

Scenarios for Upper Gila River Watershed

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The University of Arizona Water Resources Research Center (WRRC) promotes understanding of critical state and regional water management and policy issues through research, community outreach and public education.



The Water Research and Planning Innovations for Dryland Systems (Water RAPIDS) program at the WRRC specializes in assisting Arizona communities with their water and natural resources planning needs. Our goal is to help communities balance securing future water supplies for residential, commercial, industrial, and agricultural demands with water needs of the natural environment.



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Introduction

It is always wise to look ahead, but difficult to look further than you can see.

- Winston Churchill

Certainty about the future is impossible. This does not mean that we should forgo thinking about what might happen in the future completely. On the contrary, thinking systematically and creatively about an uncertain future helps us illuminate options for action and make better decisions now. Thinking about the future is never straight-forward, especially when trying to incorporate differing values, ideas, and opinions about something so unknown and vast. Scenario planning is one tool that can be used to help us explore what might happen in the future as a way to make more informed decisions today. Building scenarios is not an attempt to predict what the future will bring, but is instead an acceptance of uncertainty, and a way to prepare for the wide range of events that may come to pass. Thinking about the future before it arrives can help us make decisions today that will perform better over time by: 1) providing insight into the forces that shape the system; 2) revealing implications of following the status quo; 3) exploring possible futures; and 4) illuminating options for action. Most often, scenarios are firmly secured on an understanding of the past circumstances and how systems got to where they are, in order to gain context for where they are going.

From the start, the process of scenario planning in the Upper Gila Watershed has been approached from the perspective that “you must know where you’ve been to know where you’re going.” To help us think about the future, we worked with the Gila Watershed Partnership and the Watershed Restoration and Planning Steering Committee to compile the *Atlas of the Upper Gila River Watershed*, which examines the region’s natural, water, and cultural resources.¹ Published in January of 2014, the Atlas is the foundation upon which this scenario planning process was built. Along with having a firm basis in the past and present, the scenarios presented here are the product of a stakeholder-driven process that emphasized understanding what people were most concerned about for the future of the Upper Gila Watershed. To create these scenarios the WRRC first interviewed select members of the Upper Gila Watershed community about what drives change in the watershed.

We used these interviews to build a draft list of driving forces of change that were then reviewed and refined at a full-day scenario planning workshop and a separate meeting with



farmers and ranchers in the Watershed. At the workshop, participants created a problem statement, identified and ranked driving forces of change and discussed the most critical uncertainties for the future of the watershed. The WRRC then took the drivers and uncertainties and created scenario frameworks and the scenario narratives presented here. To determine the frameworks and write the narratives we provided an online survey and conducted additional one-on-one interviews. Participation and review from the Watershed Restoration and Planning Steering Committee throughout this process has been invaluable.

The problem statement was determined by participants at the scenario planning workshop is as follows:

In the face of uncertain physically and legally available water supplies, how do we:

- ***Provide reliable long-term water supplies for a resilient community,***
- ***Preserve the rural, agricultural lifestyle, and***
- ***Sustain and enhance the health of the Upper Gila River Watershed?***

The four scenarios presented here span the next 30 years, and demonstrate how the key drivers of change in the watershed are influenced and changed by the major uncertainties. These major uncertainties are the overarching themes for the four scenarios and include: New Mexico's decision to divert water from the Gila and San Francisco Rivers; the tamarisk beetle; local versus federal control of the watershed; and fluctuation in cotton prices. The scenarios are written as stories to help the community think about what the future might look like and weave together information from interviews with people from the watershed and research on impacts to the watershed by elements such as tamarisk defoliation or prolonged drought. It is also important to note that while the future is full of many possibilities, these scenarios focus on likely and high-risk events that require extensive planning. For example, a return to average annual rainfall in the future is possible, but years of normal rainfall do not require the same amount of preparation as responding to prolonged drought. Increased precipitation within normal ranges, is therefore not emphasized as strongly in this report, drought and intense storms that would cause flooding are discussed. Thinking about a future with extended droughts and intermittent flooding can be intimidating. It is important to remember that *scenarios are not necessarily ideal visions of the future, we must try to use them to understand what we would like to see happen as well as what we would not like to see happen.*



Major Drivers

To give fuller meaning to the scenario narratives presented in this report, the major drivers of change and their general role within the watershed are first described individually. These driving forces were selected based on their significant ability to influence the future of the watershed, as agreed upon by stakeholders during interviews and meetings. In the formulation of each scenario narrative, the possible interactions of these drivers were considered in concert with the events of the scenario to understand more fully the impact they might have on the watershed in the future. Listed below are the major drivers explored in this section:

- Informed Populace
- Cooperation
- Fire
- Infrastructure
- Drought
- Intense Storms
- Population Growth
- Fluctuating Copper Prices
- Federal Involvement
- Physical Water Supply Availability
- Legal Availability of Water Supply
- Commodification of Water

Informed Populace

Throughout the world, water shortages are regarded as the biggest resource threat for societies.² Since the Organization for Economic Co-operation and Development (OECD) made that assertion in 1998, the world has continued its rapid population growth, which places greater pressures upon limited freshwater supplies, especially in arid lands. Historically, communities with limited access to freshwater supplies adjust their lifestyle to match water scarcity or they generate enough money to afford the infrastructure and technology to maximize water resources.³ Human adaptations in the arid Southwest have been built upon a complex web of water policies and engineered infrastructure to manage limited water supplies that make widespread, stationary settlement possible.⁴ These human adaptations also allow a disconnect to form between people and their environments.

In the United States, the USGS estimates that each person uses roughly between 80 to 100 gallons per capita per day, and the typical household uses approximately 260 gallons of water per day at home.^{6,7} In Arizona, outdoor water use accounts for 58% of residential water use – 80-90% dependent on landscaping practices, according to the Arizona Department of Water Resources (ADWR). Water consumption varies by community based on general awareness about water processes and issues. Public awareness can be impacted by a number of variables, such as educational programs, public policies, conservation incentives, visibility of the issue, culture and values, and socio-economic levels. Signals of an informed populace, specific to water conservation, might include:

- Water-efficient appliances and fixtures (toilets, faucets, shower heads, appliances, hot water systems)
- Landscaping (choose natives, reduce turf, xeriscape) and irrigation practices (“less is more”, use alternative sources of water, make every drop count)

- Managing stormwater (methods to slow run-off, capture rainwater, reduce fertilizer and pesticide use)
- Understanding of connection between water use and energy
- New homes that incorporate “WaterSense” principles as laid out by the EPA

Cooperation

Resolving water issues on a regional scale involves cooperation and collaboration across jurisdictions and organizations. Finding common ground is often a prerequisite to developing an understanding between groups of different backgrounds or affiliations who are beginning collaborative efforts. Because “collaborative problem solving facilitates resolution of inter-related issues that previously seemed too complex for one organization to resolve alone,”⁸ developing a common understanding among diverse sets of interests can be vital to success in tackling complicated water problems. For instance, riparian scientists working in partnership with land managers have a greater chance of success if they evaluate applications of management practices together in order to tailor practices to the system needs and retain the accomplishments achieved.⁹ Another example is public-private cooperation; FEMA has encouraged emergency planners to take a broader view of disaster response by including the private sector and initiate public-private partnerships for disaster relief. The idea is that forming partnerships to secure common goals will help restoration, public outreach, and other aspects of recovery that would be more time-consuming and less effective if entities tackled the problems on their own. Barriers to these partnerships can be complex and often lodged in tradition or habit, but often are attributed to the variables of cultural conflict, diverse values, histories of antagonism, and widespread examples of NIMBY sentiments (“Not In My BackYard”). Players that hold a stake in the Upper Gila Watershed, and could have common goals traced between them for collaborative purposes, might include:

- City and Town governments
- Federal agencies
- Tribes
- Cattle growers
- Farmers
- Universities
- Environmental advocacy groups
- Non-profit organizations
- Gila Valley Irrigation Districts
- Mining Companies
- Utilities
- Religious organizations
- Media sources

Fire

Fire has been an integral part of the Watershed for millennia, although its role has been significantly altered by one hundred years of fire suppression efforts by land managers across the Western United States.^{10 11} Fire, particularly in the upland forested areas, functioned as a mechanism for maintaining ecosystem health in a fire-adapted landscape. The removal of fire for such a long period of time has caused a substantial change in the composition of these forests. The absence of relatively frequent, low-intensity fires has led to the accumulation of a high level of combustible biomass in these areas. As a result, these regions are

exposed to an increased risk of catastrophic fires that are very difficult to extinguish and can rapidly engulf very large areas, especially in comparison with average fire sizes of only twenty years ago. Recent large fires in the last decade in the Upper Gila River Watershed include the Nuttall Complex, Horseshoe I, Horseshoe II, Wallow, and the Whitewater-Baldy Complex.¹² Large fires are most common in areas of highest relative precipitation in the watershed, since the moisture that supports plant growth in turn generates additional potential fuel for fires. Including these large fires, there have been 58 fires alone on US Forest Service lands in the watershed since 2001. The distribution of sizes is as follows: 1 class-C (10-99.9 acres), 17 class-D (100-299.9 acres), 14 class-E (300-999.9 acres), 13 class-F (1000-4999.9 acres), and 13 class-G (5000+ acres).¹³

While the scale of riparian fires is very different, such fires can have direct and immediate impacts on water quality. The accumulation of combustible materials, such as leaf litter and dead vegetation following a major disturbance such as an infestation, combined with low water levels and hot, dry conditions can result in substantial fires. While vegetation removal can lead to temporary increased surface flows due to less transpiration, evaporation rates can increase from the loss of shade-cover. New plants, sometimes not the same species as those removed by the fire, will grow to fill the niche. A fire-denuded riparian buffer is also subject to greater erosion.

Fire risk can be exacerbated by the interplay of other drivers in the watershed. Extended drought will result in critical water-stress on plants, with large areas of dead or dying vegetation. Land management practices, such as forest thinning, can lessen the risk of large fires. Such efforts are particularly resource and time-intensive, however, and these efforts are complicated by a patchwork of public and private land ownership as well as the often challenging terrain in the basin.

The many possible consequences of fires are dependent in large part on the severity of the burn. After most fires, there is some loss of tree canopy and a decrease in water losses from transpiration since fewer plants are present to uptake water. Overall, however, there is usually a decrease in the retention of precipitation-sourced water in the watershed. Evaporation losses and runoff rates increase. After high severity fires in particular, where scorched soils can develop hydrophobic (water-repellent) qualities, runoff can increase substantially. This contributes to flooding and higher erosion rates as well, which in turn negatively impacts water quality in streams and rivers from the high sediment loads.¹⁴



Highway 191 south of Alpine on the 5th day of the Wallow Fire, which burned over 500,000 acres, including almost 200,000 acres in the Watershed. Photo Courtesy of the White Mountain Independent

Infrastructure

An estimated 70% of the population of the Upper Gila Watershed lives within five miles of the Upper Gila or the San Francisco rivers. With the exception of Peridot and San Carlos, the larg-

est municipalities are all located along these two rivers. The region's settlement from the mid-1800s onward was concentrated along these corridors in order to take advantage of the water for human uses, particularly for agriculture and mining. Infrastructure similarly is closely associated with the river. Public and private actors are responsible for a variety of infrastructure in the region, from irrigation ditches and diversion dams to roads and bridges. Much of the costs associated with maintaining the public infrastructure is carried by local governments, with some assistance from state and federal entities. In recent years, there has been a marked decrease in the amount of funds made available by these other levels of government. As a result, an increasing amount of the burden of maintaining this infrastructure falls on county and city/town governments. In addition, compliance costs regarding certain state or federal regulations (such as the National Historic Preservation Act, the National Environmental Planning Act, or the Endangered Species Act) increases the expenses born by governmental entities.

Major disasters, such as floods, can seriously degrade or destroy much of this infrastructure. During the "wet period" of the 1980s and early 1990s, a series of floods caused tremendous amounts of damage to infrastructure in the valley. Federal disaster relief programs made some funds available for the repair or reconstruction of affected areas. These federal programs often added restrictions regarding the type of construction that could be funded, with the result that some potential upgrades to infrastructure were not permitted.¹⁵

Drought

Severe and extended droughts are inevitable and part of natural climate cycles. Drought can be difficult to describe and measure because of its diverse geographical and temporal distribution across a country as vast as the United States, but the common aspect of all droughts is the same – a deficiency of precipitation. A region can experience long-term weather patterns that produce drought, but have short-term changes in the overall pattern that result in short-term wet spells. Using tree ring science, it is known that the Southwest region has experienced "mega" droughts that have lasted for over 50 years.¹⁶ While Arizona streams are under drought conditions for 60 to 80% of the time, prolonged and severe bouts of drought are capable of significantly altering flow patterns and hydrologic connectivity in dryland streams, with dire consequences for endangered species of fish. An increased number of "zero-flow" days - or the number of days that any given section of the river will dry up each year - combined with human impacts will put more pressure on a fish species' ability to survive in coming years.¹⁷ The current drought also makes native species of vegetation in the Southwest vulnerable to certain negative impacts: increased susceptibility to disease, reductions in plant primary production and water use, mortality of immature plants and eventually mature plants, and susceptibility to invasion of non-native species. There is also an associated higher demand for water in areas of limited water supply that increase with the severity of drought.¹⁸



San Carlos Reservoir during drought. Photo courtesy of Arizona Republic.

In regions that have weathered extensive, multi-decade drought conditions, resulting economic losses to agriculture, ranching, industry, and other sectors are common. Most recently, Tom Vilsack, the secretary of USDA, declared all of Arizona’s counties as disaster areas due to drought as of March, 2014. This disaster designation makes farmers and ranchers in both primary and contiguous areas eligible to be considered for federal, low-interest emergency loans and other forms of assistance.¹⁹ Furthermore, media coverage throughout the United States depicting a situation in which “The Future is Drying Up” could have negative consequences for attracting large businesses that could stimulate economic benefits.^{20 21} The Drought Interagency Coordinating Group meets biannually and makes recommendations to the governor about drought declarations. ADWR uses the following categories to define Watershed Drought Levels with associated impacts:²²

Trigger Levels (based on precipitation & streamflow percentiles)	Drought Status	Possible impacts
>30	Normal Conditions	
21-30	Abnormally Dry	Measurable reduction in precipitation Stress to seasonal grasses Stock pond storage somewhat reduced
11-20	Moderate Drought	Noticeable reduction in precipitation Some vegetation stress; depending on season, could result in major stress Stock pond storage reduced Reduced streamflows Lower than average reservoir levels
6-10	Severe Drought	Long-term reduction in precipitation Low snowpack Reduction in reservoir levels Vegetation stress affecting trees and shrubs Habitat and pasture degradation Reduced stream- and spring- flows
2-5	Extreme Drought	Multi-year precipitation deficits (including snowpack) Noticeable reduction in reservoir levels Measurable reduction in groundwater levels Near-record low streamflows Considerable stress on trees and rangeland degradation Diminished wildlife populations
1-2	Exceptional Drought	Significant multi-year precipitation deficits (including snowpack) Significant reduction in reservoir levels Drastic reduction in groundwater levels Record low streamflows Major stress on trees, rangeland degradation, diminished wildlife habitat and population mortality

Storm Intensity

Between 1921 and 2009, there have been 45 tropical cyclones that have impacted Arizona – 20 of which occurred between 1989 and 2009.²³ If global weather patterns continue, a higher frequency of extreme precipitation events are expected during the summer months with more extreme fall precipitation events.²³ Another possible impact of climate trends include more frequent 100-year floods, which have a one percent probability of occurring once every year, sometimes striking in consecutive years.²⁵ Areas with development in the floodplains are at a greater risk than those that do not.



1983 flood damage in Clifton. Photo courtesy of Arizona Daily Star

Fall and winter storms usually affect rivers and larger streams and wet winters can bring large amounts of precipitation. These storms have been known to cause catastrophic floods, which are brought on by several days of intense regional rainfall, sometimes combined with snowmelt. High flow that is maintained for several days can cause major erosion damage as a river can move hundreds of feet laterally, undercutting building and irrigation works and destroying bridge foundations and pipelines. Regional floods generally happen between September and March in drainage basins larger than 200 square miles, such as the Upper Gila Watershed.²⁶

On the other hand, summer storms usually affect smaller washes and are caused by intense surface heating that results in moisture being drawn into Arizona from the Pacific Ocean and Gulf of Mexico. Characteristics of intense summer storms include:

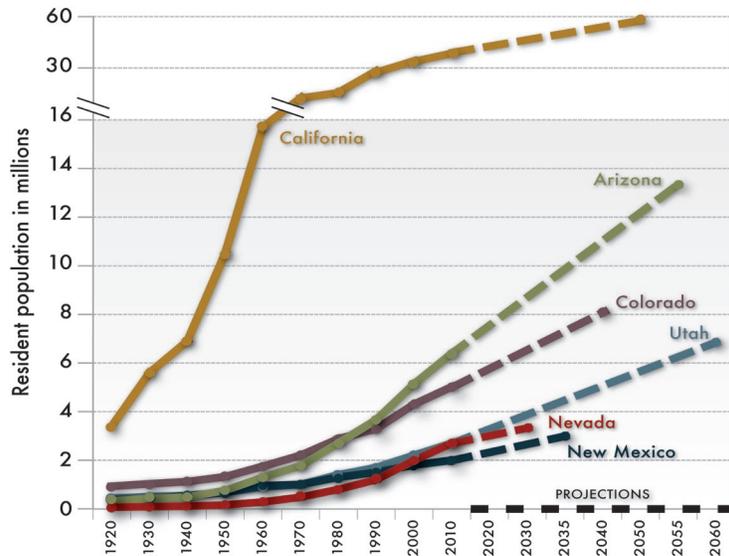
- Thunderstorms
- Highly localized
- Develop quickly
- Generate intense wind and lightning
- Three inches or more of rainfall in an hour over small areas
- Flash floods that travel many miles

Population Growth

The Upper Gila Watershed contains portions of six different Arizona counties, although Graham (37,220 residents) and Greenlee (8,437 residents) counties account for most of the watershed in terms of geographic extent and population. The region experienced mixed changes in population from 2000 to 2010, with 11% growth in Graham County, but a -1.3% change in Greenlee County. A recent increase in employment at the Morenci mine has led to a projected 7.3% increase in population in Greenlee County since 2010.

Other watershed economic activities, such as farming and ranching, appear to have relatively small impacts on population changes in recent years. These two areas are notable for their multi-generational aspects, in that most farmers and ranchers are part of family opera-

Scenarios for the Upper Gila River Watershed

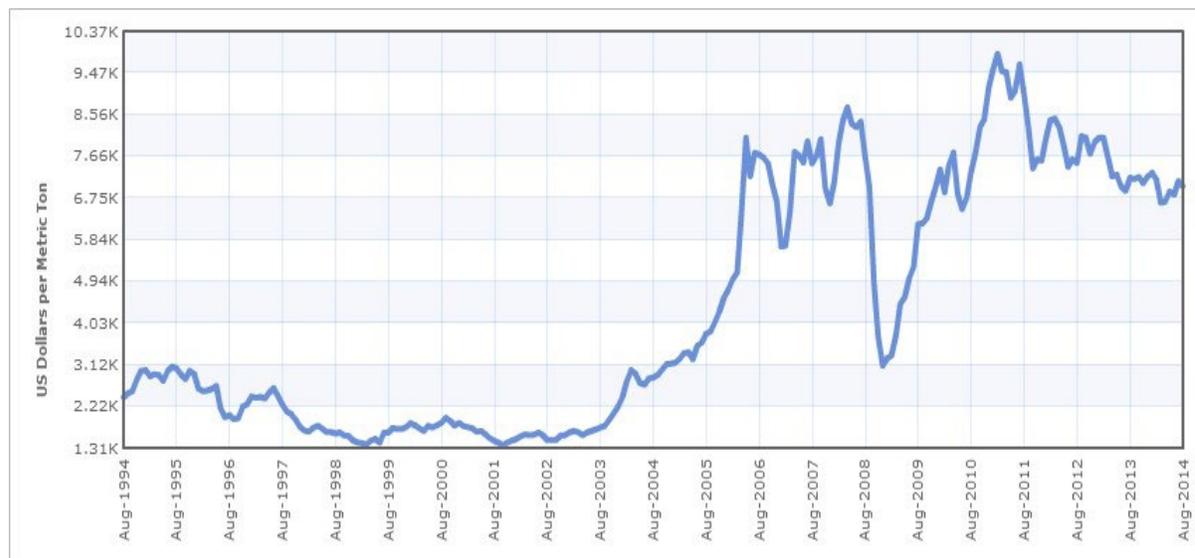


Historical and projected population growth in the Southwestern United States (Source: Southwest Climate Change Assessment Report, 2013)

tions with deep roots in the area. Mining, however, is subject to substantial fluctuations in international commodity markets for copper, and these shifts can result in major additional investments in mining operations (and increases in employment) in both counties. Mine employees are much more likely to relocate to the watershed from elsewhere, and also may leave upon reaching retirement or when work opportunities in mining end. Clifton has investigated options for increases in housing to address the recent short-term spike in new residents working for the mine, as well as to prepare for possible mine retirees who must leave the company housing in Morenci upon retirement. Seasonal shifts in population can be difficult to estimate. The snowbird effect appears to be less in the Upper Gila Watershed than in other somewhat comparable rural watersheds, such as the Verde and the San Pedro. Mining is therefore the activity most likely to have a notable impact on shifts in population levels in the region over the short- to medium-term.

Fluctuations in Copper Prices

Fluctuations in copper prices have historically had significant impacts on the regional economy of the Upper Gila River Watershed. Significant mining operations in the Morenci area began in the 1870s, and led to substantial capital investments, including the construction of the first railroad in Arizona. Slumps in copper prices have occurred during periods of slackened demand in national and international copper prices, such as during the Great Depression of the 1930s as well as during the 1980s. Alternately, increases in demand for copper



Fluctuation in international copper prices, 1994-2014 (Source: World Bank)

have led to a surge in mining activity, such as during World War II (1940s) as well as in recent years into the 2010s with the opening of the new Safford mine by Freeport-McMoRan.

Growth in mining activity promotes mine investments that spill over into the local economy. The type of investments have changed over time, however, as mining has become more technology and capital intensive. The size of the mining labor force in relation to the amount of mining activity has decreased as new machinery has been brought online. Even so, the current boom in mining has led to a population surge in several places in the valley, including Clifton and Safford. Hotel occupancy rates have remained high as mine workers fill empty rooms. Because of the somewhat temporary nature of substantial number of mining positions, however, and the skewing of the labor force to young, unmarried workers, there are particularized demands on the local housing market and on government services (such as public schools). Some housing is provided by the mining company, such as in Morenci, but this housing is available only to active employees of the mine (and families, if any). Municipalities such as Clifton are investigating ways of providing housing for miners who choose to live off-site or would like to retire and remain in the Upper Gila Watershed.

Federal Involvement (Funding and Oversight)

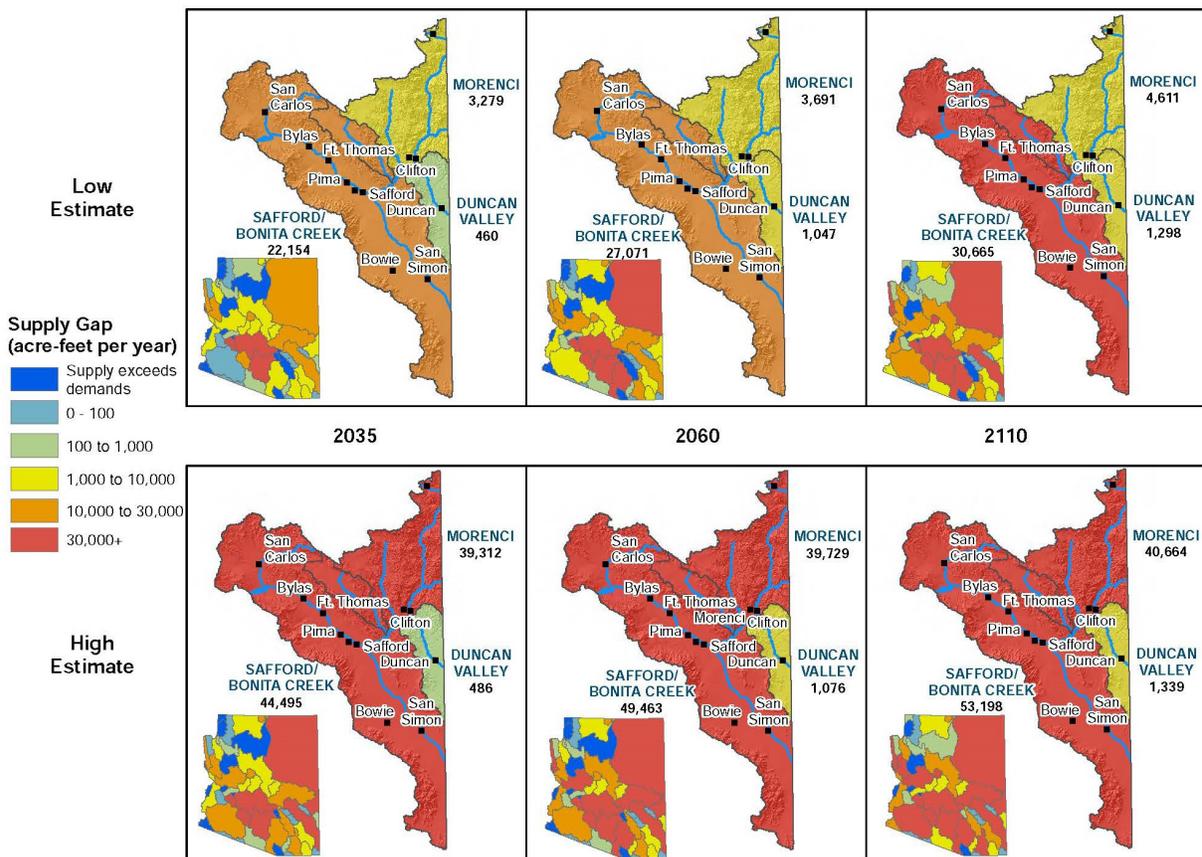
The federal government is a major stakeholder in the Upper Gila River Watershed. The majority of the lands in the watershed fall under federal ownership and management through a variety of agencies and departments, including the US Forest Service, the Bureau of Land Management, the US Bureau of Prisons, National Park Service, and the Bureau of Reclamation, among others. Federal reserved rights, such as for the Gila Box Riparian National Recreation Area and the San Carlos Apache Reservation, make the federal government a major actor in water management in the valley. Under federal Indian law, the US government's Bureau of Indian Affairs is also involved in land and water management issues affecting recognized Indian tribes in the valley, such as the San Carlos Apache, as well as others further downstream, such as the Gila River Indian Community. Finally, a variety of laws relating to environmental protection, water quality, and wildlife necessarily involve federal funding and oversight.

Federal actions can have significant impacts on the regional economy. The allocation and restrictions placed on grazing allotments impact the ranching community. Ongoing negotiations in water rights through the adjudication process may impact water users, such as farmers and municipalities, although the Arizona Water Settlements Act of 2004 already serves to guide the exercise of water rights at present. Forest management policies affect timber sales, logging jobs, and recreational opportunities. Forestry management is also related to water quantity and quality through its impacts on watershed planning, percolation of runoff, and mitigation of catastrophic fire risk. Enforcement of federal laws like the Clean Water Act (CWA) and the Endangered Species Act (ESA) can have major effects on the actions of private landowners and local government operations. The listing of new species as endangered or threatened can create new requirements for how land and water is managed in the region. Riparian habitat serves as a useful illustration in the ways that different goals and objectives regarding resource stewardship can overlap. The increase in density of exotic/introduced species, such as tamarisk, can negatively impact native vegetation and wildlife; however, the exotic plants can also partially fill certain niches in the local ecosystem in ways that benefit other endangered or threatened species of concern (e.g., Southwestern Willow Flycatcher). Such unanticipated developments can complicate management plans and create competing objectives across agencies.

Water Supply Availability (Groundwater and Surface Water)

Surface water supplies in the watershed are heavily dependent on precipitation. The bimodal precipitation regime in this semi-arid region results in the concentration of snowfall and rainfall into winter and summer monsoon periods, with long intermediate periods of dryness. Surface flows in the Gila River are strongly tied to snow melt in higher elevations, such as in the headwaters in neighboring New Mexico. The prolonged drought conditions, combined with the predictions of climate change, contribute to ever decreasing flows. Warmer temperatures earlier in the year result in more rapid snow melt and decreased flows during the summer months, when downstream irrigators are most in need of water. Higher temperatures also increase evapotranspiration rates, causing increased loss of soil moisture and greater stress on crops and native vegetation alike.

Various aquifers underlie the basin, each with differing water quality attributes. Salts and total dissolved solid concentrations can differ substantially, and affect the intended uses of the groundwater. The City of Safford currently draws some of its drinking water from an aquifer, and the quality of the water is such that minimal treatment is needed at present. Decreasing groundwater levels have forced several municipal wells to go off-line on a regular basis. While water is available from a deeper aquifer, the poorer water quality would require higher levels of treatment, at a notably higher cost than under current practices. Further, extended drought conditions results in minimal surface flows in the Gila River itself, with the result that farmers turn to groundwater supplies for crop irrigation. Heavy use of water for such purposes can result in further decreasing groundwater levels, which then can lead to higher



Source: WRDC Water Supply and Demand Working Group Report 2011.
 Water supply gap calculated as: Supply Gap = (Projected Future Demand - Currently Available and Adjusted Supply)



Estimates of gap between water supply and demand in the Upper Gila Watershed

costs for well users (e.g., drilling new wells, higher fuel costs) as well as related problems, such as subsidence.

Legal Availability of the Water Supply

Aside from the hydrologic cycle, the legal mechanisms governing water availability and access play a critical role in the economy of the Upper Gila River Watershed. Arizona has a bifurcated system of laws such that groundwater and surface water are regulated under separate regimes.²⁷ Under the prior appropriation doctrine, surface rights are privileged based on seniority. The older the original claim, the more senior its status. In times of low flow, the water rights of senior appropriators are met first, even when such appropriators are located downstream. Groundwater is governed under a reasonable use standard. While the State of Arizona passed a Groundwater Management Act in 1980, no Active Management Area or Irrigation Non-Expansion Area was created within the Upper Gila River Watershed, so the restrictions applicable in certain other parts of the state do not affect water users in this region.²⁸

The surface waters of the Gila River have been over-appropriated for over 100 years. A series of legal actions have occurred in the intervening time period in attempts to clarify water rights and address historically contested claims. The Office of the Gila Water Commissioner oversees the adjudication process, begun in the 1970s, which built upon the earlier Globe Decree. Thousands of claims are under consideration, and final adjudication is likely a decade or more away. The Arizona Water Settlements Act (AWSA) of 2004 was a federal legislative effort to bring additional clarity and certainty to the region's water rights, in part through the use of water from the Central Arizona Project canal to help in satisfying water claims on the part of the Gila River Indian Community downstream.²⁹ The current allotment under AWSA limits farmers within the statutorily defined area (a subregion within the watershed) to six AF/yr. A variety of monitoring tools are used to ensure compliance on the part of farmers, municipalities, and other affected water users. These limitations affect the users' total water budget, and are applicable both to surface water and groundwater use.

As part of the AWSA, the State of New Mexico has the option of availing itself of federal funds to assist in the development of water rights in its part of the Upper Gila River Watershed – upstream of the Arizona section. These rights, potentially totaling 14,000 AF/year, would only be exercisable during years of excess flow in the Gila.³⁰ Existing claims in Arizona would need to be satisfied prior to New Mexico's use of its potential water rights. Federal funds could be used to support in-stream uses or the development of infrastructure for diversion dams and off-stream reservoir storage. Under the AWSA, New Mexico will be required to declare its intent to exercise these rights by the end of 2014. Construction of infrastructure, if any, would take several additional years before any such system would be fully operational. The continuation of current drought conditions in the basin would result in no available water for use by New Mexico.

Commodification of Water

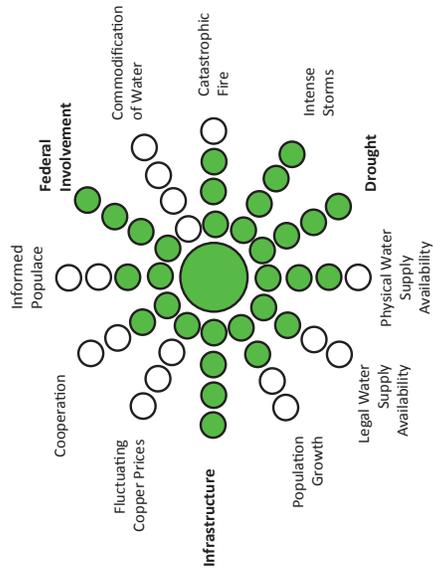
As Fortune Magazine stated at the start of this century, "water promises to be to the 21st century what oil was to the 20th century: the precious commodity that determines the wealth of nations."³¹ Perhaps the largest stance that statement makes is defining water as a commodity in the first place, which has not historically been the case in the United States. Simply stated, the commodification of water is the process by which water is transformed from a "public good" into a tradable commodity, or an economic good. Water is generally not sold

at market prices for a few different reasons, including a wide-held belief that something as important for sustaining life should not be controlled by wealthy private interests, bought and sold at market-clearing prices to the highest bidders, regardless of their ties to a community or watershed. This idea is so embedded in the fiber of our country that providing clean running water is usually a basic function of local government and is subject to federal oversight regarding water quality. However, the commodification of water is not a new phenomenon, especially outside of the U.S. Some economic and social researchers hold the view that commodification of water would assign an economic value to the scarce resource, which could prevent its misuse as well as provide more financial backing to maintain and make greater improvements to the water infrastructure and systems already in place.

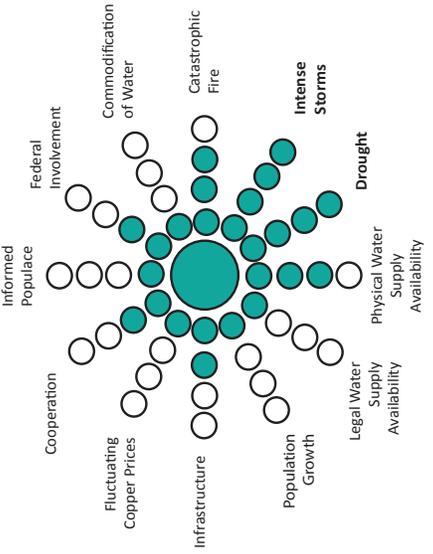
While these discussions have occurred to some degree in other Western states, such a commodification of water is very unlikely in Arizona for the foreseeable future. Given the complexities of state water law, efforts to make market-based transfers of large quantities of water across large distances would face several challenging hurdles.³² Surface water and groundwater are subject to differing treatment under Arizona state law. With very limited exceptions, transfers of groundwater from one basin to another are currently expressly prohibited by state law. Surface water transfers are complicated as well by issues like ongoing adjudication proceedings, water settlement acts passed by Congress in relation to federal reserved rights for Indian Tribes, and the treatment of return flows. Rivers crossing state lines are likely subject to the requirements of existing interstate compacts and/or court decrees. Further, large municipalities downstream of the Safford Valley have already made major investments in firming their future water supplies by securing as-yet untapped water reserves. For example, the cities in the Phoenix metropolitan area began in the 1980s to acquire farms with transfer-eligible water supplies in the areas like the Harquahala groundwater basin or like Scottsdale's acquisition of Planet Ranch in the Bill Williams groundwater basin, and, while these water farms have sometimes been resold, they became investments for cities like Scottsdale and Phoenix in firming their long-term water supplies.^{33 34 35} In short, there is little likelihood that the state laws and numerous other obstacles to transfers of water from the Upper Gila to water users downstream will be amended or otherwise surmounted within the time span of this scenario planning exercise through 2045.

Major Drivers and the Scenarios

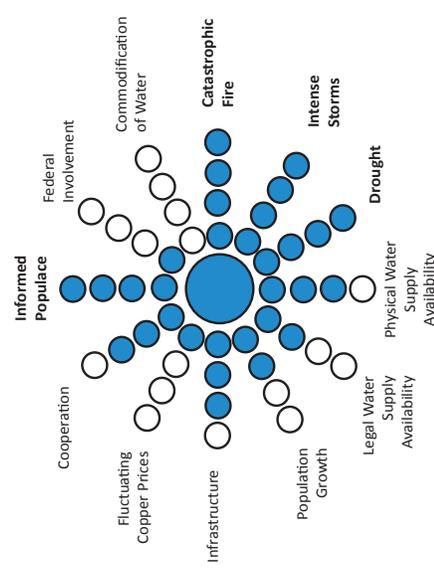
Each of the drivers discussed here plays a role in the four scenarios. The following figure provides a quick look at the importance of each driver for each scenario or sub-scenario. Drivers that are relatively important in all scenarios, e.g., drought, indicate important subjects to discuss further and plan for during the next phase of this project. The degree of driver relevance for these scenarios was determined by a review of the scientific literature and feedback from a variety of stakeholders. Some drivers have far-reaching impacts among the scenarios while other drivers are more specific to certain scenarios.



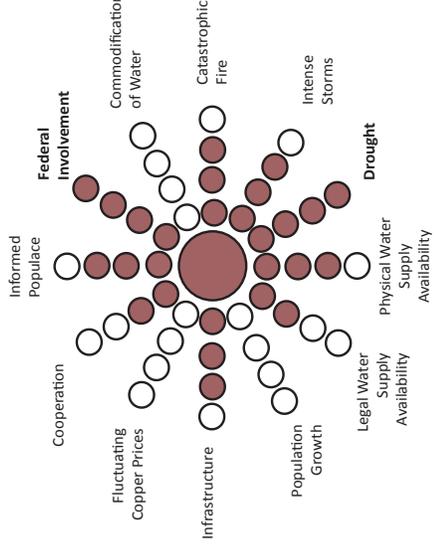
Scenario 1(a): New Mexico Diverts



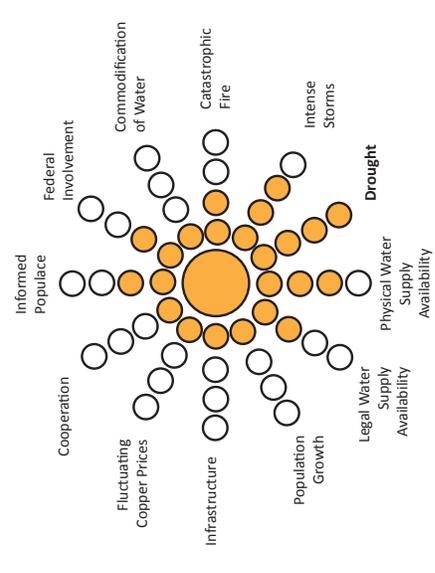
Scenario 1(b): New Mexico Conserves



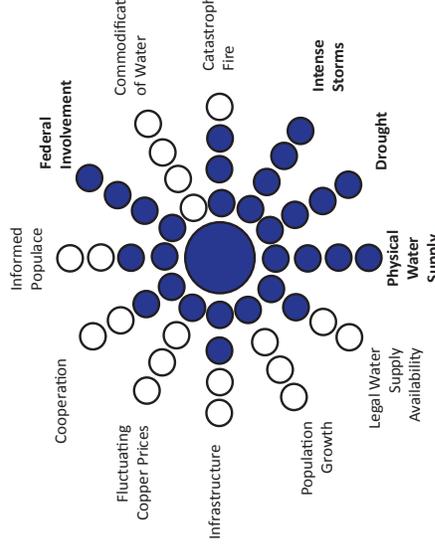
Scenario 3(a): Increasing Local Control



Scenario 3(b): Increasing Federal Control

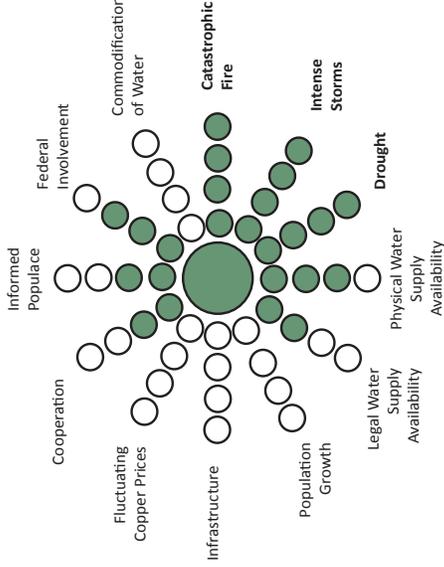


Scenario 4(b): High Cotton



Scenario 4(a): Low Cotton

Scenario 2: Impacts from the Tamarisk Leaf Beetle



Graphic display of the importance of the 12 drivers in each of the scenarios. Drivers that are most important are indicated with 4 filled circles. The only driver that is critical to all scenarios is drought. Other commonly important drivers include intense storms and federal involvement in the watershed.

SCENARIO 1 – To Divert or Not to Divert: The Fate of New Mexico’s CAP Allotment

In 1968 the Secretary of the Interior was authorized by the Colorado River Project Act to provide New Mexico with additional water from the Gila system, but only if the Secretary can assure that main-stem Gila River water users in Arizona suffer no economic injury or cost. (Colorado Basin Project Act of 1968, §§304(d) & (f)) The mechanism to make this exchange was created almost 40 years later through the Arizona Water Settlements Act (AWSA). The AWSA gave New Mexico the opportunity to build a diversion to use up to 14,000 acre-feet of surface or groundwater from the Gila River system, but New Mexico must protect downstream water users by paying to exchange that water for Central Arizona Project water in Arizona. Among other requirements, and in addition to paying for the CAP exchange, water diverted in New Mexico cannot exceed 64,000 acre-feet in any one year, combined diversions from the Gila and San Francisco River may not exceed 350 cubic feet per second at any time, and water can only be diverted when 30,000 acre-feet or more of water is in storage in the San Carlos Reservoir.³⁶

Average amount in storage on May 1st in the San Carlos Reservoir between 1980 and 2008 was 440,000 acre-feet and during this time the lowest recorded storage was 32,346 acre-feet in 2004 (ADWR 2010). On January 1, 2012 stored water in the San Carlos Reservoir amounted to 14,241 acre-feet or 0.501% of capacity (Gila River Water Commissioner, 2012). Average daily discharge at the Gila River at Duncan gage between 2004 and 2014 ranged from 3.2 cfs to 3,030 cfs with a maximum daily mean of 25,800 cfs and a minimum daily mean of 0 cfs mean during this time period.

Why is it uncertain?

The AWSA authorized \$66 million dollars, provided over 10 years beginning in 2012, to meet water demands of the southwestern portion of the state through conservation. If New Mexico decides to move forward with a project to allow the diversion of water from the Gila or San Francisco Rivers (a New Mexico CAP unit), the federal government will provide the state an additional subsidy of \$34 to \$62 million dollars to do so. The decision to divert must be made by December 2014. In early 2014 the New Mexico Interstate Stream Commission released their report outlining options for conservation and diversions. The options include five watershed restoration projects, four diversion and storage projects, three agricultural conservation projects, two effluent reuse projects and one municipal conservation project. These 15 options were reviewed by the U.S. Bureau of Reclamation in an appraisal level study released in July 2014. Diversion alternatives ranged from 1,000 acre-feet of storage to 62,000 acre-feet of storage and would have \$41 to \$598 million dollars in construction costs. According to their analysis in all of the diversion options and many of the non-diversion options the costs would exceed the benefits. Reclamation found six of the non-diversion options to have estimated benefits that would exceed the estimated costs. These projects include: Grant County recharge and reservoir, Deming wastewater reuse, municipal water conservation, Pleasanton ditch improvements, sunset/New Mexico new model pipeline and San Francisco Watershed restoration.

Why is it important for the future of the watershed?

Although the AWSA agreement indicates that there can be no harm to downstream water users and the diversions would be predominately of flood flows, there is concern on the Ari-

zona side of the watershed of the impacts to the downstream users. Among these concerns is the impact a diversion would have to natural recharge of the aquifer and plant and wildlife values in New Mexico and in Arizona. While flood flows can be very destructive to human infrastructure along the river they are also an important part of life cycles for riparian and aquatic species in the Gila River. Perhaps most importantly, considering the decision over to take or not to take the allocation is important to the future of the watershed because its direct impacts either to hydrology or to interactions with the New Mexico side of the watershed are very uncertain. The following scenario examines possible outcomes both if New Mexico exercises its option to divert and, alternately, chooses instead to implement conservation measures.

Scenario 1(a): New Mexico Diverts

Year 10 (2025)

New Mexico has decided to divert Gila water. As the federal environmental review process for the construction of a diversion has begun and lawsuits challenge various aspects of the findings and create added delays in the procedural review. Negotiations have been ongoing with various groups in attempts to mitigate some of the potential expected impacts of the construction. As a result, additional modifications to the initial design are being made. There is a small possibility that new scientific findings in areas such as hydrology, ecology, or potential habitat loss have resulted in recommendations for extraordinary construction measures. If such modifications are too costly, the entire diversion project could be undermined.

Extended drought has increased support for the diversion project among many in New Mexico and reinforced frustrations regarding the delays in construction. Local NM communities are struggling with the tensions generated between the build vs. no-build groups. Across the state line, drought has fueled **anxieties regarding the unknown consequences to natural groundwater recharge** and other possible impacts of the diversion project in Arizona. Catastrophic fires in New Mexico, particularly when followed by extreme precipitation events, result in heavy erosion levels. Large sediment loads are deposited in the side canyons targeted for reservoir sites, as well as the San Francisco or the main stem of the Gila, driving up **diversion construction costs and creating additional delays.**

A proactive series of public meetings in Arizona regarding the diversion project has allowed residents to learn about the expected planning and construction phases, as well as provide opportunities for residents to voice their questions and concerns. As a result, **improved networks are established** linking the public and its local officials. The demand for more monitoring and research has led to **improved understanding** of the potential known or likely impacts of the New Mexico CAP Unit on those communities living downstream. Even with information-sharing, the considerable uncertainties tied to the construction and operation of the diversion will fuel animated discussions and feed **suspensions and distrust among the two sides of the watershed.**

Federally-funded scientists have been conducting extensive studies for many years in the upper section of the watershed in support of the environmental impact statement. Engineers and surveyors have also begun preliminary field studies. Eminent domain proceedings will begin regarding any private lands directly impacted by the planned construction. The increasing amount of activity in New Mexico will have **spillover economic effects in Arizona,**

since much of the traffic will be directed through the Safford Valley.

Modest temporary population growth has occurred as part of the initial survey and planning phases of the New Mexico Unit. Given limited accommodations in the New Mexico watershed, many workers are commuting from Arizona. This initial phase is unlikely to generate long-lasting population growth, however. Since little, if any, actual construction work has occurred during this time period, there have been no direct or indirect impacts from diversions or the building of the infrastructure itself. Environmental conditions (e.g., drought, increased temperatures, flooding) remain the primary variables influencing the physical water supply. Widespread defoliation and high mortality rates of tamarisk due to the rapid spread of the tamarisk leaf beetle has resulted in **modest increases in water availability**, but only in the short-term. (Refer to the Tamarisk Scenario.)

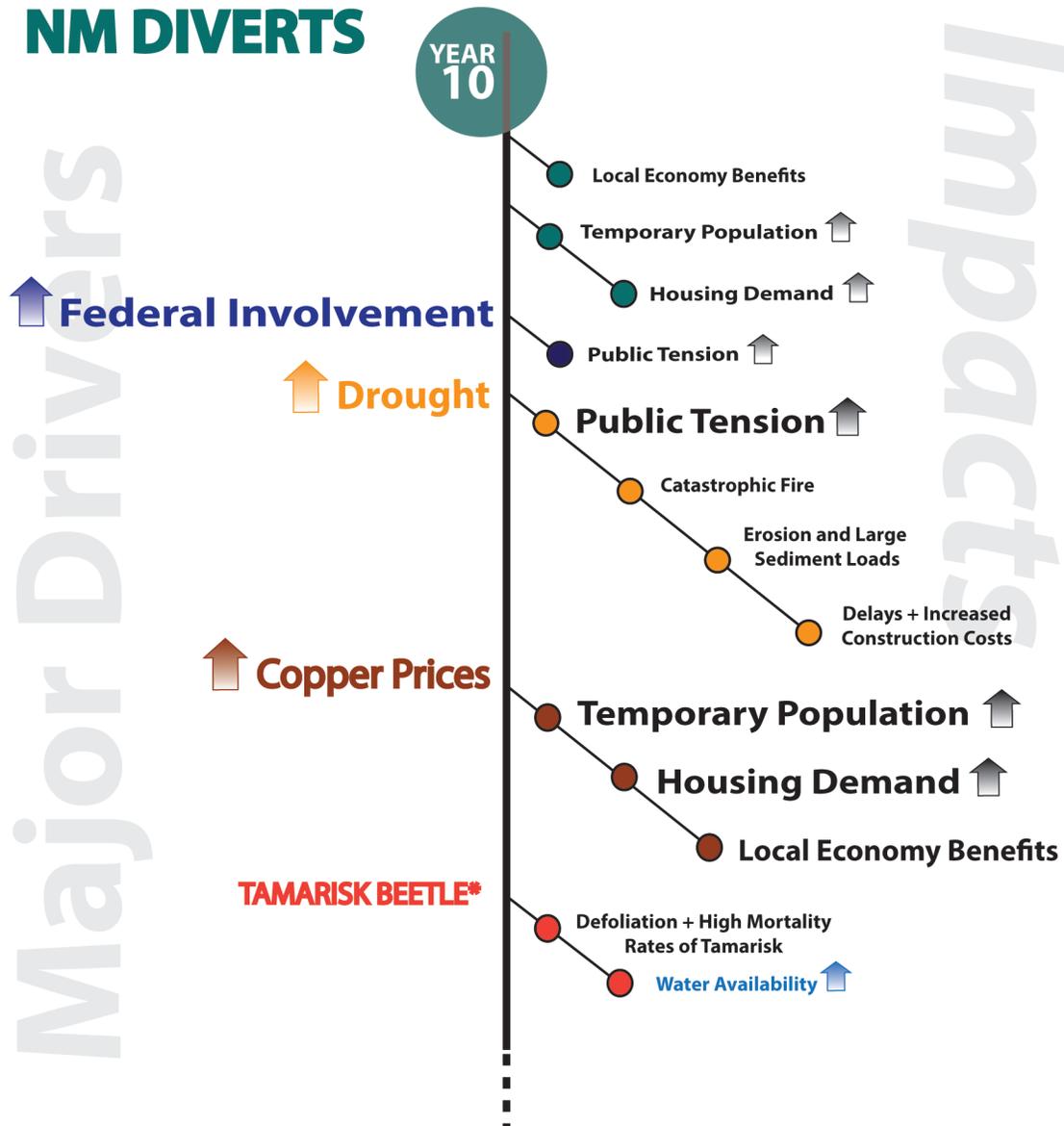
Administrative rule-making continue, and guidelines are established over **construction work in sensitive areas**. Further administrative appeals and litigation over construction oversight contribute to and further delay construction phases. In addition, the administrative triggers regarding the limiting elements for New Mexico's ability to divert water, such as the water elevation at the San Carlos Reservoir, will be carefully prescribed in regulations. Particular attention is devoted to water availability for plant and animal species of concern in riparian areas, including aquatic life. These regulations must take into account **an expansion of the federal Threatened and Endangered Species List** over the last ten years, due in part to the Fish and Wildlife Service's court-brokered Listing Work Plan involving the review of a backlog of 250 candidate species (at least 12 of which are thought to occur in Arizona and/or New Mexico) by 2018.

A coincidental **increase in copper prices has spurred a rise in mining activities, creating additional demands in the Valley for housing and accommodations**, as well as food and other services. This has reduced vacancy rates in the region and made accommodations for diversion-related workers harder to find and more expensive. **Once major construction activities begin, these overlapping effects will become more pronounced.**

Questions to consider:

- 1. What groundwater monitoring programs could be put into effect in the short-term in order to develop a better understanding of the relationship between drought, flood flows, and groundwater recharge?*
- 2. What planning activities are necessary to prepare for the projected increase in temporary workers, as well as the impacts on roads and other infrastructure from increased heavy duty tractor trailer trucks and other traffic?*
- 3. What factors, such as regulatory compliance, increased construction costs, or drought-driven decreases in water supply, would cause the New Mexico Project to be postponed or canceled? How would this uncertainty affect Arizona?*

NM DIVERTS



Year 20 (2035)

The environmental review process, and associated appeals and litigation, have been completed. The early phases of construction of the diversion are well underway. Construction time lines have been affected by a complicated mixture of weather patterns. The extended drought, with its low precipitation levels, has generally reduced weather-related delays. However, a couple of **unusually large storms** generated by hurricane remnants have created problems. The challenging terrain of the New Mexico section of the watershed makes construction and the movement of large equipment susceptible to the direct and indirect impacts of massive fires or extreme weather events. Bare soils exposed by the construction process and not effectively treated with erosion control techniques have also heavy

sediment loads to the river, resulting in **decreases in water quality** downstream. These types of developments have motivated Arizonans to take keen interest in the construction process and its consequences. An additional twenty years of studies and monitoring have dramatically **improved the understanding of hydrologic processes in the region**. Subsequent public outreach efforts have been successful at engaging Arizona residents in how they will be affected, from well water issues to surface water use for irrigation to effects on recreation.

There has been a marked increase in federal presence in the entire region. Federal managers are coordinating the work of different private contractors and ensuring that safety requirements and environmental protection specifications are effectively carried out during the building of the diversion. Inter-agency and inter-governmental disagreements have developed due to **negative impacts on public road infrastructure, forestland, and threatened/endangered species**. Substantial construction complications as well as a few on-site accidents have led to talk of additional litigation on the part of local residents, downstream water users, and advocacy groups.

While there have been drawbacks to the construction, there have also been some substantial **economic benefits for Arizona communities**. The largest short-term boost to the population is occurring during this period of active construction. Towns in Greenlee County have been helped in particular, because of their proximity to the construction sites in New Mexico. For more food and shopping options, construction workers can choose between Safford in Arizona or Silver City and Deming in New Mexico. The short-term scars on the landscape and the decrease in water quality in the Gila, combined with the heavy construction traffic and the decreased availability of accommodations, have **weakened the tourism-based economy**, but the overall economic activity has increased. Earlier estimates from Phelps Dodge (before the merger with FMI) indicated that the Tyrone and Chino mines in New Mexico near Silver City would become inactive before 2035; however, the other FMI activities in the Arizona side of the watershed remain robust with the high copper prices. This high level of mining activity, and the related boost in mining-related employment, has generated **strong demand for accommodations** in the region. Restaurants, bars, and retailers in general in Arizona continue to experience a boost in sales from the increase in workers from both the mining and the construction of the diversion. The combination of heavy tractor trailer usage of roads and other infrastructure from both mining operations and the diversion construction project, however, have taken a heavy toll. Road maintenance costs are a major concern, and the increase in traffic has resulted in more frequent accidents. Without many road choices in certain parts of the Valley, **travel delays and increased driving times** have become commonplace. While the economic boost has helped local businesses, differences between the temporary workers and the local residents have been a source of constant friction.

Questions to consider:

- 1. How can public officials and the business community work together to prepare for the increase in demand for accommodations, food, and retail during the construction phase?*
- 2. What advance planning and road maintenance expenditures will be needed in anticipation of the wear and tear on public infrastructure in the Valley from the increased flow of construction equipment and trucks for the diversion project – and possibly mining operations as well?*
- 3. How can structured public engagement be sustained during the construction process so that residents in Arizona have opportunities to learn about the ongoing work – and express their comments and concerns?*
- 4. What kind of intergovernmental task force might facilitate information-sharing and the coordination of rapid response efforts in the event of unforeseen problems tied to the construction work?*

Year 30 (2045)

The Bureau of Reclamation has deemed most of the **initial infrastructure as substantially complete and ready for service.**

While occasional wet years have generated additional water flows for diversion, the dogged persistence of **drought conditions have prevented New Mexico from being able to store much water in its CAP unit.** Three primary triggers have prevented this storage: low flows in the New Mexico Gila, insufficient water storage at San Carlos reservoir (below 30,000 AF), or lack of available CAP water in central Arizona to offset the diversions in New Mexico. The New Mexico reservoirs remain substantially below capacity, and the **lack of reliable water storage inhibits anticipated population growth and economic development** in New Mexico's part of the watershed.

The riparian areas of the Gila have still experienced notable alterations. River systems that are highly engineered with substantial diversions and changes in flow regimes have been shown to be particularly susceptible to shifts in riparian ecosystems. **New plant community regimes**, often dominated by non-native plant species, commonly take hold under such conditions. **New Mexico's diversions effectively capture most of the occasional flood flows**, and riparian restoration efforts downstream are at a decisive disadvantage. Tamarisk die-offs have resulted in its replacement with a new riparian regime involving other non-native species (such as Russian olive) in some areas, and a shift toward a mesquite-dominated landscape in others. The impacts due to the diversion have combined with other factors, such as elevated temperatures, increased evapotranspiration, reduced surface flows, and shifts in species richness, to create a **much altered river corridor.**

Because of a strong link between natural groundwater recharge in the Safford Basin with flood flows, so the New Mexico diversions are strongly suspected of having contributed to a **steadily decreasing groundwater table downstream.** Arizonans have become particularly sensitive to the New Mexico diversion because of such complications. Farmers rely ever more on groundwater pumping to irrigate their fields. Individual residential well owners have great difficulty with increasing depths to groundwater. **Such increasing costs are driving people out of certain areas and depressing real estate values.** Large systems like Safford will be able to spread out the cost of new wells across the customer base, but **rates are likely to rise significantly, especially if there are major expenses tied to the treatment of brackish well water. Water usage (per capita per day) has decreased in large part because of the higher costs to consumers.** Well drilling and tiered pricing changes could exacerbate **tensions over water availability** between the haves and the have-nots.

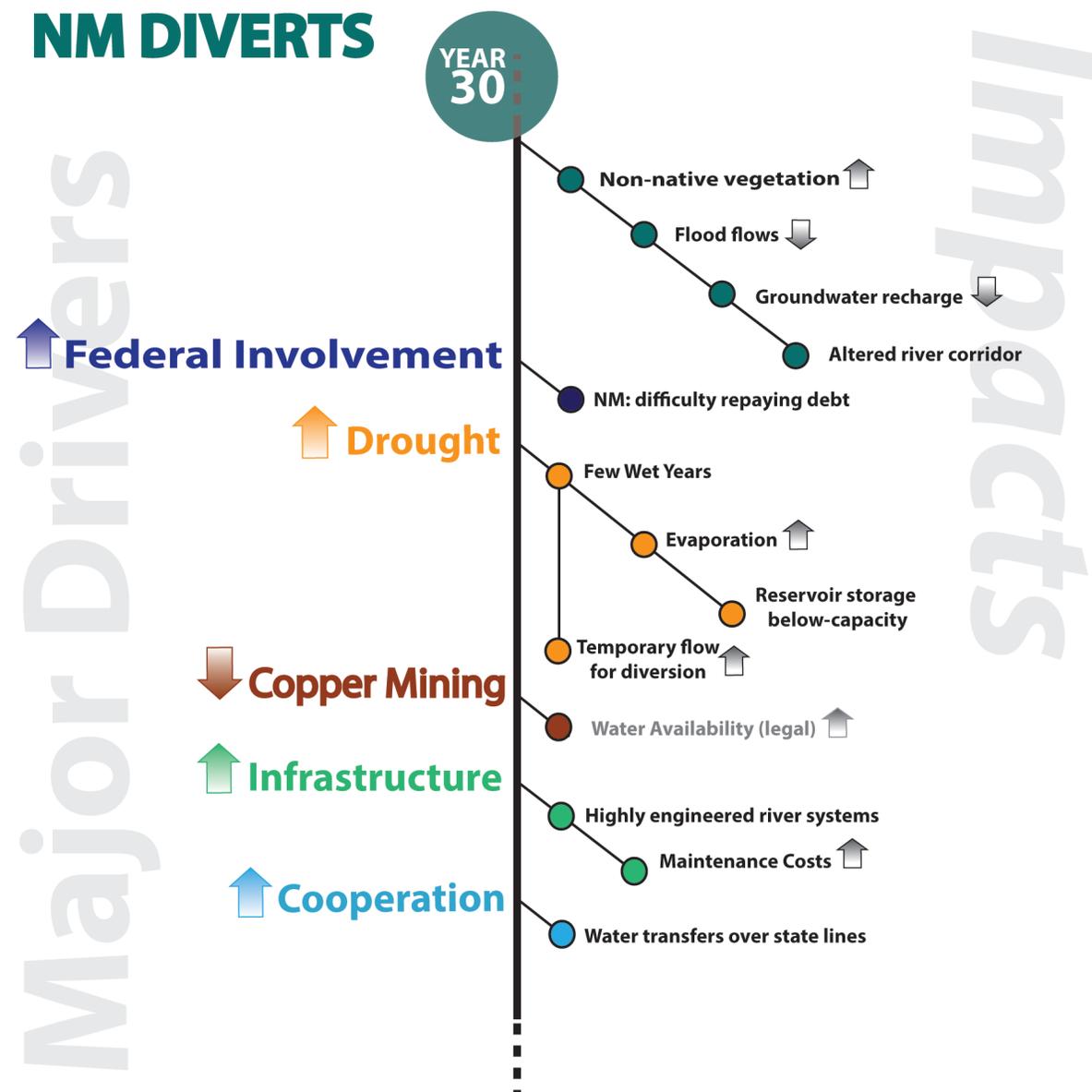
The ever spiraling costs of constructing and maintaining the infrastructure tied to the diversion projects will push the diverted water to **higher-value uses, such as municipal and industrial uses, at the expense of agricultural uses.** Under-utilization of the diversions, caused by extended drought, increased evaporation rates from the reservoirs, and the inability to capture the full allotment hypothetically granted to New Mexico, will push the water to be applied to such higher-value applications. Municipal and industrial uses could pay such elevated prices, but conservation efforts have offered a cheaper alternative for now.

There is a hint of greater cooperation between the states on the horizon. New Mexico seems willing to consider transferring some of its (limited) stored water to users in Arizona. This could benefit the Safford Valley, since no water storage capacity exists above Coolidge

Dam. Arizona water users are willing to pay a higher price per acre foot than any users in New Mexico for this water. While interstate political considerations have also come into play, the high cost of New Mexico's repayment obligations to the federal government for the infrastructure appear to be driving this transaction. The relative low levels of water in the off-channel reservoirs make it increasingly difficult for New Mexico to pay its debt obligations. Certain mining operations, such as the Dos Pobres mine near Safford, have reached the end of their projected productive lives (2045), and have become inactive. **The water rights associated with the mines have become available for municipal water systems to buy or lease**, although this source of augmented water comes with an expensive price.

Questions to consider:

- 1. How can groundwater monitoring be facilitated in the coming years so that complex interactions between pumping, surface flows, and recharge be better understood?*
- 2. In a future with flooding driven by extreme weather events and functionally impaired riparian areas, what steps should be taken for floodplain management?*



Scenario 1(b): New Mexico Conserves

Year 10 (2025)

New Mexico will have used the last of its annual payments of \$6.6 million from the federal government (\$66 million in total) for non-diversionary, water conservation-related efforts. These investments have generated a variety of direct and indirect riparian restoration benefits. After ten years' worth of accumulated investment, the growth of resilient native plant communities and the animals dependent on them have created healthy riparian areas in New Mexico with robust ecological functionality. **There has been growth in eco-tourism/recreational opportunities as a result, with a small spillover effect into Arizona, thanks to the spending of tourists in transit and Arizona draws like the bird walk in Duncan and the Gila Box Riparian National Conservation Area.**

Year 20 and Beyond (2035+)

At this point in the scenario, we offer an overview of the non-diversion choice by New Mexico, with associated impacts on Arizona. In most cases, the long-term effects are likely to be a further expansion on the short-term developments.

The effects from events in previous years will have continued to grow. In addition, groundwater recharge programs have made substantial cumulative additions of water to the area's hydrology. **Recurring drought continues to affect the Upper Gila watershed in both states.** New Mexico has completed groundwater studies to understand the relationship between heavy levels of groundwater pumping and surface flows in its section of the Upper Gila. With this information, New Mexico has applied a portion of its annual funding to pay heavy pumpers to reduce, relocate, or turn off their wells. Programs have also been established to support targeted groundwater recharge and/or near-stream recharge. Studies indicate that these actions have had the effect of mitigating the **drought-caused reduction in base flows on the Gila.**

New Mexico's riparian restoration projects have supported the **establishment of a more resilient plant community, which has responded to tamarisk die-off and mitigated the impacts of fire in river corridors.** Since the Gila is a dynamic and unstable river system, occasional flood flows still occur, even in times of drought. Extreme weather events, such as a tropical storm remnant or a powerful monsoon system, periodically release large amounts of water in a short period in a particular catchment. The terrain collects and focuses that precipitation into a rapid buildup of water, such as the one on the San Francisco River that affected Clifton in the summer of 2013. **Improved floodplain management and wetland protection efforts have helped to mitigate the damage caused by these events, while promoting groundwater recharge in the process.**

The scientific community has taken a strong interest in the Upper Gila as an unusual example of an undammed river in a semi-arid environment. **Federal funding has supported several projects examining a closer study of the complex effects of drought and flood** on the fluvial geomorphology and the plant and animal communities that develop and thrive in those conditions. This research has led to helpful insights on surface water management and groundwater recharge programs.

The detailed documentation of the Upper Gila River Watershed, including its role in supporting a broad variety of migrating species, has provided a **strong boost to the local econo-**

my in terms of eco-tourism. There are increased opportunities for recreation, birding, hiking, and camping, with a boost to local economies. Water-based activities, such as canoing and rafting, remain very seasonally limited. Early and mid-spring offer the most reliable times for adequate flows to support such waterborne recreation. This is circumscribed further by **lower annual average snowfall in the New Mexico side of the watershed and an earlier snowmelt time frame**. Other activities likewise have strong seasonal fluctuations, tied to bird and insect migrations as well as moderate temperatures. While eco-tourism does not have as large an impact as other large regional economic drivers, it nonetheless brings in a substantial amount of dollars from outside the watershed and also introduces tourists – who are potential new residents – to the area. These overlapping effects are particularly relevant in the context of the baby boomer demographic reaching retirement age. They seek both new travel opportunities and new retirement homes, and the Upper Gila has been successful in addressing both of these areas. Public support for riparian health has continued to grow with the increase in eco-tourism revenues. **The relevance of the river’s ecological functions has been linked more directly to the regional economy.** Local communities have found new ways to promote their water-saving programs and water conservation ethos to visitors and potential new residents.

New Mexico’s decision not to divert water has not only avoided uncertainty regarding the potential negative impacts downstream, but has generated some modest benefits for Arizona. Sustained conservation efforts in New Mexico for 20+ years, such as through groundwater and near-stream recharge efforts, have led to slightly augmented base flows in the Gila. This has been helpful in promoting the capture and slow release of increasingly earlier snowmelt-fed spring flows. These benefits have been subject to the other expected challenges of increased temperatures and increased evapotranspiration rates, as well as the related need for farmers to use their full allotment of water for irrigation. **Overall, however, conservation in New Mexico has allowed for a moderately increased ability to mitigate the effects of long-term drought.**

Questions to consider:

- 1. Will the continued lack of any infrastructure affect floodplain management along the Upper Gila in Arizona?*
- 2. What incentives, from an Arizona perspective, would be sufficient to partner with New Mexico to protect base flows in the Gila?*
- 3. What could be learned from native plant restoration efforts along the Gila in New Mexico?*
- 4. How can the area prepare for possible population and economic activity increases as a result of enhanced recreational and eco-tourism based activities?*
- 5. What steps could be taken now to encourage a regional economic partnership (including New Mexico) in promoting the growth of recreation, birding, and tourism generally in the Upper Gila River Watershed?*
- 6. What types of such tourism and recreational activities could be feasibly scaled up, given the local attractions and what is expected regarding future environmental conditions (e.g., surface flows, fishing, hunting, bird and insect migration patterns)?*

NM CONSERVES

YEAR 20+

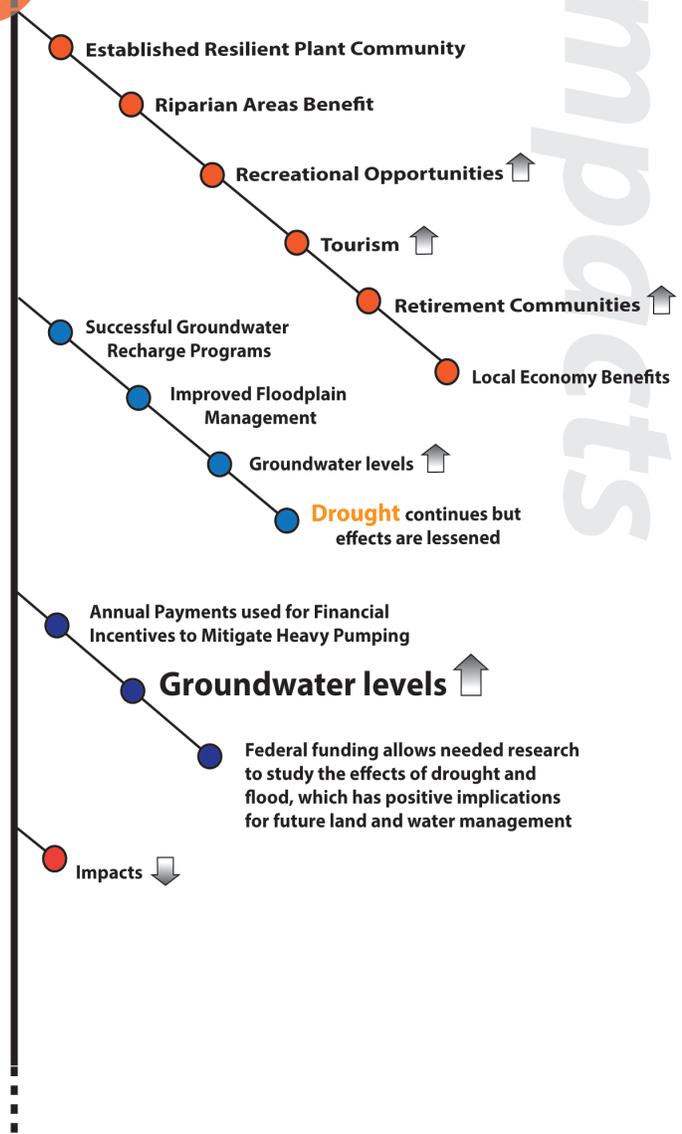
Major Drivers

Impacts

Water Supply Availability

Federal Involvement

TAMARISK BEETLE*



SCENARIO 2 – Eat and Run: Impacts from the Tamarisk Leaf Beetle

Given the rapid spread of the tamarisk leaf beetle (*Diorhabda* spp.) along riparian areas in the Southwest since its first introduction less than fifteen years ago, and the abundance of tamarisk (the beetle's primary and almost complete food source) along the Upper Gila River and its tributaries, the eventual arrival of the beetle in the watershed is a near certainty. What is much less clear are the consequences of the beetle's arrival on the region's future. While tamarisk trees and the tamarisk leaf beetle have attracted a great deal of research, the relative newcomer status of the beetle results in many unanswered questions regarding the medium- and long-term consequences of beetle-induced tamarisk die-offs.

Why is it uncertain?

Uncertainty takes several forms in the case of the tamarisk leaf beetle. There are questions regarding how soon the beetle will arrive in the watershed, as well whether or when different species of beetle will co-exist in the region. There has been notable variability in the extent of inter-annual defoliation and subsequent tamarisk mortality in other riparian areas. When this is added to the uncertain speed with which the beetle spreads throughout the valley, the level of likely impacts is capable of extending across a large range, from fairly moderate to severe. At one early release site for the tamarisk leaf beetle near Lovelock, NV, notable die-offs of tamarisk have occurred.³⁷ At other locations, however, tamarisk has shown a robust resilience despite several years of defoliation by dense beetle populations.³⁸ Local conditions therefore may have a strong effect on the scale of tamarisk die-off.

Why is it important for the future of the watershed?

Rapid colonization of the beetle in the Upper Gila River Watershed, followed by widespread defoliation and tamarisk mortality, would likely have far-reaching impacts felt by the riparian areas and beyond. Opportunities will likely exist for re-establishing a more resilient mixture of native plant and animal species, which would offer a range of valuable ecosystem services to the region. Alternately, the rapid loss of such a dominant species could result in a wholesale shift in plant and animal communities and a heavily degraded landscape that has lost much of its ecological functionality. This could include the establishment of other non-native species more pernicious than tamarisk. Preparing for the potential consequences of the tamarisk leaf beetle will allow the people of the region to respond in a timely and organized manner, and thus act to support a healthy riparian ecosystem that provides benefits to the entire Valley.

Since beetles are considered to be selective feeders, with tamarisk as their near-exclusive food source, the potential for collateral negative effects on other vegetation from the feeding of the beetle have been considered marginal (McCleod, 2013). These four beetle species were released under varying conditions in southwestern riparian ecosystems beginning in 2001 by different groups of federal, state, local, and private actors. Given the rapid spread of the beetle and potential negative impacts on nesting sites for the endangered southwestern willow flycatcher (*Empidonax traillii extimus*), federal agencies have halted further releases. The beetle populations have become well established, however, and continue to spread quickly along riparian corridors in the west (Tamarisk Coalition, 2014). The beetle has also been documented as having traveling 40 miles overland to new colonization sites, indicating that the beetle has the ability to enter new watersheds unaided by humans.

One variety of beetle was first released along the Virgin River in Utah, and appears to be migrating down the Colorado River mainstem. This species was originally thought to be unable to establish a permanent foothold below 38 degrees north latitude, but the beetle has already migrated below that point and has reached Lake Mead. Researchers estimate (need source) that this population will arrive at the junction of the Gila River and the Colorado River mainstem by 2016, and the beetle is expected to migrate quickly up the Gila River. A second population of beetle introduced along the Pecos River has spread through Texas and up the Rio Grande in New Mexico. This population is anticipated to arrive in the Arizona portion of the Upper Gila River Watershed by or before 2020.

Year 10 (2025)

One or more species of **tamarisk leaf beetle has arrived in the watershed**, beginning the process of defoliating stands of tamarisk. Particularly during the late spring and early summer, when the beetle is most active, areas of dense tamarisk affected by the beetle will appear heavily damaged. In areas where this defoliation has occurred prior to the monsoon rains, and particularly in years of drought/low flows in the Gila, the riparian corridors will be notably degraded. Monsoon rains may support the growth of understory plants, although the summer dormancy of the beetle may allow the tamarisk to leaf out again with less damage from herbivory. **Widespread and rapid loss of vegetative cover**, as well as salt cedar mortality, would result in loss of microclimates and habitat for a variety of animals and plants. It is supposed that this process will be particularly negative for nesting habits of the federally endangered southwestern willow flycatcher. Some of the largest known populations of the southwestern willow flycatcher are located in the Upper Gila, and threats to their habitat within stands of tamarisk may result in initial federal actions to protect flycatcher habitat.

The extent of federal involvement will likely depend on the perceived **threat to breeding populations of flycatcher**. While tamarisk is a riparian species, extended drought has added to the stress experienced by plants under attack by the beetle. Plants in wet areas, where access to shallow groundwater could be impacted, are particularly susceptible. Large concentrations of dead or dying tamarisk, with the increased collection of dry leaf litter, will increase the **fire risk in riparian areas**. This will be particularly problematic in the dry season before the summer rains and increased surface flows in the Gila. Fires will result in decreases in water quality, including a likely increase in pH, salt, and potash, which would complicate the use of surface flows for agriculture. Aquatic life is negatively impacted, raising the concerns of the US Fish and Wildlife Agency. **Fires will also contribute to a deterioration of air quality**. Since most residents of the Valley live near the river, the smoke and airborne particulate matter will present a health hazard to many, especially vulnerable populations. Atmospheric inversions trap the smoke at low altitudes and prevent dissipation. Public health campaigns, however, are successful in increasing local awareness about the dangers of poor air quality. Emergency calls to 911 and visits to the emergency room decrease in the wake of coordinated education and outreach efforts.

The degradation of the riparian buffer and loss of the dense network of tamarisk roots have also led to greater soil erosion. Increased nutrient loads are carried into the river by runoff. Flooding potential has also increased for similar reasons, as stormwater flows would enter the river more quickly and in greater volume than otherwise. The destruction caused by flooding events is exacerbated by the increase in detritus and plant matter from the dead

tamarisk. Infrastructure, such as bridges and diversion dams, is heavily damaged during such events.

While the arrival of the beetle has led to reduction in nonnative tamarisk, **a rapid decrease in tamarisk has also resulted in a loss of habitat for the southwestern willow flycatcher.** The US Fish and Wildlife Service has issued new regulations in response that further restrict activities in the riparian areas. New plants and animals are under consideration for inclusion in the federal Threatened and Endangered Species List. These **regulatory actions spur along cooperative efforts among governmental entities and nonprofits** in efforts to restore stands of native vegetation suitable for flycatcher habitat, as well as for certain other species of concern.

Major landscape scale emergencies, such as riparian fires and floods that impact infrastructure and farmland, are aggravated by widespread tamarisk losses. Managers of federal lands in the watershed, as well as representatives of emergency/disaster relief efforts such as FEMA and USDA, develop larger roles in the region through the operation of rescue and reconstruction programs. Restrictions on the use of such funds, such as to “replace, not improve” infrastructure, however, continue to **inhibit resilient planning and preparedness for subsequent disasters.**

The rapid loss in tamarisk led initially to a decrease in transpiration and an increase in evaporation in riparian areas, leading to a small **short-term increase in surface flows.** However, the reputed thirst of the tamarisk has turned out to be less than rumored, and the subsequent **water savings have been underwhelming.**³⁹ Even in areas of high tamarisk mortality, other opportunistic species (native and non-native) move in to fill the niche, with the result that ET levels quickly approximate earlier levels within a few years. In line with recent research, tamarisk ET rates in the Upper Gila are determined to average about same or even less than native phreatophyte species. **The decline in tamarisk as a dominant species has led to the rapid infill by other plant communities, with increases in ET and very little change in the long-term water supply availability.**

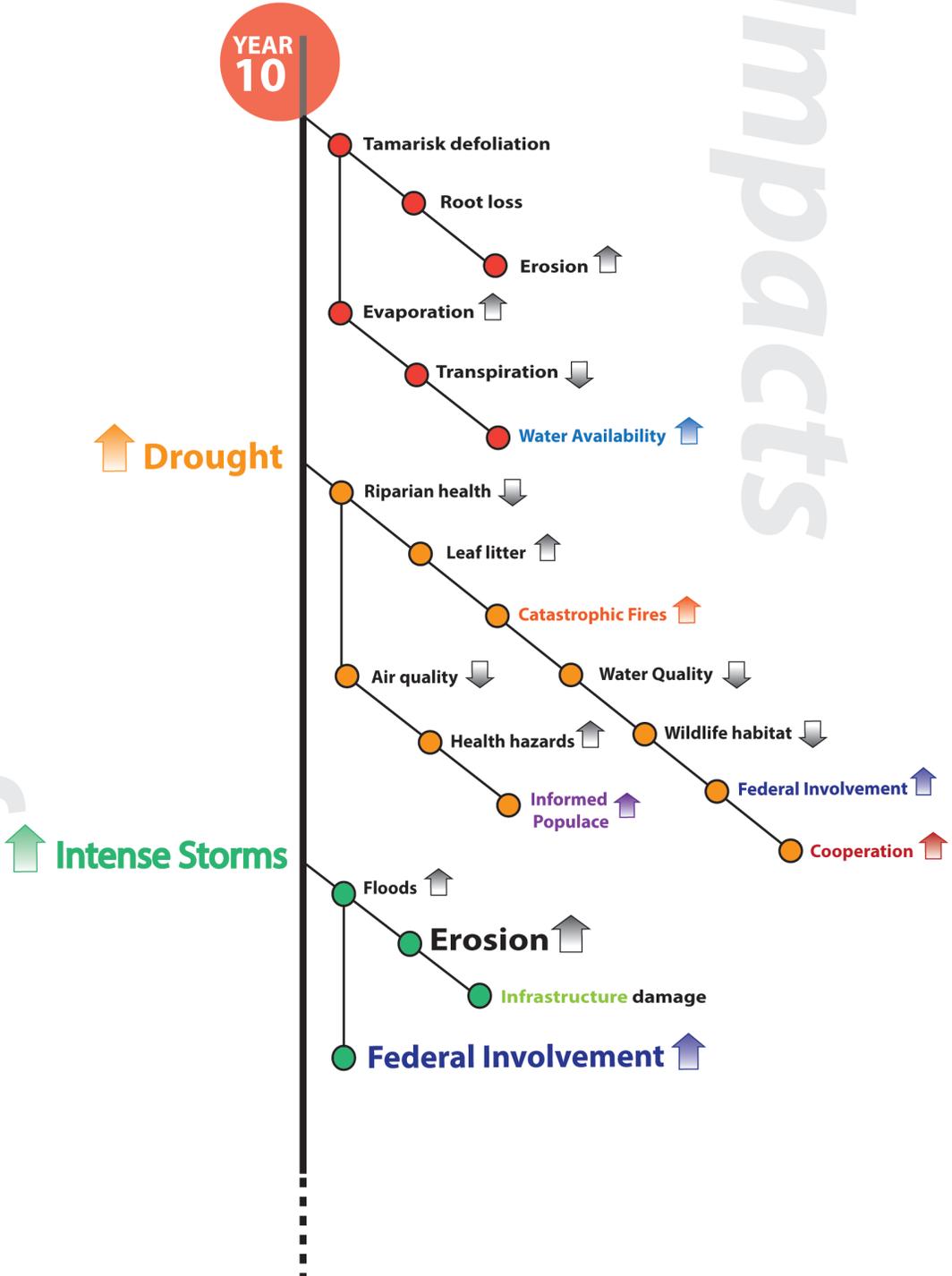
Questions to consider:

- 1. How can riparian restoration efforts be enhanced to encourage the most appropriate riparian replacement community in terms of biodiversity, habitat, and historical precedence?*
- 2. What kinds of coordination and cooperative resource management strategies will be necessary among different entities like the federal government, counties and tribes to address the downstream impacts of fire and extreme floods?*

TAMARISK BEETLE

Major Drivers

Impacts



Year 20 (2035)

The most significant direct impacts of the tamarisk leaf beetle are already largely completed. In some areas along the Upper Gila, the tamarisk has proven resilient despite the onslaught of the beetle. In others, the result has been high tamarisk mortality rates and **opportunities for other plant species to fill the gap**. While tamarisk populations will most likely always be present in the watershed, they are kept in check by the residual beetle populations. As a result, **tamarisk will no longer be the dominant species** along many stretches as it once was. The resulting newly open areas witness the **growth of other plant communities** along the Gila. While the new plants are becoming established, however, **erosion levels have increased**. The capacity of the **San Carlos Reservoir has experienced continued declines** as a result of the deposition of heavy sediment loads, and this, along with **CAP cuts due to drought**, contributed to **heightened tensions** between Indian and non-Indian water users. The large stands of new vegetation will also be vulnerable to **flood events** that could wipe out most the plant life before it becomes firmly established. Further, certain unpredictable environmental conditions will heavily govern the development of new riparian plant communities. Regular riparian fires could alter the **species diversity**. Flooding at opportune times will assist in the recruitment of cottonwood as seeds are carried downstream and deposited along stream banks by receding floodwaters. Flooding at inopportune times will open the door for other plant species to become dominant, leading to a regime shift in the riparian ecosystem. This eventuality could result in the establishment of other types of **non-native plants as dominant species** (such as Russian olive), or the creation of mesquite bosques (similar to the Great Mesquite Bosque of the late 19th century south of Tucson) that can out-compete cottonwoods and willows under certain conditions.

Public education and outreach programs remain a vital part of assisting residents in adapt to new circumstances in the valley. **Awareness of stresses on the Gila River promotes mote greater resident-initiated efforts at water conservation**. Stresses on local potable water supplies have been substantially addressed by extensive retrofitting existing homes, as well as construction of new homes, with continually improving water saving technology. Xeric landscaping has reduced outdoor water consumption, and individual initiatives, like active rainwater harvesting with barrels and landscape design to capture stormflows, will be particularly prevalent in the Valley. Use of desert-adapted landscaping will also result in decreased pesticide and fertilizer usage, with a related **improvement in the water quality** of runoff flowing into the Gila.

Federal agencies continue to respond to the **widespread changes in plant communities** along the river. The worst of the damage represented by the tamarisk leaf beetle toward **southwestern willow flycatcher habitat loss** will have been sustained by the 20 year mark. Federal efforts will have shifted toward supporting successful restoration efforts regarding native plants and to addressing the consequences of other new non-native species. These new arrivals have opportunistically become entrenched in the riparian areas, to the detriment of the hoped-for cottonwood-willow gallery riparian system. In several areas, the new species have demonstrated increased evapotranspiration rates, more so than either native plants or tamarisk.

Local governments are hit with substantial costs after a couple of **major floods**. The damage caused by the floods is magnified by the plant community regime change along the river and the increased runoff during extreme precipitation events. Depressed land values have

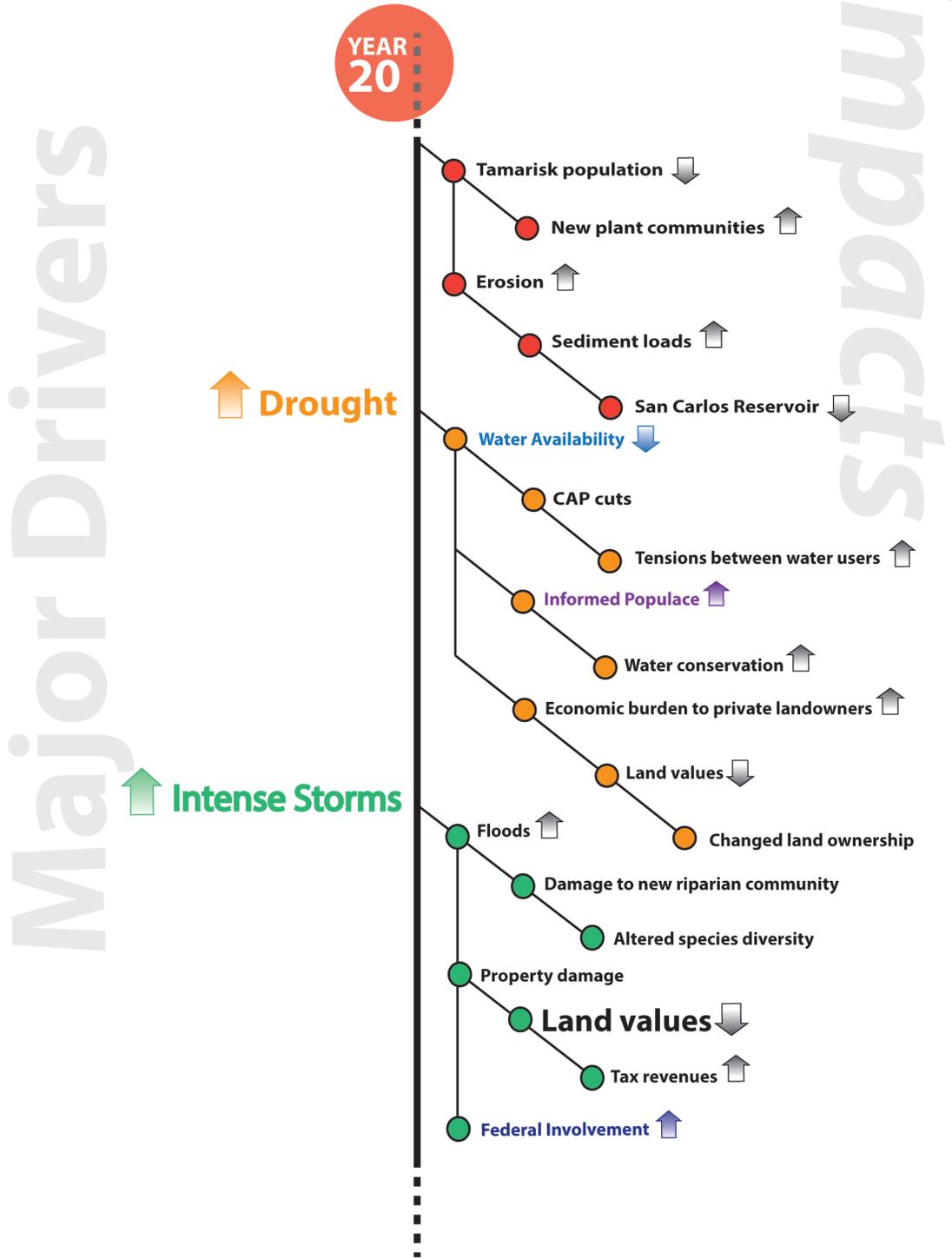
had the effect of **constraining property tax revenues**, and counties and municipalities are hard pressed financially. Some federal relief comes in the form of disaster aid and certain types of reconstruction support.

The 20-year average of drought and increased input costs have also created **severe economic burdens on many private landowners**, especially farmers. **Land prices are weak**, but many of these landowners have resorted to the sale of portions of their land in order to weather the economic hard times. Certain areas near the river have been either bought up or put under conservation easements by a mixture of large national/regional nonprofit organizations as a way of creating or protecting certain habitat areas and ecosystem functions tied to the Gila River. Post-tamarisk restoration efforts in these areas would continue. Mining companies may also participate in these activities as part of their mitigation efforts.

Questions to consider:

- 1. What other management strategies might be considered to eradicate or reduce remaining tamarisk strongholds to prevent future encroachment?*
- 2. What treatments, if any, should be used to address the buildup of dead tamarisk biomass in the riparian area?*

TAMARISK BEETLE



Year 30 (2045)

Tamarisk will still be a noticeable part of the landscape, particularly where specific local site conditions give tamarisk an ability to withstand beetle infestation. **Signs have emerged of new strains of super-tamarisk due to the intense selection pressures of the beetle attacks.** One strain appears to be unpalatable to the beetle, and another can store more nutrients in its roots to support new growth during the beetle's late summer dormancy period. These strains have begun to appear in different areas, but **mega-drought conditions** have limited the spread of a second wave of tamarisk colonization. The historic drought conditions are gripping the entire Southwest, and they have created very challenging impacts in the Upper Gila River Watershed. Increases in average temperatures have raised evapotranspiration rates and created added stress on vegetation throughout the region. **Earlier snowmelt, combined with the decrease in total precipitation, has increased the risk of catastrophic crown fires in the upland forests as well as frequent burns in the riparian area.** The arrival and widespread distribution of other fire-adapted non-natives, such as a higher-altitude buffelgrass species, have made the desert floor more prone to fires as well, leading to a regime shift in desert plant communities and impacts on forage availability (positive and negative) for ranchers. **Increases in severe fires and loss of cover vegetation** in several parts of the watershed have contributed to higher runoff rates. Sedimentation in the Gila will increase, and water quality will be negatively affected. When there is precipitation, it arrives more frequently in extreme precipitation events. Greater intensity of monsoon rainstorms will lead to increased stormflows – especially in recently burned areas with hydrophobic soils. Since the diversion projects in New Mexico offer only moderate flood control benefits at best, and **significant floods will periodically continue to pulse through the drought-stricken watershed.** Even with the floods, precipitation levels remain far below long-term historical averages. By 2045 the majority of debris related to tamarisk die-offs will have been cleared by floods, fires, or decomposition. Any increase in near-surface salt levels from the Tamarisk Period will have been diluted by the periodic floods.

Widespread changes in plant communities on BLM and Forest Service lands, due to extended drought, increased temperatures, new non-native species, and/or fire, will prompt **modifications to federal land management.** This will range from lumbering to grazing permits to endangered species protection along riparian corridors. Certain types of federal funds will be made available to help with a variety of pilot projects in addressing federal land management as well as cooperative management efforts with other landowners. New strategies to respond to the fires will be tested, with efforts ranging from mitigation of fire risk and to new approaches in trapping sediment before it reaches the Gila. Debates will continue regarding the **“assisted migration” of different plant and animal species** to new biodiversity refuges established on federally owned sites at varying elevation and water availability. Some designated sites are in the Gila Box Riparian National Conservation Area in areas formerly colonized by tamarisk, creating concerns from downstream users about potential regulations on water use. **Exhaustion of the local mines, combined with decreases in copper demand worldwide, have caused the mining companies to withdraw from the region.** They no longer serve as notable sources of additional funds and in-kind services for the region's communities.

Any temporary increases in water availability through widespread tamarisk defoliation and/or mortality will be long past, as other species will have colonized riparian areas. As mentioned in Year 20, these new arrivals consume more water than tamarisk, and have created other **adverse impacts on water quality and quantity.** Further, with increased tempera-

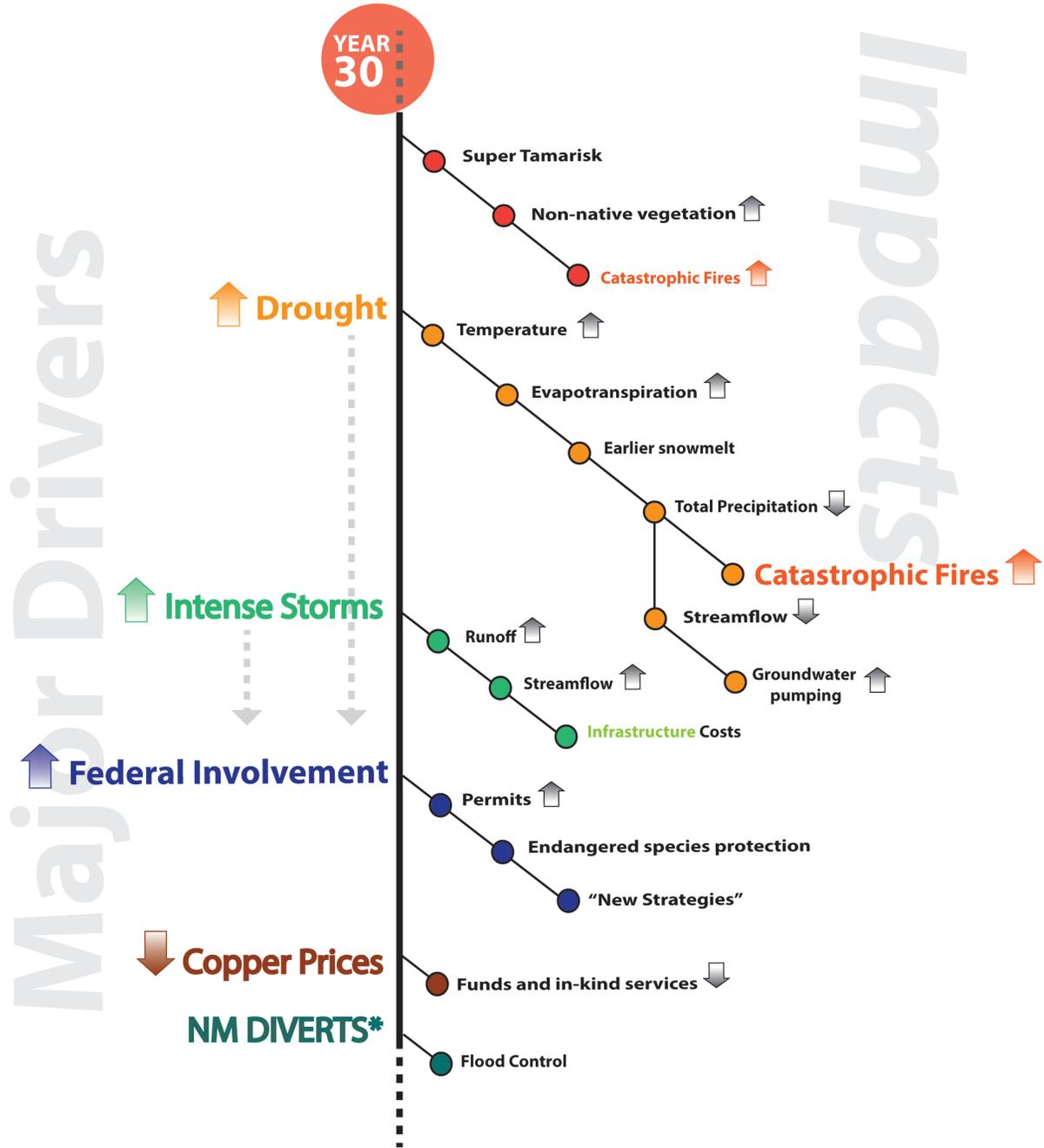
tures and elevated ET rates, average flows in the Gila have decrease somewhat. Farmers are forced to rely more on groundwater pumping for irrigation, which in turn lowers the water table. **Public and private groundwater users are compelled to drill deeper wells and accept higher pumping costs.** Increases in the costs of other inputs as well as unstable cotton market prices have driven many farmers to experiment with a new mix of crops to support the economic viability of the farming enterprises. The long-term hydrological impacts of New Mexico's diversions on the Arizona portion of the Upper Gila River Watershed are more fully understood, with negative impacts on groundwater recharge and on the reestablishment of native riparian species. Litigation is ongoing regarding these impacts. Additional water leasing arrangements with area Tribes are under negotiation, and there are cautiously optimistic signs of greater cooperation.

Questions to consider:

1. What kinds of drought-adapted crops might be appropriate, assuming market demand, in the event of higher production costs due to drought and decreased water availability?

2. How will joint intergovernmental efforts to remove/manage tamarisk, if any, affect how local governments work cooperatively on other water issues?

TAMARISK BEETLE



SCENARIO 3 – Mayberry versus the Beltway: Local to Federal Control

Why is it uncertain?

James Madison stated in Federalist No. 51 “the power surrendered by the people” would be “divided between two distinct governments,” creating a balance of power that would allow the “different governments to control each other.” As this statement refers to State and Federal as the two distinct governments, it neglects to mention the role of local governments in the mix. The three levels of government are intricately linked and have changing dynamics depending on the political atmosphere at the time. Depending on the ideology of the majority political party and elected presidential administration, the role of federal power can be leveraged with more or less authority. The swing of that political pendulum is erratic and highly uncertain. The same uncertainties play out with the make-up of the local government, which is largely dictated by the static or changing demographic of the local population in terms of age structures, ethnicity, income and education levels. More baby-boomer generation people are moving to the southwest for economic and climate-related reasons. This influx of newcomers is changing the demographic of local communities in the watershed.

Why is it important for the future of the watershed?

As the old saying goes, all politics are local. The policies put in place by state and federal governing bodies will generally trickle down to the small scale and have multitudinous effects. For instance, the federal government plays a significant role in funding the building of roads and other infrastructure with programs such as the Highway Trust Fund. In order to qualify for federal funding, Congress often requires the state to enact various kinds of legislation. Meanwhile, towns and cities have distinct methods of deliberation, which allows variability and independence from the federal government in their management decisions. Proposed policies have less chances of being effective if they do not consider the real people being affected. However, even without federal funding, local governments are required to enforce certain laws stated under such legislation as the Clean Water Act, Safe Drinking Water Act, and Endangered Species Act (ESA).⁴⁰ Finally, 46% of the land in the Upper Gila Watershed is managed by the federal government through the Forest Service and the Bureau of Land Management. Decisions made by the federal government on how to manage those lands have a significant impact on the watershed and the economy of local communities.

Scenario 3(a): Increased local control

Year 10 (2025)

The year is 2025 and the nation has seen a political shift in federal control as the presidential administration focuses its attention on reining in regulation with the goal of **limiting federal expenditures and reducing the regulatory burden for Americans**. The alternative emphasis is to encourage local government to take action and private industry to step into certain regulatory roles for profit. In response to this national political tide, local governments within the Upper Gila Watershed have decided to stop applying for federal funds to do capital improvements. The responsibility to provide financial backing for public works projects now lies with local governments. The depressed economic climate of the nation as a whole lends itself to **dramatic changes in federal controls, but Arizona fares well** overall and is seeing more physical development as Americans continue to migrate to

the Southwest to live either on full-time or part-time basis. Federal lands in the watershed remain managed by federal agencies, however, these agencies are provided more leeway to manage them according to local conditions and are encouraged to seek **public/private partnerships** for the development of recreational uses on the lands.

Stepping into this political and economic atmosphere on a local scale, the emphasis on growth and **inviting new economic opportunities takes precedence throughout the region** in order to stimulate a much needed flow of money. There is competition amongst towns to bring businesses to their individual communities and businesses are able to use this competition to their advantage, asking for certain liberties and relaxation of zoning. This situation results in land development and industrial practices occurring in, or adjacent to, areas that are ecologically sensitive. Widely, **zoning is not enforced** and a sprawling land use pattern breaks up wildlife corridors and infringe on important riparian areas. As land use control has always been an intensely local area of law, it is a relatively easy for planning to be piecemeal and not coordinated amongst different towns.⁴¹

Investments are required from local taxpayer dollars to build and maintain public facilities and services. Since federal funds are no longer available, **local taxes have gradually risen every few years** to provide for necessary repairs and construction. It has gotten to the point that local taxes are now twice what they were 20 years prior and resemble the tax burden in much larger municipalities. In conjunction with these tax increases, the public has become highly educated and involved in order to know (and contest) where their money is going – **attendance at town and regional meetings has increased, public rallies are common, and most people are voting**. Division exists within the community but there is also dialogue amongst the populace and the representative governments. The decision-making process moves slowly in order to incorporate the influx of voices, but money is put where the community wants it to go in many cases. However, riparian restoration efforts are neglected as the public is more concerned about water for their homes and families, less so for the environment. One widely-acknowledged benefit of the local management is that **new industry has found its way to the valley**, so there are more employment opportunities and sparks of population growth.

When a serious flood causes widespread damage to the area, the public and local decision-makers band together and neighbors come to help. Agricultural lands and roads are most affected, but private property damages are worse in some areas over others. Towns aid their citizens as best they can, but most aid efforts are community-based and volunteer-oriented. Religious organizations and non-profits take the lead in efforts to get individuals and families back on their feet. Local businesses are struggling as well, but contribute to the aid in whatever ways they can. Fortunately copper prices are high at this time and mining companies give out grants and fund the rebuilding of roads that are necessary for shipping routes.

As the drought drags on with only dwindling glimpses of relief during intense storms in the fall and winter, **groundwater is pumped to greater depths** as towns endeavor to provide a reliable water source to its population. Water shortage alerts are broadcasted and placing limits on agricultural water use is strongly supported by some and gaining popularity with other groups. **Support for direct potable reuse** is present in pockets, but decisions take a long time to receive approval and the public is unwilling to take the leap just yet.

Questions to Consider:

1. What public-private partnerships exist that could be expanded or modeled to create more sustainable solutions to problems that affect everyone, such as water availability?
2. What model ordinances, codes and plans can be anticipated or adopted locally ahead of time to pre-empt the need to conform to 'new' federal standards?
3. What are the largest hurdles facing the development of direct potable reuse in communities of the Gila Watershed? What kind of steps can be taken now to help prepare for that possible eventuality?



Year 20 and Beyond (2035 +)

By the year 2025, the drought has continued and intensified to the point that **winter months no longer see any significant rise in groundwater recharge** and well levels drop dramatically. The public feels the strain as taxes are increased yet again and restrictions are enforced for all landscaping water use. New technology allows utilities to meter individual homes and charge **large fines for overages in water use**.

Local governments attempt to halt any new growth of their service demands and cut back in any way possible, which eliminates the possibility of new economic growth. At this point, agriculture has felt the heat (and dryness) for over a decade and several farms have gone out of production, but water shortages have finally become so severe that **agriculture can no longer survive in the valley**. As agriculture leaves the area, farming as an economic and cultural mainstay of the area eventually becomes a piece of historical hearsay. People look to large high-tech businesses for the future of employment and economic stability in the area. Although, with the water shortage being reported nationally and through every media outlet, no businesses are willing to take the glaring risk of moving in.

The impacts of the tamarisk beetle's arrival in Gila Watershed have been felt for some time now and different stages of defoliation of tamarisk trees have been witnessed locally. The desperate situation for the Southwest Willow Flycatcher and link to the tamarisk defoliation have garnered national attention in certain instances. This issue has prompted more federal action and involvement in local affairs as **endangered species are more threatened than ever in the Upper Gila**. Unwillingness to cooperate with federal entities is blatant now that an absence of federal interference has largely been standard for a decade's time. Using contracted organizations as the bridge, the federal government gains more traction with restoration projects that require landowner involvement.

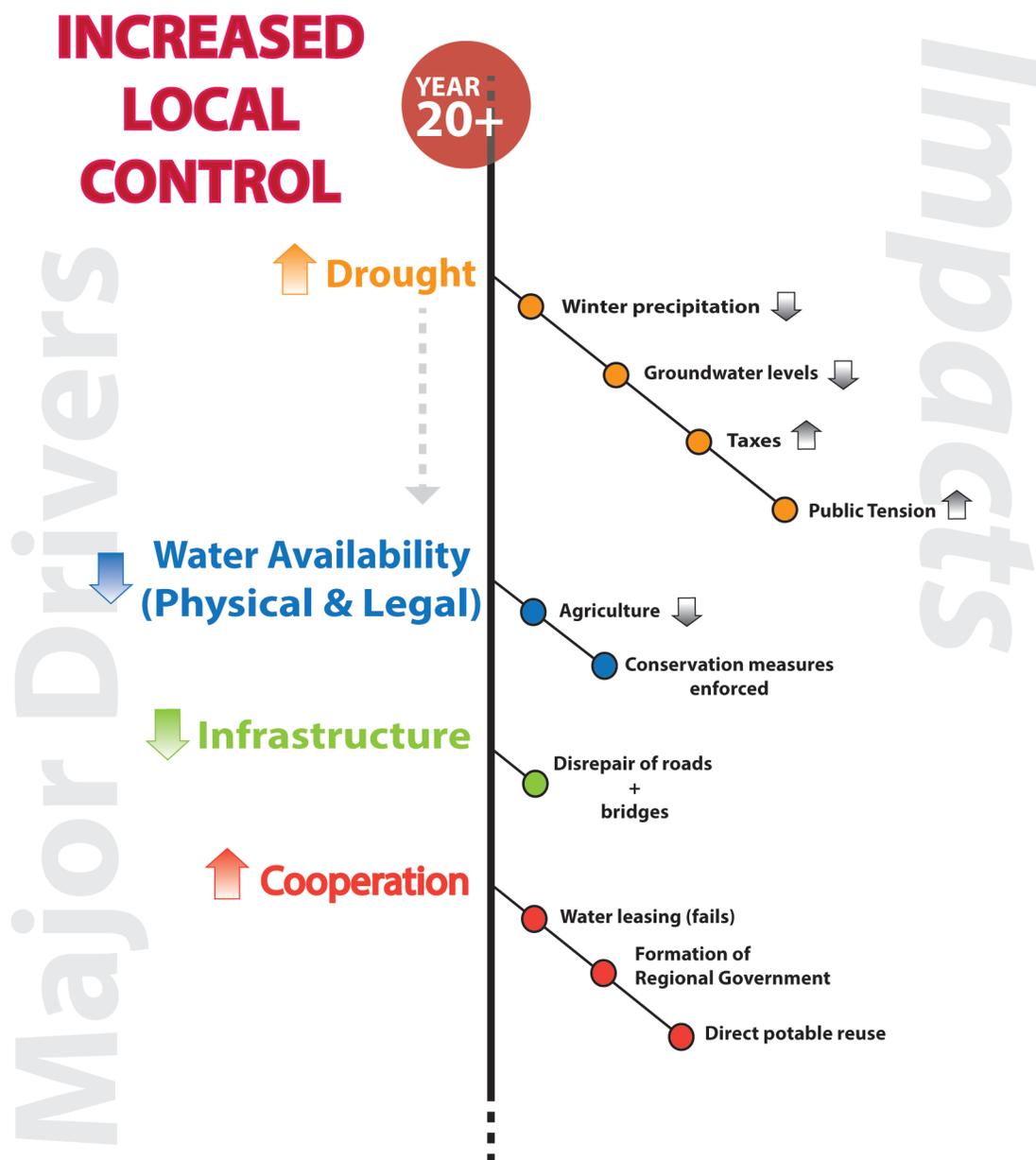
The media and citizenry is targeting local government leadership as the source of negligence and mismanagement of resources, which has led to a perceived ill-preparedness. Suggestions and **instances of recall votes are numerous**. Solutions are badly needed as these tensions rise. With these dire circumstances in mind along with the hardships of the 2025 flood still fresh in the collective memory, **a regional planning authority is created** with the intention to coordinate land use and water planning. Overcoming town differences, crossing county borders, and reconciling individual preferences is a contentious affair, but a lack of options and alternatives proves the necessity of a shift. The first act of this partnership of governments is to jointly lease water from the San Carlos Apache Tribe. When negotiations fall through with the Tribe, the partnership transfers its attention to brokering the same water deal with New Mexico. The deal goes through, but this **highly expensive "fix" can't last long** and financial resources are heavily strained to the point of breaking.

By pooling resources and dedicating the time to public outreach, the regional government is able start the process of installing a **direct potable reuse system throughout the area**. Refitting of past and future development for environmentally-friendly standards creates a new economic market – though, an expensive one. Meanwhile, without the aid of federal government funds, **roads and bridges are in a sad state of disrepair** for the most part. While incomes have risen with time, maintaining yesterday's quality of living standards is difficult because of inflation. Incorporation into even larger regional governments is on the horizon in order to unite powers and resources for the overarching goal of finding water to keep Arizonan towns alive. The **prospect of new technology** to make water available from

either brackish sources or other localities is a hope and expectation.

Questions to consider:

1. Where would people go if a 500-year flood hit the valley tomorrow?
2. How many people could be sheltered by current emergency relief provisions?
3. What are the recovery options for after a major natural disaster?



Scenario 3(b): Increased federal control

Year 10 (2025)

The year is 2025 and, with a federalist swing in the political tide, the nation's government has asserted control over local codes and laws by **several expansions of authority** (i.e. under the Clean Water Act and the Endangered Species Act). One of the stated goals of this shift is to reorganize federal-state-local partnerships in order to better integrate vertical and horizontal planning efforts for a more sustainable country and future. Coordinating each level of government to integrate water and land planning is a top priority. Stricter standards are enforced, which closely follow nationwide trends in environmental conservation, resulting in requirements such as stormwater infrastructure. **Negative stormwater runoff effects**, such as flooding, should be diverted on a regional scale as infrastructure projects are implemented throughout the federally controlled jurisdictions. Construction standards, flood plain restrictions, land use plans, zoning, and new building codes are all put under **heightened pressure to reflect designated conservation measures**.

Consequently, **local considerations and concerns take a backseat to national priorities** as funding and capital improvements are steered toward regional development and national standards. Community leaders and members are unsupportive as they perceive the integrity of local concerns to be compromised by a national agenda that does not take their values and priorities into account. There is **widespread criticism that this heightened level of federal involvement only exacerbates the tensions between competing management agencies and increases the number of policies to which local governments must adhere**.⁴² The time to gain approval and begin projects takes longer than ever as the web of agencies, motivations, restrictions, partnerships and funding sources become increasingly complex and difficult to navigate. Other difficulties arise as the stormwater infrastructure that is advocated by federal agencies is based on models researched in wetter climates of the American Midwest and Northeast regions, leading to time-consuming and **expensive attempts to fit square infrastructure shapes into round, desert holes**.

After years of seeing only a small number of species being removed from the endangered species list, ESA regulatory reform creates **stricter laws and enforces new codes** to ensure regional implementation efforts. These mandates hit hard in the Valley, prompting discord at the threat of private property rights being too heavily burdened. In response to the increased regulation, more clarity is called for to explain the decisions to add more species to the list. Thus, more bureaucracy in the ESA is promoted by more visibility, which involves more paperwork, publishing of data, and review. **Relations with landowners are continuously strained** as planning efforts are diverted away from local concerns and money is spent in ways in which the populace does not support. The restoration efforts are narrowly focused, but widespread and large scale effects can be seen as more lands are put under protection and riparian areas are closely monitored. To the chagrin of landowners, **greater populations of the endangered southwest willow flycatcher are recorded in the area**, indicating benefits to the species but without concrete proof of progress for the ecological system or biodiversity. In an effort to gain more cooperation with ESA goals and regulations, **tax breaks are initiated for landowners** affected by restoration efforts on their property. This legislation receives some good will, but it cannot mend the breadth of damaged fences.

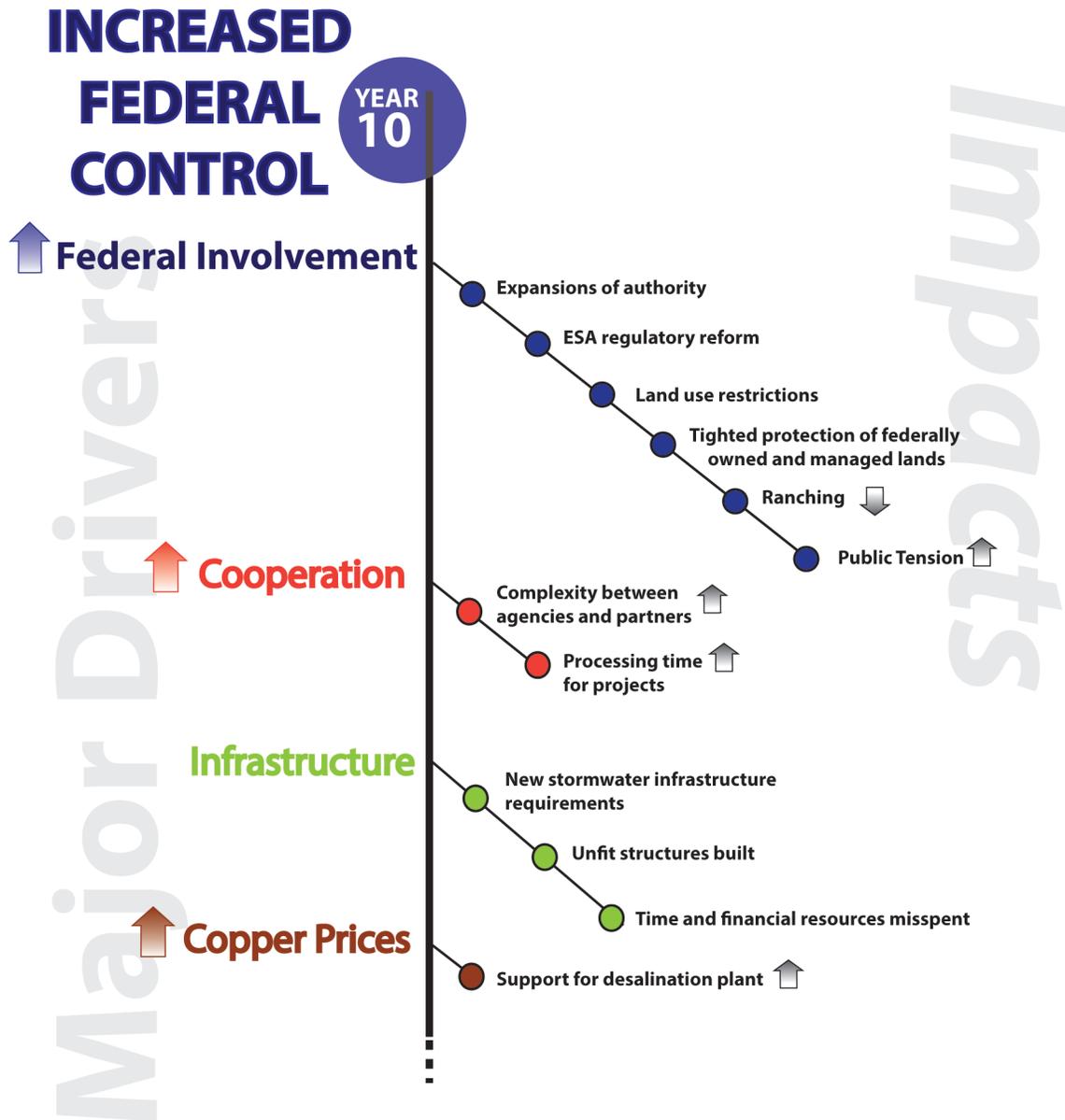
Ranching is hit hard in the region as control of federally-owned land is tightened. When contracts for rangeland allotments end, many are not renewed by the BLM or other manag-

ing agencies as **large expanses of land are designated as sensitive ecological areas**. All other rangeland contracts are offered only on condition of acceptance of more terms including heightened restrictions on the number of head of cattle per acre, shortened length of grazing, etc. At the end of this period, of the 76% of land owned and managed by federal agencies, e.g., Bureau of Land Management, United States Forest Service, Bureau of Indian Affairs, and Bureau of Reclamation, in the watershed, only a small percentage of that is available for the use by ranchers to lease or graze.

The planning of a federally funded desalination plant begins consideration of utilizing the large stores of saline water in the basin-fill aquifer. This project will require local governments to implement strict conservation measures and restrict groundwater pumping to receive the treated water, which are not supported by a populace that is already wary of an interfering federal government. Thus, not only does public discontent slow this planning stage, but it becomes evident early-on that federal funds will not cover the high costs of constructing and running a desalination plant, especially disposing of the byproduct of the process. The plan is almost thrown out as infeasible and costly when a startling rise in copper prices and mining activity allows a conversation to be struck between government officials and FMI to make up the necessary funding for a desalination plant. The plan remains an option; negotiations begin.

Questions to Consider:

- 1. What public-private partnerships exist that could be expanded or modeled to create more sustainable solutions to problems that affect everyone, such as water availability?*
- 2. What model ordinances, codes and plans can be anticipated or adopted locally ahead of time to pre-empt the need to conform to 'new' federal standards?*



Year 20 and Beyond (2035 +)

The year is now 2035 and **federal control has been strongly exerted over local governments to promote national interests across large regions for 20 years**. Drought has intensified leading to a dramatic drop in groundwater levels, which are the sole water supplies relied upon for municipal and agricultural uses. As groundwater and streamflow are intimately linked, riparian areas suffer and wildlife habitat is degraded despite extensive ecosystem management efforts. The increased severity of climatic forces such as drought, bouts of flood and fire damage slow and undo restoration efforts. **Agriculture is losing the ability to function** as water shortages are extremely severe and wells need to be drilled deeper and deeper, which is a costly project that is not possible for farmers that have already seen hard times. As farming disappears, pollution and negative agricultural runoff effects like phosphorous and nitrate pollution decrease. **Local economy reflects the loss**

of agricultural industry.

Agreements were reached; federal and private funding has been allocated so that the **desalination plant is nearing completion** and has the ability to provide communities with a reliable, but expensive water supply. As a baseline comparison value, the 2012 average cost to produce 1 acre-foot of desalinated water from brackish groundwater ranged from \$357 to \$782 in Texas.⁴³ After over 20 years of innovations in technology, the costs of the desalination process have only lowered slightly as energy prices have continued to rise. Taxes now account for almost 25 percent of the average household income. Additionally, the question of **dealing with the desalination byproduct of brine is a daunting question** and the plant cannot start functioning until a storage or dump site is located.

Meanwhile, higher levels of regulation and enforcement are required to receive benefits from federally funded projects. There is a **loss of local identity and unique sense of place** as the federal government continues to require national standards in most aspects of education, health, environmental conservation, land development, etc. The 5 C's of Arizona include cotton and cattle; the inability of the climate and policies to support these staples ultimately results in the diminishment of agriculture in the Southwest and take with it traditionally perceived characteristics that make up the local identity.

A series of 'storms of the century' cause widespread damage to infrastructure, crops and private property. Funding to help manage large-scale emergency response and recovery operations is shared across regions. Resources are directed towards most impacted areas and political minorities and neglected areas lose out. Areas are rebuilt, but not improved. The population decreases due to funding and resource allocation issues and further tax increases are proposed in order to support the new desalination plant. Reformed land use patterns are observed as a result of reactionary efforts to reduce hazardous storm effects in the future.

Questions to Consider:

- 1. What are forms of either official petition or political activism that are effective when the people do not agree with their government's decisions? Are there success stories to look to or larger partnerships to join?*
- 2. In what ways can regular people become involved with their local governments?*
- 3. How are these modes of involvement advertised to the public?*
- 4. What kinds of sustainable, drought-tolerant agriculture might replace the more intensive, higher water use crops that will disappear as a result of water shortages?*
- 5. How might the region benefit from new water conserving technology?*

INCREASED FEDERAL CONTROL

YEAR 20+

↑ Federal Involvement

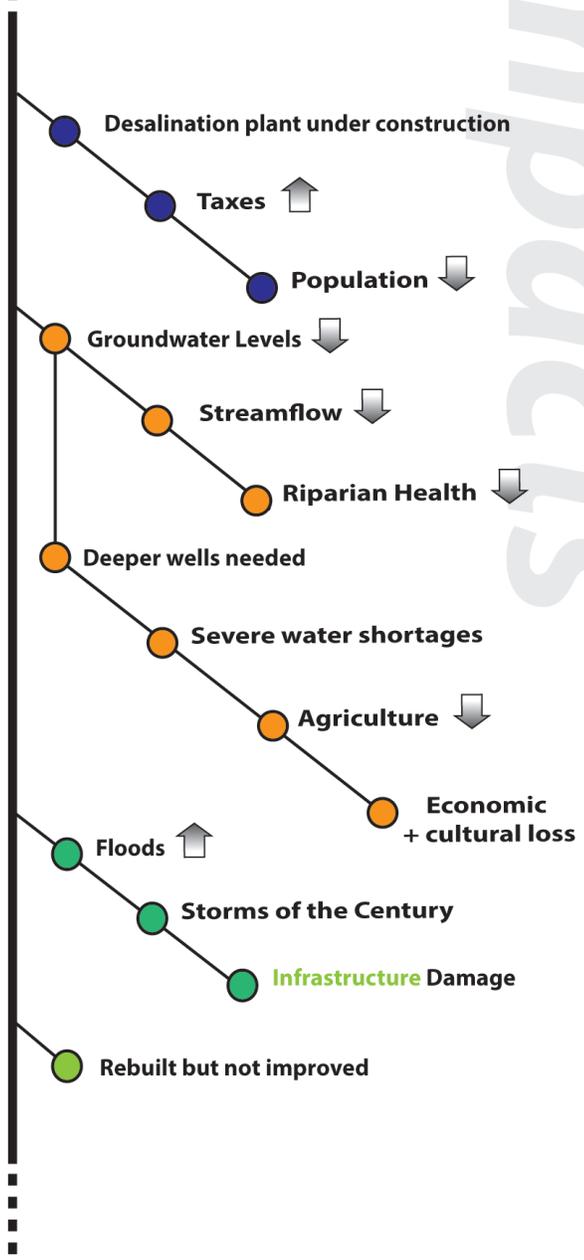
↑ Drought

↑ Intense Storms

Infrastructure

Major Drivers

Impacts



SCENARIO 4 – From Cotton Boll to Dust Bowl: Fluctuation in Cotton Prices

Why is it uncertain?

Cotton farming involves a suite of uncertainties. The price of cotton internationally and within the United States fluctuates based on weather, consumer demand, and speculation on the commodities market. Rising fuel, energy, and utility costs can also have a significant impact on associated costs of producing cotton. Finally, government policy, e.g., the Farm Bill, and regulation, e.g., Clean Water Act, can influence the price farmers receive for their cotton or cost to produce it. Beyond prices and policies other factors such as pests, like the pink worm and boll weevil, can further contribute to the uncertainty of cotton farming. Ultimately when the market demand for cotton fluctuates, farmers are provided with few options but to accept the buying price.

Why is it important for the future of the watershed?

The cowboy, the miner, the farmer, the fruit grower, and the health seeker are inextricable parts of our history- and our mythology. They personify who we are and what we strive to be. But, most of all, they are reminders of the optimistic outlook and pioneering spirit that continues to motivate Arizona and Arizonans. From this perspective, they are as relevant as ever.

– Bruce Dinges, Arizona Historical Society ⁴⁴

As one of the 5 C's, cotton farming is an important cultural and economic element in the towns within the Upper Gila Watershed. Overall cotton farming only contributes 0.1% to the Arizona GDP. In 2012, 14% of the population in Graham County and 48% of the population in Greenlee County were employed by agriculture, forestry, fishing and hunting, and mining. ⁴⁵ Statewide, only 1.4% of the population is employed in agriculture, forestry, fishing and hunting, and mining. ⁴⁶ Agriculture uses a significant amount of water compared to other uses. In the Safford groundwater basin, 181,700 acre-feet of water per year is used on average for agriculture as compared to 3,300 acre-feet per year for municipal uses. ⁴⁷ Cotton specifically needs about 2.5 acre-feet of water per acre. These scenarios explore what might happen in the Upper Gila Watershed if cotton prices drop or rise extensively over a 30 year period.

Scenario 4(a): Low cotton prices on average

Year 10 (2025)

The year is 2025 and a lack of market demand for cotton combined with global competition begins to lower cotton prices appreciably throughout the United States and in Arizona. ⁴⁸ The buying price of cotton has only reached break-even rates of approximately 72 cents per pound for a single year out of the last ten, while **prices have even sunk to the levels from the Great Depression era for two years**. Otherwise, there have only been sporadic and inconsequential rises in prices that do not even cover production costs – seed, labor, shipping, etc. Cotton farmers are able to keep afloat and continue production in these first ten years, but the financial strain is felt throughout the community. **Seasonal employment drops** in the region as farmers cannot afford as many laborers during peak season. The average wage for farm work also falls. There is less money to spend in the communities as

a whole and **Main Street businesses suffer.**

When major storms hit China, the top producer of cotton in the world, causing massive damage to the crops early in the planting season, economic forecasting widely predicts that the demand for cotton would be high and the product scarce. Prices for U.S. cotton are roundly predicted to increase by as much as 42%, which would be significant enough to provide a net profit for farmers for the first time in ten years. Based on these seemingly trustworthy forecasts, several farmers in the valley pre-sell their crop months in advance. However, a bad crop year coincides with this series of events due to a Bt-resistant insect species that attacks cotton at an unprecedented rate.⁴⁸ Farmers begin heavy pesticide use to fight the invasion of insect, but with little success. **The increased pesticide use has negative impacts on stream quality and aquatic life.** Furthermore, due to international market forces, including the Indian government stepping up cotton production and accepting lower prices than the U.S., the price for cotton is only 10% higher after all, which puts farmers below break-even level once again. Market loss assistance and crop insurance premium subsidy programs available from the federal government are of some relief to farmers, but just enough to keep heads above water as debt rises.

By the end of a ten year period, **many fields are appearing fallow** in order to save money by not planting full acreage with the record-low cotton prices. The federal government also provides financial incentives to farmers to leave their fields fallow to conserve water in light of worsening drought. This also means that farmers have stopped rotating their fields with alfalfa, so **ranchers must spend money on feed from outside the Valley.** The **federal government is relied upon** heavily during this time to supply farm subsidies, benefits, grants, loans, and financial aid. Temperatures increase on average leading to greater evapotranspiration and a general “drying out,” which is most distinguishable in historical wetter seasons as people miss the landscape greening with the rains. **Erosion and air quality problems increase as the drought is cruel to dry, dusty fields** that are left to the open air. The public contests the air quality problems at public meetings and there is tension between homeowners and farmers. As the low prices wear on, water is leased to other uses as farmers endeavor to maintain their water rights.

At this point, the tail-end of **a large tropical storm hits** the Valley and major flooding occurs. After a few successive years of fallow fields, there is little vegetation to hold soil in place for large expanses of area, which allows massive **erosion and sedimentation** that results in dramatic **stream degradation.** Property damages are severe and the already strained cotton industry is almost entirely dependent upon federal aid to restore their operations. The communities at large are too burdened with their own rebuilding efforts to be concerned with the struggling agricultural community.

LOW COTTON

YEAR 10

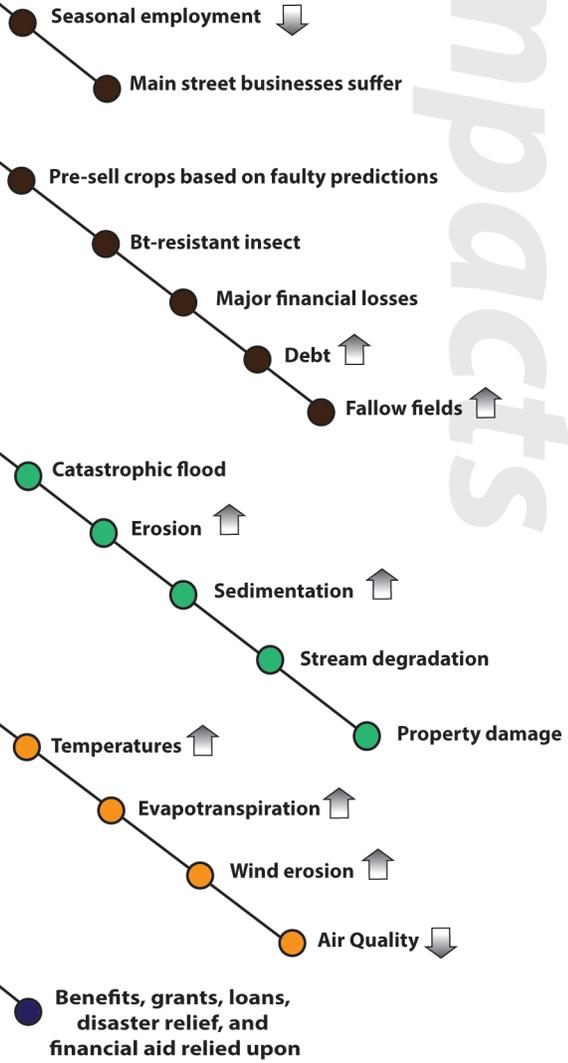
Major Drivers

Impacts

↑ Intense Storms

↑ Drought

↑ Federal Involvement



Year 20 and Beyond (2035 +)

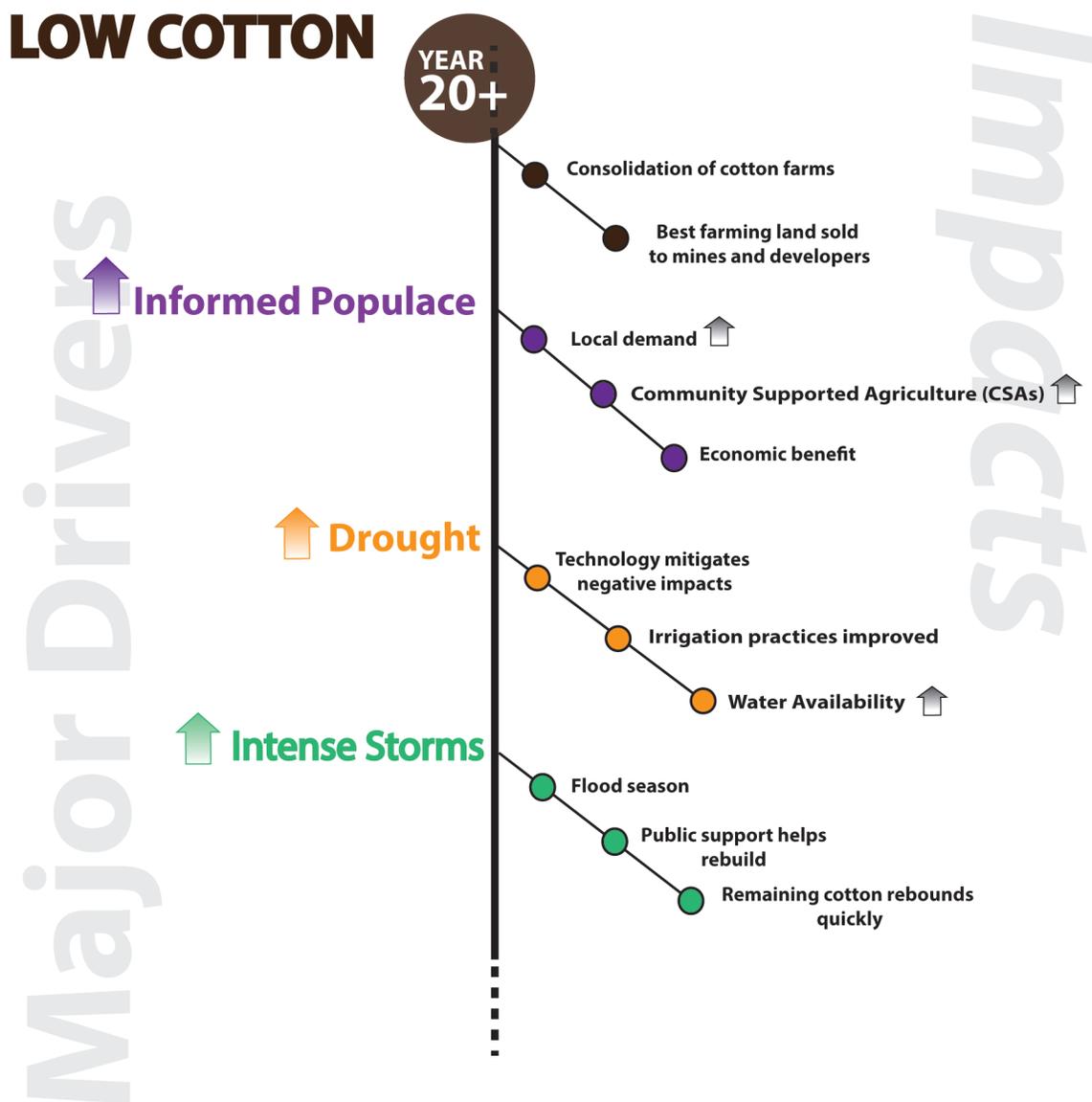
By the year 2035, the price for cotton seems permanently low and **cotton farming has all but ceased to exist in the valley** except for one large green spot on the map. This green spot is the result of a few cotton farmers who have consolidated in order to pool resources and support one large cotton operation that has the capacity to weather the bad years for a while longer. Other farmers have sold their land to developers and mining companies, so that some of **the best agricultural land in the watershed is put out of production forever**.

After the events of 2025, a few farmers cut their losses in cotton and took advantage of the growing popularity and sustainability of **community supported agriculture (CSA)**. Although cotton has historically been a prosperous crop because it is suited to the saline soils found in the region, increases in technology (genetically modifying vegetables to be more salt tolerant) makes other crop-raising a successful option.⁵⁰ With the help of outside supporters of CSA's from Tucson and Phoenix, farms shifted over to vegetables and fruits. This shift required heavy investment to provide an infrastructure for storing and shipping different crops than cotton, but federal sources, private loans, and wide community support made the transition possible. Due to a learning curve and operational hiccups, the first years of vegetable farming is difficult and the amount of crops going to market is relatively low. Luckily, there is a wide demand for their crops nearby and people are willing to pay more to support their local economy and community. Operations are expanded and a greater variety of fruits and vegetables is able to be grown. **Employment is boosted in the area** and there is some new blood in the communities as the Upper Gila region begins to be known as a CSA hub. Additionally, farmer's markets in the region and in nearby cities are large enterprises as buying locally is emphasized throughout Arizona, and the United States, in order to boost local economies and limit produce imports.

Just as there is a **surprising rise in cotton prices and CSA's are moving out of the red**, a season of intense storms sweeps into Arizona and hits the watershed especially hard. **Damage to fields and diversion dams** requires hard-to-find capital to restore fields and restart farming operations. At the threat of cotton disappearing in the past decade, there has been an increased public awareness of the cultural and economic value associated with Arizonan agriculture. Support is expressed throughout communities with fundraisers and advocacy to "Buy American" and increase cotton-utilizing textiles in the U.S. A Main Street shop opens up, selling clothes made from cotton produced locally. Technological advances in agricultural practices allow cotton and other crops to be produced at less cost to the farmer and with greater efficiency of water application. The one mega-farm that has survived the protracted depression in cotton prices takes full advantage of this technology and yields per acre increase significantly. **The drought has continued and intensified, but water efficiency in irrigation methods and their associated maintenance, including drip irrigation, has lowered agricultural water use and spray-irrigation is no longer utilized** due to the high evapotranspiration rates. This also means that there is less return flow infiltrating to the groundwater during winter months and supporting riparian areas, which has negative consequences for wildlife habitat and biodiversity decreases.

Questions to Consider:

1. What could be done to support cotton farmers when cotton prices are low for prolonged periods of time?
2. What proactive steps could be taken to reduce air quality concerns? Are there more local solutions to supporting farming in the Gila Valley?
3. How can CSA's and farmers markets be established and supported now to create the precedent and market for future crops and fluctuating demands?
4. What would be some long-lasting effects of losing cotton in the Valley as this scenario presents?



Scenario 4(b): High cotton prices on average

Year 10 (2025)

The year is 2025 and cotton prices have been higher on average for the last several years due to **less acreage worldwide being devoted to the crop resulting in a shortage**. The United States continues to be one of the only countries to support the cotton industry with subsidies and insurance, while the high production costs put farmers in other countries out of business, especially those countries with limited access to highly-mechanized agricultural methods. Floods in Australia and Southeast Asia also lower the input of cotton product on the market and further increase the price. This is a **golden era for cotton farming in the U.S. and Arizona** as cotton prices are higher than in even the Civil War – almost \$2.50 per pound. Farmers in the valley are ready to take full advantage of this good fortune by putting every acre into production, hiring more workers, and fully utilizing their water rights. Increased revenue allows application of new technologies that yield more crop and require less water. **This scale of farming also requires more frequent shipping schedules, increasing non-point pollution and resulting in negative impacts to air quality and infrastructure conditions.**⁵¹

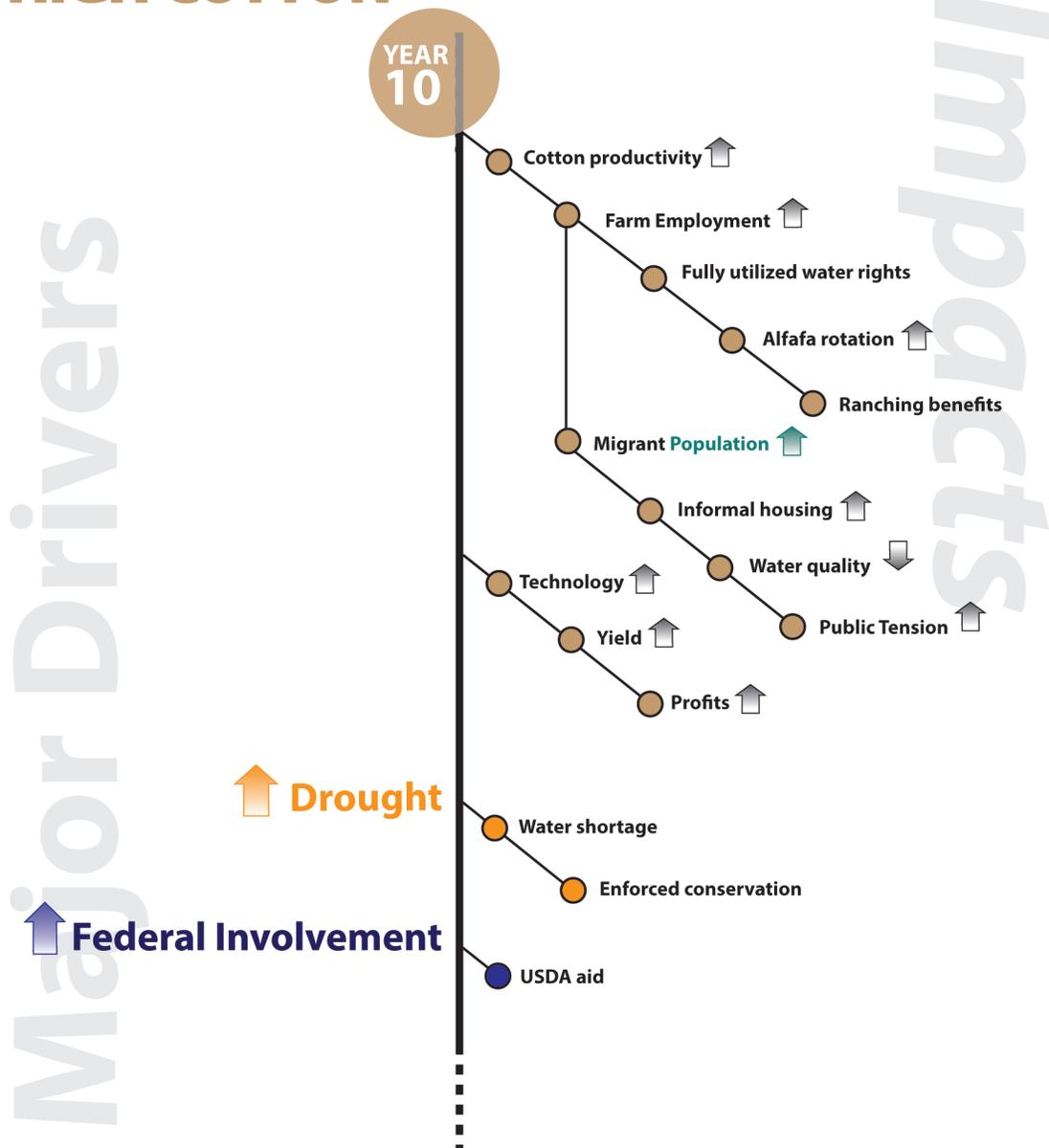
To meet the increased labor demands, there is an **influx of migrant workers**. Since a lack of affordable housing makes it nearly impossible for workers to reside close to the fields, temporary and unsanitary accommodations result in small settlements on federal land outside of towns. These circumstances are blamed for **increased incidence of water-related disease, increased inequity, and weak community infrastructure**. Town residents resent the presence of these encampments and urge their public officials to remedy the situation. Local government struggles to provide an adequate police force for the temporary population.

Ranching in the Valley benefits as cotton farmers rotate their fields with alfalfa, allowing ranchers to buy locally and at lower cost for feed. Water shortages and enforced conservation policies that are imposed on the general public. Groups of citizens write their legislators to put greater restrictions on agricultural uses of water, which heightens political pressure. As water supplies dwindle, cotton farmers band together and seek strong representation in state congress to ensure their supplies. Federal resources provided by the USDA, who still considers Arizona as a drought “disaster area,” are used to keep water in cotton fields.

Questions to Consider:

1. What steps can be taken to diversify agricultural production in the Valley?
2. In anticipation of the increased demand for farm labor, what land use policies and zoning can be developed with regard to work-force housing and schools?
3. How can creative solutions be encouraged among the agricultural industry with the high level of risk involved with involved with yearly production rates and crop prices?

HIGH COTTON



Year 20 and Beyond (2035 +)

As cotton prices have remained consistently high in the last twenty years with only slight drops from time to time, cotton is earning the title of “cash crop” once more – or it is dubbed that way by popular media. Farmers and those involved with the cotton industry know the **pressures that drive up production costs and reduce total revenues**. The land becomes degraded as it is untiringly cultivated and some farmers shorten their crop rotations to maximize profits. While cotton can do well in saline soils, the rising salinity in the limited water supply is becoming more of a cost and concern for farmers. Noticeable soil degradation occurs and farmers must cope with **problems of increased salinity** that is negatively affecting production. Responding to these issues is increasingly costly for farmers and employment falls somewhat to make up for the expense and negative consequences for intensive cotton production. The drought marches on and there is damage to riparian areas and downstream ecosystems due to reduced water quantity and quality. Due to water shortages on the Gila, farmers are pumping groundwater for almost all of their irrigation needs. Cotton production is now functioning at almost 100 percent efficiency and technological advances are attractive to farmers when they become available. **All the water used goes directly to the crops and almost none is returned to nature or travels downstream.**

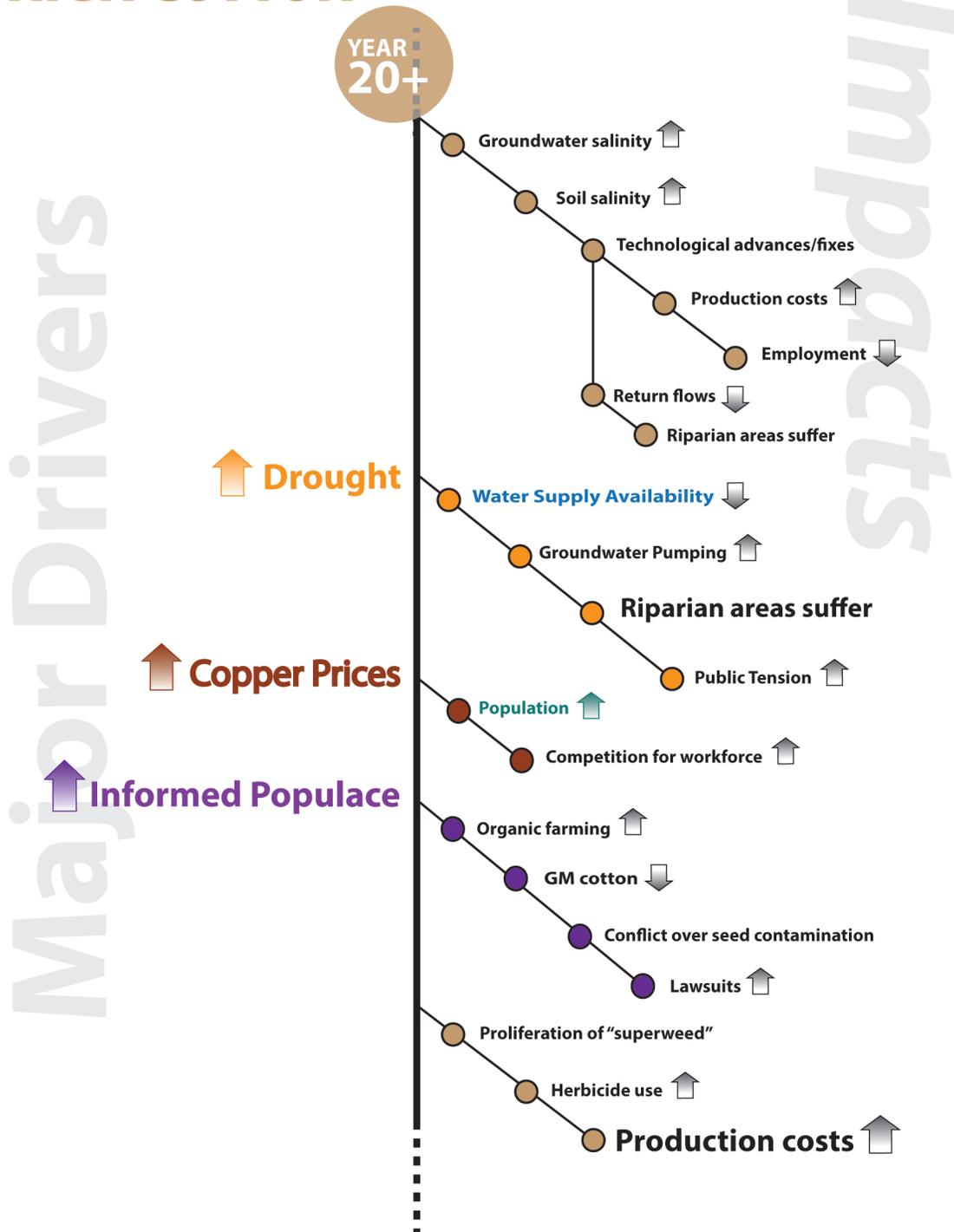
Around this time, **copper prices increase significantly** and mining picks up in activity after a long lull in the region. This additional economic stimulus allows population growth and development in the region, as well as competition for resources as more people move in and cotton land doesn’t budge. Fast, cheap construction activity increases where it can. There is **competition for the available workforce between cotton and mining**. The mining industry is able to give higher wages to its workforce on average, so cotton farmers strain to find reliable labor.

Organic cotton farming gains significant traction nationally and some farmers in the Valley have made the switch because of the higher price that is offered with the higher demand. Increased incident of malignant tumors found throughout the US has been a story avidly reported on by the major media sources and the link to pesticide use is the targeted as the main cause. As a result of media coverage and a well-publicized, groundbreaking lawsuit in which a biotech company producing GMO seeds lost against the plaintiff (consisting of a coalition of organic farmers), the **“buying organic” sees a dramatic rise** throughout the country and all agricultural sectors are shifting to meet this demand. Cotton is also under pressure to meet this demand as well and after several years of organic yields, the USDA reports that the use of genetically modified seeds has gone from around 95 percent down to 60 percent. Conflict arises between neighboring farmers in the cotton community as contamination of GMO seeds into organic fields is a consistent issue. While the patent law is under debate, organic farmers are still responsible for keeping genetically modified seeds out of their fields. Failure to do so exposes them to potential lawsuits for violating patent law and could cost them organic certification if the contamination is more than five percent.

However, after almost 30 years of the domination of cotton fields by Bt cotton in US and throughout cotton-growing countries, the **emergence of a seemingly unstoppable “superweed”** has become a major threat against cotton production, both GMO and organic. Much greater application of herbicide is required to combat these resistant weeds along with investments in research of new methods to combat the pernicious weed, which means more cost for the farmer and **heightened levels of toxins in the air, soil, and water** in the meantime.

Between lawsuits, an expensive and limited water supply, and costly production investments, the higher cost of cotton is not covering the cost of producing cotton in Arizona. As a cultural legacy of the Valley and encouraged by high prices, cotton farmers and their supporters press on to keep cotton as a 5 C of the state.

HIGH COTTON



What's Next? Using the Scenarios to Build a Watershed Plan

The scenarios and major drivers described here paint a picture of the issues the Upper Gila Watershed may face in the future. Over the next two years the WRRC, through funding by the Bureau of Reclamation, will work with the Gila Watershed Partnership and others to explore answers to the scenario key questions, and other questions you may have, and use these answers to shape a plan for managing the watershed's land and water resources. Much like the creation of these scenarios, the format the "watershed plan" will take is entirely up to you.

Work on the plan will begin in November 2014 with the formation of a steering committee, who we will depend upon to help us make critical decisions about the format of the watershed plan, what is included within it, management goals and objectives, and metrics for measuring successful implementation of the plan. One of the key elements in 2015 will be to take a closer look at water supply and demand in the watershed through the creation of water budgets and alternatives to closing any gaps between water supply and demand. Even if you choose not participate in the steering committee, we still hope to have your help in early 2015 when we will host a workshop similar to those for the baseline assessment and scenario planning, to come together as a larger group to discuss the scenario questions and decide on watershed management needs and objectives.



Appendix I

How to Read the Scenario Diagrams

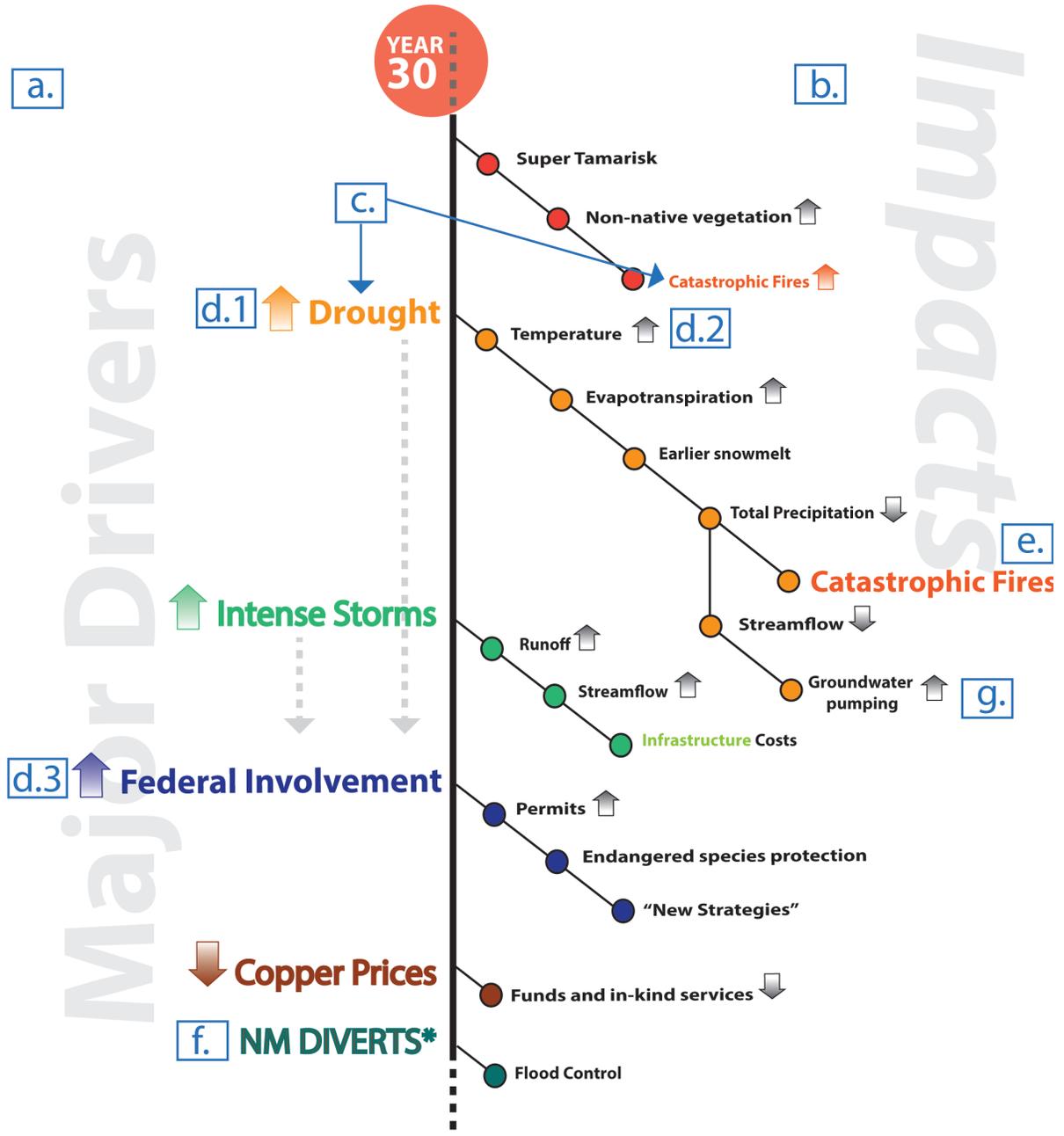
To help pull together driving forces and their impacts for a succinct review, a snapshot of scenario events is provided at time markers: Year 10, Year 20(+), and Year 30. For each of these timeframes within the scenarios, a synopsis of the events and impacts that have occurred by that year mark is visually represented. These diagrams are not detailed guides that explain the progression and complexity of all the scenario events – they are supplementary to reading to help summarize and reinforce main points. *The diagrams are brief summaries of scenario events – they are not timelines.*

Tips for interpreting the scenario diagrams:

(Refer to the following page, Tamarisk Beetle diagram at Year 30, for examples of the explanations offered below. Letters are indicated next to the feature discussed.)

- a. The scenario event and major drivers of the scenario are located on the left side of the diagram
- b. Impacts specific to the event/driver branch off on the right side
- c. All major drivers are colored differently and can be located on the “Driver” or the “Impact” side of the diagram, because the drivers effect each other
- d.  and  indicate whether a driver or factor has increased/decreased (refer to respective scenario narratives for further detail into why something increased/decreased)
Examples: (d.1) drought increases as a major driver of the scenario narrative, (d.2) temperature increases due to drought, (d.3) federal involvement increases due to the increased severity of drought and intense storms
- e. “Impacts” with larger text size indicate the compounding effect of that impact occurring more than once within a single scenario timeframe – i.e. the impact has more significance because of its multiple appearances
Example: catastrophic fire has increased as an impact of the tamarisk defoliation and also because of drought
- f. An asterisk indicates another scenario impacting the current scenario
Example: NM Diverts (Scenario 1a) may have an impact of flood control for the Tamarisk Beetle Scenario
- g. The impacts branch off from the major drivers or from the main scenario event. An impact can also initiate another branch of impacts.

TAMARISK BEETLE



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³⁷ Dudley, T. (2006)

³⁸ Hultine, K.R. et al., 2010; Kevin R Hultine et al., 2010

³⁹ The observed rate of ET loss varies widely in the literature, where low levels around 15% (and sometimes less) have been documented in the field. Further, subsequent revegetation in late summer after the beetle enters dormancy leads to a return to earlier ET levels.

⁴⁰ Federal agencies are directed, under section 7(a)(1) of the ESA, to utilize their authorities to carry out programs for the conservation of threatened and endangered species. Thus, Federal agencies must consult with NOAA Fisheries Service and/or FWS, under section 7(a)(2) of the ESA, on activities that may affect a listed species.

⁴¹ From the turn of the century, the governments of a given locality have been deemed the appropriate agencies for planning physical development. Throughout past decades, judges and legal scholars have communicated doubts that local governments make land development decisions "with a reasonable distribution of burdens among individuals, and with the care and deliberation commensurate with the long-term implications of land development." (See: Rose, C. (1983). "Planning and Dealing: Piecemeal Land Controls as a Problem of Local Legitimacy." In *California Law Review* Vol. 71: 3.) However, the more recent trend, especially in largely urbanized areas, has been toward coordinated, regional planning and development.

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⁴⁹ Bt cotton seeds, intellectual property of Monsanto Company, are used by most cotton farmers throughout the United States. The seeds are encoded with extra genes containing the soil dwelling bacterium, *Bacillus thuringiensis*, which cause the cotton plant cells to produce crystal insecticidal proteins to protect against pests (Hardee, D.D. et al. *Bt Cotton & Management of the Tobacco Budworm-Bollworm Complex*. USDA, 2001.)

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Below the gaging station near Solomon large amounts of water are diverted from the Gila River for irrigation and the river receives considerable inflow from groundwater and irrigation return flows. As a result large increases occur in the concentration of dissolved solids in the river water. The average concentration of dissolved solids at the head of the Safford Valley near Solomon is 562 mg/l (Earth-info, Inc., 1992). The mineral matter of the water passing through the Safford Valley consists mostly of sodium, chloride, and sulfate. (ADWR, http://www.azwater.gov/azdwr/StatewidePlanning/RuralPrograms/OutsideAMAs_PDFs_for_web/Southeastern_Arizona_Planning_Area/Upper_Gila_River_Watershed.pdf)