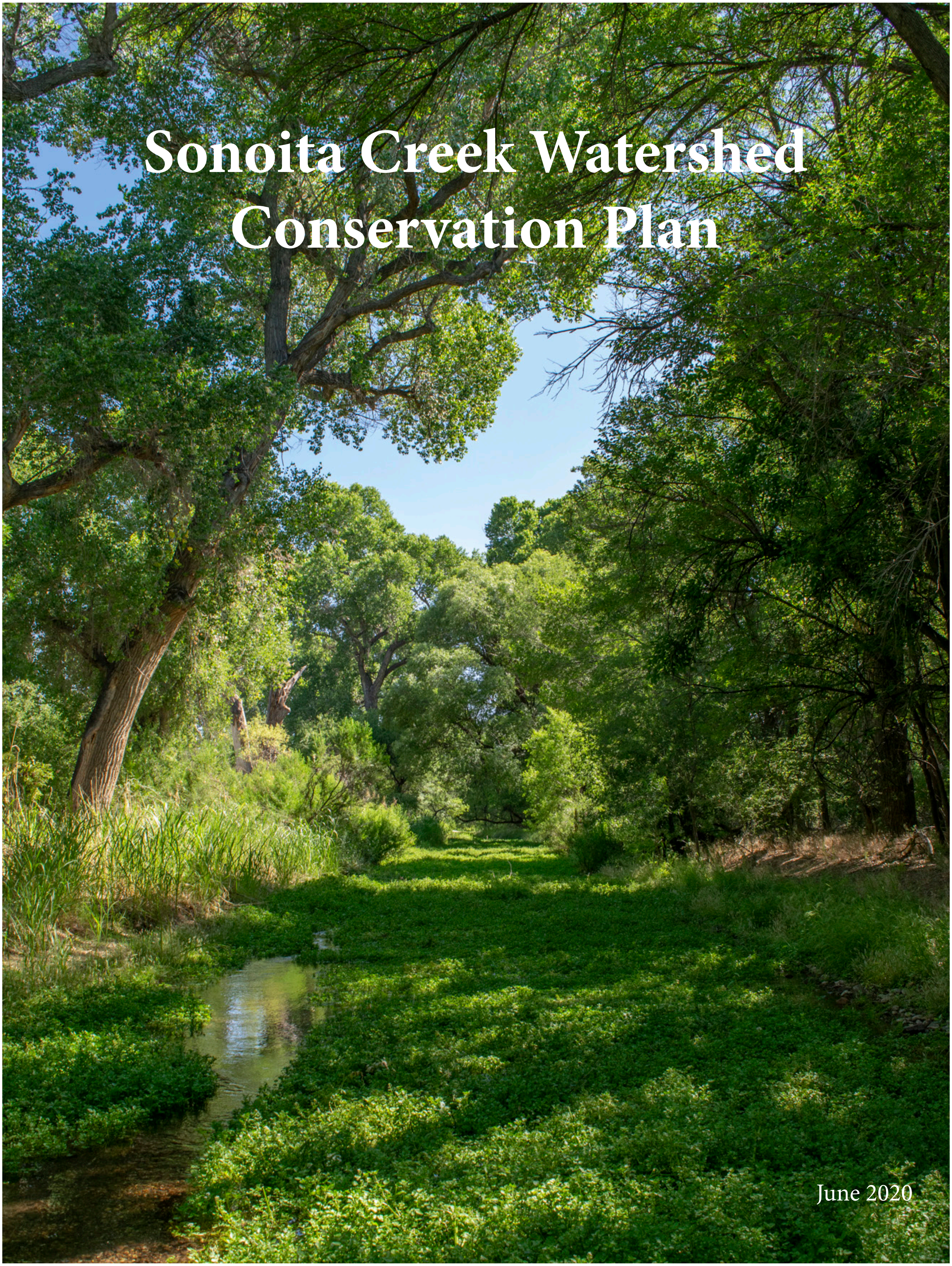
Sonoita Creek Watershed Conservation Plan



June 2020

Partners in this plan

Sonoita Creek Watershed Conservation Plan was prepared by four organizations that own and manage land for conservation purposes in the watershed.

Borderlands Restoration Network's mission is to foster ecological and cultural place-based learning and leadership, to restore and support healthy, regenerating water sources and flourishing plant and animal communities, and to support prosperous borderland communities by expanding a vibrant and sustainable restoration economy. Within that mission, BRN's lifelong-learning programs fill critical local and regional socio-ecological needs by integrating environmental, educational, and economic development programs.

Tucson Audubon inspires people to enjoy and protect birds through recreation, education, conservation, and restoration of the environment upon which we all depend. We work throughout southeastern Arizona to preserve and restore critical landscapes and riparian areas. Tucson Audubon has worked on Sonoita Creek since joining with TNC to protect the Fremont Cottonwood gallery by forming the Patagonia-Sonoita Creek Preserve, has identified and achieved designation for multiple Important Bird Areas in the watershed, and now manages the world-famous Paton Center for Hummingbirds in Patagonia.

The Circle Z Ranch has been in operation as a dude ranch just outside of Patagonia for more than 90 years. In addition to offering unique vacation experiences to our guests, we are committed to preserving the canyons, riparian areas, and grasslands for the health of Southern Arizona. In addition to introducing guests to all this desert oasis has to offer, we also sustainably graze cattle and horses on our more than 6500 acres.

The mission of The Nature Conservancy is to conserve the lands and waters on which all life depends. From our historic work in land acquisition to our cutting-edge research that influences global policy, The Nature Conservancy is constantly evolving so that we can take on the world's most important challenges. Since our start in 1951, the Conservancy has grown to work in 72 countries around the globe. The founding of our Arizona Chapter was marked by the establishment of the Patagonia-Sonoita Creek Preserve in 1966. Each year, thousands of visitors come to the Preserve to enjoy this spectacular Southwestern oasis and its abundant wildlife.

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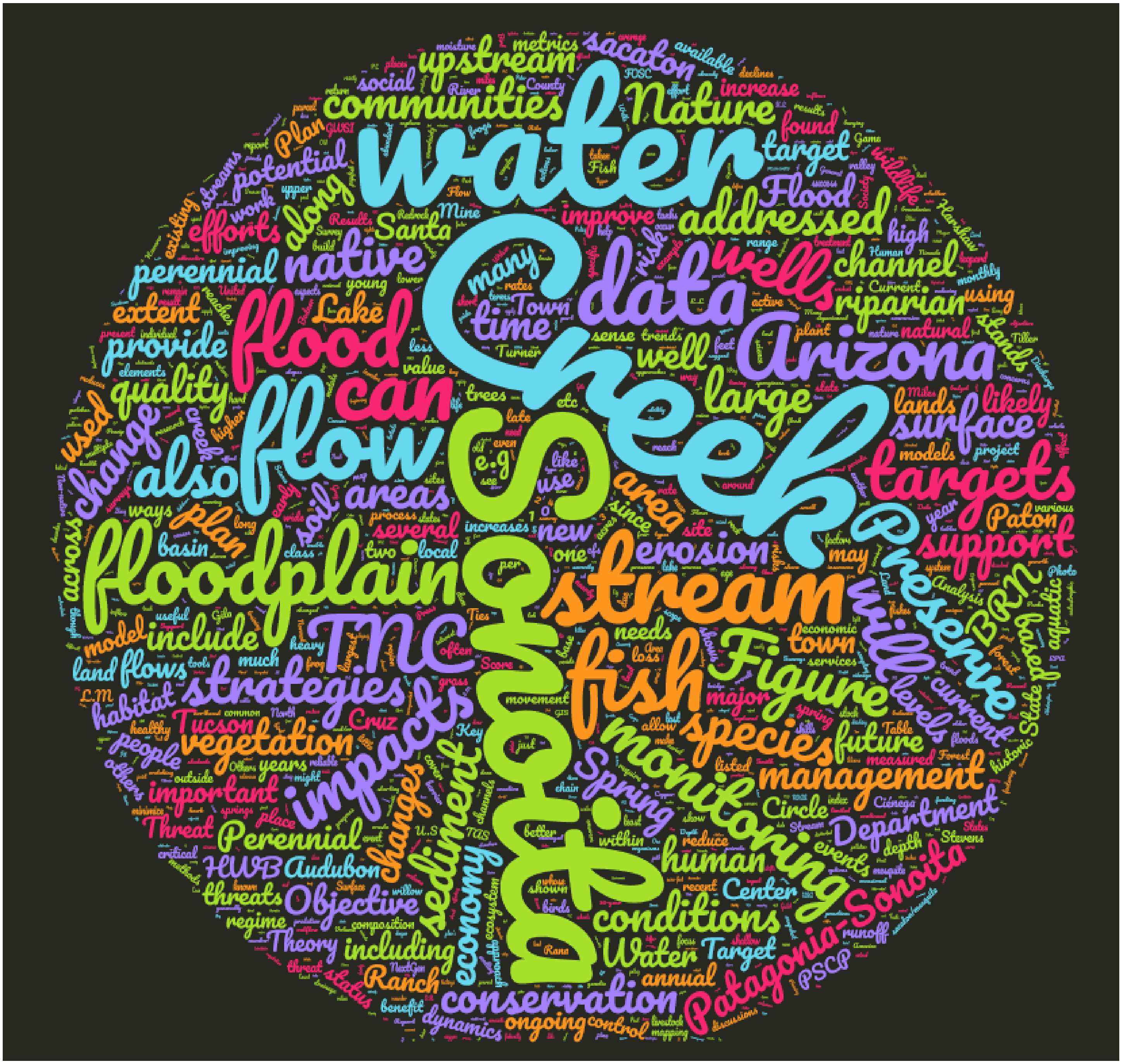

Word cloud for all the text in this plan. Word size is proportional to frequency of use, with common "connector words" omitted.

Vision Statement for Sonoita Creek Watershed

We envision a broadly engaged community that invests in and is supported by healthy social and natural environments within the Sonoita Creek watershed, including a sustainable nature-based economy.

Scope

This plan addresses the Sonoita Creek watershed above the dam at Patagonia Lake (Figure 1). This geographic scope was based on the active interests of the partners involved in the plan, and on recognition that conditions and issues are somewhat different below the dam. In addition, non-native fish and frogs from the lake have significant effects on native species upstream in the creek, while stream flow and sediment in the creek have effects on conditions in the lake.

The watershed covers approximately 146,054 acres, or 228 square miles. It has more than a mile of vertical relief, ranging in elevation from 9,456 feet at Mount Wrightson in the Santa Rita Mountains to 3,766 feet at Patagonia Lake dam. There is perennial flow in Sonoita Creek for approximately 10 miles beginning in the town of Patagonia, along with shorter perennial reaches in some of the tributary streams. Several large springs occur in the upper valley that sustain short stretches of perennial stream flow. At the highest elevations of the watershed (6,000+ ft) steep, rocky slopes are forested with ponderosa pine (*Pinus ponderosa*), Southwestern white pine (*P. strobiformis*), Douglas-fir (*Pseudotsuga menziesii*), Chihuahua pine (*P. leiophylla*) and a mixture of oaks (*Quercus gambelii, Q. hypoleucoides,* and *Q. arizonica*). Vegetation cover at middle elevations consists of evergreen oak-alligator juniper woodlands. At lower elevations, vegetation includes upper Sonoran semi-desert grasslands, and within the riparian zone of Sonoita Creek are found mesquite bosque, sacaton grassland, Fremont cottonwood-Goodding willow gallery forests, and ciénegas.

The primary human community in the watershed is the town of Patagonia.

Sonoita Creek is one of very few remaining streams in Arizona that support four or more native fish species. At least 267 species of birds have been observed on The Nature Conservancy's Patagonia-Sonoita Creek Preserve (PSCP), and 233 at Tucson Audubon Society's Paton Center for Hummingbirds (ebird.org, on 8/30/2019). Sonoita Creek is one of the most important recreational bird-watching sites in the United States, with visitors contributing a significant benefit to the local economy.

The Sonoita Creek watershed's relatively unfragmented uplands, riparian corridors, and perennial water provide resiliency and a critical corridor of connectivity within the larger landscape linking the Rocky Mountains and Sierra Madre Occidental.

Conservation Targets

<u>Cottonwood/willow community</u>

The watershed includes about 366 acres of Fremont cottonwood-Goodding's willow riparian forest along Sonoita Creek between Town of Patagonia and Patagonia Lake, and upstream from Cottonwood Spring (Figure 2). Many of the cottonwood-willow riparian forests in the Southwest were altered, degraded, or lost in the last century. Sonoita Creek supports some of the largest known Fremont cottonwood trees.

These forests generally consist of linear bands of cottonwood and willow (with lesser amounts of ash and walnut) trees of same-aged cohorts which parallel primary and/or secondary stream channels. Optimal conditions for forest development are found along depositional environments, where

Figure 1. Sonoita Creek watershed planning area. Black box shows location of Figure 2.

fine-grained alluvial substrates are present in the floodplain. The channels of such streams undergo continual lateral adjustment, as they meander, migrate, and form new alignments.

Cottonwoods and willows are both pioneer species colonizing newly disturbed areas. Flooding is the primary disturbance factor shaping cottonwood-willow systems. As a result, germination and establishment of many cottonwoods and willows temporally coincide with flood events that occur during or prior to the year of establishment. Sparsely vegetated, bare alluvium, or mineral soil along primary or secondary stream channels with little or no post-germination flooding are prerequisites for cottonwood-willow germination and seedling survival (Stromberg et al. 1991). Sustained high spring flows or episodic spring flooding or rains enhance germination, as well. Of utmost importance for germination is abundant soil moisture. Sufficient soil moisture during early seedling growth is critical to seedling survival as mortality is likely if the return to base flow conditions is too rapid to allow root growth to keep pace with declining water tables (as is characteristic with well-entrenched streams).

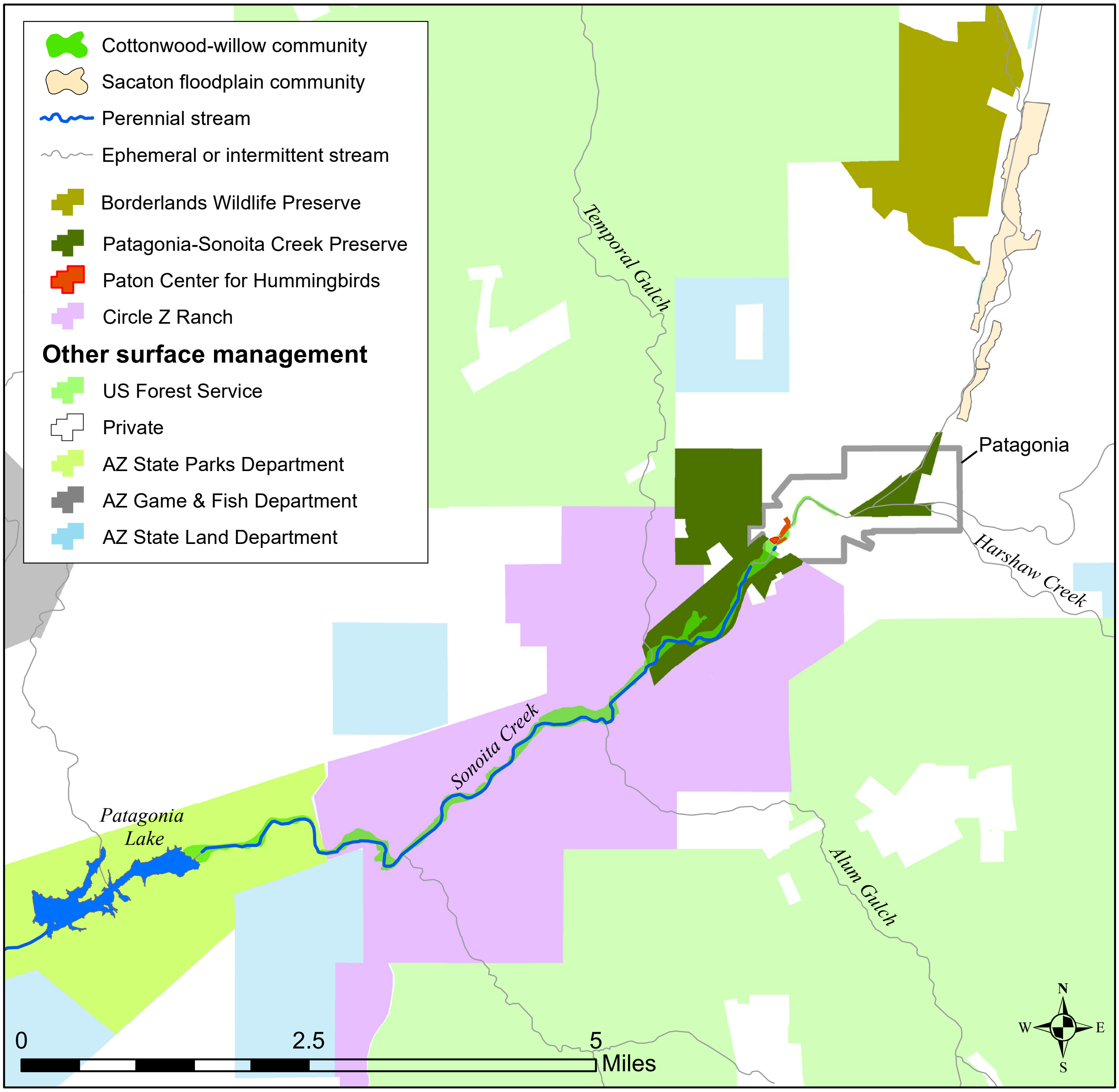

Figure 2. Conservation targets and land management in the vicinity of Patagonia.

In areas with vigorous cottonwood-willow communities, stands of young cohorts typically have much higher densities than older cohorts. Entrenchment of streams which reduces the frequency and degree of overbank flooding can lead to reductions in recruitment of young cohorts. Livestock grazing also reduces or eliminates cottonwood and willow seedlings through browsing and/or erosion.

These riparian forests support some of the highest breeding bird densities in the United States. Cottonwood-willow and mixed deciduous broadleaf riparian forests in the basin support a population of the western yellow-billed cuckoo (*Coccyzus americanus*, federally listed as Threatened). They also provide habitat for an unusual assemblage of other neotropical migrant birds, many of which reach their northern range limits in southern Arizona, including rose-throated becard, green kingfisher, northern gray hawk, zone-tailed hawk, common black hawk, violet-crowned hummingbird, northern beardless tyrannulet, thick-billed kingbird, and tropical kingbird.

Perennial stream community

This conservation target includes perennial flow segments of streams in the watershed that support native fish and frog species: Sonoita Creek upstream from Cottonwood Spring, Sonoita Creek between the Town of Patagonia and Patagonia Lake, Redrock Canyon, Harshaw Creek, and Big Casa Blanca Canyon.

The Sonoita Creek watershed historically supported seven native fish species, and at least seven nonnative fish species. Current occupants include Longfin dace (*Agosia chrysogaster*), Desert sucker (*Pantosteus clarki*), Speckled dace (*Rhinichthys osculus*), and Gila topminnow (*Poeciliopsis o. occidentalis*, listed as Endangered). The topminnow is rarely found on the Patagonia-Sonoita Creek Preserve, and the only persistent population within the planning area seems to be in Redrock Canyon.

The watershed once held the Monkey Spring pupfish (*Cyprinodon arcuatus*) and Gila chub (*Gila intermedia*). The pupfish was formerly distributed throughout the upper Santa Cruz River watershed, but was last collected from Sonoita Creek in 1927 and was only found at Monkey Spring in later decades. It went extinct in the late 1960s during modification of an irrigation system fed by the spring (Minckley et al. 2002). The chub was never taken from Sonoita Creek, but was historically abundant in Monkey Spring and associated ponds on the Rail X Ranch. It was last documented there in 1968.

The Sonora sucker (*Catostomus insignis*) was collected from Sonoita Creek in 1904, but not since.

Sonoita Creek also supports the federally protected Mexican garter snake (*Thamnophis eques megalops*, listed as Threatened) and Huachuca water umbel (*Lilaeopsis schaffneriana* ssp*. recurva*, listed as Endangered). The creek and its tributaries have historically supported Lowland leopard frog (*Rana yavapaiensis*), Chiricahua leopard frog (*Rana chiricahuensis*, listed as Threatened), and Tarahumara frog (*Rana tarahumarae*), though we lack data on the current status of all those native frogs.

Ciénega wetlands

A ciénega is a freshwater marsh in southwestern North America, typically supported by shallow or upwelling groundwater. Ciénegas are known to support a large number of rare species, and provide important habitat for migratory birds. A high proportion of ciénegas in this region have been lost due to dewatering or severe alteration, and many of those which remain have little or no protection (Minckley et al. 2013).

Ciénega wetlands occur downstream from Cottonwood Spring and on the Patagonia-Sonoita Creek Preserve.

Spongy uplands

The grasslands and woodlands at higher elevations in the watershed support valuable plant and animal communities. For this plan, we identified primarily their value for capturing precipitation, releasing it slowly to plants, and storing some as groundwater. This is important because precipitation increases with elevation, so the higher areas of the watershed contribute a disproportionate share of both storm water runoff and groundwater that appears in Sonoita Creek. Average precipitation at Patagonia is about 19 inches/year, while the upper portions of Mount Wrightson are estimated to get about 37 inches/year.

Sacaton/mesquite floodplain community

Grasslands dominated by big sacaton (*Sporobolus wrightii*) once occupied millions of acres of alluvial floodplains in semi-arid southwestern North America, forming nearly pure stands of this robust, tussock-forming perennial grass. Sacaton riparian grasslands are recognized for their important ecological functions and landscape values — absorbing flood flows, controlling soil erosion, and intercepting and retaining sediments. As the most productive of semi-arid grassland communities, they provide abundant forage for livestock and habitat for wildlife. Across the region, these grasslands now occupy less than 5% of their original distribution. Causes of decline include agricultural conversion, historical downcutting of rivers and consequent reductions in overbank

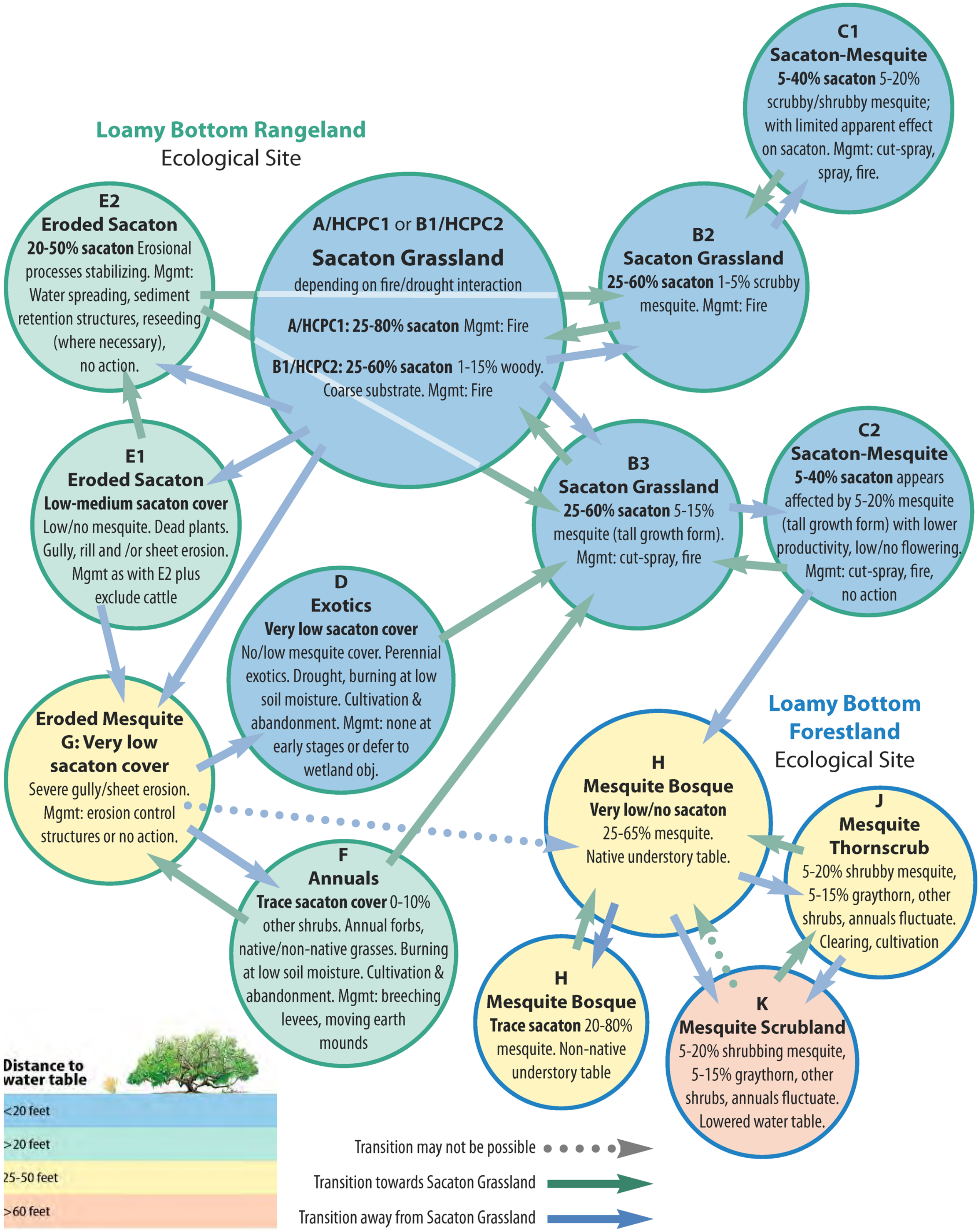

Figure 3. State and transition model for sacaton/mesquite floodplain community. Model was refined for at Las Cienegas National Conservation Area. Reprinted from Tiller et al. 2012.

flow, dropping of water tables from groundwater pumping and stream diversion, sheet erosion, overgrazing, and shrub encroachment. Despite steep declines, sacaton grasslands can be found scattered across much of their former range, often occurring in smaller patches or less productive states than historic accounts suggest (Tiller et al. 2012).

The Sonoita Creek watershed has several large remaining sacaton/mesquite communities, including both big sacaton (*S. wrightii*) and alkali sacaton (*Sporobolus airoides*). These include floodplain terraces along Sonoita Creek from Cottonwood Spring ciénega downstream to the Town of Patagonia (Figure 2), and along Redrock Creek just above its confluence with Harshaw Creek. Several small but high quality bosques and grasslands occur in mouths of small tributaries of Sonoita Creek west of Route 82. The majority, approximately 212 acres, occurs on Sonoita Creek Ranch, recently purchased as mitigation lands for the proposed Rosemont Copper Mine.

Fire, groundwater elevation, and grazing can all affect the health and persistence of sacaton, and can be used to drive communities from one compositional state to another. These are summarized in Figure 3, and were described in detail by Tiller et al. (2012).

Human well-being targets

The planning partners recognized that human well-being is inextricably linked to our conservation work, both in the services provided to people by Nature and the support that people can provide to Nature.

Positive sense of place and community

Residents of the area describe positive aspects of this community in terms of both human and ecological attributes, and the ability of the two components to support one another. The cottonwood/willow forest along Sonoita Creek plays an important role in the attractive character of Patagonia. That was described in the Santa Cruz County Comprehensive Plan (2016) and the Town of Patagonia General Plan (2009).

Flood protection

Approximately 65% of Patagonia is in the designated 100-year floodplain (Figure 11). The State Highway 82 bridge over Sonoita Creek is the major constriction, and poses the most serious threat of aggravating the flood problems in the town area. The bridge over Harshaw Creek located outside the northeast corner of town is another major constriction to floodwaters.

A healthy watershed and a properly functioning floodplain may be the cheapest and most durable forms of flood protection available, since they use natural processes to reduce the peak flow rate during floods. Conservation of cottonwood-willow, perennial stream, and sacaton-mesquite floodplain communities therefore has the double benefit of limiting additional building in flood-prone areas, and reducing flood impacts to existing structures.

Water security for residents and businesses

Human demands for water may compete with the environmental water needs that contribute to the quality of life, such as riparian areas and wildlife habitat. In the face of predictions for a hotter, drier climate, solutions for water security need to incorporate both.

A healthy watershed and properly functioning floodplain can improve water security by increasing the amount of precipitation that gets captured as groundwater. This benefits residents in the town of Patagonia, and also those in the much larger city of Nogales, Arizona. By state law, Nogales has rights to 4,200 acre-feet of water annually from Patagonia Lake. While the infrastructure to deliver that water has not been constructed, preliminary plans have been developed and the city may depend on that water during times of extended drought.

Nature based economy

The primary human community in the watershed is Patagonia, and Nature-related efforts provide significant contributions to the community's economy. This includes tourism dollars spent by wildlife-watching and other visitors to the PSCP and Paton Center, dude ranch visitors to Circle Z Ranch, restoration contract work done by Borderlands Restoration Network, and spending by hunters on their way to and from nearby public lands. Visitation estimates include more than 10,000/year to PSCP, and more than 16,000/year to Paton. Arizona residents spend more than 236,000 days/year at Patagonia Lake (Audubon Arizona 2019).

A 2018 survey of Arizona residents showed 30,700 visitors annually engaged in outdoor recreation along Sonoita Creek, spending about 96 thousand visitor days there. Wildlife watching in Santa Cruz County contributes $21.2 million to the county's economy (Tucson Audubon Society 2013).

These contributions are important since the population of Patagonia is estimated at less than 1,000 people, and is more impoverished than the state of Arizona as a whole. Median household income is $28,594 (vs. $53,510 for AZ). The unemployment rate is 6.7% (7.1% for AZ). People whose income is below the poverty level comprised 23.7% of the population (17.0% for AZ). (American Community Survey estimates for 2017; factfinder.census.gov, downloaded 13 May 2019.)

Multi-generational community

The local area's limited economy has resulted in a net outflow of young people seeking employment opportunities elsewhere, and limited recruitment of new young residents. As a result the population of Patagonia is older than the state of Arizona as a whole, with a median age of 51.6 years, and 46% of residents being 55 or older (vs. 37.2 years and 28% for Arizona, respectively) (factfinder.census.gov, downloaded 13 May 2019).

Restoring a multi-generational community will require developing a more resilient economy while maintaining the attractive qualities of the area. These attractive qualities include a shared sense of optimism and willingness to invest in the future of the community; these, in turn, are supported by a belief that ecological systems are healthy enough to persist into the future, and that human activities are at least somewhat sustainable.

Hydrology

Sonoita Creek and the riparian forest it supports are central to conservation and social interests in the watershed. The perennial stream flow is supported by groundwater, which is recharged by rainfall across the watershed. Analyses of the available data suggest that streamflow has been declining in recent decades while precipitation has not changed. This implies that some other factor has affected streamflow, likely through impacts to groundwater supplies.

Surface flow in the PSCP and Circle Z is generally derived from groundwater, which gets pushed to the surface by a subsurface ridge of rock crossing the basin just downstream of Patagonia. For the base flow of Sonoita Creek, 50% to 70% is derived

Table 1. Water budget for Sonoita Creek basin.

Inflow	Volume (acre-feet/year)	**Outflow**	Volume (acre-feet/year)
Precipitation	207,000	Evapotranspiration	187,000
Groundwater flow	4,000	Surface water discharge	6,000
Total	**211,000**	Groundwater flow	3,000
		Groundwater pumping	less than 500
		Total	**196,000**

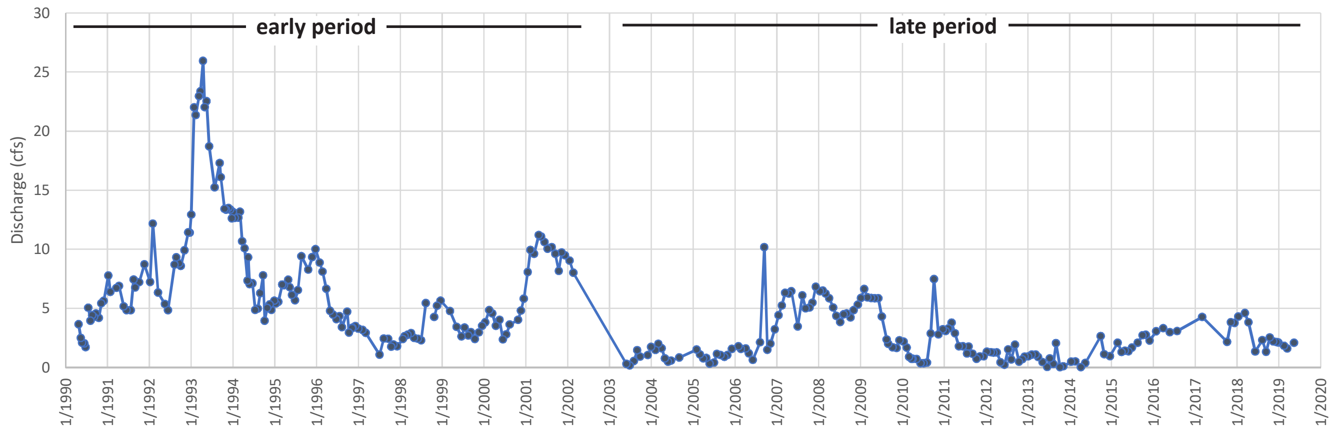

Figure 4. Sonoita Creek flow at Patagonia-Sonoita Creek Preserve. Discharge is measured in cubic feet per second (cfs).

from the alluvial aquifer in the valley northeast of Patagonia. The remaining contributions are equally divided between groundwater inflows from the Patagonia and Santa Rita Mountains (Gu et al. 2008).

E.L. Montgomery and Associates (1999) developed a water budget for Sonoita Creek basin (Table 1). Assuming that the hydrologic system in Sonoita Creek basin is in steady-state equilibrium, average inflow to the basin should equal average outflow from the basin. However, the water balance shows a discrepancy of about 15,000 acre-feet, or 8 percent of total estimated inflow. This is attributed to uncertainty around individual components of the water balance, most likely precipitation or evapotranspiration. Typical uncertainty for a basin-wide hydrologic water balance is 10 percent (E.L. Montgomery and Associates, 1999).

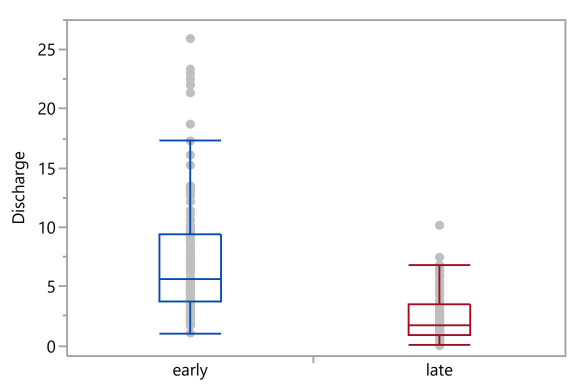

Figure 5. Sonoita Creek flow during 1990-2002 and 2003-2019.

<u>Stream flow</u>

The US Geologic Survey operated a stream gauge from 1930 to 1972 on Sonoita Creek within Circle Z Ranch, about 1.2 miles upstream from Patagonia Lake. That recorded a mean annual flow of 8.1 cubic feet per second (cfs).

Stream flow in Sonoita Creek has been measured regularly at the PSCP since 1990 (Figure 4), with occasional measurements taken in 1979-1989. These have been manual flow measurements taken monthly by Conservancy staff near the MW-1 well. These do not include flood flows, and thus are meant to represent base flow supported by groundwater. The 30-year (1990-2019) median flow was 3.6 cfs (mean = 4.8 cfs). Preliminary analysis suggests that period shows a declining trend, but it includes a wet period in 1993-1994. The early period, 1990-2002, had higher flows than a later period, 2003-2019 (Figure 5). Despite some year-to-year fluctuations in the later period, there was no apparent trend in flows from 2003-2019.

<u>Precipitation</u>

Precipitation has been consistently measured at the Paton Center in Patagonia from 1921 to present, with an annual average of 18.02 inches (Figure 6; wrcc.dri.edu/cgi-bin/cliMAIN.pl?az6280). While it is a great record, that represents just one site in a large watershed where precipitation varies with elevation. Mount Wrightson, the highest point of the watershed, is estimated to receive

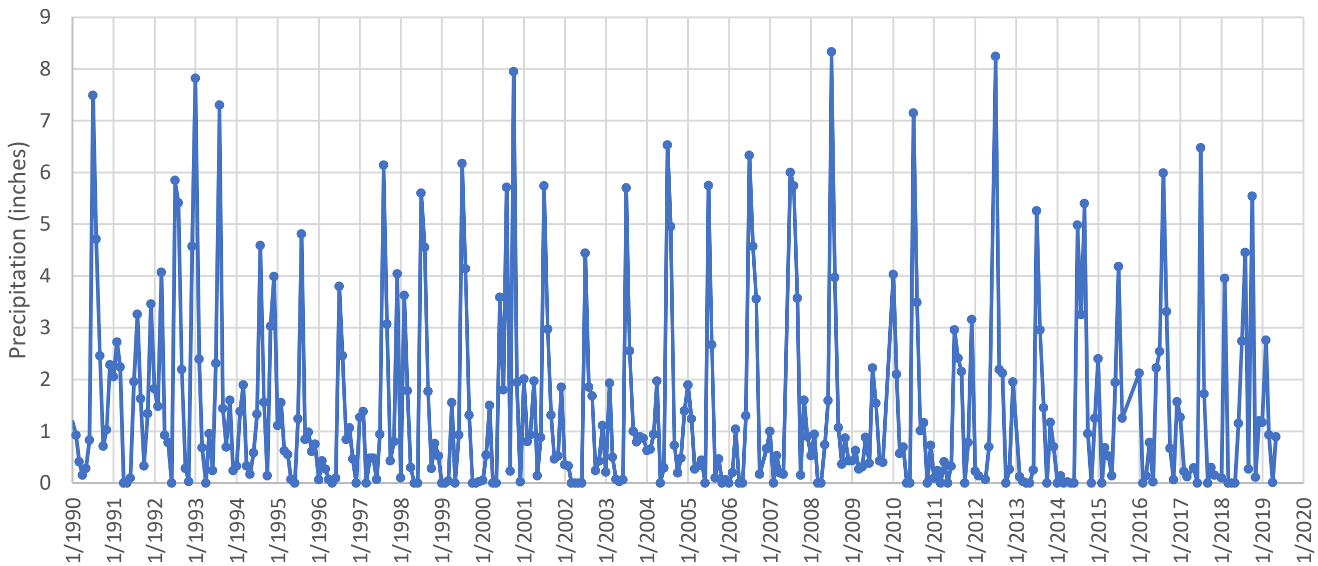

Figure 6. Monthly precipitation totals at Paton Center in Patagonia.

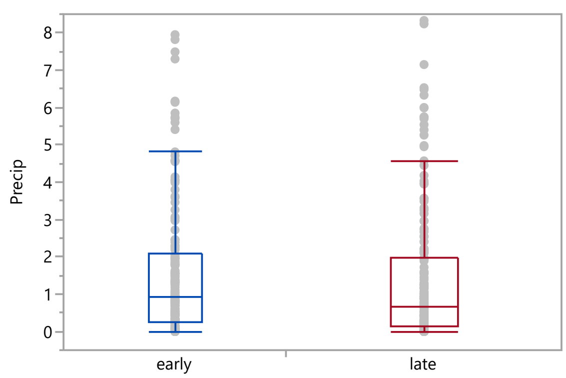

Figure 7. Precipitation during 1990-2002 and 2003-2019.

36.9 inches/year (PRISM 30-year normal, 1981-2010; www.prism.oregonstate.edu).

In contrast to stream flows, the available data for precipitation shows only a slight difference between those two periods. The monthly precipitation totals for the Paton Center show a declining trend over the 30-year period, but only a slight difference between the two periods (Figure 7).

<u>Groundwater</u>

Groundwater has been measured monthly in 27 monitoring wells on the PSCP during the past 30 years (Figure 8), but there is wide variation in the period of record for different wells. Most of the wells with long records have fairly stable groundwater levels over time (Figure 9). However, those wells closest to the upstream end of the preserve show much higher fluctuations, sometimes changing more than ten feet between years. None of those upstream wells have been monitored since 2012, but there is a well just upstream of the preserve that has had annual monitoring by Arizona Department of Water Resources through this year as part of their Groundwater Site Inventory (shown as "GWSI" on Figure 9).

The data and physical arrangement of these wells suggests that groundwater pumping in town has affected groundwater on the upstream end of the preserve, but that additional groundwater moves in as you shift downstream. There is evidence of groundwater inflow from several "seepage runs," sequential flow measurements along the stream conducted in 1996 and 1998. Those showed steadily increasing surface flow from the beginning of the perennial reach until a half-mile downstream of the confluence with Temporal Gulch, and then fairly consistent flow for more than two miles.

The Sonoita Creek watershed includes two major springs that support riparian and aquatic communities (Figure 1). Monkey Spring, with an estimated discharge of 430 gallons per minute, and Cottonwood Spring, with an estimated discharge of 150 gallons per minute (ADWR 2009). The watershed also includes a spring-fed ciénega on the PSCP.

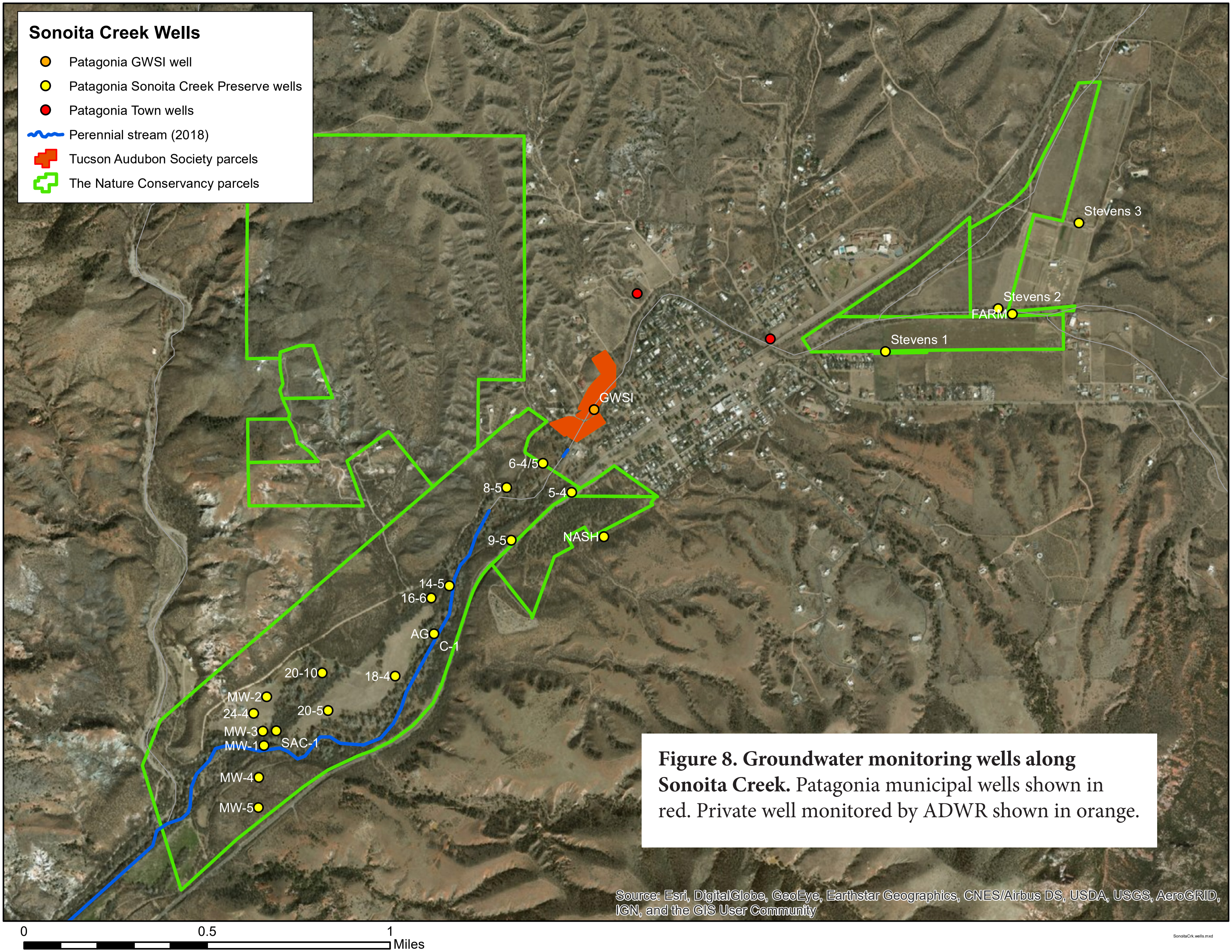

Figure 8. Groundwater monitoring wells along Sonoita Creek. Patagonia municipal wells shown in red. Private well monitored by ADWR shown in orange.

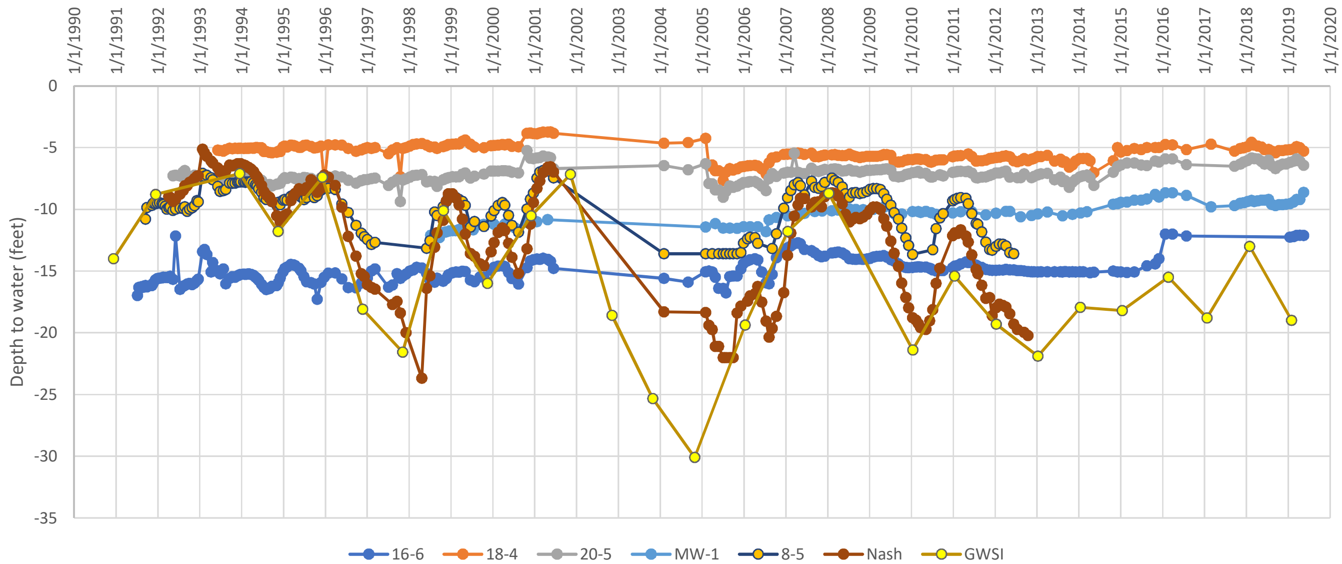

Figure 9. Depth to water in select monitoring wells. Well locations shown in Figure 8.

Patagonia Town water pumping has a reliable monthly record from 2008 to date. For January 2008 through August 2016 this record shows an average annual groundwater pumpage of 39.8 million gallons per year or 122 AF/yr (NextGen 2017). The current town wells were installed in 1965 and 1974.

There are approximately 780 wells in the Sonoita Creek watershed (ADWR Wells-55 database, Oct. 2015). About 40% of those are within a 1 mile radius of Patagonia (Figure 10). Most of the large agricultural wells are up the valley to the northeast, while all of the large mining wells are in the Patagonia Mountains to the south. The boundaries of the groundwater basin do not exactly match the surface water basin in the vicinity of the town of Sonoita, so additional wells around Sonoita (outside the surface water basin) may be drawing groundwater that would otherwise appear in Sonoita Creek.

There is one wastewater treatment facility in the watershed, located on the southwest side of Patagonia. This facility serves 945 people and generates 73 acre-feet of effluent per year, discharged into Sonoita Creek (ADWR 2009).

Threats

We identified major threats to all our conservation targets, listed below, and ranked their relative importance by evaluating the scope, severity, and reversibility of impacts to each target. We also identified the major contributing factors to those threats, looking for the systemic drivers (Appendix 1). That analysis provided a strong basis for discussions of strategies. Some of these contributing factors drive multiple threats and have large cumulative effects on targets. For example, poorly regulated mining and its expanding infrastructure in and around this watershed drives major threats to water quality and quantity, altered flood regimes, wildlife movement connectivity, and major disruptions to human well-being targets of Nature-based Economy and Positive Sense of Place and Community.

<u>Altered flood regime</u>

Within the Sonoita Creek watershed, several factors have altered the natural flood regime in ways that can make floods more destructive and more frequent.

Sonoita Creek has a long history of deliberate channel and floodplain alterations. The 1880s saw

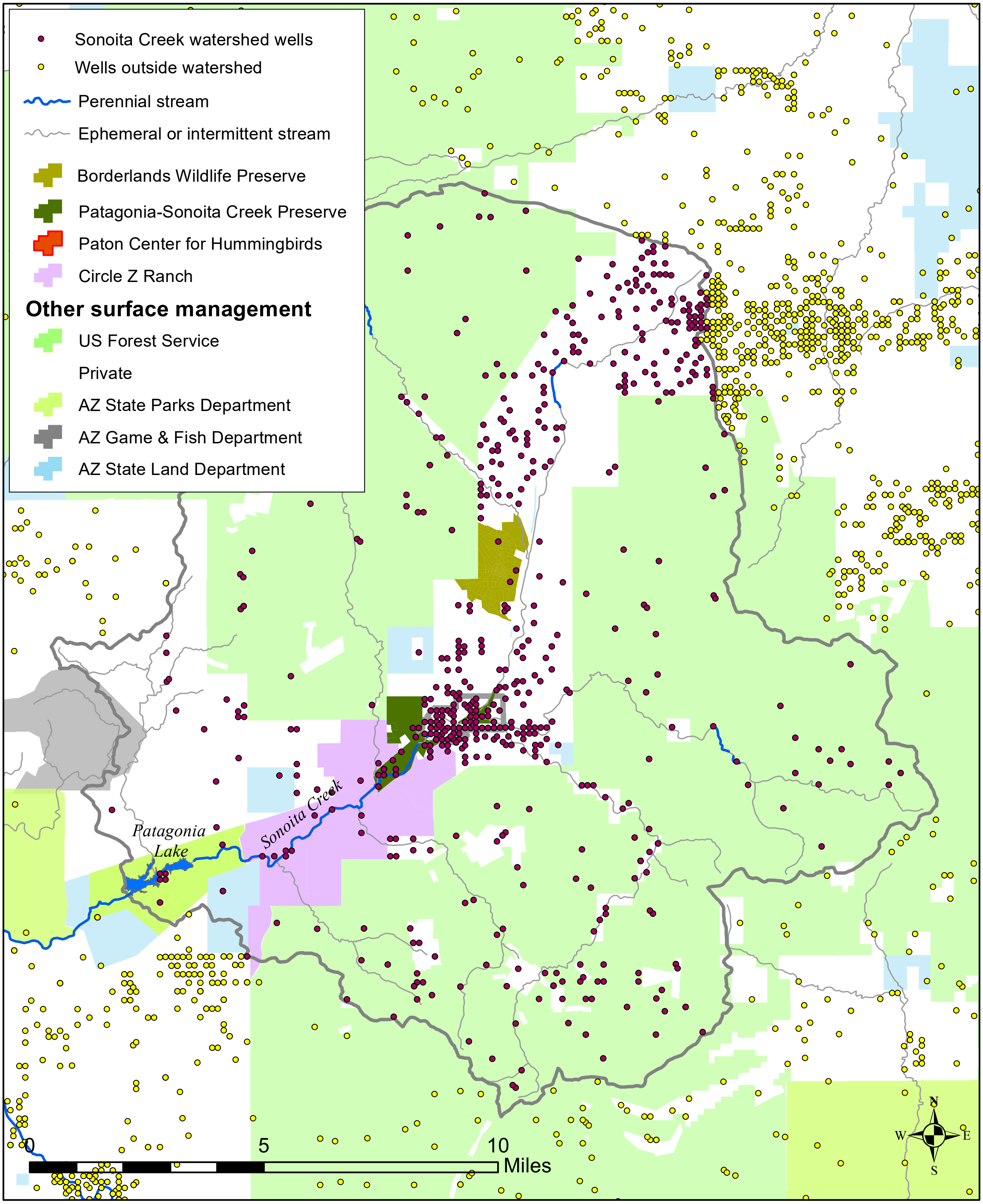

Figure 10. Wells in and near the Sonoita Creek watershed.

the completion of a railroad through the Sonoita Creek valley. That included straightening of the creek channel to allow construction of berms. Those berms, and associated abutments for bridges, constrict streamflow during flood events thereby preventing natural dissipation of water across the floodplain and prevents the stream from its natural tendency to meander. Despite that, the stream channel seems to have reached a new equilibrium such that any attempts to induce meandering carry risks of destabilizing the system.

Entrenchment of the stream coupled with groundwater depletion affect the height of the water table, soil moisture, and sediment deposition which, in turn, are limiting factors to recruitment of cottonwood, willow, sacaton, and mesquite. Stream entrenchment reduces habitat diversity, increases duration and severity of flood events, and increases scouring.

One of the most solid scientific predictions about climate change has long been greater extremes of precipitation, as the climate warms and the atmosphere's capacity to hold water increases. While overall precipitation in the Southwest has been declining, occasional heavy rainfall events have become more common. Evidence for this has been reported for the global and continental scale, and a recent study in the San Pedro River basin found intensification of brief monsoon rainfall intensities starting in the mid-1970s (Kunkel et al. 2010, Demaria et al 2019). More intense events can cause devastating flash floods with increased erosion, and may accelerate the transition of grassland to shrublands (Zhang et al. 2012).

Another well-documented effect of climate change has been increasing size and frequency of catastrophic wildfires (Abatzoglou and Williams 2016). In the aftermath of such fires, large flash floods are common and can cause tremendous damage to human communities and riparian vegetation. The southern drainages of the Santa Rita Mountains have not experienced a large fire in more than 35 years and thus are at high risk (www.mtbs.gov; referenced 10/2/2019).

<u>Increased erosion and sedimentation</u>

Historic overgrazing by livestock in the Sonoita Creek watershed produced lasting effects on watershed condition and thus on the flood regime. Watershed quality is largely determined by upland semi-desert grassland conditions. Increased perennial grass and light shrub cover "anchor" the landscape, providing greater infiltration of precipitation, less surface runoff, reduction of flood peaks, less soil movement, and higher water quality through reduced sedimentation. Perennial grasses also produce litter that gives soil greater aggregate stability, increases soil fertility, and permit increased infiltration. The composition and structure of semi-desert grasslands have changed significantly since 1900 as a result of fire suppression and intense cattle grazing (Hastings and Turner 1965; Branson et al. 1981).

As noted above, catastrophic wildfires in the watershed pose an additional threat to the stream. After large fires, flash floods cause increased erosion of stream channels in some places and large sediment deposits in others. In Sonoita Creek, there is risk that stream segments with perennial flow could be buried by sediment, eliminating habitat for fish and other aquatic species.

A potential threat involves a proposed mitigation project on Sonoita Creek Ranch for the Rosemont Mine, proposed for an area outside the Sonoita Creek watershed. Current plans by Hudbay, developers of the Rosemont Mine, involve constructing a new channel for Sonoita Creek. As designed, the new channel would have a very sinuous alignment (Hudbay 2017). This creates significant risk that the creek would cut a straighter path during large flood events (EPA 2017). Such an event would transport large volumes of sediment downstream, potentially causing greater flood risks in Patagonia and burying the perennial stream flow in the Patagonia-Sonoita Creek Preserve (Figure 11).

In a slower example of increased erosion, an active headcut in Sonoita Creek is currently moving upstream from Patagonia Lake State Park. If it continues to expand, it carries a risk of incising a much deeper channel through the floodplain

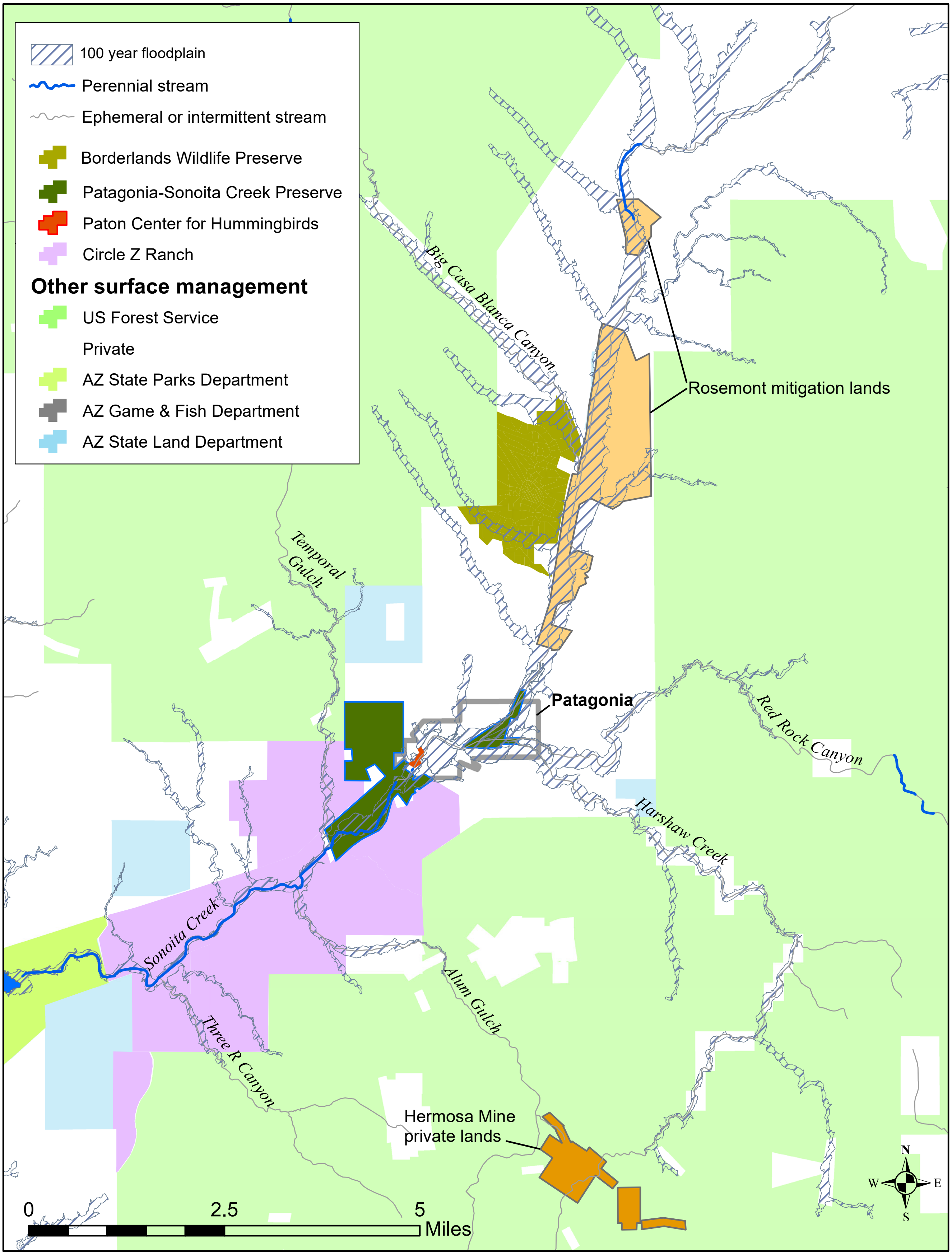

Figure 11. Floodplains and current mine-related projects in the Sonoita Creek watershed.

which could lower the adjacent groundwater levels, damaging the riparian community. That incision would change the flood regime by focusing floodwaters and increasing their erosive ability. It would also change fish habitat in the stream, potentially eliminating one or more native species.

Competition by non-native plants

Deliberate and accidental introduction and spread of non-native plants throughout the watershed reduces species diversity and the amount of suitable habitat and forage for native fauna that have evolved with native flora. Non-native plants may increase their abundance and distribution due to competitive advantages that can be exacerbated by the effects of climate change, further reducing overall biodiversity and habitat resilience. Notable problems in this watershed have been found with Johnson grass (*Sorghum halepense*) in floodplains and Lehmann lovegrass (*Eragrostis lehmanniana*) on grassland slopes.

Increased predation on fish, birds

Non-native fishes are generally recognized as the biggest threat to the survival of native fishes in the Southwest (Minckley and Marsh 2009). Some of them are major predators on native fish, while others directly compete for food and other resources. Non-native fish (e.g., mosquitofish, bass, green sunfish, red shiner) migrate upstream from Patagonia Lake, and can be swept into the creek from upstream springs and stock tanks.

Non-native crayfish are also known to significantly reduce the biodiversity of stream systems because they voraciously feed on native fish, frog tadpoles, young gartersnakes, and aquatic invertebrates.

Introduced bullfrogs have been implicated in the decline or displacement of many amphibians and a few reptiles, including Mexican garter snakes (*Thamnophis eques*), lowland leopard frogs (*Rana yavapaiensis*), and Chiricahua leopard frogs (*Rana chiricahuensis*) (Schwalbe and Rosen, 1988). Bullfrog populations do not reach high levels in streams that experience regular flooding, since their tadpoles can be washed away during the months or years required to metamorphose, but they can recolonize Sonoita Creek from Patagonia Lake or stock tanks in the watershed.

Feral cats and free-ranging pet cats kill 1.3–4.0 billion birds and 6.3–22.3 billion mammals annually in the U.S. (Loss et al. 2013). Their abundance and impacts along Sonoita Creek have not been studied, but the proximity of Patagonia suggests they are common and likely reduce local wildlife populations.

Reduced groundwater levels

Stream flow in Sonoita Creek and health of the riparian corridor depend on groundwater supplies. Preliminary analysis suggests a declining trend in stream flow, and the limited groundwater data available for the town of Patagonia suggests that pumping there has direct effects on groundwater levels. While not the only wells in the area, the town's two primary wells for drinking water are adjacent to the creek channel (Figure 8). A large well for industrial purposes was recently drilled near the mouth of Harshaw Creek, with the potential to intercept groundwater inflows from that tributary. If pumping within the town boundaries increases substantially, due to population growth or other causes, it could rapidly affect flow in the creek downstream. Other wells in the watershed, whether higher along Sonoita Creek or along tributary canyons, would also capture groundwater from the creek but the effects on perennial flow would be delayed.

Any changes that reduce aquifer recharge would also lower groundwater tables, harming the humans and ecosystems that depend on shallow groundwater. Long-term drought, climate change, and land use changes in upper elevation recharge zones pose long-term threats that would be hard to reverse.

Diversion of spring flow

The watershed has a number of springs but the largest, Monkey Spring, has been highly altered to divert water for agricultural and other uses. The ecological impacts have been very high, including loss of species and habitat.

The next largest spring, Cottonwood Spring, has been conservatively managed by private owners. The Nature Conservancy holds a conservation easement over an adjacent reach of Sonoita Creek.

Impaired water quality

The water quality in Sonoita Creek is affected by materials from throughout its watershed. This includes heavy metals from historic mining waste and naturally fractured bedrock. Arizona Department of Environmental Quality has rated Sonoita Creek as impaired due to high zinc and low dissolved oxygen levels. Metals and acidity in tributary stream reaches of Alum Gulch and Harshaw Creek have exceeded standards for aquatic and wildlife, partial body contact, and livestock watering (ADWR 2009), though some recent testing found lower contaminant levels and official impairment status is under review. The area also experienced high profile releases of metallic and acidic mine drainage after large rainstorms. The complex network of tailings, tunnels, and rock fractures makes predicting and remediating this type of contamination difficult (Norman et al. 2008).

There is the potential for additional pollution from the Hermosa Mine, currently under development in the Patagonia Mountains.

Impaired water quality poses a threat to human well-being targets on both chronic and episodic time scales. Many wells in the area have tested above drinking water standards for cadmium, copper, arsenic, fluoride, and lead (ADWR 2009). Ongoing remediation and research by USGS and others will likely provide better data on the magnitude of the water quality problems from old mining activities and options for addressing these, but easy and inexpensive solutions are unlikely.

There is also potential for contamination from aging infrastructure at the Patagonia wastewater treatment plant and from aging septic systems. Additional nitrogen and fecal contamination is likely provided by livestock in the watershed.

Existing pollution in Sonoita Creek at current levels appears to be a chronic condition that might impair aquatic life but allow it to persist. However, the potential for a major toxic spill or greater inflows from an existing site remain active threats.

Persistence of historic degradation

Some impacts from historical human activities in the Sonoita Creek watershed have persisted long after the initial disturbance. These include the legacy of heavy grazing impacts, which changed the vegetation community, the soil structure that supports vegetation, and the hydrologic function of tributary watersheds. The lasting impacts of early mining exploration and development include polluted water drainage, piles of waste rock that provide little or no support for native plants and animals, and abandoned shafts and adits that can trap wildlife (though old mines can also provide important roost sites for bats). Old roads, often constructed for mining purposes, change surface water flow patterns and can increase erosion. Old roads, even when not maintained, attract recreational off-road vehicle use which can extend the impacts beyond the original road alignment.

Among the most visible impacts is that of the old railroad alignment along Sonoita Creek. While the tracks are long gone, its earthen berm disrupts surface water flows from tributary areas, the Sonoita Creek channel was straightened in places, and several bridge abutments prevent the channel from shifting across its floodplain.

Objectives and Strategies

The partners in this plan collectively identified objectives and strategies that will address some of the major threats in the watershed. Some of the strategies directly focus on known threats, while others focus on gathering information and preparing conditions for future strategies. Leadership on individual strategies is noted in parentheses, while details about implementation, funding, and other support roles will be determined in the future. Results chains showing the logic behind many of the strategies are presented in appendices.

Objective 1: By 2030, stabilize or improve groundwater conditions across the watershed to levels that will support conservation target communities.

Strategy: Support Patagonia's town-sanctioned Flood and Flow Committee in groundwater data collection and analysis of trends. (TNC)

Support development of a groundwater model. (TNC)

Monitor and analyze groundwater and surface flow data at TNC Preserve. (TNC)

Convene discussions within community about groundwater management when NextGen report is available, based on better understanding of conditions. (BRN)

Target addressed: Cottonwood-willow community, Perennial stream community, Ciénega, Sacaton-mesquite floodplain community, Water security for residents and businesses

Threat addressed: Reduced groundwater levels

Theory of change: Groundwater is essential for maintaining plant, animal, and human communities in the Sonoita Creek watershed. In the face of potential changes in human demand for water and a drier climate, water management will require a much better understanding of impacts from proposed activities, and of trade-offs between possible management options. A groundwater model would allow testing of scenarios, such as predicting impacts from new groundwater pumping or recharge projects. It could also be used to evaluate questions like whether moving the Patagonia town wells upstream could minimize impacts to streamflow while maintaining a reliable water supply. The accuracy and precision of a model depends on the data available, so maintaining and expanding the network of groundwater and surface water monitoring sites will improve the value of the model. How a model is used, and how decisionmakers respond to results, depends on how the process of developing a model engages with the community and develops trust in the process. This strategy is focused on improving our tools and shared knowledge base. Future discussions will be needed to develop strategies that directly target maintaining or improving groundwater conditions. (Appendix 2)

Objective 2: Restore a healthy cottonwood-willow community with multiple age cohorts of trees.

Strategy: Develop pole planting project on Patagonia-Sonoita Creek Preserve. (TNC, BRN)

Target addressed: Cottonwood-willow community, Positive sense of place and community, Flood protection, Nature based economy

Threat addressed: Altered flood regime

Theory of change: Sonoita Creek has seen very little recruitment of new cottonwood trees in recent decades. While this is probably not a crisis yet, the existing trees will need replacement in the foreseeable future. Developing a project to grow and plant a new cohort of young trees will provide those replacements while supporting the nature-based restoration economy of Patagonia. Engaging local residents to help with the planting will increase their appreciation for the cottonwood/willow forest as they see the trees grow and document progress (Appendix 3). Maintaining or improving the cottonwood-willow community will also support the resident and migrant bird populations, which provide a major economic driver for Patagonia, support the positive sense of place for human residents, and provide a recreational benefit to visitors from across Arizona and the rest of the country.

Objective 3: Increase native vegetation communities in the Sonoita Creek floodplain.

Strategy: Replace Johnson grass with sacaton on the Johnston parcel. (TAS)

Restore sacaton and other grasses on the Stevens parcel. (BRN)

Create Cooperative Weed Management Area and compile best management practices for weed control. (TAS)

Revegetate with locally adapted native species (TAS, BRN, TNC)

Target addressed: Sacaton-mesquite floodplain community

Threat addressed: Altered flood regime, Competition by non-native plants

Theory of change: Sacaton communities have been lost or degraded through most of their historic range. Some large patches remain relatively intact along Sonoita Creek, but others have been cleared for historical agriculture. One of the major threats to sacaton recovery here is non-native plants, and there are opportunities to directly address that threat. Removal of Johnson grass and other weeds, followed by planting of sacaton, has potential for restoring large patches. Past experience with weed management and sacaton planting has shown wide variations in effectiveness, so compiling and sharing best practices would improve the chances of success. Restored sacaton communities in the Sonoita Creek floodplain will slow floodwaters and reduce the risk of severe erosion during high flow events. (Appendix 4)

Objective 4: Sustain geomorphic floodplain function of sacaton/mesquite community to regulate sediment movement and attenuate large flood flows.

Strategy: Support LiDAR data collection of current floodplain elevations, and modeling of floodplain and sediment dynamics that can compare alternatives for floodplain and channel management, using a process that develops public support for the model and its application. (TNC)

Develop ways to avoid or minimize damage from the planned Hudbay project on Sonoita Creek Ranch. (TNC)

Increase community awareness of upstream floodplain values for Patagonia. (BRN)

Target addressed: Perennial stream community, Sacaton-mesquite floodplain community

Threat addressed: Altered flood regime, Increased erosion and sedimentation

Theory of change: The largest remaining sacaton community in the watershed is on Sonoita Creek Ranch. Current plans by Hudbay involve uprooting many of the plants as part of constructing a new channel for the creek, and burying additional plants under the excavated soil. Some of the plants would be replanted into soil placed on the existing channel. As proposed, the newly constructed, highly sinuous channel alignment carries a high risk of failure in the form of large flood events cutting a straighter path. This might transport large volumes of sediment downstream, potentially causing greater flood risks in Patagonia, and burying the perennial stream flow in the Patagonia-Sonoita Creek Preserve. Developing a better scientific understanding of those hazards will increase the options for minimizing or avoiding serious impacts. These could include revegetation or other floodplain projects on TNC lands upstream from Patagonia that might capture sediment and reduce flood peaks.

Gila topminnow in the Santa Cruz River, Sonora, Mexico. Photo © *Dale Turner/TNC*

Objective 5: Reduce erosion, increase infiltration, and prolong soil moisture in strategic places in the watershed.

Strategy: Analyze the watershed for the most strategic places for restoration projects. (BRN)

Develop and raise funds for watershed restoration projects. (BRN)

Conduct restoration projects. (BRN)

Work with Patagonia, Nogales, and Santa Cruz County to influence Forest Service management and funding priorities, e.g. apply for designation of a Municipal Watershed. (TNC)

Work with USFS, ASLD, and private landowners to improve range and forest condition by ensuring that broader land management actions support healthy vegetation cover across the watershed, e.g. by engaging on sustainable grazing, fire management, erosion control, and limiting impacts from roads and other infrastructure. (TNC, BRN)

Target addressed: Spongy uplands, Nature based economy

Threat addressed: Reduced groundwater levels, Altered flood regime, Increased erosion and sedimentation, Persistence of historic degradation

Theory of change: The Sonoita Creek watershed stills shows the legacy of historical grazing impacts, resulting in flashy response to rain events that causes ongoing erosion and poor infiltration. The most effective approach to restoring watershed conditions is often construction of many small structures to slow runoff and capture sediment in first- and second-order stream channels. While that approach would require a huge effort to cover the whole watershed, there may be subwatersheds with strategic importance that can be identified by entities such as U.S. Geological Survey, while the U.S. Forest Service's designation of the Sonoita Creek uplands that include the Patagonia Mountains as a Municipal Watershed could leverage federal support and approvals that also align with federal goals for managing public lands. Improving watershed health would increase water security for residents of both Patagonia and Nogales, reducing potential impacts of prolonged droughts, enhancing vegetation productivity and resilience, and supporting the nature-based economy more broadly.

Objective 6: Protect native fish and prevent erosional loss of Sonoita Creek habitat.

Strategy: Build a fish barrier and grade control structure to block movement of nonnative fish from Patagonia Lake and to stop an active headcut. (TNC lead, support from TAS, BRN, Circle Z)

Conduct annual fish monitoring and control of nonnative fish. (TNC lead, support from BOR, AGFD)

Survey stock tanks in watershed for nonnative fish and initiate control programs where feasible. (AGFD)

Target addressed: Perennial stream community, Cottonwood-willow community

Threat addressed: Increased predation on fish, Increased erosion and sedimentation

Theory of change: The biggest threats to native fish in the desert Southwest are nonnative fish and loss of stream habitats. Patagonia Lake is managed as a recreational fishery, with a variety of predatory nonnative fish present though only rainbow trout are currently stocked. There is also an active headcut in Sonoita Creek, moving upstream from Patagonia Lake State Park. There is potential that both of these could be addressed by construction of a barrier on Sonoita Creek. The Bureau of Reclamation has a mandate and a budget to build several new fish barriers, as mitigation to offset the potential impacts to native fish by the construction of the Central Arizona Project. Sonoita Creek is a potential site for one of their barriers. If further studies support building a barrier now, a suitable site is identified, and the relevant land owner agrees with the associated impacts and conditions, this could be an effective solution. (Appendix 5)

Objective 7: Improve security for Sonoita Creek native fish populations.

Increase public support for native fish conservation.

Strategy: Create an off-channel refuge for Sonoita Creek fish with interpretive materials on Patagonia-Sonoita Creek Preserve or Sonoita Creek Wildlife Corridor. (TNC or BRN)

Target addressed: Perennial stream community, Positive sense of place, Nature based economy

Threat addressed: Increased predation on fish, Increased erosion and sedimentation, Altered flood regime

Theory of change: The Sonoita Creek populations of speckled dace and Gila topminnow are the largest and almost the last in the Santa Cruz River watershed, and may contain unique genetic adaptations for the species. Arizona Game and Fish Department has a goal of maintaining refuge populations for each species of declining native fish, and currently does not have enough populations or individuals of these two species. Developing an off-channel refuge for Sonoita Creek fish would provide greater insurance against the loss of genetic diversity in these species. It would allow reintroduction into Sonoita Creek in the case of catastrophic events, such as a plume of toxic materials from mining waste or a large sediment deposit from a poorly designed upstream channel realignment. Developing a refuge site in the watershed allows infiltration losses from the refuge to return to the creek's aquifer, and any escaping fish would return to their native habitat. A fish refuge would also allow public education about native fish and other aquatic life in Sonoita Creek, in ways that are difficult along the creek itself while providing another attraction for visitors. Potential sites include the Patagonia-Sonoita Creek Preserve and the Sonoita Creek Wildlife Preserve owned by Wildlife Corridors LLC and managed by BRN. (Appendix 6)

Objective 8: Minimize impacts of new mining in the watershed and surrounding area.

Strategy: Research wastewater discharge plans from dewatering the Hermosa Mine and look for opportunities to recharge groundwater. (TNC)

Monitor groundwater levels on the Stevens parcel for impacts from adjacent well operated by South32. (TNC)

Engage with partners to understand opportunities for restoring parts of the watershed and minimizing new impacts.(BRN, TNC)

Photo © *Peter Warren/TNC*

Vermilion flycatcher.

Proactively engage with mining interests to minimize new impacts. TNC leadership and program staff will develop relationships with mining companies, seeking opportunities to inform mining development and mitigations plans in ways that address concerns and minimize impacts from mining activities. (TNC)

Target addressed: Spongy uplands, Perennial stream community, Cottonwood-willow community

Threat addressed: Reduced groundwater levels, Increased erosion and sedimentation, Persistence of historic degradation

Theory of change: New mining activities in the Patagonia Mountains pose a variety of risks to our conservation interests. The partners in this plan are unlikely to directly challenge legal mining activities and prefer to work to minimize the potential impacts, particularly to surface water and groundwater resources. These include watching for groundwater impacts to the Conservancy's Stevens parcel by the mouth of Harshaw Creek. Assuming the Hermosa Mine is developed, there might be opportunities for using water removed from the mine to recharge the aquifer in strategic locations that would benefit Sonoita Creek and the town of Patagonia. There might also be mitigation needed for upland impacts that could result in funding for restoration work elsewhere in the watershed. The Conservancy and partners are well positioned to guide the meaningful use of mitigation funds, as well as encourage mining companies to fully offset the environmental impacts of their operations beyond legal mitigation obligations. Maintaining the quantity and quality of water supplied by Sonoita Creek will be critical to the long-term viability of Patagonia, and possibly Nogales.

Objective 9: Improve the economic viability of Patagonia by addressing regulatory issues.

Strategy: Research additional activities under the Community Rating System that would further lower flood insurance costs. (BRN)

Explore opportunities of upgrading the wastewater treatment plant in ways that increase environmental benefits. (TNC)

Target addressed: Perennial stream community, Cottonwood-willow community, Flood protection, Nature based economy, Positive sense of place, Multi-generational community

Threat addressed: Altered flood regime, Reduced groundwater levels, Impaired water quality

Theory of change: The National Flood Insurance Program's Community Rating System is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum requirements. The system offers discounts from 5% to 45% on flood insurance premiums based on specific public information and floodplain management activities. Recent efforts by the Patagonia Flood and Flow Committee qualified Patagonia to join the Community Rating System, in large part due to recognition of the Patagonia-Sonoita Creek Preserve as meeting the Open Space Preservation activity. The town could see further benefits with additional efforts to preserve or restore natural conditions in the floodplain. This would serve as a useful model for export to other communities in the region.

In a separate regulatory realm, there may be opportunities to improve the wastewater treatment plant with constructed wetlands or other approaches that improve water quality while providing other environmental benefits.

Objective 10: Increase public visitation and understanding of natural areas in the Sonoita Creek watershed.

Strategy: Develop a cooperative birding guide to Paton Center, Patagonia-Sonoita Creek Preserve, and Sonoita Creek Wildlife Corridor. (TAS)

Target addressed: Nature based economy

Threat addressed: Limited local economy

Theory of change: Bird watching is a significant contributor to the economy of Patagonia and has been a major driver of conservation efforts in the watershed. With the recent improvements and expansion of the Paton Center and creation of the Sonoita Creek Wildlife Corridor, there is an opportunity to share resources between conservation groups and encourage further exploration by visitors. A cooperative birding guide could highlight the opportunity to see different bird species at the various protected lands, where complementary materials and demonstrations could extend public interest to associated species, habitats, and restorative/restoration benefits and opportunities.

Objective 11: Explore opportunities to protect key properties in the Sonoita Creek watershed, with a focus on maintaining resilient and connected landscapes and supporting water security.

Strategies: Prepare for the opportunity when the Monkey Spring property goes on the market by researching water availability, including data on outflows and diversions, and researching land ownership and water rights, including those linked to the Hudbay mitigation project. (TNC)

Analyze other strategic places for the potential value and cost of conservation easements or other land protection arrangements, and opportunities to build capacity for local partners to protect key lands and waters. (TNC)

Target addressed: Perennial stream community

Threat addressed: Diversion of spring flow

Theory of change: Monkey Spring is the largest spring in the watershed, and historically supported an important wildlife community. It is privately owned. While the current owner has not taken any apparent actions that would increase consumptive use of the water, that will always be a risk, especially in the event of sale to new owners. This strategy is meant to improve our understanding of the current situation and potential for keeping the water available for wildlife and for maintenance of the Sonoita Creek aquifer. Sonoita Creek Ranch, the proposed mitigation site for the Rosemont Mine, includes surface water rights to 590 acre-feet per year from Monkey Spring, 85% of the annual flow. As proposed, the mitigation project there would use the water in ponds with the intent to support recovery efforts for sensitive species, and overflow into Sonoita Creek.

Additionally, this objective and its strategies are meant to support and improve the conservation community's ability to promote resiliency, maintain and improve landscape connectivity, and sustain biodiversity as climate change impacts are better understood and development and other changes occur in the watershed.

Monitoring framework

Sonoita Creek has been subject of a wide range of research and monitoring activities in the past, and will likely continue to be so into the future. This plan aims to inform collection and use of data specific to targets and strategies for lands in the plan. This Monitoring section identifies several specific monitoring needs, describes an overall approach to monitoring, and gives examples of the types of data collection that could be useful in evaluating the status of ecosystem and human wellbeing targets while tracking progress towards strategy benchmarks. It also provides a framework that can help make use of existing data and information collected for various other purposes. It does not attempt to be comprehensive, but rather illustrates an approach to evidence-based adaptive management that can be built out and refined as needed.

Table 2 lists existing monitoring being done by partners in the plan and shows gaps that could be filled.

Priority monitoring needs

Critical needs: Tracking of several hydrology-related metrics is critical for enabling partners to advocate for the needs of conservation and human wellbeing targets in the Plan. In addition to their immediate value, all of these would contribute to eventual development of a groundwater model. *Monitoring needs include data collection, analysis, interpretation, and communication for the following metrics*:

<u>Depth to groundwater</u>

• Currently measured by TNC in shallow wells on Preserve and nearby TNC-owned lands; needs to be analyzed by professional hydrologists to describe status and trends, refine locations and timing of future monitoring.

• Periodically measured by ADWR in well sweep measurements of index wells (see ADWR 2009); needs to be continued, possibly expanded, and analyzed for status and trends.

• Additional well level data being gathered by Town of Patagonia Flood and Flows committee, needs analysis in conjunction with other water data.

<u>Surface water flows</u>

• Flow rates currently being measured by TNC on Preserve. Needs to be analyzed by professional hydrologists to describe status and trends; and to test for correlations with rainfall, groundwater depth, nearby pumping, and other potential explanatory variables.

<u>Floodplain and sediment dynamics</u>

• A high-resolution Digital Elevation Model (DEM) for the Sonoita Creek floodplain is needed to show current configuration and inform analyses of how flood events are likely to affect the landscape. TNC plans to acquire baseline LiDAR data in 2020, expects to repeat measurements after any major channel/floodplain alteration projects such as the Hudbay proposed mitigation project, and again in the event that a substantial flood event results in significant sediment transport downstream. Professional modeling will be needed to use this DEM data to predict flood and sediment dynamics and to compare alternatives for floodplain and channel management projects.

• Baseline data on sediment dynamics from storm flows. TNC expects to collect water quality data on TNC lands along Sonoita Creek; analyses by a professional hydrologist will then be needed to interpret the data and any changes through time.

<u>Hydrologic monitoring plan</u>

• Preparation of a detailed hydrologic monitoring plan for groundwater and surface water, including locations and timing, frequency of analysis and discussion for adaptive management, and schedule for updating plan. This will increase the return on investment from effort spent on monitoring by helping ensure that data is collected, analyzed, interpreted, and utilized in consistent and targeted ways.

Table 2. Current monitoring efforts. Key concerns with no monitoring efforts listed represent unmet needs.

	Key concerns	TNC	BRN	Audubon	Circle Z	Others
Components key to multiple other targets						
Groundwater	declines in shallow groundwater	30+ years measuring well levels on TNC-owned lands (ongoing; analysis pending)				ADWR tracks depth in index wells (periodic, ongoing); Flood and Flows compiling water depth data from other wells
Surface water flows	declines in flow rates, extent	Baseflow measurements since 1990 (ongoing); will add storm flow measurements				
Water quality	sedimentation; heavy metals; acidification; dissolved oxygen	Planned for 2020: sediment load in stream, PSCP	monitoring sediment retention behind erosion control structures			ADEQ: occasional measurements in several stream reaches. FOSC using Water Sentinel protocols to do seasonal, monthly, and precip-event sampling. Reinthal (UA): Has collected aquatic inverts as bioindicators; heavy metals in bug tissues. USGS: has measured heavy metals, acidity at several locations.
Floodplain sediment dynamics	Large sediment flows entering stream	High-resolution mapping of floodplain topography planned for 2020				
Erosion	expanding gullies, headcuts					Friends of Sonoita Creek (FOSC) tracking movement of headcut above lake

Table 2 (continued)

	Key concerns	TNC	BRN	Audubon	Circle Z	Others
Precipitation	Drought/flood driver of other changes			weather station run since 1921 (ongoing)		NOAA manages data from several surrounding coop weather stations (ongoing)
Conservation targets						
Cottonwood/willow community	missing young trees (lack of recruitment)	mapped 2019; old data on size class distribution		bird counts: Xmas, breeding, IBA		USFWS conducts annual training for Yellow-billed Cuckoo monitoring, starting 2018. USFWS conducts annual training for Yellow-billed Cuckoo monitoring, starting 2018. FOSC have used Rapid Stream Riparian Assessment (RSRA) methods for repeat surveys, 2014 and 2018.
Perennial stream community	loss of native fish, frogs; flow declines	fish and aquatic habitat surveys conducted 1991-2001				Fish surveys UA-AGFD. FOSC see RSRA above.
Ciénega wetlands	flow declines; invasive species					
Spongy uplands	loss of watershed function		developing database of all erosion control structures in the watershed			USGS: research and modeling
Sacaton/mesquite floodplain community	johnsongrass invasion; floodplain function	extent of large sacaton stands mapped 2019	experimental plantings on farm, with UA	planted 5 acres upstream of PSCP, tracking results		

Table 2 (continued)

	Key concerns	TNC	BRN	Audubon	Circle Z	Others
Human well-being targets						
Positive sense of place and community	loss of riparian forest and natural landscape; disconnection from nature					
Flood protection	flood risk areas; flood warning					FEMA mapped risk areas (once unless revised), sets Community Rating System classification
Water security for residents and businesses	declining groundwater supply; water quality impairment					Town of Patagonia: monthly volume pumped from city wells, 2008-present (ongoing) ADWR: well locations, permits; annual effluent discharge (ongoing)
Nature based economy	conflict with extractive economy; recognition of value from ecosystem services	periodic estimates of visitation	periodic estimates of visitation	periodic estimates of visitation, economic impacts from ecotourism	periodic estimates of visitation	US Census (decadal, ongoing), American Community Surveys (annual, ongoing)
Multi-generational community	loss of young and working age residents					US Census (decadal, ongoing), American Community Surveys (annual, ongoing)

Additional value: The following additional metrics would add value in various ways— informing specific strategies, tying the above metrics to other attributes of interest, illustrating links with human wellbeing targets, providing data on possible explanatory variables, providing context, etc. More value-added monitoring suggestions can be found below in the discussions of each target.

• Bird populations in target habitats (community composition, abundance, nesting success, etc.)

• Extent and permanence of surface flows

• Fish population numbers, plus distribution of fishes (native and exotic) and fish diseases across the watershed

• Use of high-resolution LiDAR data, collected for other purposes, to describe current canopy structure of cottonwood-willow (Swetnam and Powell 2010), which would allow for the future comparisons

• Analysis of water quality samples, including tissue samples from aquatic invertebrates and other organisms, to better understand the nature, duration, extent, and severity of water quality problems, and to inform strategies to reduce impacts from water quality impairments

Conservation targets

Describing basic *extent* and *condition* of targets goes a long way towards evaluating status and enabling detection of changes through time. Assessing extent can (often) be distilled into a mapping exercise, with the recognition that various mapping efforts may differ in how they define the target community, and in how accurately they represent what is found on the ground. Scale is especially important: regional-scale mapping efforts may give useful context for how a site like this compares with others, but often are too coarse to accurately represent what is found at any individual site. Mapping extent of a target represents a snapshot in time, a baseline or benchmark. Re-mapping targets to determine change through time must take care to match definitions, scales, and accuracies, and report those whenever possible. Assessing condition can be more nuanced and requires an articulation of what aspects of condition are both relevant to threats and strategies and are feasible to assess and track.

In this case, hydrologic conditions—stream flow dynamics, rainfall runoff and infiltration, depth to groundwater, aquifer recharge dynamics, contamination pathways for surface and groundwater, rates and locations of water withdrawn, etc.—affect all of the conservation and human well-being targets identified here. For this reason, we call out some aspects of hydrologic monitoring separate from the summary comments on individual targets. *These tie directly to objective 1*, and most others indirectly.

Key Ecological Attributes approaches describe and rate the most relevant condition and extent elements for each target (e.g. Turner et al. 2009). Completing this type of Target Viability Analysis is outside the scope of this planning process but could be a useful future addition.

<u>1. Cottonwood/willow community</u>

a. Extent: Mapped by presence of target trees, since these are indicators of the hydrologic and associated conditions needed by other members of the community. Current plan map is based on polygons drawn by eye on high-resolution aerial images (DigitalGlobe, 0.5 m resolution, acquired 11/28/2018), informed by close familiarity with what many of those stands look like on the ground.

i. Tracking changes through time: Would likely require local ground-based surveys or high-resolution imagery. Regional-scale efforts to map riparian vegetative communities (e.g. Southwest Re-Gap, National Land Cover Database) would likely not have the accuracy needed to show changes to cottonwood/willow community extent in this plan's area, or to compare this area with others.

b. Condition: Can be described in any combination of the following terms: Species composition, size/age class distributions, primary productivity, vegetation volume, phenology, percent live cover, etc.


Matt Killeen with TNC monitors stream flow at the Patagonia-Sonoita Creek Preserve. Photo © Brian Prescott

i. Lack of recruitment has been flagged as a problem in this area, with strategies developed to improve size/age class distribution. *Ties to Objective 2.*

2. Perennial stream community

a. Extent: Mapped as extent of surface flow in driest time of the year. Current plan map is based on expert knowledge of participants, who describe perennial water in the following reaches: Sonoita Creek upstream from Cottonwood Spring, Sonoita Creek between the Town of Patagonia and Patagonia Lake, Redrock Canyon, Harshaw Creek, and Big Casa Blanca Canyon. *Ties to Objective 1.*

i. Tracking changes through time: Wet-dry mapping has shown to be a reliable way of tracking changes in perennial stream extent through time, and can be implemented well by citizen scientists. Repeat photography and automated cameras can also be used to document flow timing and permanence in target reaches.

b. Condition: Key components include volume or rate of streamflow, water quality, geomorphology, and composition of flora and fauna that depend on perennial waters. *Ties to Objectives 4, 6, 7.*

i. Health of native fish populations are a key component of this community as conceived in this planning effort. Past monitoring by TNC, Dr. Peter Reinthal (Univ. of Arizona), and AGFD has been one of the most rigorous fish monitoring programs in the state, with ability to estimate population numbers and community composition at several sites. It should be renewed and maintained.

ii. Understanding the distribution of fish and their threats in the watershed would benefit from different monitoring methods. Recent years have brought new "Environmental DNA" tools to aquatic surveys. E-DNA methods, which screen water samples for the presence of genetic material left by aquatic organisms, are especially useful for detecting the presence of rare or cryptic organisms, so are well suited to surveying for endangered species, invasive species, and diseases. This approach could provide a snapshot of which fish are currently in various reaches of Sonoita Creek and tributaries, and off-channel waters like stock tanks, to inform efforts to control invasives. It could then be used to evaluate success at removing invasives, and doing early-detection screening for re-invasions into the future.

3. Ciénega wetlands

a. Extent: Cienegas, including the two described in this area, have been mapped as point locations across the region but most do not have perimeters mapped.

b. Condition: Repeat photography, aerial image analyses, and vegetation transects have been used at other cienegas to document changes in water, primary productivity, and vegetation conditions (e.g. Wilson and Norman, 2018). Water isotope analyses have been used to describe origin of waters emerging from cienega locations.

4. Spongy uplands

a. Extent: This target was conceived as a way to describe the function of upper watersheds in providing ecosystem services of holding soil in place, providing for productive vegetation communities on hill slopes, absorbing rainfall, and slowly releasing water to plants, streams, and aquifers. In that sense, the extent would be all areas above the riparian zones that are captured in other targets, *except for* areas that no longer provide such services: impervious surfaces (roads, rooftops, parking lots, etc.), highly disturbed areas (e.g. mines, tailings, landfills), and areas where runoff or subsurface water flow is diverted or prevented from contributing to down-gradient water budgets (e.g. mine pits, impermeable holding ponds).

i. Tracking changes through time: NLCD or disturbance datasets could be used to document land use conversion that removes lands from "spongy upland" classification. Efforts to shape land conversion patterns *tie to Objective 8.*

b. Condition: A main goal of many management and restoration projects is to increase the sponginess of existing upland areas. Erosion control structures in drainage channel do this in discrete locations; improved land management that increases vegetative groundcover does this across large areas. If these interventions and vegetation improvements are documented, watershed modeling efforts can estimate the resulting changes in "sponginess" in terms of changes in runoff dynamics, erosion rates, sediment movement, rainfall infiltration and aquifer recharge, and soil moisture. Some relevant models have already been developed and calibrated for this area, and are available for use (Niraula et al. 2012, Boyanova et al. 2017). Models like these can also be used to execute the strategy of identifying where improved sponginess is likely to make the most difference, then focusing rock work and other interventions there. Models can also be used to estimate quantitative benefits from this type of intervention (Norman et al. 2019); such data has already proven highly effective in furthering ecosystem restoration and monitoring projects that iteratively feed back into modeling and other science, and improve reliability and acceptability to funders and to the public of transparent, integrated methods. *Ties to Objective 5.*

5. Sacaton/mesquite floodplain community

a. Extent: This target describes a range of vegetation types, blurring the distinction between extent and condition. Potential extent of sacaton/mesquite floodplain communities could be estimated using NRCS loamy bottom Ecological Sites as a proxy for soil and topographic conditions that can support these communities. Current extent could then be estimated by subtracting areas that have experienced land cover conversions.

b. Condition: Key aspects of condition include geomorphology, floodplain function, depth to groundwater, and vegetation density and composition, including native versus exotic species. *Ties to Objective 3, 4.*

Great blue heron at Sonoita Creek. Photo © Sandy Weaver

i. High-quality "sacaton flats" have been mapped as areas of wide floodplain terrace with dense stands of the target grass (*Sporobolis wrightii* and *S. aeroides*). As with cottonwood-willow stands, surface area of sacaton stands was visually estimated from aerial photographs (DigitalGlobe, 0.5 m resolution, acquired 11/28/2018), informed by close familiarity with what many of those stands look like on the ground (Figure 2).

ii. Other condition classes or ecological states of this community –mesquite bosque stands, mixed mesquite-sacaton stands, regenerating stands of younger and smaller mesquites, etc.—have not been specifically mapped or characterized. In the nearby Cienega Creek watershed, two efforts were used to map similar elements: a "state-mapping" approach mapped sacaton-dominated areas and described conditions (Tiller et al. 2012), and a remote sensing effort worked to distinguish various types of mesquite stands (Petrakis et al. 2019). Similar approaches could be used here.

iii. Tracking changes through time could involve documenting land use conversions, vegetation removal, restored areas with vegetation recovery, and areas showing shifts between states or condition classes. In contrast to documenting changes in vegetation states, shifts in geomorphology and depth to groundwater would indicate changes in site potential that reflect longer-term conditions.

Human well-being targets

As with other targets in this Plan, we are defining the scope of human well-being (HWB) targets as including residents and visitors to the Sonoita Creek watershed upstream of the dam at Patagonia lake, with a concentration of people in and around the town of Patagonia. The HWB targets chosen here include elements from across the six domains described by Biedenweg et al. (2016): physical, economic, social, cultural, psychological, and governance. Others have classified these components in slightly different ways, and have mapped them to ecosystem service elements (Alcamo et al., 2003; Summers et al., 2012; Wu, 2013); any of these frameworks could be used to guide additional work on HWB targets.

Though the plan focuses on this geography, HWB benefits go far beyond these defined boundaries; water-related physical benefits also apply to most of Santa Cruz County's population which lives downstream in Nogales, Rio Rico, and along the Santa Cruz River. Cultural and social benefits are felt much more broadly across the region, especially given the many environmental education and restoration training programs based out of Patagonia. Statewide, Patagonia serves as an important test case for how rural communities can approach water sustainability and economic viability. The international draw of ecotourism in the area would likewise spread spiritual, cultural and psychological benefits across an even broader area, as has been consistently demonstrated by visitors who visit the watershed one time or rarely, and express satisfaction and encouragement that restorative work is underway here, regardless of whether or not the visitor will be physically present to benefit from the work directly.

Flood protection

Of these HWB targets, Flood Protection is perhaps most straightforward to define and track. Flood risk, and the protections that come from mitigating flood risk, can be estimated in a variety of ways, e.g. using FEMA floodplain or other flood maps (e.g. Wing et al. 2018) to assess number of people or value of investments at risk. FEMA maps currently show 65% of Patagonia is in the designated 100-year floodplain. Evaluation criteria in the FEMA Community Rating System could be used to describe the status of efforts to mitigate risks, and the financial benefit to residents from taking these actions. Hydrologic models provide more sophisticated tools for estimating flood-related metrics (runoff, sedimentation, peak flow rates and depths, etc.) and comparing these across time or under different scenarios, e.g. to predict the effects of actions like installation of small-scale erosion control structures in particular locations, or improving vegetation cover over a given area. Such models can also be used to estimate the nature-based services currently provided by spongy uplands, stream channels and flood plains in their current state. *Ties to Objectives 4, 9.*

Unlike many other flood-prone communities in Arizona, there are currently no flood warning stations above Patagonia.

Multi-generational community

US Census reports and the associated American Community Surveys can provide data for assessing some of the HWB indicators such as demographic indicators of a multi-generational community (including current condition examples above). Applying these data to community-based questions and analyzing them though time would provide considerable insight.

Other targets

Other indicators would need supplementary data collecting, with survey tools designed specifically for these targets. Including well established tools like the Connectedness to Nature scale (Mayer and Franz 2004) where possible would deepen the conclusions and expand the relevance of tracking HWB metrics locally. Thinking through and describing more specific components of each of these HWB targets (e.g. Biedenweg et al. 2016) would help identify useful metrics and indicators for each, and would likely suggest additional strategies to sustain or improve these targets. In the meanwhile, we note major domains for each HWB target:

1. Positive sense of place and community: social, psychological;

2. Flood protection: physical, economic;

3. Water security for residents and businesses: economic, governance;

4. Nature based economy: economic, physical, governance;

5. Multi-generational community: social, cultural.

A process of fleshing out metrics for HWB targets could provide additional value if it were incorporated into some of partners' existing programs. Generating additional insights from within the community could, in fact, actively build up cultural, social, and governance elements of these same HWB targets, and could have surprising benefits to conservation targets.

For example, HWB elements could be more explicitly incorporated into curricula for field schools, in-depth workshops, youth programs, and other trainings by working with existing organizations and schools to share the burden and enhance existing frameworks for education and data collection simultaneously.

Carefully designed programs can enable students to contribute to social science knowledge while learning about its methods and contributing to students' own reflections on sense of place and value. Questions such as the following situate learning at the intersection of social and natural sciences: "How are restoration outcomes likely to differ depending on whose perspectives are included and whose aren't? How could broadening the involvement of community members change what we get, short- and long-term, from our projects? Why is it important to build interview skills, and how do the questions asked influence possible answers?” Coursework could include modules on social science skills more explicitly, and range from basic semi-structured interview skills and snowball sampling among friends and family, to more complex survey instrument creation and focus group facilitation that together inform an infinite, open-ended data set that can literally be passed on inter-generationally.

Many such databases and storymaps exists today with basic frameworks customizable and adaptable to local needs, and even minimal amounts of targeted funding could contribute to the creation of such a set and a first pass at the data that can begin to build it out. In the process, regular community presentations and updates would be provided via social media, public presentations would also function as focus groups, and private presentations would be offered in an attempt to reach those who remain reluctant to participate in the most common, dominant-culture venues that often dissuade minority opinion voices.

Along the way, teachers and students occupy and even trade roles over time, while all benefit from the opportunity to draw out perspectives of the same youth we are imagining as future leaders. At the same time, the area’s unique natural settings—as captured in this plan’s conservation targets—provides a multiplier effect that has been shown to increase the effectiveness of learning in many tangible ways, from improving attention spans to reducing stress and even fostering self-discipline and teamwork (Kuo et al. 2019). Building on the arts and ecology and similar programming already active in local communities, it is possible to expand and deepen knowledge and appreciation by incorporating storytelling and other creative arts for all ages, further reinforcing the connections between people and nature and empowering folks to engage on their own terms, and in their own time.

Hydrology

There has been much demand for a comprehensive snapshot of status and trends in the area’s groundwater and surface water hydrology (see, for example, Town of Patagonia, Flood and Flows Committee meeting minutes). The complexity of this ask, however, is hard to overstate. Data on any one element (say, depth to groundwater) is scattered across people and institutions, varies across space and time, has many sources of error in collecting and reporting, and much uncertainty in interpreting results. Each element is tied to others in complex ways (e.g. depth to groundwater affecting streamflow rate and/or extent) and many are affected by factors that are hard to observe (e.g. sub-surface geology affecting where groundwater surfaces in a channel). Lag times between causes and effects are often unknown (e.g. poor correlation between rainfall and streamflow) and even counterintuitive (e.g. springs may be flowing with water that fell as rain thousands of years in the past, yet still have flow rates affected by recent droughts). In addition, hydrology investigations with strong vested interests can easily produce biased or incomplete results.

In short, it can be hard to ask the right questions, much less get reliable answers. Yet those answers are critically important when trying to protect targets such as perennial streams and town water security from threats, and when evaluating success of strategies designed to, say, increase aquifer recharge or reduce impacts from pumping.

For these reasons, the objective to “stabilize or improve groundwater conditions by 2030” has several strategies and multiple targets. The most comprehensive of these strategies is development of a groundwater model that is both well calibrated and widely embraced. Groundwater models can describe impacts of pumping and other activities from throughout the modeled area, including lag times associated with features such as cones of depression whose impacts will affect the creek but do not yet appear in near-stream measurements. Models can enable a community to compare alternate suites of actions and visualize tradeoffs.

Rainbow over the Patagonia-Sonoita Creek Preserve.

Photo © Luke Reese/TNC

Other strategies are designed to build a strong foundation for the future groundwater model by providing better calibration information (monitoring data collection and analyses by TNC, Flood and Flow Committee) and by fostering the governance skills needed to apply it well (Flood and Flow Committee tackling important questions, convening community discussions around findings about current conditions, etc.). In this light, progress on this strategy should include metrics of governance as well as metrics related to data analyzed.

Because developing good groundwater models takes considerable time, money, and expertise, other strategies in this objective are also designed to provide more timely feedback on items of critical interest. For example, TNC and contractors expect to complete analyses of groundwater and surface flow data from the Patagonia-Sonoita Creek Preserve in 2020. The many years of surface water and groundwater data from the Preserve, and rainfall data from the Paton Center, will be analyzed by a qualified hydrologist for trends and correlations. Rainfall data should be examined for trends in both annual and seasonal totals. This will greatly improve our knowledge of the preserve's current status and threats. This is also a critical step to identifying goals for any future hydrologic monitoring efforts, and will inform the sampling design and protocols for ongoing monitoring.

To improve flood modeling and inform strategies for protecting water quality, a high-resolution Digital Elevation Model for the Sonoita Creek floodplain is needed to develop models of floodplain management impacts and sediment dynamics. Such a model could be used to compare alternatives for floodplain and channel management projects before committing significant resources to the planning and permitting required for such projects, and would help identify risks as well as benefits of such modifications. Additional information on water quality at key locations —sediment load, rainfall-runoff relationships, water chemistry, etc.— would be extremely useful for documenting current conditions as a benchmark to understand future changes, calibrate models, and inform future strategies.

In short, several sets of data are needed to inform strategies for sustaining water security for people and ecosystems. Partners in the Plan can play important roles in helping gather this data, and in fostering conditions that will enable the community and its decisionmakers to make good use of it. To be effective, this process will need to have a combination of thoughtful community input, and input from professional hydrologists (analyses, interpretations, communications) throughout.

Implementation

This plan is intended to be a high-level, strategic framework to guide the work and priorities for all of the planning partners. Partners will meet on a bi-annual basis to discuss status of ongoing strategies and discuss each partner's pertinent contributions, as well as new opportunities that may present themselves where collaboration will be key in achieving positive conservation and human outcomes.

For The Nature Conservancy, these objectives and strategies will inform annual work plans, project management plans, funding proposals, and budgets. We will utilize the formal chapter approval processes outlined in the Arizona chapter strategic framework to define chapter commitments in support of priorities, where higher levels of detail will be developed including costs, timing, and needed resources.

Planning Team

This plan was developed through collaboration between representatives of the four partner organizations:

The Nature Conservancy: Pete Leiterman, Bob Rogers, Gita Bodner, Marty Lawrence, Dale Turner.

Tucson Audubon Society: Howard Buchanan, Jonathon Horst.

Borderlands Restoration Network: David Seibert, Kurt Vaughn.

Circle Z Ranch: Diana Nash.

The plan was prepared by Dale Turner and Gita Bodner, with contributions from the team.

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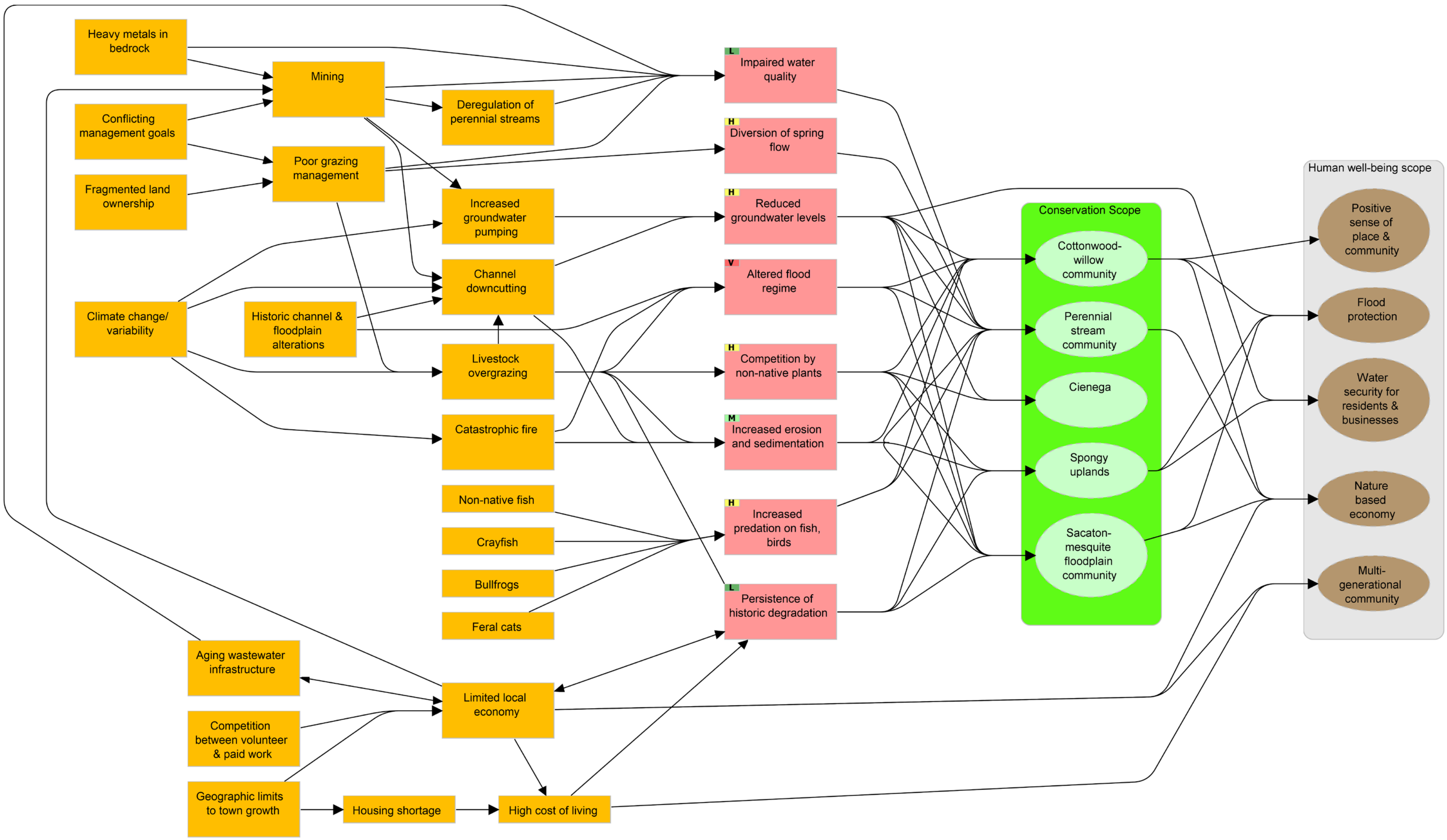
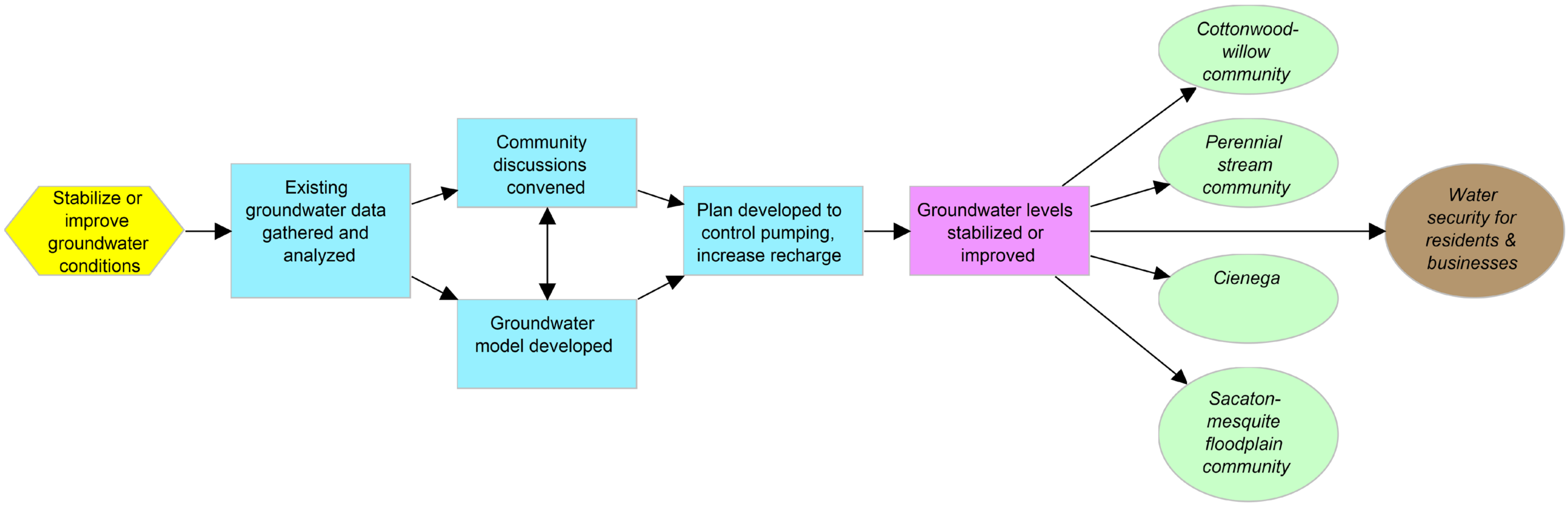
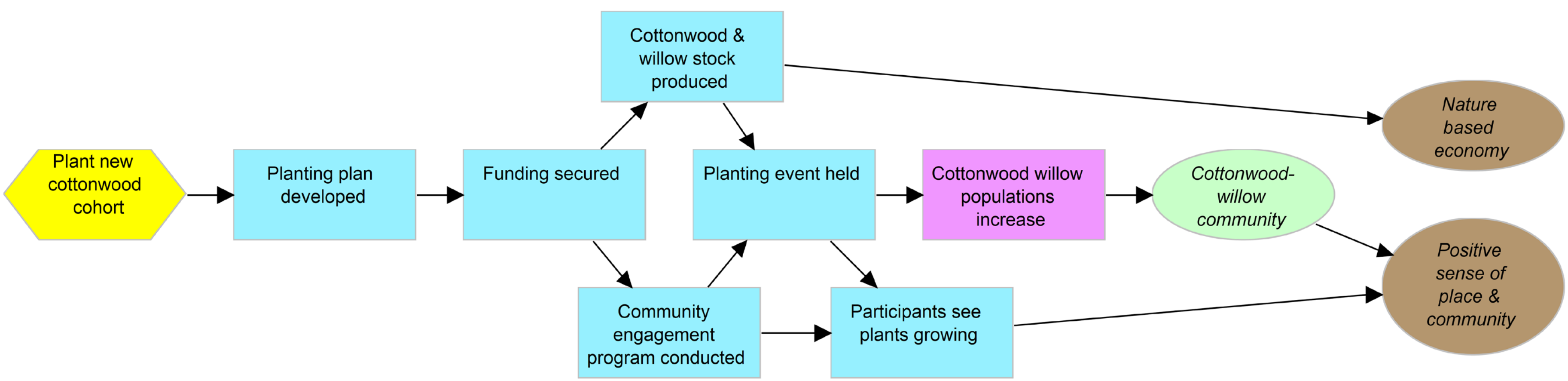
Appendix 1. Situation diagram for Sonoita Creek watershed.



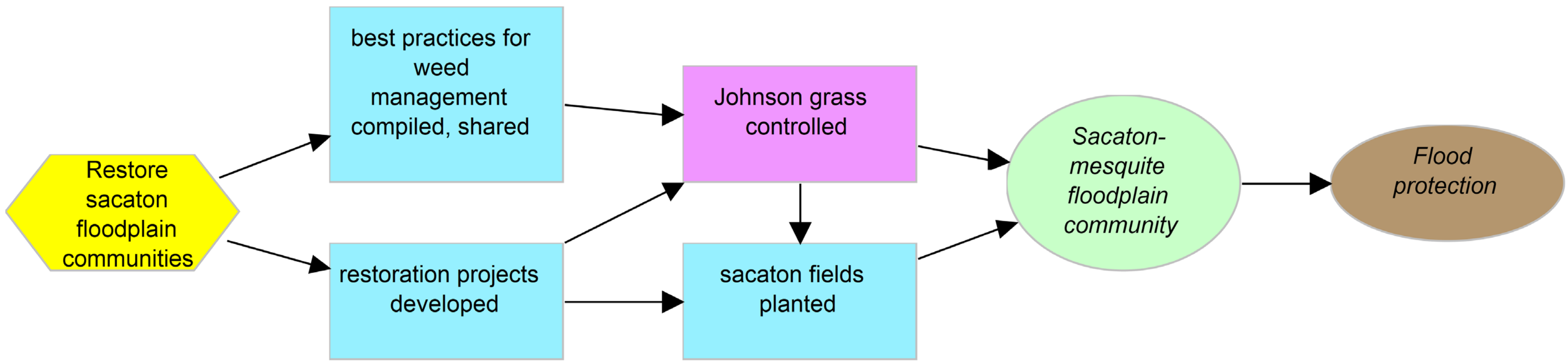
Appendix 2. Results chain for groundwater strategies.



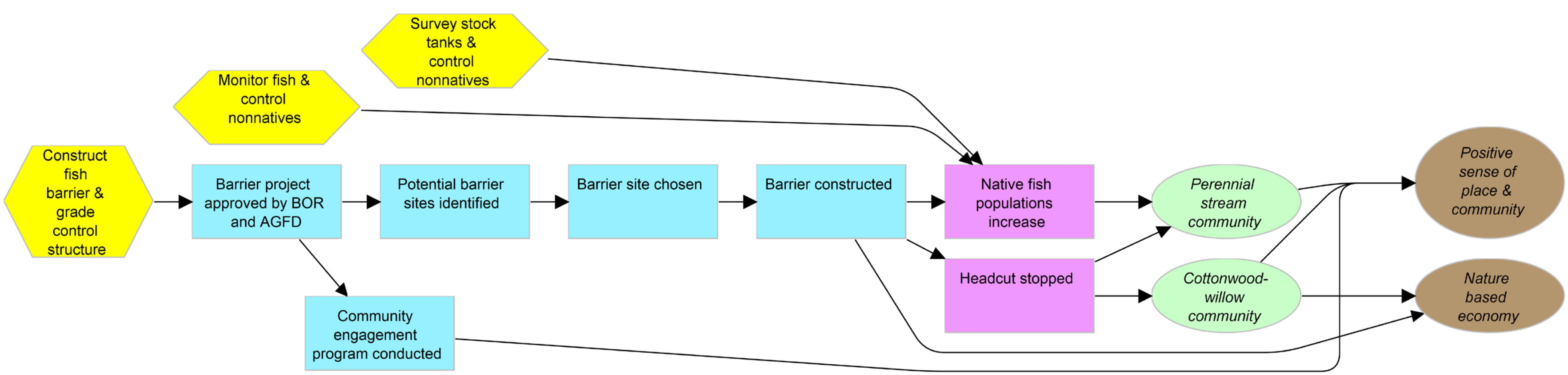
Appendix 3. Results chain for cottonwood restoration strategies.



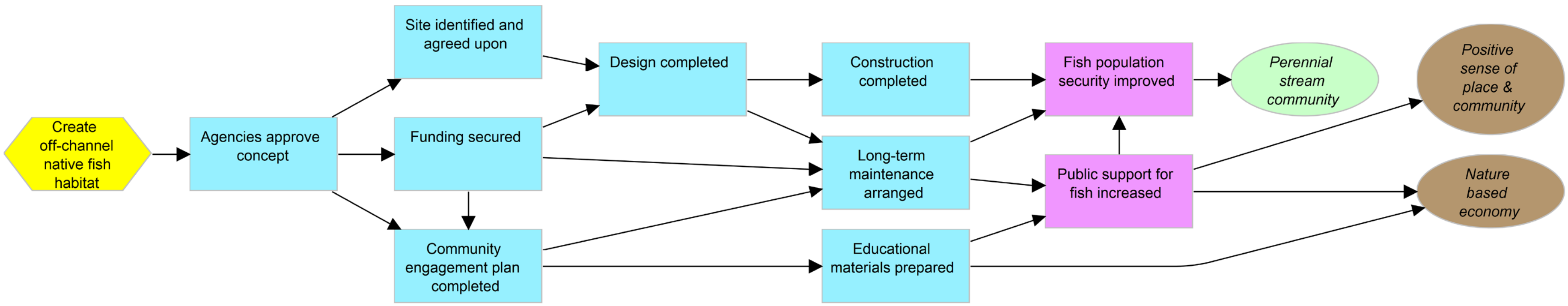
Appendix 4. Results chain for sacaton restoration strategies.



Appendix 5. Results chain for fish barrier strategies.



Appendix 6. Results chain for off-channel fish population strategies.



Appendix 7. Sonoita Creek Watershed Plan, Shared Conservation Agenda, and The Nature Conservancy's Arizona Chapter Strategic Framework

The current path that our planet is on is unsustainable. Without significant changes, we will experience devastating impacts to people and nature by 2050. The Nature Conservancy's science has established that there is another way: it is possible to have a world where both people and nature thrive, yet it will require significant changes from the current "business-as-usual" path (Tallis et al. 2018).

To put the world on the path to sustainability, we need to make significant progress in the next 10 years. TNC has developed a plan* for how we can help to make that happen. Called the Shared Conservation Agenda (SCA), this plan includes strategies that focus on two core themes:

• TACKLE CLIMATE CHANGE: Implement and increase emphasis on readily available, cost-effective natural climate solutions, such as reforestation, and drive policy changes to accelerate our transition to a clean energy future

• PROTECT OCEANS, LAND, AND WATER: Complete large protection deals using innovative finance, share smart infrastructure siting principles to encourage sustainable development and partner with indigenous people to strengthen their rights as environmental stewards

The Arizona chapter of The Nature Conservancy has developed a Strategic Framework to guide our work across the state. It includes three strategic imperatives to guide our work and investment decisions through fiscal year 2023. Specifically, those form a commitment to strategies and solutions that allow the Arizona Chapter to make our optimal contribution to the SCA, are financially sustainable, and are scalable.

This Sonoita Creek Watershed Conservation Plan contributes to achieving the Shared Conservation Agenda and Arizona Strategic Framework in the following ways.

The strategy "Conserving Resilient Lands and Waters" under the Protect Oceans, Land, & Water theme of the SCA and the AZ Strategic Framework, focuses on legal protection of new lands within a representative network of resilient, connected lands and waters that will allow nature to adapt to climate change. It also includes effective management and restoration within that network, both in protected and unprotected areas. This does not mean TNC will take the lead on every action, but should engage and support the work of like-minded partners. The Sonoita Creek floodplain is shown as part of a resilient and connected network of lands on the preliminary map for the Rocky Mountains and Southwest Deserts, bringing confirmed diversity and climate resilience. That includes multiple cross-valley corridors, such as Monkey Canyon on the east side connecting with canyons and foothills of the Santa Rita Mountains to the west. It also includes a continuous corridor from the Patagonia-Sonoita Creek Preserve to Patagonia Lake, with cross-valley connections to Forest Service lands on both sides. To safeguard and expand conservation of these lands into the future, partners in this plan bring a diverse history of innovative finance for land protection, and ongoing emphasis on sustainable development.

Objectives 1, 2, 3, 4, 5, 6, and 11. will directly support Conserving Resilient Lands and Waters in and along Sonoita Creek through effective management and restoration activities. Objective 11 will secure legal protection for an important wildlife connection between blocks of federal land. The strong engagement of partners in developing and achieving these objectives should help provide financial sustainability. In particular, partners will likely be key to funding land protection projects under Objective 11. The groundwater strategies under Objective 1 were directly shaped by our

* This description is current as of April 2020.

experiences in the San Pedro River, and represent the next step in scaling up those strategies.

Objectives 9 and 10 will contribute to the strategy “Inspiring People for Nature” under the Protect Oceans, Land, & Water priority by helping people recognize ways that healthy natural areas can support the local economy. Plan partners’ emphasis on fostering a Restoration Economy also showcases a new model for “providing food and water sustainably.” These are scalable approaches that can be applied in other rural settings across Arizona. With their focus on economic viability of the local community, they should also allow access to non-traditional funding sources and thus have financial sustainability.