The Cornerstones Report

Market-based Responses to Arizona's Water Sustainability Challenges

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Acronyms

ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
AF	acre-feet
AMA	Active Management Area
ASR	aquifer storage and recovery
AWS	Assured Water Supply
CAP	Central Arizona Project
DRC	Deschutes River Conservancy
GMA	Groundwater Management Act
HCP	Habitat Conservation Plans
MAF	million acre-feet
SRP	Salt River Project
SPRNCA	San Pedro Riparian National Conservation Area
SAR	shallow aquifer recharge
SDCP	Sonoran Desert Conservation Plan

Glossary

Active Management Areas: Management regions defined under the 1980 Groundwater Management Act, which guides the development of plans and rules to achieve the management objectives established for each of the original Active Management Areas of Phoenix, Tucson, Pinal, and Prescott, as well as the Santa Cruz, which was split off from Tucson in 1994.

Adjudication: A legal proceeding to determine the extent, validity, and relative priority of surface water from the Gila River and Little Colorado Rivers. Underway since the 1970s, the adjudication delineates important administrative zones and subregions that affect the enabling conditions, institutional development, and water management rules. For example, both the Verde and San Pedro Subbasins have involved technical studies to distinguish groundwater and surface water rights.

Demand Management: A management strategy that seeks to enhance the water productivity (output per unit of water) or water efficiency (water required per unit of output).

Exempt Well: Wells for domestic and household use with a capacity of less than 35 gallons per minute. While these wells do require a permit, owners are not required to report how much water they pump, and are thus exempt from oversight.

Market: A place where buyers and sellers meet to trade. A water market entails a specific set of laws and rules that establish tradable property rights to water. The existence of a cap or limit on water use provides an incentive for trading in response to shifting values across competing uses.

Market-Based Responses: The use of tradable water rights and institutions to facilitate voluntary reallocation of water to meet environmental needs in overallocated areas.

Supply Augmentation: A management strategy that involves new infrastructure or technologies to enhance supply.

Water Stress: A condition that is the result of scarcity in the amount, timing, and quality of available water that may affect the degree to which human and/or ecosystem water requirements are met.

Water Sustainability: Meeting the interdependent water needs of people and ecosystems.

Executive Summary

Key Message: This report identifies the Cornerstones, or foundational elements, that are required to develop and apply market-based options to sustain the freshwater environment and the water users who depend on it. By examining these elements, we find that the barriers to market-based reallocation—namely the absence of sustainable limits on freshwater use, the lack of tradable water rights, and limited institutional capacity for measurement and enforcement—also hinder water sustainability efforts more broadly. Options for addressing these barriers are most effectively pursued at a local level in concert with state and federal agencies within the unique institutional, ecohydrological, and economic conditions of Arizona's water geographies.

Introduction

In 1986, the Ford Foundation touted the Arizona Groundwater Management Act for its innovative approach to water management. Thirty-one years after the Act's passage, Arizona's water-scarce future has arrived. The Act and the state's water management structure are hard-pressed to cope with the challenge of water scarcity. To help address this challenge, the Cornerstones Report has been prepared based on information gained from a series of workshops and associated research, with funding support from the Walton Family Foundation.

Cornerstones Process and Report

The Cornerstones Report focuses on water sustainability as the challenge of meeting the interdependent water needs of people and ecosystems within the context of intensifying water stress and competition for scarce water supplies. In May and July of 2010, representatives from nonprofit conservation groups, municipal water utilities, and water managers at the state and federal levels met to discuss water sustainability in Arizona, focussing specifically on how market-based approaches might contribute to the protection and restoration of ecosystem water needs. These specific groups were selected to develop a set of concepts and case studies intended to inform a broader range of stakeholders and water users.

The Cornerstones Report explores how market-based tools can contribute to the protection and restoration of ecosystem water needs. The overarching goal of this report is to demonstrate how a market-based response—defined as the use of tradable water rights by institutions to facilitate voluntary reallocation of water to meet ecological needs—can be an integral part of water management in Arizona. To meet this goal, the report identifies the foundational elements needed to develop and apply market-based options by examining:

- Arizona's water sustainability challenges and their driving forces
- The diverse water geographies in Arizona
- Market-based reallocation alternatives
- Challenges and opportunities for market-based responses

Outcomes from the Cornerstones process will depend upon ongoing policy and management discussions within the state and are defined within the context of Arizona's diverse geography of water.

Arizona's Water Sustainability Challenge and the Driving Factors of Water Stress

Achieving full water sustainability in Arizona would mean water is successfully divided among the water needs in the state—including maintaining the health of freshwater ecosystems—at a level that meets the goals of water users and the state.

Arizona's water sustainability challenge can be viewed through the lens of water stress, a condition wherein demands on water—including the needs of freshwater ecosystems—exceed reliable supplies, and the full range of water needs cannot be met without tradeoffs across multiple uses. Climate variability, prolonged drought, and growing demand exacerbate water stress around the state, as indicated by reductions in both freshwater ecosystem health and overall water availability.

Water stress influences not just ecosystems, but Arizona's economy, quality of life, and cultural heritage—each of which require water to thrive.

A defined set of forces has driven trends in Arizona's water stress. These forces and trends shape the barriers and opportunities to pursuing market-based approaches for improving water sustainability.

Law Inherited from the Past. The prior appropriation doctrine has wedded Arizona's surface water to history, freezing surface water allocations to historic uses and resulting in an ongoing struggle to cope with a changing climate and shifting demands. Additionally, Arizona law partitions the allocation and administration of groundwater and surface water.

Growth. Arizona has grown more rapidly than much of the nation, and recession may offer only a breather. Permanent water solutions are elusive, leaving the state with temporary triage strategies—conservation, groundwater overdraft, and aquifer recharge-and-recovery—that can buy time but not a long-term sustainable solution.

Change and Uncertainty. Climate change will exacerbate the challenge of managing risk and uncertainty in an already highly variable environment. Furthermore, while climate change science can frame the choices and tradeoffs that lie ahead, science cannot provide certainty about how changes will unfold.

This report identifies the Cornerstones, or foundational elements, that are required to develop and apply market-based options to sustain the freshwater environment and the water users who depend on it.

Tribal Settlements. Settlements have secured water for some tribes but not all, leaving future settlements as an unknown. Completed settlements have not always provided the water management flexibility expected. Additionally, settlement water may not be used for leasing to the degree expected.

Environment. Arizona's approach to environmental protection and regulation is premised upon a separation between the needs of people and the needs of freshwater ecosystems rather than on a connection between these needs. Due to land- and water-use changes and diminished water availability, significant segments of freshwater ecosystems have been lost across the state.

Competition and Conflict. Water managers are often focused on meeting local needs. Achieving water sustainability requires planning at both local and broad scales, building partnerships among all users—municipal, agricultural, industrial, mining, recreation, and ecosystem—and moving past zero-sum approaches, while respecting the diverse goals and values of all water users.

Institutional Capacity. The deficits in institutional capacity are primarily due to regulatory disconnects between elements (air, water, land, and species) and jurisdictions (federal, state, and local) and a lack of resources to fund agencies and nonprofits.

Economics. Water markets and associated institutional reforms are limited. Price signals are largely absent and do not guide choices between market and other water management alternatives. However, the growing competition for scarce water supplies and the emergence of new environmental values will likely lead to higher costs and higher water prices.

Strategies to achieve water sustainability fall into three categories: supply, demand, and reallocation.

Arizona's Diverse Water Geographies

A scan across Arizona reveals a varied landscape for addressing sustainable water management challenges. Although state policies and regulations unify some aspects of water management, a variety of geographic, legal, socioeconomic, and ecological factors distinguish the context for water sustainability challenges and opportunities. Arizona can be viewed through the lens of three water geographies, each of which present opportunities to fit solutions to the scale and complexity of regional challenges. Conditions within the three regions exhibit similarities in ecohydrological characteristics, water supply and demand trends, and institutional settings that shape challenges and opportunities for market-based responses to water sustainability challenges. These regions are i) Central Arizona and the Mainstem Colorado River, ii) Northern Arizona, and iii) Southern Arizona.

Arizona's water geographies frame the context for the enabling conditions required for market-based mechanisms, namely the need to: i) establish limits and rights to water use, ii) define necessary authorities for trading to accommodate ecological uses, and iii) strengthen institutional capacity for sustainable water management. Diverse water geographies therefore shape both water management challenges and the range of solutions that can balance supply and demand at multiple interacting scales, including the scope, application, and feasibility of market-based mechanisms that could help in achieving sustainable water management.

The Colorado River and Central Arizona Project (CAP) Service Area Region is distinguished by a reliance on imported supplies through the CAP service area and Salt River Project. Surface water supplies are supplemented by groundwater pumping from deep basin-fill aquifers and increasing use of municipal effluent. Demand is driven by municipal use and population growth in the Phoenix-Tucson urban corridor and irrigated agriculture throughout Central Arizona and the Lower Colorado River region.

The Headwater Region of Northern Arizona encompasses the southern portion of the Colorado Plateau, the Grand Canyon, and the Mogollon Rim. Roughly half the streamflow originating in Arizona begins in Northern Arizona and many of the state's reservoirs are filled by rainfall runoff and snowpack drainage from this region. Water from surface flows, groundwater, and a growing effluent supply are used to meet obligations to senior water rights holders, growing communities, and small-scale agricultural operations.

The Basin and Range Region of Southern Arizona consists of broad, low-elevation valleys rimmed by north-south trending mountain ranges, often referred to as 'sky islands.' The San Pedro and Santa Cruz Rivers flow from south to north through valley bottoms before their confluence with the Gila River. Water supplies in the upper and middle Santa Cruz Valley and the San Pedro Valley are limited to local groundwater aquifers, surface diversions from mainstem rivers, and effluent releases that sustain river flows and recharge shallow water tables. Water demands are primarily driven by rapidly growing communities, with additional demands from family-owned agricultural operations and industries.

Strategies for Sustainability: The Role of Market-Based Reallocations

There are a number of strategies available to achieve water sustainability, each varying by the degree to which government, the market, and/or civil society drive them. These strategies fall into three categories: *supply, demand management,* and *reallocation*. Choosing between these strategies requires understanding of the relative costs and benefits of allocating water between multiple demands, including the needs of the environment.

On the supply side, traditional strategies include utilizing surface water diversions, surface water storage, groundwater withdrawals, and interbasin transfers. Newer and more innovative supply options include shallow aquifer recharge-and -recovery, effluent reuse, and desalination.

On the demand side there are a wide range of strategies that focus on increasing the productivity of existing supplies, i.e. using less water to achieve the same purpose, or working to limit water consumption at the point of end use. For example, water conservation efforts may reduce the amount of water

Arizona's Water Geography

that needs to be diverted or pumped by eliminating leakage during transportation (such as piping irrigation canals) or reducing water use at the point of delivery (such as crop switching and water efficient-toilets).

A third set of strategies results from the direct reallocation of water from one user to another. This may be accomplished involuntarily, i.e. through legal or administrative decree, or voluntarily, when existing and prospective water users can engage in willing buyer/willing seller transactions for mutual benefit. These transactions can involve rights created through developed supply or water saved through demand management. Transactions between willing buyers and willing sellers are often taken as evidence that a 'market' exists, either informally through ad hoc transactions or through more robust and organized marketplaces.

Market-Based Reallocation for Environmental Purposes

Western U.S. water law evolved under the Prior Appropriation Doctrine. Initially conceived as a permit-based system of surface water rights that could be traded between users to meet mining and agricultural needs, water laws have evolved over time to accommodate new beneficial uses, as well as new supplies such as groundwater and effluent. Under this historic and increasingly complex system of water laws, there are two main options for accommodating public and environmental uses: the Public Trust Doctrine and market-based reallocation.

Public Trust Doctrine. The first option was initially pursued in the 1970s, when the Public Trust Doctrine was invoked to assert the public interest in water management, particularly for environmental needs. The public trust approach often embodies the idea of superseding the existing property rights system, with water potentially reallocated to the environment through legislative, regulatory, or judicial action. As a consequence, the Public Trust Doctrine can be politically controversial and has seen limited implementation.

Market-Based Reallocation. The second option is to work within the existing legal and economic framework and reallocate or acquire water from willing sellers to meet ecological needs. A cap and trade system can preserve the environment by incorporating the needs of water-dependent environments into regulatory limits on water use. A water market trading system can be used to reallocate existing water rights to environmental restoration purposes in places where established water uses have already impacted water-dependent environmental resources.

Necessary Conditions for Market-Based Reallocation

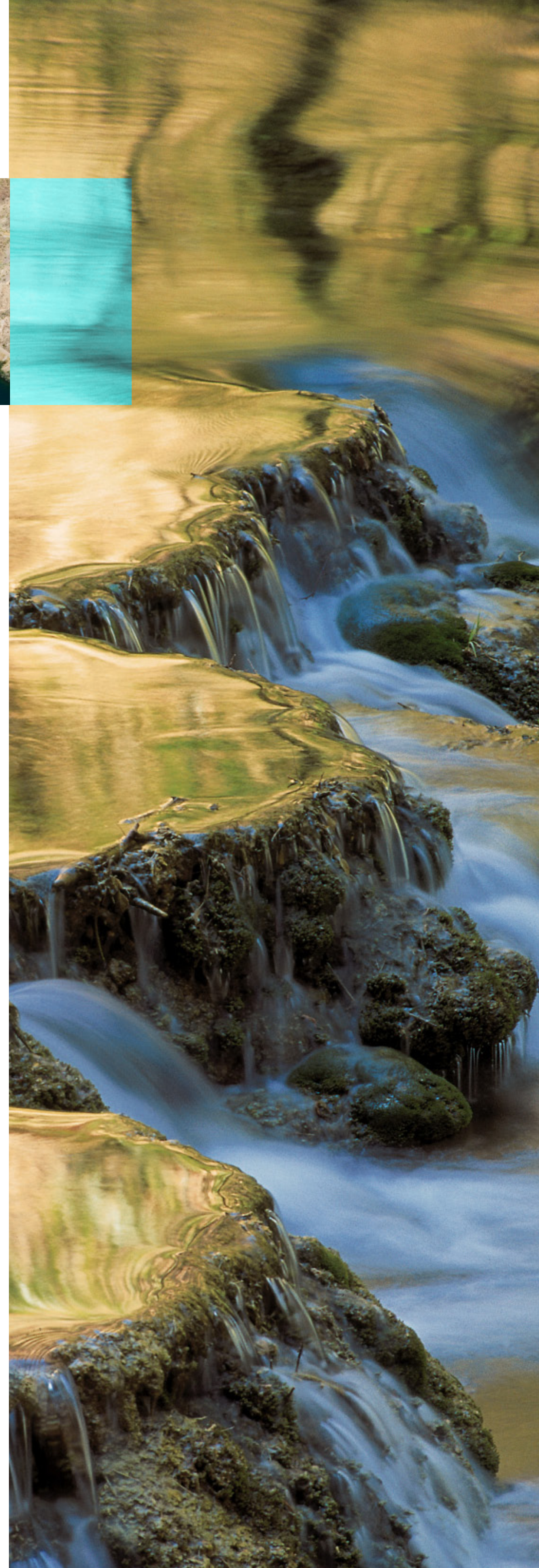
Once a series of necessary conditions exist, market-based transactions are enabled by both financial exchanges and administrative procedures. These necessary conditions include: i) water scarcity, ii) the presence of willing buyers and sellers, iii) clearly defined water rights, and iv) the institutional capacity to measure and manage the rights.

Water Scarcity. When water supplies are scarce, market-based reallocation among existing rights becomes an attractive alternative to expensive conservation and risky supply augmentation strategies to meet and balance water needs between people and ecosystems.

Buyer and Seller. In order for a water rights transaction to occur, a willing buyer and a willing seller must be identified, both of whom will potentially benefit from the exchange. Successfully engaging willing buyers and sellers hinges in large measure on the transaction costs—the costs of defining, managing, and transferring water rights—and on addressing the positive and negative impacts water transactions might have on third parties. Transaction costs must be reasonable for buyers and sellers to overcome the hydrologic, legal, administrative, and cultural complexities of water transactions without prohibitive expense or delay.

Water Rights. For scarcity to foster market-based reallocation strategies, a system of clearly defined and tradable water rights must be in place. Surface water rights transactions depend on adjudication—the administrative procedures for defining the transferable quantity of water under the prior appropriations-based twin principles of 'first in time, first in right' and 'no injury.' The former principle defines secure water rights while the latter principle safeguards against negative impacts from changing patterns of water use. In addition to keeping transaction costs reasonable, any negative impacts of water transactions on third parties must be mutually and beneficially resolved.

Institutional Capacity. The transactions involved in market-based reallocation occur within both a local and regional context. The participation of public institutions with sufficient capacity is necessary to conduct such transactions. Institutions will need scientific information, financial resources, and the capacity for planning, monitoring, and evaluation to coordinate buyers, sellers, and the interests of third parties.



Three Types of Water Rights Transactions

There are three types of water rights transactions subject to state regulation: i) permanent transfers, ii) water exchanges, and iii) banked water. These transactions are most easily considered within the context of surface water rights transactions, but can just as easily refer to transactions in groundwater, effluent, and conserved water.

Transfer. A transfer is a permanent change in the water right without altering the source of water. Typically the motivation is to change the point of diversion, the place of use, or the manner of use. Associated with these may be a change in the type or water right or amount or season of use.

Exchange. An exchange involves a change in the source of a water rights and there are several types of exchanges: permanent exchange, open exchange, flexible or variable exchange. Exchanges can provide much needed flexibility in water user, but typically require water to be available in the new source or for there to be a close hydraulic connection between the two sources. In Arizona the separation of groundwater, surface water, and effluent as well as classes within these supply sources creates both challenges and opportunities to such approaches.

Banking. Banking of water refers to a temporary change in a water right. This may consist of moving water from its permanent authorized use to another use for a limited period of time in the same season, i.e. changing the place of use or one of the other elements of the water right only temporarily, or, in the case of storage, the carrying of water over from one season to another (for the same or another use). In the case of water banking, the seller is not transferring the title to the water right: once the term of the agreement is complete the use reverts to that specified under the water right.

Framework for Assessing Challenges to Market-Based Reallocation in Arizona

Experiences drawn from development of environmental water transaction programs and water markets throughout the western United States help in identifying the fundamental elements that are necessary to design Arizona's environmental market-based reallocation options.

The framework developed within this report diagnoses challenges to market-based reallocation, distinguishing between policymaking and implementation in Arizona. This framework demonstrates that barriers to markets also impede progress toward sustainable management more generally. The framework also illustrates how policymaking and implementation relate to each other. Ideally, there is steady evolution and adaptation within, and between, policymaking and implementation.

Policymaking. Allocating water to the environment and market-based reallocation are relatively new concepts in Arizona and the western U.S. As with any innovation, it takes time for the underlying science to evolve and mature, time for cultures and society to absorb the knowledge and adopt new concepts, and time for institutions to apply the knowledge. These are challenges for all market-based reallocations and are even more acute challenges for market-based reallocation for environmental purposes.

Most of the policies, statutes, and rules needed to enable general market-based reallocation are present but limited in Arizona, and are especially limited as they apply to reallocation for environmental purposes. Challenges include the lack of statewide adjudication of surface water rights, limited administrative capacity in water-related utilities and agencies, and onerous requirements for case-by-case approval by the Arizona Department of Water Resources Director. In addition, there is a lack of clear and open standards and requirements for transfer applications under statute and rule. Enabling conditions required for general market-based reallocations are shown in Table 1. Additional enabling conditions necessary for reallocations specific to environmental purposes are summarized in Table 2.

Table 1. Enabling Conditions for General Market-Based Reallocation

MARKET-BASED REALLOCATION FOR GENERAL PURPOSES		
Enabling Conditions	**Status in Arizona**	
	Present/ Absent	**Qualifications**
Appropriation of surface water and groundwater for beneficial uses is well defined, subject to priority, and permits/rights are tradable.	Present	Limited function due to lack of surface water adjudication and administrative capacity gaps.
Appropriation of new groundwater permits and management of existing groundwater rights adequately accounts for impacts on surface water.	Absent	
Reclaimed wastewater is permitted and is tradable via contractual agreement.	Present	Function is limited due to legal uncertainty about downstream surface water rights that are met through effluent discharged into the river channel.
Appropriation of groundwater adequately accounts for overdraft and plans for long-term sustainable supplies.	Present for permits/ rights within Active Management Areas (AMAs)	• Spatial mismatch in AMAs persists between area of groundwater withdrawal and recharge. • Enabling conditions not in place outside AMAs. • Enabling conditions not met for exempt wells.
Mitigation for groundwater appropriations can be provided through the recharge-and-recovery of water.	Present	Spatial disconnect between recharge basins and groundwater withdrawals creates localized overdrafts.

The barriers to market-based reallocation—namely the absence of sustainable limits on freshwater use, the lack of tradable water rights, and limited institutional capacity for measurement and enforcement—also hinder water sustainability efforts more broadly.

Table 2. Additional Enabling Conditions for Market-Based Reallocation for Environmental Purposes

MARKET-BASED REALLOCATION FOR ENVIRONMENTAL PURPOSES		
Enabling Conditions	**Status in Arizona**	
	Present/ Absent	**Qualifications**
The use of water for environmental purposes including water for instream flows, riparian habitat, and off-stream needs in floodplains or wetlands is recognized as a beneficial use.	Present	Only certain environmental uses are recognized as beneficial uses (fish and wildlife), and these are only a subset of the ecological values sustained by Arizona's freshwater systems.
The permanent or long-term change of out-of-stream rights to environmental purposes (sever-and-transfer) is permitted, without loss of priority and subject to normal injury review.	Present	
The short-term change of out-of-stream rights to environmental purposes is permitted, without loss of priority and subject to expedited injury review.	Absent	
Residual environmental water is protected, either through limits on further appropriation (closure) of surface water and groundwater (including exempt wells), or through a system of instream water rights of junior priority.	Absent	Enabling conditions are not met with the exception of junior instream water rights, which can act as a 'valve' on future appropriations and changes to existing appropriations that would cause injury to established instream rights.
Appropriation of groundwater rights in closed basins is allowed when accompanied by effective mitigation for surface water impacts.	Absent	
Appropriation of non-consumptive water saved through demand management (conservation) by the proponent is permitted for 'spreading' to other non-consumptive uses, particularly environmental uses.	Absent	

A Status Check of Market-Based Reallocation in Arizona

The degree of activity and market development varies across Arizona's water geography. In the Colorado River region, the CAP facilitates exchanges of water rights but limits activity to recharge-and-recovery arrangements or isolated transactions. Central Arizona has well-defined legal and regulatory frameworks, but lacks true water-marketing institutions, such as water banks that reallocate water based on price. Historically, water pricing in Arizona has been used to recover costs of operating and maintaining water supply infrastructure rather than allocating water according to its productivity. In rural Arizona the capacity to market water has been tied to the ability to transport water from rural to urban places of use. As such, transactional activity has been very limited and focuses on major transportation projects and proposals.

Key market development needs in Arizona include:

- Experimenting with water bank structures that facilitate not only administrative changes to water rights but also use price to make the reallocation (instead of administratively set prices).

Table 3. Summary of Policymaking Challenges and Next Steps for Market-based Reallocation in Arizona

MARKET-BASED REALLOCATION FOR ENVIRONMENTAL PURPOSES		
Component	**Challenge**	**Recommendation**
Policy Research & Formulation	• Scientific, legal, and economic uncertainties. • Cultural resistance to addressing freshwater ecological needs due to perceived competition.	• Pursue research that identifies community priorities, ecological needs, and mutually beneficial reallocation opportunities. • Provide research about how and to what degree water transfers might alter the status quo.
Legal & Regulatory	• Spatial disconnect between locations of groundwater recharge and use. • Lack of limits on groundwater extraction or lack of instream permits for residual flows. • Lack of authority to conjunctively manage surface water and groundwater. • Lack of authority to allow mitigation in the form of instream transfer of consumptive use offset. • Lack of authority for temporary (leased) and conserved water mechanisms. • Uneven water planning between rural and urban regions in Arizona. • Piecemeal and limited integration of ecological needs into planning and water budgets.	• Detailed diagnoses of specific statutes and rules that would further reallocation efforts in specific basins and regions around the state. • Policy reform to establish a full foundation of enabling legal and regulatory conditions for market-based reallocation, particularly for meeting ecological needs.
Administration	• Capacity and resource constraints at the Arizona Department of Water Resources.	• Develop monitoring, regulation, and enforcement capacities outside of state institutions. • Utilize local nonprofit and individual capabilities for administration work.
Judicial Review	• Uncertainty over validity and extent of pre- versus post-1919 surface water claims. • Questions regarding the transferability of pre- and post-1919 rights and uncertainty over the validity and extent of those rights.	• Develop collaborations between local management agencies and stakeholders to develop and adopt changes to claims that allow for local flexibility with statewide oversight.

- Addressing spatial controls on the places of use and third party impacts of market transactions under the Groundwater Management Code.
- Developing groundwater mitigation programs that incorporate streamflow restoration (through sever-and-transfer) as a form of offset for new consumptive groundwater allocations.
- Proving up on sever-and-transfer approach, as well as developing a full suite of tools for administrative changes of water rights for environmental purposes, including both leasing and conserved water.

Organizations in Arizona have pursued options to work around challenges identified in this report, however such actions can involve high transaction costs that can be prohibitive to repeat efforts. Case studies from around the western United States, including Arizona, provide examples of effective pathways to address some of these challenges, as well as avenues to avoid them (Table 4).

Table 4. Case Studies Around the Western United States

REGION	CASE STUDY	LESSONS LEARNED
Pacific Northwest	Deschutes River Basin, Oregon; Klamath Basin, California/Oregon	Conflict or Cooperation as Drivers for Public Investment
	Oregon & Washington	Groundwater Mitigation Programs
	Idaho & Montana	Water Rights Administration and the Role of Non-State Participants
	Yakima Basin, Washington	Water Transfers
Arizona	San Pedro River	Linking Science, Stakeholder Collaboration, and Innovative Solutions
	Sonoran Desert Conservation Plan	Connecting Land-Use Planning, Water Resources, and Conservation
	Upper Santa Cruz River	Tracking River Health

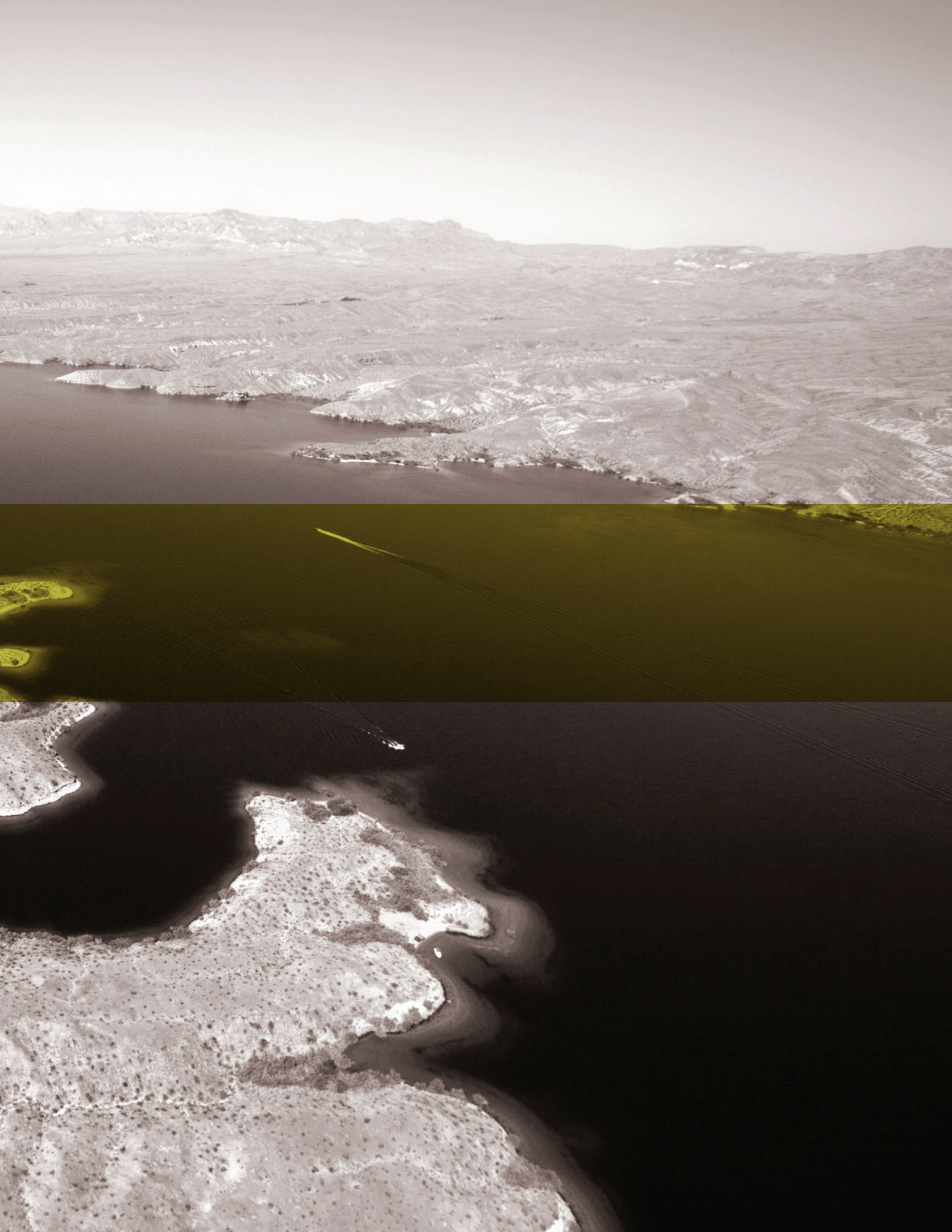
- Increasing participation, transparency, and accountability in the design and launch of water market segments and marketing efforts.

Regulatory and management institutions both enable and constrain the coordination of water market buyers and sellers. In order to implement environmental water transactions at a larger scale, Arizona needs to develop institutional capacity in the following areas at multiple scales and jurisdictions:

- Water compacts, interdistrict agreements, reservoir operating agreements, etc.;
- State-run water banks intended to streamline administrative changes to water rights;
- Irrigation district water storage rental pools;
- Marketplace clearinghouse functions (including auctions, transfer/exchange/banking agreements with irrigation district or Tribal users); and
- Private/Nonprofit groundwater and surface-to-groundwater mitigation banks.

Challenges and Recommendations

Arizona's policy framework includes potential building blocks to enable market-based reallocation for environmental purposes throughout the state. Utilizing these building blocks, in tandem with input from local stakeholder communities, can highlight areas where human and ecological water needs overlap. Table 3 summarizes the challenges and opportunities in Arizona that point the way towards potential near-term next steps. ■



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Introduction

In 1986, the Ford Foundation touted the 1980 Arizona Groundwater Management Act (GMA) for its innovative approach to water management. Thirty-one years after the GMA's passage, Arizona's anticipated water-scarce future has arrived. The GMA and the rest of the state's water management framework are hard-pressed to cope with the challenge. Previous challenges such as groundwater overdraft remain pressing, while once distant threats like shortage on the Colorado River are now approaching rapidly. Meanwhile, population growth and competition for drought-prone water supplies have strained the ecological integrity of Arizona's rivers and shallow groundwater tables with a cumulative loss of roughly 35% of the state's perennially flowing waterways. The decline of the state's rivers and stream-aquifer systems has threatened the ecological functions that support not only sensitive riparian habitat but that also support water supply, aquifer recharge, and flood control. In short, the challenge of sustainability becomes more tangible by the day as Arizona grapples with how to meet the diverse needs of people and ecosystems.

Recent statewide initiatives—from the Governor's Blue Ribbon Panel on Water Sustainability to local efforts in the San Pedro River, the Tucson region, and Northern Arizona—signal that the concept of sustainability is increasingly accepted by stakeholders and water managers as a core objective of Arizona's water future. Despite the attention to sustainability as a goal for water resource management, consensus on the definition and intent of the term has proven elusive. The meaning of sustainability differs among planning, management, economic, and scientific circles. This report focuses on water sustainability as the challenge of meeting the interdependent water needs of people and ecosystems within the context of intensifying water stress and competition for scarce water supplies. In this context 'people' implies the full range of human uses including residential, agricultural, mining, power, transport, and other uses.

The Cornerstones Report has been prepared based on information gained from a series of workshops and associated research, with funding support from the Walton Family Foundation. In May and July of 2010, representatives of conservation groups, municipal water utilities, and water managers from the state and federal agencies met to discuss sustainability within Arizona, with specific focus on how market-based reallocation could contribute to sustainability and ecosystem water needs (Appendix A). This effort identifies the Cornerstones, or foundational elements, that are required to develop and apply market-based options to sustain the freshwater environment and the users who depend on it.

The first meeting highlighted the barriers to opportunities for market-based reallocation to establish environmental water supplies in water-stressed regions. The second meeting reviewed an interim report that provided the framing, key concepts, and messages, and preliminary synthesis of challenges, opportunities, and lessons learned. The day's breakout sessions revealed both the challenge of establishing a common language and the need to ground the discussion locally to address the diverse conditions that exist among the major regions of Arizona's water geography.

The workshop series occurred within a context of political and economic change in Arizona, including significant budget cuts and restructuring in Arizona's water management institutions. These broader changes infused the discussion with a sense of pragmatism about the challenges of launching new ideas and institutional frameworks. However, conversations also highlighted the appeal of market-based arrangements that stimulate private incentives and a new spirit of cooperation among diverse stakeholders with potential mutually beneficial opportunities. In this sense, the workshop series was an important step forward in stimulating a broader dialogue and process of engagement about water sustainability.

This report combines input gathered during these meetings with contributions from a multi-disciplinary research team to assess the role of market-based reallocation to accommodate diverse and shifting demands on Arizona's freshwater resources. The report provides a specific set of follow-up analyses aimed at promoting policy reform and developing on-the-ground projects. The eventual goal is to demonstrate how market-based response—defined as the use of tradable water rights and institutions to facilitate voluntary reallocation to meet ecological needs—can be an integral part of water management for ecosystem purposes in Arizona. However, workshop participants recognized that key issues needed to be addressed in certain sequences and that demonstration projects were useful for identifying approaches that could work in Arizona. Outcomes from the Cornerstones process therefore depend upon ongoing policy and management discussions within the context of Arizona's diverse geography of water.

The workshop process and analytical review suggest that while market-based reallocation is not a silver bullet for water sustainability, it can serve as a useful and integral component of water management actions to address ecosystem needs in Arizona. Despite the focus on ecosystems, this report finds that many of the constraints that Arizona faces in applying market-based reallocation for ecological purposes are the same limitations that hinder efforts at water sustainability more broadly. While many of these constraints are widely acknowledged, they are reiterated in the report to keep sight of the broader more comprehensive efforts being made toward policy reform.

The report is organized into five sections. Following the Introduction, Section 2 sets the scene by framing the water sustainability challenge in terms of water scarcity and resulting conditions of water stress. Section 3 inventories market-oriented solutions as part of a coordinated set of supply development, demand management, and reallocation strategies for meeting the water needs of people and ecosystems in a context of mounting water stress. The fourth section defines Arizona's water geography by areas where similar hydrology, water use, water institutions, and other factors shape the challenges to water sustainability. In the final section, the focus of the report is narrowed to market-based reallocation as a potential tool for addressing the ecological component of water sustainability. This section attempts to both diagnose and respond to the challenges and opportunities that Arizona faces in developing and implementing market-based responses. ■

This report identifies the Cornerstones, or foundational elements, that are required to develop and apply market-based options to sustain the freshwater environment and the water users who depend on it.

2.0

Arizona's Water Sustainability Challenges

Arizona's water sustainability challenge can be viewed through the lens of water stress, which refers to conditions where demand for water exceeds reliable supplies. This imbalance forces allocation tradeoffs across multiple uses. Water stress is a result of scarcity in the amount, timing, and quality of available water, with the result that shortfalls may reduce the degree to which human and/or ecosystem water needs are met. While water requirements for humans and ecosystems are often viewed as mutually exclusive, healthy ecosystems support human economies and quality of life and are therefore essential in meeting human needs. Even further, if human uses expand beyond local supplies, ecosystems may eventually be stressed to the point where negative feedback loops reduce the pool of water available to both human and ecosystem uses. ■

2.1

Water Stress and Sustainability

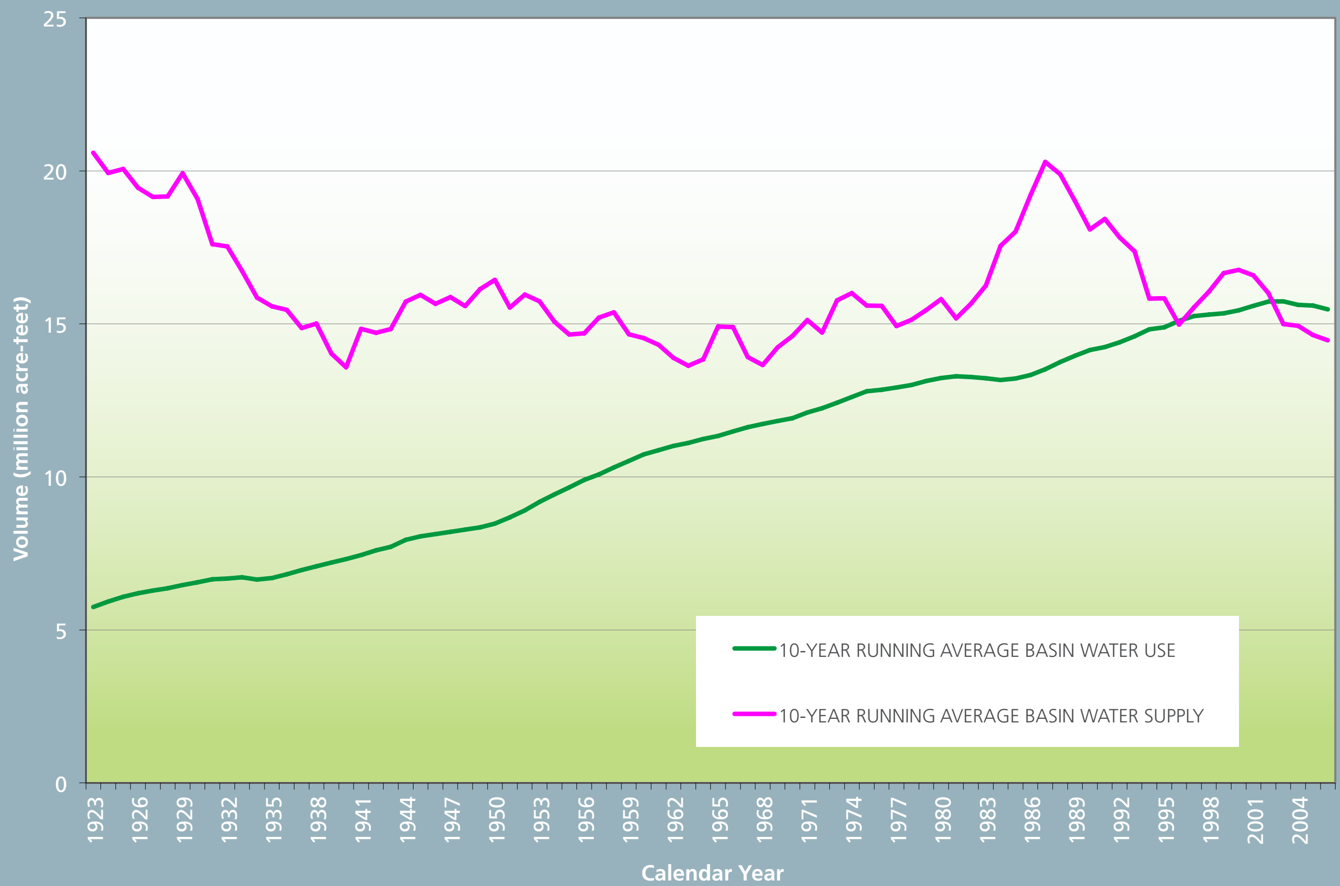
Arizona confronts the challenge of water stress at multiple scales across a variety of hydrologically connected surface water and groundwater supplies. The Colorado River exemplifies the regional experience with overallocation of water resources. The Colorado River Compact of 1922 set basin-wide legal allocations at more than 16.5 million acre-feet (MAF). These allocation decisions were based on anomalously wet conditions occurring in the early 20th century, while the long-range average runoff is approximately 15 MAF. In the late 1990s, basin-wide water use reached 15 MAF, intersecting with the long-run (ten-year) average supply for the first time (Figure 1). By the early 2000s, the ten-year moving average for basin-wide use had trended higher, exceeding the corresponding ten-year supply average, which was itself falling in response to drought conditions. These developments herald the onset of a new era in which basin water users will need to adapt and live within the basin water budget.

Basin-wide surface water shortages are a lagging indicator of water stress that has long been felt by fish, wildlife, and ecosystems. For instance, upstream water use, storage, and water quality issues have resulted in unmet water needs at the bottom of the system along the once-fertile Colorado River Delta. Other indicators of water stress are evident in waterways across Arizona, including groundwater overdraft and local surface water shortfalls, which affect supplies for established farms and cities and newly recognized water needs of sensitive riparian habitat. Water budgets in the Tucson and Phoenix Active Management Areas (AMAs) have demonstrated groundwater overdraft conditions. Reductions in surface flows and riparian habitat along the San Pedro and Verde Rivers results from groundwater pumping, as well as depletions of pockets of shallow aquifers within deep basin-fill groundwater basins. These reductions illustrate the dependence of riparian ecosystems on access to groundwater, as well as a growing connection between the local water needs of rural communities and ecological health. The alignment between water reliability and ecological health links the mutual fate of people, agriculture, and ecosystems under conditions of water stress in regions as diverse as Cienega Creek and the San Pedro and Verde Rivers.

Several indicators of water stress have been developed in Arizona (Table 1). The GMA established the standard of achieving safe yield to address the imbalance between annual groundwater withdrawals and groundwater recharge from natural and artificial sources within the boundaries of respective AMAs. Groundwater overdraft is used as the indicator of water stress measured against this safe yield standard. The GMA applies the safe yield standard to four of the five Arizona AMAs and has been used to track progress toward meeting management goals. The most recent official estimates for achieving safe yield indicate the severity of water stress. For example, the Prescott AMA faces an annual deficit of over 9,000 acre-feet (AF) as measured by groundwater overdraft in the Department of Arizona Water Resource's Third Management Plan. While far lower than the overdraft volumes experienced in other AMAs, the renewable supplies in the Prescott AMA are only around 9,500 AF, so baseline demands are twice the volume of available renewable supplies (ADWR 2010b).

Members of recently formed partnerships in rural Arizona have recognized the limitations of the safe yield standard for maintaining groundwater-dependent riparian resources. In response, some have expanded beyond the safe yield concept to consider the 'sustainable yields' needed to offset annual withdrawals, while reserving adequate recharge to maintain river baseflows and associated environmental needs. The sustainable yield approach addresses the localized balance of groundwater recharge and withdrawal. Municipal effluent can also be used to meet riparian water requirements by providing surface flows and groundwater recharge; however, these uses for effluent are not legally secure.

Figure 1. **Ten-Year Moving Average Supply and Demand in the Colorado River**



Source: U.S. Bureau of Reclamation, 2011.

Surface water is considered overallocated when there is a chronic deficit in renewable supplies to meet demands. The Colorado River is overallocated in terms of the difference between legal entitlements and average inflows, as depicted in Figure 1. The U.S. Bureau of Reclamation estimates an annual deficit of 1.2 MAF under average conditions by comparing inflows to releases, although Arizona and the Lower Basin states are currently receiving their full allocation. As the junior rights holders on the system, Arizona and CAP will be vulnerable to the future declines in reservoir levels when this chronic deficit coincides with prolonged drought conditions. The Colorado River Supply and Demand Study (U.S. Bureau of Reclamation 2010) is underway to assess the imbalances between supply and demand through 2060. This and other efforts in rural Arizona have addressed several regions in Northern Arizona, the Verde Watershed, the Upper San Pedro Watershed, Yavapai Highlands, and elsewhere.

Water sustainability therefore entails choosing not just how to allocate water among various uses, but how to apportion the stresses that will invariably appear in overallocated water systems. This choice is a social decision and one that must account for economic, ecological, and cultural conditions in a given place. Until this choice is made explicit, water sustainability will remain an elusive and unrealized goal. For this reason participation, transparency, and accountability in water governance institutions are central to achieving water sustainability. ■

Table 1. Indicators of Water Stress

Indicator	Description	Estimates of Overdraft (thousands of acre-feet)
Safe Yield (Groundwater Overdraft)	Long-term balance in Active Management Areas (AMAs) between average annual groundwater withdrawals and average annual natural and artificial recharge. In the Santa Cruz AMA, long-term decline of local water tables must also be prevented.	• Phoenix: 360 (1995) to 471 (2025, projected) • Pinal*: 120 (1995) to 319 (2025, projected) • Prescott: 9 (baseline) to 15 (2025, projected) • Tucson: 164 (1995) to 53 (2025, projected) • Santa Cruz: Safe yield conditions are difficult to quantify due to the highly variable nature of the hydrologic system.
Sustainable Yield (Stream-Aquifer System)	*"Management of groundwater in a way that it can be maintained for an indefinite period of time, without causing unacceptable environmental, economic, or social consequences"***	• Upper San Pedro Basin, application in Section 321 of the 2004 Defense Authorization Act
Overallocation (Surface Water)	Long-range average demand (consumptive use and evaporative losses) exceeds long-range average renewable supply (inflows)	• Colorado River: 1.2 MAF (long-range average annual deficit in Lake Mead, accounting for average inflows, annual deliveries to the Lower Colorado and evaporation losses.)
Stream Baseflows	Annual and monthly baseflows as tracked by streamflow gauges	• Conditions vary by stream reach and are measured against long-term average flows and/or instream flow applications.

Notes: *Pinal AMA is not governed by the safe yield standard. ** This definition is taken from the Upper San Pedro Partnership definition—Information available at: www.usppartnership.com
Sources: Arizona Department of Water Resources Third Management Plans 2000-2010 (Safe Yield), Upper San Pedro Partnership Long-Range Five Year Planning Document, 2007–2011 (Sustainable Yield), U.S. Bureau of Reclamation (average deficit in the Colorado River) 2010

2.2

Ecological Water Requirements

Ecological needs in Arizona refer to the timing, quantity, and quality of water required to sustain the connection between aquifers and surface flows that support water-dependent ecosystems. Under natural conditions the physical and biological characteristics of a stream-aquifer system are maintained by a dynamic balance between water flowing into and out of a system. Water contributions to a stream-aquifer system include precipitation, surface flow from upstream areas, and underground flow from higher elevation aquifers. Water naturally flows out of a system through surface flows, groundwater discharge into streams or wetlands, underground flow to lower elevation aquifers, and evapotranspiration. The hydrological inputs and outputs of a stream-aquifer system must be in balance in order for the consumptive pool of water to be sustainably available to meet both human and ecosystem needs.

Figure 2 conceptualizes four stages of water stress as human demand encroaches on ecological needs and results in an overall reduction in the consumptive pool of water. In addition to growing human demand, climate variability and prolonged drought exacerbate the effects and lower the thresholds for the dropping consumption pool.

Stage 1 illustrates baseline conditions that are environmentally safe because natural hydrologic processes provide sufficient water to support human water demands and meet ecological requirements. In this stage, cumulative water demands do not fully exceed the available consumptive pool, so the system provides resiliency during periods of drought.

In Stage 2, growing consumptive demands encroach on the hydrologic limits in a specific location and during a discrete period of time, such as areas where late summer peak irrigation demands coincide with seasonally low baseflows. In Arizona, these conditions occur in the upper tributaries of snowmelt-dominated streams that supply water for irrigation and rural water needs.

Figure 2. Stages of Water Stress

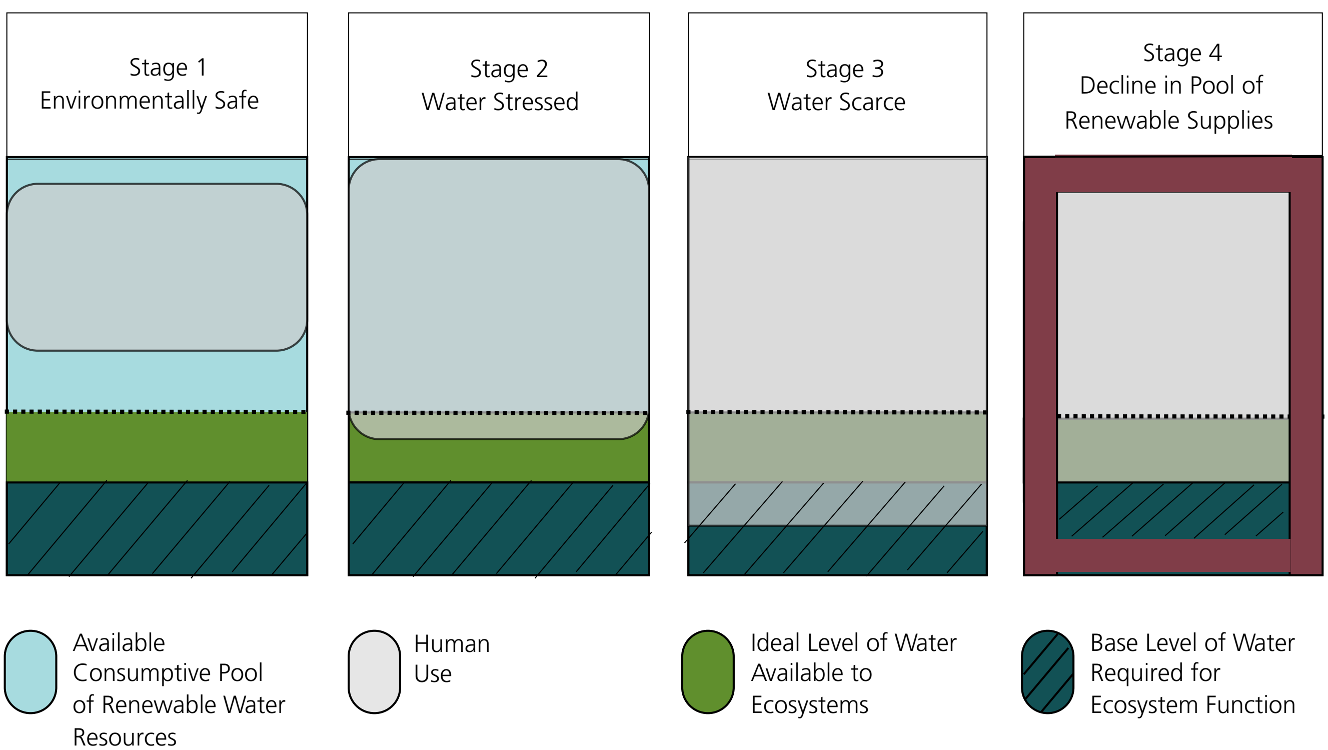
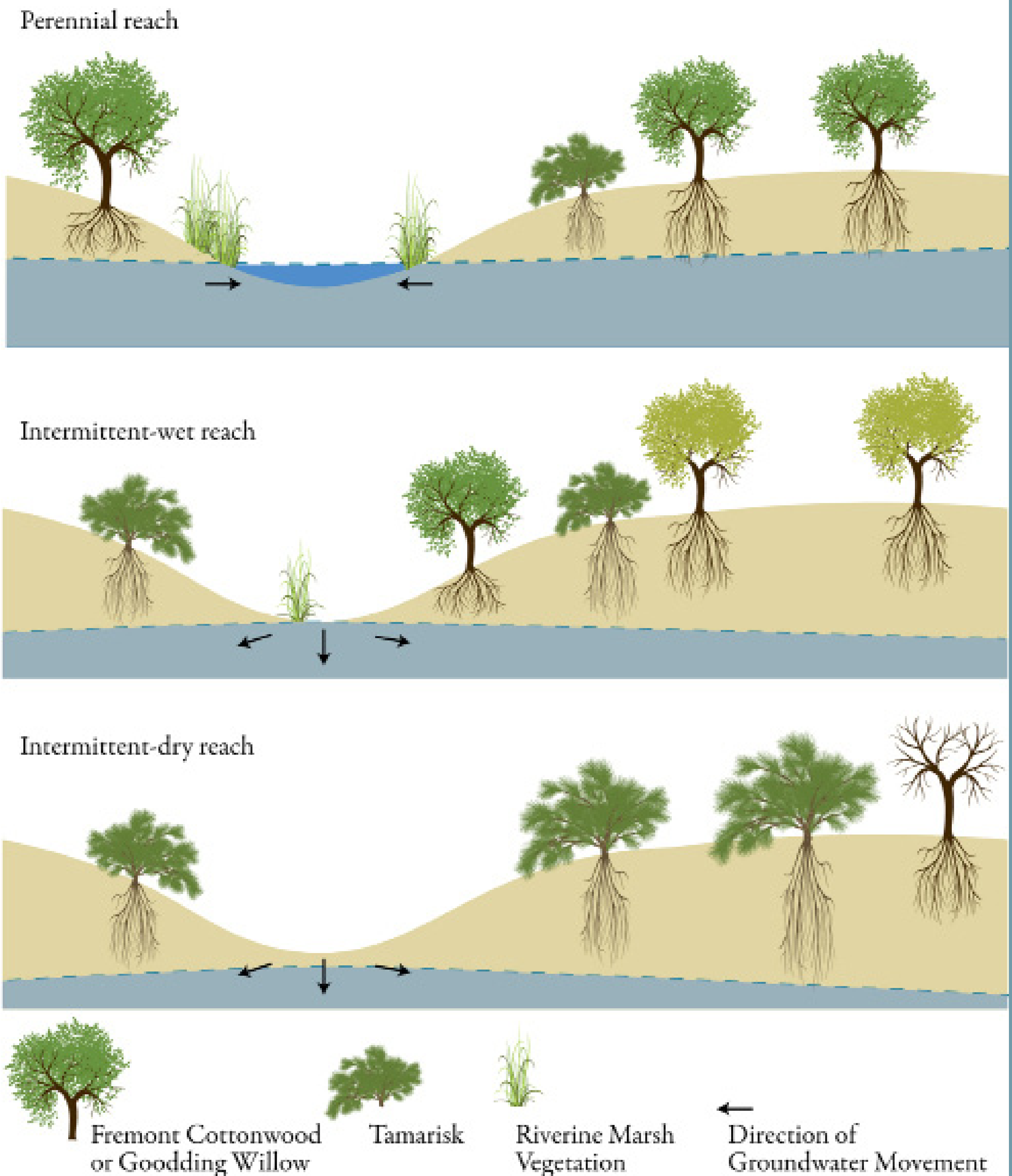


Figure 3. Three Stages of Ecological Water Stress



Source: Figure adapted from Leenhouts et al 2006 and used with permission from Citron & Garrick 2010.

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Stage 3 illustrates prolonged and chronic deficits in water availability in contrast to the temporary, seasonal impacts of overallocation depicted in Stage 2. Stage 3 conditions are evident in the dewatering of the Colorado River Delta and the loss of connectivity between shallow groundwater levels, dependent surface flows, and riparian habitat.

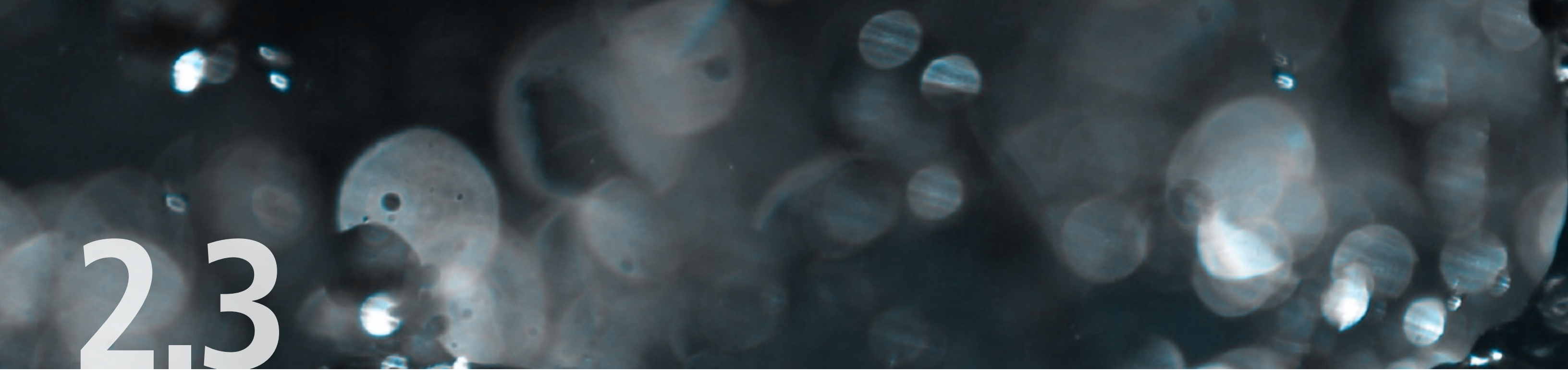
Stage 4 occurs when withdrawals exceed water inputs over time and the total consumptive pool diminishes to a point where sufficient water is not available to meet human and ecological needs. These conditions are most pervasive in groundwater-dependent systems where overallocation of both surface and groundwater has diminished the baseflow, floods, and/or peak flows that provide for recharge and sustain natural stream functions. As human uses further drawdown groundwater, streamflow, and riparian habitat, negative feedback loops further reduce the usable consumptive pool available to humans and ecosystems. Rural areas that depend primarily on local surface water and groundwater are particularly vulnerable at this stage. Conversely, in areas that import supplies, there are opportunities to deliver restoration water to areas where human needs and ecological priorities align.

Water supplies that support ecosystems are vulnerable across Arizona. Figure 3 is a conceptual illustration of the conditions that affect the transition thresholds between the four stages presented in Figure 2. The conditions in each stage reflect the connections between human water uses, ecological water requirements, and the sustainability of the consumptive pool.

In areas where ecological needs are currently met and healthy riparian areas persist (Stage 1), environmental uses of water often lack formal allocation, water rights, or recognition in water budgets. When environmental water uses are not legally recognized, water can be diverted to meet growing demands for established human uses. Shallow aquifers and stream-aquifer systems are particularly vulnerable. For example, shallow groundwater recharged by runoff from the Rincon Mountains feeds streamflow in Tanque Verde Creek in Pima County. The groundwater-surface water interactions that sustain Tanque Verde Creek's riparian ecosystem are neither legally recognized nor protected from diversion. As a result, new surface water or groundwater diversions could diminish the water available to support the riparian ecosystem.

In other areas, human water demands already compromise the health of stream-aquifer systems and associated vegetation to varying degrees (Stages 2 and 3). In some cases, surface flows vary during the year, only intermittently providing the water needed for ecological functions. Surface diversions for agriculture can exacerbate these seasonal shortages. Examples include intermittent streams outside urban areas, such as the diverted reach of Cienega Creek in Southern Arizona or portions of the Upper Verde River in Northern Arizona. In these streams, reduced water availability has degraded native riparian habitat and allowed proliferation of drought-tolerant and frequently nonnative plant species.

In more extreme cases (Stage 4) the degree of degradation is irreversible, resulting from multiple stressors, including diminished surface flows and lowered groundwater tables. Examples include dewatered rivers and concrete-lined channels within urban areas such as the Rillito River in Tucson and the Gila River south of Phoenix. In these systems historical ecological needs are unmet. Restoration would require coordinated planning to determine the water needed to re-establish ecohydrologic functions and habitat, and would require stakeholders to collectively deem reallocation a priority and work collaboratively to plan and implement the work. ■



2.3 Driving Factors

Scarcity and heightened water stress highlight the link between functioning freshwater ecosystems and the need to maintain sustainable, renewable supplies from rivers, streams, and aquifers. Water stress impacts go beyond environmental losses, since Arizona's economy, quality of life, and cultural heritage require water to thrive. Arizona has long recognized the environmental values of its freshwater resources; wildlife and fish were approved as beneficial uses in 1941 and 1962, respectively (Arizona Court of Appeals, 1976). Despite this expansion of beneficial uses, historic recognition of ecological water needs typically depicted people and ecosystems as competing users. More recently, contemporary definitions of water sustainability consider ecological needs in terms of their contribution to human well-being. However, the disconnect between human and ecological water uses continues, which—along with other key factors described below—drives Arizona towards increased water stress, underpins water sustainability challenges, and highlights the need for a diverse and innovative suite of water management tools.

Law Inherited from the Past. The prior appropriation doctrine has wedded Arizona's surface water to history, freezing surface water allocations to historic uses and resulting in an ongoing struggle to cope with a changing climate and shifting demands. Additionally, Arizona law partitions the allocation and administration of groundwater and surface water. This leads to inconsistency and uncertainty in the context of a variable, interconnected hydrological system and a lack of protection for baseflows.

Growth. Arizona has grown more rapidly than much of the nation, and recession may offer only a breather. Permanent water solutions are elusive, leaving the state with temporary triage strategies—conservation, groundwater overdraft, and aquifer recharge-and-recovery—that can buy time but not a long-term sustainable solution.

Change and Uncertainty. Climate change will exacerbate the challenge of managing risk and uncertainty in an already highly variable environment. Furthermore, while climate change science can frame the choices and tradeoffs that lie ahead, it cannot provide certainty about how changes will unfold.

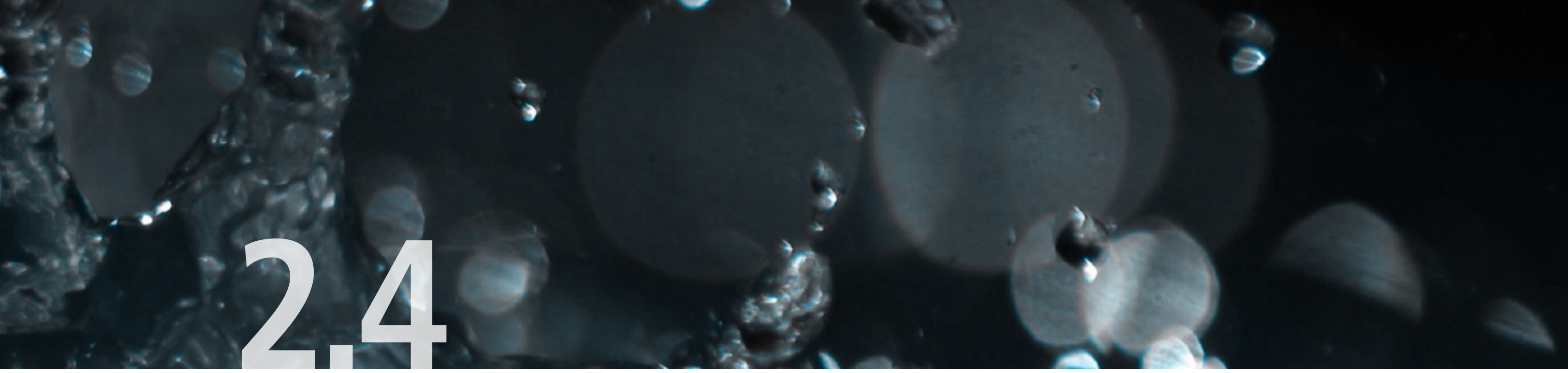
Tribal Settlements. Settlements have secured water for some tribes but not all, leaving future settlements as an unknown. Completed settlements have not always provided the water management flexibility expected. Additionally, settlement water may not be used for leasing to the degree expected.

Environment. Arizona's approach to environmental protection and regulation is premised upon a separation between the needs of people and the needs of ecosystems rather than on a connection between these needs. Due to land- and water-use changes and diminished water availability, significant stretches of riparian habitat across the state have been lost. However, some incidental riparian recovery has occurred in response to reductions in groundwater pumping, agricultural retirement, and effluent discharge. There is the potential for riparian restoration despite gaps in the legal framework if ecological water needs are secured in tandem with complementary restoration activities in specific sites.

Cultures of Conflict. Water managers are often focused on local water needs. Achieving water sustainability requires planning at both local and broad scales, building partnerships among all users—municipal, agricultural, industrial, mining, recreation, and ecosystem—and moving past zero-sum approaches, while respecting the diverse goals and values of all water users.

Institutional Capacity. The deficits in institutional capacity are primarily due to regulatory disconnects between elements (air, water, land, and species) and jurisdictions (federal, state, and local) and a lack of resources to fund agencies and noprofit organizations.

Economics. Water markets and associated institutional reforms are limited. Price signals are largely absent and do not guide choices between market and other water management alternatives. However, the growing competition for scarce water supplies and the emergence of new environmental values will likely lead to higher costs and higher water prices. ■



2.4

Desired Conditions

The goal of sustainable water management is to meet existing and future needs of people without compromising long-range ecological health. Communities are challenged to equitably meet multiple needs with finite supplies of water. Community-specific needs can be identified, defined, prioritized, and endorsed through social decision-making about the desired economic, ecological, cultural, and legal components of water management. Numerous stakeholder processes in Arizona have defined desired outcomes for water sustainability that recognize economic, ecological, and cultural goals.
In 1997, the 71st Arizona Town Hall meeting articulated the need for water management goals in the next 50 to 100 years that will:

> "...address the needs of sustainable development and preservation of water supplies for future generations of Arizonans. They should include achieving safe yield in certain areas and looking beyond domestic, industrial and agricultural uses to the effect water use and allocation has on riparian areas, the environment, and our overall quality of life" (Colby et al., 2004).

Most recently, the Arizona Department of Water Resources (ADWR) convened a Blue Ribbon Panel on Water Sustainability with the stated purpose to:

> "...advance water sustainability statewide by increasing reuse, recycling, and conservation to protect Arizona's water supplies and natural environment while supporting continued economic development and to do so in an effective, efficient, and equitable manner" (ADWR, 2010a).

The desired conditions highlighted in the progression of these goal statements link water sustainability with protecting water supplies and the natural environment in cultural, ecological, and economic terms. Human communities depend upon local supplies of water, including surface water diverted from flowing rivers and streams and groundwater pumped from regional aquifers. When ecological processes that maintain the hydrologic cycle break down, water stress and uncertainty can impact the collective welfare of the community. From an economic perspective, functioning groundwater-surface water ecosystems have direct fiscal benefits that accrue to local communities through tourism revenues, enhanced groundwater recharge, and reliable water supplies. Culturally, sustainable water management results from processes of governance and decision-making that ensure fairness and recognize the dependence of people on functioning ecosystems. ■

2.5

Summary

Water stress conditions are increasing across Arizona, both in scope and duration, and necessitate allocation tradeoffs across multiple uses. Sustainable water management hinges not only on allocation choices among various users, but also on the degree and extent of water stress that results from overallocated systems. The goals of this Cornerstones effort are to identify market-based reallocation options that contribute to meeting the objectives of sustainable water management in Arizona and to also provide tools to meet ecological goals and water requirements. ■

3.0

Arizona's Water Geography

In this section the ecological, institutional, and socioeconomic dimensions of water management challenges in Arizona are explored within three geographic areas that share related conditions. The distinct dimensions of Arizona's water geography define the context for water management problems and solutions at multiple and interacting scales. By extension, these dimensions also shape the context and design of market mechanisms in Arizona's framework for sustainable water governance. ■

3.1

Water Stress and Sustainability

A scan across Arizona reveals a varied landscape for addressing sustainable water management challenges (Figure 4). Although state policies and regulations unify some aspects of water management, a variety of geographic, legal, socioeconomic, and ecological factors distinguish the context for water sustainability challenges and opportunities. The discussion about sustainable water management often breaks along the differences between urban and rural Arizona, based on the regulatory framework under the 1980 GMA and the ensuing rules for assuring renewable water supplies to meet new growth.

For purposes of this report, three regions are proposed for Arizona's water geography, which—despite important differences within each of the regions—present opportunities to fit solutions to the scale and complexity of the challenges. Each of the three regions exhibit similarities in ecohydrological conditions, water supply and demand trends, and institutional settings that shape challenges and opportunities for market-based responses to water sustainability challenges. These regions are i) Central Arizona and the Mainstem Colorado River (Figure 5), ii) Northern Arizona (Figure 6), and iii) Southern Arizona (Figure 7).

The notion of 'three Arizonas'—i.e those governed by Active Management Areas; rural areas with less, albeit growing, state regulatory oversight; and the mainstem of the Colorado River—is a well-established axiom in management discussions. The divide between the three Arizonas is narrowing through the common challenges of securing sustainable, renewable supplies in urban and rural areas alike. Reliance on imported, renewable supplies continues to distinguish Central Arizona from the rural parts of the state dependent primarily upon local supplies, including dispersed exempt and non-exempt wells. A spectrum exists between rural locations that have locally available water supplies sufficient to meet the current and future needs of people and ecosystems and areas where supplies are already limited based on existing or prior growth pressures and drought conditions.

The dimensions of Arizona's water geography can be grouped into four categories: i) ecohydrologic and hydroclimatic conditions, ii) water supplies and infrastructure, iii) demand drivers, and iv) administrative and institutional framework, each of which is explained below. These multiple dimensions help shape solutions to local- and state-level water sustainability challenges.

Ecohydrological Conditions. The interactions between surface water and groundwater resources and ecological processes are defined as ecohydrologic conditions (Newman et al., 2006). These conditions determine the water resources available to meet the needs of people and ecosystems in Arizona.

The ecohydrological classification of Arizona's water geography includes flow regimes, hydrogeologic (aquifer) conditions, and ecological responses to stream-aquifer interactions. The flow regime is determined by the duration and extent of streamflow—perennial, intermittent, or ephemeral—as well as the degree of dependence on groundwater versus snowpack for baseflow. Hydroclimatic variability in the time, place, and intensity of precipitation, temperature, and runoff affect

Figure 4. Arizona's Water Geography

Arizona's Water Geography

interactions between streams and aquifers. Arizona's groundwater recharge-and-recovery facilities and effluent discharges from wastewater treatment facilities augment natural flows in some locations. The presence of keystone species or critical habitat for fish, migratory birds, and other wildlife bring the Endangered Species Act and other federal, state, and local conservation programs into ecohydrologic consideration.

Water Supply and Infrastructure. Arizona's water geography includes multiple, interacting sources of supply including both in-state and Colorado River water, surface water, groundwater, and effluent. The diverse landscape of the state is made up of 51 groundwater basins; the mainstem of the Colorado; the Salt, Verde, San Pedro, and Gila Rivers; other surface water tributaries to the Colorado River; and effluent-dominated stream-aquifer systems, such as the Santa Cruz River. In addition, water supply and wastewater treatment infrastructure and the various jurisdictions and agencies that manage them also shape the portfolio of water resources. This complex array of physical supply and management affects water supply reliability and defines the supply and demand context for market-oriented responses. These factors also inform the water budget that is used to guide planning and allocation decisions across competing needs from the pool of available renewable and non-renewable supplies.

Demand Drivers. Patterns of water use and management respond to two primary forces driving demand: population growth and land use. Historically, water demands in the state were primarily driven by agricultural water use, but this has shifted in recent years as urban populations and corresponding water demands have increased. The Arizona Water Atlas calculates that from 2001 to 2005, municipal demands accounted for 23% of water use, while agricultural demands accounted for 71%. By 2006, those percentages started to shift with 25% of demand directed towards municipal uses and 69% for agriculture (ADWR, 2006–2011). This shift in demand is occurring as municipal populations increase. However, since land-use planning and water resource and infrastructure management have progressed independently, municipal boundaries typically have not aligned with water service area boundaries and management areas. This disconnect leads to inadequate water supply infrastructure available to serve growing populations and continued groundwater dependence in regions outside of the AMAs.

Administrative and Institutional Framework. A complex framework of laws, rules, and administrative policies has developed for decision-making, planning, allocation, and enforcement at multiple scales. The rules and agencies governing surface water and groundwater resources are not consistently aligned with ecohydrological boundaries and interactions. Hydrologically based planning boundaries include the surface water adjudication areas of the Gila River and Lower Colorado River, planning areas of the Arizona Water Atlas, the water district proposed for the Sierra Vista Subwatershed (formation of which did not pass in the 2010 election), and the AMAs. Other management boundaries are based on factors that drive demand for different water-use sectors, such as various water user groups, agricultural irrigation districts, municipal water providers, and wastewater treatment facilities. ■

3.2

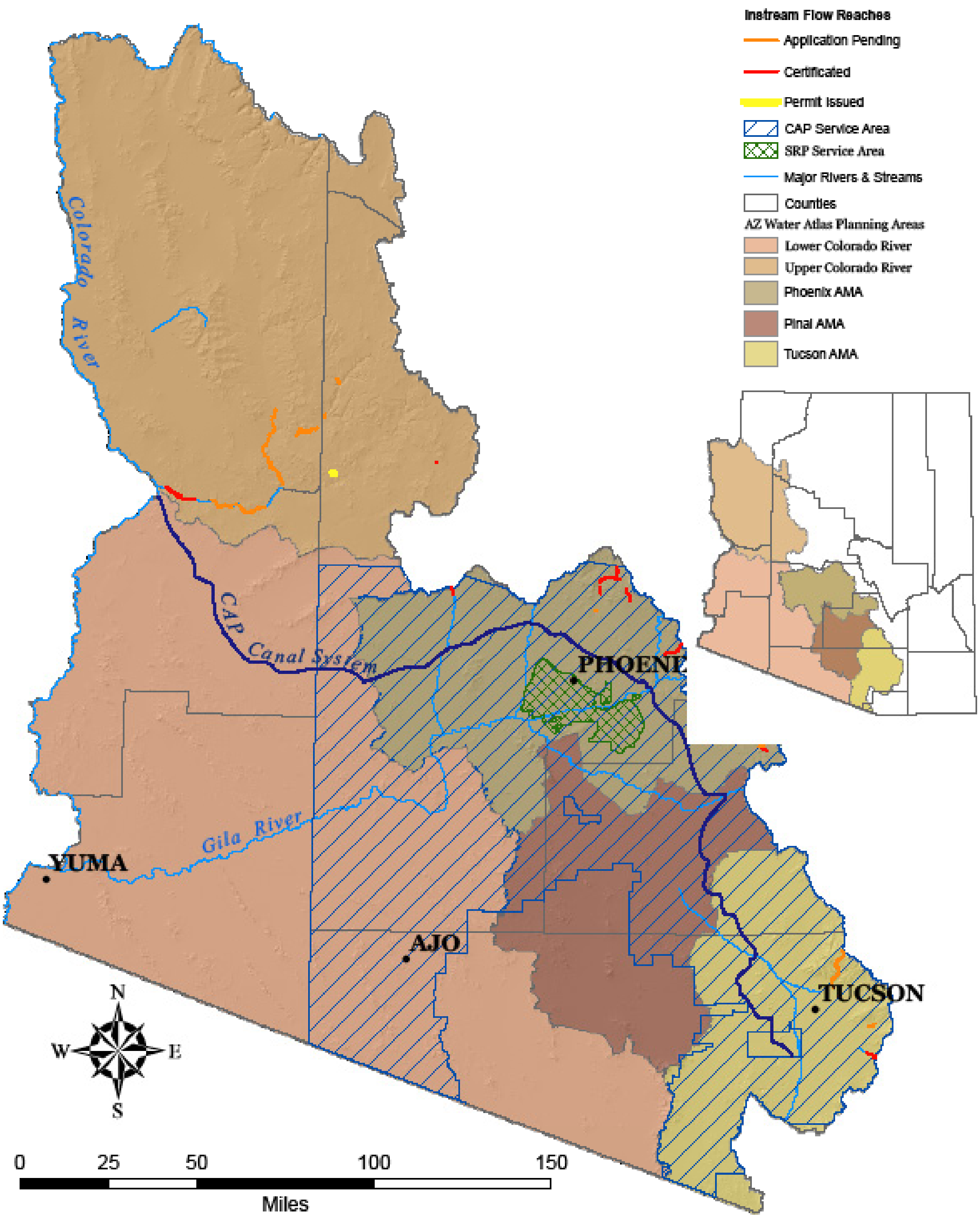
Mainstem of the Colorado River and CAP Service Area: Central Arizona

The Colorado River, the Lower Salt River, and the Lower Gila River are the main surface rivers in Central Arizona (Figure 5). This region is managed by a system of reservoirs and canals, including the Central Arizona Project (CAP), a 335-mile canal delivering 1.5 MAF of Arizona's 2.8 MAF Colorado River allocation to farms and cities in the state's urban centers. The Salt River Project (SRP) is comprised of two entities: the Salt River Project Agricultural Improvement and Power District, which is a political subdivision of the state, and the Salt River Valley Water Users' Association, which is a private entity. SRP manages eight reservoirs on the Lower Salt and Verde Rivers. The water resources of Central Arizona serve municipal providers and agricultural districts.

Ecohydrologic Conditions. The ecohydrology of the Central Arizona region is defined by deep basin-fill aquifers and snowmelt-fed mainstem rivers. Extensive infrastructure for the CAP, recharge-and-recovery sites, and wastewater treatment facilities shape ecohydrological interactions. The region's perennial rivers have largely been dewatered or substantially modified and regulated by reservoirs and associated delivery infrastructure. Annual average precipitation varies from 12

Figure 5. Central Arizona

Mainstem of the Colorado River and CAP Service Area: Central Arizona



inches in Tucson and seven inches in Phoenix, to four inches in Yuma at the confluence of the Lower Colorado and Gila, making the Central Arizona region the most arid in the state. Effluent-dominated systems are widespread throughout the region's urban centers along the Lower Santa Cruz and Salt Rivers. The ecohydrological conditions prevailing in Central Arizona support a variety of water-dependent species and habitats. The mainstem of the Lower Colorado River is covered by the Multi-Species Conservation Program, implemented to address the needs of threatened and endangered wildlife listed under the Endangered Species Act.

Water Supply and Infrastructure. Water management in Central Arizona is defined by supply infrastructure that converts scarce and variable surface water sources into reliable supplies for growth. Less than half of the water supply is comprised of groundwater. Supplies in Central Arizona, integrate surface water from the SRP, surface water along the mainstem Colorado and from the CAP, and groundwater pumped from deep basin-fill aquifers. Effluent supplies are a growing component of the portfolio. Water budgets have substantially different ratios of a range of water sources within each of the three AMAs located within Central Arizona.

Demand Drivers. Demand is driven by population growth and conservation levels in the Phoenix-Tucson urban corridor, historically irrigated acreage in Central Arizona and the Lower Colorado, industry, and mines. In 2006, over 75% of the population in the state was concentrated in Central Arizona and the majority of future growth is estimated to occur within the AMAs, particularly in Central Arizona. While agriculture remains the largest demand sector, municipal demands will continue to increase in tandem with population growth. Mandatory conservation requirements for industrial and agricultural water users in the AMAs, along with requirements for reducing per capita water use for the municipal sector through voluntary residential conservation programs, contribute to shifting patterns of demand across Central Arizona. The GMA mandates that water providers serving more than 250 acre-feet (AF) institute conservation measures that reduce per capita water use within their service area. Conservation measures include rebate programs to update household water fixtures, commercial and residential water harvesting requirements and incentives, irrigation efficiency programs, and increased use of effluent.

Administrative and Institutional Framework. Water resource conditions throughout Central Arizona and the Lower Colorado are governed by a patchwork of surface water, groundwater, and effluent management rules. Groundwater governance has established an important overlay on surface water management since the 1980 GMA. Three of the state's five AMAs fall within the Central Arizona region—the Phoenix, Pinal, and Tucson AMAs, along with ADWR's Upper and Lower Colorado River planning areas. The GMA established different management goals for the AMAs, to reflect the unique hydrologic and water-use conditions within each. A safe yield management goal guides the Phoenix and Tucson AMAs, along with Assured Water Supply (AWS) rules designed to reduce reliance on mined groundwater. In addition, recharge-and-recovery efforts have endeavored to slow and ultimately reverse groundwater depletion.

The use of surface water is governed by the principle of prior appropriation or 'first in time first in right' for Arizona rivers. The Law of the River—a group of court decisions, international treaties, laws, regulations, and organizations—governs the Colorado River. The Mohave County Water Authority is active in the Upper Colorado River planning area, which also includes tribal governments and growing municipalities. Central Arizona's surface water management areas include large portions of the Gila River Adjudication Area, service areas for the CAP and SRP, and water utility and irrigation district service areas reliant on surface supplies. ■

3.3

Headwaters Region: Northern Arizona

The headwaters region encompasses signature Arizona landscapes including the southern portion of the Colorado Plateau, the Grand Canyon, and the Mogollon Rim, which forms the distinctive southern transition edge of the Colorado Plateau (Figure 6). Much of this region is sparsely populated, with major municipal areas centering around Flagstaff, Prescott, Payson, the Verde Valley, Show Low/Pinetop/Lakeside, and Page on Navajo Tribal lands. The topography of this landscape varies widely from high elevation mountains to low desert canyons and incorporates a wide distribution of ecosystems. Water infrastructure includes both shallow and deep groundwater wells and surface flow diversions. Effluent is increasingly utilized for groundwater recharge and to meet AWS requirements for new developments in Prescott.

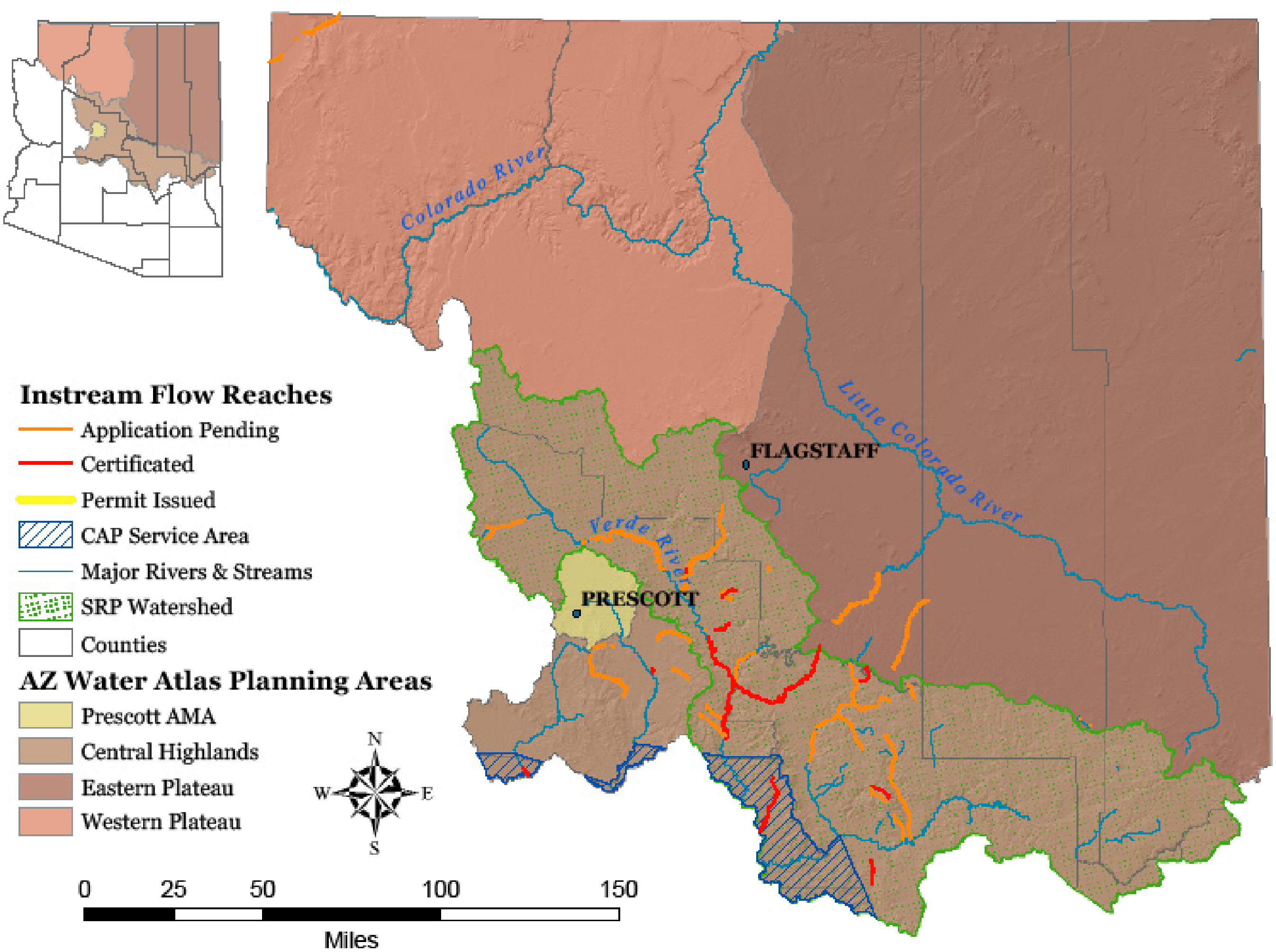
Ecohydrologic Conditions. Roughly half of all the streamflow originating in Arizona begins in Northern Arizona, and many of the state's reservoirs are filled by drainage from snowpack and runoff from this region. Aquifers are found primarily in sedimentary, volcanic, and metamorphic rocks, with water emerging from springs and through groundwater discharge into streams. A number of rivers and streams support native cottonwood-willow riparian ecosystems including the Verde, Hassayampa, Salt, and Little Colorado Rivers, as well as Granite and Agua Fria Creeks.

A focal point of the region is the Verde River, which originates in Northern Arizona and flows approximately 125 miles before entering Horseshoe and Bartlett Reservoirs en route to the Salt River. Groundwater discharge from the Big Chino Basin contributes to the flow in the Upper Verde River, with additional inputs from the Little Chino Aquifer and groundwater discharge from the Big Black Mesa and the Coconino Plateau.

Water Supply and Infrastructure. Groundwater is derived from groundwater basins on the Colorado Plateau. Surface

Figure 6. Northern Arizona

Headwaters: Northern Arizona



water is drawn from the Colorado River and diversions from streams flowing downgradient from the Colorado Plateau and along the Mogollon Rim. Effluent provides a small but growing pool of water that can offset use of potable water for irrigation and recharge in some contexts. As a result of the 1999 declaration that the Prescott AMA was out of safe yield, communities within the AMA started looking outside the basin for additional water supplies. As permitted by state law, the Prescott AMA can utilize interbasin transfers from the Big Chino Valley Aquifer to provide water to growing communities, although it is not yet utilizing this option. Other municipal centers in the region, including Flagstaff, are taking steps toward establishing a framework for local adequacy and securing future water supplies. In addition, Flagstaff has significant conservation and effluent use programs in place.

Demand Drivers. Groundwater demand is driven by both urban and exurban development around Flagstaff, Prescott, and the Verde Valley. Surface water demand is driven by obligations to large senior water rights holders, as well as diversions for small-scale agricultural operations. The Verde River is unique among Arizona rivers in that a large portion of surface flow is obligated to downstream users, including the SRP, the City of Phoenix, the Salt River Pima-Maricopa Indian Community, and the Fort McDowell Indian Community. Exempt wells and irrigation ditches withdraw groundwater and divert surface water, but the amount of water they utilize is not monitored so their cumulative impact on water resources has not been quantified. Industry plays a major role in this region due to the presence of electrical generating stations and mining operations. Tribal water rights and infrastructure needs also influence the use patterns and distribution of surface water and groundwater.

Administrative and Institutional Framework. The Little Chino Aquifer, which contributes to baseflows in the Verde River and provides water to Prescott and surrounding communities, is managed within the Prescott AMA. A safe yield goal guides management in the Prescott AMA. The Gila and Little Colorado adjudication areas will influence the allocation and use of surface water in those basins, as well as within the Prescott AMA. In an effort to align land-use planning with water resource management, some communities are working on city or county growth plans that include water supply and infrastructure needs. Watershed initiatives are addressing multiple levels of water supply planning, including the impact of exempt wells on surface-groundwater connections. ■

3.4

Southeastern Arizona

Southern Arizona, south of the Mogollon Rim, is geologically defined as the Basin and Range Province (Figure 7). This dynamic landscape consists of broad, low-elevation valleys rimmed by long, thin, north-south trending mountain ranges, often referred to as 'sky islands.' The San Pedro and Santa Cruz Rivers flow from south to north through valley bottoms before intersecting with the Gila River. This region includes a mosaic of institutional frameworks that manage limited local water supplies for growing populations.

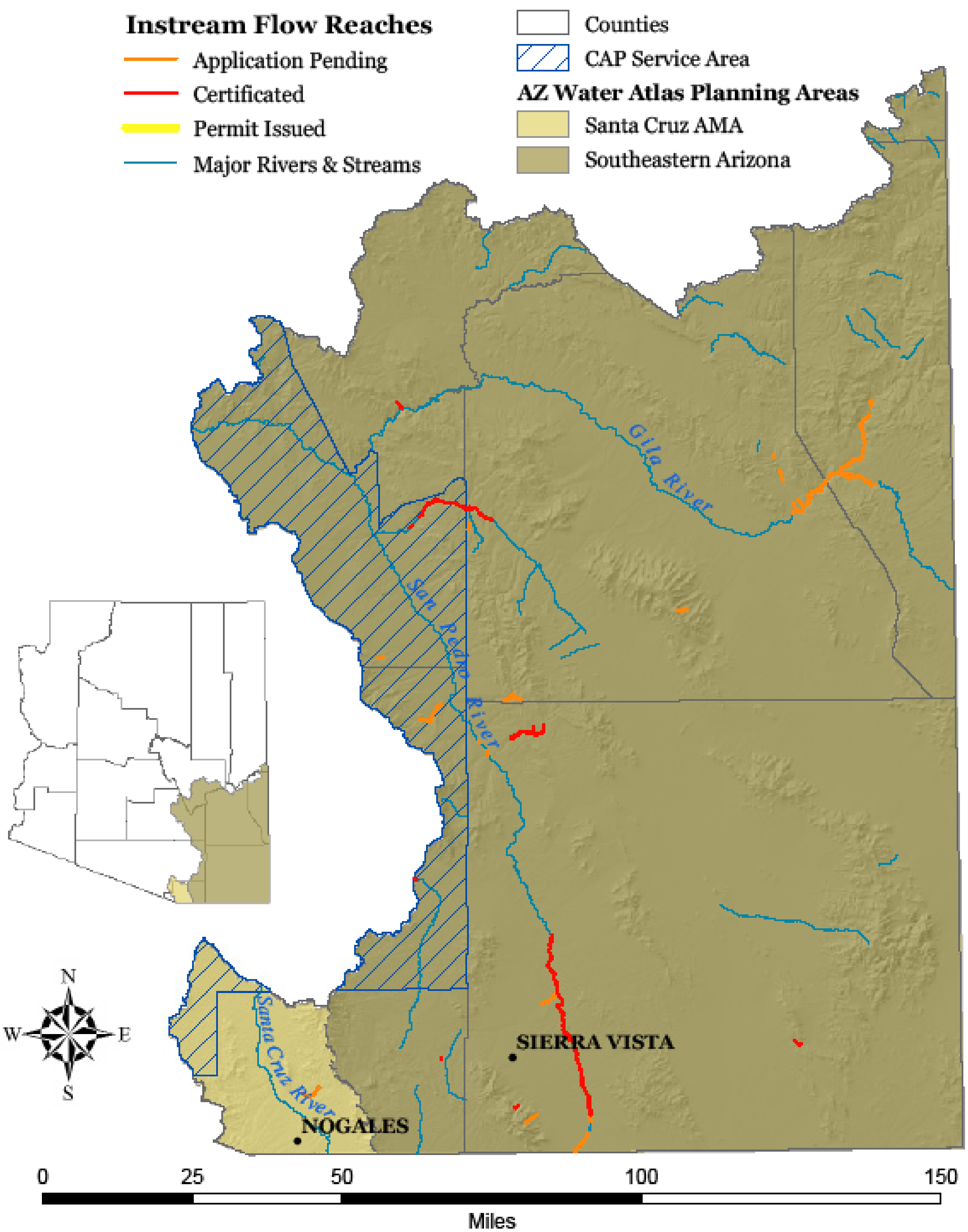
Ecohydrologic Conditions. Despite the size of the Basin and Range Province, runoff and natural recharge is limited, occurring along mountain fronts and a mix of perennial, ephemeral, and intermittent streams. The San Pedro River and the Upper Santa Cruz River are the main rivers in Southern Arizona. The Upper Santa Cruz River arises from headwater springs in Arizona, flows south into Mexico, and then curves back into Arizona east of Ambos Nogales. The Middle and Lower Santa Cruz River reaches extend north to Tucson then northwest past Marana into Pinal County. The San Pedro originates from runoff in Mexico and the west side of the Huachuca Mountains and flows north to its confluence with the Gila in east-central Arizona. The upper reaches of both rivers derive a significant percentage of their flow from groundwater discharge, are very responsive to changes in the stream-aquifer system, and support ecologically important riparian ecosystems.

The San Pedro Riparian National Conservation Area (SPRNCA) is nationally recognized for its ecological values. It was established by an act of the U.S. Congress in 1988 and is managed by the U.S. Bureau of Land Management. SPRNCA supports one of the most robust Sonoran riparian forests in the region and provides habitat to over 350 species of birds, 80 species of mammals, and 40 species of amphibians and reptiles. A number of species found within SPRNCA are listed as federally threatened or endangered.

A 25-mile cottonwood-willow riparian corridor along the Upper Santa Cruz River provides habitat to over 500 species of

Figure 7. Southern Arizona

Southeastern Arizona



plants, insects, birds, reptiles, and mammals. The Upper Santa Cruz River is defined by tight interactions between surface flow and shallow aquifers that fill rapidly during the rainy seasons and deplete rapidly during dry seasons. As a result of this close connection, the Upper Santa Cruz is prone to flooding and has a highly variable natural flow regime.

Water Supply and Infrastructure. Water supplies in this region are limited to local groundwater aquifers and surface diversions from mainstem rivers. The groundwater basin underlying the San Pedro River has been highly studied and is the focus of a number of management efforts. Effluent sustains surface flows and recharges shallow water tables in the Upper Santa Cruz River; in the Upper San Pedro, effluent is utilized as recharge to create a groundwater mound to protect the river from regional groundwater pumping. Currently, water is not imported into any communities in this region; however, there are continued discussions of extending the CAP line to the Sierra Vista Subwatershed.

Demand Drivers. High rates of population growth and new residential developments in the Sierra Vista Subwatershed are increasing water demands around SPRNCA. The 1988 Act that created SPRNCA acknowledged that without adequate and purposeful management of water resources in tandem with the population growth in the Sierra Vista Subwatershed, the continued health and viability of the riparian system, as well as the water supplies for local area communities, could be at risk (Leenhouts et al., 2006). Surface flow in the Upper Santa Cruz River provides the majority of recharge to the shallow aquifer basins on which the twin border towns of Nogales, Sonora and Nogales, Arizona depend. In addition, Upper Santa Cruz River water resources support growing communities, industries, and family-owned agricultural operations. Water withdrawals from the Upper Santa Cruz River aquifer system in Mexico provides about 60% of the potable water needs of Nogales, Sonora, a portion of which is then returned to the Santa Cruz River in the form of effluent discharges from the Nogales International Wastewater Treatment Plant. This municipal effluent supports the riparian habitat and augments groundwater recharge in Santa Cruz County. As populations along the river increase, supplies of effluent could increase, but at the cost of drawing down water tables upstream of the urban cores.

Administrative and Institutional Framework. The San Pedro River is located outside of AMA administrative boundaries and is subject to decisions by the local municipality about land use and water management, in addition to federal land management regulations. The Upper Santa Cruz River is located within the Santa Cruz AMA, which is managed to achieve AMA-wide safe yield and prevent drawdown of local water tables. The U.S.-Mexico border adds an international layer to the management decisions, as Mexican land-use decisions influence both the quantity and quality of water that flows into the San Pedro and Santa Cruz River Watersheds. Collaboration across local, state, and national boundaries is an important—but often challenging—aspect to water management in Southern Arizona. ■

3.5 Summary

Table 2 summarizes the dimensions of Arizona's water geography across the four categories reviewed above: ecohydrologic conditions, water supply and infrastructure, demand drivers, and the administrative and institutional framework. These dimensions of Arizona's water geography determine water management challenges and solutions at multiple and interacting scales. These dimensions also shape the range, application, and feasibility of implementing market-based mechanisms within the context of sustainable water management. ■

Table 2. Dimensions of Arizona's Water Geography

Geography	Central Arizona Colorado River and CAP	Northern Arizona Upper Gila, Verde, and Little Colorado Rivers	Southern Arizona Upper San Pedro and Upper Santa Cruz Rivers
Ecohydrological Conditions	• Snowmelt-fed surface water • Deep basin-fill groundwater aquifers • Isolated shallow aquifers • Recharge-and-recovery	• Groundwater-dependent surface water fed by snow-melt, rainfall runoff, and springs • Complex, varied hydrogeo-logic and aquifer conditions	• Flood-dominated, groundwater-dependent surface water • Microbasin hydrogeology with isolated shallow aquifers • Effluent-dominated perennial stream-aquifer
Water Supply and Infrastructure	• Colorado River (Central Arizona Project and Mainstem) • In-state surface water (Salt River Project, Lower Gila and Verde) • Groundwater allowances (Active Management Areas) • Recharge-and-recovery • Municipal effluent	• Surface water diversions, ditch systems, and interbasin transfers (Verde) • Groundwater pumping, including exempt wells • Gila River effluent	• Groundwater depen-dence (San Pedro & Upper Santa Cruz Rivers) • Effluent-dominated stream-aquifer systems (Upper Santa Cruz) and ephemeral systems
Demand Drivers	• Urban demand in Phoenix-Tucson corridor • Grandfathered agricultural use in AMAs and mainstem Colorado River, agricultural use in Yuma • Tribal demands expressed by Southern Arizona Water Rights Settlement Act	• Urban and exurban develop-ment (Flagstaff and Verde) • Small-scale and hobby agricultural practices • Tribal demands and infra-structure requirements (Navajo) • Mines and power generation	• Urban growth and exurban development (Sierra Vista and Nogales) • Historical agriculture, including family farms and ranches • Mines and power generation
Administrative and Institutional Framework	• Active Management Areas (Phoenix, Pinal, Tucson) • Central Arizona and Salt River Project Service Areas • Gila Adjudication Area • Central Arizona Groundwater Replenishment District • Water utility service areas (Assured Water Supply) • County and city planning areas • Arizona Corporation Commission	• Active Management Areas (Prescott) • Gila and Little Colorado Adjudication Areas • Watershed initiatives • County and city planning areas • Arizona Corporation Commission	• Active Management Areas (Santa Cruz) • Gila Adjudication Area • Watershed initiatives • County and city planning areas • Arizona Corporation Commission

4.0

Water Sustainability and Market-Based Reallocation

In order to successfully address variation in local conditions—hydrological, socioeconomic, environmental, political, and cultural—solutions to water sustainability problems must include consideration of a full range of strategies rather than relying on a single approach. These strategies span the full gamut from regulatory to voluntary solutions. They also vary in terms of the extent to which government, the market, and/or civil society drive them. In this section, the relationship between water sustainability and the full range of solutions is explored, before moving on to a discussion of how market-based reallocation works and how it can be a useful tool in meeting ecological needs. This discussion provides the basis for examining challenges and opportunities in Arizona that are examined in Section 5. ■

4.1

Strategies for Water Sustainability

There are a wide variety of solutions available to achieve water sustainability. These solutions can be categorized as i) supply, ii) demand, or iii) reallocation strategies. On the supply side, traditional strategies include developing surface water diversions, surface water storage, groundwater withdrawals, and interbasin transfers. Newer and more innovative supply options include shallow aquifer recharge (SAR), aquifer storage and recovery (ASR), effluent reuse, and desalination. These strategies typically rely heavily on engineered solutions that involve the development of water infrastructure. In the case of SAR, ASR, and effluent reuse, meeting new consumptive demands with groundwater storage or treated effluent continues to decrease the available consumptive pool. Desalinization has the unique advantage of adding to the available supply of water.

On the demand side, strategies include increasing the productivity of existing supplies, changing governance or institutional approaches, and reallocating water from one use to another. Increasing the productivity of existing supplies can take the form of using less water to achieve the same purpose, or limiting water consumption at the end use. For example, water conservation efforts may involve eliminating leakage during water transportation by repairing pipes or irrigation canals, or removing water demand at the point of use by switching to lower water-use crops or installing water-efficient toilets. In addition, better measurement, monitoring, and irrigation efficiency efforts, such as using supervisory control and data acquisition systems in irrigation water management, can increase the efficiency with which water is delivered, resulting in less discharge at the end of a system. These water conservation efforts typically rely on the adoption of new technologies and/or the installation of new infrastructure.

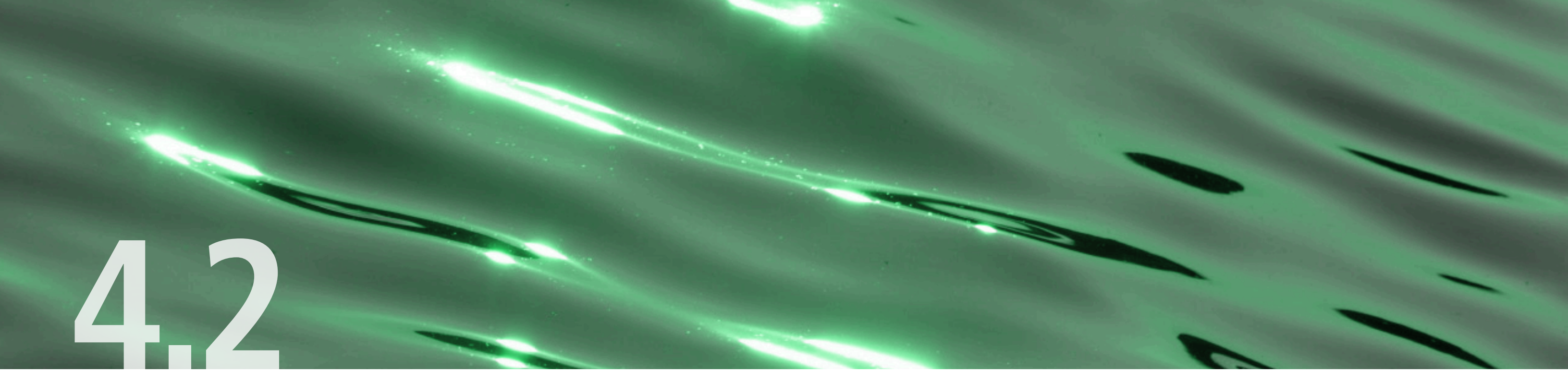
Another set of demand side options are related to governance and institutional approaches. These 'softer' approaches can also result in large savings or reduced end use. For example, better planning and adoption of new governance structures such as water user associations may resolve inefficiencies in water management or unlock new ideas for more profitable, less water-intensive use. A series of 'downsides' or barriers to water conservation have inhibited efforts. These barriers include the dependency of public utilities on water revenues to support the costs of maintenance and delivery, which creates a mismatch between the incentives of households to conserve and the need for utilities to recover costs. Another downside is the 'hardening' of demand by encouraging conservation measures during wet periods that decrease the resilience and responsiveness of water consumers to drought events. Finally, there is a lack of a connection between individual water use and community-level decisions to either conserve or restore water for environmental benefits or free up water to meet new demands.

By improving efficiency, many of these demand side water conservation approaches can reduce diversions or pumping, thereby benefiting ecosystems and improving sustainability. However, where such improvements are used to underpin new consumptive uses, benefits might not materialize and flows and water availability might be diminished downstream or downgradient, with negative impacts to human users and ecosystems.

A third set of strategies comes from the direct reallocation of water from one user to another. This may be accomplished involuntarily by legal or administrative decree, or voluntarily, as through compensated exchanges in a water market. The former is often the result of legislation or regulatory action to implement tribal water settlements or to remedy water management practices within the context of major environmental legislation such as the Clean Water Act or the Endangered Species Act. As with any government action that affects property rights, questions of compensation arise. The alternative approach is to engage in market-based reallocation. Existing and prospective water users can engage in willing buyer–willing seller transactions for mutual benefit. These transactions involve rights created through developed supply or water saved through demand management. In some cases these transactions will evolve into formal markets—places where buyers and sellers meet to trade.

There are a wide variety of solutions available to achieve water sustainability. These solutions can be categorized as i) supply, ii) demand, or iii) reallocation strategies.

In Arizona, each of these three strategies has been utilized. From the perspective of supply, the infrastructure development era culminated with the establishment of the CAP, which was authorized in 1968 and substantially complete in 1993, when it reached Tucson. In the last decade efforts to provide 'new supplies' have also taken hold, although these solutions tend to be more localized. Demand management efforts were jumpstarted as a condition of federal approval of the CAP, including conservation requirements mandated by the 1980 GMA. These conservation requirements are updated in management plans prepared at ten-year increments for each AMA. The more recent push toward reallocation remains in its infancy but includes efforts such as the CAP ADDwater (Acquisition, Development and Delivery of new Water supplies) auctioning concept to allocate 'excess water' on the Colorado River. Reallocation efforts also include the use of pilot forbearance agreements and interstate water marketing through the 'intentionally created surplus' program to exchange storage rights in Lake Mead among the Lower Basin states. ■



4.2

Economic Incentives, Prices, and Sustainability

Sustainability is not a predetermined end point, but rather a set of criteria and outcomes that need to be defined by the relevant stakeholders and modified as underlying supply and demand conditions change or as social needs and scientific understanding evolve. With supply and demand management strategies, it can be difficult to discern the true economic cost of the alternatives. This is due to many factors, including a lack of transparency and full cost accounting on public projects, and the existence of subsidies and taxes that can hide the economic opportunity cost of resources dedicated to these projects.

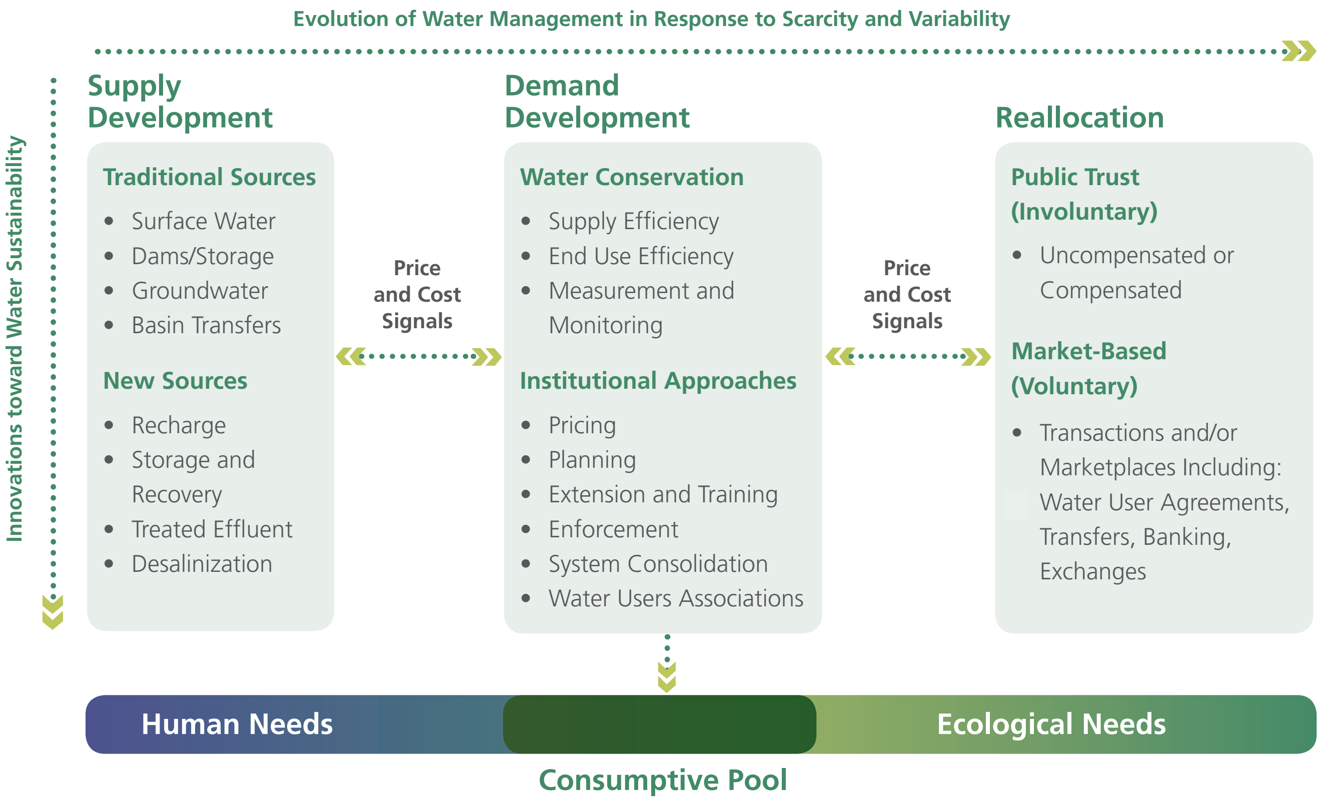
Cost figures for supply and conservation projects are often expressed in dollars/AF of water supplied or saved. These figures often reflect only engineering cost estimates and might or might not be accurate representations of the costs of these projects to the economy. Choosing the least-cost alternative may be the recommended approach but can be difficult in practice. A larger question arises about whether the economic benefits generated by the beneficial use of the resulting water exceed the economic costs of undertaking the alternative. For example, federally funded water projects are intended to address this question under federal guidelines. However, this comparison of costs and benefits can be a difficult undertaking and subject to criticism. Nevertheless, it remains a useful exercise to attempt to estimate these economic indicators and test alternative strategies in terms of their comparative costs and net benefits.

Figure 8 illustrates the full set of strategies discussed above, laying them out on a continuum from an emphasis on supply, to management of demand, and finally to reallocation as scarcity of the resource grows. Within each set of strategies, it is also possible to identify, somewhat generically, how innovations further develop and evolve these strategies. As suggested above, in a given location at a given time, each strategy and each potential set of strategies will have their own relative advantages, disadvantages, and cost-effectiveness. From an economic perspective, and as shown in Figure 8, these strategies can be assessed based on the relative cost per unit of water via supply development, demand management, or reallocation.

A unique feature of market-based reallocation is that it provides observable data on the price of water. Such market prices establish incentives that can be useful in two ways. First, prices can be compared to the cost of other alternatives for accomplishing water supply needs of buyers. In other words, the prices emerging from transactions and markets can be compared to the costs of water secured through demand management or new supply development. Thus, market-based reallocation provides a third bucket alongside supply and demand solutions. For example, if the federal government is deciding on financing a project that will supply 'new' irrigation water at a cost of $3,000/AF, or a city council is considering investing in conservation efforts that are projected to save water at a cost of $4,000/AF, or a large business is scrutinizing a proposal for treating wastewater that would produce clean water at $3,500/AF, these decisions would benefit from reference to the market price of water in the area or to the cost of reallocating an AF of water in the absence of an active market. Such comparisons may require further analysis to ensure that the effects of other policy and economic factors at play (e.g. subsidies) are accounted for in cost figures or prices. Developing market-based reallocation strategies can therefore assist overall water sustainability by providing price signals that can inform the choice of strategies going forward. Making such information available may also increase the economic incentive for providers to improve the cost-effectiveness of supply-and-demand management alternatives.

Price signals from a water market can also provide a check on the economic benefits of water use. In the federal financing scenario presented in the preceding paragraph, if water is trading at $2,000/AF, the federal government may reconsider a project that provides 'new' irrigation water at a cost of $3,000/AF. In effect, having a competitive market for the reallocation of water rights provides some 'market discipline' with respect to choices being made in terms of supply and demand management strategies. For example, CAP water was initially too expensive for the primary beneficiaries, which led to a combination of subsidized water prices for users and the creation of source substitution arrangements to reduce groundwater pumping—cheaper to pump than CAP but with

Figure 8. Responses to Water Sustainability Challenges



Sustainability is not a predetermined end point, but rather a set of criteria and outcomes that need to be defined by the relevant stakeholders, and modified as underlying supply and demand conditions change or as social needs and scientific understanding evolve.

high environmental costs—as a substitute for more expensive CAP supplies.

Ideally, choices are made using the full set of criteria including issues of equity and accountability, not just economic criteria. However, in decision-making it is often helpful to compare the varying costs of different alternatives to the varying benefits in terms of cultural, ecological, and other criteria. Making economic tradeoffs transparent can help to make better decisions. For example, in the case above there may be important social reasons why new irrigation water is needed. Making the tradeoff clear—in this case social objectives could be met either by buying water on the open market or by building the project and incurring an extra $1,000/AF in cost—is an important step in the direction of sustainability. In sum, achieving water sustainability includes making the best use of a portfolio of demand management, supply development, and reallocation options. The risks, costs, and benefits of all approaches—as well as their political feasibility and accommodation of diverse stakeholder views and decision-making processes—will dictate the mix of management responses. The efficiency with which water sustainability is achieved will partially depend on the extent to which all solutions are market-based, meaning they respond to price and cost signals. Creating a water market and establishing a price for water is part of achieving the broader agenda of water sustainability. ■

4.3

Market-Based Reallocation of Water Rights

Addressing a series of enabling conditions and defining elements are prerequisites to successfully implementing market-based reallocation alternatives. However, the local context will determine the sequence of institutional changes and key ingredients necessary for achieving success in any given setting. Being in a state of water scarcity is the first prerequisite for water markets to become attractive for meeting emerging water needs for people and ecosystems. Only after cheap, reliable, and environmentally sound supply-and-demand management strategies are exhausted will it make sense to explore reallocating existing rights as an alternative to pursuing more expensive or risky conservation and supply augmentation strategies.

For scarcity to lead to market-based reallocation, a system of clearly defined and tradable water rights must be in place. In the surface water context, transactions depend on adjudication or administrative procedures to determine the extent and validity of all the water rights in a basin in order to define the transferable quantity of water under the twin principles of ‘first in time, first in right’ and ‘no injury’ under prior appropriation. The former principle defines secure water rights while the latter principle safeguards against negative impacts from changing patterns of water use. Institutional capacity must develop to overcome the legal, economic, cultural, and physical barriers to reallocation. Historically, Arizona has struggled to apply these principles in practice. Groundwater trading is governed by a separate set of rules and is limited to AMAs where the regulatory framework establishes a cap and enables trade in type 2 rights (non-irrigation grandfathered rights) and groundwater credits generated through irrigation conversions.

The lack of fully adjudicated surface water rights is a deterrent to transactions but is not always fatal. With sufficient due diligence and the requisite set of administrative procedures or agreements from affected stakeholders, transactions in unadjudicated claims can take place. In Arizona, the lack of a general adjudication, including preliminary disputes about the interaction between groundwater and surface water rights, has been highlighted as the “Adjudication that ate Arizona water law” (Feller, 2007) and has hampered the resolution of property rights issues and water-trading rules to facilitate the type of market-based reallocation envisioned. Despite this barrier and the expectation that general adjudications will require a generation or more to resolve, other states in the West have demonstrated that even these weighty costs of institutional reform do not inhibit interim measures to secure water for the environment or to uphold existing senior water rights facing pressure from groundwater pumping.

The lack of fully adjudicated surface water rights is a deterrent to transactions, but is not always fatal.

In order for water rights transactions to occur, a buyer and a seller must exist who have the potential for gains from exchange between the two. Transactions between willing buyers and willing sellers are often taken as evidence that a ‘market’ exists. However, markets are often considered to be more than a limited set of ad hoc transactions. A more ambitious definition of a 'market' is a place where buyers and sellers meet to trade. This place can be a physical place or a virtual (on-line) place. The distinction between ad hoc transaction and such a 'marketplace' may also simply reflect opportunity. Where there are few opportunities for trade, or few opportunities for gains from trade, then ad hoc transactions are likely. Where there are many buyers and sellers, and much to gain from trade, a marketplace may evolve as an efficient solution to bringing buyers and sellers together. For the purposes of this paper the term 'water market' includes both situations where ad hoc transactions are occurring and more robust and organized marketplaces.

There are two key elements that define market transactions in water rights: financial and administrative. The first element, which is always present, is the exchange of value. Typically, this is the financial part of the transaction, although water rights may be donated from one party to another. Money is paid either to acquire the water right, for the use of water under the water right, or for the conversion of land with appurtenant water rights to facilitate a change in the type of use or the location of use. As noted above, this may be a transaction negotiated directly (with or without brokers), or it may be conducted through an intermediary that facilitates and handles the transaction. In some cases the intermediary will match buyers to sellers, but in others it may buy water rights on one side of the market and sell water rights on the other, aggregating and disaggregating water rights as necessary. Few examples of such formal intermediated marketplaces exist in the United States. Still fewer examples exist where such marketplaces are distinct from a state-run 'water bank' and where prices are determined by supply and demand, instead of being set by the bank.

The second part of the transaction, which does not happen in all cases, is the administrative change to the water right. Water rights represent the permission granted by the state, tribal authorities, or owner (e.g. municipal wastewater treatment plants) to the water right holder to use the water resource according to the terms and conditions of the right. The water rights owner retains the ownership—on behalf of the public—of water and is responsible for administering its use under the water code. Once the financial part of the transaction is consummated, the buyer may petition the state to change how the water is used, for example, by moving its use from the seller's property to the buyer's property. Water rights are rights that are circumscribed by the source of water, the point of diversion (or abstraction), the place of use, the manner of use, the amount of the use, and the season (or timing) of the use. The buyer may submit an application to the state to formally change any of these parameters, which is subsequently processed by the state.

Only after cheap, reliable, and environmentally sound supply-and-demand management alternatives are exhausted will it make sense to explore reallocating existing rights as an alternative to pursuing more expensive or risky conservation and supply augmentation strategies.

In Arizona, the sever-and-transfer statute (ARS 45-172) regulates sales of surface water rights. Rules govern changes to contracts for Colorado River water and for different classes of groundwater rights. In some contexts across the West, state agencies have established specific programs that facilitate certain types of changes in water rights. These are often referred to as water banks and include groundwater mitigation banks, storage rental pools, groundwater (ASR) banks, lease programs, and others.

It is important to note that in some cases it is both feasible and advantageous for the buyer and seller to avoid making a formal change to the seller's water rights. Where such a change is not pursued, the transaction can be called simply a 'water user agreement.' This is a financial arrangement between existing and potential water users for a change in water use that is implemented outside any formal marketplace or government procedures. Such agreements are limited to conditions where the change in water use and the benefits for the prospective buyer do not affect upstream or downstream users.

There are three types of water rights transactions subject to state regulation. These include permanent transfers, water exchanges, and banked water.

Transfer. A transfer is a permanent change in the water right without altering the source of water. Typically the motivation is to change the point of diversion, the place of use, or the manner of use. Associated with these may be a change in the type of water right or amount or season of use.

Exchange. An exchange involves a change in the source of a water right. A permanent exchange would be a switch from one source, such as surface water, to another source, such as groundwater. An open exchange refers to an exchange in source that is not permanent, where there is the option to return to the original source. A flexible or variable exchange could refer to the case where the user can go back and forth from one source to another. Exchanges can provide much-needed flexibility in water use but typically require either water to be available from the new source or for a close hydraulic connection to exist between the two sources. The regulatory distinction among sources of groundwater, surface water, and effluent, as well as the divisions of each of these water types into difference classes, creates both challenges and opportunities to such approaches in the Arizona context.

Banking. Banking of water refers to a temporary change in a water right. This may consist of moving water from its permanent authorized use to another use for a limited period of time in the same season, such as a dry-year option triggered to reduce or forbear water use during temporary deficits in water supplies (in other words, changing the place of use or one of the other elements of the water right only temporarily). In regard to storage, banking can refer to the carrying of water over from one season to another for the same or another use. In the case of water banking, the seller is not transferring title to the water right, since once the term of the agreement is complete the use reverts back to that specified under the water right.

These transactions are most easily considered in the context of surface water right transactions but can just as easily refer to transactions in groundwater, effluent, and conserved water. In this manner water rights transactions incorporate the property rights created through supply or demand management activities. ■

A water market provides a framework for addressing two ecological contexts—preservation and restoration. In contexts with high ecological values where human demands have yet to encroach on resilience and sustainability, imposition of a cap can preserve environmental values.

In contexts where the ecological thresholds have already been exceeded by existing water use patterns, trading can be used to reallocate existing water rights to an environmental purpose, effectively restoring flow conditions.

4.4

Regulatory Reform to Meet Ecological Needs through Market-Based Reallocation

Building from the rationale for, and mechanics of, market-based reallocation, how can water markets and associated institutional preconditions be used to protect or restore environmental needs? The use of water to meet mining needs, agricultural needs, and eventually other needs evolved as a property interest that could be traded between users. Incorporating public and environmental uses into the discussion of the sustainability of the existing water management system poses a challenge. The choice is between i) restructuring the existing market system (public trust) or ii) creating a method and opportunities to obtain water for environmental uses within the existing water system (market-based reallocation for environmental purposes).

In the 1970s the public-trust doctrine was invoked to assert the public interest in water management, particularly for environmental needs. Landmark case law (*National Audubon Society v. Superior Court* 1983) in the mid-1980s in Mono Lake, California, recognized the environment as a basis for the public trust in water, including the potential to reallocate water for environmental purposes without compensation through involuntary administrative and court decisions. The public trust doctrine in Arizona has not been asserted through the courts, but rather through a range of voluntary policy and planning processes to promote sustainability. Because the public trust approach often embodies the idea of superseding the existing property rights system, with water reallocated to the environment through legislative, regulatory or judicial action, it is politically controversial and has seen limited implementation. The alternative is to work within the existing system and reallocate or acquire water from willing sellers in order to meet ecological needs.

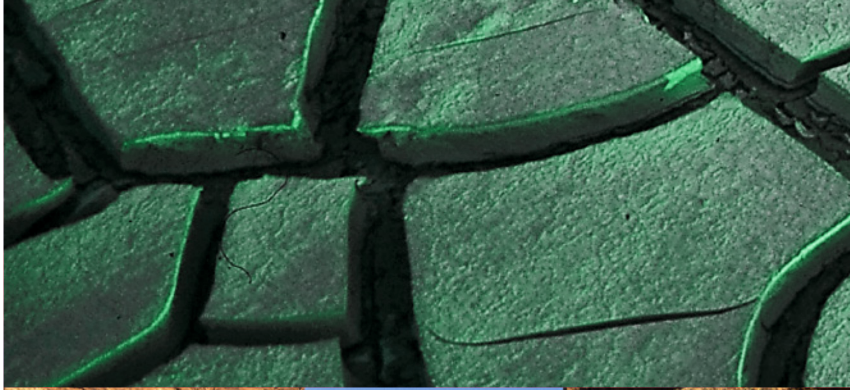
Whichever way is chosen, environmental uses of water need to be included within the beneficial use framework. Prior appropriation sets up a permit-based system of surface water-use rights for a resource supply that can be highly variable from year-to-year. As demand grows, new users seek additional permits. Eventually, all of the reliable water permits are distributed at no cost to the applicants. In many cases across the West, permits continued to be handed out until systems were fully allocated or overallocated. If there are shortages in surface water supplies, water is allotted according to the dates of the permits. Thus, lesser or junior rights are by their nature interruptible due to variable hydrological conditions and the low priority of rights in the system.

Since surface water rights can be traded, prior appropriation is essentially a cap and trade system. The permit system, when combined with variable supply, effectively caps reliable water allocations based on the physical limits of the water resources. Once the system is closed or fully allocated, new users must (and can) purchase a senior right if they require a reliable water supply for their economic activity. In such a system, ecological needs are only met if the existing beneficial uses do not require the water. Over time, as demands on the resource grow, less and less water is likely to be available for what are in effect 'non-permitted' or residual claims and uses. Ecological needs are therefore outside the cap and trade system (the 'market') as long as they have no status as beneficial uses. For water to be provided for in- and out-of-stream ecological needs, environmental uses must either be inserted into the priority system as priority needs—the public trust approach—or be brought into the beneficial use system so that environmental buyers can acquire and protect water for these uses.

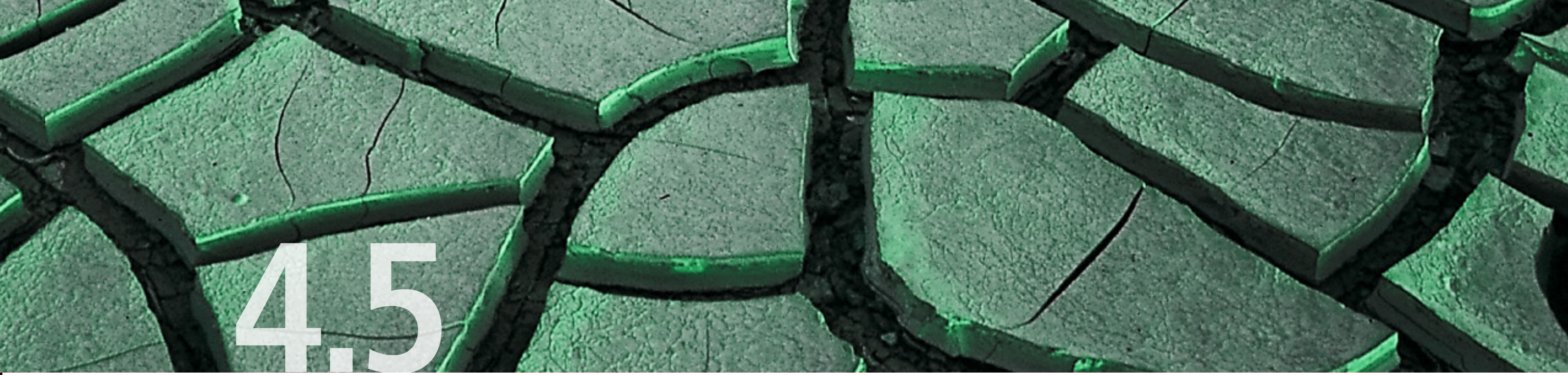
Unfortunately, many water-scarce regions in the West have recognized ecological needs for water only after ecosystems and ecological functions have been compromised. There is a need for mechanisms to reallocate water from existing users to riparian and aquatics ecosystems in order to restore the important ecosystem services they provide for plants, animals, and human communities. The challenge of meeting ecological needs has led to efforts to incorporate environmental water uses into the design of water market reforms. In cases where a deficit in environmental water already exists, authority must also be provided to transfer existing rights to an environmental use without losing the underlying priority or security of the right. In short, environmental uses must become a valid purpose for receipt of water rights, and the environmental buyer must have full authority to enter the market on behalf of these needs.

Ecological needs could also be addressed by inserting these requirements into the rules defining the available consumptive pool—the 'cap.' This could be done so as to elevate the ecological needs in the hierarchy to ensure that these needs are met prior to water diversions and pumping. The rules-based framework has been limited in cases of overallocation because of the threat of involuntary, uncompensated reductions to established property rights. This problem has been addressed in some contexts through pro rata reductions in all rights to ensure the collective pressure on the consumptive pool is managed at sustainable levels of extraction.

A water market provides a framework for addressing two ecological contexts—preservation and restoration. In contexts with high ecological values where human demands have yet to encroach on resilience and sustainability, imposition of a cap can *preserve* environmental values. The Upper Verde River and parts of the Upper Santa Cruz River present examples where ecological thresholds have not been irreversibly exceeded: therefore, an ecologically motivated cap on water withdrawals could limit risk of future declines due to growth in consumptive demands. In contexts where the ecological thresholds have already been exceeded by existing water-use patterns, trading can be used to reallocate existing water rights to an environmental purpose, effectively *restoring* flow conditions to a level below existing consumptive uses. The emergence of such a market system may provide benefits for consumptive users while presenting the opportunity to integrate ecological limits and needs into water allocation for both preservation (cap) and restoration (trade). ■



Water requirements for ecological needs do not occur in a vacuum. These needs develop within the larger context of environmental strategies put forward by state agencies, nonprofit environmental groups, civil society, and the private sector.



4.5 Institutional Capacity Needed for Environmental Water Transactions

Regulatory reforms can establish the potential for environmental water transactions such as an environmental buyer acquiring water rights and transferring them to an environmental use to meet ecological needs. However, the presence of such reforms do not in and of themselves result in the reallocation of water. Environmental water transactions occur within a given cultural, ecological, and economic context. In addition to needing regulatory reform to establish conditions allowing environmental water transactions, one also needs demand and institutional capacity. These needs are often satisfied through institutional change.

Demand implies there are quantifiable ecological needs and at least some cultural acceptance of these needs. If these conditions are met, then the economic challenge is turning this demand into financial resources for transactions or otherwise providing economic incentives for shifting water use to meet ecological needs. On the one hand, reductions in consumptive use to protect or restore environmental needs concentrate costs on existing water users and those with new demands who are facing higher prices. On the other hand, the benefits derived from meeting ecological needs are diffuse and hard for any one individual or group to capture or express. These benefits are in essence public goods that do not lend themselves to a market framework.

However, water requirements for ecological needs do not occur in a vacuum. These needs develop within the larger context of environmental strategies put forward by state agencies, nonprofit environmental groups, civil society, and the private sector. Developing financial resources to implement environmental water transactions requires converting demand into both financing and political will to secure water for the environment. It takes effort and expense to generate and pursue public and private funding opportunities. This effort often occurs first in the nonprofit environmental sector, where capacity is already in place to conduct the needed outreach, advocacy, and fundraising efforts.

Turning demand into financial resources requires collaborative processes and the institutional capacity—in the form of financial, staffing, and technical resources—to enter the water market and engage in environmental water transactions. This can be complex and difficult and requires organizations with knowledgeable staff available to tackle the challenges. Pursuing market-based reallocation puts proponents in the middle of the water resource arena, which is replete with its own institutions, management opportunities, and challenges. Overcoming cultural resistance from the water user community and developing willing sellers are the key challenges to address.

Organizations with sufficient institutional capacity can undertake the necessary planning, coordination, and oversight in partnerships they pursue with stakeholders and market participants. The price of water can motivate sellers to explore mutually beneficial trades, but price is difficult to establish because the value of water rights varies based on multiple attributes. Willing sellers often include agricultural users who are part of irrigation districts or communities in which others resist due to negative impacts on group well-being. There may also be legal impediments to selling. Buyers—especially those who want to purchase water for municipal or ecological needs—have the challenge of persuading multiple beneficiaries to become willing participants in market-based reallocation.

The challenge of identifying and engaging willing buyers and sellers highlights the importance of i) reasonable transaction costs and ii) addressing impacts of water transactions on third parties—both positive and negative. Transaction costs—the costs to define, manage, and transfer water rights—can determine the degree to which willing buyers and sellers can avoid prohibitive expenses or delays in overcoming the hydrologic, legal, administrative, and cultural complexities of water transactions. In addition, any negative impacts of water transactions on third parties must be mutually and beneficially resolved (Box 1).

Box 1. Third Party Impacts

A market transaction between a buyer and seller for appropriable water may have unintended or underestimated consequences for other water users and members of the community or economy. Impacts on these 'third parties' fall into two categories. The first is a legal category of third party impact known as 'injury.' Injury refers to illegal infringement on established water rights. Regulatory safeguards for water rights transfers have been developed to prevent injury to upstream or downstream water rights that depend on historic water-use patterns. According to ARS 45-172(2):

> "Vested or existing rights to the use of water shall not be affected, infringed upon nor interfered with, and in no event shall the water diverted or used after the transfer of such rights exceed the vested rights existing at the time of such severance and transfer, and the director shall by order so define and limit the amount of water to be diverted or used annually subsequent to such transfer."

The second category of third party impacts involves the broader effects that a transfer may have on cultural, economic, or environmental values as patterns of water use are changed. This second category may include i) financial and operational difficulties that may arise when a water user leaves an irrigation district or a shared conveyance, ii) loss of secondary and tertiary agricultural inputs and processing industries that depend on primary agricultural production in a region, iii) loss of cultural values associated with a rural way of life when water moves to the city, and iv) environmental impacts resulting from removing water from the land such as weed emergence, wind erosion, and dust problems. This second category of third party impacts is the major challenge confronting market-based approaches, and regulations or methods to address these issues are difficult to develop. In order for market-based reallocation to take hold, solutions to these issues need to be developed and institutionalized in some manner, just as injury is addressed through a formal process.

Moving beyond a focus on ad hoc water transactions, the larger scale transactions require broader and deeper institutional frameworks. The design of such frameworks depends on the types of water users and infrastructure involved and varies with water sources and the goals for water transactions. In order to implement environmental water transactions at a larger scale, Arizona needs to develop capacity in the following areas:

- Water compacts, inter district agreements, reservoir operating agreements, etc.;
- State-run water banks intended to streamline administrative changes to water rights;

- Irrigation district water storage rental pools;
- Marketplace clearinghouse functions including auctions and transfer/exchange/banking agreements with irrigation districts and tribal users; and
- Private/nonprofit groundwater and surface-to-groundwater mitigation banks.

Institutional needs include science, planning, financing, monitoring, and evaluation to coordinate buyers, sellers, and the interests of third parties. The types of partnerships that emerge will vary depending on the scale of water management decisions; the levels of regulatory and administrative oversight; the context of water users and infrastructure; and the variety of social, ecological, and economic values at play. There are several types and scales of institutions that could address market-based programs for environmental flow:

- Nonprofit water trusts or river conservancies,
- State water trusts or water acquisition programs,
- Federal transactions programs,
- Watershed or river basin partnerships, and
- Regional water districts.

One challenge of third party impacts is resolving issues with local community organizations, such as irrigation districts that can veto decisions by individual water users. Questions about the impact of reallocations on the quantity, timing, and quality of third party water rights and use can impede transactions and should ideally be resolved in a context of local multi-stakeholder decision-making prior to the transaction. Hydrologic interactions between upstream and downstream users and between groundwater and surface water systems impose high information burdens on those proposing to transfer water. There are benefits for reducing transaction costs by addressing third party concerns programmatically so issues do not always have to be resolved by a group prior to each individual transaction. Streamlining rules and processes for transferring water rights could minimize impediments to transactions and encourage voluntary reallocations. Finally, trust at multiple levels, but particularly between buyer and seller, is essential for market-based reallocation strategies. ■

4.6 Summary

Strategies for achieving water sustainability can be organized into supply, demand management, and reallocation categories. Market-based reallocation is one of many strategies that may be included in a portfolio of strategies for addressing sustainability challenges in the context of environmental water needs. Growing scarcity and efforts to find new and innovative strategies have driven the development of market-based reallocation across the West. Market-based reallocation is not only an alternative to other strategies, but when implemented,also provides decision makers with price signals that can inform planning and selection of the full portfolio of strategies.
On the marketing end of the financial arrangements, water markets may range from ad hoc water rights transactions to water rights transactions conducted in an organized marketplace. Water rights transactions are made up of water user agreements and transactions that involve administrative changes to the water rights, including transfers, exchanges, and banking.

A more recent phenomenon is reforming regulations to include instream flows as beneficial uses, opening up the possibility of meeting ecological needs through environmental water transactions. However, such reform needs to be accompanied by efforts to convert the demand for ecological benefits into financial resources, and investing in building institutional capacity to implement such transactions. ■

5.0

Market-Based Reallocation of Water to Environmental Uses in Arizona

Experience drawn from the design and development of environmental water transaction programs and water markets throughout the western United States points to a range of fundamental elements that need to be addressed in establishing market-based reallocation for environmental purposes. This section examines multiple areas of water geography in Arizona for the presence/absence of these elements in order to identify challenges to establishing market-based reallocation for environmental water. Many of these conditions underpin both market-based reallocation and sustainable water management in general.

This section presents a framework for assessing challenges to market-based reallocation in Arizona. Analysis begins at the state policymaking level and includes a discussion of the main challenges, potential next steps, and examples of western regions where related challenges have been addressed. The assessment tool is applied to each of the three geographies described in Section 3 to highlight intersections between the state framework and constraints within each region. While pursuing a region-specific analysis presents an opportunity to examine challenges and opportunities with a finer level of detail, there remains considerable variation within each of the geographies. This assessment exercise can therefore be applied with increasing levels of geographic focus (e.g. basins, watersheds, individual stream reaches) to identify the precise challenges and possible mechanisms for overcoming them. ■

5.1

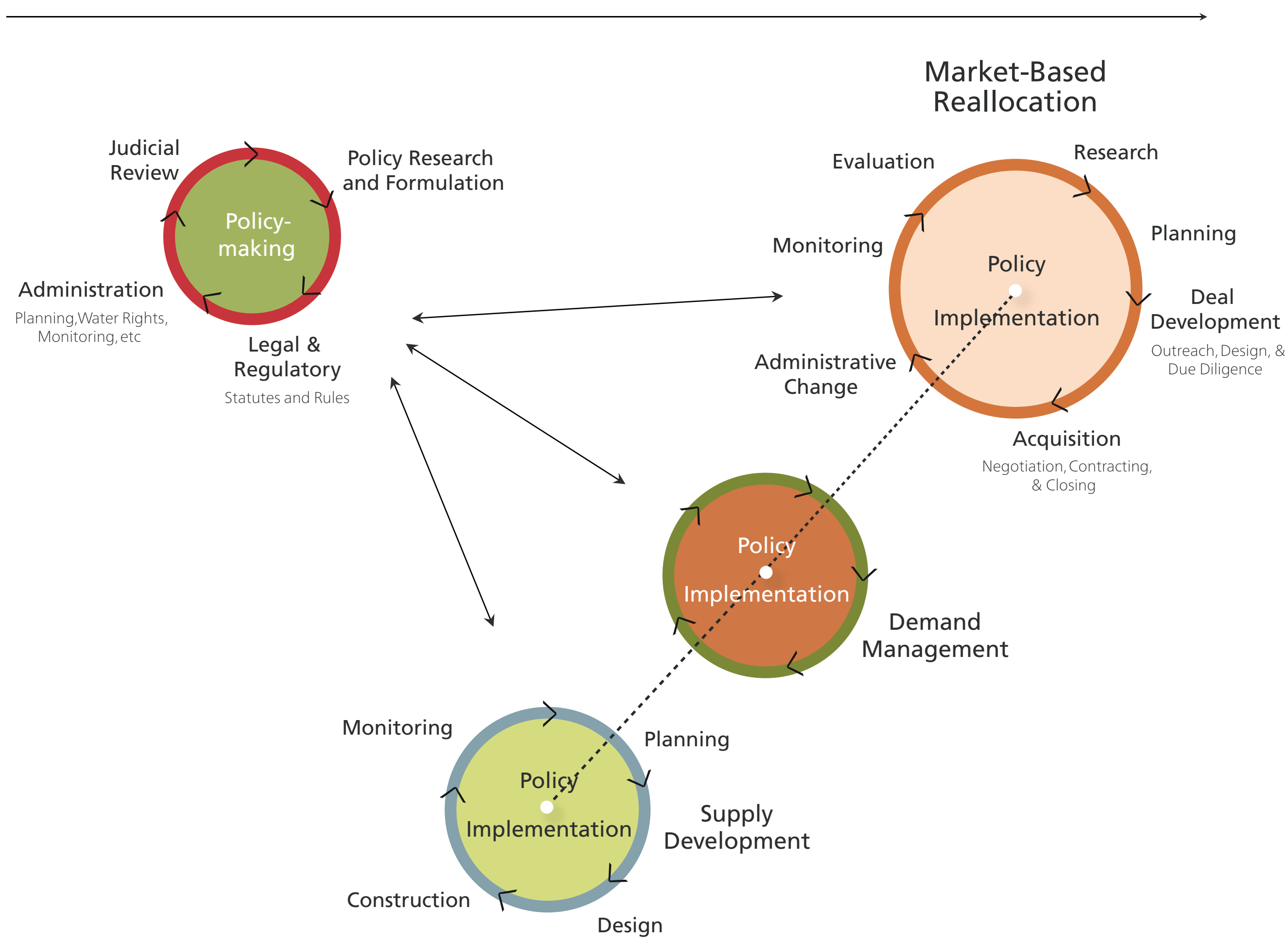
Policymaking and Implementation: Framework for Diagnosing Challenges

In identifying, categorizing, and analyzing regional challenges to market-based reallocation tools, we distinguish between policymaking and policy implementation, as depicted in Figure 9. Ideally, both of these processes involve feedback, learning, and adaptation, so they are characterized as feedback cycles. To connect market-based reallocation to the broader set of water sustainability strategies, the three responses to water scarcity identified in Figure 8—supply development, demand management, and market reallocation—are represented. Although depicted as cycles, they can be conceptualized as wheels or gears that are constantly moving in relation to one another.

Policymaking shapes implementation of one or more management strategies—market reallocation, supply development, and demand management—which in turn informs efforts to reshape the policymaking setting. When the system is functioning well, the cycles turn in coordination with one another. When one wheel turns and reforms are generated or transactions and projects are undertaken, feedback loops occur within that individual wheel and in relation to other wheels. Thus, 'gearing' occurs between the three policy implementation cycles and between the implementation cycles and the policymaking cycle.

These cycles take multiple forms. When a market transaction takes place in the market-based reallocation wheel, that price information can help turn the supply wheel faster or slower by increasing or decreasing incentives to undertake the next supply project. Similarly, as the policy implementation wheels turn affecting supply and demand, this information should feed back into the policymaking wheel, where legislators and administrators adjust their course of action to what works and what does not work in the field. Ideally there is adjustment on the policy implementation wheel, as well as adjustment between the policy implementation wheels and the policymaking wheel.

Figure 9. Policymaking and Implementation Cycles in the Evolution of Water Sustainability



This characterization of policymaking and policy implementation provides a useful way to organize challenges and solutions and helps diagnose challenges when an impasse is reached. For example, if no environmental water transactions have occurred in a particular basin, it is possible to walk back through the implementation cycle to see where efforts have faltered and evaluate how to move things forward. If enabling policies or administrative capacity is not in place, then it is also possible to consider the policymaking cycle and pinpoint critical issues there.

The policymaking and market-based reallocation cycles are conceptualized as having a number of stages or components. The intention is that policy makers can use these stages as a basis of analysis to distinguish between different problems in general, and then to encourage site-specific and in-depth analysis of problems within stakeholder communities.

The following stages occur within the policymaking cycle:

- ***Policy Research and Formulation:*** Various actors (legislators, academics, consultants, think tanks, and civil society groups) analyze, discuss, and propose changes to existing policies articulated in statute and rule.
- ***Legal and Regulatory:*** The executive and legislative branches negotiate and pass new statutes governing water, and agencies and stakeholders engage in rule making to provide clear rules to agencies responsible for carrying out the statutes.
- ***Administrative:*** Various local, state, and federal government agencies interpret and apply rule and law in the processing of water rights applications for new permits, changes in existing permits, and other requests.
- ***Judicial Review:*** Courts settle claims through adjudications and settle cases over specific transactions and their administration by the agency involved.

For the market-based reallocation policy implementation wheel, the following stages are used:

- ***Research:*** Academics, consultants, agencies, and stakeholders carry out research on basin- or watershed-level ecohydrological conditions and environmental requirements to inform planning efforts and respond to evaluation of past implementation efforts.
- ***Planning:*** Stakeholders engage in basin- or watershed-level water resource or integrated river-basin planning, ideally developing visions, strategies, and desired outcomes, as well as action plans.
- ***Development:*** Transactional development includes coordination with local entities, outreach to willing sellers, identification and evaluation of alternatives, and technical due diligence. Development also includes funding proposals for selected transactions conducted either on an ad hoc basis or through a formal marketplace.
- ***Acquisition:*** Negotiating, contracting, and closing transactions.
- ***Administrative Changes:*** As applicable, filing and processing changes to water rights with the relevant agencies.
- ***Monitoring:*** Monitoring of compliance with contract terms, water use, and ecological response.
- ***Evaluation:*** Assessing compliance and the effectiveness of the transaction.

Insights and experiences drawn from implementation efforts around the western United States help guide assessment of the Arizona context to determine: i) whether the critical enabling conditions for establishing market-based reallocation for environmental water are present, ii) whether they are functioning and, if so, iii) what additional challenges remain.

The discussion starts at the state jurisdictional level by examining the policymaking context and proceeds to discussing policy implementation across the geographies of Central, Northern, and Southern Arizona. Assessing these challenges statewide and regionally helps highlight interactions between the state policymaking framework and local implementation efforts. ■

5.2 Policymaking

Like many states in the West, the enabling conditions for market-based reallocation for environmental purposes are only partially developed in Arizona. This section walks through the policymaking cycle and identifies missing or incomplete pieces and uncertainties that, if addressed, would help the market reallocation wheel 'turn' in Arizona. Many of these enabling conditions in the policymaking arena also affect policy implementation more broadly, so this suite of challenges is not necessarily unique to market-based reallocation strategies. ■

5.2.1

Policy Research and Formulation

Allocating water to the environment and market-based reallocation are both relatively new concepts in the West and in Arizona. As with any innovation, it takes time for the underlying science to evolve and mature, as well as time for cultural adaptation to emerge to the point where society can absorb the knowledge and institutions can apply the knowledge. Increasing scientific understanding, overcoming cultural resistance, and gaining social acceptance are challenges for market-based reallocation in general, and are even more acute in market-based reallocation for environmental purposes. These cultural challenges are expressed in many ways and run through both the policymaking and implementation cycles.

Scientific Research. The scientific uncertainty and complexity of ecological interactions pose a challenge in designing water transactions that can meaningfully improve environmental conditions. Scientific knowledge of the effect of water supply and demand on ecohydrologic conditions varies widely around the state. This disparity in knowledge impacts the degree to which transactions can effectively address ecological water needs. In addition, community input is essential in defining the social and ecological values for desired flow conditions. Changing historic water use can alter patterns of land use and can have unintended consequences on vegetation composition, return flows, and other environmental conditions habituated to preexisting patterns.

Research—supported by sufficient funding—is needed to fill these gaps in knowledge. Such research is underway and includes work at the University of Arizona to catalogue statewide environmental flows (Nadeau and Megdal 2011), the Water Resources Development Commission's efforts to define environmental water needs throughout the state, studies of surface and groundwater interactions in the Verde Basin, and research and reporting on the impacts of effluent releases on the ecohydrologic functions of the Upper Santa Cruz River (Box 2 and Sonoran Institute, 2009, 2010).

Box 2. Upper Santa Cruz River

The Upper Santa Cruz River offers an example of collaborative interdisciplinary efforts to track the changing ecological conditions of a riparian forest in response to water availability, water quality, and climate variability. Information from these efforts could be used to help design water reallocation and management strategies that address the needs of both water users and the riparian corridor.

As an effluent-dominated river that supports important and rare Sonoran cottonwood-willow riparian habitat, the Upper Santa Cruz River responds to stressors from climate variability, shifting ecohydrological conditions, and increasing human populations. The extent of riparian vegetation decreased from the 1930s to the 1970s as a result of groundwater pumping; however, vegetation cover increased in the 1980s and 1990s. This increase in the extent, density, and diversity of riparian vegetation coincided with increasing discharges of effluent into the river and abundant precipitation from favorable climate conditions.

While two decades of plentiful rains supported vigorous vegetation growth, poor effluent quality slowly hindered hydrologic functions as high nutrient levels spurred expansion of an algal-based clogging layer on the bottom of the stream channel. This clogging layer likely limited the hydrologic connection between surface flows and groundwater and in part contributed to a significant vegetation die-off event in 2005. This die-off event, combined with monitoring records showing declining water quality, highlights the uncertainties associated with effluent discharges into the Upper Santa Cruz River and underscores the need for scientific and legal mechanisms to ensure that effluent bolsters, rather than degrades, riparian function.

Culture, Economics, and Policy Research. The politics surrounding market-based reallocation for the environment are a major challenge. Water users and water resources are historically connected through place and time, which creates a broad array of cultural, historic, economic, and ecological values. Cultural values connect family farmers and ranchers to rural livelihoods and a way of life. Impacts of water transactions reach beyond individual buyers and sellers by changing historic patterns of water and land use. These changes can impact values in both positive and negative ways, so attention must be given to the unintended consequences of transactions on the wider community.

At the same time, pressures to shift water are a consequence of wider economic conditions in agricultural markets and land-use changes associated with development. While economics drive water transactions, culture and societal values temper change and often favor the status quo. This is exacerbated by the nature of water spurring the development of large institutions that govern and manage water delivery. These institutions subscribe to the status quo and change only gradually.

This is not to say that all the economic drivers lead toward reallocation. Economic concerns arise because agricultural communities and irrigation districts require a critical mass to remain viable. Irrigators may also have concerns that their participation in the market will undercut the potential value of their water assets. The growing demands of residential developers and associated land-use changes underpin perceptions that water values will continue to rise as competition grows. The economic concerns fuel speculation activity that freezes the assets in their current use and impedes the short-range opportunities for flexibility through market-based reallocation tools.

The cultural, economic, and environmental issues tied to market-based reallocation have curbed progress toward mutually beneficial water-sharing arrangements throughout the western United States, including Arizona. In 2006, a U.S. Bureau of Reclamation demonstration program endeavored to enlist Arizona farmers in a fallowing program. The program met with challenges due to the concern about community

Box 2. Upper Santa Cruz River, Continued

During the past ten years, a number of planning and research efforts have focused on the Upper Santa Cruz River to both understand the ecohydrologic characteristics of an effluent-dependent system and develop riparian conservation opportunities. The Sonoran Institute, Friends of the Santa Cruz River, the National Park Service, ADWR, and other stakeholders have been monitoring water quality, riparian vegetation, surface flows, groundwater levels, and other river system components. To provide an annual snapshot of river conditions, Sonoran Institute and its partners synthesized ecological information and compared it to published standards to chart the health of the Upper Santa Cruz River. Data are published annually by water year (October 1–September 30) in the Living River reports (Sonoran Institute, 2009, 2010).

During the 2008 water year, water samples did not meet standards set by the Arizona Department of Environmental Quality (ADEQ), and poor quality water was likely negatively impacting populations of aquatic species (Sonoran Institute, 2009). Conditions significantly improved during the 2009 water year when the Nogales International Wastewater Treatment Plant was upgraded to remove ammonia and improve treatment processes. Following the upgrade, water quality parameters regularly complied with ADEQ threshold standards, and fish populations started to recover (Sonoran Institute, 2010). Coordinated monitoring efforts continue and the next Living River report will focus on building a long-term picture of variable ecohydrologic conditions along this effluent-dominated river. The baseline conditions documented through this research, coupled with the consensus-based process used to undertake the research, provide the foundation for assessing water supply and demand conditions and for identifying needs and opportunities for reallocation through market-based water transactions.

impacts coupled with political resistance from Arizona irrigators who feared that they would bear the full burden of shortage because other states in the basin did not participate. Economic concerns thus play a role due to irrigation district requirements to maintain infrastructure and group entitlements.

Key challenges and consequences for policy research and formulation include:

- Scientific, legal, and economic uncertainties surrounding ecological water requirements, surface-groundwater interactions, and market-based mechanisms, all of which tilt the balance in favor of the status quo.
- Cultural resistance to the emergence of ecological water requirements as a legitimate use of water on par with existing human uses, which limits social acceptance and makes policymaking and implementation time consuming and costly.
- Socioeconomic conditions wherein real and perceived injury to communities, regional economies, and the rural way of life caused by water transfers raises doubts and supports political skepticism.

Recommendations. To address these challenges, it is important to pursue research opportunities that align community water interests with ecological water requirements in order to identify mutually beneficial reallocation opportunities. In light of persistent and widespread scientific uncertainties, funding entities must weigh the costs of further research against the gains that could be made from better management resulting from the research. Modeling and research funds are often provided by federal, state, and local governments, which tend to focus funding on areas of potential conflict or on communities that have a demonstrated interest in resolving water and environmental issues (Box 3). Cultural priorities therefore spur investment in science and modeling.

Given the resources required for research, it is not practical for the state to legislate or prescribe when and how research takes place. Instead, internal conditions will determine when a basin is ripe for the research phase and to what extent this research is attractive to potential funders. This mechanism drives the sequence in which basins are studied and modeled, rather than an all-encompassing mandate. However, fleshing out the full range of basin research needs that should ideally progress concurrently with a planning and stakeholder process helps to align ecological and community needs. Several of the basin studies authorized under the Secure Water Act of 2009 examine the whole-of-basin water supply and demand and include environmental demands as explicit aims of the study.

Overcoming cultural resistance and gaining social acceptance for reallocation of water for environmental purposes is a challenge. Generally, a combination of research and action is needed to gain stakeholder acceptance of water reallocation options. Stakeholders may respond to research that demonstrates the credibility of claims regarding the consequences of the status quo for long-term sustainability of the resource and impacts on ecosystems. For others it will take completion of pilot projects and effective communication of results to calm their fears and concerns. Drawing community leaders and public authorities into such initiatives can also be effective, as seen in the case of the Deschutes River Conservancy (DRC) (Box 3). ■

Box 3. Conflict or Cooperation as Drivers for Public Research Investment: The Deschutes Basin

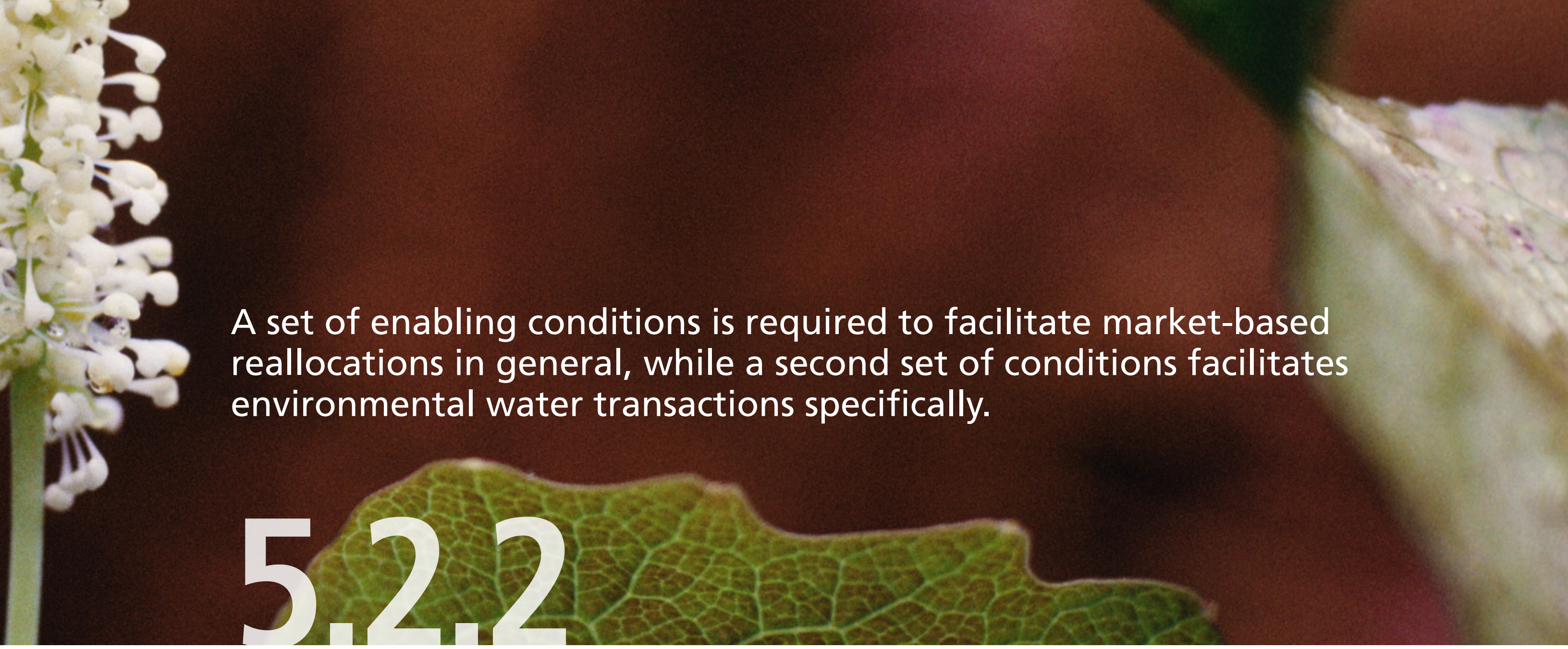
Adjoining basins in Oregon demonstrate the paradox that both conflict and cooperation can serve as drivers for the investment of public funds in water research and planning. In the Deschutes Basin, a dispute over new groundwater permits arose in 1995 between the City of Bend and the environmental nonprofit WaterWatch of Oregon. Due to the hydrologic uncertainties about the characteristics of the basin, collaborations between state and federal scientists were funded by local, state, and federal funds. These funds were used to develop the hydrogeologic framework and collect the necessary information to develop a groundwater model to inform policy and water rights administration in the basin. The Deschutes Groundwater Mitigation Program was initiated in 2002 and offers the community the flexibility to meet municipal demands while conserving perennial flows in the Deschutes River.

While the mitigation controversy and research played out in the Deschutes, a collaborative, multi-stakeholder Deschutes River Conservancy (DRC) was created in 1996. The DRC grew out of efforts by the Environmental Defense Fund to bring tribal leaders and irrigators together to identify key environmental issues facing the basin. Improving water quantity and quality became the mission of the new organization and federal funds were appropriated to kick start the effort. Starting with a set of relatively ad hoc projects, the efforts of the DRC grew to include a full range of water reallocation programs, such as leasing, groundwater mitigation banking, transfers, and conserved water.

The collaborative effort has proved singularly successful and durable in raising state and federal funds for planning, capacity-building, and environmental water transactions. Choosing a collaborative path helped the DRC move early and gain access to critical start-up and demonstration funding. In 2005 water stakeholders in the basin were successful in obtaining one of the initial Water 2025 grants provided by the U.S. Bureau of Reclamation under the umbrella of a Deschutes Water Alliance. The grant was used to carry out research and planning efforts to try to chart the current status of water and water rights in the basin and provide scenarios for how reallocation and conservation might proceed in the future. In 2010, this same group obtained further federal funding to update the Water Alliance study and carry out an even more ambitious basin planning exercise. Whether the basin could have accessed so much funding without the specter of conflict, as raised by the groundwater mitigation issue, is debatable. However, it is clear that in the face of controversy and conflict, collaborative initiatives seem to be well-received by funders.

To the south of the Deschutes lies the Klamath Basin, which drains into California instead of north into the Columbia. Conflicts in the Klamath Basin between fish and farmers made the national news in the early 2000s. Limited surface water flows in the basin impacted salmon runs and pitted the water needs of the stream against historic agricultural water uses. Following the back and forth between fish and farmers, the U.S. Bureau of Reclamation devised a water banking effort to try to compensate irrigators for forbearing the use of groundwater. The same state and federal entities that collaborated in the Deschutes obtained government resources for hydrogeologic research in the Klamath. This research was needed to determine if the water banking approach would work and to determine the flows needed to maintain healthy stream conditions and balance ecohydrological requirements with the cultural priorities in the basin.

Meanwhile, efforts were made to develop consensus-based approaches among resource managers, the fishing community, and agricultural interests. In late 2010 these combined efforts yielded a comprehensive framework for reform—the Klamath Basin Restoration Agreement—and the launch of a Klamath Basin Watershed Partnership. Again, conflict brought government resources to bear on the problem, but in this case a collaborative approach arose only after a long period of conflict and controversy.



A set of enabling conditions is required to facilitate market-based reallocations in general, while a second set of conditions facilitates environmental water transactions specifically.

5.2.2

Legal and Regulatory

Legal uncertainty about water availability and rights threatens ecological needs in parts of Arizona facing chronic overallocation. The lack of surface water adjudication weakens incentives to protect senior surface water rights. In Arizona, the Gila River Adjudication covers 24,000 claimants and remains focused on resolving issues tied to hydrologic interactions. The development of the CAP and SRP entitlements, infrastructure, and operating plans has influenced the limits and rights to surface water supplies in Arizona. The ongoing adjudication has languished in part due to the spatial and legal separation between water use and availability, groundwater and surface water management, and recharge-and-recovery. Regulatory responses to groundwater overdraft, recharge-and-recovery, and effluent traditionally lack requirements to balance water withdrawals, and lack local ecologically defined limits to water availability. Groundwater mitigation requirements and AWS rules do not integrate the ecological needs of riparian habitat, floodplains, and instream flows as a component of physical water availability.

In order to identify key challenges with regard to existing statutes and rules, it is useful to review the authorities necessary to conduct market-based reallocation for environmental purposes. A set of enabling conditions is required to facilitate market-based reallocations in general (Table 3), while a second set of conditions facilitates environmental water transactions specifically (Table 4). Currently, most of the policies, statutes, and rules required for market-based reallocation for general purposes are present in Arizona.

Key challenges and consequences to enabling market-based reallocation in Arizona:

- Lack of authority to regulate groundwater overdraft outside of AMAs limits the ability to ensure sustainable supplies over the long term.
- Lack of authority to regulate and/or require mitigation for wells outside of the AMAs and exempt wells within AMAs contributes to groundwater overdraft and limit sustainable management of groundwater resources.
- Spatial disconnect between groundwater recharge and use under the AWS and Central Arizona Groundwater Replenishment District programs allows for recharge in areas that are unconnected or distant from the impacts of groundwater pumping, leading to localized overdraft and concerns over long-term sustainability of supply.
- Lack of authority to conjunctively manage surface water and groundwater leads to an inability to enforce a priority system between surface and groundwater or to limit new groundwater appropriations when surface water is fully allocated, causing junior groundwater users to injure senior surface water users.

Ecological needs are generally only met from residual flows and have suffered under the legal framework within the western United States. Arizona's progress in addressing policymaking issues on this front is only partial to date, as described in Table 4. Arizona has established environmental purposes as a legitimate beneficial use and has taken initial steps toward providing for the market-based reallocation of water rights for this use. Although these legal steps have been taken to establish the environment as a beneficial use for fish and wildlife purposes, water management efforts have perpetuated a separation between human and ecological needs. This divide has prevented meaningful progress to reallocate water for ecological purposes.

Nonprofit groups and federal agencies have tested these mechanisms. The Nature Conservancy in Arizona petitioned for its first instream appropriation on Ramsey Creek in 1978. The U.S. Forest Service also resolved legal disputes on new instream appropriations in Cherry Creek, thereby clarifying that instream flow appropriations do not require a physical diversion to establish fish and wildlife as a beneficial use.

The statutory authority for environmental water transfers under the sever-and-transfer clause exists, but successful implementation has yet to be realized on test cases underway in the Lower San Pedro River. Challenges include administrative issues such as the absence of adjudication and limited administrative capacity, as well as the requirement for case-by-case approval by the ADWR director and the corresponding lack of clear and open standards and requirements for transfer applications under statute and rule. For example, the restriction of sever-and-transfer to political subdivisions of the state limits incentives for private participation in market-based environmental water allocation. Work-arounds to resolve these problems simply increase transaction costs, with more or less the same effect of providing disincentives to use this authority.

The diagnosis in Table 4, as well as the environmental consequences of some of the remaining gaps in policy shown in Table 3, reveal important challenges market-based reallocation for environmental purposes.

Key challenges and consequences to enabling market-based reallocation for environmental purposes include:

- Spatial disconnect between groundwater recharge and use does not encourage an alignment between ecological restoration goals and recharge/reuse priorities.
- Lack of limits on groundwater extraction outside AMAs and for exempt wells within AMAs, and lack of instream permits for residual flows, continuously diminishes the amount of water available to sustain riparian habitat, floodplains, and instream flows.
- Legal separation of surface water and groundwater limits the ability to conjunctively manage surface water and groundwater, which leads to injury of senior instream rights, as well as erosion of residual water going to ecological needs.

Table 3. Policymaking: Enabling Conditions for Market-Based Reallocation in Arizona

MARKET-BASED REALLOCATION FOR *GENERAL* PURPOSES		
Enabling Conditions	**Status in Arizona**	
	Present/ Absent	**Qualifications**
Appropriation of surface water and groundwater for beneficial uses is well defined, subject to priority, and permits/rights are tradable.	Present	Limited function due to lack of surface water adjudication and administrative capacity gaps.
Appropriation of new groundwater permits and management of existing groundwater rights adequately accounts for impacts on surface water.	Absent	
Reclaimed wastewater is permitted and is tradable via contractual agreement.	Present	Function is limited due to legal uncertainty about downstream surface water rights that are met through effluent discharged into the river channel.
Appropriation of groundwater adequately accounts for overdraft and plans for long-term sustainable supplies.	Present for permits/ rights within Active Management Areas (AMAs)	• Spatial mismatch in AMAs persists between area of groundwater withdrawal and recharge. • Enabling conditions not in place outside AMAs. • Enabling conditions not met for exempt wells.
Mitigation for groundwater appropriations can be provided through the recharge-and-recovery of water.	Present	Spatial disconnect between recharge basins and groundwater withdrawals creates localized overdrafts.

- Lack of authority to allow mitigation in the form of instream transfer of consumptive use offset does not encourage an alignment of ecological needs and development demand.
- Lack of authority for temporary (leases) and conserved water mechanisms to meet ecological needs means that flexible incentives for meeting ecological needs with senior water rights are not available, short of sever-and-transfer.

Recommendations. Policy reform is required to establish the full foundation of enabling conditions. However, given the scale and extent of the needed reform, this requires a longer vision. Consultation with stakeholders is desirable to identify which single reform has the highest priority or whether there is some specific sequence or packaging of reforms that is required. At that stage more detailed diagnoses of formulations of specific statutes and rules would be required to develop proposals for review, vetting, and ultimately moving forward with likely sponsors, champions, and supporters. Many states, including those in the Pacific Northwest (Box 4), are struggling with these same issues, so Arizona can consult with others for guidance on good practices and avenues to avoid. ■

Table 4. **Policymaking: Additional Enabling Conditions for Market-Based Reallocation for Environmental Purposes**

MARKET-BASED REALLOCATION FOR *ENVIRONMENTAL* PURPOSES		
Enabling Conditions	**Status in Arizona**	
	Present/ Absent	**Qualifications**
The use of water for environmental purposes including water for instream flows, riparian habitat, and off-stream needs in floodplains or wetlands is recognized as a beneficial use.	Present	Only certain environmental uses are recognized as beneficial uses (fish and wildlife), and these are only a subset of the ecological values sustained by Arizona's freshwater systems.
The permanent or long-term change of out-of-stream rights to environmental purposes (sever-and-transfer) is permitted, without loss of priority and subject to normal injury review.	Present	
The short-term change of out-of-stream rights to environmental purposes is permitted, without loss of priority and subject to expedited injury review.	Absent	
Residual environmental water is protected, either through limits on further appropriation (closure) of surface water and groundwater (including exempt wells), or through a system of instream water rights of junior priority.	Absent	Enabling conditions are not met with the exception of junior instream water rights, which can act as a 'valve' on future appropriations and changes to existing appropriations that would cause injury to established instream rights.
Appropriation of groundwater rights in closed basins is allowed when accompanied by effective mitigation for surface water impacts.	Absent	
Appropriation of non-consumptive water saved through demand management (conservation) by the proponent is permitted for 'spreading' to other non-consumptive uses, particularly environmental uses.	Absent	

5.2.3 Administration

Insofar as the administration of the state's water resources is concerned, market-based reallocation relies heavily on effective planning and institutional capacity for water rights administration and enforcement consisting of regulation in the field. These are explored in turn.

Planning. Arizona has a track record of innovation in planning for water supply reliability. The AMAs prepare ten-year management plans that assess progress toward each AMA's management goals, such as reaching safe yield by 2025, which is applicable to the Prescott, Tucson, Phoenix, and Santa Cruz AMAs. The AWS program requires evidence of legal, physical, and continuous water availability for 100 years at the land parcel or designated water-provider level. In addition, the AWS requirement to use renewable water supplies has sparked the development of the Central Arizona Groundwater Replenishment District and recharge credits, both of which support the development of water-marketing strategies.

Long-range planning for the Colorado River has included mainstem communities in assessments of Arizona's vulnerability to shortage on the Colorado River. The ongoing Colorado River Basin Study includes an effort to address long-range supply and demand imbalances. Recent legislation extended authority for water adequacy requirements to rural Arizona at the discretion of local governments. Regions outside of the Colorado River and its mainstem have made strides to develop the hydrogeologic understanding necessary to establish water budgets in order to control groundwater overdraft and sustain local supplies (Staudenmaier, 2007).

Efforts in the Upper San Pedro Basin lead the recent trend toward regional water planning for sustainability, and U.S. Bureau of Reclamation studies in the north–central and Yavapai regions of Arizona reflect the growing progress toward these enabling planning efforts. ADWR embarked on an ambitious planning effort as part of the nine-volume Arizona Water Atlas (ADWR, 2006–2011). In-depth water supply and demand conditions have been assessed in seven volumes—one for each of the seven planning areas in the

Box 4. Groundwater Mitigation Programs: Spotlight on the Pacific Northwest

Growing reliance on groundwater demonstrates the need to incorporate groundwater supplies into a system of limits and rights. Although this challenge arguably first manifested in Arizona, California, and other southwestern states, it has since become a pressing challenge throughout the West. Each of the four Pacific Northwest states are at various stages in defining a legal, regulatory, and administrative basis for establishing mitigation for new groundwater rights (and in some cases for exempt wells). The state of Oregon initiated a basin-specific program in the Deschutes River Basin of Central Oregon. New groundwater rights applicants in the Upper Deschutes are required to offset their hydrologic impact on streamflows in the Lower Deschutes. Since 2003, a large number of municipalities, irrigators, and other applicants have acquired temporary and permanent mitigation credits based on instream leases and transfers of senior surface water rights.

In the Walla Walla and Kittitas Basins in Washington, basin closure has resulted in the establishment of programs similar to those in the Deschutes, with the exception that these programs explicitly target new permit-exempt wells. In Walla Walla, retirement of groundwater rights has been used to create mitigation, and in Kittitas, instream flow transfers are also underway for this purpose. In Idaho and Montana, court cases have left the relevant departments with no choice but to require mitigation for new groundwater appropriations where such appropriations would injure senior users. Although rule making is underway in Montana, until explicit statutes or rules are established, the applicant can only guess at what mitigation is required and risk being denied approval if their guess is incorrect. The Deschutes River Basin distinguishes itself in offering very specific and clear guidelines. For example, when a new application is processed within the Deschutes Basin, the state will only approve it after the delivery of a specified number of mitigation credits—each credit being one acre foot of consumptive use offset—in a specified zone of impact.

state. The seven volumes are bookended by the introduction and a forthcoming 'sustainability evaluation' that assesses vulnerabilities at multiple scales within and across groundwater basins situated in the regional planning areas.

Recent planning efforts have attempted to integrate ecological needs, starting with the 2001 Governor's Water Management Commission recommendation to define zones of riparian impact, and most recently with the University of Arizona Statewide Water Needs Assessment (Nadeau and Megdal, 2011). Local and regional Habitat Conservation Plans (HCPs) have incorporated riparian and aquatic water needs. Several of the state's ten HCPs are marked by their efforts to address riparian conservation needs as part of the plan. The Sonoran Desert Conservation Plan (SDCP) and the Roosevelt Dam and Verde plans have each included market-oriented allocation strategies to secure water for riparian habitat preservation and conservation (Box 5). Historically however, many efforts have been limited to the quantification of evapotranspiration for riparian habitat. Efforts to define microbasin water budgets in the Upper Santa Cruz and to pursue spatial water management in the San Pedro and Verde reflect the transition from safe yield to sustainable yield, which recognizes the baseflow and flood pulse components of the hydrograph in stream-aquifer systems.

Key challenges and consequences for planning include:

- Uneven water planning between rural and urban regions in Arizona.
- Piecemeal and limited integration of ecological needs into planning and water budgets, which leads to an asymmetrical playing field between existing agricultural and municipal water rights, and new attempts to garner water to meet ecological needs.

Institutional Capacity. Inadequate institutional capacity for enforcement of water rights and processing changes to water rights is an extension of legal and regulatory barriers. The issues include financial capacity, coordination across jurisdictions and stakeholders, and leadership. The budget cuts to ADWR in 2009 and 2010 have spotlighted the growing capacity gaps. In the space of two years, staffing was slashed from 200 employees to fewer than 90, with drastic cuts to the budget continuing. These cuts could impact the ability of ADWR to prepare ten-year incremental management plans, as mandated by the 1980 GMA.

Other administrative barriers in the area of market-based reallocation for environmental purposes predate the recent financial crisis. Discretionary authority for instream appropriations and implementation of sever-and-transfer tools have lagged due to limited administrative capacity and political will to streamline applications.

ADWR, which administers the Arizona Water Protection Fund to support riparian habitat restoration projects, explored the viability of new mechanisms for acquisition and management of surface water rights and related conservation easements in a September 2008 meeting. Local governments, water utilities, and federal programs complement the state's institutional capacity in this area. Pima County and the City of Tucson have active programs and coordination in riparian habitat protection, and have established a conservation effluent pool of up to 10,000 AF/year for use in riparian enhancement and restoration. The U.S. Bureau of Reclamation provides capacity through its operations in the Colorado River, its consultation with states and regions as part of the Multi-Species Conservation Program, and its regional water studies in North Central Arizona and the Yavapai area.

Key challenges and consequences for policy reform and institutional capacity include:

- The fact that a conservative approach along with capacity and resource constraints at ADWR contribute to limited regulation of water rights and imposition of surface water measurement, lengthy application processes, and information-intensive monitoring and reporting requirements to establish evidence of beneficial use in new instream appropriations.
- High transaction costs of using market-based tools to meet ecological needs.

Recommendations. Planning is largely discussed under policy research and formulation in Section 5.2.1. The funding crisis faced by ADWR makes implementing the suggestions here very difficult. An option to bolster state capacity requires investments in local and regional capacity as a way to complement ADWR. For example, monitoring, regulation, and enforcement can be delegated by the state to local institutions or even contracted out, subject to appropriate accountability and oversight mechanisms (Box 6). Ideally the state either carries out these roles or provides the funds for a duly designated entity to do so. However, if this is not feasible, other solutions must be explored. ■

Box 5. Sonoran Desert Conservation Plan

The Sonoran Desert Conservation Plan (SDCP) established a conservation land system to address multiple vulnerable and threatened species affected by growth in the greater Pima County region. Many of the region's vulnerable species depend on the washes, streams, and rivers that provide riparian habitat used at one or more stages of the species' life cycles. Development pressure threatens this habitat. Pima County undertook an ambitious and comprehensive planning effort to address the key science and governance barriers to sustainable water management by defining riparian values and prioritizing them regionally. Planning began in 1997, and a science and technical commission identified riparian zones as part of the regional conservation land system. To meet the goals of the SDCP, a subsequent financing initiative to secure land and water was part of an open space bond election in 2004.

Implementation of the SDCP has included a range of land and water conservation projects coordinated by Pima County and the Arizona Land and Water Trust since the early 2000s. Several projects protect riparian habitat through land acquisition and management of the associated water rights. A County report analyzed progress toward implementing the SDCP by reviewing the effectiveness of acquisitions through 2009 (Fonseca, 2009). Key progress on riparian habitat protection included the finding that over 16% of perennial streamsides are under the County's management, and 2,000 of the 16,000 acres of intermittent streamsides are part of the County's preserve network.

Report recommendations include adding priority areas for riparian habitat protection through land acquisition on the Brawley Wash and Lower Santa Cruz River, and acquisition of low-elevation riparian habitat and floodplain land. These projects have ranged in size and acquisition mechanisms with a focus on fee-title purchase of land and water. In addition, up to 10,000 AF of effluent has been allocated for future riparian enhancement projects. Focus on water rights elements of land acquisitions has increased to ensure the riparian values are protected or enhanced. The Arizona Land and Water Trust has been a focal partner of the County in planning and implementation. Its projects include the recent acquisition of the Clyne Ranch along the Cienega Creek, the Six-Bar along a tributary to the San Pedro, and extensive work along the West Branch of the Santa Cruz.

Box 6. **Water Rights Administration: Roles for Nonprofits**

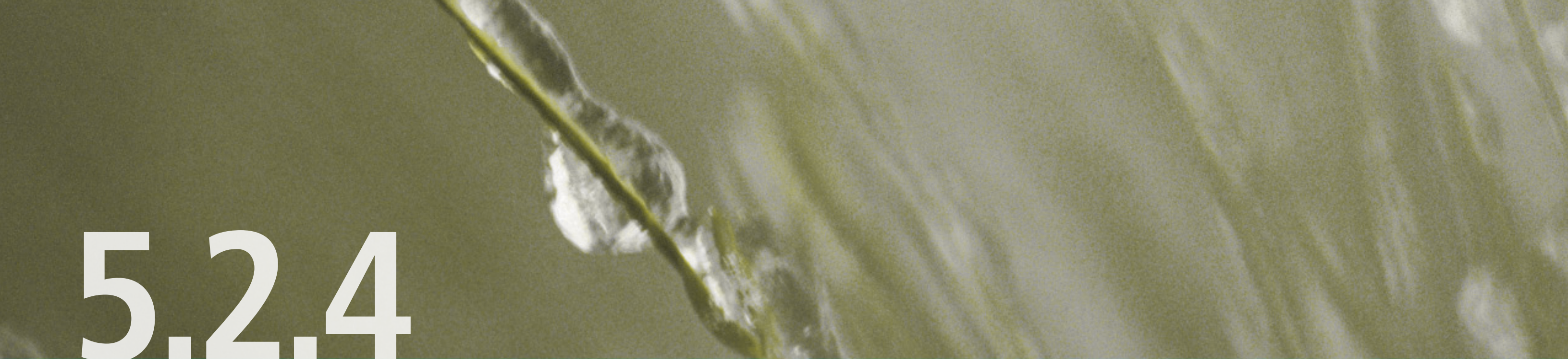
In the Teton River Valley, the Idaho Department of Water Resources contracts out all water-monitoring tasks to an environmental nonprofit, Friends of the Teton River. This organization has also sought and obtained a Model Watershed grant from the Bonneville Environmental Foundation to conduct additional monitoring and evaluation work. This relationship demonstrates that nonprofit groups are capable of filling gaps left by the state and raising funds to conduct essential tasks. Work by the Friends of the Teton River has drawn support from local water users who appreciate the benefits of improved monitoring.

Similarly, enforcement responsibility can be delegated to local entities. In this situation, large water management organizations like irrigation districts can recover the costs of regulation from patrons. In watersheds without such institutions, the regulatory role and funding burden can be delegated to local users.

In Montana, local water users can appoint so-called Water Commissioners to carry out regulation and enforcement of water uses on a stream. The costs must be borne by the users, but if users perceive a benefit to using a commissioner to regulate diversions, the users will likely be willing to pay for this service. In a recent transaction undertaken by the Montana Water Trust (now merged into the Clark Fork Coalition), the Trust acquired a senior right at the bottom of a creek but found that an upstream junior user was 'poaching' on the right. This was affecting other senior users, so the Trust organized the users to appoint and pay for a commissioner to regulate and deliver rights in order of priority.

With regard to the timing and cost of processing administrative changes to water rights, some states (e.g. Washington and Oregon) have reimbursement—or receipts—authority that allows change applications to be processed by consultants. The applicant pays for the additional cost of processing. While not a perfect solution for all tasks, shifting state personnel to an oversight role reduces staff time spent processing applications. Alternatively, the state could charge the full cost of processing applications, though this is unlikely to be feasible due to rigid state personnel rules and potentially large variations in demand for services over time. The best option for the state might be to define a limited processing role, charge full cost recovery for these tasks, and enable the remainder of the processing to occur through a reimbursement authority.

While delegating roles and shifting costs directly to users or beneficiaries is a work-around of sorts, the lack of state funding and capacity does not mean that needed administrative tasks in water management must be left undone.



5.2.4 Judicial Review

Under adjudications proceedings, courts examine, verify, and authorize claims for water that predate the water code (1919 in Arizona) and reconcile these claims with permits issued under the water code. Adjudication is a critical step in defining property rights, particularly if the objective is to acquire older and reliable water rights—as is the case with acquiring water for environmental use. Unadjudicated claims are not rights recognized by the state, and therefore a seller cannot guarantee to a buyer that these are valid or that any change in their use would be approved by the state. Further, with senior rights unverified, acquiring and transferring rights established under the water code is risky since the full amount of senior rights is unclear. Uncertainty on the part of water users regarding the status of their water rights and future water availability impacts incentives to invest in developing economic uses of water in a system, and leaves the residual user—typically ecosystems—at risk.

A number of important basins have yet to be adjudicated in Arizona. Ongoing adjudications include the Gila River and the Little Colorado River (Figure 10), which cover about three-quarters of the state and include most of the basins referred to in this paper. Adjudications are lengthy and complicated processes that can take many years, sometimes stretching into decades. For example, the Gila River Adjudication started in 1974 and includes more than 81,000 claimants and 53,000 square miles of territory. It is still ongoing and remains focused on resolving issues tied to hydrologic interactions. The development of the CAP and SRP entitlements, infrastructure, and operating plans has influenced the limits and rights to surface water supplies in Arizona. The pending adjudication has exacerbated the spatial disconnect between water use and availability, particularly in regions outside of the CAP and SRP services areas where water claims are based on historically irrigated acreage dependent on locally available surface water and subflow.

The lack of adjudication does not mean that market-based reallocation is impossible, but it does create uncertainty for market participants. This uncertainty varies with local conditions and the extent and validity of all the claims made on water. Within larger irrigation projects, adjudications probably are less critical than they might be in a system dominated by a large number of individual users. However, if customary use is fairly well-established in a rural watershed, then adjudication may be of less importance than in a larger system where rapid land development has altered historic patterns of water use. For market-based reallocation to function efficiently and in high volumes, it is ideal to have fully adjudicated water rights. Finishing the existing basin adjudications will be an important milestone in providing enabling conditions for market activity. Moreover, efforts to advance market-based reallocation in the absence of an adjudication process provides an on-the-ground policy and implementation feedback loop that address unresolved legal, hydrologic, and technical issues impeding the wider adjudication.

Key challenges and consequences for judicial review include:

- Uncertainty over the validity and extent of pre- versus post-1919 surface water claims—those before and after the state water code—as well as other distinctions about relative priority between rights.
- The combination of questions regarding the transferability of such rights, and uncertainty over their validity and extent, which impede market development due to lack of information on the reliability of these rights in meeting new uses, including environmental uses.

Recommendations: Adjudication is valuable as it establishes property rights and confirms the total allocations, which assists in water budgeting. However, adjudication takes a long time to implement and is therefore not a short-term solution to solve pressing problems for people or ecosystems. While adjudications proceed, efforts are needed to develop collaborative opportunities with local management agencies to approve changes to claims based on stakeholder concordance. One example of such collaboration is the Yakima Basin Transfers Working Group in Washington State (Box 7). ■

Figure 10. General Stream Adjudication in Arizona

Source: ADWR, Arizona Water Atlas

Box 7. Yakima Basin Transfers Working Group

The Yakima River of Central Washington is a drought-prone basin with important agricultural, tribal, and salmon water needs, as well as growing needs from residential development. An adjudication commenced in 1977 and remains incomplete. The Yakima Basin Transfers Working Group was established in 2003 to facilitate technical review of proposed changes to water rights and instream flow projects occurring under the interim decisions issued by the Yakima Superior Court in *Ecology v. Acquavella*, a general stream adjudication with over 5,000 claimants. The Working Group has provided a forum for decision-making and capacity in market-oriented transfers to streamline projects for "speed, certainty, and convenience." The activities of the group have spurred its key participants in the state water resource agency (Washington Department of Ecology) and U.S. Bureau of Reclamation to enable water transactions in response to drought and instream water needs. The lesson is that the lack of an adjudication should not be viewed an as insurmountable obstacle. *http://www.ecy.wa.gov/programs/wr/ywtwg/ywtwg_qanda.html*

5.3

Market-Based Reallocation in Arizona: A Status Check

Before transitioning from policymaking to policy implementation challenges, this section offers an overview of market-based reallocation efforts in Arizona and briefly characterizes activity directed toward reallocation for environmental purposes.

Arizona water markets include a series of institutional arrangements that enable and constrain the coordination of buyers and sellers, and regulate their interactions. The degree of activity and market development varies across Arizona's water geography (Table 5). Water pricing historically has been used to recover costs of operating and maintaining water supply infrastructure rather than to allocate water according to its productivity. In the Lower Colorado region, the infrastructure under the CAP facilitates exchanges in water rights, but the entitlements system limits activities to recharge-and-recovery arrangements or isolated transactions. Spot market activity in the Yuma area has begun under demonstration programs. The Colorado River Basin states have developed a novel experiment in reservoir storage credits as a component of the shortage-sharing agreements passed in 2007 that is used to enable interstate marketing by establishing intentionally created surplus. As a result, transactional activity in the Lower Colorado region has increased during the past decade (Box 8).

The emphasis of water banking in Arizona has been tied to the administration of annual and long-term storage and recovery credits. The Arizona Water Bank was established in 1996 to store water from that portion of the state's 2.8 million AF allotment of the Colorado River that is not being directly used by existing entitlement holders. The Bank acquires water to store underground as a buffer against drought-year impacts on Colorado River entitlement holders. The Bank acquires the excess water at fixed price and does not perform other market clearinghouse activities, such as coordinating buyers and sellers.

The Central Arizona Groundwater Replenishment District is an outgrowth of the AWS requirements aimed at coordinating mitigation and replenishment obligations for new development that does not have access to direct delivery of renewable supplies in the CAP service area. The GMA provides an institutional framework for market transactions

Box 8. A Survey of Water Transactions on the Lower Colorado River

Transactions on the Lower Colorado River have occurred in the past decade, although an active market does not exist within the context of the Law of the River. Water entitlements in the Lower Basin include Section 5 contracts, decreed water rights, and U.S. Secretary of the Interior (Secretarial) reservations. Below is a brief summary of water market activity in the region.

1970s–Ongoing. Native American water rights settlements in Southern and Central Arizona. CAP provides infrastructure and additional water supplies.

1999. Storage and Interstate Release Agreements. Off-stream underground water storage for later delivery to another state; used by Arizona to store water for California (8,159 AF) and Nevada (582,412 AF), and by California to store water for Nevada (70,000 AF).

1995 and 2004. Mohave County Water Authority. Assignments from Kingman (15,000 AF) and Cibola Valley Irrigation and Drainage District (5,997 AF).

2006. Demonstration program to determine whether Lower Colorado River water entitlement holders would be willing to fallow irrigated farmland in return for financial compensation. Participation by Palo Verde Irrigation District in 2006 and 2007 (10,000 AF) and by Yuma Mesa Irrigation and Drainage District in 2008–2010 (varying from 3,138 to 3,705 AF/year).

2007. Interim guidelines prepared for a full range of operations—including scarcity conditions—on Lakes Powell and Mead. As one management option, intentionally created surplus is a mechanism that is in place through 2026 to encourage efficient, flexible use and management of water. Intentionally created surplus for system efficiency was established for the Warren H. Brock Reservoir and the Yuma Desalting Plant Pilot.

Table 5. Water Market Activity by Region

Element	Central Arizona	Northern Arizona	Southern Arizona
Prior Activity	Lower Colorado Region (see Box 8)	Prescott Effluent Auction; Big Chino Acquisition	Land and water transactions in San Pedro River area and Pima County
Price Information	Fixed Price	Site specific	Site specific
Water Marketing/ Banking	AMA groundwater and storage credits; Arizona Water Bank; Yuma Desalination Working Group	Reverse auction in Prescott	None
Integration of Ecological Needs in Bank Design	No	No	NA

involving groundwater rights (type II rights that can be separated from the land and land conversions from irrigated grandfathered rights to type I groundwater rights, which must remain attached to the land), effluent, and an increasingly active market in groundwater credits for annual and long-term storage and recovery. The GMA provides incentives for reallocation but lacks spatial controls on the places of use and third party impacts caused by shifts in land and water use—particularly impacts to the environment and to local water utilities. Under this institutional scheme, markets have developed in response to regulatory limits and rights. A novel approach to effluent credit auctions in the Prescott AMA reflects the unique local market conditions arising under the GMA. The complex credit auction arranged a price floor to ensure a buyer and resulted in a sale of credits at $24,000/AF.

In rural Arizona the ability to market water has been tied to the ability to transport water from rural to urban places of use. As such, transactional activity has been very limited and focuses on major transportation projects and proposals, exemplified by the water ranch concept of acquiring land to access underlying groundwater resources for export. The Big Chino project in the Verde demonstrates this approach. Notably this project was authorized under special groundwater transportation authority after the Prescott AMA determined it would be unable to utilize its 14,000 AF CAP entitlement.

Central Arizona has well-defined legal and regulatory frameworks but lacks true water-marketing institutions such as water banks that reallocate water based on price. In part this is due to the dominance of large centralized water agencies administering the region's water supply. The integration of ecological needs has lagged in water supply reliability planning efforts because the region's streams are already highly degraded. In Southern Arizona, nonprofits and counties have led efforts to deploy land and water acquisition as a means to restore streamflow or other riparian values in groundwater-dependent ecosystems. This strategy has been expensive—acquisition of land and water—and has been stymied by the inability to complete sever-and-transfer transactions. Northern Arizona has seen little or no market-based reallocation to support growth in rapidly expanding areas. Within the region the Verde stands out as a system where good science, collaborative planning, regulatory markets, and proactive environmental water transactions could meet downstream surface water rights, restore environmental functions in the near term, and forestall long-term environmental degradation.

Looking across the state, key market development needs in Arizona include:

- Experimenting with water bank structures that facilitate not only administrative changes to water rights but uses market prices to make the reallocation (instead of administratively set prices).
- Addressing spatial controls on the places of use and third party impacts of market transactions under the GMA.
- Developing groundwater mitigation programs that incorporate streamflow restoration through sever-and-transfer mechanisms to offset new consumptive groundwater allocations.
- Clarifying the sever-and-transfer approach and developing a full suite of tools for administrative changes to water rights for environmental purposes, including both leased and conserved water.
- Increasing participation, transparency, and accountability in the design and launch of water market segments and marketing efforts. ■

5.4 Central Arizona and the Mainstem Colorado River

Context. Market-based reallocation for environmental purposes in Central Arizona has been limited by multiple cultural, socioeconomic, and ecological factors that translate into enduring legal and regulatory constraints on water trading. Culturally, the region has been dominated by the legacy of major infrastructure projects that support the notion that the next bucket of water is best acquired through new engineering works rather than through reallocation. Utilizing the strategy of reallocation to the environment is hindered by the level of degradation and hydrological discontinuity of the region's mainstem rivers and stream-aquifer systems. As a result, the value of shifting water to ecological uses does not motivate a groundswell of social concern or consensus, nor does it overcome the concentrated costs and ripple effects to the region's shrinking agricultural community.

Economic resistance to market-based reallocation stems, in part, from the risks of 'free markets' and speculation. Affordable water supplies have been a mainstay of water management objectives since the region's initial population boom in the 1940s. Agricultural communities have economic concerns tied to their need to preserve the critical mass of irrigation districts, infrastructure, and political strength required to protect their interests in long-range water planning and management.

Extensive restoration projects have been developed within this region, although many projects lack secure water supplies to establish and sustain riparian and aquatic habitat. The chief environmental challenge stems from the need to prioritize and deliver water in areas of high ecological value and connectivity to landscape-level goals.

Research and Planning. Central Arizona and the mainstem Colorado River have the most advanced framework for water planning and reallocation within Arizona's differing regions. After a century of impacts to the ecological and hydrologic conditions within this region, ecological water needs will principally be realized through restoration projects rather than preservation. Legal preconditions have been established for water use and management. Surface water rights along the Colorado River are well-defined under the Law of the River, and groundwater extraction in Central Arizona is tightly regulated under the GMA.

The recharge-and-recovery programs in Central Arizona reflect a recurrent theme about the need to plan and design facilities to serve multiple purposes. In Arizona, tools for obtaining water for instream and environmental flows exist for new surface water appropriations and sever-and-transfer transactions; however, neither is viable in the Central Arizona and mainstem context because no unappropriated surface water remains (in the case of new appropriations) and competition for existing entitlements is too high to allow transfers to the environment (in the case of sever-and-transfers). In addition, transfers of Colorado River contracts involve complex procedures and multiple layers of administrative review within the Colorado River's Law of the River.

Governance conditions in Central Arizona and along the Lower Colorado River are advanced in long-range planning, water budgets, and administrative rules. However, the integration of ecological needs has lagged behind in other areas of water planning and institutional capacity. Financing for efforts to meet ecological water needs has developed through local government programs and water utilities. The Arizona Water Protection Fund has previously provided support for restoration in the entire state including Central Arizona, although funding is frequently diverted to other needs due to increasingly tight state budgets. Moreover, the financing proves limited given the rising price of water and competition for water with growing cities and groundwater replenishment districts.

Deal Development and Acquisition. Preconditions for markets are limited by the legal and infrastructure-driven entitlement system to Colorado River water. Groundwater trading and conversions of grandfathered rights into credits have both been more active, especially within the AMAs. The recent Demonstration System Conservation Program in the Yuma region suggests that the will to participate in temporary fallowing arrangements is growing. Price information is readily available, but major issues are speculation and the need to ensure affordable rates for renewable water supplies now and in the future for the growing population. Banking institutions have been chiefly administrative in nature and are connected to the recharge-and-recovery activity used to firm supplies during drought and to secure renewable supplies. Integration of ecological needs into market rules and banking institutions is the prime challenge as the region explores mechanisms to expand the productivity of water through allocations to serve people, farms, and the environment alike. Overall, the legal, regulatory, and governance preconditions are largely in place for market-based reallocation to contribute to regional ecological restoration needs.

Key challenges and consequences in Central Arizona and the mainstem Colorado River include:

- Spatial mismatches between recharge and withdrawal that create risks of localized depletions, injury, and environmental degradation.
- Lack of integration of ecological needs into limits, rights, and long-range planning at the scales needed to ensure a sustainable water allocation regime.
- Insufficient financing for environmental restoration.
- Negligible integration of markets and water banks into long-term water planning.
- Narrow approach to water resources management, i.e. defining water supply solely as an engineering problem without regard to the possibilities inherent in a reallocation approach.
- Growing urban populations that are disconnected from the environmental value of rivers.

Recommendations. Several innovative mechanisms hold potential for market-based reallocation to expand availability to meet ecological water demands. Some of these innovations include Colorado River programs under the Multi-Species Conservation Program and intentionally created surplus innovations; land and water deals through converting agricultural rights and utilizing groundwater credits to change the spatial distribution of water use, particularly in proximity to sensitive stream-aquifer zones; and use of effluent or groundwater recharge-and-recovery credits to align recharge projects with restoration aims. Building on the foundation these mechanisms have established, an as of yet unexplored next step would be to develop lease banks within the major districts and projects to meet localized ecosystem needs.

Additional promising next steps revolve around the water banks. A comprehensive review and evaluation of existing water bank structures in Arizona and the western United States would help identify the potential for Arizona water banks to provide water for environmental purposes. Additional opportunities may include developing new water banks in regions with ecological water needs and population growth, meeting mitigation and restoration needs through leasing and sever-and-transfer mechanisms, or utilizing source-switching to meet seasonal ecological needs. Given the necessary focus within Central Arizona on restoration as opposed to preservation, a region-wide effort to identify critical instream and habitat needs for species conducted in tandem with a spatial analysis of water reallocation possibilities would aid in developing resources and on-the-ground partnerships. ■

5.5

Northern Arizona, Prescott and Verde Valleys

Context. The search for sustainable water management strategies in areas of Northern Arizona has been at the forefront of Arizona debates about the balance between environment and growth in water allocation decisions. Water management entities in the Prescott and Verde Valleys include the Prescott AMA, the SRP, and several local jurisdictions for irrigation, water utilities, and local governments. This diverse region has long-standing hot spots of water stress and ecological water needs. The groundwater basins and rivers in this region are dependent on local supplies, and the Prescott and Verde Valleys have important upstream/downstream linkages. The Big Chino Aquifer is an important source of water for the Verde River. The Prescott AMA has a plan to achieve safe yield that relies on the importation of groundwater from the Big Chino Aquifer, but even that may be inadequate to balance withdrawals with available water supplies (Table 6). This has led to debates over mandating mitigation of the impacts of upstream water demands on downstream discharge and flows.

Research and Planning. An initial set of challenges in the region ties closely to research and planning to assess long-range supply and demand with respect to ecological limits and needs. According to preliminary figures from the U.S. Bureau of Reclamation's Central Yavapai Highlands Water Resources Management Study, projected water demand in 2050 will outstrip existing available supplies, and ecological needs have not yet been quantified (Table 6). A recent ADWR assessment of Prescott AMA's progress toward achieving safe yield underscores the inadequacy of current strategies to address the safe yield goal. Beyond issues of overdraft, scientific research and stakeholder processes are needed—and are underway—to address uncertainties of hydrogeologic interactions. The prospect of reduced discharge to the Verde due to pumping in Prescott Valley represents a long-term threat to the ecology of the Verde Valley. However, current water management practices in the middle Verde that dewater the river or diminish water quality at various points represent an immediate opportunity to engage in environmental restoration. As explored below, market-based reallocation might provide incentives to

Table 6. Projected 2050 Water Demands for Central Yavapai Highlands

Water Planning Area	2006 Population	2050 Population	Total 2006 Demand (AF/yr)	Available Water Supply (AF/yr)	Total 2050 Demand (AF/yr)	2050 Water Supply, incl shortages (+/-) (AF/yr)
Camp Verde	12,497	23,277	11,804	11,804	10,022	1,782
Dewey Humboldt	4,134	6,943	1,214	1,214	1,692	-478
Clarkdale	3,999	22,460	512	512	2,218	-1,706
Cottonwood	20,400	77,630	6,289	6,289	13,412	-7,123
Jerome	510	800	282	282	282	0
Prescott Valley	44,000	146,000	6,821	6,821	20,696	-13,875
Chino Valley	12,690	63,690	3,537	2,755	9,731	-6,976
Prescott	49,072	100,000	10,907	10,907	17,609	-6,702
Sedona	11,080	17,100	4,112	4,112	7,140	-3,028
Paulden CDP	5,342	14,099	2,272	2,272	3,005	-733
Big Park CDP	7,731	8,810	2,514	2,514	3,107	-593
Cornville CDP	4,075	7,448	3,781	3,781	3,455	326
Lake Montezuma CDP	4,237	8,308	1,919	1,919	2,228	-309
Ctn-Verde Village CDP	3,373	11,706	1,243	1,243	2,390	-1,147
Verde CCD	1,700	4,525	2,554	2,554	2,802	-248
Prescott CCD	16,120	42,909	7,770	7,770	9,131	-1,361
Mingus Mtn CCD	1,700	4,525	1,695	1,695	2,164	-469
Humboldt CCD	230	612	813	813	628	185
Ashfork CCD	470	36,250	2,832	2,832	6,849	-4,017
Total	**203,360**	**597,092**	**72,871**	**72,089**	**118,561**	**-46,472**

Source: Adapted from a November 27, 2009 newspaper piece in *The Daily Courier* on the Central Yavapai Highlands study. *Daily Courier* article available at: www.dcourier.com/main.asp?SectionID=1&subsectionID=1&articleID=75066

manage both of these threats, while securing future water supplies for development, agriculture, and the river.

Planning efforts in the Verde Valley have incorporated scientific analysis of flow-ecology relationships to integrate environmental needs into water management discussions. Work is currently in the field-testing phase to quantify water needed to sustain critical ecological functions. This work promises to provide a model for integrating ecological needs into long-range planning, water allocation limits, and preservation and recovery options through infrastructure projects and market-based allocation strategies. However, substantial institutional capacity and financing is needed for science-policy assessment and associated stakeholder processes, which may be an obstacle to adopting these practices elsewhere in the region where such work is merited.

As residential development and hobby farming increase, economic fears and incentives are affected by the needs of irrigation districts and ditch companies to maintain their viability across jurisdictions with small lots and dynamic land-use patterns. The cultural issues affecting these economic fears are the priorities of maintaining historic land uses, agricultural heritage, and the vibrancy of rural culture. Tribes play a significant role in the cultural and economic development of water management in Flagstaff and the Colorado Plateau. The lack of adjudication, tribal settlements, and supporting infrastructure present a fundamental stumbling block to water-sharing arrangements that use market-oriented mechanisms to secure water for environmental needs.

Deal Development and Acquisitions. Previous market transactions consist largely of efforts within the Prescott AMA to meet water supply needs. The Prescott effluent credit auction is the most well-known transaction. The auction established a $24,000/acre foot price for effluent credits. In the highly regulated AMA framework, this transaction has altered expectations of water values both inside and outside the AMA. Supporting institutions for banking, mitigation, and oversight remain limited in the region, posing a challenge to establishing additional market information and tempering speculative pressure on water transactions.

Legal and regulatory impediments to transactions stem from the lack of adjudication and the dual system of groundwater-surface water rights. In this regard, the region's experience mirrors that of other rural areas undergoing urbanization in the state. Gaps between land-use regulation and water allocation also pose challenges for efforts to define limits and rights in the Verde and Flagstaff region. Lot splits, exempt wells, and water adequacy rules do not require mitigation for groundwater pumping in many parts of the region. Recharge-and-recovery projects have potential to integrate ecological needs into their design and operation, but the scale and scope of this work remains limited by infrastructure and permitting in this region.

Key challenges and consequences in the Prescott and Verde Valleys of Northern Arizona include:

- Limited understanding of the hydrogeological linkages between pumping and river flows and flow-ecology relationships impede planning for water sustainability.
- Legal and regulatory limitations on conjunctive management imply that new groundwater allocations and exempt wells pose a long-term threat to the Upper Verde, which is currently a relatively healthy river.
- Legal and regulatory limitations on instream leasing and use of conserved water may impede efforts to invest jointly with water users to address water use and practices that currently dewater the Middle Verde River during irrigation seasons.
- Market infrastructure that enables restoration and mitigation funding to address priority ecological needs in an integrated fashion is lacking.

Recommendations. In the Verde, the alignment of interests is well-suited to undertaking market-based water-sharing arrangements to preserve or enhance environmental water allocations upstream, while securing water needs downstream. Opportunities for market-based mechanisms consist of restoration investments and transactions in the Middle Verde River to address current streamflow challenges and to develop groundwater mitigation projects that address aquifer-pumping impacts on the Upper Verde River. Reallocation might take the form of including near-term efforts to develop Verde River water delivery efficiency projects to restore streamflow, and longer term collaborations on groundwater mitigation banking for the Big Chino to offset new depletions.

By integrating voluntary restoration and regulatory mitigation demand into a single market infrastructure on the Verde River, demand from upstream development, river conservation funders, and SRP water rights holders could be channeled to fund agricultural and municipal water conservation projects, municipal effluent treatment and recharge projects, and individual sever-and-transfer transactions. Stakeholder concerns may be addressed by situating short- and long-term transactions in the context of a basin-wide planning framework that aims to meet multiple water demands while relying on willing seller participation. These strategies will require better understanding of the hydrogeology of the system and policy reforms. ■

5.6

Southern Arizona

Context. The water needs in the Southern Arizona region include historic agricultural water-use practices on family farms and ranches and new demands that have emerged principally to support expanded residential development, military base operations, and mining. Dependence on local supplies has placed pressure on groundwater resources in Southern Arizona. Drought and climate change have exacerbated vulnerability to local shortages and impacts on riparian habitat along the stream-aquifer systems of the Santa Cruz and San Pedro, while the Upper Gila is affected by diversions and proposed dam development upstream in New Mexico.

The types of ecological needs that are threatened or unmet vary with the ecohydrological context. The common thread is dependence on local supplies and localized interactions between groundwater and surface water in microbasins (Santa Cruz), subareas (San Pedro), and isolated shallow aquifer systems throughout the region. As a result, individual work-around transactions have been used to make incremental steps forward in meeting landscape-level goals. The Nature Conservancy, Pima County, and Arizona Land and Water Trust have pioneered agreements with landowners aimed at this strategy.

Cultural, socioeconomic, and environmental issues in the Southern region include a mix of concerns both specific to the region and that resonate around the state. Issues with statewide relevance include the cultural value of agricultural lands that support local food security and traditional family farms and ranches. Economic concerns are tied to the twin issues of the fear of losing agricultural asset values and the pressures of development needing to secure reliable water supplies to support new growth. Agricultural operations include small family ranches in the Upper Santa Cruz and large-scale agricultural operations in the Safford region. In addition to statewide issues, local challenges include pressures from drought and from lot splits arising from development, which have made the prospect of relinquishing water rights a particular concern for rural communities who want to preserve their way of life.

Research and Planning. The legal and regulatory framework in the region is diverse but characterized by challenges similar to those in other regions of the state. Confusion about water rights ownership and the interaction between groundwater and surface water present ongoing barriers to sustainable water planning and allocation. A system of dual surface water and groundwater claims exists in the Upper Santa Cruz. In anticipation of an eventual adjudication, landowners within the Santa Cruz AMA have been working to reconcile their surface water rights with estimates of the upper and lower limits of water availability and reliability in the basin.

In the Upper San Pedro, a technical report has been filed with the adjudication court regarding the delineation of the subflow zone (ADWR, 2002). This report will inform the court as it makes a decision determining subflow. Once the court makes its decision, then distinguishing appropriable surface water from groundwater will be possible. Federal reserved rights for SPRNCA and Fort Huachuca also play a significant role in the Upper San Pedro. The Upper Gila has recently undergone legal changes stemming from to the Southern Arizona Water Rights Settlement Act of 2004. The settlement established the Upper Gila Watershed Maintenance Area to control impacts of new pumping on downstream deliveries, illustrating the overlap between surface water adjudication and groundwater management. Mitigation requirements are most advanced in the Upper San Pedro and in the Upper Santa Cruz—given the GMA-based goal to prevent long-term declines in water tables. The gap between rules and practice remains substantial but efforts continue to integrate ecological needs in designing and implementing broader water supply management requirements in the Santa Cruz AMA.

Innovative governance arrangements in Southern Arizona reflect trends similar to those in Central Arizona. Emphasis has been placed on ecological needs in the development of water budgets and plans by virtue of restrictions to local water supplies and impacts of complex hydrogeologic interactions in the shallow stream-aquifer systems prevalent in many parts of the region. The Santa Cruz AMA, which split apart from the Tucson AMA in 1994, published its first ten-year Management Plan in 1999 and has endeavored to specify criteria for achieving its management objective of preventing long-term declines in local water tables.

The Upper San Pedro Partnership developed science and planning to respond to growing groundwater demands, particularly those related to impacts on baseflow conditions affecting the SPRNCA, which holds a strong claim to baseflows via the federal reserved water right established with its 1988 designation. In addition, Section 321 of the 2004 Defense Authorization Act (PL 108-136), which was instigated in large part by the Endangered Species Act, has established a 2011

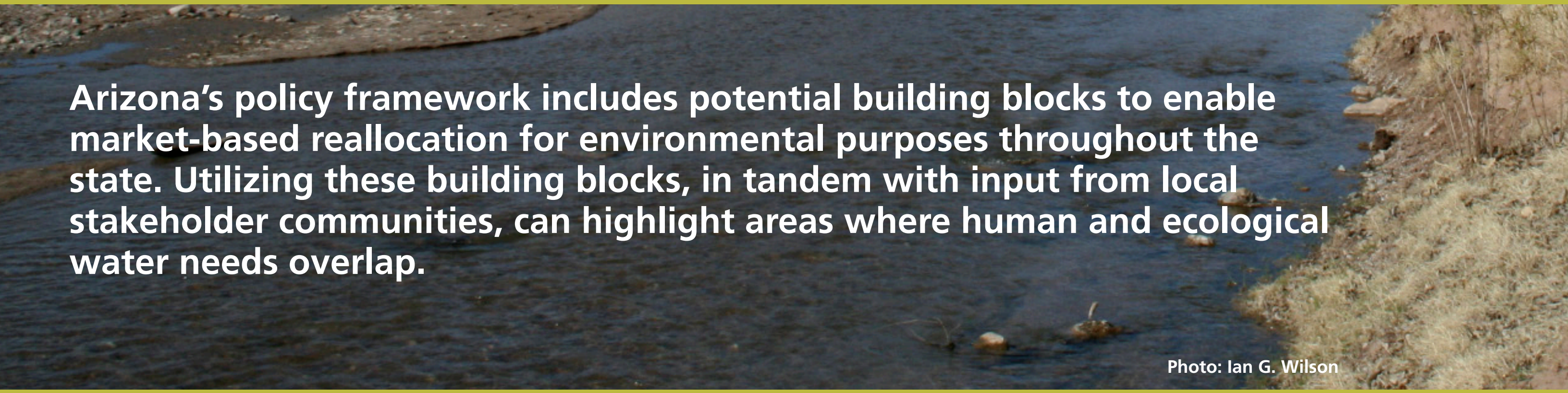
Box 9. San Pedro River

The San Pedro River, one of Southern Arizona's most celebrated—and threatened—free-flowing rivers, provides ecologically significant cottonwood-willow habitat. Its vulnerability stems from drought and intensified competition for water for historically established irrigation, Fort Huachuca, and residential development. Utilization of groundwater to satisfy new water needs has altered the timing and distribution of streamflow. Increasing water stress has dewatered reaches once considered perennial and placed the stream-aquifer system at risk of long-range declines in ecological resilience.

Fort Huachuca's requirement to reduce the impact of groundwater pumping on the river under the 321 provisions of the 2004 Defense Act has spurred a range of science, planning, and projects in the Sierra Vista Subwatershed of the Upper San Pedro. The projects have featured tools that reduce or redistribute water impacts through land acquisition, conservation easements, and, more recently, water transactions. The Upper San Pedro Partnership and its member organizations have convened meetings to gather agency, nonprofit, and stakeholder input on key scientific questions behind the legal and planning barriers to sustainable water management and market-based reallocation for ecological purposes.

The Nature Conservancy's land and water protection program has developed several projects to acquire land and retire groundwater pumping in the Upper San Pedro. Protections along the Babocomari—a tributary to the Upper San Pedro—yielded 1,400 acres and 4.6 miles of river protection. A lesson from early experience in the Palominas area of the Upper San Pedro Basin demonstrated the importance of establishing limits when designing acquisition projects to achieve net increases in the water available for ecological needs. The benefits of an acquisition deal in the Palominas area were undercut when the irrigator who sold his land and water rights moved operations immediately upstream and resumed pumping. Recent efforts have built on this past experience to develop coordinated and comprehensive approaches to mitigation, including partnerships with the Fort to implement projects that established conservation easements to retire or restrict groundwater pumping, such as the projects noted on the Babocomari.

In the Lower San Pedro, The Nature Conservancy has partnered with the SRP in its implementation of the Roosevelt HCP to pioneer the use of the state's sever-and-transfer provision (45-172). After acquiring the Three Links Farm, The Nature Conservancy commenced a then untested provision of the state's surface water code to sever the reliable water claims from the historically irrigated acreage to transfer the place of use instream. The process has been underway since 2002 and has exposed the legal and regulatory barriers tied to adjudication and groundwater-surface water interaction. The efforts to work around those barriers in the Lower San Pedro demonstrate that barriers may not be insurmountable to individual projects or to groups of projects (several other sever-and-transfer projects are underway on the nearby Aravaipa). Lessons from these experiences and test cases can offer precedents and pilot implementation experiences that inform efforts elsewhere in the region.



Arizona's policy framework includes potential building blocks to enable market-based reallocation for environmental purposes throughout the state. Utilizing these building blocks, in tandem with input from local stakeholder communities, can highlight areas where human and ecological water needs overlap.

Photo: Ian G. Wilson

target to comply with requirements to mitigate water-use impacts of the Fort Huachuca military base (Box 9).

Deal Development and Acquisition. Efforts to apply market tools for the purpose of instream and environmental flows protection are most advanced in Southern Arizona. Due to the water policy challenges in the region, land transactions are utilized as a work-around option to secure water rights for environmental purposes. While this strategy has been effectively utilized, it does raise the implicit cost of addressing water over-allocation issues. The state enables protection of instream and environmental flows through prior appropriation tools, including new instream flow permits. However, low priority dates on new instream flow permits renders them almost meaningless in overallocated basins. The impact of over-pumping on streamflow can also be addressed through the existing system by acquiring and retiring groundwater rights in the AMAs. The latter approach is, however, of limited efficacy unless the system is closed to further appropriations of surface water and groundwater.

The San Pedro is a proving ground for these land and water acquisitions. Lands with surface water rights have been acquired with the intent to sever-and-transfer water rights for instream purpose. Unfortunately, debates over the standards for establishing new instream use permits have prevented completion of applications filed years ago. Fallowing senior rights represents a secondary approach to formally changing the water right since the unused water is not protected instream and is consumed by junior users. Other potential work-around solutions such as forbearance arrangements for drought mitigation or rotational arrangements for water sharing have yet to be tried.

Key challenges and consequences in Southern Arizona include:

- Capping new appropriations of groundwater.
- Streamlining sever-and-transfer administrative procedures in order to eliminate the confusion and inefficiency of work-arounds that have emerged in the face of this problem.

Recommendations. Southern Arizona includes a number of functioning riparian areas and perennial streams that would benefit from the application of market-based tools as part of wider and ongoing planning and management. Sever-and-transfer options offer significant potential but are stymied by uncertainties over administrative standards and associated information requirements in the absence of adjudication. A detailed evaluation of the requirements and hurdles of sever-and-transfer policies could assist in developing a collaborative strategy for addressing and clearing roadblocks for effective implementation.

Effectively closing new groundwater appropriations in areas with perennial groundwater-dependent streams would set the stage for mitigation opportunities and trading. It would also provide an opportunity to use alternative water sources to support instream flows, such as treated municipal effluent. The Upper Santa Cruz River offers an ideal testing ground to secure an instream flow from effluent that would not impinge upon existing surface water rights and could recharge shallow groundwater basins. Given the complexities of purchasing effluent within the international context of the Upper Santa Cruz River, a scoping effort involving agency representatives from both sides of the border to develop international agreements securing flows would be an important and critical next step. ■

5.7 Summary

Arizona's policy framework includes potential building blocks to enable market-based reallocation for environmental purposes throughout the state. Utilizing these building blocks, in tandem with input from local stakeholder communities, can highlight areas where human and ecological water needs overlap. Table 7 and Table 8 summarize the challenges and opportunities identified in Section 5 and help point the way toward potential next steps in the near term. ■

Table 7. **Summary of Policymaking Challenges and Next Steps for Market-based Reallocation in Arizona**

Policymaking Component	Challenge	Recommendation
Policy Research & Formulation	• Scientific, legal, and economic uncertainties. • Cultural resistance to the emergence of ecological water needs due to perceived increases in competition.	• Pursue research that identifies both community priorities and ecological needs to identify mutually beneficial reallocation opportunities. • Provide research to demonstrate the degree to which water transfers may alter the status quo.
Legal & Regulatory	• Spatial disconnect between groundwater recharge and use. • Lack of limits on groundwater extraction and/or lack of instream permits for residual flows. • Lack of authority to conjunctively manage surface water and groundwater. • Lack of authority to allow mitigation in the form of instream transfer of consumptive use offset. • Lack of authority for temporary (leases) and conserved water mechanisms. • Uneven water planning between rural and urban regions in Arizona. • Piecemeal and limited integration of ecological needs into planning and water budgets.	• Detailed diagnoses of specific statutes and rules that would further reallocation efforts in specific basins around the state. • Policy reform to establish a full foundation of enabling conditions for market-based reallocation, and in particular for meeting ecological needs.
Administration	• Capacity and resource constraints at the Arizona Department of Water Resources.	• Develop monitoring, regulation, and enforcement capacities outside of state institutions, and take advantage of local nonprofit and individual capabilities.
Judicial Review	• Uncertainty over validity and extent of pre- versus post-1919 surface water claims. • Questions regarding the transferability of pre- and post-1919 rights and uncertainty over the validity and extent of those rights.	• Develop collaborations between local management agencies and stakeholders to approve changes to claims that allow for local flexibility with statewide oversight.

Table 8. Summary of Policy Implementation Challenges and Next Steps for Market-Based Reallocation in Arizona

Arizona Water Geography	Challenge	Recommendation
Central Arizona	• Spatial mismatch between recharge and withdrawal. • Lack of integration of ecological needs into limits, rights, and long-range planning. • Insufficient financing for environmental restoration. • Negligible integration of markets and water banks into long-term water planning. • Growing urban populations that are disconnected from the environmental value of rivers and the historical perspective about the values that are under threat or already lost.	• Develop localized leasing banks to meet local mitigation and ecosystem needs. • Evaluate existing water bank structures in other states to identify the potential for Arizona water banks to provide water for environmental purposes. • Conceptualize a new water bank that can meet mitigation and restoration needs through leasing and sever-and-transfer mechanisms, or by utilizing source-switching to meet seasonal ecological needs. • Conduct a region-wide spatial scoping effort of environmental needs in tandem with water reallocation opportunities.
Northern Arizona (Prescott and Verde Valleys)	• Limited understanding of the hydrogeological linkages between pumping and river flows, as well as flow-ecology relationships. • Legal and regulatory limitations on conjunctive management. • Legal and regulatory limitation on instream leasing and conserved water. • Lack of market infrastructure that enables restoration and mitigation funding to address priority ecological needs.	• Pursue water delivery efficiency projects to restore streamflow. • Strengthen long-term collaborations on groundwater mitigation banking for the Big Chino to offset new depletions. • Integrate voluntary restoration and regulatory mitigation demand into a single market infrastructure. • Situate short- and long-term transactions in the context of basin-wide planning frameworks to meet multiple demands.
Southern Arizona	• Increasing numbers of exempts wells due to loopholes in AMA rules and lack of regulation outside of AMAs. • Lack of sever-and-transfer administrative guidelines or other mechanisms for assessing the validity and economic value of water rights.	• Evaluate requirements and hurdles of sever-and-transfer policies. • Regulate new exempt wells to reduce impacts in areas with groundwater-dependent streams and impacts of aquifer drawdown on existing groundwater users. • Pursue international agreements for securing effluent for instream flows.

6.0 Conclusions

"Potential solutions must be evaluated in a basin-by-basin manner to adequately account for the wide divergence of conditions throughout rural Arizona… any proposed solutions must be discussed with, and accepted by, local stakeholders."

L. William Staudenmaier 2007. *Arizona Law Review*

Sustainable water management in Arizona depends upon a diverse set of regulatory, administrative, and incentive-based tools that can be applied in various combinations to address basin-specific challenges and opportunities. The sustainability challenge includes the need to share and allocate water among people and ecosystems. Market-based reallocation of water among multiple users offers one tool to bring ecological water needs to the table while meeting broad water sustainability goals. This report explores market-based reallocation as a general tool, and then examines the necessary enabling conditions for reallocating water for environmental purposes.

The project consisted of research and the convening of practitioners from the water management and conservation communities. First, the report authors developed and tested a framework integrating market-based reallocation for ecological needs in water-stressed areas within Arizona's state and regional context. A two-part workshop series comprised the second element of the project. The workshop series enlisted leading Arizona practitioners from the conservation and water management communities to provide input on the scope and content of the report, specifically the framework, barriers, and opportunities for market-based reallocation to address ecological needs in a context of growing competition.

The third component of the project applied the framework developed and tested with practitioners to elaborate a range of challenges and opportunities in Arizona—both statewide and within three regional areas defined by their common characteristics. The framework and barriers inform a range of diagnostic questions to assess Arizona's progress toward achieving the preconditions and capacity necessary for market-based reallocation to contribute to sustainable water-sharing arrangements and allocate water for ecological preservation or restoration. The final element of the project provides a set of recommendations drawn from solutions and responses to the barriers. Illustrative cases from Arizona and elsewhere in the West delve into the evolution of science, policy, and institutional partnerships.

This project is grounded upon the premise that Arizona's water sustainability challenges are defined by water stress, where demands on water exceed reliable supplies. Imbalances in supply and demand have historically existed across the state in localized regions and/or at specific times. Today, with climate uncertainty, an expanding population, and growing recognition of environmental water needs, water-stress conditions are increasing across the state and forcing allocation tradeoffs across multiple uses.

Analysis in the report focused on two key processes for market-based reallocation: policymaking and policy implementation. Within policymaking processes, most of the policies, statutes, and rules needed to provide the enabling conditions for general market-based reallocations are present in Arizona, although their implementation could be improved. Under the prevailing legal framework, ecological water needs benefit from residual flows when these are available but are superseded by human needs. However, Arizona has established environmental purposes as a legitimate beneficial use and has taken initial steps towards providing for the market-based reallocation of water rights to this use. Nonetheless, a number of key enabling conditions needed to support reallocation of water for environmental purposes have not yet been established and must be developed to effectively meet these needs.

Multiple key challenges and associated recommendations were identified at both the state and regional levels throughout the four stages of this project. Key recommendations include aligning planning efforts with scientific analysis to determine environmental water needs. With this information, efforts can be made to address social resistance to water transfers by aligning community priorities with opportunities to reallocate water from low-value uses to high-value uses. Additional evaluations can contribute to greater understanding of the hurdles of sever-and-transfer policies and opportunities for water banks to direct water to mitigation and environmental restoration projects.

Limiting new groundwater allocations in areas with perennial and groundwater-dependent streams can open up opportunities for new mitigation banks and precedent-setting allocations of treated municipal effluent. Ultimately, the success of these efforts depends upon the strength of diverse partnerships and a collaborative commitment to undertaking innovative projects that meet multiple water needs. Building on workshop momentum and report feedback, the next steps for this project will be to identify near-term projects that could further establish market-based reallocation options as a tool for water sustainability efforts and protection of environmental flows in Arizona.

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