

5<sup>th</sup> Annual

# **Science on the Sonoita Plain**

**June 8, 2013**



**Quarterly Meeting of the Sonoita Valley Planning Partnership  
And the Cienega Watershed Partnership**

At the  
Appleton-Whittell Research Ranch of the  
National Audubon Society  
Elgin, AZ

The Sonoita Valley Planning Partnership (SVPP) is a voluntary ad hoc association of agencies, user groups, conservation organizations, and individuals working together to achieve community-oriented solutions to local and national issues affecting public lands within the Sonoita Valley. The SVPP was created in 1995 in response to the Bureau of Land Management's (BLM) initiation of a collaborative planning process for Las Cienegas National Conservation Area. The SVPP meets quarterly and provides a forum for participants to share information and work together to perpetuate naturally functioning ecosystems while preserving the rural, grassland character of the Sonoita Valley for future generations. The SVPP is now administered and supported by the Cienega Watershed Partnership (CWP), a 501c(3) non-profit organization that was founded in 2007 to facilitate cooperative actions that steward the natural and cultural resources of the Sonoita Valley while enabling sustainable human use.

The Science on the Sonoita Plain symposium was established to bring together and share the results of scientific investigations that are occurring within and informing us about the unique and diverse resources of the Sonoita Plain in the upper watersheds of Cienega Creek, Sonoita Creek, and the Babocomari River.

This year, the focus was on water resources, drought and climate change, with updates on new and continuing scientific efforts on other topics. We hope you enjoy this recap of the 5th annual Science on the Sonoita Plain Symposium.

Proceedings compiled by Amanda D. Webb

Planning Committee: Gita Bodner (The Nature Conservancy), Larry Fisher (CWP, University of Arizona), Linda Kennedy (Audubon), Amy Markstein (BLM), Julia Fonseca (Pima County Office of Sustainability and Conservation), Mead Mier (Pima Association of Governments), Annamarie Schaecher (CWP)

Thanks also to:

Shela McFarlin for organizing the refreshments provided by the Cienega Watershed Partnership with financial support from Jeff Williamson and by the Research Ranch.

David Murray provided technical support. Funding to compile these proceedings was provided by The Nature Conservancy and the Bureau of Land Management.

Photos provided by Linda Kennedy

<p>A <u>Certified Professional in Rangeland Management</u> Continuing Education Workshop, 6 CEUs</p>
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## Welcome and Introduction



Karen Simms, Assistant Field Manager of the BLM Tucson Field Office and member of the Sonoita Valley Planning Partnership, welcomed symposium participants. Karen shared with the group that she has been working on Las Cienegas National Conservation Area for 25 years.



Shela McFarlin of the Cienega Watershed Partnership arranged refreshments.



Jelena Vukomanovic introduced her new publication on ecological threat mapping of the Sonoita Plain.



The National Audubon Society's Appleton-Whittell Research Ranch offered the use of their facilities for the symposium. Over 80 people attended, from land managers to local residents, hydrologists to historians, researchers to recreationists.



## ***Assessment of Climate Change in the Southwest United States: Key Findings***

**Gregg M. Garfin**

University of Arizona, School of Natural Resources and the Environment, Biological Sciences East, Room 301C, Tucson, AZ 85721

The *Assessment of Climate Change in the Southwest United States*, is a technical input to the National Climate Assessment. The 120-author report summarizes knowledge about climate change and its impacts across Arizona, California, Colorado, Nevada, New Mexico, and Utah. The *Assessment* looks at links between climate and natural resources, vulnerabilities to climate variability and change across the region and along the U.S.-Mexico border, and adaptation and mitigation choices for addressing future changes. The following statements from the *Assessment* highlight observed and projected climate changes, and climate impacts; they were chosen for their relevance to ecosystems and natural resources in the Sonoita Plain:

- The period since 1950 has been warmer than any period of comparable length in the last 600 years. Climate models project continued temperature increases, with longer and hotter summer heat waves. Under a scenario of continued high greenhouse gas emissions in the future, Sonoita Plains regional annual average temperatures will increase by more than 4°F in the 2041-2070 time frame and more than 7°F in the 2070-2099 time frame. These changes are approximately similar to a 1000 foot decrease in elevation.
- Droughts of the past 2,000 years have exceeded the most severe and sustained drought during 1901-2010. In the last decade, flows in the major river basins of the Southwest have been lower than their 20th century averages; many snowmelt-fed streams in the region exhibited earlier snowmelt and earlier center of mass of annual streamflows. An average of model simulations exhibits runoff reductions of 10-15% over the Colorado River Basin, by the 2070-2099 time frame.
- Under a scenario of continued high greenhouse gas emissions in the future, climate models project decreases of 5-10% in annual average precipitation for the area encompassing the Sonoita Plain. Soil moisture is also projected to decrease.
- Ecosystems impacts observed in historical records and ongoing monitoring include changes in phenology, widespread forest disturbance due to the confluence of drought, increased temperatures, and changes to insect life cycles.
- Area burned by wildfire is projected to increase in most of the Southwest. Estimates are often aggregated by state or ecoregion, and studies make different assumptions about future climate and the time period of interest. Estimates range from a 43% increase in acres burned in Arizona and New Mexico, by 2050, to a 380% increase in acres burned in the *mountains* of Arizona and New Mexico.
- Plant and animal species' distributions will be affected by climate change, and studies show that observed climate changes are strongly associated with observed changes in species' distributions. The differences in phenological changes in response to a changing

climate may reduce abundance, population growth rate, and local persistence of individual species. Recent environmental changes have led to both earlier and later timing of phenological events and have exceeded the ability of some species to adapt to such changes. In the Southwest, changes in the phenology of bird species corresponding to climate change include earlier egg-laying by Mexican jays.

- Climate changes are projected to affect agriculture and livestock. In the case of multi-year drought, (a) the length and severity of the drought and (b) the timing of drought in the cattle price cycle are important considerations for livestock ranchers. Two adaptation strategies are to provide supplemental feed to cattle and to reduce herd sizes. Supplemental feeding appears to be a viable long-term strategy. It allows more animals to be sold after the drought (when prices are higher) and avoids aggressive herd reduction during drought, which has a higher replacement cost. However there is no single “right” strategy and the advantages of supplemental feeding depend on drought and price cycle timing.

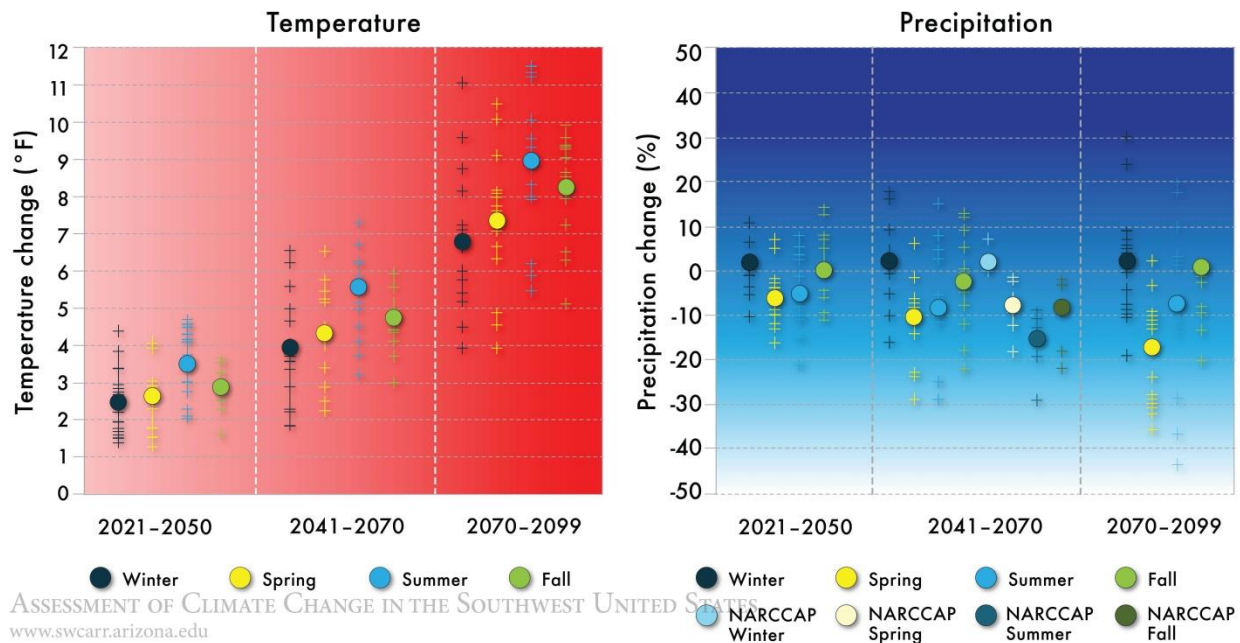
The Assessment also reports on energy, transportation, and urban areas, and these findings include:

- Energy supplies will become less reliable due to potential climate-related increases in demand, and lost power generation efficiency due to increased heat and decreased water supplies. The region’s energy infrastructure is also vulnerable to disturbances, such as wildfires that affect power lines and power transmission.
- Regional climate change will exacerbate heat-related human illness and death. Particular concerns include the effects of extreme heat, and respiratory illness due to increased concentrations of particulate and pollutants from wildfires and dust storms.

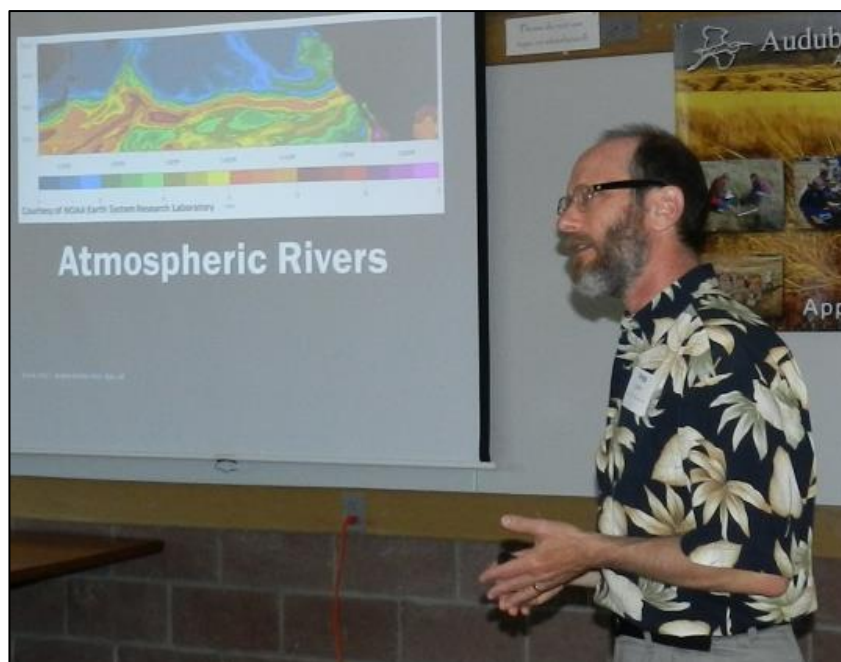
Regional entities have already made strides in implementing greenhouse gas mitigation policies and assessing options for changes in water and energy policy. Coastal communities and several urban centers, including the City of Tucson, have begun adaptation planning, as have federal resource management agencies. Private sector corporations have also initiated policies to directly reduce emissions, or indirectly reduce emissions through changes in transportation and materials in their supply chains. For example, the mining corporation Freeport McMoRan is working on overall emission reductions, energy efficiency, and carbon offsets. Levi Strauss & Co. has reduced carbon emissions by almost 6% since 2007, and they introduced a jeans product line that reduces both water and energy consumption.

#### Reference

Garfin, G., A. Jardine, R. Merideth, M. Black, and S. LeRoy (eds.), 2013. [\*Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment\*](#). Washington, DC: Island Press, 509 p.



**Figure Caption.** Mean annual temperature changes (°F; left) and precipitation changes (%; right) for early-, mid- and late-twenty-first-century time periods. Temperature changes and precipitation changes are with respect to the simulations' reference period of 1971–2000 for 15 CMIP3 models, averaged over the entire Southwest region for the high (A2) and low (B1) emissions scenarios. Also shown are results for the NARCCAP simulations for 2041–2070 and the four GCMs used in the NARCCAP experiment (A2 only). The small plus signs are values for each individual model and the circles depict the overall means.



Dr. Gregg Garfin, co-investigator of Climate Assessment of the Southwest (CLIMAS) at University of Arizona, delivered the keynote address ***Assessment of Climate Change in the Southwest United States: Key Findings.***

## ***Trip Notes on Endangered Desert Pupfish Effort at the Research Ranch***

Date: 8 JUNE 2013

Purpose: desert pupfish survey @ Science on the Sonoita Plain

Location: Appleton-Whittell Research Ranch

Personnel: Doug Duncan, Ross Timmons, Jeff Simms, Chuck Minckley

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Set four (4) baited Gee metal minnow traps in four corners of the pond at 1030-1040 hrs. Traps were set for about two hours each: checked at 1245-1255 hrs. Size class break for adult and juvenile was 20mm. Most fish captured were greater than 20mm. Just before pulling traps, I estimated 20 to 25 pupfish, mostly adults, were still swimming free outside the traps. Only 13 pupfish, basically all adults were captured. In 2012 almost 300 pupfish were captured, about half of them juveniles. The few fish appeared healthy. The catch per unit effort (fish/trap hour) was 2 (37 last year). Minimum number in traps and swimming free was 30. The amount of open water habitat was about one-third of what it was in 2012. While pupfish use vegetated areas, especially very young fish, more open habitat would support more pupfish. We discussed with Audubon staff methods of minimizing plant growth in the pond to increase open water.



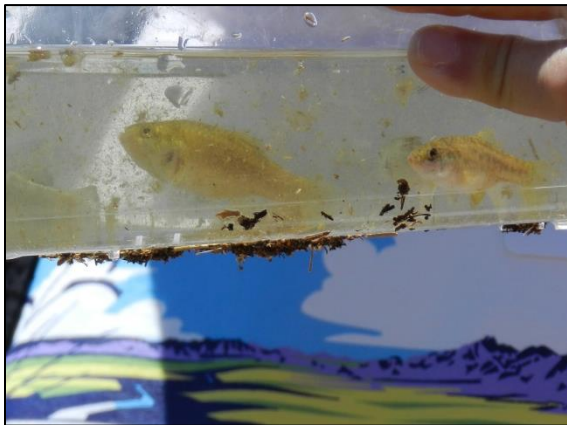






### ***Pupfish Monitoring at HQ Pond***

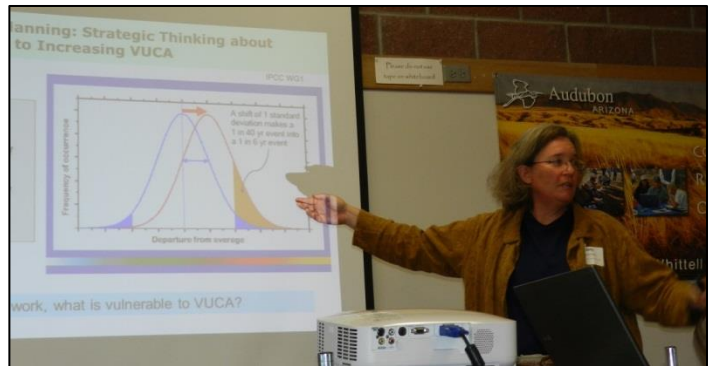
Doug Duncan of the US Fish and Wildlife Service, seen here (right) surveying endangered Desert pupfish in a pond at the research ranch headquarters, had earlier in the morning provided an update on efforts to preserve and restore populations of pupfish in the region. Desert pupfish were released at another site on the research ranch following the conclusion of the afternoon session. Symposium participants assisted with the release.



During breaks and at lunch, people gathered at the headquarters pond to observe and learn more about native fish with fisheries experts Ross Timmons (AZGFD), Doug Duncan (USFWS), and Jeff Simms (BLM).

## Climate Change and Scenario Planning

Holly Hartmann (photo at right) from the Climate Assessment for the Southwest (CLIMAS) program at University of Arizona provided an introduction and overview of climate change scenario planning. Since first presenting the approach at Science on the Sonoita Plain in 2011, Holly has been facilitating the scenario planning process with Kiyomi Morino and a steering



committee of representatives from BLM, TNC, and CWP. More than 100 people have attended presentations and/or participated in workshops for this scenario planning project so far.

Work began in earnest this February, with training of team leads to guide their colleagues through Phase 1, Development of Scenario Narratives. In April and May, four teams (Montane, Riparian, Uplands, Cultural) met several times to flesh out these narratives that describe possible future conditions that would challenge land managers, including not only radically different climate regimes but also possible changes in societal concerns, environmental laws, and economics. Teams used this year's forum to present results of this work and get feedback from an even wider range of stakeholders. The teams' work tapped into the expertise and energy of staff from many agencies, research groups, NGO's and residents including BLM, CWP, TNC, US Fish and Wildlife Service, National Park Service, USDA Agricultural Research Service, Pima Association of Governments, Cuenca Los Ojos Foundation, Pima County, Natural Resources Conservation Service, UA School of Natural Resources, US Forest Service Coronado National Forest, and the Audubon Appleton-Whittell Research Ranch.



Dennis Caldwell (FROG), Mead Mier (PAG), and Doug Duncan (USFWS) of the riparian ecosystem scenario planning team shared their perspectives and lessons learned.



## ***Climate Change and Scenario Planning for the Cienega Watershed***

Holly Hartmann, Kiyomi Morino, Gita Bodner, Amy Markstein, Shela McFarlin.

The University of Arizona, The University of Arizona, The Nature Conservancy, Bureau of Land Management, Cienega Watershed Partnership.

**An Uncertain Future.** The Cienega Watershed is facing a wide range of challenges—an unpredictable future with significant climatic change uncertainties in an already stressed and rapidly changing landscape. Current plans have objectives and strategies based on what is known about natural and socio-cultural systems. These plans did not address uncertainties related to rapid changes in climate whether warming temperatures, change in precipitation, or seasonality, nor is a feedback mechanism for re-considering such information well developed.

**Scenario Planning.** Scenario planning is a deliberate approach to adapt identified visions, goals, objectives, and activities in a risky, uncertain future. Scenario planning uses a deliberative, inclusive process and fine-tuned climate narratives to: (1) challenge assumptions about the future, (2) foster strategic thinking about how to respond in different situations, (3) gain insight into how to prepare for and manage change in the face of uncertainty, and (4) test management strategies that can solve problems here and elsewhere. Scenario planning offers a way of using existing information, addressing uncertainties, and incorporating new information as it becomes available to develop more robust management plans that are based on stakeholder visions, goals and objectives. The scenarios emphasize key sources of change that are outside the control of managers of Cienega resources. They emphasize what could happen and what may be unlikely, but would have important consequences.

**The Cienega Watershed Scenario Planning Project.** People in the Cienega Watershed have long used partnerships and science to sustain the area's natural and cultural resources and the benefits they bring to communities. The Cienega watershed scenario planning project builds on the area's existing partnerships, plans, and science. It focuses on the Cienega watershed but takes in adjacent areas where appropriate, and for this phase of creating the scenario narratives, involves federal, state and local agencies; non-profit organizations; and stakeholders of interested public, academic, resident, and other land users.

Heavily involved are those watershed partners who form the ongoing technical teams initiated by the BLM for the LCNCA in 2010 with expertise in riparian, upland, heritage and landscape issues. However, this project uses four resource area teams: Montane, Riparian, Upland, and Cultural. Teams average 7 to 10 members with some overlap; all include agency and public members. Co-team leads for each team help ensure continuity throughout the process, and work with the steering committee (Figure 1) to design workshop content, accumulate materials, communicate in all directions, assess and adapt the scenario development process and components.



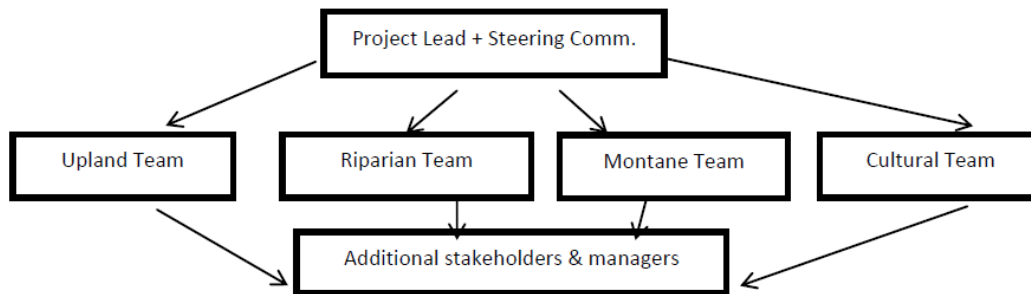


Figure 1 Organization of scenario teams.

**Developing Cienega Watershed Scenarios.** The Cienega Watershed Scenario Planning project has been developed around a 3-phase, 20-step process that has been used in many other locations. A training workshop prepared team leaders to develop, with their teams, the management-relevant scenario narratives that incorporate climate change and other key external forces. Team leaders also tested and reviewed activities to be implemented by their entire team during the day-long Cienega watershed scenario development workshop.

At that workshop, each team independently identified their specific resource management issues, shared understanding about external drivers of change and their impacts on Cienega resources, and developed rudimentary scenario narratives. Each team expanded and refined their basic narratives, combined with three regional climate narratives, into more detailed forms over the following two months. The regional climate narratives were developed using a similar workshop process that engaged climate and impacts scientists from the Climate Assessment of the Southwest (CLIMAS).

The stories produced by the resource teams explore ways in which the challenges facing managers and stakeholders within the Cienegas watershed may evolve over future decades. The scenarios are not forecasts or predictions of the future. They do not indicate a "most likely" future. They do not contrast "best case" or "worst case" possibilities. Rather, they simply present plausible future conditions that would challenge resource managers and communities in very different ways. Their purpose is to stimulate thinking and discussion, not to indicate any preferences for future conditions or management approaches.

*"Many thanks to the numerous individuals and organizations who have helped shaped this scenario planning effort, and especially to those who put additional time and creativity into the most recent phase of fleshing out scenario narratives for each resource area."*

In the next phase of Cienega watershed scenario planning project, the resource teams and others will explore the implications of the scenarios. The scenarios will also provide a tool for examining how well future management options may perform under the widely different and challenging conditions posed by a changing climate.

## ***Regional Climate Scenarios for the Southwest***

**Holly Hartmann** and Kiyomi Morino.

The University of Arizona, The University of Arizona.

The following preliminary climate scenarios pertain to Arizona and New Mexico. These are neither forecasts, predictions, projections nor most probable futures. Rather, they are portrayals of plausible climate futures that emphasize key scientific uncertainties. They were incrementally developed through by CLIMAS (Climate Assessment of the Southwest) scientists using a process that integrated creativity and expert knowledge. Please note that these scenarios are still in revision and that some features may change before they are finalized. In the text below, a synopsis of each scenario is provided, followed by its evolution over this century.

**Scenario #1: Habooby Trap.** The Southwest becomes drier and dustier. This scenario is the result of a combination of drier winters and windier summers. The widespread nature of the winter rainy season means that low precipitation will be a uniform feature across the region. Meanwhile, on a more local scale, powerful downdrafts generated by monsoon thunderstorms with little moisture act upon loose sand and soil kicking up clouds of dust that can attain heights of one mile and leading edges of 100 miles in length.



**Figure 2** Dust storm near Scottsdale, AZ on July 12, 2012. Photo credit: R. Behnke

**Time evolution.** Currently, winter precipitation in some parts of the Southwest has already begun to decrease. In early July 2011, the Phoenix area was hit by the “100-year dust storm.” A total of 24 dust storms occurred in Arizona in 2011. Some evidence suggests that the incidence of dust storms is already increasing. By 2050, annual average temperatures have increased by about 4.5 °F, with summer temperatures showing the highest increases – about 5.5 °F on average. Heat waves are common. Early spring precipitation has dropped by nearly 10% compared to late 20<sup>th</sup> century levels. Winter precipitation has also decreased by about 10%. Dust storms are larger and more frequent. On average, 30 dust storms occur every year in Arizona and New Mexico with average storm fronts of 50 miles in length. By 2100, annual average temperatures have increased by 8°F. Summer still exhibits the greatest increases – about 9 °F on average. Heat waves are longer and more frequent. Early spring precipitation has dropped by nearly 20%. Winter precipitation has also decreased by about 20%. Dust storms continue to increase in size and frequency. On average, 50 dust storms occur every year in Arizona and New Mexico with average storm fronts of 75 miles in length.

**Scenario #2: Tucson Good Ol’ Days.** In this scenario, the onset of the monsoon season shifts to an earlier start date but the end date remains unchanged, yielding an extended summer rainy season. A longer monsoon season means more rain, boosting the importance of the summer precipitation pulse across the region. The other component of this scenario is reduced tropical Pacific cyclonic activity. Tropical Pacific cyclones can generate intense storms in the Southwest during the late summer and fall and can be associated with extreme flooding. Reduction in cyclone activity means fewer of these storms penetrating the region.

**Time evolution.** Currently, the monsoon season in Arizona and New Mexico typically begins in early July, with the earliest onset occurring in mid-June. Tropical cyclones in the Southwest are not common and tend to affect Arizona more than New Mexico. Twenty tropical cyclones have entered into the Southwest with varying levels of severity between 1989 and 2009. By 2050, annual average temperatures have increased by about 4.5 °F by now, with summer temperatures showing the highest increases – about 5.5 °F on average. Early spring precipitation has dropped by nearly 10% compared to late 20<sup>th</sup> century levels. The monsoon season is now, on average, beginning in mid-June.

Tropical cyclones impact Arizona and/or New Mexico about once every three years. By 2100, annual average temperatures have increased by 8°F. Summer still exhibits the greatest increases – about 9 °F on average. Early spring precipitation has dropped by nearly 20%. The monsoon now starts, on average at the beginning of June. Tropical cyclones impact Arizona and/or New Mexico about once every five years.



Figure 3 Monsoon storm over Sabino Canyon with Tucson in background. Photo credit: J. Malusa



Figure 4 2004-5 winter floods in Oak Creek Canyon near Sedona, AZ. photo credit: FARK.com

**Scenario #3: No Analog.** In this scenario, the onset of the monsoon season shifts to a later start date but the end date remains the same. The dual effect of this change in timing is a longer, hotter dry season and a shorter summer rainy season. The monsoon season blends into a more active fall rainy season. An increased number of tropical Pacific cyclones in the fall (September through November) result in more direct and indirect impacts to the Southwest. Fall storms are widespread, multi-day events.

**Time evolution.** The monsoon season in Arizona and New Mexico typically begins in early July, with the earliest onset occurring in mid-June. Tropical cyclones in the Southwest tend to affect Arizona more than New Mexico. Between 1921 and 2009, 45 tropical cyclones have impacted Arizona. Twenty of those events occurred between 1989 and 2009. By 2050, annual average temperatures have increased by about 4.5 °F, with summer temperatures showing the highest increases – about 5.5 °F on average. The monsoon season is now, on average, beginning in mid-July. Tropical Pacific cyclones impact Arizona and New Mexico, on average, every year. Occasionally (10% of the time) no tropical storm systems will enter into the Southwest. These years are offset by years when 2-3 tropical storms enter the region. Storm duration is about one week and affects about 30% of the region on average. By 2100, annual average temperatures have increased by 8°F. Summer still exhibits the greatest increases – about 9 °F on average. The monsoon now starts, on average at the end of July. Tropical cyclones impact Arizona and New Mexico every year. About 20% of the time, 2-3 tropical storms enter the region. Storm duration is about 10 days and affects about 45% of the region on average.

## Montane Resources in the Cienega Watershed: Scenario Narratives

**Craig Wilcox**, David Hodges, Scott Stonum, George Ferguson, Perry Grissom, Michele Girard, Louise Misztal.

US Forest Service, Cuenca Los Ojos & Coronado Planning Partnership, National Park Service, The University of Arizona, National Park Service, US Forest Service, Sky Island Alliance.

With the assistance and input of several individuals who participated in the larger process of Scenario Planning, we developed our scenario narratives based on the following management question: *How do we enhance resilience and persistence of montane systems and their components?* As used in this scenario planning project, “montane resources” are comprised of vegetation types including oak woodlands up to mixed conifer forest. Of all forest types, oak woodlands cover the largest area in the Cienega watershed.

To construct our scenarios, we first selected two non-climate drivers of change that would have a high impact on montane resources in our area, but that are not confidently predictable over the coming decades. These were: 1) fire, and 2) insect outbreaks. We elected to define fire impacts with respect to a reference: “Departure from current fire regime condition class.” A low departure signifies a fire regime similar to what we have today and a high departure indicates a very different fire regime. Insects may impact trees by boring into trunks and branches, stripping bark and defoliating.

We then selected three of our four non-climate scenarios (Figure 5) and nested them in three regional climate scenarios (described in more detail in “Regional Climate Scenarios for the Southwest”). Below is a proposed evolution of how each of these scenarios plays out by 2020, 2050 and 2100. These timelines are followed by a list of potential management challenges that emerged as we developed these scenarios.

**Scenario #1: Descent into Decadence** (Figure 5: low fire regime departure, many insect outbreaks)

**nested in a Habooby Trap climate** (drier winters, windier summers). By 2020, it is not yet evident that climate has shifted to a Habooby Trap regime. The condition of montane resources is similar to what is seen today: topographically mediated drought stress, presence of invasives like Lehmann’s lovegrass, and damage from insects like the Gold-spotted oak borer. By 2050, the climate regime can be definitively identified as Habooby Trap. A couple of exotic insect species have colonized the forests of the Cienega watershed. Several large, high-intensity fires have decimated upper elevation forests. Drought stress and insect pressure are forcing the rapid retreat of woodlands. Pinyon are disappearing from the landscape. By 2100, widespread insect outbreaks are common, occurring every 7-10 years in remaining woodlands and forests, mostly found at higher elevations. Meanwhile, under this drier, hotter climate, there have been wholesale conversions of lower elevation woodlands to desert scrub-type vegetation.

**Scenario #2: Land of Milk and Honey** (Figure 5: low fire regime departure, few insect

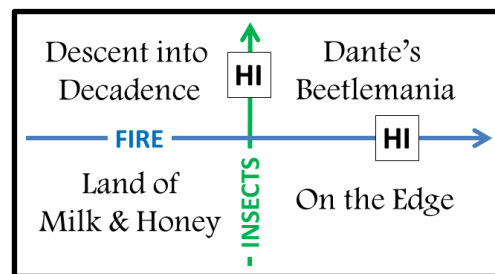


Figure 5 Four scenarios for montane resources as defined by insect outbreaks (many vs few) and departure from current fire regime condition class.



*outbreaks) nested in a Tucson Good Ol' Days climate (earlier monsoon, fewer fall storms).* By 2020, it is not yet evident that climate has shifted to a Tucson Good Ol' Days regime. The condition of montane resources is similar to what is seen today: topographically mediated drought stress, presence of invasives like Lehmann's lovegrass, and damage from insects like the Gold-spotted oak borer. By 2050, the longer monsoon season will have begun to transform the montane system to include patches of forest that resemble the more southern pine-oak Madrean systems. Insect species from Mexico will have invaded the region but their activities will be mostly innocuous. By 2100, there has been a more extensive conversion to pine-oak forest.

**Scenario #3: Dante's Beetlemania** (*Figure 5: high fire regime departure, many insect outbreaks) nested in a No Analog climate (later monsoon, more fall storms).* By 2020, it is not yet evident that climate has shifted to a No Analog climate regime. The condition of montane resources is similar to what is seen today: topographically mediated drought stress, presence of invasives like Lehmann's lovegrass, and damage from insects like the Gold-spotted oak borer. By 2050, cool season grasses prevail as do tap-rooted woody species, at least at lower elevations. Disturbance frequencies and impacts are high, leading to a highly dynamic system. By 2100, the system has stabilized.

**Potential Management Challenges.** In taking into account the uncertainties posed by both climate and non-climate drivers, these narratives suggest that managers might want to consider:

1. The montane system may undergo rapid changes that essentially amount to a re-shuffling of species, with new and surprising combinations and interactions
2. Wholesale conversion of mixed conifer forests to oak woodlands, with increased spring fire risk, challenges the ability to sustain critical parts of the montane system.
3. Many parts of the montane system may experience disturbance simultaneously, so that management resources will be spread thin.

Craig Wilcox from Coronado National Forest presented the montane resources scenarios.



## ***Riparian Resources in the Cienega Watershed: Scenario Narratives***

**Mead Mier**, Cat Crawford, **Doug Duncan**, **Dennis Caldwell**, Kelly Mott Lacroix, David Scalero, Matt Killeen, Karen Simms, Aaron Lien, Andrew Salywon.

Pima Association of Governments, US Fish and Wildlife Service, US Fish and Wildlife Service, FROG, The University of Arizona – Water Resources and Research Center, Pima County, The Nature Conservancy, Bureau of Land Management, The University of Arizona – Water Resources and Research Center, Desert Botanical Garden.

With the assistance and input of several individuals who participated in the larger process of Scenario Planning, we developed our scenario narratives based on the following management question: *How do we maintain the ecological values (ecosystem functions) of riparian and aquatic systems?* The resources considered by the riparian and aquatic group were those that we considered the most sensitive and at risk: water, native frogs and fish, and the cottonwood and willow gallery forests. Without water, frogs, fish, and riparian forests will be lost.

To construct our scenarios, we first selected two non-climate drivers of change that would have a high impact on riparian resources in the Cienega Watershed area, but that are not confidently predictable over the coming decades. These were: 1) rates of population growth, and 2) environmental ethic. Environmental ethic refers to the value placed on the natural environment, including but not specific to riparian ecosystems.

We then selected two of our four non-climate scenarios (Figure 6) and nested them in three regional climate scenarios (described in more detail in “Regional Climate Scenarios for the Southwest”). Below is a proposed evolution of how each of these scenarios plays out by 2020, 2050 and 2100. These timelines are followed by a list of potential management challenges that emerged as we developed these scenarios.

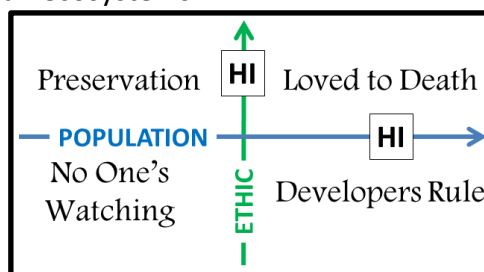


Figure 6 Four scenarios for riparian resources as defined by rates of population growth and environmental ethic.

**Scenario #1: Developers Rule** (Figure 6: high population growth, low environmental ethic) nested in a **No Analog climate** (later monsoon, more fall storms). By 2020, the climate impacts of No Analog are not quite distinguishable from current climate. Urban sprawl is prevalent outside of towns and cities with more restrictive water use legislation. Increased groundwater pumping has already impacted shallow aquifers, leading to fewer perennial stream miles. Older cottonwoods have begun to die-off without natural replacement. By 2050, there are no more perennial creeks or springs. Invasives such as tamarisk and mesquite are dominant. New residents lack any connection with the riparian systems of twentieth century, having never seen water flowing all-year around. A handful of massive storms have caused major headcutting and incision of arroyos; local water tables have dropped precipitously. Extended and more intense dry season coupled with a drying of riparian ecosystems has led to more fire events and more extreme fire behavior. By 2100, all creeks in the watershed are ephemeral, flowing only after rain events. Rates of erosion and sediment

transport are high. The area between Tucson and the Cienegas is one continuous swath of housing developments. Funding, heritage knowledge and monitoring no longer exists for riparian ecosystems.

**Scenario #2: Developers Rule** (*Figure 6: high population growth, low environmental ethic*) **nested in Tucson Good Ol' Days climate** (*earlier monsoon, fewer fall storms*). By 2020, the climate impacts of the Tucson Good Ol' Days are not quite distinguishable from current climate. But the continuing drought and population growth continues to stress human and natural systems. These stresses continue to impact and reduce riparian and aquatic areas and the resources that depend on them. There is increasing recreation use of riparian areas due to the increasing population. By 2050, because people are moving to higher elevations seeking cooler living conditions, the Sonoita and Elgin area grows, as does groundwater pumping. Also, with reduced delivery of Colorado River water through the CAP, combined with more people, groundwater pumping in the Tucson basin increases. Riparian and aquatic habitats become rarer, and more heavily impacted. By 2100, due to higher temperatures and summer-dominated precipitation, sub-tropical plants and animals continue their march north into the Cienega watershed. The only remaining cottonwood trees subsist on reclaimed water at the Paseo de las Iglesias project. Lastly, invasive aquatic species are no longer problems, as there are virtually no perennial aquatic habitats left in the Cienega Creek watershed.

**Scenario #3: Preservation** (*Figure 6: low population growth, high environmental ethic*) **nested in Habooby Trap climate** (*drier winters, windier summers*). By 2020, the climate impacts of the Habooby Trap are not quite distinguishable from current climate. Nevertheless, riparian areas in the Cienega watershed have become highly managed systems. Recreationists begin volunteering and joining conservation groups. With increased numbers of volunteers, invasive aquatic species can be controlled and native species populations can be bolstered. Water conservation per capita is increasing. The environmentally-minded citizenry of the basin begin to affect policy that protects recharge areas. By 2050, Habooby Trap climate is in full swing. Exposed soils and high summer winds have led to some major dust storms in the watershed, unlike any experienced before. All perennial springs and stream reaches have disappeared. Former wetlands and streams are now ephemeral with a few cottonwoods still remaining. Mesquite is now much more common on the floodplain and in the stream channel. Native aquatic flora and fauna are protected in small, highly controlled habitats. Wastewater treatment wetlands in Sonoita help recharge the upper aquifer and support a Sonoran mud turtle preserve. By 2100, riparian or aquatic resources are only encountered in highly controlled preserves maintained with built infrastructure with water from desalination and harvested rainwater. Migratory bird species have been absent since the 2060s. Non-migratory wetland species can be found at preserve wetlands and sewage treatment wetlands.

**Potential Management Challenges.** In taking into account the uncertainties posed by both climate and non-climate drivers, these narratives suggest that managers might want to consider:

1. How do we maintain riparian systems in a world of dry-wet extremes and development priorities?
2. Riparian systems will be in trouble even with a seemingly benign climate, given societal pressures.
3. What would it take for riparian systems to withstand a drying climate, even when societal priorities are highly favorable?

## Upland Resources in the Cienega Watershed: Scenario Narratives

Heather Swanson, Marcos Robles, Phil Heilman, Katie Predick, Brian Powell, Gita Bodner.

Bureau of Land Management, The Nature Conservancy, Agricultural Research Service, The University of Arizona, Pima County, The Nature Conservancy.

With the assistance and input of several individuals who participated in the larger process of Scenario Planning, we developed our scenario narratives based on the following management question: *How can we maintain effective groundcover and productive vegetation to sustain ecosystem functions?* Upland resources are most easily considered as those lands existing between the montane and riparian areas. The uplands include saguaros, desert scrub, and semi-desert grasslands.

To construct our scenarios, we first selected two non-climate drivers of change that would have a high impact on upland resources in the Cienega Watershed area, but that are not confidently predictable over the coming decades. These were: 1) the character of governmental funding, and 2) environmental laws. Government funding could occur at consistently low levels, or with high variability in a 'boom or bust' pattern. We considered that environmental laws could be repealed or be maintained at their current levels of use.

We then selected three of our four non-climate scenarios (Figure 7) and nested them in three regional climate scenarios (described in more detail in “Regional Climate Scenarios for the Southwest”). Below is a proposed evolution of how each of these scenarios plays out by 2020, 2050 and 2100. These timelines are followed by a list of potential management challenges that emerged as we developed these scenarios.

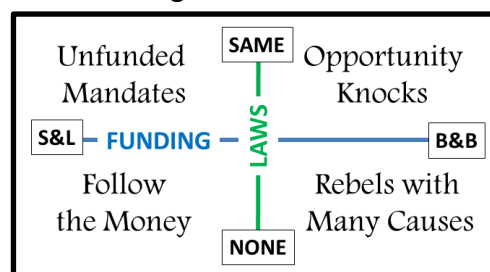


Figure 7 Four scenarios for upland resources as defined by Government Funding: Steady but Low vs Boom and Bust; and Environmental Laws: current laws unchanged (same) vs current laws abolished (none).

**Scenario #1: Unfunded Mandates** (Figure 7: environmental laws unchanged, steady but low government funding) **nested in a Habooby Trap climate** (drier winters, windier summers). By 2020, the climate impacts of the Habooby Trap are consistent with persistence of recent droughts. The uplands face increased fire risk and experience grass mortality due to drought. By 2050, the uplands are dominated by shrub and scrub vegetation, which results in lower fire risk because the overall ground cover is more sparse, with limited ability to recover after any fire occurs. By 2100, the persistent dryness and winds have scoured the landscape, producing large bare patches and loss of soil productivity. Throughout the decades, agencies continue to bear responsibility for sustaining sensitive species, although budgets are consistently insufficient to provide active management.

**Scenario #2: Follow the Money** (Figure 7: environmental laws abolished, steady but low government funding) **nested in Tucson Good Ol' Days climate** (earlier monsoon, fewer fall storms). By 2020, the climate impacts of the Good Ol' Days appear to be typical of some recovery from recent droughts. Over the decades through 2050 and 2100, precipitation is generally favorable for sustaining uplands vegetation in southeast Arizona, although warmer temperatures and shorter winter seasons provide challenges of pre-monsoon dryness earlier in



the year. With the loss of land and conservation laws by 2020, economic priorities dominate, with haphazard exurban and agriculture development facilitating the spread of buffleggrass. By 2050, development has stressed groundwater supplies due to development and mining projects. Buffleggrass is a dominant upland species. By 2100, many species presently listed as threatened or endangered have disappeared from the region.

**Scenario #3: Opportunity Knocks** (*environmental laws unchanged, boom & bust government funding*) **nested in No Analog climate** (*later monsoon, more fall storms*). By 2020, the climate of the No Analog scenario is seen as atypically weak monsoons and that, nevertheless, still produce an extremely intense precipitation event that is considered to be a rare occurrence. Poor monsoon precipitation under warmer conditions produces grassland mortality; the associated stress on ranching results in an infusion of federal funding similar to programs of the 1930s. However, by 2050, those funds have not been replenished, even though ranching operations continue to experience stress as annual grasses come to dominate the uplands, with overall lower plant diversity. No federal funds are available to replace flood control structures that have destroyed by a series of precipitation events more intense than in the historical record. By 2100, the entire uplands area is experiencing nearly annual land surface disturbance by erosion and deposition from extreme precipitation. The emphasis on protecting buildings, roads, and people dominates the attention of managers and communities.

**Potential Management Challenges.** In taking into account the uncertainties posed by both climate and non-climate drivers, these narratives suggest that managers might want to consider:

1. How to facilitate the transition of vegetation types, no matter the species involved, while meeting regulatory obligations for protection of threatened and endangered species?
2. How to ensure the expansion of native vegetation under the pressures of development, even under a productive climate, if development pressures continue to grow?
3. How to use surge funding effectively, to deal with continuous disruption and disturbance, especially from extreme events that have widespread impacts?



Heather Swanson (BLM) presented the upland resources scenarios.



Shela McFarlin (CWP) presented the cultural resources scenarios.

## Cultural Resources in the Cienega Watershed: Scenario Narratives

**Shela McFarlin**, Larry Fisher, Chris Shrager, Martie Meirhauser, Annamarie Schaecher, Alison Bunting, Tahnee Robertson.

Cienega Watershed Partnership, University of Arizona and Cienega Watershed Partnership, Colossal Cave Mountain Park & Cienega Watershed Partnership, Cienega Watershed Partnership, Empire Ranch Foundation, Southwest Decision Resources.

With the assistance and input of several individuals who participated in the larger process of Scenario Planning, we developed our scenario narratives based on the following management question: *How do we make triage-type (no regret) decisions about which resources and which treatments to employ to preserve, conserve, manage and restore our cultural resources?* As used in this scenario planning project, “cultural resources” refers to physical locations such as historic properties or standing structures, archaeological sites, and significant places that have been identified, and to heritage values that represent the groups who have resided in, utilized or placed value to the Cienega Watershed.

To construct our scenarios, we first selected two non-climate drivers of change that would have a high impact on cultural resources, but that are not confidently predictable over the coming decades. These were: 1) disturbance, both natural and human, and 2) values about cultural resource preservation. Some of the disturbances that are threats to cultural resources in the Cienega watershed include: wind, flooding, fire and freezing events, as well as vandalism, resource over-use and development projects related to water, energy and minerals. In most cases, disturbance is a highly destructive agent for cultural resources but occasionally, it can serve to uncover previously unknown sites. Values relating to cultural resource preservation indicate the extent to which cultural resources will be maintained, restored and interpreted. Interpretive programs are particularly important for making connections between cultural resources and the public at large.

We then selected three of our four non-climate scenarios (Figure 8) and nested them in three regional climate scenarios (described in more detail in “Regional Climate Scenarios for the Southwest”). Below is a proposed evolution of how each of these scenarios plays out by 2020, 2050 and 2100. These timelines are followed by a list of potential management challenges that emerged as we developed these scenarios.

**Scenario #1: Just Let It Go** (Figure 8: high disturbance, low values) nested in **Habooby Trap climate** (drier winters, windier summers). By 2020, natural disturbances are more destructive than human activities. For example, high winds have blown off roofs and increased weathering of small adobe structures and fires are threatening historic structures. Restoration is questionable and preservation funding and staffing has been greatly reduced. By 2050, both archaeological and historic sites have deteriorated due to regular exposure to a variety of natural disturbances. Human activities are also taking their toll on cultural resources, including vandalism, and energy, water and mining projects. Federal funding, law enforcement, and

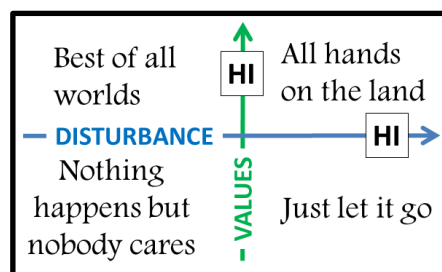


Figure 8 Four scenarios for cultural resources as defined by disturbance and values about cultural resource preservation.

emergency work have all been cut. Traditional collecting areas have become stressed and not worth the trip for elders. Volunteer and stewardship activities are almost gone. By 2100, most historic properties have been destroyed. Buried archaeological sites are intact in locations where flooding and erosion did not occur. Federal agencies and the county no longer have a preservation staff. No preservation funding or expertise exists. The public is willing to let heritage properties go because other priorities take funding and time.

**Scenario #2: Nothing Happens But Nobody Cares** (*Figure 8: low disturbance, low values*) **nested in Tucson Good Ol' Days climate** (*earlier monsoon, fewer fall storms*). By 2020, major historic interpretive projects such as the Empire Ranch and Kentucky Camp are impacted by reduced federal funding, and public support in the form of volunteers or private funding is starting to decline. A few historic sites caught in wildfires have burned and not restored. By 2050, fires de-stabilize several more historic structures; no efforts to repair are made. A severe cold snap bursts pipes incurring heavy damage on historic buildings and high mortality of natural vegetation and gardens. No great public outcry over lost places is heard and no resources are flowing into preservation under the mistaken notion that all is well. By 2100, most archaeological sites have burned over but some of the larger sites still have significant information value. Historic buildings have suffered from both vandalism as well as fires. Adobe buildings not stabilized by 2050 have “melted” into the ground. There is no significant public support and no federal preservation programs exist.

**Scenario #3: All Hands On the Land** (*Figure 8: high disturbance, high values*) **nested in No Analog climate** (*later monsoon, more fall storms*). By 2020, historic structures like the Vail Post Office are losing roofs during intense storms and other buildings are burned during wildfires. Fire, flood and wind undo efforts already made to preserve specific historic sites making it tough at the Empire Ranch Headquarters and Kentucky Camp. But, local citizens and groups who support cultural resources respond through emergency volunteer services, fundraising, and expanding the site steward program to monitor resources. Floods have also eroded one or two archaeological sites along the edges, revealing organic and datable materials. By 2050, flooding from major storms has destroyed small archaeological sites and eroded significant portions of major sites. Public demand for recreation has increased erosion. Hands-on education is in high demand resulting in well-trained volunteers to aid emergency and longer-term stabilization projects. By 2100, human damage is up from a variety of uses ranging from digging deeper wells to sustain local communities to widespread recreation. Projects abound from disaster funding made available by federal agencies, leading to site over-use in some cases. Publicly-adopted sites are still preserved because local groups are connected to the resources.

**Potential Management Challenges.** In taking into account the uncertainties posed by both climate and non-climate drivers, these narratives suggest that managers of cultural resources consider:

1. How to manage under a drying climate with increased damage potential to resources but reduced public support, funding and engagement.
2. How to deal with increased threats to cultural resources given an apathetic and disconnected public.
3. How to respond to increased damages from wet-dry climate extremes by capitalizing on high public engagement and support.

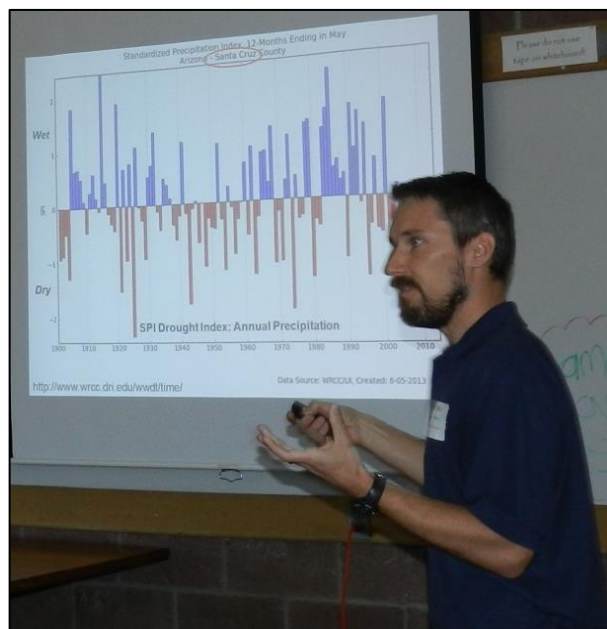
## **Presentations and Updates**

### ***Tracking Drought in a Changing Climate***

**Michael A. Crimmins**, Department of Soil, Water, and Environmental Science, P.O. Box 210338, The University of Arizona, Tucson, AZ 85721. [crimmins@email.arizona.edu](mailto:crimmins@email.arizona.edu).

Southeastern Arizona has been gripped by drought conditions for well over a decade with impacts being felt across many sectors and systems from water resources to wildlife and vegetation condition. Several very dry winters in the past ten years can be directly attributable to a handful of strong La Nina events occurring including a rare back-to-back event that spanned from 2011 into 2012. Summer precipitation amounts have also varied dramatically from year to year across the region over this period as well including very wet conditions in late July of 2006 and record dry conditions through much of the summer of 2009. Temperatures were also very warm over the past decade with almost every year experiencing annual average temperatures way above the long-term average, further exacerbating drought stress on vegetation and water resources.

High levels of natural, inter-annual variability in precipitation forced by the El Nino-Southern Oscillation, a strong seasonality in precipitation and warming temperatures characterize the climate of southeast Arizona, all of which create great challenges in tracking local drought conditions. This presentation will review the evolution of drought conditions across the region using a suite of new drought monitoring tools that assess changes in precipitation and temperature at fine spatial scales and multiple temporal scales. How these tools are being used with respect to guiding the production of the U.S. Drought Monitor and the role of impact information in the drought monitoring process will also be discussed.



Michael Crimmins



## ***Trends in Groundwater and Surfacewater Resources in the Cienega Valley***

**Claire Zucker**, Director of Sustainable Environment, Pima Association of Governments, 177 N. Church Ave., Suite 405, Tucson, AZ 85701

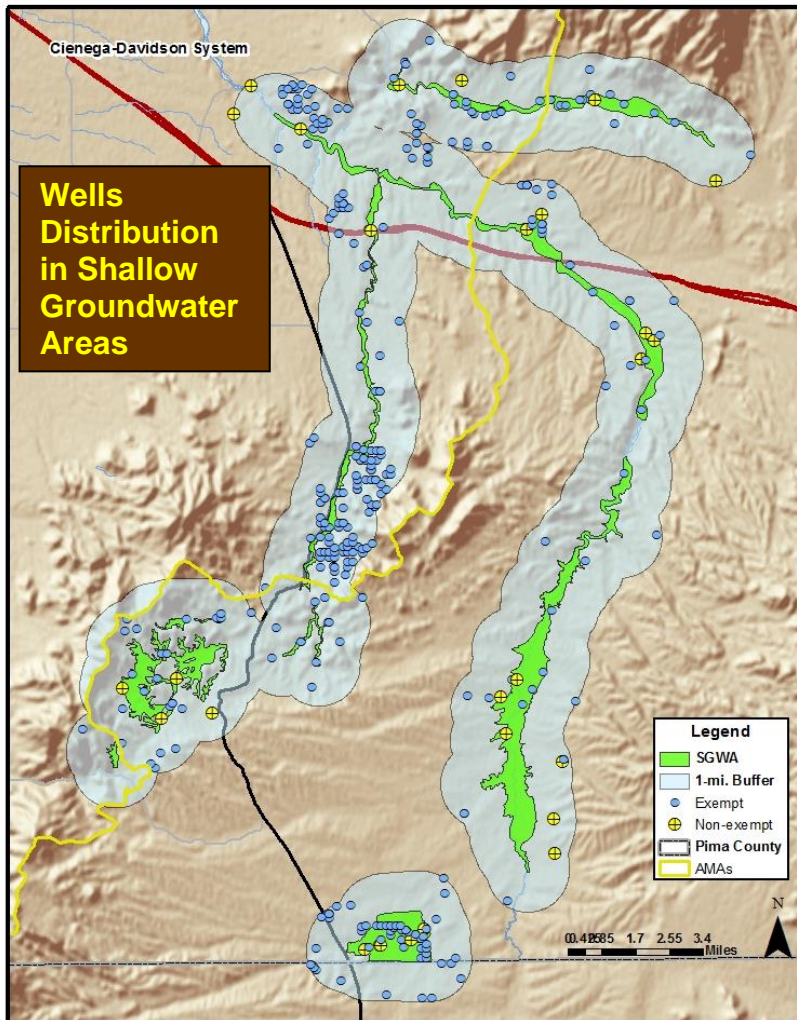
**Brian Powell**, Program Manager, Pima County Office of Sustainability and Conservation, 201 North Stone Ave, Rm. 629, Tucson, AZ 85701

Cienega Creek is a rare, low-elevation perennial stream that depends on groundwater, channel subflow and replenishment through stormflows for its water resources. Desert riparian streams, such as Cienega Creek, are increasingly at risk due to drought, rising temperatures associated with climate change, and increasing human use of water. Pima Association of Governments recently completed an overview report showing the number of exempt and non-exempt wells, drilling histories, and water production estimates for shallow groundwater areas in eastern Pima County. A one-mile buffer around the Cienega-Davidson shallow groundwater system contains 29 non-exempt wells and 355 exempt (private low-water use) wells. This area contains upper and lower Cienega Creek, Davidson Canyon, Barrel Canyon, Gardner Canyon, and Agua Verde-Posta Quemada, and areas show unique well histories and groundwater level trends. Overall, the total number of exempt wells drilled in the region has steadily increased since 1990. PAG, in coordination with Pima County, has monitored groundwater and surface water in the Cienega Creek Natural Preserve (lower Cienega Creek) since 1989, thereby providing over three decades of water resource information. As a result, the quantity and quality of water resource data for lower Cienega Creek is dramatically better than that available for many other parts of the Cienega Valley. The result of a recent analysis of these data shows a decline of most water-related parameters monitored in the Preserve. From 1993-2011, precipitation showed a declining trend in the winter, but no trend in the summer. During the same period, streamflow declined by approximately 50% with the most significant decline during June, which is a critical period for aquatic plants and animals each year. The extent of surface flow declined from a high of 9.5 miles (1984-1996), to a low of 1.24 miles in June of 2012. These trends cause researchers in the region to be concerned about the prospects for long-term health of the aquatic and riparian system of Cienega Creek.

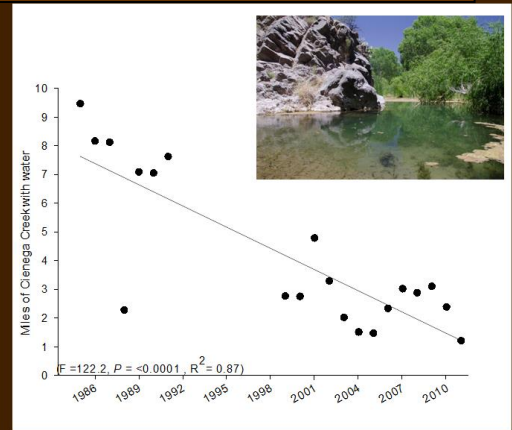


Claire Zucker  
and Brian Powell

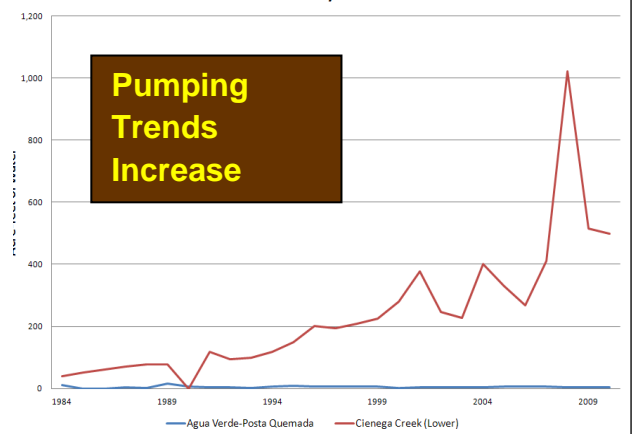




## Streamflow Extent Declines



Total Water Withdrawals from Non-exempt Wells in the Cienega-Davidson System



## Trends in Landscape and Vegetation Change and Implications for the Santa Cruz Watershed

Miguel L. Villarreal, Laura M. Norman, Robert H. Webb and Raymond M. Turner

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Monitoring and characterizing the interactive effects of land use and climate on land surface processes is a primary focus of land change science, and of particular concern in arid

environments where both landscapes and livelihoods can be impacted by short-term climate variability. Using a multi-observational approach to land-change analysis that included land-ownership data as a proxy for land-use practices, multitemporal land-cover maps, and repeat photography dating to the late 19th century, we examine changing spatial and temporal distributions of two vegetation types with high conservation value in the southwestern United States: grasslands and riparian vegetation. Our study area is the bi-national Santa Cruz Watershed, a topographically complex watershed that straddles the Sonoran Desert and the Madrean Archipelago Ecoregions. In this presentation we focus on historical changes in vegetation and land use in grasslands and riparian areas of the Madrean Ecoregion (San Raphael Valley, Cienega Creek, Sonoita), and compare changes in these areas to changes in the warmer and drier Sonoran Ecoregion. Analysis of historical photography confirms major 20th century vegetation shifts documented in other research: woody plant encroachment, desertification of grasslands, and changing riparian and xeroriparian vegetation occurred in both ecoregions following human settlement. However, vegetation changes over the past decade appear to be more subtle and some of the past trajectories appear to be reversing; most notable are recent mesquite declines in xeroriparian and upland areas, and changes from shrubland to grassland area in the Madrean ecoregion. Land cover changes were temporally variable, reflecting broad climate changes. The most dynamic cover changes occurred during the period from 1989 to 1999, a period with two intense droughts. The degree of vegetation change driven by climate was related to topographic setting: vegetation declines were greater per unit area in the lower elevation Sonoran ecoregion where temperatures are higher and precipitation lower than in the Madrean. Fine-scale changes within these broad climate patterns were likely the result of land use practices: declines were highest on state lands (grazing) and increases highest on private ranches and some federal lands (active mesquite removal and watershed restoration).



Miguel Villarreal



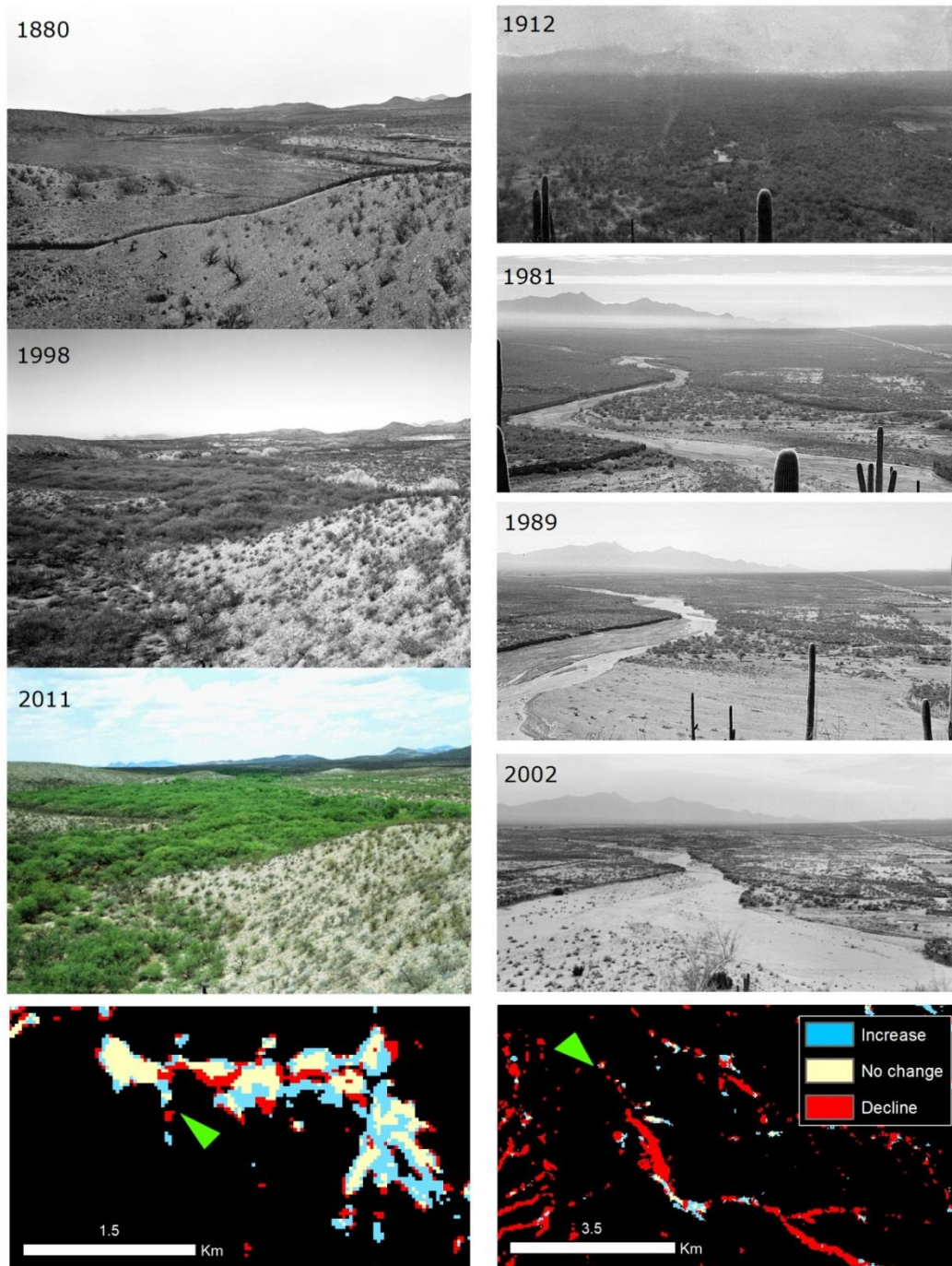


Figure 1. Repeat photographs and land-cover change maps of Cienega Creek and the Santa Cruz River with the locations and orientation of the cameras (arrow). Left: Stake 3411, Cienega Creek Natural Preserve (31.99578, -110.59408). This area was a wetland in 1880, but groundwater drawdown and likely influenced the change to a riparian forest. The area is now a county preserve and has seen very little change since 1998. Right: Stake 1057, Martinez Hill (32.10444, -110.98778). The view looking south over the Santa Cruz River shows the decline of the mesquite forest after 1912 caused by channel erosion. Signs of upland vegetation loss are apparent in the 1989 photograph, likely due to urban and agricultural groundwater uses.

## ***Natural Resources Conservation Service Assistance with Drought Preparation and Response to Ranchers.***

Kristen Egan, Natural Resource Conservation Service, Tucson, AZ

After evaluating all of NRCS' 160 conservation standards, our experts have identified 35 standards as positively reducing greenhouse gas emissions and increasing carbon sequestration. In addition to the conservation planning assistance that we have always offered, we are beginning to look at these practices and how they can assist local ranchers during drought. We also provide reporting for drought monitoring via reports to Farm Services Agency, Snow Survey and Basin Outlook Reports. A new USDA Regional Hub for Risk Adaptation and Mitigation of Climate Change was announced this week. Proposals for locations of these hubs will be forthcoming. ARS, NRCS and Land Grant Universities can coordinate to put in a competitive application to bring a hub to our area.



Kristen Egan

## ***Dealing With the Affects of Drought In Cattle Ranching***

Ian Tomlinson, Vera Earl Ranch

I'll start with the assumption that no one ranch is the same: they all react differently to drought, the drought has a different intensity on locations in southern Arizona, and each manager manages drought affects differently. There is no one correct answer that can be used as a blanket for every ranch in Southern Arizona, otherwise this process would be easy. Get Affect A, apply Plan B and everything is perfect! If only it were that easy...

The ranches we manage are diverse from one another in topography, ecological sites, grass types, and cover. The Vera Earl is predominantly rolling grasslands, with some mesquite,



and mountain oak country in the Santa Ritas. The Empire is comprised of a little bit of everything. It has rolling grasslands without much mesquite on the south end, grasslands with mesquite in the middle, Sacaton in the middle and more desert type grasslands on the north end. The Sands is rough mountainous country in the Huachuclas and flat brush country below. Although our principles are the same, we manage each a little differently, based on each ranch's unique attributes. In consideration of time, we will discuss our principles of grazing plans during drought, and not focus on the specifics of each ranch.

We are seeing less perennial grass cover on each ranch with the exception of the Sands, smaller plant size, and an increase in annual grass that is providing sufficient cover. The dirt tanks are not holding water as long or filling up like they have.

We try to stay ahead of droughts rather than reacting to them. It's not a perfect science by any means, but something we make a goal to attain. We do this by watching long-term weather forecasts, analyzing our rainfall each month, and assessing our stocking rates. Prior to each year we review the monitoring data with the Federal Agencies and determine what stocking rate will be appropriate for the winter months. Once that is determined, we will also set a time that we will cull cows in the spring if winter rains are insufficient. We usually cull cows in late April and May when we work the calves for branding. Ordinarily we will cull about 6% of our herd that ran through the winter. If the drought dictates culling more, we will do so. During the summer months, we are watching rainfall amounts and patterns and grass response and growth. We can react to less rainfall in the summer months by changing rotation, adjusting the length of time for grazing each pasture, skipping a pasture, or using more pastures and spreading the cattle out. We can also wean the calves early, cull less productive cows and put out supplement feed (we already do).

In an effort to make each ranch a little more drought resilient we have expanded the number of waters in each pasture and make a great effort to push the cattle to each water source and spread them out in each pasture. This will keep concentrated affects to a minimum, allowing us to use the entire pasture with the cattle and meet our utilization objectives. We also keep a few pastures as "grass banks" as back up or a place to go with cattle in a pinch.



Ian Tomlinson

## ***Coordinated water monitoring on the LCNCA: an update***

Amy Markstein<sup>1</sup>, BLM. **Gita Bodner**<sup>2</sup>, TNC

<sup>1</sup>Bureau of Land Management, Tucson Field office. <sup>2</sup>The Nature Conservancy in Arizona.

Cienega creek is one of a small and dwindling number of streams with perennial flow left in southern Arizona. The Bureau of Land Management began consistently monitoring surface and groundwater in the upper part of this watershed in the early 2000s; the Pima Association of Governments (PAG) has tracked waters in the lower portion of the creek since the 1990s. Several stakeholder organization and interested parties have identified water as a vulnerable resource across this area. As a result, partners are coming together to coordinate data collection, analysis and interpretation to create a cohesive picture of water dynamics in the watershed.

We began conducting annual wet-dry mapping on the BLM-managed portion of Cienega Creek and tributaries in 2006. Monthly measurements of a suite of wells across the NCA was begun in March of 2011. Prior to this, the only wells in the basin being measured on any ongoing basis were a handful of Groundwater Site Inventory (GWSI) wells tracked sporadically by the Arizona Department of Water Resources and US Geological Service. Three of the 14 deep wells in this new circuit are also GWSI wells. BLM and The Nature Conservancy installed five additional shallow streamside wells (piezometers) for a total of eight, to better track changes in the shallow waters that have the most direct influence over riparian vegetation, and enable generation of a shallow groundwater contour map. In February of 2012, the Cienega Watershed Partnership, TNC, and BLM installed six transducers to get automated measurements four times per day and provide insight into fine-scale dynamics like water use by riparian vegetation and bank recharge following high flows. In 2013, the Desert Botanical Gardens began sampling water from several shallow wells and using isotope analyses to identify major sources of groundwater recharge that appear in surface and near-surface settings and support riparian vegetation.

Extent of surface water appears to have declined substantially since fish studies in the late 1980s. The past seven years of wet-dry data shows considerable variability in flow extent but no clear pattern over this short time period. The Pima County portions of Cienega Creek have shown precipitous declines from the 1990s to present. Additional years of data for the upper creek will allow us to test for differences in trend between the sub basins. We expect some similarities based on climatic factors experienced across the watershed, and perhaps some differences based on geology and human use. For example, the upper basin has more extensive alluvial deposits that can buffer streams from short-term drought, fewer extractive wells, and more intact upper watershed conditions.

As expected, shallow wells close to the creek show variation by season, with levels rising in the winter when riparian trees stop transpiring, and hitting their lowest points for the year in the pre-monsoon dry period. With just two years of data so far, though, no inter-annual trends are apparent; more years of groundwater data should allow us to detect trends in this part of the basin and compare these with significant downward trends found in the lower basin. Deeper wells, most of which have a few sporadic measurements dating back 30-40 years, show

less consistent patterns, with some apparently declining through time, others showing no obvious trends, and some measurements possibly confounded by other factors. More in-depth analyses are pending. These measurements serve to clearly document current groundwater levels across the NCA, in shallow and deeper aquifers, near-stream and more distant locations. This preliminary data will also allow us to make water monitoring here more efficient: narrowing our selection of wells for long-term monitoring by selecting a smaller suite with the clearest signals and least noise for each area of interest, and sampling less often at wells that do not show large seasonal fluctuations. Long-term monitoring is essential to delineate trends and to document possible causes. Water levels from wells can help establish the response of the hydrologic system to climate change, as well as serving as an early warning of potential impact from human actions outside the LCNCA, thus helping to protect the freshwater resources of the LCNCA.



Gita Bodner

## ***Environmental Flow Needs and Responses in the Cienega Watershed: Current Understanding and Research Gaps***

**Kelly Mott Lacroix, Brittany Choate Xiu, and Dr. Sharon B. Megdal**

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Humans have an interconnected and dependent relationship with the environment. Nature provides recreation opportunities, economic benefits, and water supplies to sustain our communities. For example, southeastern Arizona was identified as the number one birding site in the United States in terms of economics and demographics (Kerlinger, 1993); Pima County alone generated \$258.56 million in retail sales in 2001 from hunting, fishing and non-consumptive wildlife use such as bird watching (Southwick Associates, 2002). Although human and environmental demands are not always mutually exclusive, some streams in Arizona no longer contain perennial flows because of human water uses. The interactions between human and environmental water demands are complex, and understanding the connections between them can create opportunities for water management that is mutually beneficial. The University of Arizona's Water Resources Research Center (WRRC), through its Arizona Environmental Water Needs Assessment (AzEWNA), has assembled information essential for considering environmental water demands in water management decisions and is exploring how we can use this information to include the environment in water planning. This extended abstract provides information from the AzEWNA database on the current understanding of water needs of the environment and research gaps for the Cienega Creek region.

### ***Current Understanding***

Water dependent natural resources such as fish, riparian trees and birds along Cienega Creek up to the Pantano Wash near Vail gage are currently supported by an estimated 8,819 to 9,096 acre-feet (af) per year (Water Resources Development Commission, 2011). The amount of water currently supporting the environment is calculated based on the annual baseflow of the Creek (797 af) plus the amount of evapotranspiration by riparian vegetation along the creek (8,022 to 8,299 af). To put this in perspective, over the past fifty years annual average flow at the Pantano Wash near Vail gage has ranged from 9,417 af (1966) to just 537 af (2012). Mean annual flow during this time was 4,311 af. In most years the amount of water supporting the environment exceeds the average annual flow, meaning that it is very likely that groundwater, in addition to surface water, sustains the Cienega Creek environment. This is supported by specific indication of a groundwater and surface water connection in five of the six studies in the AzEWNA database on Cienega Creek.



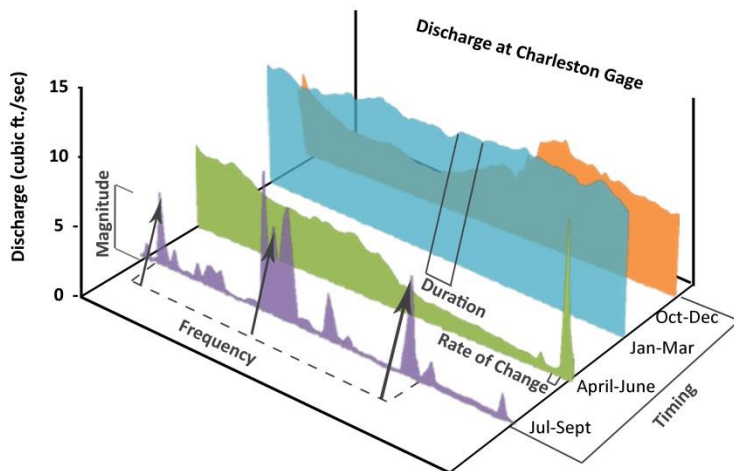


Figure 1: Elements of the Natural Flow Regime from a Seasonal Hydrograph

frequency, timing and rate of change (Figure 1). For example, seasonal flood events (e.g. timing) and flow permanence (e.g. duration and magnitude) cue important biological events, like reproduction. For example, a study of Cienega and Sonoita Creeks found an increased abundance of four bird species with increased stream permanence. The AZEWNA inventory contains six studies of environmental flow needs or flow responses for the Cienega Creek Region between 1990 and 2010. In addition to birds, these studies examined the water needs of gila topminnow (*Poeciliopsis occidentalis*), arthropods and herbaceous riparian vegetation.

### Research Gaps

When examining research gaps for a region it is important to consider three things: 1) where the studies are; 2) what was studied (single species, multiple species or ecosystem) and 3) have flow needs been quantified or described. Understanding these three aspects may help pinpoint where more research is needed, what species should be studied and what types of data are needed from those studies. The word *may* is used because any study of environmental water demand is also dependent on the goals of the regional water-using community for their riparian environments.

In the Cienega Creek region two streams have been studied for at least one reach, Cienega Creek and Sonoita Creek. Figure 2 is a map of the areas within the region that have been studied for at least one element of the natural flow regime. The studies on Sonoita Creek focused predominately on water availability (or magnitude) for birds and the studies on Cienega Creek looked at gila topminnow,

Knowing the amount of water used by the environment can be helpful; however, it does not tell us if the environment is healthy or sustainable over the long term. If we are going to incorporate the environment into planning, we must first study the water demands of ecosystems. Environmental water demand (or flow needs) refers to how much water a freshwater ecosystem needs to sustain itself. Arizona's native animals and plants are dependent on dynamic flows, which are commonly described according to five elements: magnitude, duration,

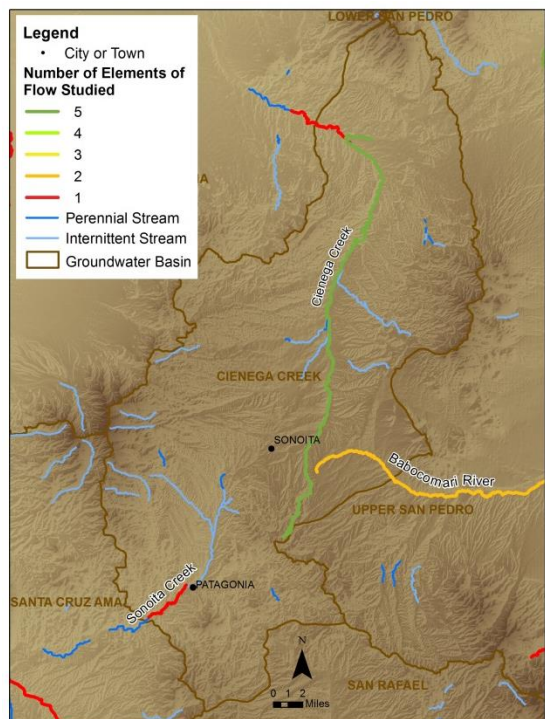


Figure 2: Studied Streams in the Cienega Creek Area

birds and the ecosystem as a whole. Based on the data in the AzEWNA inventory, all studies of the Cienega Creek region have been descriptive (e.g., surface water permanence increases the abundance of herbaceous vegetation); one study of the gila topminnow described the relationships between the fish species and all five elements of the natural flow regime.

Additional quantitative data is needed for the Cienega Creek region to properly inform local management decisions based on regional priorities (e.g. maintain or enhance the birding industry or preserve flows necessary for the Gila top minnow). The AzEWNA inventory is still evolving and does not necessarily contain all information available in the region. Additional studies in the region on environmental water demands or monitoring efforts could be instructive in identifying a link between changing groundwater levels or streamflow and the health, reproduction, diversity or abundance of the species present. Furthermore, information from adjacent basins (such as the Santa Cruz or San Pedro) where water needs of the environment have been more frequently studied could be used to inform planning and management in the Cienega Creek region.

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## ***Cooperating Across Large Landscapes to Inform Water and Ecosystem Management in Response to Climate Change and Other Stressors***

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The Desert Landscape Conservation Cooperative (LCC) is an applied science and conservation partnership supporting the strategic, science-based conservation of natural and cultural resources in the Mojave, Sonoran, and Chihuahuan deserts in the U.S. and Mexico and the montane "sky islands" within this region (see [www.usbr.gov/dlcc](http://www.usbr.gov/dlcc) for a map of the Desert LCC geographic area). The Desert LCC develops and delivers science and decision support tools that directly inform conservation design and help resource managers address landscape-scale stressors. The partnership is currently focused on six Critical Management Questions related to priority science needs identified in the Desert LCC Comprehensive Science Needs Assessment that are of immediate relevance to conservation partnerships and programs.

The Desert LCC is developing interdisciplinary, multi-organizational teams to engage managers and experts from various sectors of the conservation community in assessing and addressing each Critical Management Question. Developing these "applied science think tanks" increases the capacity needed for integrated problem-solving that addresses landscape-scale stressors, such as climate change. These focused efforts will produce information and decision support tools that resource managers need. Team members develop the relationships, processes, systems, and capacity to successfully fulfill the Desert LCC's niche within the conservation community. These teams are working together to:

- assess and understand needs related to the Critical Management Questions;
- develop and support opportunities to collaborate on new applied science research;
- develop and advance new science products and decision support tools; and
- inform and communicate with a broad group of managers and experts throughout this process.

One of the Critical Management Questions we are focusing on relates to water management and climate change, specifically: How are climate change and water management interacting to affect the physical processes that support springs, aquatic and riparian habitats, species, and human cultures? What are viable management options to mitigate these effects and support ecosystem functions? How can the use of climate change, hydrological, ecological, and/or biological models be integrated to better understand the potential future effects of climate change, inform adaptive management and development of best management practices for aquatic and riparian ecosystems, and create related decision support tools?



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