelbush (*Fremontodendron californicum*), and ceanothus (*Ceanothus* spp.) (Brown 1982). Shrub canopy cover ranges from 80% or more on wetter sites, to 40% on dryer sites, where annual and perennial grasses and forbs may be found more commonly (Hendricks 1985).

In the Upper Gila River Watershed, Interior Chaparral covers 5.7% of the land, and is primarily found in the northwestern portion with an additional patch stretching northwest from Morenci Mine, at elevations from 3,400 to 7,000 feet. The Federally Endangered Arizona hedgehog cactus (*Echinocereus triglochidiatus* var. *arizonicus*) may be found in Interior Chaparral where it has a more open canopy, adjacent to Madrean Evergreen Woodland.

Sonoran Desert Scrub

Where it occurs in Arizona, Sonoran Desert Scrub is sparsely vegetated, composed of low-growing trees, shrubs, cacti, and perennial herbs. Common species include saguaro (*Carnegiea gigantea*), palo verde (*Cercidium spp.*), bursage (*Ambrosia spp.*), and creosote bush (McClaran and Brady 1994). This vegetation type provides habitat for the lesser long-nosed bat and the Mexican long-nosed bat which are both Federally Endangered and both feed on the saguaro cactus and other desert scrub plants. In addition, the northern aplomado falcon and Federally Endangered jaguar use desert shrublands for foraging.

In the Upper Gila River Watershed, Sonoran Desert Scrub is found from 2,350 to 4,700 feet in elevation. It occupies 18.2% of land in the watershed and is the dominant vegetation type along the Gila River in the lower half of the upstream end of the Gila Box and throughout the downstream end to below the reservoir. The Federally Endangered Arizona cliffrose (*Purshia subintegra*) is found in Sonoran Desert Scrub, and is threatened by grazing, urbanization, pesticides, inundation, off-road vehicle use, and development activities associated with petroleum and mineral exploration, roads, and utility corridors (USFWS 1995). Wright's marsh thistle (*Cirsium wrightii*) is a Candidate Species for listing as Federally Endangered or Threatened and has the potential to occur in Sonoran Desert Scrub, though it is thought to now be extirpated from Arizona. It is typically found in seeps, marshes, and edges of streams and ponds, and is threatened by loss of habitat due to alteration of hydrology, introduced plants, drought, and cattle impacts (USFWS 2018b).

Plains and Great Basin Grassland

Plains and Great Basin Grasslands are scattered throughout the southwest, from southern Colorado and northwestern Texas to west-central Arizona and south into Chihuahua, Mexico (Brown 1982). Primarily composed of mixed or short-grass communities, Plains and Great Basin Grasslands are widespread at elevations generally from 5,000 to 7,000 feet that receive an average of 17 inches of rain per year (Hendricks 1985). Eurasian annual species such as cheatgrass (*Bromus tectorum*) have largely replaced the native bunchgrasses, and portions of the grasslands are being colonized by shrubs due to grazing and fire-suppression practices (Grahame and Sisk 2002). In Arizona, plains grasslands consist primarily of short grama grasses (*Bouteloua* spp.), blue oat grass (*Helictotrichon sempervirens*), and black oat (*Avena strigose*), with shrub species absent or nearly absent (Hendricks 1985). The grasslands of southeastern Arizona provide hunting habitat for the northern aplomado falcon which also inhabits oak savannah and desert shrublands.

In the Upper Gila River Watershed, Plains and Great Basin Grasslands are found on 3.4% of the land at elevations from 4,800 to 6,700 feet. The largest segment is in the San Carlos Reservation; several smaller segments are located to the northeast.

Semidesert Grassland

Semidesert Grasslands are found from Trans-Pecos Texas to southeast Arizona and south into Mexico. These grasslands are located at higher elevations than desert scrub, and lower elevations than evergreen woodland, chaparral, or plains grassland. Semidesert Grasslands

were originally dominated by perennial bunchgrasses (Brown 1982). However, drought and heavy grazing by cattle, sheep, and goats have contributed to the evolution of these grasslands into semi-arid mixed high desert (Gila Watershed Partnership 2012), while elsewhere the grasslands face competition from a variety of tree, shrub, and cactus life-forms. The most characteristic perennial grass species are tobosa grass (*Pleuraphis mutica*) and black grama (*Bouteloua eriopoda*) (Brown 1982). The grasslands of southeastern Arizona provide hunting habitat for the northern aplomado falcon which also inhabits oak savannah and desert shrublands.

In the Upper Gila River Watershed, Semidesert Grassland is the most abundant vegetation type, occupying 25.4% of the land. It is found at elevations from 3,300 to 6,200 feet in large patches throughout the watershed, except it is not found in the northeast portion. Wright's marsh thistle (*Cirsium wrightii*) is a Candidate Species for listing as Federally Endangered or Threatened, and has the potential to occur in Semidesert Grassland, though it is thought to now be extirpated from Arizona.

Invasive species

Certain non-native invasive species are of particular concern due to their potential to spread explosively and ability to impact wildlands, which may cause serious ecological impacts to plant and animal communities. Within the Upper Gila River Watershed, particularly noxious terrestrial plants include non-native annual grasses, buffel grass (*Pennisetum ciliaris*), bull thistle (*Cirsium vulgare*), giant reed (*Arundo donax*), musk thistle (*Carduus nutans*), onion weed (*Asphodelus fistulosus*), Russian knapweed (*Acroptilon repens*), Russian thistle (*Salsola tragus*), Sahara mustard (*Brassica tournefortii*), Scotch thistle (*Onopordum acanthium*), sweet resin bush (*Euryops multifidus*), tocalote or Maltese star-thistle (*Centaurea melitensis*), and yellow star-thistle (*Centaurea solstitialis*) (AGFD 2012b and Brandau, personal communication). Information on these documented plant species is provided in Table 8 as well as the *Riparian habitat* section for tamarisk.

Table 8. Noxious terrestrial plants known to occur within Upper Gila River Watershed.

Scientific name	Common name	Status[1] (Arizona/USDA)	Family	Lifeform	Location within Upper Gila River Watershed	Ecological threat[2]
Acroptilon repens	Russian knapweed	PNW, RNW/–	Asteraceae	perennial herb		Can cause chewing disease in horses. Native to Eurasia; introduced into the United States in the early 1900s.
Arundo donax	giant reed	–/–	Poaceae	perennial grass		Invades wetlands; competes for water, nutrients and radiation; suppresses and excludes native vegetation which degrades wildlife habitat, increases fire risks, and interferes with flood control. Native to India; introduced into the United States in the early 1800s for ornamental purposes.
Asphodelus fistulosus	onion weed	–/noxious	Asphodelaceae	annual to short-lived perennial herb		Found in roadsides, pastures, disturbed areas, grasslands, and suburban settings; drought resistant and prefers sandy or gravelly soils. Native to the Mediterranean region and from western Asia to northern India.
Brassica tournefortii	Sahara mustard	–/–	Brassicaceae	annual herb		Prefers disturbed areas such as roadsides and abandoned fields. Native to Africa, Asia, and Europe.
Carduus nutans	musk thistle	–/–	Asteraceae	biennial herb		Invades a variety of disturbed areas. Unpalatable to livestock. Once established, can spread rapidly due to high seed production (120,000 seeds/plant). Native to Western Europe; accidentally introduced into the United States in the early 1900s.
Centaurea melitensis	tocalote or Maltese star-thistle	–/–	Asteraceae	annual herb		Prefers disturbed areas such as grasslands, open woodlands, roadsides, fields, and pastures. Native to Europe and North America.
Centaurea solstitialis	yellow star-thistle	PNW, RNW/–	Asteraceae	annual herb		Invades woodlands, fields, pastures and roadsides.

Scientific name	Common name	Status[1] (Arizona/USDA)	Family	Lifeform	Location within Upper Gila River Watershed	Ecological threat[2]
Cirsium vulgare	bull thistle	–/–	Asteraceae	annual or biennial herb		Invades disturbed areas including forest clearcuts, riparian areas, and pastures. Can form dense thickets, displacing other vegetation. Unpalatable to wildlife and livestock and reduces the forage potential of pastures. Native to Europe, western Asia, and northern Africa; thought to have been introduced to the eastern United States during colonial times and the western United States in the late 1800s.
Euryops multifidus	sweet resin bush	RNW/–	Asteraceae	shrub		Displaces native plants and forms monospecific stands. Native to Africa; introduced to the United States in 1930s (Invasive Species Specialist Group 2015).
Onopordum acanthium	Scotch thistle	PNW, RNW/–	Asteraceae	biennial herb		Major agricultural weed in western United States. With enough moisture, it can resprout from roots cut up during cultivation. Produces over 20,000 seeds that can be dispersed by wind, water, or animal fur.
Pennisetum ciliare (also referred to as *Cenchrus ciliaris*)	buffel grass	PNW, RGNW/–	Poaceae	perennial grass		Can form extensive dense monocultures excluding native species and promoting intense and frequent fires. Native to Africa, Asia, and Europe (Invasive Species Specialist Group 2015).
Salsola tragus	Russian thistle	–/–	Chenopodiaceae	annual herb		After matures, detaches from the root system and tumbles in the wind, spreading seed. Native to Eurasia.
Tamarix ramosissima and other *Tamarix* species or hybrids	tamarisk	–/–	Tamaricaceae	Shrub		Invades stream banks, sandbars, lake margins, wetlands, moist rangelands, and saline environments. Can crowd out native riparian species, diminish early successional habitat, and reduce water tables; interferes with hydrologic process.

Scientific name	Common name	Status[1] (Arizona/USDA)	Family	Lifeform	Location within Upper Gila River Watershed	Ecological threat[2]
n/a	non-native annual grasses	Various/–	Poaceae	annual grass	widespread	Replace native grassland and shrublands, increase fire risk, reduce diversity

[1] Status

– Not rated

Arizona

PNW Prohibited noxious weed

RGNW Regulated noxious weed

RNW Restricted noxious weed

U.S. Department of Agriculture (USDA) federal noxious weed list

noxious Listed on the federal noxious weed list

[2] Source: Swearingen and Bargeron 2016 (unless otherwise cited).

RIPARIAN AND AQUATIC HABITATS

Riparian areas in Arizona and throughout the southwest are important habitats for wildlife and are considered the most productive and ecologically diverse habitats in the state (AZGFD 2012). Riparian areas provide fish and wildlife habitat, water supply to livestock, serve as wildlife movement corridors, and provide a variety of ecological functions and ecosystem services such as moderating local air temperature and humidity, stabilizing stream banks, contributing nutrients to streams, attenuating flood waters, and providing recreational opportunities and aesthetic enjoyment for humans. Riparian communities and aquatic habitat make up less than 2% of the total land area in the arid western United States, but in Arizona 70% of all threatened and endangered vertebrate species (AGFD 2012b) and up to 80% of all species depend on riparian areas.

KEY TAKEAWAYS

- Riparian and aquatic habitats are unique and valuable ecosystems that warrant special protection, conservation, and in some cases restoration to preserve their ecological functions and ecosystem services that benefit fish, wildlife, and humans.
- Special-status species protection may conflict with other land uses, including human water needs, development, agriculture, and recreation.
- Particular threats to riparian and aquatic systems include drought, recreational use, water diversion, and non-native invasive species.
- Fish are disproportionately at risk in the watershed, as evidenced by the occurrence of designated critical habitat for four native fish species.
- Streams in the watershed are "free-flowing" but aquatic habitat connectivity is interrupted by many small dams.
- The watershed may bear a disproportionately large portion of the burden of protecting endangered species; i.e., development in the relatively pristine portions of the watershed might be limited because species have previously suffered extirpation in more heavily developed areas.
- Preserving riparian habitat will maintain and improve dispersal, access to suitable habitat, population structure, and genetic diversity of a variety of species and will provide valuable ecosystem services that benefit humans.
- Invasive species, such as tamarisk (salt cedar) and Russian knapweed, compete with native species for resources in the watershed and can negatively impact human uses.
- The recently introduced tamarisk leaf beetle is projected to reach the watershed in the near future but, based on data through 2017, has not yet done so. It is expected to defoliate tamarisk trees leading to some mortality, a decrease in cover, and a reduction in flower/seed production. The beetle also poses a potential threat to the Southwestern Willow flycatcher (SWFL), a Federally Endangered bird species that uses the non-native trees as habitat. Defoliation of tamarisk may also impact ecosystem services including human recreational use and aesthetic enjoyment.
- Because high quality SWFL habitat corresponds strongly with vegetation density and the riparian vegetation is mostly composed of tamarisk, it is anticipated that these areas will experience the greatest impact initially following beetle colonization unless strategic planting of native vegetation is undertaken prior to arrival of the beetle.
- Declining groundwater levels will eventually reduce the amount of surface water available for fish, wildlife, and human uses.

Riparian and aquatic habitats in Arizona have been changed considerably from their pre-settlement condition. Among the major sources of impact are persistent drought, impacts to riparian areas and uplands from livestock management, and introduction of non-native species (AGFD 2012b). Other landscape changes and land/water uses that have impacted riparian and

aquatic systems include wildfire, stream diversions and impoundments, vegetation removal, pollution, and recreational activities. Drought conditions in Arizona have recently been at their most extreme within recorded history, resulting in the drying of formerly perennial springs and reduced surface water supply and groundwater recharge (AGFD 2012b). The reduced availability of water resources substantially impacts aquatic and riparian habitat functions and the species that depend on them.

Despite widespread impacts to aquatic and riparian systems in Arizona, the Upper Gila River Watershed contains areas of these habitats that remain relatively unaltered and continue to support native species and provide important ecological functions.

Riparian habitat

The Gila River flows free of large dams above the San Carlos Reservoir and sustains several perennial stretches that provide riparian and aquatic habitat for numerous plants and animals. Generally, riparian areas in portions of the upper watershed are richly vegetated with cottonwoods, native willows, sedges and grasses while other areas are dominated by the invasive tamarisk (*Tamarix ramosissima* and other *Tamarix* species or hybrids, herein referred to as "tamarisk") (Gila Watershed Partnership 2012). In the riparian communities within the Upper Gila River watershed, variation in vegetation composition and structure occurs both along the river length and across the valley width. The description of riparian habitat provided here is based largely on information for the mainstem Gila River corridor in the upper portion of the watershed, as little information is available on riparian habitat in the tributaries.

The densest riparian vegetation along the upper Gila River is generally found at downstream locations due to the agricultural return flows and areas in closest proximity to the river due to the availability of surface water or shallow groundwater. Historically, the river bottom was lined with willow (*Salix* spp.), cottonwood (*Populus* spp.), and mesquite (*Prosopis* spp.) based on surveys made in the mid- to late-1800s (Burkam 1972, Turner 1974, Webb et al. 2007). Recent research by the BLM suggests that giant sacaton (*Sporobolus wrightii*) may have also been a dominant plant species in some riparian bottomlands. Most of the native riparian vegetation was severely scoured during the 1905–1909 flood period and subsequently replaced by tamarisk soon after its introduction in the early 1920s (Burkham 1972). Tamarisk was planted along the river channel to control riverbank erosion and protect adjacent cultivated fields. In the Safford Valley, tamarisk has replaced most of the native riparian vegetation and associated habitat over the last century and continues to be the dominant tree species in the riparian corridor (Figure 25). Tamarisk can change the soil under the trees by increasing the soil salinity, reducing the ability of other plant species to grow there. Tamarisk density in riparian areas can range widely, from nearly continuous to only 10% tamarisk cover, and canopy heights are typically no more than 16 feet (Stillwater Sciences 2014). Some isolated stands of native species, including Fremont cottonwood (*Populus fremontii*), Goodding's willow (*Salix gooddingii*), narrowleaf (coyote) willow (*Salix exigua*), mulefat (*Baccharis salicifolia*), desert broom (*B. sarothroides*), Emory's baccharis (*B. emoryi*), and mesquite (*Prosopis glandulosa* and/or *P. velutina*) persist at low cover densities (Orr et al. 2014).

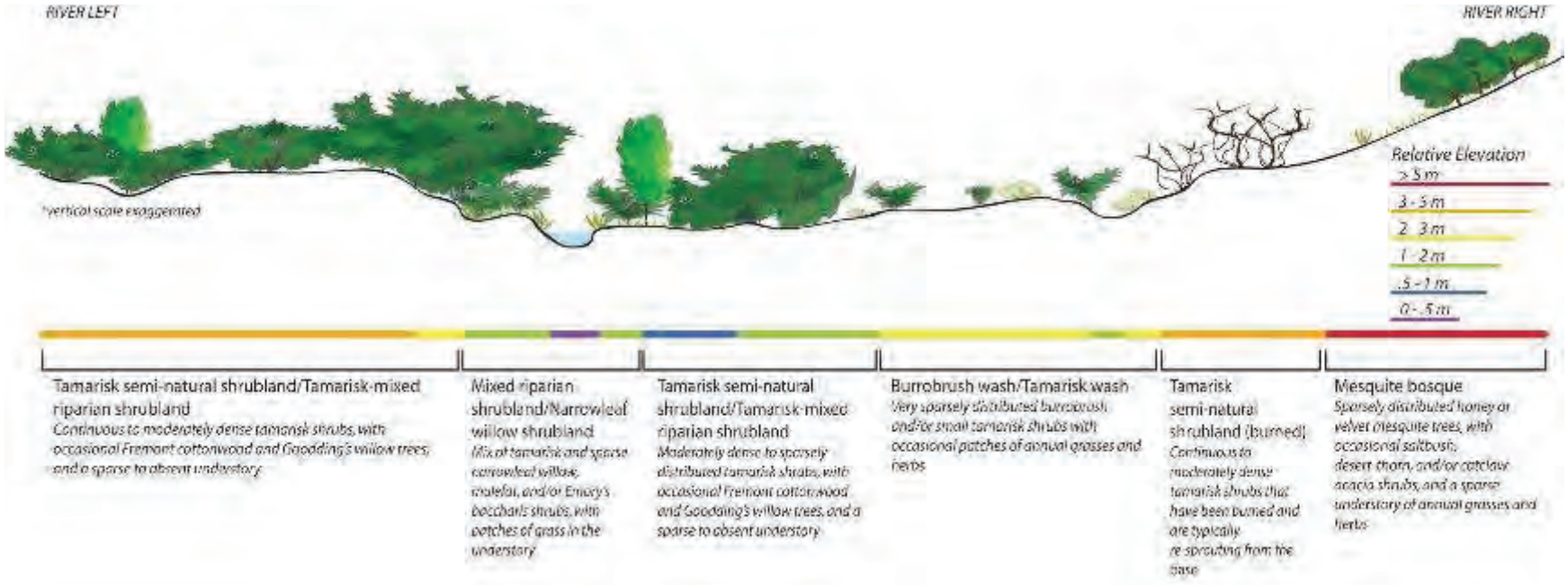


Figure 25. Illustration of the typical cross-sectional distribution of vegetation in the Gila River valley downstream of Pima, looking downstream (illustration by Stillwater Sciences).

There are also stands of cottonwood-Goodding's willow woodland in the Upper Gila River, typically along the outer margin of the riparian corridor and the banks of abandoned and/or high flow channels, which form a dense, high canopy 15–30 ft tall. Most cottonwood and Goodding's willow trees are mature or decadent, appearing to have been established soon after the 1983 and 1993 flood events, and there appears to be very little to no recent natural recruitment of either species. Tamarisk, and less often mesquite, still dominates the sub-canopy in these stands. In general, the herbaceous layer is very sparse to absent and the ground layer has a moderate cover of downed wood and other organic litter. Cottonwood-Goodding's willow woodland typically occurs where substrates are silty or sandy and generally dry, and at elevations where they are frequently inundated by floods of lower magnitude but are not subject to intense scouring (Stillwater Sciences 2014).

Riparian vegetation provides habitat for many species in the watershed including seven federally listed species: Chiricahua leopard frog, narrow-headed garter snake, northern Mexican garter snake, least tern, southwestern willow flycatcher, yellow-billed cuckoo, and New Mexico meadow jumping mouse. Each of these species is dependent on the habitat features provided by riparian vegetation during some or all of its life cycle. The relatively large number of special-status species in this vegetation type highlights the importance of riparian habitat for conservation of biodiversity. Further information regarding species of special concern for riparian restoration in mainstem portions of the Upper Gila River can be found in Appendix C.

Aquatic habitat

Aquatic habitat in the Upper Gila River Watershed occurs mainly as flowing water in rivers and streams, but springs, seeps, cienegas, stock ponds, and natural ponds and lakes (including beaver ponds) also provide habitat for aquatic species in the watershed. Perennial and intermittent waters above 5,000 ft elevation may be designated by ADEQ as providing cold water aquatic and wildlife uses, whereas waters below 5,000 ft elevation can be designated for warm water aquatic and wildlife uses. The majority of surface waters in the upper Gila River with designated aquatic and wildlife uses are in the warm water category. Cold water aquatic and wildlife uses in the watershed are designated only in the highest elevation headwater streams. A surface water (e.g., stream) may be designated as an Outstanding Arizona Water if it is free flowing, has good water quality, and is of exceptional recreational or ecological significance and/or provides essential habitat to support a threatened or endangered species. The lowermost 14.7 miles of Bonita Creek and the entirety of KP Creek, a headwater tributary of the Blue River, are designated Outstanding Arizona Waters in the Upper Gila River Watershed.

The mainstem Upper Gila River downstream of the Gila Box is characterized by a wide, low gradient channel composed predominantly of sand and lesser amounts of gravel substrate. Several agricultural diversions are located within this section of the Gila River that partially contribute to decreased flows in downstream sections of the river. The river in this area provides perennial aquatic habitat that supports fish and other aquatic and semi-aquatic species. Streamflow is typically greatest in the winter and lowest in the summer, but high

intensity and short-duration high flow events often occur during the summer when flows rise quickly and can exceed 50,000 cfs or more for a few hours to a few days. Within the Gila Box, the river becomes more confined with coarser gravel substrate (Orr et al. 2014). Perennial flows persist year-round in the Gila Box reach, with a similar seasonal pattern as described in the downstream reach. Three large perennial tributaries enter the Gila in this section including Bonita Creek, Eagle Creek, and the San Francisco River. Upstream of the Gila Box the river flows through the Duncan Valley where the channel is relatively wide with primarily sand substrate. Several diversions are located within this reach and flows often become intermittent during the summer months with all surface flow diverted during dry years (ADEQ 2002).

Major tributaries to the Upper Gila River include San Simon River, Bonita Creek, Eagle Creek, and the San Francisco River. Although considered a major tributary, the San Simon River provides little to no flow during the summer. The San Simon River is a low gradient ephemeral river that enters the Gila downstream of the Gila Box near the town of Solomon. Because it is often dry it is expected to provide little if any aquatic habitat for fish. Bonita Creek is a perennial tributary that enters the Gila River at the downstream end of the Gila Box about ten miles upstream of the Safford Valley. Bonita Creek flows for approximately 48 miles before joining the Gila River. Infiltration galleries for a public water system are located in Bonita Creek approximately four miles above its confluence with the Gila River (Hem 1950, as cited in ADEQ 2002). Bonita Creek is recognized as one of the state's outstanding resource waters and it is designated as a "Unique Water" (ADEQ 2002). Stream flows in Bonita Creek are largely perennial with some intermittent stretches. Bonita Creek has a similar seasonal pattern as most other streams in the Upper Gila River Watershed, with low summer flows and higher winter flows. Eagle Creek, another perennial tributary, empties into the Gila River about two miles downstream from the confluence of the San Francisco River. Flow in Eagle Creek is supplemented by a water transfer from the Black River, a tributary to the Salt River. The water is subsequently pumped from Eagle Creek to Morenci and Clifton, Arizona where it is used for mining purposes and municipal supply (Hem 1950, as cited in ADEQ 2002). The San Francisco River watershed is the largest tributary to the Gila River, with perennial flows averaging 200 cfs to 400 cfs during the winter and 50 cfs to 100 cfs during the summer. The Blue River is a major tributary to the San Francisco River which enters approximately 18 miles upstream of the town of Clifton. Numerous tributaries to the San Francisco River and the Blue River provide coldwater habitat that supports trout and other native fish species (USFWS 2011).

Aquatic Species

Aquatic habitat within the Upper Gila Watershed supports numerous native and non-native fish species. Five threatened or endangered fish species occur within the upper Gila River, four of which have designated critical habitat in the watershed: Gila chub (*Gila intermedia*), loach minnow (*Tiaroga cobitis*), spikedace (*Meda fulgida*), and desert pupfish (*Cyprinodon macularius*). Although no longer found in the Upper Gila River, critical habitat has been designated for the endangered razorback sucker (*Xyrauchen texanus*). One additional listed fish species, the Gila topminnow (*Poeciliopsis occidentalis*) also occurs in the Upper Gila River Watershed on land managed by BLM (H. Blasius, BLM, pers. comm., June 2018). Gila trout (*Oncorhynchus gilae*) do not currently occur in the mainstem Gila River or its tributaries, but

there are plans to stock them in some tributaries to the Blue River (H. Blasius, BLM, pers. comm., June 2018). . Listing status and a brief description of their habitat association for these species is included in Appendix B. Other native fish species found in the Upper Gila Watershed include roundtail chub (*Gila robusta*), desert sucker (*Pantosteus clarkii*), Sonora sucker (*Catostomus insignis*), longfin dace (*Agosia chrysogaster*), and speckled dace (*Rhinichthys* o*sculus*).

Numerous non-native primarily warm water fish species also occur within the Upper Gila River Watershed. Channel catfish (*Ictalurus punctatus*), flathead catfish (*Pylodictis olivaris*), largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus*), and sunfish (*Lepomis* spp.) have been documented in San Carlos Reservoir (BOR 2004). and likely occur throughout most of the upper Gila River based on other observations reported in the San Francisco River (USFWS 2011). Fathead minnow (*Pimephales promelas*), red shiner (*Cyprinella lutrensis*), common carp (*Cyprinus carpio*), bullheads (*Ameiurus* spp.), and rainbow trout (*Oncorhynchus mykiss*) are also reported to occur in the San Francisco River (USFWS 2011). Western mosquitofish (*Gambusia affinis*) are also expected to occur throughout most of the mainstem and lower sections of most tributaries based on Whittier et al. (2011), although observations were not reported in San Carlos Reservoir or in the San Francisco River (BOR 2004 and USFWS 2011).

SECTION 5: LITERATURE CITED

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Appendices

Appendix A

Watershed Condition Indicators Worksheet

Watershed condition indicator	Organization working on the issue N/A if issue is not being addressed	Methods e.g., fish diversity and abundance surveys, aerial photo analysis, etc.	Priority level ranking between 15; 1 = low, 5 = high	Location in the watershed	Status Ongoing, future, completed
Water quality – impaired waters	University of Arizona (Natalie Brassill, Dr. Channah Rock)	Water sample collection to detect E. coli bacteria and turbidity as well as other water quality health components, river clean ups, education and outreach and planting of native species to slow overland flow	4	San Francisco - Blue confluence (impaired from E. coli bacteria)	Ongoing (combine efforts with native plantings to reduce erosion and allow more water infiltration to help reduce E. coli bacteria)
	ADEQ Water Quality Unit				
	BLM	Suspended sediment monitoring		San Simon River	Past and Future
Water quality – other	BLM	Water Quality Monitoring; salinity monitoring of soils and groundwater wells in San Simon River valley; salinity monitoring of suspended sediment in San Simon (future).		Gila Box, San Simon	Ongoing
		Suggested: UA (N. Brassill) can provide DNA source tracking to identify which species maybe causing impairments			
Water quantity – flow characteristics	USGS				
		Suggested: UA (N. Brassill) can measure flow when taking water samples using a flow meter and referencing USGS meters			
	BLM	Proper Functioning Condition Assessments; Stream gage (San Simon);		Through out the field office: Perennial and intermittent	Ongoing

Watershed condition indicator	Organization working on the issue N/A if issue is not being addressed	Methods e.g., fish diversity and abundance surveys, aerial photo analysis, etc.	Priority level ranking between 15; 1 = low, 5 = high	Location in the watershed	Status Ongoing, future, completed
		Rosgen classifications of streams including stream characteristics, flows, profiles, etc		streams; Springs/seeps supporting riparian biodiversity.	
Aquatic habitat – fragmentation					
Aquatic habitat – large woody debris	BLM	Proper Functioning Condition assessments			Ongoing
Aquatic habitat – channel shape and function	BLM	Proper Functioning Condition assessments			Ongoing
Aquatic biota - life form presence	BLM	Fish Surveys		Gila Box San Simon	Ongoing
Riparian vegetation – vegetation condition	BLM	Proper Functioning Condition assessments			Ongoing
Roads & trails – open road density	BLM	Travel Management Planning Resource Review		Gila San Simon	Ongoing
Roads & trails – road maintenance					
Roads & trails – proximity to water	BLM	Travel Management Planning Resource Review		Gila San Simon	Ongoing
Roads & trails – mass wasting					
Soils – soil productivity		Suggested: Plant native veg to help infiltrate water and bacteria			

Watershed condition indicator	Organization working on the issue N/A if issue is not being addressed	Methods e.g., fish diversity and abundance surveys, aerial photo analysis, etc.	Priority level ranking between 15; 1 = low, 5 = high	Location in the watershed	Status Ongoing, future, completed
Soils – soil erosion	BLM	Sediment traps and erosion monitoring		San Simon River Valley; Field Office Jurisdiction	Ongoing
	BLM	Suspended sediment monitoring			Past and future
	BLM	San Simon channel cross-sections			Ongoing
	BLM	Rangeland monitoring including soils			Ongoing
	BLM	Proper Functioning Condition Assessments			Ongoing
Soils – soil contamination					
Fire regime or wildfire – fire condition class					
Fire regime or wildfire – wildfire effects					
Forest cover – loss of forest cover					
Rangeland vegetation – vegetation condition	BLM	Rangeland health monitoring		Field Office	Ongoing
Terrestrial invasive species – extent and rate of spread	BLM	NISIMS data collection-National Invasive Species Information Management System (geospatial database for invasive species treatments,		Field Office	Ongoing

Watershed condition indicator	Organization working on the issue N/A if issue is not being addressed	Methods e.g., fish diversity and abundance surveys, aerial photo analysis, etc.	Priority level ranking between 15; 1 = low, 5 = high	Location in the watershed	Status Ongoing, future, completed
		occurrence and extent)			
Other watershed condition indicator	BLM	Recording rain gages for watershed characteristics: runoff, sediment monitoring in San Simon, etc.		Field Office	Ongoing
Other watershed condition indicator					

Appendix B

Special-status Species and Critical Habitat with Potential to Occur in the Upper Gila River Watershed

Table B-1. **Special-status species with potential to occur or with critical habitat designated within the upper Gila River Watershed Assessment Plan Area.**

Common and Scientific Name	Federal Listing Status [A]	Critical Habitat in the Upper Gila River Watershed (Y/N) [B]	Habitat Association [C]
Fish			
Razorback sucker *Xyrauchen texanus*	E	Y	Razorback sucker has been extirpated from the Upper Gila River Watershed but critical habitat for the species is designated within the watershed. Occupies a variety of habitat types from mainstem channels to slow backwaters of medium and large streams and rivers.[1] Spawns over gravelly substrates in lakes and rivers.[2]
Gila chub *Gila intermedia*	E	Y	Pools in smaller streams, springs, and cienegas (desert wetlands). Can survive in small artificial impoundments. Prefer quiet, deeper waters, especially pools, or remaining near cover including terrestrial vegetation, boulders, and fallen logs.[3]
Gila trout *Oncorhynchus gilae*	T	N	Occupies moderate- to high-gradient perennial mountain streams above 5,400 ft elevation, typically in narrow, steep-sided canyons and valleys. Requires water temperatures below 77°F. Cover needs include woody debris, undercut banks, boulders, deep water, overhanging vegetation.[4]
Spikedace *Meda fulgida*	E	Y	Mid-water habitats of runs, pools, and swirling eddies at depths less than 3.3 ft (1 m).[5] In larger streams they are often found near the mouth of tributary streams.[6]
Gila topminnow *Poeciliopsis occidentalis*	E	N	Headwater springs and vegetated margins and backwater areas of intermittent and perennial streams and rivers. Prefer shallow warm water habitat with moderate velocity and dense aquatic vegetation or algae mats.[7]
Desert pupfish *Cyprinodon macularius*	E	Y	Desert pupfish occur occupy a variety of aquatic habitats and can persist in a wide range of temperature and salinity conditions. They are found at elevations up to 4,000 feet. The desert pupfish was historically extirpated from Arizona but has been reintroduced at multiple locations including the upper Gila River watershed on BLM managed lands.[8]
Loach minnow *Tiaroga cobitis*	E	Y	Small to large perennial streams; shallow, turbulent riffles with primarily cobble substrate and swift currents. Uses rocks for resting and spawning but fine sediment

Common and Scientific Name	Federal Listing Status [A]	Critical Habitat in the Upper Gila River Watershed (Y/N) [B]	Habitat Association [C]
			must be absent from interstitial spaces. Distribution: portions of the Gila River and its tributaries—the West, Middle, and East forks.[9]

Common and Scientific Name	Federal Listing Status [A]	Critical Habitat in the Upper Gila River Watershed (Y/N) [B]	Habitat Association [C]
Amphibians			
Chiricahua leopard frog *Lithobates chiricahuensis*	T	Y	Occupies a variety of valley and montane aquatic habitats like springs, pools, lakes, cattle tanks, reservoirs, streams, and rivers. Currently limited to headwater streams and springs and livestock tanks [10]; typically found at elevations between 3,281 and 8,890 feet.
Reptiles			
Narrow-headed garter snake *Thamnophis rufipunctatus*	T	P	Strongly associated with clear, rocky streams, primarily uses pool and riffle habitat deeper containing cobbles and boulders. Elevations between 2,300–8,200 ft in Petran Montane Conifer Forest, Great Basin Conifer Woodland, Interior Chaparral, and the Arizona Upland subdivision of Sonoran Desert scrub communities
Northern Mexican gartersnake *Thamnophis eques megalops*	T	P	Strongly associated with permanent water with vegetation, including stock tanks, ponds, lakes, cienegas, cienega streams, and riparian woods. In Arizona it is usually found in or near water in highland canyons with pine-oak forest and pinyon-juniper woodland, sometimes in mesquite grassland and desert areas, especially along valleys and stream courses.
New Mexican ridge-nosed rattlesnake *Crotalus willardi obscurus*	T	Y	Uses rock shelters and perennial bunch grasses for cover in montane woodlands, bottoms of steep, rocky canyons with intermittent streams or talus slopes. Elevations between 5,000–8,500 feet.
Birds			
Northern aplomado falcon *Falco femoralis septentrionalis*	EX	N	A non-essential experimental population is listed for Arizona. Experimental populations are a designation under the ESA applied to a population of a threatened or endangered species prior to reestablishing it in an unoccupied portion of its former range. Mainly found in palm and oak savannahs, yucca-mesquite and other desert grassland/shrub associations.
Least tern *Sterna antillarum*	E	N	Beaches and islands sparsely vegetated due to tidal and river action, near shallow waters. Primarily coastal, but also breeds along inland rivers of the U.S., including Arizona.

Common and Scientific Name	Federal Listing Status [A]	Critical Habitat in the Upper Gila River Watershed (Y/N) [B]	Habitat Association [C]
Yellow-billed cuckoo *Coccyzus americanus*	PT	P	Nests in low to moderate elevation riparian woodlands, primarily in willows. Habitat in Arizona includes box elder (*Acer negundo*), Arizona walnut (*Juglans major*), Arizona sycamore (*Platanus wrightii*), oak, netleaf hackberry, velve ash, Mexican elderberry, tamarisk, and seepwillow, mesquite, Fremont cottonwood.
Mexican spotted owl *Strix occidentalis lucida*	T	Y	Dense, multi storied montane forests of mixed conifer and madrean evergreens. Deep, cool, fractured canyons.
Southwestern willow flycatcher *Empidonax traillii extimus*	E	Y	Breeds in areas from near sea level to over 8,500 ft elevation (Durst et al. 2008) in riparian vegetation or other wetlands. Establishes nesting territories, builds nests, and forages where mosaics of relatively dense and expansive growths of trees and shrubs are established, near or adjacent to surface water or underlain by saturated soil (Sogge et al. 2010).
Mammals			
Mount Graham red squirrel *Tamiasciurus hudsonicus grahamensis*	E	Y	Mature to old-growth montane forests containing mixed conifer, spruce-fir [1] and less often in Douglas-fir [2]. Requires full forested canopy cover for travel and protection from predators [1] and is seldom found below 9,500 ft elevation [2]
New Mexico meadow jumping mouse *Zapus hudsonius luteus*	E	Y	Endemic to New Mexico, western Arizona, and southern Colorado. Nests in dry soils, but uses moist, dense riparian and wetland vegetation. Depends on two riparian communities: persistent emergent herbaceous wetlands (i.e., beaked sedge and reed canary grass alliances); and scrub-shrub wetlands (i.e., riparian areas along perennial streams that are composed of willows and alders).
Lesser long-nosed bat *Leptonycteris curasoae yerbabuena*	E	N	Requirements include caves and mines for roosting and healthy stands of saguaro cactus and paniculate agaves for foraging. In southwestern Arizona, the Sonoran desert scrub vegetation community provides early summer forage base. In southeastern Arizona, the semi-desert grassland and oak woodlands provide late summer agave.

Common and Scientific Name	Federal Listing Status [A]	Critical Habitat in the Upper Gila River Watershed (Y/N) [B]	Habitat Association [C]
Mexican long-nosed bat *Leptonycteris nivalis*	E	N	Desert scrub, wooded elevations at higher elevations. Require caves or abandoned mines and tunnels. Feeds on agave and cactus nectar and pollen.
Jaguar *Panthera onca*	E	Y	Marginal habitat in open arid areas of northwestern Mexico and the southwestern U.S., includes habitat containing thornscrub, desert scrub, lowland desert, mesquite grassland, Madrean oak woodland, and pine-oak woodland communities.
Ocelot *Leopardus pardalis*	E	N	Dense vegetation cover is required, generally recorded in subtropical and tropical thornscrub, and tropical deciduous forests. A depleted population exists in southeastern Arizona.
Grey wolf *Canis lupus*	PEX	N	Currently extirpated from Arizona, but a non-essential proposed experimental population is listed for Arizona. Occupies a wide range of habitats including temperate forests, mountains, tundra, taiga, and grasslands.
Mexican wolf *Canis lupus baileyi*	EX	N	A non-essential experimental population is listed for parts of Arizona, where the only known populations exist. Most often recorded in mid- to high-elevation woodlands, including oak, pinyon pine, juniper, ponderosa pine and mixed conifer forests. May be dependent on ungulate populations more than vegetation types. Most historical records occur above 4,500 ft elevation.
Plants			
Arizona cliffrose *Purshia subintegra*	E	N	Gravelly clay or loam soils over limestone located in low rolling hills found in desert formations often dominated by creosote bush (*Larrea tridentata*), rabbit brush (*Chrysothamnus nauseosus*), false palo verde (*Canotia holocantha*), and catclaw acacia (*Senegalia greggii*).
Arizona hedgehog cactus *Echinocereus triglochidiatus* var. *arizonicus*	E	N	Dacite or granite bedrock, open slopes, in narrow cracks between boulders, and in the understory of shrubs in the ecotone between Madrean Evergreen Woodland and Interior Chaparral[11].

Common and Scientific Name	Federal Listing Status [A]	Critical Habitat in the Upper Gila River Watershed (Y/N) [B]	Habitat Association [C]
Wright's marsh thistle *Cirsium wrightii*	C	N	Springs, seeps, marshes, stream banks, often in alkaline soil[11].
Zuni fleabane *Erigeron rhizomatus*	T	N	Chinle shale and associated soils in pinyon-juniper association.

A. Federal Listing Status: E = Endangered; Listed in the Federal Register as being in danger of extinction; T = Threatened; Listed as likely to become endangered within the foreseeable future; C = Candidate for listing; PEX = Proposed Experimental Population, Non-Essential; EX = Experimental Population, Non-Essential.

B. Critical Habitat: Y = Yes; N = No; P = Proposed

C. Habitat association information comes from the USFWS Environmental Conservation Online System (ECOS), or NatureServe Explorer databases, unless otherwise noted

1 AGFD. 2002a. *Xyrauchen texanus*. Unpublished abstract compiled and edited by the Heritage Data Management System, Arizona Game and Fish Department, Phoenix, AZ. 5 pp.

2 USFWS. 1998. Razorback sucker (*Xyrauchen texanus*) Recovery Plan. Denver, Colorado.

3 https://www.federalregister.gov/articles/2002/08/09/02-19872/endangered-and-threatened-wildlife-and-plants-listing-the-gila-chub-as-endangered-with-critical#h-8

4 https://www.federalregister.gov/articles/2005/05/11/05-9121/endangered-and-threatened-wildlife-and-plants-reclassification-of-the-gila-trout-oncorhynchus-gilae; and USFWS 2002. Gila trout recovery plan (third revision). Albuquerque, New Mexico. 60 pages.

5 AGFD. 2002b. *Meda fulgida*. Unpublished abstract compiled and edited by the Heritage Data Management System, Arizona Game and Fish Department, Phoenix, AZ. 5 pp.

6 USFWS. 1990. Spikedace recovery plan. Prepared by P. C. Marsh, Arizona State University, Tempe for USFWS, Region 2, Albuquerque, New Mexico.

7 AGFD. 2001. *Poeciliopsis occidentalis occidentalis*. Unpublished abstract compiled and edited by the Heritage Data Management System, Arizona Game and Fish Department, Phoenix, AZ. 6 pp.

8 https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=E044#crithab; and H. Blasius, BLM, pers. comm., June 2018.

9 http://www.fws.gov/southwest/es/arizona/Documents/SpeciesDocs/Spikedace/SD-LM_pCH_FR_pub_10-28-10.pdf

10 http://www.gpo.gov/fdsys/pkg/FR-2011-03-15/pdf/2011-4997.pdf

11 https://www.fws.gov/southwest/es/arizona/Documents/Redbook/Arizona%20Hedgehog%20RB.pdf

12 http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=250066407

Appendix C

Native Species of Primary Concern for Riparian Restoration in the Mainstem Upper Gila River

Species of Concern for Riparian Restoration

The following sections describe several species of concern for riparian restoration along the mainstem of the upper Gila River, including the non-native invasive tamarisk as well as several special-status species (southwestern willow flycatcher, western yellow-billed cuckoo, and razorback sucker). Other invasive plant species affect waterways and restoration areas including giant reed (*Arundo donax*), giant salvinia (*Salvinia molesta*), hydrilla (*Hydrilla verticillata*), and Eurasian water-milfoil (*Myriophyllum spicatum*), kochia (*Kochia scoparia),* tree tobacco (*Nicotiana glauca*), and Johnson grass (*Sorghum halepense*). Additional invasive aquatic wildlife species are known to have devastating effects on native aquatic fish and wildlife species – for example, quagga mussels impacts to the food web, crayfish impacts to native gartersnakes, turtles, mollusks, and fish, and bullfrog predation on a wide variety of reptiles and amphibians (AGFD 2012b).

Tamarisk

Native plants face extreme competitive pressure in tamarisk-dominated stands where woody material from dead cottonwoods and willows is often present. Tamarisk is highly flammable – tamarisk dominated areas burn approximately ten times more frequently than native plant-dominated counterparts (Busch 1995)—and has fueled a number of fires in the riparian corridor. For example, in areas burned by the Clay Fire in March 2013 near Fort Thomas, nearly all tamarisk biomass was burned away—later in 2013 only the main trunks and branches remained. However, nearly all burnt tamarisk trees were observed to be re-sprouting vigorously from the base in November 2013, indicating there is only a limited window of opportunity to establish native species before tamarisk biomass once again dominates the site. Escaped fire from land-clearing on adjacent agricultural areas is a concern for land managers in the Safford Valley, particularly where weedy forbs next to fields carry fire into the arid, tamarisk-dominated riparian edges, and then into the mixed native/tamarisk vegetation along the river. This establishes a feedback loop in which fire promotes tamarisk, which recovers readily from burning to become even more abundant, eventually displacing native elements in the stand (Orr et al. 2014). In addition, native vegetation along the upper Gila River currently lacks the spatial distribution and inherent growth rates to rapidly reestablish.

A key concern in the watershed is the anticipated arrival of the tamarisk leaf beetle (*Diorhabda elongata* and *sublineata* species groups) which has the potential to disturb existing riparian habitat conditions, particularly for southwestern willow flycatchers (see Section 3.8). The tamarisk leaf beetle (*Diorhabda elongata* and *sublineata* species groups), which was released in portions of Colorado, Nevada, Texas, Utah, and Wyoming during 2001–2009 by the U.S. Department of Agriculture (USDA) for biological control of tamarisk, is expected to arrive in the upper Gila River valley in the next 2 to 3 years and result in the defoliation and ultimate mortality of large tracts of tamarisk, as has been observed elsewhere in the southwest region (Tracy and Robbins 2009; J. Tracy, pers. comm., 2014, as cited in Orr et al. 2014). The beetle has not yet reached the Gila River Watershed from the east as expected, but in 2017, neared the upper reaches of the

watershed near Silver City, New Mexico (Tamarisk Coalition 2017). Defoliation by the leaf beetle does not exacerbate the risk of wildfire, as tamarisk is highly flammable regardless of whether it is "browned-out" by defoliation or in a "healthy green" state (Dudley and Brooks 2011). Biocontrol eventually reduces tamarisk volume, and after 3+ years, repeated defoliation can lead to mortality (Bean et al. 2013).

Southwestern Willow Flycatcher

Endangered southwestern willow flycatchers (SWFL; *Empidonax traillii extimus*), listed as endangered in 1995, are present in the plan area, including designated critical habitat. They typically establish nesting territories, build nests, and forage where mosaics of relatively dense and expansive growths of trees and shrubs are established near or adjacent to surface water and/or underlain by saturated soil (Sogge et al. 2010). Many areas where the SWFL was formerly locally abundant now support few or none. Two riparian areas continue to support substantial numbers of SWFL, one of which is the Gila River (AGFD unpubl. Data; Magill et al. 2005; Dockens et al. 2007; Dockens and Ashbeck 2009, 2012; Graber and Koronkiewicz 2009a, 2009b, 2011, and 2012), where SWFLs have been known since the early 1900s (Willett 1912, Phillips 1948). SWFL along the upper Gila River now nest in tamarisk, due to the ubiquity of the plant and its suitable nesting structure, and when these trees and shrubs are defoliated they will become unsuitable for nesting. In other southwestern U.S. rivers, large areas of SWFL nesting habitat have been adversely affected as a result of defoliation from tamarisk leaf beetle, such as along the Virgin River in Arizona, Nevada, and Utah (R. Dobbs, pers. comm., 2013; BOR 2014).

USFWS (2013) has determined that the primary constituent elements (PCEs) of habitat essential to the conservation of SWFL are:

1. Riparian vegetation in a dynamic river or lakeside, natural or manmade successional environment that is comprised of trees, shrubs, vines, and herbs and some combination of:
    a. Dense riparian vegetation with thickets of trees and shrubs that can range in height from about 6 to 98 feet. Lower-stature thickets (6 to 13 ft tall) are found at higher elevation riparian forests and tall-stature thickets are found at middle- and lower-elevation riparian forests; and/or
    b. Areas of dense riparian foliage at least from the ground level up to approximately 13 ft above ground or dense foliage only at the shrub or tree level as a low, dense canopy; and/or
    c. Sites for nesting that contain a dense (about 50 to 100%) tree or shrub (or both) canopy (the amount of cover provided by tree and shrub branches measured from the ground); and/or
    d. Dense patches of riparian forests that are interspersed with small openings of open water or marsh or areas with shorter and sparser vegetation that creates a variety of habitat that is not uniformly dense. Patch size may be as small as 0.25 acre or as large as 175 acres.

2. A variety of insect prey populations found within or adjacent to riparian floodplains or moist environments.

SWFL may use a larger area than their initial territory after their young are fledged, and use non-riparian habitats adjacent to the breeding area (Durst et al. 2006). Even during the nesting stage, adult SWFL sometimes fly outside of their territory, often through an adjacent SWFL territory, to gather food for their nestlings.

Western Yellow-billed cuckoo (WYBC)

The western yellow-billed cuckoo (WYBC) is a federally threatened species (USFWS 2014a) and critical habitat was proposed in 2014 (USFWS 2014b). Critical habitat for WYBC in the upper Gila River extends from near the Bonita Creek confluence downstream to San Carlos reservoir.

Primary constituent elements (PCEs) of critical habitat for WYBC include: (1) riparian woodlands > 325-feet wide and ≥ 200 acres in extent, (2) an adequate prey base (e.g., large insects and insect larvae and tree frogs), and (3) dynamic river processes that maintain riparian vegetation patches at a variety of successional stages (USFWS 2014b).

WYBC nest in large (10–40 acres) patches of structurally complex riparian habitat with tall trees and a dense understory of woody vegetation, such as is often found in cottonwood-Goodding's willow woodlands (Hughes 1999, Laymon et al. 1997). Nests—typically a loose platform of twigs on a horizontal branch—are typically located in dense vegetation under 70 ft high near surface water where humidity is high and temperatures are cooler (Launer et al. 1990, as cited in Laymon 1998; Gaines and Laymon 1984, as cited in Suckling et al. 1998). Occasionally the nest of another species is used (Jay 1911, Bent 1940). In California and Arizona, cottonwood trees are an important habitat (Laymon et al. 1997, Holmes et al. 2008, Johnson et al. 2010). Nesting in the western states occurs almost exclusively near water, leading to some researchers hypothesizing that sufficient humidity may be necessary for successful reproduction (Hamilton and Hamilton 1965, Rosenberg et al. 1991).

The main nest-tree species in Arizona are Goodding's willow (*S. gooddingii*), cottonwood (*P. deltoides*), and tamarisk, although other trees or large shrubs, such as mesquite and seep willow (*Baccharis salicifolia*), may also be used (McNeil et al. 2012). In Arizona, Johnson et al. (2010) found WYBC detection rates to be highest in cottonwood-willow-ash (*Fraxinus* species [spp.]) and mesquite bosque–hackberry (*Celtis* spp.) habitats and much lower in Arizona sycamore (*Platanus wrightii)*–cottonwood habitat, sycamore-alder (*Alnus* spp.) habitat, and areas with more than 75% tamarisk cover. Aerial-photo and satellite models applied on the lower Colorado River found that important features associated with WYBC breeding habitat included: (1) a 4.5-ha core area of dense cottonwood-willow, (2) a large native forest (72 ha) surrounding the core, and (3) moderately rough topography. In contrast, the odds of WYBC occurrence decreased

rapidly as the amount of tamarisk cover increased or when cottonwood-willow vegetation was scarce (Johnson et al. 2012).

Razorback Sucker

A member of the sucker family (*Catostomidae*), razorback suckers can reach sizes of up to 3 feet and may live 40 years or more. They are endemic to the Colorado River basin and historically occurred throughout much of the Gila River. By the 1950s the razorback sucker was extirpated from the Gila River and its tributaries (USFWS 1998). A number of factors led to the decline of this species, but the primary threats are considered to be habitat alteration from dams and diversions, and predation by non-native fish species (USFWS 1998). Efforts to reintroduce razorback suckers in the watershed took place from 1981 through 1990 but proved unsuccessful in establishing a self-sustaining population (Desert Fishes Team 2003), likely as a result of predation by non-native fish species such as channel catfish (*Ictalurus punctatus*) and flathead catfish (*Pylodictis olivaris*) (Marsh and Brooks 1989 and Maddux et al. 1993, as cited in USFWS 2002d).

In rivers where they occur, razorback suckers can be found in a variety of habitat types, from mainstem channels to slow backwaters of medium and large streams and rivers (AGFD 2002a). Adults tolerate water temperatures ranging from near freezing up to 90°F, with preferred temperatures between 72 and 77°F (AGFD 2002a). Spawning occurs from late winter through early summer over gravely substrates in lakes and rivers, when flows are typically high and the water column is generally highly turbid (USFWS 1998). Young razorback suckers require quiet, warm, shallow water nursery areas typical of tributary mouths, backwaters, or inundated floodplains (USFWS 2002). The diet of razorback suckers is similar to other members of the sucker family and includes algae, plankton, insect larvae, and detritus (AGFD 2002a).

The razorback sucker was listed as endangered in 1991 (USFWS 1991) and critical habitat was designated in 1994 (USFWS 1994). In the Gila River, critical habitat for razorback sucker is designated from the Arizona/New Mexico border to Coolidge Dam, where water quantity and quality are suitable (USFWS 1998). Although razorback suckers are not present in the Upper Gila River Watershed, the upper Gila River is still designated critical habitat. Despite intensive water diversion in this area and reaches that go intermittently dry, pools in the mainstem channel and tributaries can provide suitable water quality, water quantity, and other habitat features for this species during low flow periods (USFWS 1998).

Appendix D

Stakeholder Feedback from 2015 Water Supply and Demand Alternatives Workshop

The following information was developed in the 2015 Water Supply and Demand Alternatives Workshop.

Demand Reduction:

- A combination of potential approaches was thought to be most effective in decreasing water demand.
- Priorities should include *public education*, *coordination of water conservation activities*, *building codes/conservation ordinances*, and *conservation pricing.*

Small-scale Supply Alternatives:

- *Educating the community is important* - creating a sense of urgency, while avoiding a sense of panic, by focusing on specific education topics like greywater reuse, encouraging research into the ability to capture stormwater in canal systems, and targeting specific "early-adopter" groups like millennials.
- *Diversifying crops to promote efficiency and resilience* – in support of maintaining or improving the local agricultural economy.
- S*upporting already-existing teaching models like "Ag in the Classroom"* - an ongoing Farm Bureau initiative that includes lessons on water usage/conservation.
- Make continuous efforts to learn about best practices and effective models elsewhere
- Collect and publicize stories of water trends and challenges and creative responses
- Be aware of water conservation and public education "fatigue"
- Appreciate the particular social ethic in the watershed
- Develop a "Dynamic Education" model/process
- Prepare for strategic and frequent engagement with regional decision-makers
- Find opportunities for pilot projects
- Support coordinated education efforts
- Be aware of how new technology and shifts in the affordability of different conservation strategies will affect opportunities
- Explore ways of realizing the Mission Statement and evaluate what specific concerns or threats exist regarding regional water availability and determine how a coordinated response can bring people together to address these problems

The technology for automatic meters is readily available. Cost of installing a ¾" water meter is about $6,000. Farmers could consider installing automatic meters, which can improve measurements substantially and reduce labor costs over the long-term. Each farmer would need to perform his/her own cost analysis to determine if this is feasible. Similarly, drip irrigation would be more supported if funding issues and salinity problems were addressed.

Water efficiency for large (commercial, industrial) water users was also reviewed. Sheet flow is being lost unnecessarily in many parking lots and on slopes. Better design could allow this water to be utilized. For example, FMI has designed its parking lots to direct water into the canal. Recommendations include implementing urban watershed restoration, rainwater harvesting, and setting in place erosion control measures.

Increased use of reclaimed water was viewed by source and potential use. Use of reclaimed water for agriculture may be viable, depending on the crop. Questions were raised about the current incentive structures for municipal reuse of reclaimed water, and what kinds of fit-for-purpose options would make the most sense economically. Some effluent from Clifton and Morenci is used at FMI's Morenci mining operation, but it was unclear whether all was reused and whether other fit-for-purpose options were also available. Recommendations included exploring the possibility of transfers between jurisdictions or basins as well as maximizing the use of Clifton/Morenci effluent to the mine.

The group also discussed the development and treatment of lower quality sources. There is currently no incentive for agricultural users to use, store, or transfer reclaimed water. Agricultural users have a "use it or lose it" mentality because of uncertainty and the pressure to maintain their water rights. According to participants, some water transfers from agriculture to municipal sources are in the works in Graham County (such as for open space). Greenlee County has been involved in short-term transfer agreements. These depend on price point, and, again, there are concerns about losing water rights. Also, participants wondered whether there was a feasible way to store the extra water within the canal systems to rectify the problem of lost water when the canals sometimes overflow. Questions were also asked about the uncertainty regarding laws/regulations on use and storage of water. Recommendations included investigating the suitability and feasibility of evaporation ponds and permits for wells, encouraging short-term transfers (to help get around the "use it or lose it" mentality of water rights), building storage into canal systems (e.g., San Joaquin Valley – ponds interspersed to catch overflow water running through canals), and considering the sealing of canals. Overall, a desire to conserve water over the long-term was expressed, however, this conservation could only occur in the context of maintaining water rights.

Increased Agricultural Efficiency Measures were addressed in the context of Installing pumps at the end of agricultural fields and finding broader support for research into using desert adapted, low-water-use species in agriculture. Participants also reviewed water restrictions and enforcement options in the context of farming. Agricultural water use in the valley is limited to 28,000 irrigated acres at 6 AF/acre of surface water. This is allocated per canal, per farmer. Farmers can make agreements to adjust the amount of water they use on a shared canal. They cannot, however, use canals they are not assigned to. The estimated cost of water is about $2,600–$2,800 AF/acre. Under current use, drip irrigation methods uses at most 3 AF/acre, which offers substantial water

conservation potential depending on other factors. Challenges to widespread adoption of such water conservation tools are varied. There is little incentive (and some disincentive) to use less water. This can help explain farmers' reluctance to use drip irrigation. Also, such conservation comes at a significant cost to farmers. Although conservation is a general best practice, farmers have reasons to use as much of their 6AF as possible under the current system. Municipal leaders have voiced a preference for reducing water use by a small amount versus returning large amounts back to the system. There have also been tenuous relationships between judicial bodies and the agricultural sector, where legal proceedings have been very expensive, and have resulted in controversial rulings. Recommendations included encouraging the transfer of excess water and supporting programs that encourage/incentivize drip irrigation while also including provisions for salinity management.

Rebate programs are currently not in use in the region for residential water use. There had been an incentive program in the past, but it was unsuccessful because residential users did not make much use of it. The point was made that most people in the region probably agree in the abstract that water conservation is important, but the behavior is difficult to change, particularly without incentives. One recommendation centered on the creation of a proposal that evaluated different conservation incentives at a broad-based, regional scale. This proposal could then be presented to various leaders and decision-makers in different water sectors to develop wider support and potentially a more extensive base for securing funding.

Further, efforts to document and publicize how water management works here in the Upper Gila region continues to be a challenge. There is probably a different social ethic in Safford than other municipalities, so there is value in accounting for those unique demographics (renters, etc.).

There was also a discussion of how other similarly-situated regions have looked at managing water. While there have been efforts in the past to look at other regions' approaches to water management, no formal investigations or documents have been created. By way of example, the Upper San Pedro Partnership (USPP) in Cochise County conducted a study of which methods would be effective at getting people to conserve water; now the USPP has successfully implemented some of these methods. It was recommended that there be further use made of GWP's connections to different groups in order to get agreement among different sectors on the problems and possible solutions of water.

Gila Watershed Partnership of Arizona









Monitoring & Adaptive Management Plan for Rehabilitation in the Upper Gila Watershed of Southeastern Arizona

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ABBREVIATIONS & ACRONYMS

BA – Biological Assessment

BO – Biological Opinion

CWA—Clean Water Act

EFF – Electronic Field Form

ESA – Endangered Species Act

GIS – Geographic Information System

GPS – Global Positioning System

GWP – Gila Watershed Partnership of Arizona

MU – Monitoring Unit

SMART – Specific, Measurable, Achievable, Relevant, Time-bound

SOP – Standard Operating Procedure

SWFL – Southwest Willow Flycatcher

USACE – United States Army Corps of Engineers

USFWS – United States Fish and Wildlife Service

YBCU – Yellow-Billed Cuckoo

INTRODUCTION

Background:

Since 2015, the Gila Watershed Partnership of Arizona (GWP) has been actively restoring and rehabilitating tamarisk *(Tamarix spp.)* infested floodplains along the Gila River in southeastern Arizona. Tamarisk, or salt cedar, is a non-native plant that was originally introduced to the American southwest as a form of erosion control along river banks. This species occupies riparian zones and floodplains and is known for growing in dense monotypic stands that are at high-risk for wildfires and can have strong impacts on ecosystem balance as well as hydrologic functions (Barrows 1996, Cleverly et al 1997, Pataki et al 2005). Although there is still a debate as to whether the impacts of tamarisk are completely negative (Hummel & Caplan 2007; Shafroth et al 2005), the altered hydrologic regime of the Gila River has facilitated colonization of dense stands of tamarisk across the floodplain where they compete with native riparian and upland plant species for light, nutrients, and water. Today the Gila River floodplain in southeastern Arizona is dominated by tamarisk and weedy herbaceous cover.

The GWP rehabilitation program focuses on re-establishing native landscape conditions to increase wildlife and vegetation species diversity along the river, with a preference for establishing native habitat conditions for sensitive wildlife species, most notably the endangered southwestern willow flycatcher *(Empidonax traillii extimus;* SWFL*).* Rehabilitation in this area is critical, as the tamarisk leaf beetle *(Diorhabda spp.)* is rapidly expanding its territory and threatens to defoliate tamarisk stands that currently serve as important nesting habitat for flycatchers. While their precise arrival time is hard to predict, the concern is that this will occur before native tree species planted by GWP have had a chance to regenerate into viable habitat. To mitigate these anticipated impacts, GWP's work currently prioritizes controlling tamarisk and planting native vegetation within these critical riparian zones. GWP also seeks to advance a scalable rehabilitation strategy for use throughout riparian areas of the desert southwest, including using the newly created refuges to provide seed sources that support passive rehabilitation at a larger scale.

Rehabilitation in the arid southwest is replete with challenges, and as a result, GWP has a strong emphasis on adaptive management. Adaptive management is dictated by challenges and lessons learned in the field with an effort towards linking project actions with monitoring results to better inform future rehabilitation (Geosystems Analysis 2014, Parametrix 2010, Thom and Wellman 1996). Key challenges in this project include limited water access and quantity, deep and fluctuating groundwater depths, extreme summer temperatures, ESA regulated work seasons, intense herbivory pressures on newly planted seedlings, delays and changes in bi-annual rainfalls, and the expense and effort involved in controlling both tamarisk and extreme densities of secondary weeds. Monitoring actions addressed within this document attempt to assess GWP's success at mitigating these factors and to inform necessary future adaptations in areas where success was limited.

Current rehabilitation treatment sites (herein referred to as 'sites') are located within the historic floodplain along 25-miles of the upper Gila River watercourse. Sites were selected using a thorough, criteria-driven process (Stillwater Sciences 2013). Some of the factors considered included,

- The likelihood of successful removal of tamarisk and selected other invasive species;
- The likelihood of successful revegetation with native species and subsequent natural recruitment;
- Proximity to nesting sites of endangered and threatened bird species;
- Site access and land ownership considerations.

The mission of GWP is to engage the community in improving the water quality and ecosystem condition of the Upper Gila Watershed through education and economic opportunity. The goals are to conserve natural resources, enhance the environment, improve local economy, increase recreational opportunities, and avoid or minimize damage to the river from natural and unnatural disasters.

Rehabilitation work on the project, including maintenance, is guided by the Gila Watershed Partnership Restoration Plan for the Upper Gila River, that is updated annually, and the secondary weed management plan (see **Appendix 1**). The overall project plan was developed through prior research efforts including multiple locally based studies (Banister et al. 2014, Gori et al. 2014, Lacroix et al. 2014). This monitoring and adaptive management plan will assess and guide the ongoing work through the life of the project. The following monitoring approach will assist in evaluating the progress of the rehabilitation actions toward the establishment of native plants, inform continuing rehabilitation efforts, and guide maintenance needs.

PROJECT & SITE DESCRIPTIONS

The Gila Watershed Partnership rehabilitation program is currently being implemented along a 25-mile stretch of the Gila River from Pima, AZ to Geronimo, AZ (**Figure 1**). At present all work sites are privately owned, but federal lands will be incorporated following an environmental assessment. Work areas were established in discreet management zones along the river in order to create 'islands' of native vegetation ranging in size from 10-acres to 62-acres. When the plan was designed in 2014 there was a high-level goal to rehabilitate 200-acres of river-adjacent land. To date, GWP has removed 177.23-acres of tamarisk within the original 200-acres of land selected for rehabilitation. We have also retreated 97.72-acres and revegetated 73.47-acres with native plants. Retreatment of tamarisk and secondary weeds within cleared acres is a primary concern in this area and is implemented on an annual basis (**Appendix 1**). Active seeding is being increased to combat invasive herbaceous weed cover. A seed collection strategy is currently being created to ensure seeds are locally sourced, sustainably collected, and viable. In addition, revegetation will also include out-planting of native tree seedlings grown at the GWP-operated Gila Native Plant Nursery.

As of 2019, GWP is in the process of actively rehabilitating six distinct sites (**Table 1** and **Figure 1**) and is currently permitted to begin work on an additional two sites. Each site is situated around the riparian corridor and has habitat zones appropriate for both riparian species and upland species. At present, tamarisk occupies the Upper Gila River in a relative monoculture, however, there are a number of secondary weed species that are problematic within sites, and quickly become dominant post-tamarisk removal. The most common of these are kochia (*Bassia scoparia*), Russian thistle (*Salsola kali*), and chenopode (*Chenopodium spp*). There are also several problematic grass species and other exotics, such as Johnson grass (*Sorghum halepense*) and star thistle (*Centaurea spp.)* that occupy much of the sites.

GWP defines an area as rehabilitated when it has reached the following conditions:

- Less than 10% total[1] tamarisk cover
- Less than 25% total secondary weed cover (see **Table 1** for specifics)
- At least 75% relative canopy cover by native woody species
- Natural recruitment of phreatophytes is observed annually

[1] For this report, "Total" cover refers to the percent of vegetation canopy cover within a MU. "Relative" cover refers to the proportion of total cover comprised by a given plant species. For example, the Total canopy cover in a MU may be 25%, but all (100%) of that cover may be from a single species. In this case, the Relative cover of that species is 100%.

Table 1: GWP Site Descriptions. The following table describes the size, cover, and current status of all GWP restoration sites.

Site Name	Size (acres)	Pre-Treatment Description	Site Status	Notable Comments
R03	46.07 (not incl. BLM)	Mixed closed canopy of cottonwood and tamarisk	Active: initial and secondary treatment in progress; planting just beginning	A fire in early 2018 burned many tamarisk cut piles, as well as the cottonwood gallery on site--about 50% are dead or dying, with some re-sprouts occurring
R04	31.13	Closed canopy tamarisk	Inactive: awaiting permits (BLM land)	A fire in 2018 burned through and killed many older tamarisk, opening the canopy some, however, there is active tamarisk recruitment and re-sprouting
R08	9.85	Closed canopy tamarisk	Active: initial removal complete; secondary treatment required and planting not yet begun	This site is in a moist area and secondary weeds sprung up quickly following initial treatments
R09	17.38	Closed canopy tamarisk	Active: initial and secondary treatment in progress; planting not yet begun	Following initial treatments, baccharis has had good success along the river; in upland areas black greasewood and kochia have taken over much of the landscape
R10	47.01	Closed canopy tamarisk	Active: initial and secondary treatment in progress; Rx burning and planting just beginning	In 2019, this became the first site that GWP was able to burn tamarisk piles on; burned areas are being replanted and seeded
R11	26.95	Closed canopy tamarisk	Active: initial treatment just beginning	GWP is using a patchwork approach on this site, approved by USFWS, to ensure cut areas are not large enough to be detrimental to bird species
R14	61.73	Closed canopy tamarisk	Inactive: some work done in 2014	Access to this site is very difficult due to multiple washes through road and pathways
R15	39.60	Closed canopy tamarisk	Inactive: potential to begin in 2020	N/A
R18	56.23	Closed canopy tamarisk	Active: initial treatment complete; retreatment in progress; burning and planting to begin 2019	Riparian species doing well along the river edge, especially baccharis; this one of the only sites with active cottonwood recruitment present



Figure 1. GWP Site Map. The above figure shows current sites, both active and inactive (see **Table 1**).

PROGRAM GOALS, OBJECTIVES, AND MONITORING APPROACH

(see protocols as appendices)

The GWP habitat rehabilitation program has two overarching goals:

- Reduce wildfire risk, and
- Transition work sites from non-native to native-dominated vegetation (**Table 2**).

Field treatments are prescribed to achieve both goals, and GWP uses various monitoring methodologies to document and evaluate whether these goals have been achieved within different project sites. To guide both rehabilitation and monitoring work, each project site is divided into discreet "map units" (MUs; **Appendix 2**) based primarily on dominant vegetation composition and structure using the modified Hink & Ohmart vegetation classification system (Callahan & White 2002; Hink & Ohmart 1984). These data are collected in the field along with other management-relevant field attributes (e.g., previous treatments, differences in land-use history, unique soil or topographic conditions, etc.). These field-based vegetation and site attribute data are entered into a Geographic Information System (GIS).

Dividing project sites into discreet MUs enables us to develop spatially explicit maps of pre- and post-rehabilitation vegetation conditions. In turn, these data, along with other management-relevant information collected during vegetation mapping (e.g., soils, topography, previous management activities, etc.) are used to develop fuels treatment prescriptions, revegetation plans, and estimate implementation costs (McKenna et al 2019). Another advantage of MUs is it provides a foundation for planning and implementing monitoring procedures and to track and quantify spatially explicit changes in relative cover of native and invasive species and for generating maps and other visual tools to aid in reporting monitoring results.

Monitoring for success following rehabilitation work is often categorized into multiple monitoring types, including compliance monitoring, implementation monitoring, validation monitoring and effectiveness monitoring (Caplan and McKenna 2019 and Geosystems Analysis 2014). Brief definitions of each are as follows:

Compliance Monitoring

Certain regulatory agencies require monitoring of the work done along the river. This compliance monitoring is implemented to evaluate whether an organization is following state or federal regulations and whether further action needs to be taken. The GWP is legally required to implement certain monitoring protocols for habitat work done along the Gila River per the following regulating agencies:

1. Endangered Species Act (ESA) – A biological Assessment (Stillwater Sciences 2014) and a biological opinion (USFWS 2016)
2. Clean Water Act (CWA) – A Section 404 Nationwide Permit #27

<u>ESA Compliance</u>

The United States Fish and Wildlife Service (USFWS) issued a biological opinion (BO) on September 19, 2016 that evaluated the effects of vegetation management work along the Gila River on threatened and endangered species (consultation number: 02EAAZZ00-2015-F-0151). The biological assessment (BA; Stillwater Sciences 2014) concluded that our project *may affect, is likely to affect* both the SWFL and the Yellow-billed cuckoo (YBCU) because of the immediate removal of potential nesting and foraging habitat. However, the BO concluded that our actions were "neither likely to jeopardize the continued existence of the SWFL [or YBCU],

nor likely to destroy or adversely modify critical habitat for the species" (USFWS 2016, pgs. 47—48). Accordingly, the BO requires three monitoring actions to occur on an annual basis:

- Monitoring of riparian plantings to assess survival, determine the need for replacement plantings, alternative species, or alternative planting locations
- Monitoring presence/absence of threatened and endangered species (SWFL & YBCU)
- Annual overall monitoring reports submitted by 12/31 that include the following:
    - Summary of threatened and endangered species monitoring
    - Summary of tasks accomplished
    - Comparison of effectiveness of treatment and revegetation efforts before and after the beetle arrives to inform future work (to be done upon beetle's arrival in the project sites)
    - Recommendations for future actions to enhance species protection

CWA Compliance

The US Army Corps of Engineers (USACE) issued GWP a Nationwide Permit 27 as an Aquatic Habitat Restoration, Establishment, and Enhancement Activity (Permit No. SPL-2014-446-KWG) for proposed vegetation management actions within the Gila River Floodplain. The only permit requirements stipulated by the USACE are compliance with the State of Arizona environmental and cultural resources laws (i.e., 401 Water Quality Certification (SWGP14-0168) and Section 106 cultural resources compliance through the State Historic Preservation Office.

Implementation Monitoring

Implementation monitoring doesn't address whether or not a project goal has been met, but rather, it evaluates and documents whether a project was carried out according to its original design (Geosystems Analysis 2014). The main type of implementation monitoring occurring with GWP projects is GPS (Global Positioning System) and photo documentation of plantings, tamarisk removal, and retreatment work that was implemented as originally planned. GPS points and polygon data are integrated into a GIS. Supporting photographs are organized in an electronic folder associated with each project area.

Validation Monitoring

Validation monitoring assesses the correctness of basic assumptions about how management actions will affect biological outcomes (MacDonald et al. 1991; Noss and Cooperrider 1994; Woodward and Hollar 2011). While the definitions for validation monitoring vary somewhat among sources, some discussions of validation monitoring focus on the evaluation of whether organisms are responding in a positive way to restoration treatments (Collins 2003; Woodward and Hollar 2011). For this monitoring plan, the only validation monitoring currently implemented are presence-absence surveys for the SWFL and YBCU.

Effectiveness Monitoring

Most monitoring conducted by GWP to evaluate restoration success utilizes effectiveness monitoring procedures. Effectiveness monitoring is conducted to directly assess whether restoration project actions produce a desired physical habitat response (Woodward and Hollar 2011). It involves assessing restoration progress in relation to project objectives and is the primary informative mechanism used to guide adaptive management. Effectiveness monitoring requires development of clearly articulated goals and objectives, identification of informative monitoring metrics (what will be monitored) and quantitative success criteria

(Block et al. 2001). These elements form the core of an effectiveness monitoring framework and serve as the building blocks for determining monitoring methods, timing, and frequency.

To develop a structured effectiveness monitoring framework, it is important to briefly define and differentiate between *goals* and *objectives*. *Goals* are generally worded statements that described a desired end state. They are typically open-ended statements in the sense that no timeframe is identified, and they reflect broad ideals, aspirations or benefits pertaining to specific issues (BCMSRM 2004, as cited in Caplan & McKenna 2019).

Objectives are more specific and concrete than goals. Management objective statements convey desired end results and contain explicit metrics for determining whether goals have been achieved, or whether quantitative thresholds have been crossed that should trigger corrective adaptive management actions. Management objective statements should also describe the spatial extent and timeframe within which the objective will be achieved (BCMSRM 2004, as cited in Caplan & McKenna 2019).

Several management objective statements were developed to guide monitoring procedures for assessing whether GWP's project goals are being achieved over the life of the monitoring program. These objective statements were structured following broadly accepted **'SMART'** objective criteria (e.g., McDonald et al. 2016). The '**SMART'** acronym stands for:

- **S**pecific: an objective should target a specific area of improvement or answer a specific need.
- **M**easurable: an objective must be quantifiable to allow monitoring to determine if the objective is being/has been achieved.
- **A**ttainable: an objective should be technically, financially and administratively attainable.
- **R**elevant: an objective should align with other management objectives to be considered worthwhile.
- **T**ime-bound: an objective should have a defined deadline or target end-date.

The boxes below present SMART objective statements developed for GWP's effectiveness monitoring program, along with brief summaries of the associated monitoring metrics, the proposed monitoring approach, the monitoring output/deliverable(s), the adaptive management trigger(s), and potential adaptive management actions. Information from all the boxes are combined and presented in **Table 2**. Detailed descriptions of recommended field data collection procedures (Standard Operating Procedures) are provided in **Appendices 2-4 and 6**.

Goal 1: Reduce Wildfire Risk

Management Action: Remove standing biomass of tamarisk and use herbicide to treat re-sprouts.

SMART Objective: Implement fuels treatments to reduce total tamarisk cover to <10% in individual Map Units (MUs) within 5-years following initial primary treatment.

Monitoring Metric: Total percent canopy cover of tamarisk in overstory and understory canopy layers within individual MUs.

Monitoring Timing & Frequency: Annually for first 5-years following primary treatment. Every 2-3 years after.

Monitoring Approach: Divide project sites into discreet MUs based on vegetation composition, structure, and other management-relevant attributes. Document within each map unit total percent canopy cover by vegetation plus relative cover of individual woody plant species. **A *Standard Operating Procedure* with step-by-step monitoring instruction is provided in Appendix 2.**

Monitoring Output: GIS data layers and maps classifying MUs into vegetation types following modified Hink & Ohmart vegetation classification terminology.

AM Trigger: Monitoring indicates total tamarisk canopy cover exceeds 10% in any single MU.

Potential AM Action: Implement control treatments (basal bark herbicide applications) before stem diameters exceed 1-inch to avoid need for chainsaw treatment to reduce biomass.

***Goal 2**: Transition Restoration Sites from Non-Native to Native Dominated Cover*

Management Action #1: Control cover of non-native herbaceous plant species.

SMART Objective: Implement control treatments to reduce total non-native herbaceous plant cover to the following management thresholds within 5-years following initial primary treatment:

- Kochia & Russian thistle: <25% total cover
- Giant cane (*Arundo donax*) and all Arizona state-listed noxious weed species: 0% total cover
- Other species in Appendix 1: <25% total cover

Monitoring Metric: Percent aerial cover of individual, non-native herbaceous plant species.

Monitoring Timing & Frequency: Annually for first 5-years following primary treatment. Every 2-3 years after.

Monitoring Approach: Record ocular estimates of total aerial cover of non-native herbaceous plants within MUs. **A *Standard Operating Procedure* with step-by-step monitoring instruction is provided in Appendix 2.**

Monitoring Output: GIS data layers and maps showing aerial cover of non-native herbaceous species in different MUs. Summary tables listing number of map units with aerial cover greater than or less than management thresholds. Species lists documented in each map unit.

AM Trigger: Management thresholds for aerial cover are exceeded in any single map unit.

Potential AM Action: Implement species specific treatments described in Appendix 7.

Goal 2: Transition Restoration Sites from Non-Native to Native Dominated Cover

Management Action #2: Plant site-adapted native trees and shrubs.

SMART Objective #1: Survival of planted native tree and shrub species will achieve the following thresholds 12- to 18-months following planting.

- Cottonwood, willow and other species planted in MUs where maximum depth to groundwater is ≤ 6 feet below ground surface: 70% survival.
- Mesquites, acacias and other species planted in MUs where maximum depth to groundwater is ≥ 6 feet below ground surface: 50% survival.

Monitoring Metric: Percent survival of different native trees and shrub species within individual MUs.

Monitoring Timing & Frequency: Once within 12-18 months following primary treatment.

Monitoring Approach: Use electronic maps (e.g., Avenza Maps™) showing native tree and shrub planting locations. Navigate to these locations and use electronic field forms (e.g. Data Collector) to record whether each planted species is alive, dead or missing. Use results to quantify percent survival of planted species. **A *Standard Operating Procedure* with step-by-step monitoring instruction is provided in Appendix 3.**

Monitoring Output: GIS data layers and maps showing planting locations; summary tables/bar charts showing percent survival of individual species within each project site where planted.

AM Trigger: Monitoring indicates survival of individual native tree and/or shrub species is less than 70% in any project site.

Potential AM Action: Plant additional native trees and/or shrubs to compensate for mortality. If survival is very low for some species, use data to consider replacing with different species.

***Goal 2**: Transition Restoration Sites from Non-Native to Native Dominated Cover*

Management Action #2: Plant site-adapted native trees and shrubs.

SMART Objective #2: Native tree and shrub species will comprise at least 75% relative canopy cover in planted MUs within 5-years following planting.

Monitoring Metric: Relative percent canopy cover of native trees and shrubs within individual MUs.

Monitoring Timing & Frequency: Three times within 5-year period: baseline (prior to clearing non-natives), 2-years following planting, 5-years following planting.

Monitoring Approach: Divide project sites into discreet Map Units (MUs) based on vegetation composition, structure, and other management-relevant attributes. Document within each map unit percent canopy cover of individual woody plant species. Determine relative cover of native phreatophytes.

A *Standard Operating Procedure* with step-by-step monitoring instruction is provided in Appendix 2.

Monitoring Output: GIS data layers and maps classifying MUs into vegetation types following modified Hink & Ohmart vegetation classification terminology.

AM Trigger: Monitoring indicates relative canopy cover of native trees and shrubs is less than 75% in any single MU.

Potential AM Action: Plant additional native trees and shrubs to achieve cover goal criteria. If survival is very low for some species, use data to consider replacing with different species.

***Goal 2**: Transition Restoration Sites from Non-Native to Native Dominated Cover*

Management Action #3: Create 'safe sites' for cottonwood-willow seedling establishment.

SMART Objective: New cottonwood and/or willow seedlings are present in at least 1 in 5 years along channel banklines cleared of tamarisk**.**

Monitoring Metric: Presence/absence of cottonwood and/or willow seedlings.

Monitoring Timing & Frequency: Annually in August.

Monitoring Approach: Perform presence/absence surveys along channel banklines in locations where tamarisk has been cleared to the edge of the river channel. **A *Standard Operating Procedure* with step-by-step monitoring instruction is provided in Appendix 6.**

Monitoring Output: GIS data layers and maps showing locations and density classes where seedlings are observed.

AM Trigger: No new cottonwood and/or willow seedlings observed within five years following bankline clearing treatments.

Potential AM Action: Evaluate potential causes (e.g. flow records, depth to groundwater, etc.).

***Goal 2**: Transition Restoration Sites from Non-Native to Native Dominated Cover*

Management Action #4: Seed native grasses and shrubs.

SMART Objective: Native seeded species will comprise at least 15% total canopy cover in seeded zones within 5-years following seeding.

Monitoring Metric: Total cover of seeded grass and shrub species.

Monitoring Timing & Frequency: 1st, 3rd and 5th years following seeding.

Monitoring Approach: Ocular estimates of total plant cover within quadrats spaced along line transects. Long-term photo monitoring stations will also be established in seeded areas. ***Standard Operating Procedures for both ocular cover estimates and photo point monitoring*** **instruction are provided in Appendix 4.**

Monitoring Output: Table of percent cover with trends over time. Photographic records showing change over time.

AM Trigger: Seeded species fail to achieve ≥15% aerial cover within 5-years following seeding.

Potential AM Action: Evaluate potential causes (e.g. drought, competition by non-natives, insect or animal herbivory, etc.). Evaluate need to modify seeding methods.

Table 2: The following table is a summary showing linkages between rehabilitation program goals and management actions in the field. There are two overall goals and a series of SMART objectives (specific, measurable, achievable, relevant, and time-bound) associated with each goal that outline the ideal outcomes from rehabilitation field work.

Goals	Management Action	SMART Objective	Monitoring Approach	Monitoring Frequency	Monitoring Output	AM Trigger	AM Actions
Reduce wildfire risk	Remove standing biomass of salt cedar & treat salt cedar re-sprouts	Implement fuels treatments to reduce total salt cedar cover to <10% of all treated sites within 5 years of initial primary treatment	Utilize electronic field forms to document total cover of woody plant species within individual MU	Annually for first 5-years following treatment. Every 2-3 years thereafter	GIS maps/layers showing relative vegetation cover within MUs; Table showing percent cover	Salt cedar cover in a treated area exceeds 10% cover	Implement control treatment (Appendix 7)
Transition treatment areas from non-native to native dominated cover	Control cover of non-native herbaceous plants	Implement control treatments to reduce herbaceous plant cover to the following management thresholds within 5-years following initial primary treatment: - Kochia & Russian thistle: <25% total cover - Giant cane (*Arundo donax*) and all Arizona state-listed noxious weed species: 0% total cover - Other species in Appendix 1: <25% total cover	Document total cover of non-native herbaceous species within each MU. Use electronic field forms to document species of management concern	Annually for first 5-years following treatment. Every 2-3 years thereafter	GIS maps/layers and a table showing relative cover of weedy herbaceous vegetation	>0% for Giant cane and AZ state listed noxious weeds >25% cover for all other non-native herbaceous species	Implement control treatment (see Appendix 7)
	Plant native trees and shrubs in hydrologically suitable locations	Native tree and shrub species will achieve the following survival goals within 5 years following planting: - 70% in zones where max. dtw ≤ 6 ft. - 50% in zones where max. dtw > 6 ft.	Utilize GIS maps loaded on Avenza Maps to navigate to species planting locations at each project site. Complete electronic field forms to document status of each species according to live, dead or missing.	1st year after planting; Annually if planting occurs annually	GIS maps/layers showing planting locations and survival; Tables/bar charts of individual species survival rates by project site.	Survival of planted species fall below survival threshold 12-18 months after planting	Supplemental planting; Evaluate potential causes of failure, i.e., drought, pests, herbivory, etc. Look at groundwater hydrograph. Change future planting methods accordingly
	Planting native trees and shrubs in hydrologically suitable locations	Native tree and shrub species will comprise at least 75% relative canopy cover in MUs within 5-years following planting	Utilize electronic field forms to document relative cover of woody plant species within individual MU	Three times: 1st baseline (pre-treatment) 2 years after planting 5 years after planting	GIS maps/layers showing relative vegetation cover within MUs; Table showing percent cover	Relative woody phreatophyte cover <75%	Investigate the need for control treatment of invasive species; Implement additional planting and seeding strategies
	Create 'safe sites' for native cottonwood and willow seedling recruitment by removing salt cedar along channel bank lines	New cottonwood and/or willow seedlings are present/observed in May in at least 1 in 5 years along channel bank lines cleared of salt cedar	Presence/Absence surveys in May that are walked along bank-lines in previously treated areas	Annually in May for at least 5 years following bankline clearing	Presence/Absence points plotted within a GIS landscape (shapefile)	No new seedlings are observed along bank-lines for 5 consecutive years	Evaluate causes and treat (i.e. crowded out with weeds); Increase supplemental hand seeding or N/A
	Seeding native grasses and shrubs	Native seeded species will comprise at least 15% of aerial cover in seeded zones within 5 years (quads or line intercepts)	Transects with quadrats within seeded zones Photo points prior to seeding and each year (install 2-3 points around seeded zone depending on acreage)	First, third, and fifth years following seeding event	Table of percent cover within seeded zone; (quadrats and transects allow a subset that can be extrapolated)	<15% of aerial cover is comprised of seeded species after five years	Look for potential causes of failure, i.e., drought, drowning, pests, herbivory, etc. Look at groundwater hydrograph. Change future seeding methods accordingly

Monitoring & Reporting Schedule

Timing of each type of monitoring activity is outlined in **Table 4**. All activities will take place at pre-determined time intervals. Not all activities are for implementation or effectiveness. For example, photo point monitoring (**Appendix 5**) is used to inform future rehabilitation work rather than being indicators of past actions. That protocol will occur quarterly as timing and conditions allow.

Vegetation Cover Mapping

Vegetation cover surveys that evaluate the presence of a minimum of 11 woody species (**Appendix 2**) will occur every year during the summer season (between July and September), with more extensive vegetation ID occurring in every third season. Monitoring during the summertime will allow us to record successful spring germination of native phreatophyte species and to capitalize on the fact that said species will be large enough to be easily identifiable by field surveyors. Surveying at this time also allows for data to be analyzed prior to the fall field season and thus inform rehabilitation actors as annual field plans are being finalized.

Survival of Out-Planting Surveys

Planting zones will be surveyed for survival (**Appendix 3**) annually in early summer, approximately 12-15 months following their original planting date. This will happen between April and June annually, assuming that planting occurred the previous year. Surveys are only done once for each new planting area in part because the first year following planting is when the most tree death is likely to happen, and partly to account for the inherent challenge of identifying planted trees versus natural sprouts more than a year later.

Survival of Seeding Surveys

Surveys to check applicable management units for plant cover by seeded species will occur every other year (**Appendix 4**), with the first survey following a seeding event occurring two years later. The timing is designed this way to allow for the natural tendency of seeds to wait on the weather, making it challenging to determine success after only one year's time. Seed surveys will occur between August and October.

Photo Point Records

Photo points are marked and set up in two locations within each site (center and SW corner; set up January 2019; **Figure 2** & **Table 3**) and photos are taken from each point quarterly (Jan, Apr, Jul, Oct) (**Appendix 5**). Additional non-permanent photo points (GPS marked, but not cemented) will be set up to track seeding zones prior to seeding and during seeding surveys.



Figure 2. Example of a SW Photo Point Marker on R11.

Natural Recruitment Surveys

Surveys to evaluate natural recruitment of woody phreatophyte species will occur annually between May and August (**Appendix 6**). Since we are only looking for natural recruitment of several specific species, the ideal time to do this is after germination is likely (spring). Surveys done later in the summer are also likely to indicate recruitment survival through the hot season.

Table 3. GPS coordinates for each photo point location in active sites.

Site	Location	Longitude	Latitude
R03	C	-110.027986	33.092114
R03	SW	-110.030771	33.091362
R08	C	-109.999079	33.06955
R08	SW	-109.999583	33.068752
R09	C	-109.989298	33.061864
R09	SW	-109.990694	33.062252
R10	C	-109.981061	33.056792
R10	SW	-109.983182	33.05521
R11	C	-109.955574	33.047315
R11	SW	-109.960277	33.047852
R18	C	-109.833115	32.916259
R18	SW	-109.836249	32.917386

Table 4: Monitoring Calendar Chart for GWP. Natural recruitment surveys will be done once during the summer between May and August.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Photo Points			Plant Survival	Plant Survival	Plant Survival	Relative Cover	Relative Cover	Relative Cover	Photo Points		
			Photo Points	Natural Rec.	Weed Surveys	Photo Points	Seed Survival	Seed Survival	Seed Survival		
				SWFL Surveys			Natural Rec.				

WRAP UP AND NEXT STEPS

Habitat rehabilitation in the arid southwest is a complex task. Because of the inherent challenges of rehabilitating floodplains along the modified Gila River, this document aims to establish realistic objectives that will enable us to adapt to complex situations and take relevant action. Monitoring actions addressed within this document attempt to document GWP's ability to manage challenges and to determine necessary actions to increase success in the future.

Restoration and rehabilitation work is guided by the GWP's mission to engage the community in improving the water quality and ecosystem condition of the Upper Gila Watershed. Likewise, field work is guided by annual restoration plans and secondary weed management places, with the aim of maintaining rehabilitated areas to ensure that they are able to sustain a native-driven system on their own. Because this plan is designed to adapt to the changes and challenges of a dynamic system, it is important to keep a monitoring feedback loop (**Figure 3**) in mind when planning. Timing of monitoring, reporting, and for acting on monitoring results is extremely

important to establish prior to any on-the-ground action. In addition, the following actions will be considered and incorporated as needed following future field seasons:

- Establish an annual adaptive management meeting with all staff to incorporate feedback into future planning;
- Regularly update budgets and additional information for each task of the management plan;
- Incorporate rapid assessment site protocols to aid in informing management decisions outside of prime monitoring time-periods.

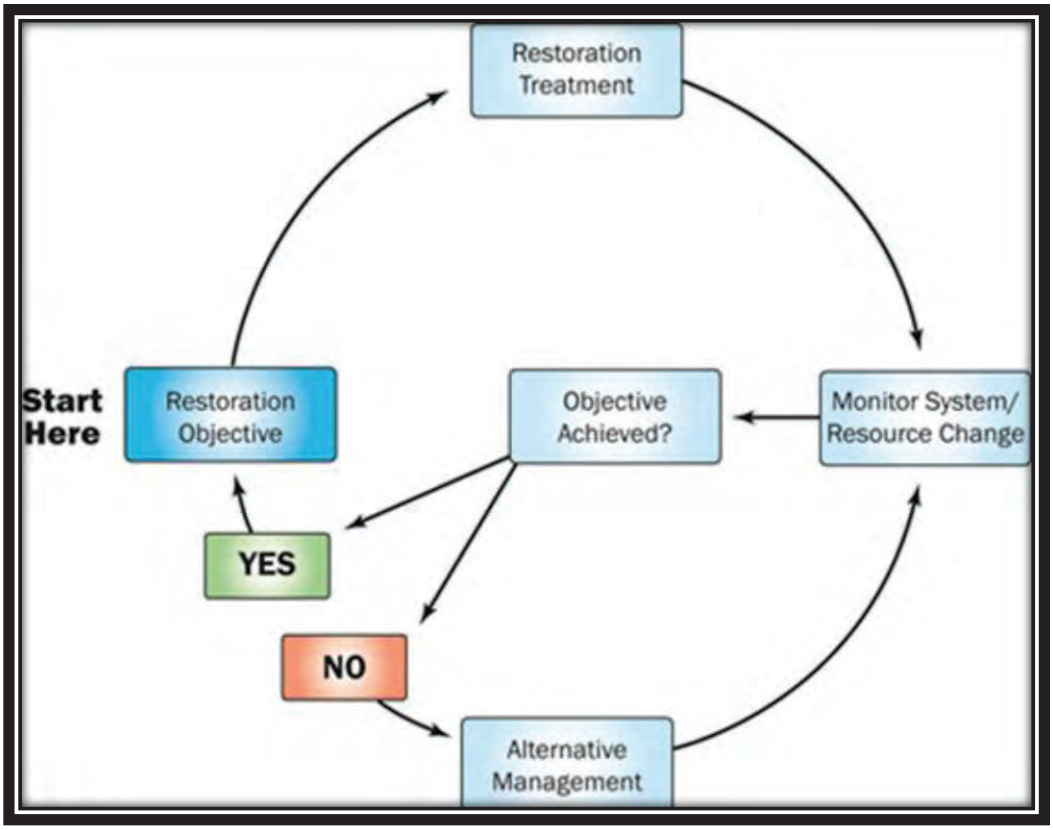


Figure 3. Monitoring feedback loop as designed by Geosystems Analysis 2014 & referenced from Elzinga 1998.

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APPENDICES

Appendix 1: Weed Management Plan

Appendix 2: Relative Vegetation Cover

Appendix 3: Survival of Out-Plantings

Appendix 4: Survival of Seeding

Appendix 5: Photo Points

Appendix 6: Natural Recruitment

Appendix 7: Tamarisk Control Treatment

APPENDIX 1: Weed Management Plan. A schedule for when management actions need to occur with priority exotic herbaceous weeds year-round.

	Common Name	Scientific Name	Goal of Removal	Fall	Winter	Spring	Summer	Notes
1	**Belvedere/ Burningbush**	*Bassia scoparia*	Reduction/ Eradication			Chemical	Manual (& Chemical)	Tends to be chemical resistant, you must use stronger herbicide or mix a weaker one with multiple kinds
2	**Oak-Leaved Goosefoot**	*Chenopodium spp*	Reduction	Manual		Manual & Chemical	Chemical	No chemical treatment designed for this plant; we will use treatments for a similar species and test for effective percentages
3	**Russian Thistle**	*Salsola kali & tragus*	Reduction			Chemical	Manual (& Chemical)	Leaving some on the site can help with other vegetation growth
4	**Giant Reed**	*Arundo donax*	Eradication	Manual & Chemical		Chemical	Chemical	Chemical twice--once in late summer to fall, once, and once in spring
5	**Yellow Starthistle**	*Centaurea spp*	Eradication (where possible)		Manual	Chemical		Either two chemical treatments (one in winter and one in spring) or higher chemical % once in late spring; only control small patches, in large patches just control the borders; please GPS mark any populations seen
6	**Johnson Grass**	*Sorghum halopense*	Reduction/ Eradication			Manual & Chemical	Manual & Chemical	Very hard to treat, repeated removals in spring when the plants are young is most likely to help--treat multiple times per season
7	**Red Sorrel**	*Rumex dentatus*	Reduction		Manual & Chemical	Manual & Chemical		Removing above-ground biomass reduces next-year growth; you must dig out root; chemicals are best applied on early stem formations--watch for this for timing

8	**Pitseed Goosefoot**	*Chenopodium cf. berlandieri*	Eradication			Manual & Chemical	Manual	Repeated treatments may be necessary
9	**Bermuda Grass**	*Cynadon dactylon*	Reduction/ Eradication	Manual	Manual & Chemical			Make sure you get all rhizomes and stolons with manual removal; do not do this if the plant has already gone to seed; we could cover small populations with plastic tarp to reduce germination
10	**Brome**	*Bromus spp*	Reduction/ Eradication	Manual (machine)		Manual & Chemical		For machine, you MUST bury seeds deeply or don't do it at all
11	**Tree Tobacco**	*Nicotiana glauca*	Eradication			Manual	Chemical	
12	**Yellow Mustard**	*Sisymbrium cf. irio*	Reduction		Manual & Chemical	Chemical		
13	**Silverleaf Nightshade**	*Solanum elaeagnifolium*	Reduction	Manual (x2) & Chemical	Manual			Only manage when found in intense densities (i.e. emery)
14	**Field Bindweed**	*Convolvulus arvensis*	Eradication	Chemical & hoeing/ burying		Chemical		In areas of heavy occupation, use mulching and mowing
15	**Poison Hemlock**	*Conium maculatum*	Eradication			Manual & Chemical		
16	**Sweet Clover**	*Melilotus spp*	Reduction/Watch	Manual & Chemical		Chemical		Manual treatments can be done whenever the ground is softest to dig deep; drowning can remove effectively too

APPENDIX 2: Relative Vegetation Cover

STANDARD OPERATING PROCEDURES

FOR DELINEATING VEGETATION AND MANAGEMENT FOCUSED "MAP UNITS"

AT GILA WATERSHED PARTNERSHIP HABITAT RESTORATION SITES

VERSION 1: JULY 29, 2019

Below is a background narrative plus step-by-step guide for delineating vegetation and maintenance/management "map units" at current and proposed Gila Watershed Partnership (GWP) habitat restoration sites. The key monitoring components include:

- Developing a formal spatial delineation of vegetation types per the Hink and Ohmart (H&O, Hink and Ohmart 1984) vegetation classification system. H&O ascribes vegetation communities based on (see Figure 1):
    - Canopy structure - six discreet structure *types* distinguished by vertical foliage distribution of woody vegetation. Structure types are assigned per:
        - the height of the overstory;
        - total overstory cover, and;
        - total understory cover
    - Relative species cover in both the overstory (>20 feet) and understory (<20 feet) canopy layers. Any species with relative cover >25% in a specific canopy layer is listed in the respective canopy layer.
    - Structure types (1 and 3) have >25% total overstory cover **and** >25% total understory cover. Dominant species (species that comprise at least 25% relative cover) in the overstory and understory layers are separated by a slash ("/").
    - When multiple species dominate a single canopy layer (i.e., "co-dominants"), they are isolated by dashes ("-"). Species are listed in descending order of dominance within a single canopy layer.
    - Non-woody structure types are assigned to a map unit when total woody cover is <25%. Non-woody structure types include grassland, wet meadow, marsh, open/barren, road, and sandbar.
- Listing other woody species present in the overstory and understory communities but not included in the H&O type (i.e., woody species that are present but contribute <25% relative cover to a canopy layer).
- Recording ocular estimates of cover for perennial graminoids, perennial forbs, bare ground, and litter.
- Recording total aerial cover of kochia (*Bassia scoparia*), tumbleweed (*Salsola spp.*), and *Chenopodium* X.
- Recording total cover of salt cedar (*Tamarix* spp.), other exotic phreatophytes, and giant cane (Arundo donax).
- Recording dominant exotic phreatophyte size/age (re-sprout, seedling/sapling, mature, or not applicable).
- Documenting noxious weed species observed and total noxious weed abundance.

- Recording presence/absence of cottonwood-willow recruitment.
- Photos, notes, etc.
- Keep in mind the following:
    - All cover classes are assigned for the entire map unit using an ocular estimate.
    - Data are normally collected in a custom app designed to promote efficiency, data quality, and consistency.
    - A "map unit" is a fixed, discrete geo-spatial block with a relatively consistent H&O vegetation type plus maintenance/management risks and priorities; thus, the site is divided into characteristic map units based on the quantity, extent, and distribution of the metrics described above.
    - When the map unit boundary cannot be precisely delineated on the hardcopy map, record GPS points and/or lines to electronically demarcate the boundary.

Vegetation Community Naming Convention

OVERSTORY LAYER SPECIES	/	*UNDERSTORY LAYER SPECIES*	STRUCTURE TYPE
SPECIES(>=25%) - SPECIES(>=25%)	/	SPECIES(>=25%) - SPECIES(>=25%)	1-6

**Species in each layer listed in descending order of dominance

Plant Species Codes

Code	Common Name
ATX	Saltbush
AW	Arrowweed
B	Baccharis
C	Cottonwood
CW	Coyote willow
SBM	Screwbean mesquite
SC	Saltcedar/Tamarisk
TW	Tree willow
VM	Velvet mesquite
WB	Wolfberry
**Add additional spp as needed*	

Structure Types

Woody

Structure Type	Overstory Cover	Overstory Height	Understory Cover	Understory Height	Description
1	**>25%**	>40 feet	**>25%**	6-20 feet	Tall trees with dense understory
2	**>25%**	>40 feet	*<25%*	NA	Tall trees with sparse understory
3	**>25%**	20-40 feet	**>25%**	6-20 feet	Intermediate-sized trees with dense understory
4	**>25%**	20-40 feet	*<25%*	NA	Intermediate-sized trees with sparse understory
5	*<25%*	NA	**>25%**	6-20 feet	Dense shrubs
6	*<25%*	NA	**>25%**	<6 feet	Short shrubs

Non-Woody (<25% woody cover)

G	Grassland
WM	Wet Meadow
MH	Marsh
OP	Open/Barren (often weedy)
RD	Road
SB	Sandbar (unvegetated or very early seral)

Figure 1. Hink and Ohmart vegetation naming convention schematic diagram

Required gear includes:

- Hardcopy field map: typically has a recent high-resolution aerial photograph or satellite image printed at a fine scale (1:2,000 to 1:10,000, depending on site size and vegetation heterogeneity). Multiple copies can be helpful for revisions.

- Black marker
- Tablet/smart phone that includes a custom-designed app, camera, and reliable GPS plus accessories (protective case, battery charger, cables, etc.)
- Safety gear, personal items, water, etc.

STEP 1. Traverse the site to generally assess the overall vegetation community diversity and select a starting location for delineating map units.

STEP 2. Use the hardcopy map to determine the boundary and shape of the first map unit. With the black marker, outline the map unit boundary and number the unit on the hardcopy map.

STEP 3. Create a new record (or feature) on the app. Typically, for workflow efficiency, records are stored as points even though you are technically describing attributes across an area (or polygon).

STEP 4. Enter the required general information (observer(s), date, site name, and map unit number).

STEP 5. Walk through the map unit to assess the current vegetation community plus other management relevant attributes. Record noxious weed species as encountered while you traverse the map unit. Periodically capture representative photographs of the map unit.

STEP 6. Record canopy cover attributes. Total canopy cover in the various height ranges will determine the H&O structure type. Select the representative structure type from the drop-down list.

STEP 7. Type in the current H&O type

STEP 8. Record whether the site has burned, or if it has been planted, treated (fuels reduction or exotic plant species control), or excavated (to create a new floodplain depression, channel, bankline manipulation, etc.). These conditions are referred to as sub-types in H&O.

STEP 9. other woody species observed in the overstory and/or understory canopy layers comprising less than 25% relative cover (i.e., species not included in the H&O naming convention)

STEP 10. Using an ocular estimate that is characteristic of the entire map unit, record total cover for perennial graminoids, perennial forbs, bare ground, and litter by selecting from the drop-down list in the appropriate fields.

STEP 11. Like the step above, in the appropriate fields, record total cover for species of management concern including, kochia/tumbleweed, saltcedar, giant cane, and other exotic phreatophytes.

STEP 12. Select the dominant exotic phreatophyte age/size from the dropdown list. Also select the most representative noxious weed abundance class from the drop-down list.

STEP 13. Record maintenance/adaptive management relevant notes.

STEP 14. Save and close the record.

STEP 15. Identify the next “map unit” at the site and repeat the above steps to document the shape and location of the map unit along with descriptive attributes. Continue this process until map units have been characterized for the entire site.

APPENDIX 3: Survival of Out-Plantings

STANDARD OPERATING PROCEDURES

FOR DOCUMENTING PLANT SURVIVAL

AT GILA WATERSHED PARTNERSHIP HABITAT RESTORATION SITES

VERSION 1: JULY 29, 2019

Below is a step-by-step guide for completing the electronic field form (EFF) developed for documenting survival of planted species at restoration sites along the Gila River. A GPS point was recorded at the location where every individual plant species was planted. The monitoring methodology described in this Standard Operating Procedure (SOP) involves navigating to each planting location and documenting whether the plant is alive, dead or missing. This SOP was developed to document survival of individual plant species such that detailed information stored in the Gila Watershed Partnership (GWP) geo-database (e.g., planting technique, material type, etc.) can be cross-referenced and used during data analysis. It is anticipated that survival monitoring will be implemented towards the end of the first two growing seasons following planting.

STEP 1: Download the ArcCollector *Data Collector* application to your smart phone or tablet

STEP 2: Once the app is downloaded, login with the username and password provided by GWP staff

STEP 3: When you arrive at a project site open the ArcCollector App on your mobile device

STEP 4: Select the map entitled *Revegetation Plant Survival (and the current year)*

STEP 5: Use the map to navigate to the first planted shrub/tree you will evaluate. Confirm the plants identity using the circular metal tag, which was marked and recorded for each tree/shrub at the time of planting. For efficiency and thoroughness, start at one end of the site and work your way across the site, assessing each tree along the way.

STEP 6: When you are ready to evaluate the first shrub, hold the GPS above the plant, and create a new record/feature.

STEP 7: Each individual plant installed during revegetation has a unique identifier (a number) labeled on the site map. Type in the individual plant identifier in the EFF.

STEP 8: From the dropdown lists, select the species and then select whether the planting is live, dead, or missing. The site map includes different colored points for each planted species, refer to the map if the planting is missing or dead and the species cannot be readily determined.

STEP 9: Record notes to communicate conditions that may improve success of future revegetation projects or to document observations not otherwise captured in the data. For example: Are certain species or clusters of individuals either showing prounounced signs of stress or high vigor uncharacteristic of the site? Does survival or vigor appear to be correlated with certain site conditions (soil, topography, hydrology, proximity to the active channel, etc.)? Is the cage intact? Were mole deterents used? Do you see insect damage, wildlife

browsing, human caused disturbance to a plant, trampling, livestock impacts, damage caused by hydrologic events, etc.? Create Y/N/ and N/A for herbivory (include likely spp if Y), cage, mole deterent, and any other herbivory deterrents used.

STEP 10: Photograph about 1/3rd of the plantings to create a representative photo log and also record photographs to provide visual evidence to support your notes.

STEP 11: Save the record and mark the plant stem with chalk indicating that plant has already been recorded in the EFF to avoid double-counting.

STEP 12: Move to the next individual and continue this process until all plantings have been evaluated at the site.

APPENDIX 4: Survival of Seeding

STANDARD OPERATING PROCEDURES

FOR DOCUMENTING HERBACEOUS SPECIES COVER AND PROMENANCE IN GILA WATERSHED PARTNERSHIP SEEDING AREAS

VERSION 1: August 20, 2019

Below is a step-by-step guide for completing the electronic field form (EFF) developed for documenting presence of native and non-native herbaceous plant species observed within individual 1-meter by 1-meter quadrats nested within 10-meter by 10-meter grid cells. The grid cells are overlaid on a pdf map of each project site (see example in **Figure 1**) and ensure even sampling distribution throughout the site.

The monitoring procedure requires a field tablet loaded with two apps: 1) Avenza Maps and 2) Collector. The field map with the grid overlay (**Figure 1**) is contained in Avenza Maps and Collector, and the EFF used to log field observations is within Collector.

Step-by-step instructions are described below, but the methods generally involve navigating to each 100ft² grid square on a field map and completing an EFF for each grid square to document presence of any herbaceous plant species observed.

The procedure is designed to be rapid, so data collection is limited to ocular estimates of cover and dominant species. This monitoring procedure should be implemented in late-summer.

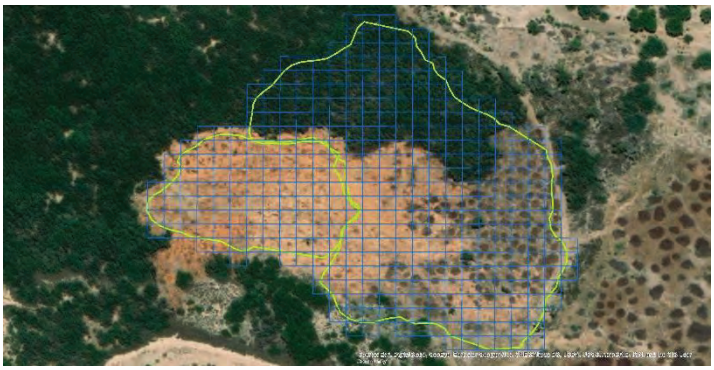


Figure 1. Map with 10m x 10m grid squares superimposed over the seeding area at site R10. These grid maps will be accessed using the Avenza Maps application on your mobile device.

STEP 1: Open the *Collector* application to your mobile device.

STEP 2: Open the Avenza Maps digital map viewer on your mobile device. Field maps of each project site with 100m² grid (10m x 10m) overlays should be transferred and then imported onto the device via ArcGIS online and/or box.org.

STEP 3: When you arrive at a project site open the relevant site map using Avenza Maps. Then navigate to the center of the first grid cell on the map. We recommend starting in one corner of the survey area, then proceed systematically from cell to cell in a manner that allows you to keep track of which grid cells you have previously surveyed.

STEP 4: At each monitoring station (directly in the center of each grid cell), drop a 1m2 sampling quadrat on the ground, add a new record, and record the vegetation attributes described in the following steps. Aerial

cover can be contributed by species rooted within and/or overhanging the PVC frame. The quadrat delimits the area where vegetation cover and other attributes are recorded.

STEP 5: Record an ocular estimate of perennial grass aerial cover within the quadrat as the most representative class: 0%, 1-5%, 6-10%, 11-25%, 26-50%, 51-75%, 76-90%, >90%.

STEP 6: Record an ocular estimate of perennial forb aerial cover within the quadrat as the most representative class: 0%, 1-5%6-10%, 11-25%, 26-50%, 51-75%, 76-90%, >90%.

STEP 7: Record an ocular estimate of non-native weed cover within the quadrat as the most representative class: 0%, 1-5%, 6-10%, 11-25%, 26-50%, 51-75%, 76-90%, >90%.

STEP 8: Record an ocular estimate of percent cover contributed by all native plant species using the following classes: 0%, 1-5%, 6-10%, 11-25%, 26-50%, 51-75%, 76-90%, >90%.

STEP 9: Record the five most prominent seeded species rooting or overhanging the quadrat in descending order, using the standard GWP species codes.

STEP 10: Record the single most prominent non-native annual and perennial weed species rooted or overhanging the quadrat using the standard GWP species codes.

STEP 11: Once every 15 cells, record representative notes to document probable variables affecting seeding success, observations of grazing/foraging, maintenance recommendations, etc. A representative photograph should also be recorded at each cell where notes are recorded. Note that if you find a critical observation that will assist with data interpretation or management at a cell, record that observation in the notes field even if it means that notes are recorded more frequently than every 15 cells.

STEP 12: Continue this process until data has been collected at every monitoring station (or grid cell) within the seeding area.

STEP 13: Note that a total of five of the monitoring stations are highlighted in yellow on the map. These, five cells are considered *Permanent Photo Monitoring Stations*. If you are located within a highlighted cell, follow the steps immediately below.

Permanent Photo Monitoring Stations

STEP 14: To establish a new photo monitoring station for the first time, place the quad on the ground in alignment with the cardinal directions, and drive two t-posts in two of the four corners, per the figure below. Spray paint the posts and mark with flagging. If the t-posts have already been setup during a previous monitoring period, simply place the quadrat on the ground with the posts oriented in two of the four corners per **Figure 2** below.

STEP 15: After the quadrat is nested on over the rebar, stand on the north side of the PVC frame, hold the tablet at chest height, and record a representative photograph showing the vegetation conditions within the quadrat. Also record a second photograph of the larger surrounding area at each photo station to document general physical change in site conditions over time.

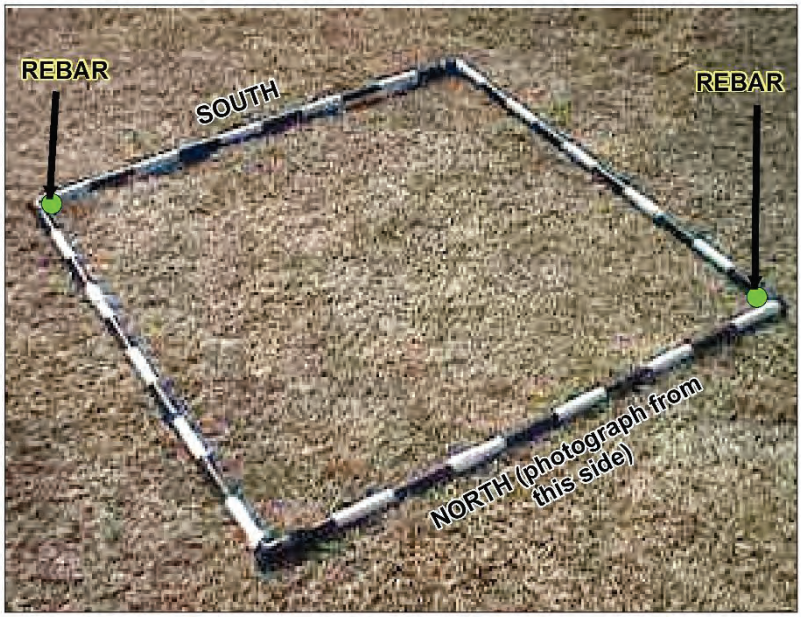


Figure 2. Photograph showing placement direction, post insertion points, and photo station at the Permanent Monitoring Stations.

APPENDIX 5: Photo Points

There are two types of photo point monitoring. One type is for monitoring seeded zones and pictures will be taken facing into the zone from each cardinal direction prior to seeding and at each monitoring event. The second type of photo monitoring is for qualitatively tracking landscape changes in restoration sites over time and is expanded on below.

Each active site has two photo points; one at the approximate center and one in the southwest corner. A spray-painted metal pole (orange at the center and pink at the southwest corner) marks each location and locations have been recorded via a mapping device with ArcCollector when they were originally placed. Subsequent monitoring's will be recorded on paper (see example below) in the following months annually: January, April, July, and October. Datasheets should then be scanned into the shared drive and associated with photos from that monitoring event.

Methods

- Center a tripod over the stake, or place directly east of the stake if it cannot be centered.
- Place laminated paper or whiteboard filled out (dry erase marker) with the date, photo point label, and bearing so it is legible in the photo.
    - Tripod height: 4-feet; Camera Model: TBD.
- Fill out the below form for each photo taken. There will be four photos taken from the center point: 0°, 90°, 180°, and 270°. From the Southwest point, there will be two photos: 0° and 90°.
- Naming Convention: The site number, followed by the location (C for center or SW for Southwest), then the direction (N, E, S, W). Follow this with the number associated with the site visit, i.e., this is the third time we've visited this site, so the number is "3" (see example below).
- Take photos *IN ORDER* and start from the center point (N, E, S, W (for center point) *OR* N, E (for SW point). If you accidently start at the wrong bearing, delete those photos and start again.
- Write down the time in military hours (from 24-hr clock).
- Use the comment section to mark down any drastic changes or noteworthy observations.

Example Data Form:

Photo Point Label	Date	Time	Compass Bearing	Number of Photo in Camera	Comments
R18_C_N_3	2/14/2018	13:30	0°	6	N/A
R18_C_E_3	2/14/2018	13:48	90°	7	Treated area, stumps in the foreground
R18_C_S_3	2/14/2018	14:01	180°	8	Lines up with mountains in the background
R18_C_W_3	2/14/2018	14:15	270°	9	POFR grove on right side of frame
R18_SW_N_3	2/14/2018	14:33	0°	10	Burned area
R18_SW_E_3	2/14/2018	14:42	90°	11	Large POFR grove in background

APPENDIX 6: Natural Recruitment

Natural native recruitment is important in the rehabilitation process to understand if the system has the potential to rehabilitate itself and be considered a 'safe' site (Polzin and Rood 2006) after the site has been cleared of tamarisk.

Methods:

Data will be collected throughout the sites with an emphasis on areas with lower depth to groundwater or within the active floodplain. Focus will be on three woody species of concern (Fremont's cottonwood, Goodding's willow, and coyote willow) to determine if natural recruitment has occurred. Because we are looking for natural recruitment, crews will not record greenhouse trees that were previously planted within the sampling area.

- Crew members will walk a complete polygon that was previously laid out for this sampling period. Crews will identify all of the areas within the polygon that contain species of concern and record them with ArcCollector.
- When an area with high densities of species of concern is identified the location should be noted and marked in ArcCollector. If it is a small area (< 4-m^2), surveyors will save a GPS point at the center and estimate cover (m^2); if it is a large area (> 4-m^2), crews will walk a polygon around the area and record using ArcCollector.
- Once the area has been recorded, crews will record the species present, their height, the number of stems, the percent cover, and whether the area contains seedlings, saplings, and/or mature trees.
    - Tree age codes: Seedling (< 1-m tall, 1 stem); Sapling (> 1-m tall, 1-multiple stems); Mature (> 1m tall, trunk or cumulative stems > 5cm diameter).
- Additionally, be sure to include the site name, observers' names, and the date and time of survey with each point or polygon recorded.
- Notes: Include where survey was started (orientation too) and the path you walked through the site. Also note anything interesting on site, i.e., evidence of flooding, significant secondary weed invasion, significant tamarisk regrowth, new land use activities, significant damage done by crews during removal, etc.

APPENDIX 7: Tamarisk Control and Treatment of Re-Sprouts

Tamarisk is a challenging species to control and often requires multiple sequential treatments in order to effectively remove the species from the landscape. Since tamarisk can re-sprout at the base very quickly following original removal, it is essential to incorporate multiple seasons of secondary treatments within an area before the tamarisk population can be considered controlled (Parametrix 2010). Because control is time-intensive and often cost-prohibitive, choosing to remove smaller sections at a time may be more effective. Furthermore, it is not recommended to revegetate intensely in areas that are not fully controlled, as chemical treatments of tamarisk can unintentionally put the neighboring native out-plantings at risk (Parametrix 2010).

Primary Initial Treatment

Primary treatment of tamarisk is done using chainsaws to low-stump trees as flat and low to the ground as possible. When not possible, trunks will be cut low and 2-3 notches will be cut into the angled top of the stump. Following cutting, an herbicide treatment will be applied within no more than 15-minutes. The herbicide will be sprayed onto the outer cambium layer of flat stumps and within the notches of angled stumps. We use a 20% triclopyr (Garlon 4 Ultra) and 80% water mixture. Because the timing of herbicide application is so essential, it is important that trees are piled as they are cut to ensure that no stumps are missed. Piles should be approximately the size of a standard van and there should be pathways around and between all piles. An area is not considered fully treated until all of these points have been met.

Secondary (Retreatment)

Retreatment following primary removal of tamarisk falls into two categories. The first being backpack spraying of small re-sprouts, and the second being chainsaw treatment of larger re-growth.

- Backpack Spraying: Also known as foliar spraying, this method of retreatment will be used when re-sprouts are no more than 5-ft high and stems are no larger than the thickness of a thumb. It is best to spray these trees in the spring and summer when they are green and taking in chemical more effectively. The herbicide mixture is 6% triclopyr.
- Chainsaw Treatment: A more heavy-duty treatment is required when re-growth is taller and thicker, often this is seen in growth greater than 1-year old. In this case the trees are treated in the same manner as a primary treatment cutting (see above), with the exception of organized piling, unless the density of re-growth demands it. It will be more usual to mulch the debris from re-growth in an effort to stymie herbaceous weed germination.