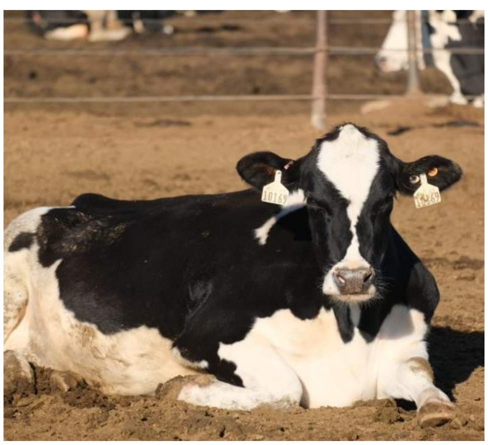
Swette Center for Sustainable Food Systems
Arizona State University

State Agricultural Water Quality Programs

Recommendations for Arizona



foodsystems.asu.edu

Swette Center for Sustainable Food Systems, Arizona State University
September 2022

This publication is a Capstone Report by the Graduate Certificate in Food Policy and Sustainability Leadership class of 2021-2022.

Suggested Citation:
Swette Center for Sustainable Food Systems. State Agricultural Water Quality Programs: Recommendations for Arizona. September, 2022. (Swette Center, 2022)

Authors

Zac DeJovine
Student/Tutor
DJVNTutoring.com

Jillian Dy
Policy Specialist
FoodCorps

Ami Freeberg
Metro Farms & Food Systems Program Manager
Cultivate Kansas City

Shelby Kaplan
Graduate Student
Arizona State University

Deborah Sadler
Food Hub Operations Manager
Food Connects

Nithesh Wazenn
Graduate Student
Arizona State University

Acknowledgements

Esteve Giraud
Research Associate
Swette Center for Sustainable Food Systems

Colleen Hanley
Senior Food Systems Specialist
Swette Center for Sustainable Food Systems

Kathleen Merrigan
Executive Director
Swette Center for Sustainable Food Systems

Suzanne Palmieri
Director of Strategic Initiatives
Swette Center for Sustainable Food Systems

Table of Contents

Executive Summary

As record-breaking drought conditions continue year after year in Arizona, the state needs to act now to fully protect its limited water resources. While current dialogue focuses on issues of water *quantity* in Arizona, with limited quantity of water resources water *quality* becomes even more important. Farmers are a major user of water, and there remains a lot of room for improvement in agricultural water usage. This report researched existing water quality programs and voluntary state agricultural water quality initiatives both in Arizona and throughout the United States to propose policy and program recommendations for agricultural water management in Arizona. Research on state water quality initiatives included a literature review, reviewing past and current water policies and regulations, and over forty interviews with water quality experts. The results of the research are presented in this report.

To understand the issues around agriculture and water usage, this report first looks at both federal and state policies around water usage, water quality standards, and how different states have varying—and in some cases conflicting—regulations on water rights. From here this report looks to acknowledge current concerns about water quantity, but to also explore the unique challenges that poor water quality can pose to farmers in Arizona. Various regulatory solutions have been proposed to address water quality, from measuring ambient pollution levels to offering Water Quality Trading credit programs. This report analyzes several of these programs to see how these regulatory tactics address water quality challenges and in what areas these tax and incentive programs fall short. Beyond these government programs, we also explore what motivates the end uses themselves: farmers who either own or lease irrigated land.

We then explore the different state agencies that work to regulate water quality and usage, as well as past and current state initiatives. Our research team then interviewed 44 individuals from ten different states to understand how these different policies and initiatives are impacting water usage. From these interviews and research, recommendations are made around improving, reinventing, and ending aspects of Arizona agriculture's water usage. Best practices learned from different climates are taken and applied to Arizona's arid climate and need for sustainable water resources.

Among these proposed recommendations, we see a strong need for increasing both public engagement and awareness of water quality issues, as well as the need for greater government agency coordination. We propose the development of the "Arizona Water Protection Plan," a voluntary water quality certification program for Arizona farmers, using best practices from other state programs. Additionally, in areas where incremental improvements will not avoid potential environmental collapse, Arizona

agriculture must reinvent itself to stay viable and maintain healthy Arizona water—both groundwater and aquifers. Finally, the report proposes ending water intensive farming where it is no longer feasible, with technical support and incentive payments to assist farmers.

Introduction

It is no coincidence that throughout human history, many important civilizations rose and fell to the ebb and flow of one or more major rivers within their domain. The Tigris and the Euphrates, the Indus and the Nile, all rivers instantly associated with the ancient societies that once flourished upon their shores. As the lifeblood of these natural ecosystems, rivers provided the water and supported the growth and expansion that would have otherwise never taken place. While less famous than the Pharaohs and their pyramids along the Nile, this same scenario can be said of Phoenix and the Valley of the Sun: Phoenix was not the first major settlement to spring up along the now dry banks of the Gila River, as the Hohokam people once utilized the flow of both the Gila and Salt Rivers to fill their intricate canal system and bring a planned desert oasis of plant growth to life. The Hohokam canal system was affected by the geological event known as the "Great Drought":

> The region affected by the Great Drought encompassed the area that extended from what is now Oregon to southern California and east to what is now eastern Texas; dendrochronology, or tree-ring studies, indicate that it began in AD 1276 and continued through 1299 (Britannica, 2012, para. 1).

Several hundred years later, modern Phoenix faces similar problems as the ancient Egyptians and the Hohokam people. Founded where it is in part due to the existence of these canals and the early settler agricultural efforts they aided, Phoenix is now dealing with drought conditions that, much like the "Great Drought," are similarly impacting agricultural production methods in the state. A burgeoning megalopolis that has seen massive growth, with no signs of slowing down, and a thirst for fresh water to match, Arizona has gone from Wild West to Desert Destination, growing from about 750,000 residents in 1950 to almost 7.5 million in 2022. Most of this growth has and will continue to take place in the Valley as new residents flock to Phoenix and the far-out fringes dispersed throughout the desert. Queen Creek, Buckeye, Casa Grande, Maricopa and Goodyear were five of the top eleven fastest growing American cities last year, and Phoenix added the second most people in the nation with 13,224 new residents (US Census, 2022). This meteoric growth coincides with the most drastic water conditions the state has ever seen. For the first time in history, the U.S. Department of the Interior declared a water shortage for the Colorado River, a decision that has sent ripples across the state water supply, leading to struggling farmers and fallowed fields.

As serious supply questions surround the issue of how to sustainably source water for so many new sun-dwellers, it helps to survey the past to determine what steps have been taken to get us here. While many have tried to mitigate this issue, they have merely delayed the water shortage that Arizona now faces. Water conservation, supplanting agricultural land in favor of residential development, and landmark legislation like the Groundwater Management Act of 1980 have all contributed to lengthening the lifespan of the dwindling water supply, but the pressures brought to bear by population growth and climate change have come to a head. Perhaps the most significant water legislation in state history, the Groundwater Management Act of 1980 represents the attempts and ultimate failures to stave off this water crisis. The Act established Active Management Areas (AMAs), centered around the major population centers, in which the expansion of agriculture was limited, and where the most ambitious goals for water conservation were set (ADWR, 2016b). Safe yield, the concept of ensuring that the same (if not greater) amount of water is replenished to the groundwater sources from which it is drawn, had a goal of being attained by 2025 for the Phoenix, Prescott and Tucson AMAs when the concept was created. Nearly 45 years later, the results are not promising: of those three AMAs, only Tucson is close to hydraulic homeostasis, with Phoenix and Prescott essentially deemed lost causes (ADWR, 2016a).

The situation outside of the AMAs is no less dire. From communities like Pine-Strawberry, to the record low levels of Lake Mead, signs of water distress are on display across the state. New water hookups for homes are no longer permitted in Pine-Strawberry, a mountainous town whose climate is so distinct from Phoenix that it would seem to be better suited to stave off drought conditions (Aleshire, 2022). Lake Mead, the reservoir on the Nevada-Arizona border responsible for generating large amounts of hydroelectric power and providing emergency water reserves, is at the lowest level ever recorded. As of May 2022, 26.8% of Mead is full, besting the previous recorded low of 33.8% in July 2016. This risks not only water for millions of residents, but the power supply generated by the dam as well. This dearth of water has developed due to decreased snowpack as well as demand for development outpacing the climate change challenges of decreased precipitation in all forms along the Colorado River basin (Carlowicz, 2022).

To understand the challenges Arizona faces, it helps to understand the stark nature of the desert climate. The National Weather Service recorded a total annual rainfall in 2021 of 7.1 inches in Phoenix, and just 2.44 in Yuma, highlighting the contrast between these busy agricultural centers and the rainfall they receive (National Weather Service, 2023). Only Los Angeles and Las Vegas are comparable American cities in terms of desert population, and those two states rank above Arizona in terms of liquid assets. While Arizona is the 6th largest state, checking in at 113,990 square miles, it is just 49th by total liquid landmass, with only 0.3% (396.22 square miles, 48th by total area) of the state consisting of water, placing it just ahead of New Mexico, last at 0.2%. While it's clear that under normal circumstances water would be scarce, the ongoing drought has occurred at a time when the Valley needed even more water to support the expanding growth, not less. To add to these challenges, agriculture uses roughly two-thirds of the water in Arizona, and most of this activity takes place in Maricopa and Pinal counties, regions of the state that also happen to house the most extreme climate Arizona has to offer. Comparing a map of Arizona agricultural activity with the Köppen climate classifications for the state visually drives this point home:

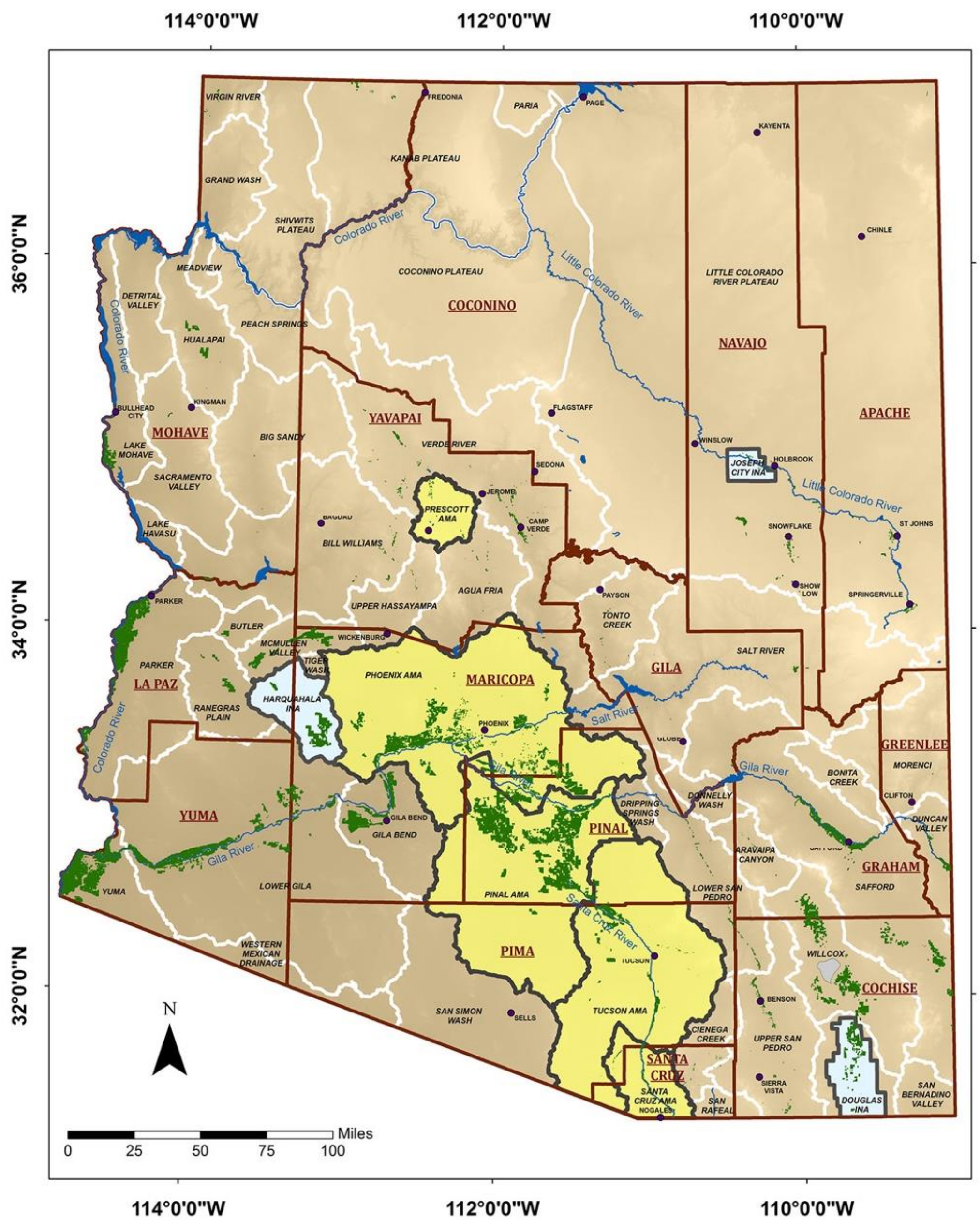


Figure 1: Agricultural areas in Arizona. Source: USGS, 2015.

The Köppen-Geiger climate classification was originally designed in 1936 and is still used as a helpful way to visualize different climate classes based on their seasonal changes in temperature and precipitation (Beck et al., 2018)

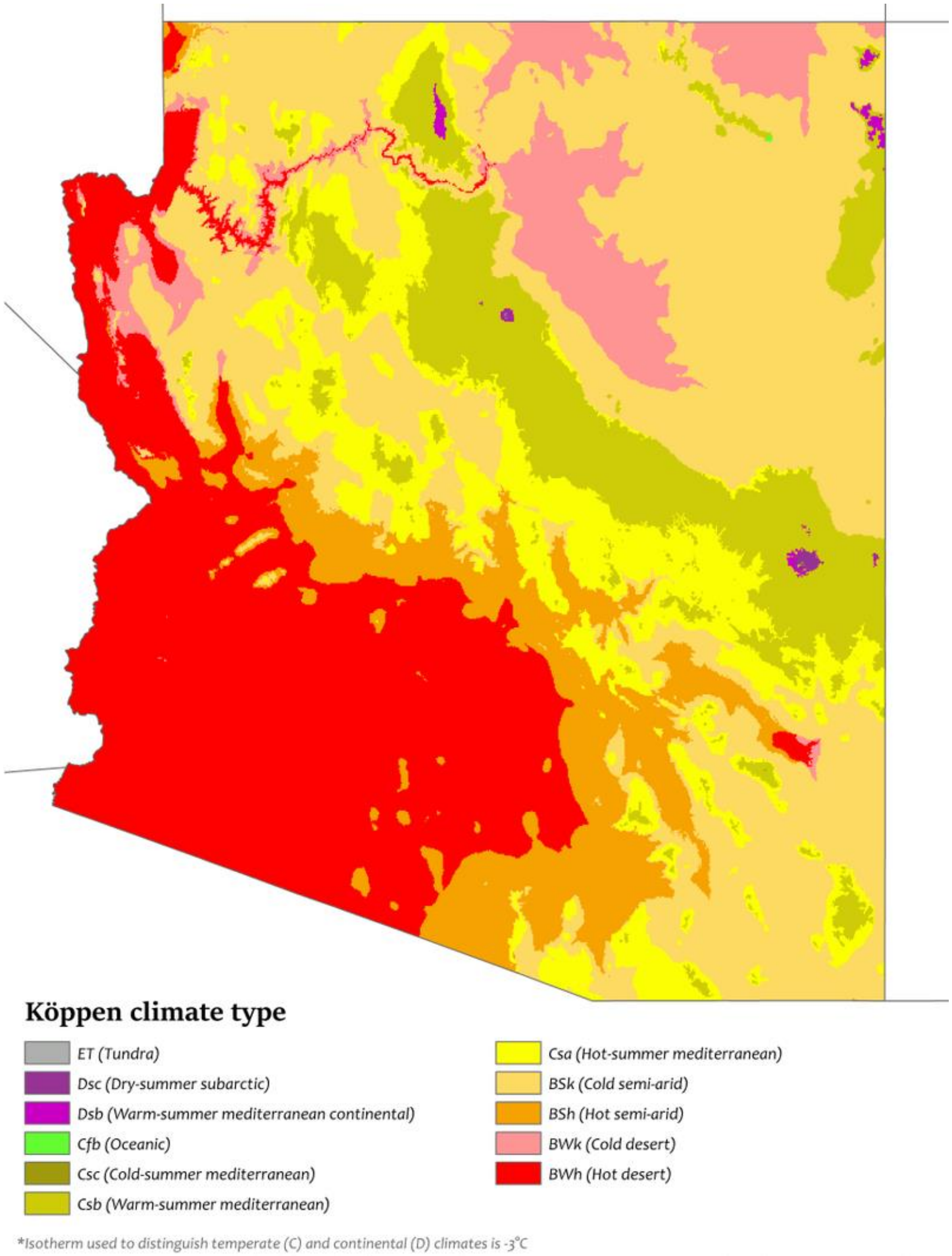


Figure 2: Köppen climate map of Arizona. Data from Prism Climate Group, Oregon State University, http://prism.oregonstate.edu; Outline map from US Census Bureau. Image used under CCBY-SA 4.0.

As the drastic shortage of water rightfully yields sensational headlines, worsening water quality becomes an even greater concern. Issues of naturally high salinity combined with desertification and pollution put a strain on the flexibility the agricultural community has in dealing with water shortages (Bureau of Reclamation, 2006; Nabhan et al., 2023). Increasing salinity in local fields and downstream on the Colorado River impacts water quality and puts demands on more water to flush out fields and fulfill commitments on water quotas to Mexico. **This situation highlights one of the unique challenges to Arizona: in a state with so little water, the issues of quality and quantity become closely intertwined.** Whether it be the standard practice of flooding fields to flush out excess salinity accrued due to agriculture, or the decreased quality water that taxes the quantity of water useful for agriculture, the issue of salinity in Arizona is a quality problem that ends up negatively impacting quantity as well.

In a state with dwindling quantity, worsening quality and a non-stop influx of new residents to feed and water, how can agriculture help prevent and protect against the further fallowing of fields and worsening of water conditions?

While conventional runoff issues associated with agriculture, such as high levels of nitrates and phosphorus, are less of an issue in Arizona compared to states with more precipitation, protecting against these quality degradations is even more pressing in a desert environment. To that end, the Arizona Department of Environmental Quality (ADEQ) has been negligent in accurately assessing the extent to which Arizona faces water contamination issues. According to a 2021 audit conducted by the state Auditor General's office:

> The Department has not conducted key ambient groundwater monitoring responsibilities since 2017, such as detecting the presence and evaluating the effect of contaminants in groundwater. The Department has not conducted required monitoring of agricultural pesticides in groundwater and surrounding soil since 2013, as required by statute. Although it has established a goal to do so, the Department has not reduced the total number of impaired surface waters in the State that do not meet federal surface water quality standards to address pollutants that affect the safe use of these waters and potentially negatively impact the environment. (Perry, 2021, p. 4)

At a time of worsening drought, stringent surveillance of the limited state supply is extremely important. This situation risks Arizona's already limited quantity, which then further strains the state's quantity.

So, what can be done? In a state with dwindling quantity, worsening quality and a non-stop influx of new residents to feed and water, how can agriculture help prevent and protect against the further fallowing of fields and worsening of water conditions? Voluntary water initiatives have strong precedent in other states as a useful tool to forego legislative action. In this report, several different state water initiatives are presented. While some plans, such as the Minnesota Agricultural Water Quality Certification Program, operate in much wetter climates, many lessons for building a new water program became apparent in the course of our research. A potential Arizona plan must consider the stark difference in water quantity and water concerns of other states. Yet despite the differences, many lessons can be learned from the plans implemented in other states, namely improvements to soil health that impact both ends of the quantity/quality spectrum.

Research Methods

Water quality issues are complex, wide-ranging, and varied across the country. The research team took a broad view in gathering information and best practices from the field to understand various components, issues, and stakeholders in state water quality programs and policy. We conducted an initial literature review to report on current federal and state regulations that govern water quality to understand the broadest scope of funding and regulation impacting state water quality programs. We also researched water coalition building to understand how stakeholders come together and build political will as a key component of policy change. Because the thrust of our project was to make recommendations for Arizona, we needed to report on the intrinsic relationship between water quality and water quantity issues in agriculture. Finally, market-based approaches to water quality and water trading and economic incentives to pollution mitigation in agriculture are part and parcel to burgeoning and existing water quality initiatives. In addition, extensive research was conducted on Arizona's current water quality initiatives and funding sources, as well as review of other state water quality programs.

The research team developed a list of questions (see Appendix 1) to guide the discovery process via 60-minute interviews with water quality experts to gain an overarching view of water quality plans in the United States and best practices for implementation, with special attention toward application to the state of Arizona. Over the course of several weeks, 41 interviews with a total of 44 individuals were conducted with stakeholders across ten states, offering perspectives from water quality experts and practitioners representing state agencies, academic researchers, nonprofits, and farmers. The research team gathered qualitative data from these interviews, which were recorded via Zoom software platform. Each question was coded with themes determined through the literature review and through the interviews themselves. A list of common themes found in the coding data, which were used to make recommendations for Arizona:

- State or federal initiatives, incentives, funding sources
- E. coli, nutrient impairment, sediment, salinity, soil health
- Modeling, water testing/monitoring
- Surface water
- Local solutions, coalition building for political willpower, trust
- Program goals
- Quantity vs Quality, water conservation
- Communication/coordination, education/outreach

- Water quality technical recommendations, motivations for participation, voluntary, policy recommendations for program building
- Difficulty in measuring

This research project was granted exemption from the Institutional Review Board (referenced at STUDY00016081) with support from Arizona State University’s IRB office.

Literature Review

This section provides a research-based overview of certain important aspects for water programs. First, an overview of federal laws and regulations and Arizona water laws and regulations is important to understand the legal framework around water and the scope of potential state programs. Next, building a coalition or network to work together around water issues is discussed, as this is necessary in successfully launching a new program. Given the context of farming in Arizona, the relationship between water quantity and quality is explored. And finally, when looking at non-regulatory initiatives, it becomes important to understand incentives to participate in voluntary programs. Therefore, an overview of market-based approaches and incentives for water quality participation is reviewed.

US Agricultural Water Regulation: Federal vs. State Responsibilities

When looking at state-level programs for water quality, it is first necessary to understand the regulatory history and legal framework. Water quality is legislated at both a national and state level, with significant interplay between jurisdictions. This section will first give an overview of U.S. water regulation and current issues in federal and state water quality laws. Then, it will look at stakeholders within water systems and how coalitions are built between different stakeholders and government groups to create water management systems.

A Brief History of Federal Water Policy

There is no comprehensive federal water management law in the United States. In their chapter "Legal and Institutional Framework of Water Management" of the book *A Twenty-First Century U.S. Water Policy*, Juliet Christian-Smith and Lucy Allen break down the different legal frameworks and agencies involved in U.S. water policy law and administration. They write that:

> The United States continues to use a complex legal and administration framework, based on a wide diversity of federal laws, regulations, and historical court rulings, to distribute authority over water between federal, tribal, state, and local governments. This framework has been built up over two centuries and is based on the US Constitution, federal and state legislation, judicial decisions, common law, and even international treaties. (Christian-Smith & Allen, 2012, p. 23)

> In addition to disperse authorities, federal funding for water is split across 30 agencies and programs. (Christian-Smith & Allen, 2012, p. 24)

Federal agencies involved in water management include the Environmental Protection Agency (EPA), the Army Corps of Engineers, the Forest Service, the US Geological Survey (USGS), the Department of Agriculture, and the National Oceanic and Atmospheric Administration (NOAA). Each agency has a separate budget, some of which must be reauthorized every budget cycle and are vulnerable to changes to political priorities over time (Christian-Smith & Allen, 2012, p. 24).

The border between federal and state water authority on water is often difficult to navigate.

> The federal government has primacy in matters concerning navigation, international treaty negotiations, federal water development projects, and water uses associated with federal lands and other property, and it has a stake in the national regulation of pollution and protection of natural resources (Christian-Smith & Allen, 2012, p. 37).

Any water not explicitly regulated by the federal government is left to state and local lawmakers. And while the federal government may have the authority to act, it can be politically curtailed through limiting funding or enforcement (Christian-Smith & Allen, 2012, p. 35). Therefore, some local waterways are only state regulated, and oftentimes in Arizona there is a lack of regulation at the state level.

1972 Clean Water Act

The first of two main federal laws governing water quality is the 1972 Clean Water Act (CWA). As explained in Copeland's "Clean Water Act: A Summary," this was a big overhaul of the previous 1948 Federal Water Pollution Control Act and its subsequent versions. The CWA seeks to address water pollution, particularly around wastewater treatment and point-source pollution. With the 1987 amendment, the CWA looked to address non-point source pollution as well. The Clean Water Act is overseen by the EPA, but in partnership with state agencies. States can set their own Total Maximum Daily Loads (TMDL) of pollutants and establish how those TMDL standards are met. States have the right to permit water discharges and to address many concerns on a local level.

> Certain responsibilities can be assumed by qualified states, in lieu of EPA, and this act, like other environmental laws, embodies a philosophy of federal-state partnership in which the federal government sets the agenda and standards for pollution abatement, while states carry out day-to-day activities of implementation and enforcement (Copeland, 2010, p. 4).

In certain cases, though, the EPA steps in and sets a TMDL level for the water body, which the state must meet. Thus, the CWA created a federal-state partnership in regulating clean surface water.

Waters of the United States

The CWA applies to all "navigable waters," also referred to as Waters of the United States (WOTUS). The Clean Water Act therefore applies to surface water, not groundwater, but over time the exact definition of WOTUS has changed many times. Prior to 2015, WOTUS included all interstate bodies of water, the oceans, and any streams or wetlands that may feed into interstate bodies of water. Wetlands not tied into interstate water were not included. In 2015, under the Obama administration, the definition of WOTUS was clarified to include an expanded vision of wetlands and headwaters. This was replaced under the Trump Administration in 2020 with a new definition of WOTUS that did not include many wetlands and streams previously covered, eliminating these waterways from EPA regulation. However, a 2021 ruling in the US District Court for the State of Arizona voided the 2020 rule, and the WOTUS definition reverted to the pre-2015 criteria (US EPA, 2018).

In the Science article "Deciphering Dueling Analyses of Clean Water Regulations," authors Boyle et al. contrast the way that WOTUS and the CWA was understood and regulated in 2015 and 2017. Under the Trump Administration in 2017, the EPA proposed a new rule and a new regulatory impact analysis (RIA) on the CWA that did not include wetlands. The authors find that the 2017 RIA is inconsistent with empirical evidence and past policy. They call for a more scientific and objective approach to conducting RIAs. Furthermore, they stress the need for water regulation to have a scientific basis, be clear, consistent, and easily understood so that regulations can be adequately understood and enforced over time (Boyle et al., 2017, p. 49-50).

Safe Drinking Water Act

The second of the two main federal water quality legislations is the 1974 Safe Drinking Water Act (SDWA). The SDWA established minimum standards to protect the quality of public drinking water systems. Whereas the CWA did not apply to underground water, the SDWA protected underground sources of drinking water from sources of pollution. Amendments in 1996 required that the EPA set and enforce scientifically backed standards for water quality and levels of pollutants. According to Michael Zarkin's article "Policy Learning Mechanisms and the Regulation of US Drinking Water," the SDWA and the regulation of US drinking water supplies is an example of a regulatory agency becoming a learning organization. Over time the SDWA was legally amended in 1996 and changed many times throughout the nearly 50-year history to remain current with changing scientific information. In effect, the EPA learned how to better protect drinking water, and was able to change regulations and water quality standards over decades to reflect that knowledge (Zarkin, 2016).

A Brief Note on Arizona's Regulatory Framework

In Arizona, surface water law follows a pure prior appropriation approach. In Eastern states' riparian law, property owners are allowed to use water adjacent to their property, if it doesn't impede on other property owners' downstream ability to use water. In Arizona and certain other Western states, however, water is allocated based on the first users to put surface water to a beneficial use, and these rights are not necessarily tied to land ownership. When there is limited water to be allocated, the initial water users have the right to the water before later users, hence the term "prior appropriation" (Christian-Smith & Allen, 2012, p. 38). One limitation on prior appropriation is that:

> Because not fully using a water right can be grounds for losing the right to the unused portion, these rules encourage use at historic levels and, thus, discourage water conservation. In addition, few states allow the transfer of conserved water to other users or change of its use to other purposes, limiting what can be done with the conserved water to avoid forfeiture and abandonment. (Christian-Smith & Allen, 2012, p. 43)

Again, these surface water laws will vary by state and are not the same as groundwater rights.

Water Coalition Building

Because U.S. water policies are administered across several agencies, it requires a great deal of coordination and cooperation to administer water policies and programs. Christian-Smith and Allen describe several non-profit organizations' requests for more specific and integrated national water policies. They find that looking ahead, "Water policy will have to adapt quickly to changing climatic conditions and do so in a coordinated fashion, reflecting the hydrologic connectivity of our nation's water resources" (Christian-Smith & Allen, 2012, p. 25). According to Christian-Smith and Allen, while many water issues can be solved at the state or local level, federal involvement and leadership is often needed when local issues intersect with federal water jurisdictions.

Because U.S. water policies are administered across several agencies, it requires a great deal of coordination and cooperation to administer water policies and programs.

In the Science article “Collaborative environmental governance: Achieving collective action in social-ecological systems,” author Orjan Bodin analyzes the ways in which collaborative environmental governance can be successful in solving environmental problems. According to Bodin, environmental governance relies on a collaborative network of individual actors, which need to have a horizontal and vertical fit across collaborators, to include multiple actors of interconnected ecological components, as well as mediating actors, such as government administration. Central actors who are well-placed within the network and also have strong leadership skills are key in creating a productive social-ecological network and collaboration. To better understand complex problems, these central actors should have experience in multiple communities (Bodin, 2017).

These central actor roles are often filled in by so-called boundary spanning organizations or actors. Boundary spanners are members of multiple communities who communicate across group boundaries. According to Petr Matous and Peng Wang’s research with rural farmers, members of the community who take part in additional training outside their community can then become boundary spanners. Boundary spanners are then given prestige for their knowledge and can become opinion leaders. Their conclusion shows that to effect change in a community, it is not necessary to reach current opinion leaders because with additional information, new boundary spanners can arise as opinion leaders in the network (Matous & Wang, 2019). However, Delozier and Burbach’s study of integrated water resource management communities in Nebraska put the focus back on individual boundary spanners. Their research found that networks who ranked individual boundary spanners as high on trustworthiness and authentic leadership were the most effective in communicating across communities. (Delozier & Burbach, 2021). However, the role of a boundary spanner can be performed by an agent or an organization.

Munoz-Erickson et. al (2010) investigate the role of collaboration in the Verde River Basin Partnership (VRBP) in Arizona. The VRBP is a federally mandated program, created to address concerns of water in the underground headwaters in the Verde River Basin, upstream of the Prescott Valley. The partnership aimed to educate involved actors to try to stem off conflict between the parties. The authors interviewed several individuals involved in the partnership to see the role of the partnership in creating bridges between diverse perspectives and stemming off conflict. They found that the group’s inability to find common ground was in part related to actors differing viewpoints on whether to accept the scientific consensus of scientific findings around water. They found that experts were not necessarily able to provide assistance to actors who came in already adverse to scientific analyses. They found that actors' deep-seated disregard towards science can prove a stumbling block towards collaboration for a watershed that looks to be managed according to scientific principles (Munoz-Erickson et al., 2010).

Agricultural Water: Relationship of Quantity and Quality Issues

In the United States, approximately 25 percent of cropland is irrigated, which is higher than the global estimate of 18 percent of irrigated cropland. While only accounting for 18 percent of cropland, irrigated areas produce 40 percent of the world's food (NASS 2018; Scanlon et al., 2007). According to a 2017 U.S Geological Survey report, in the U.S. crop irrigation accounts for 42 percent of freshwater withdrawals, and 62 percent of total water use including withdrawals and reclaimed wastewater (Dieter et al., 2017). Henry Bouwer outlines that a growing population requires more irrigation water to ensure that increasing demands for food are met. Bouwer also notes that further water protection will be needed to address issues of aquatic life, wildlife habitat, recreation, scenic values, and riparian habitats, and that increased competition for scarce water resources should be expected. Bouwer writes,

> This will require intensive management and international cooperation. Since almost all liquid fresh water on the planet occurs underground, groundwater will be used increasingly and, hence, must be protected against depletion and contamination, especially from non-point sources like intensive agriculture (Bouwer, 2000, p. 218).

As a major user of water, agriculture is under threat as water shortages intensify in arid regions of the country and precipitation patterns become less predictable with a changing climate. Dennis Wichelns and J.D. Oster explore the viability of irrigated agriculture in their article "Sustainable irrigation is necessary and achievable, but direct costs and environmental impacts can be substantial." They write:

> In some areas, the private and social costs of sustaining irrigation will exceed the benefits and irrigation will cease. Such areas will include regions in which persistent groundwater overdraft leads to unaffordable pumping costs or depletion of fossil groundwater supplies (Wichelns & Oster, 2006, p. 125).

At the same time, more frequent intense storms in humid regions are leading to challenges with increased flooding and erosion, both of which negatively impact agricultural productivity and water quality. Again, Wichelns and Oster write, "Irrigation might also be discontinued in regions where society chooses not to accept the off-farm impacts of agriculture, or the environmental harm caused by discharging drainage water into rivers and other waterbodies" (2006, p. 125). Both water scarcity and abundance play a role in agriculture's impacts on water quality and shortages.

Types of impairment

The environmental costs of agricultural water use and management show up to varying degrees depending on a region's climate, soil type, land use, agricultural practices, and implementation of best management practices. Throughout the country, agriculture is a leading source of nonpoint source pollution, in which fertilizers, pesticides, manure, salt, and soil sediment enter both surface waters and groundwater from dispersed sources such as farms, roads, parking lots, and lawns. In contrast to point source pollution, such as discharge from a factory or power plant, nonpoint source pollution is significantly harder to identify, measure, and regulate (EPA, 2017). The primary ways that agriculture contributes to impaired water quality are outlined below.

Nutrient impairment in waters

Agriculture of many scales and types introduces nutrients that make their way into water sources. In the Upper Midwest and humid regions, conventional crop management of corn and soybeans leave soil exposed through the winter. Wind and water cause significant erosion of the exposed soil, which carries phosphorus and nitrogen with it into waterways. In turn, the depleted soils require more fertilizer use in the spring for productive yields, which further exacerbates nutrient impairment in water (Weyers et al. 2021). Carpenter et al. estimate that nonpoint source impairments of Nitrogen and Phosphorus, primarily from agricultural operations, account for 82-84% of all discharge into water bodies (Carpenter et al., 1998). In the arid region of the Western states, the risk of nutrient impairments in watersheds is lower than in the Midwest and Eastern states, due to less cropland and minimal precipitation to carry the nutrients away. In particular, watersheds in and around Arizona typically are home to more rangeland and federal lands. Brown and Froemke note that these land uses have a lower risk of nutrient impairment because they limit development and animal feeding operations (Brown & Froemke, 2012).

Naturally occurring salts in the irrigation water, both groundwater and surface water, paired with a lack of effective drainage systems, leads to increasing levels of salt in the soil, which diminishes agricultural productivity.

Salinization of soil and water

Both groundwater and surface water can be salinized through irrigated agricultural practices. Scanlon et al. explain the conversion of natural ecosystems to agricultural production as the mobilization of natural salts that have accumulated in the subsurface in many semiarid and arid regions (Scanlon et al., 2007). Naturally occurring salts in the irrigation water, both groundwater and surface water, paired with a lack of effective drainage systems, leads to increasing levels of salt in the soil, which diminishes agricultural productivity. In 2011, Jeffrey Homburg and Jonathan Sandor published research on human impacts on soil quality of the American Southwest, noting, “Cases of detrimental levels of salt and sodium accumulation caused by irrigation are well-known in modern agriculture, though scientific documentation is surprisingly rare” (Homburg & Sandor, 2011, p.152) Their analysis of soil throughout the Southwest indicates that now uncultivated landscapes were once ancient agricultural fields, and the differences between soils that were irrigated or dryland in ancient agricultural systems persist today. It is likely that excessive salt and sodium accumulation in irrigated landscapes led to abandonment of those fields by pre-Hispanic cultures, or at least severe limitations on use and choice of crops (Homburg & Sandor, 2011). Scanlon et al. estimate that globally, loss of irrigated farmland due to salinization is 1.5 Mega hectares/year (Mha/yr), totaling 45 Mha across the globe. This estimate represents 16% of total irrigated agricultural land, which is especially significant considering that irrigated land is the most productive agricultural land (Scanlon et al., 2006).

Excessive naturally occurring micronutrients

Another impact agricultural production has on water quality is dissolving and mobilizing naturally occurring trace elements and micronutrients. In many cases, elements such as selenium, gypsum, arsenic, and boron are beneficial to plant health in very small amounts but can become harmful or toxic in high concentrations. Dennis Lemly discusses the impact of excessive selenium in surface waters as highly toxic to fish and wildlife, disruptive to life cycles of aquatic life, and harmful to human health if selenium-contaminated fish are consumed (Lemly, 1996). Similarly, boron is necessary for healthy plant growth and development in small amounts, but if slightly more concentrated than required, boron becomes toxic and damaging to both plants and humans. There is no simple process to remove boron from water (Hilal et al., 2011). As water quantity diminishes, the concentration of some naturally occurring elements may increase to unsafe levels and become a water quality concern.

Raising water tables or waterlogging

Waterlogging occurs when the soil is saturated with water so there is insufficient oxygen for plant roots. Irrigated cropland contributes to waterlogged areas, by raising the level of water tables over time. In addition to inhibiting plant growth, waterlogging contributes to the degradation of water quality by enabling fertilizer leaching and salt mobilization (Scanlon et al., 2006).

Livestock waste management

Modern agricultural practices have moved livestock management off pastureland and into Concentrated Animal Feeding Operations (CAFOs). The intensification of livestock production impacts water quality in a number of ways, from manure management to increased demand for fodder that relies on chemical fertilizers. In “A review of water quality concerns in livestock farming,” P.S. Hooda et al. write that manure produced in concentrated livestock farms is often applied to cropland as fertilizer in excess of agronomic requirements and application is not timed for maximum benefit to soil and crop health. Imprecise field application, as well as poor management of waste slurry, leads to leaching of nitrogen, phosphorus, organic wastes, and bacterial pathogens such as E. coli into surface and groundwater sources (Hooda et al., 2000). In addition to intensive livestock operations, ranching on public lands in the Western U.S. has created water quality issues such as bacterial pathogens and degradation of streambanks (Kauffman et al., 2022).

Impact on different water sources

The agricultural impairments to water quality outlined above cause different impacts on each type of water source with regards to water quality and water quantity. Additionally, impairments to each water source have different impacts on agriculture and the environment, detailed below.

Surface waters

Surface waters are primarily impaired by nitrates and phosphates which runoff from cropland and concentrated livestock operations. The humid region of the Midwest and Eastern U.S. are at greatest risk for water quality impairments from agricultural runoff. Arid regions also suffer water quality impairment from salinization, minerals, and bacterial pathogens. Impairments to surface waters lead to hypoxia, loss of habitat, and public health risks.

Surface water is also at risk of overuse for agricultural irrigation, particularly in arid states. According to the Arizona Department of Water Resources, 54% of water comes from the Colorado River or in-state rivers (ADWR, n.d.b). The Colorado River is governed by several sets of laws and regulations, known collectively as the Law of the River, which instead of restricting water use has actually overallocated the river’s water. Agricultural irrigation accounts for 72% of water use by sector in Arizona, so it is an obvious target for reducing water use.

In one example of the relationship between water quality and quantity, Jan van Schilfgaard points out that until the early 70s, all of the work and controversy along the Colorado River focused exclusively on allocations of water quantity and ignored its quality. She notes that the Colorado River Basin Salinity Control Act of 1974 shifted the conversation to addressing issues with salinity as the impacts of irrigation flowed downstream and municipal users suffered the consequences. Van Schilfgaard writes, “Water quality and water quantity, it turns out, are intricately linked. As the pressure for water quantity grows, the concern with water quality increases” (1993, p. 214).

Impaired surface waters are a threat to public health by way of contaminated drinking water, bacterial outbreaks on vegetable crops, and contamination in fish and seafood. Additionally, impaired surface waters are not accessible for recreational and tourism purposes which can negatively impact the economy of a state and diminish habitats for wildlife.

Groundwater

Agricultural use of groundwater is the primary cause of rapidly depleting aquifers at a greater rate than they can recharge. As the water table lowers, shallow wells are drying up, leaving those who have historically had access to groundwater without water. In some parts of Arizona, groundwater withdrawal is not regulated, which is where agricultural operations with greater resources are able to drill deeper wells and extract groundwater without constraints (ADWR, n.d.b).

Similar to surface water, groundwater becomes impaired by agricultural uses which leach salt, nitrates, phosphates, and minerals into aquifers. According to Stephen Foster et al.:

> In recent years water security concerns have centered on groundwater depletion by withdrawals for irrigated agriculture, and only limited attention has been paid to the more insidious (and more chronic) problem of progressive aquifer salinization of groundwater recharge by irrigation return-flows, which is occurring in many semi-arid regions (2018, p. 2781).

Groundwater accounts for 41% of water use in Arizona. When water extraction is greater than recharge, groundwater is not a renewable resource. Any impairment to groundwater quality further limits the safe use of the scarce and valuable resource. Every effort should be made to protect both the quantity and quality of groundwater in arid regions.

Recycled water

Recycled water accounts for 5% of Arizona's water resources, so it is a minor source of water in the state.

At this time, recycled water accounts for 5% of Arizona's water resources, so it is a minor source of water in the state (ADWR, 2020). However, as groundwater and surface water become increasingly scarce in arid regions, recycled water could become increasingly important for agriculture in the West. In 2018, Dery et al. published research on growers' perceptions and attitudes regarding nontraditional water sources such as recycled water. The survey found that, despite evidence of safety, growers continue to have reservations about using recycled water. The survey notes the top concerns are food safety, cost of infrastructure, consistency, availability, chemical contamination, public perception, and water rights. The research team hopes their work will help, "aid decision makers in understanding the perceived risks, willingness to use, drivers and constraints to grower adoption, and preferred methods of education regarding water reuse in agriculture" (Dery et al., 2018 p. 508). As water continues to become increasingly scarce with the changing climate, recycled water has the potential to secure agricultural production in arid and semi-arid regions for the foreseeable future.

While water quantity shortage is the primary issue in Arizona, it is important to consider water quality impacts as well - both how agriculture impacts water quality and how impaired waters can impact agriculture. Carpenter writes, "Water shortage and poor water quality are linked, because contamination reduces the supply of water and increases the costs of treating water for use. Preventing pollution is among the most cost-effective means of increasing water supplies" (Carpenter et al., 1998, p. 560).

Conclusion

This quote by Dennis Wichelns and J.D. Oster summarizes the heart of this issue:

> Farmers and public officials must determine acceptable levels of the direct and indirect costs involved in sustaining irrigated agriculture. Farm-level and policy decisions will vary among regions with differences in economic development, resource endowments, and public preferences regarding the inevitable impacts of irrigation on the environment. Hence, the notion of irrigation sustainability will vary among regions and over time with differences in public preferences. (Wichelns & Oster, 2006, p. 114)

In a place like Arizona, where concerns over scarcity of water quantity dramatically outweigh concerns over water quality, how do policy makers and state agencies build the political will to address agricultural water management to improve water quality? Are the environmental costs of agriculture too high, especially in the face of climate change? As this research explores these questions, it is important to keep in mind that while they are certainly separate issues, water quality and quantity are deeply intertwined and that agricultural practices that address water conservation, likely protect water quality as well, and vice versa.

Economics and Environmental Markets: Lessons from Water-Quality Trading

Environmental markets are a major conceptual innovation for environmental policy that came from research in environmental economics. As the concept moves from pages of books and journals to instruments available to policymakers, outcomes will depend on how the market programs are designed and implemented and the contexts in which they occur. (Shortle, 2013). This section will give an overview of U.S. Water Quality Trading (WQT) programs and then, it will look at how coalitions are built and some examples of successful WQT programs.

Background

Market mechanisms have gained much interest and increasing acceptance in environmental circles. Indeed, the case for markets seems to be made at least as much from advocates outside of the discipline as from within. Advocates include consulting firms involved in varying aspects of the environmental trading business, associations representing such businesses, environmental think tanks, legislators, and government agencies (Rock, 2019)

The benefits of markets include potential efficiency gains and innovation incentives. Markets, it seems, can better and more quickly deliver environmental improvements that cost less than other policy instruments.

To date, markets for environmental quality have figured most prominently in fisheries management and air pollution control, and successes in those areas have influenced expectations of what markets can accomplish for other resources. In recent years, attention has turned to markets for water. John Dales (1968) first proposed using markets to protect water quality in 1968, and experimental and demonstration water-quality-trading (WQT) mechanisms were established in the United States in the 1980s. Interest in the United States increased in the mid-1990s as state water-quality authorities explored new mechanisms by which to achieve TMDL levels for pollutants established by EPA. In 2003, EPA announced policies intended to facilitate trading and began providing financial support and technical assistance for WQT.

Mechanism

In water quality trading (WQT), a buyer purchases credits to comply with their water-quality-based permit limits. Credits represent a quantified, verified reduction in pollutant load. Credits might be generated at other permitted facilities or by reducing nonpoint pollutant loading, such as through installation of conservation best management practices (BMPs) on upstream agricultural land (US EPA, 2022). Trades used to meet the limits within a National Pollutant Discharge Elimination System (NPDES) permit are subject to the U.S. EPA trading policy (Willamette Partnership, Forest Trends, & the National Network on Water Quality Trading, 2018).

Credits may also be purchased by non-governmental organizations (NGO) or through corporate social responsibility programs. There are three possible market-based strategies for water quality improvement:

- Nutrient reduction exchange
- Wetland mitigation banking
- Environmental impact bonds

Comparable to a cap and trade program, the nutrient reduction exchange ties downstream municipalities to upstream partners through voluntary efforts. This approach focuses on reducing nitrogen and phosphorus by leveraging cost-effective projects that would be more affordable than removing nutrients at a water treatment plant.

With wetland mitigation banking, flood risks can be minimized by holding and slowing the flow of water—also allowing nutrients and sediment to filter out. In addition, wetlands can provide a natural habitat for birds and waterfowl. The idea behind this approach is to encourage new investments in water quality and flood mitigation by restoring wetlands (Rock, 2019).

Environmental impact bonds have been used recently by major cities to finance infrastructure projects to improve water quality, particularly from stormwater runoff. Washington, D.C. first used this tool in 2016, followed by Baltimore and Atlanta. What makes environmental impact bonds different from other green bonds is that they use a “pay for success” model focused on achieving environmental outcomes, which requires them to have a measuring and monitoring component for investors (Rock, 2019).

Any of these three market-based strategies could play a key role in building a cleaner, healthier, and more productive future.

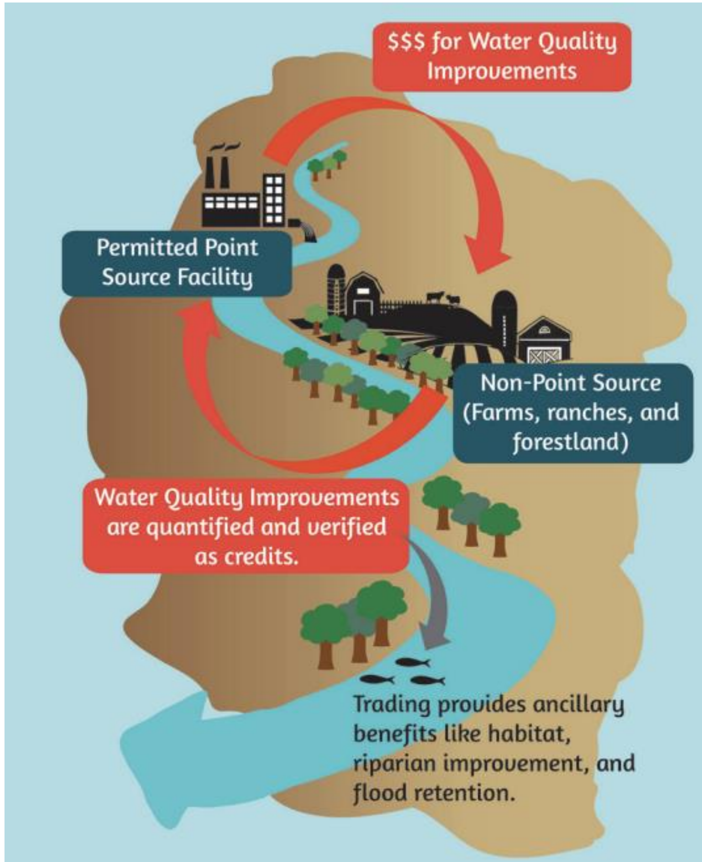


Figure 3: Water Quality Trading in practice. Source: Willamette Partnership, Forest Trends, & the National Network on Water Quality Trading, 2018.

Sample Water Quality Trading Programs

Hunter River Salinity Trading Scheme, Australia

The Hunter River Salinity Trading Scheme in New South Wales, Australia, is an important example of successful methods and of the merits of WQT between point sources and is considered the most successful WQT program in the world. This point-point salinity trading program applies to coal mines and power plants. It was initiated as a pilot in 1995 and was made fully operational in 2002. The New South Wales Office of Environment and Heritage (formerly the Department of Environment, Climate Change, and Water) administers the program under the guidance of an operations committee that includes representatives from the state government, industry, and the community. Monitoring points along the river measure whether the amount of water is low flow, high flow, or flood flow. When the river is in low flow, no discharges are allowed. During high flow, limited discharges are allowed, and they are subject to restrictions based on a licensee's supply of tradable salt credits. An online trading platform was developed for exchanging credits with prices and credit transactions negotiated by buyers and sellers. Assessments indicate that the program has achieved established targets for water quality at a lower cost than the prior regulatory scheme would have and allowed expansion of economic activity that otherwise might not have occurred (Shortle, 2013).

Connecticut Nitrogen Credit Exchange Program, United States

The Connecticut Nitrogen Credit Exchange Program (CNCEP) was established in 2002 to allocate reduced nitrogen loads among 79 wastewater treatment plants that discharged into the Connecticut River. The reductions were required by a TMDL limit that was designed to protect Long Island Sound with the limit to be achieved in 2014. Wastewater plants are annually assigned individual discharge limits to achieve the increasingly stringent cap on nitrogen loads to the sound. Facilities generate credits when they reduce nitrogen discharges below an assigned limit. If a plant fails to meet its limit, it must acquire credits to cover the shortfall. The credit price is set by the Nutrient Credit Advisory Board (NCAB), a body appointed by the state legislature. Buyers and sellers do not interact in the market. At the close of each year, the state environmental agency determines each plant's actual discharges and credits earned or required to be in compliance. The agency also purchases more credits than are needed to achieve the aggregate emission cap. Economic incentives are clearly present in the CNCEP, but the exchange is not truly a marketplace in which buyers and sellers compete. Instead, the exchange essentially involves fixed administrative penalties for undercompliance and payments for overcompliance with effluent standards (Shortle, 2013).

Water quality trading can provide greater flexibility on the timing and level of technology a facility might install, reduce overall compliance costs, and encourage voluntary participation of nonpoint sources within the watershed.

Key issues in Water Quality Trading

How do permittees identify projects that they can implement and claim credits to trade? This is a limitation due to identifying problem locations in land, and concern about taking land out of agriculture production for trading. Projects need to make sure they don’t take land out of agriculture production to help with stabilization (National Resource Conservation Service, 2011).

Another challenge is with matchmaking and how to get the buyers and sellers to trade effectively. Permits will have demand for reductions in very specific locations. If you have a practice that is closer to the water body that needs protection, it will yield many more credits than a practice at a remote location.

Water quality trading can provide greater flexibility on the timing and level of technology a facility might install, reduce overall compliance costs, and encourage voluntary participation of nonpoint sources within the watershed. Nonpoint source projects (e.g., streamside buffers, conservation tillage) installed as part of a water quality trade can provide other environmental benefits, such as reducing carbon emissions, reducing flood potential, stabilizing streambanks and providing wildlife habitat. (National Resource Conservation Service, 2011)

Policy Excerpt 1: Challenges to WQT Programs. Source: Willamette Partnership, World Resources Institute, and the National Network on Water Quality Trading, 2015.

However, moving a WQT program forward can be challenging for several reasons

- The Clean Water Act does not apply evenly to all sources of pollution within a watershed, generating debate about who is responsible for reducing what pollution
- Where watershed science is incomplete, it can be difficult to build an effective, efficient WQT program. It can be more challenging to set clear water quality goals and determine the contribution of individual projects toward those goals
- A successful trading program involves multiple stakeholders who bring different perspectives and vocabularies. The lack of a common vocabulary can hinder communication and development of shared understanding
- Different stakeholders have different tolerances for risk and uncertainty. There needs to be a holistic look at risk management in WQT. If every program design decision is the lowest risk option from an ecological perspective, WQT may not be cost effective. Conversely, if every decision entails ecological risk, WQT may not achieve water quality objectives
- It can be easy to lose sight of the bigger water quality vision when talking about the details of a WQT program, but talking about WQT at a high level without going into detail may limit confidence in a program's ability to succeed; and
- There are no easy ways to share the lessons learned from two decades of experience with new trading programs, so opportunities for reducing start-up costs and effort may be lost.

These challenges can lead to long discussions or disputes around:

- The pollution reductions expected from market participants prior to buying and selling credits (i.e., baseline requirements)
- How to manage uncertain science or other risks (e.g., selecting credit quantification methods or setting the right trading ratio)
- How to engage the public to provide comments and shape how trades will work
- Lack of numeric discharge limits
- High transaction costs
- Regulatory environment with significant costs for noncompliance, which has led permittees to implement risk-averse compliance strategies
- Lack of empirical analysis of existing programs

Incentives for Water Quality in Agriculture

Introduction

This section seeks to outline research and theory behind economic incentives in agricultural water policies, as well as challenges and potential opportunities for future policy implementation. It will provide background in the types of incentives, or economic instruments, and three alternative models by environmental economists including: a tax (subsidy) to penalize (reward) based upon measurements of ambient pollution, a proposed transition from “Pay the Polluter” to “Polluter Pay Principle” (Shortle et al., 2012) and a point-based “Abatement Action Permit System” (Kling, 2011). In addition, we will explore farmer motivations and risk assessments to participation in voluntary programs to promote environmental quality.

Background

Environmental economists have made the case for incentives since the 1960s, but their usage remains mostly theoretical due to policy design flaws and a lack of uptake in the schemes for water quality pollution (Shortle et al., 2012). Shortle et al. claims that these “highly inefficient” policies are responsible for an increasingly lower return on investment of federal funding toward water quality schemes over time. While the CWA regulates point source pollution attributable to wastewater plants and CAFOs at great cost, nonpoint source pollution (NPS)—largely attributed to agricultural nutrient runoff into rivers, wetlands, and other bodies of water—remains largely unregulated and “NPS pollution is by far the greater form of agriculture's water quality impacts” (Shortle et al., 2012). Instead, nonpoint source pollution is governed by state-led voluntary initiatives and federally funded conservation programs that are adjacent or complementary to other conservation initiatives rather than actively achieving targeted goals specific to improving water quality (Shortle et al., 2012).

The USDA has supported soil conservation since the inception of the Natural Resource Conservation Service during the Dust Bowl. But over time, with increasing pressure of climate change and drought conditions creating challenges for farmers, water quality and water conservation issues have taken up a larger share of the federal funds through these programs (Shortle et al., 2012). The USDA programs that financially support best management practices (BMPs) toward conservation initiatives inclusive of water quality include the Environmental Quality Improvement Program (EQIP), the Conservation Reserve Program (CRP), and the Conservation Security Program (CSP). Each of these programs provides a combination of financial and technical assistance for land management but Shortle et al. describes several drawbacks: (1) the programs have multiple goals, so the funding itself is not targeted to water quality; (2) funding for technical assistance has lagged behind financial support; (3) farmer self-interest (e.g. production income) can be at odds with water quality goals associated with the public good (Shortle et al., 2012).

In addition, NPS pollution is notoriously difficult to measure, track, and identify the source due to the physical nature of how nutrients are transported via land and waterways, individual farm and watershed topography, the movement of surface water, and weather patterns - all of this makes policies based on a given farm's water pollution emissions "difficult or impossible to implement" (Kling, 2011). Shortle notes that contributions from individual farms are subject to a large amount of uncertainty, therefore "regulatory cost-savings and overall efficiency will come from targeting subsets of the population of potential polluters that are higher probability sources" (Shortle, 2017).

Uncertainty and Incentives

In 1988, Kathleen Segerson proposed a regulatory scheme that would dictate punishment (tax) or reward (subsidy) based on what was measurable within nonpoint pollution: what she refers to as ambient pollutant level, which is a direct measure of environmental quality. The advantage of this method is it does not require costly individual monitoring of farm emissions or on farm BMPs. Instead, it groups assumed polluters within a given watershed or region, holding them accountable (or rewarding them) together. Her economic incentive scheme is as follows: a regulatory agency sets the water quality standard to be measured against for a given body of water, much like with the current regime of TMDLs. They determine the variable rate of a tax and subsidy level to either a penalty or reward to each farm. The tax or subsidy correlates to the pollutant level detected in the watershed level measurement (Segerson, 1988). Therefore, the higher the level of pollutants detected when measured against the goal, the higher the tax payment. The lower the pollutant level below the standard, the more the reward. This mechanism directly connects *collective* producer actions to the measured environmental impacts on the watershed, either punishing or rewarding a group of farmers as a whole.

An advantage of this tactic is it allows the farm to determine the most appropriate mitigation strategies for their operation at lowest possible cost, enabling them to maintain a sense of ownership over their land management practices while still being held accountable to the environmental outcomes (Segerson, 1988). The costly process of monitoring individual farm emissions and practices can be avoided, and more focus paid to watershed "hot spots" where pollution levels can be measured at critical times, such as after a large rainfall. Segerson (1988) also proposes a short-term cost-share program so that there is no unreasonable financial burden on the sector to comply, as long as it does not operate counter to the financial incentives structure itself.

As with other regulatory devices that must balance individual and public benefits and costs, a challenge to this incentive scheme is how to determine appropriate parameters for the tax (subsidy) level that takes into account the damages incurred by pollution and the cost of abatement strategies that will be deployed by farms (Segerson, 1988). In addition, it does not reward individual farmers who have historically used conservation practices, thus disincentivizing "good" actors in the system and it does not take into account the variability of the farm, for example in proximity to the watershed. With any incentive scheme, farmer buy-in would need to be explored to determine feasibility.

Polluter Pays Principle vs. Pay the Polluter

Like Segerson, Shortle et al. believe there is more success to be had with incentive schemes when monitored at the watershed level, rather than the individual farm level. They contest that paying the polluter "can only attain water quality goals if governments are willing and able to tax citizens or reallocate public funds to purchase sufficient water quality improvements," criticizing the decades-long track record that has not resulted in desirable environmental outcomes (Shortle et al, 2012, p. 1319). Meanwhile, asking the polluter to pay within the paradigm of nonpoint source pollution removes the public's liability from the equation.

They propose an incentive scheme that follows two main criteria: (1) economic incentives that “produce the desired water quality impacts” and (2) promote cost-effectiveness - both for the individual farm and at the watershed level, what he calls “allocative efficiency” - encompassing the practices of multiple farms within a given region, which mimics the regional distribution of polluter accountability (Shortle et al., 2012, p. 1319). Shortle et al. goes on to explain that successful policies are performance-based, meaning they are tied not only to on-farm abatement practices being deployed, but to measurements of environmental stress, what Segerson referred to as ambient pollutant level. Shortle et al. and Segerson are also in agreement about a policy mechanism that allows for flexibility and farmer choice in how to address their emissions based on the individual characteristics, management practices, and topography of their farm. Producers should be targeted individually based on “their ability to address environmental problems” which will promote cost effectiveness at the watershed level, since what is cost-effective at abatement on one farm will not be the same for the farm next door (Shortle et al., 2012, p. 1319).

Acknowledging that the Polluter Pays Principle is a difficult sell in the short term, Shortle et al. proposes some transition schemes that governments can deploy, which include (1) the aforementioned rewarding performance-based payments instead of practice-based payments, (2) more targeted payment mechanisms, and (3) integrating conservation payments with pre-existing commodity program compliance measures. We will examine each one in turn.

A recurring criticism of existing nonpoint source pollution incentive schemes is the reward of best management practices (BMPs), as seen in USDA programs named above that are performance-*related*, rather than tying incentives to explicit, measurable goals that are performance-*based* (Shortle et al., 2012). Taken at face value, it seems obvious that in order to achieve any goal, one needs to identify a goal and metrics, then take steps toward achieving it. But in policy where the public good is sometimes at odds with individual choice, things get more complicated. Shortle et al. explains that states already have TMDL plans, which effectively operate as government-set goals for emission reductions, and account for pollution from both point and nonpoint sources (Shortle et al., 2012). Perhaps this notion can be extended to incorporate current (mostly voluntary) non-point source emissions explicitly?

To more effectively target payments, Shortle et al. describes the advantages of performance subsidies and performance contracts. He defines a performance subsidy as “a payment per unit of improved performance” that is set by the implementing agency, which sets a subsidy rate that farmers can apply for and implement. This again allows for flexibility and individual choice for each farm, and incentivizes greater rewards for practices that provide greater returns on environmental impact with differentiation of each farm's baseline. On the other hand, performance contracts allow farmers to set a price and bid to provide environmental improvements to a watershed on their own terms, while allowing the government to choose a suite of awards within their given budget. Shortle et al. points out that several USDA conservation programs already operate this way, and it avoids the complexity of government-established differential subsidy levels and enables farmers who provide more environmental benefits to receive higher payments (Shortle, et al., 2012).

Another incentive scheme Shortle et al. proposes aims to eliminate perverse incentives by integrating multiple farm programs. They explain "commodity programs [are responsible for] increasing the cost and reducing the effectiveness of conservation and water quality protection programs" (Shortle et al., 2012, p. 1322). They propose that compliance provisions in existing programs, such as production flexibility contracts, disaster assistance, and other USDA conservation programs could be expanded to encompass nutrient runoff and leaching, which would incentivize farmers to adjust their practices accordingly (Claassen et al., 2000). Another idea is to offer "Green Payments" instead of commodity payments, which would provide direct farm income for environmental services that farmers provide and eliminate the conflict between production and watershed protection.

Point-based Abatement Action Permit System

Catherine L. Kling provides yet another model for reducing nonpoint emissions, by identifying proxies for the farm's emissions and creating incentives based upon them. She describes:

> One way these requirements could be operationalized is via a point-based system where conservation practices are assigned a point value based on their effectiveness at reducing emissions from a field. The points associated with each practice could vary by characteristics of the field, location in the watershed, or other variable. Each producer would be required to have an average number of points per acre to satisfy their requirement. (Kling, 2011, p. 301)

Similar to Shortle and Segerson, this model allows for the producer to choose which fields, which conservation practices, and to what extent they will be deployed. This level of flexibility enhances the overall effectiveness of the program by additionally allowing farmers to trade points earned, thus maximizing the lowest cost, most effective abatement actions (Kling, 2011).

She describes how it would work in her 2011 paper *Economic Incentives to Improve Water Quality in Agricultural Landscapes: Some New Variations on Old Ideas*. First, an implementing agency determines how many points are awarded per observable conservation or land use practice, with allowed variability depending on certain characteristics such as slope or soil type. The agency determines the total points per watershed, with the option to assign fewer points to actors with a history of conservation practices, thereby rewarding farmers with historical abatement activities. The enforcement mechanism could be tied to compliance via farm commodity payment programs, as suggested by Shortle and others. Lastly, it will be important for the implementing agency to enable room for flexibility and to reward on-farm innovation as well as continually adaptive measures (Kling, 2011).

So, what about measurement in this model? How can one tell if there is nutrient reduction? For this, Kling describes the use of a new technology called evolutionary algorithms, which can provide an adaptive model that determines the lowest cost intervention for achieving the most reductions (Kling, 2011). And counter to prior authors who focus on measuring change in environmental quality, she posits that continually improved on farm technology, such as remote sensing, will support the ability of farmers to calculate their field emissions and their proxies moving forward (Kling, 2011). Likewise, Shortle describes the option of measuring “performance indicators that are constructed from farm- or field-specific data” that then allow for trading of nutrient credits, which we discuss elsewhere in this report (Shortle et al., 2012).

Farmer Motivation and Barriers to Participation

Above and beyond the structure of incentive schemes themselves, what are the factors that drive farmer participation knowing that their buy-in is fundamental to achieving the policy outcomes? A paper from Beedell and Rehman (2000) out of the United Kingdom suggests that future research needs to involve more than just BMPs or change in environmental quality, expanding to include the role of farmer attitudes and motivational behaviors.

Another U.K. paper from Morris and Potter argues that high enrollment in an environmental program is also not enough, and that “one of the most important, if least tangible, objectives of AEP [agri-environmental programs] schemes should be to bring about a shift in the attitudes of farmers towards countryside management which will outlast the schemes themselves” (1995, p. 61). They suggest that farmers who are more “passively enrolled” in

What are the factors that drive farmer participation knowing that their buy-in is fundamental to achieving the policy outcomes?

programs - those who participate with the least amount of effort to garner the most economic benefit - can be “encouraged through a more imaginative use of advice and training and by learning from those actively engaged to move farmers along the spectrum of engagement” (1995, p. 62). Yet another paper from Ruto and Garrod agreed that there were a large number of farmers who are “low-resistance adopters” who tended to be younger, have more education, more positive attitudes toward the environment when compared to “high resistance adopters” who tended to rely on the farm revenue for more of their household income, and less likely to be landowners (2009, p. 645). Although there are still significant research gaps to determine farmer choice to enroll in incentive schemes, Ruto and Garrod concluded, perhaps intuitively, that “farmers require greater financial incentives to join schemes with longer contract lengths, or that offer less flexibility or higher levels of paperwork” (2009, p. 645).

Another barrier to entry can occur when the landowner is not the one farming the land. “Land tenure systems influence management practices. Farmers without secure land tenure lack incentive to manage soil fertility and salinity with the same care that a long-term landowner would provide” (Wichelns & Oster, 2006, p. 117). The farmer without ownership or long-term interest in the property is less likely to participate in programs that take several years to realize gains. And an owner who does not manage the land themselves may lack the ability or incentive to implement such measures. Programs must decide whether to engage the landowner, property manager, or both, and how to structure a program to best include a range of land tenure arrangements.

Conclusion

In this section we have explored the current challenges of designing policy solutions that effectively mitigate nonpoint source pollution, where collective emissions are not traceable to each source and where public good is potentially at odds with the private welfare of individual farm emitters. Given the incentive schemes described above, an effective economic instrument should:

- Target environmental “hot spots,” as determined by stakeholders of the local watershed, for example where emissions are particularly high or an area is environmentally sensitive.
- Allow sufficient flexibility to equitably reward producers who have historically deployed conservation practices (and not disincentivize “good actors”) and to provide greater ability to fully leverage each farmer’s individual capacity to contribute to water quality improvements in the most cost-effective manner.
- Incentivize toward specific, measurable goals that quantify the environmental impacts at the watershed level, monitoring change and holding collective emitters accountable to reach a given standard reduction.

- There is consensus that measuring progress against BMPs (practice-based) is insufficient to reach water quality goals, however there is potential opportunity to monitor farm-level emissions data as technology improves, and to allow for farms to trade “nutrient credits.”

Shortle concludes that “economic incentives for pollution control are not inherently beneficial - design matters crucially to effectiveness and efficiency” (2017). In some cases, mandates are the most cost-effective strategy, especially for environmentally sensitive locations with significant water quality issues, therefore a mix of incentives and regulatory schemes will be necessary (Shortle, 2017).

Results – State Plan Case Studies

This research focuses on the state of Minnesota, particularly the Minnesota Agriculture Water Quality Certification Program, but also looks at state level policies and programs from around the country that address agricultural water quality. Table 1 below summarizes key findings from research and interviews in ten states, with the intention of showcasing policies and practices that could benefit Arizona. All of the states monitor and list impaired waters in compliance with federal laws, but each state approaches agricultural water quality challenges with unique frameworks, programs, policies, and funds. Below is a brief summary of different ways states work to address agricultural water quality, followed by a table showing which of the ten states use each strategy.

Agricultural water quality certification programs

Water quality certification programs offer a framework to assess and address water quality risks on the farm, which gives public credibility to the work that a producer is doing for environmental benefit. Ideally, certification programs offer layers of support including assessment, technical assistance, cost share funding, and marketing of the certification significance.

Certification endorsements

Some water quality certification programs offer additional endorsements or assessments for different types of practices or environmental impacts. For example, in Minnesota, a producer can add a Wildlife Habitat or Soil Health endorsement to their water quality certification if they implement sufficient qualifying practices. Endorsements serve to further incentivize farmers to consider the broad ecosystem impacts of stacked BMPs.

State funding sources

The most impactful state water quality programs have developed a state funding stream specific to addressing water and related issues. In some cases, this is a designated statewide sales tax, in others there are specific state appropriations for agricultural water quality or conservation programs.

Water quality trading programs

Some states have developed frameworks and programs for water quality trading that can involve nonpoint source trades. This strategy brings in additional funding opportunities for farmers or landowners to implement BMPs to reduce harmful impacts on water quality.

Board to address state water policy

Most states have a board or council appointed by the Governor to address water policy, programs, and allocate funding.

Conservation Districts as active partners

All states have Conservation Districts (some Soil and Water Conservation Districts, some Natural Resource Conservation Districts) that address conservation issues on a county or local level. Each state structures the role and resources of their Conservation Districts differently - some are entirely volunteer-led and run, others have staff and implement state funded cost-share programs and technical assistance.

Department of Agriculture talks about water quality

In most states, agriculture uses the largest percentage of water and contributes the most to water quality impairments. For this reason, it makes sense for state Departments of Agriculture to play a role in addressing water quality and conservation, but there is a wide range of how water is discussed and incorporated in the departments of the ten states we researched.

Active Management Areas

Many states have designated management areas with more regulations around water quality and conservation. There are often more resources designated to achieving water-related goals in these targeted areas.

Watershed plans

Several states have reorganized their water quality planning efforts to focus on watersheds rather than political boundaries such as counties or districts. This allows for more coordinated efforts to address impaired waters more effectively.

Public messaging

Some states have created messaging campaigns to build public awareness and political will in support of clean water.

Table 1: Summary of the practices and policies across ten states. Data sourced from individual case studies outlined in the section below.

State	Cert. Prog.	Endorsements	State Funding	WQT	State Cost-Share	State Board to Address Water Policy	Active SWCDs	Dept. of Ag Discusses Water	Active Management Areas	Watershed Plans	Public Messaging
AZ	No	No	Yes	Pilot	No	Yes	Volunteer	No	Yes	Yes	No
CO	No	Yes	Yes	Pilot	Yes	Yes	Mix	Yes	Yes	Some	Yes
KS	No	No	Yes	Pilot	Yes	Yes	Staff	Yes	Yes	Yes	Yes
MI	Yes	Yes	Yes	Pilot	Yes	No	Staff	Yes	Yes	Yes	Yes
MN	Yes	Yes	Yes	Yes	Yes	Yes	Staff	Yes	Yes	Yes	Yes
MO	No	No	Yes	Yes	Yes	Yes	Staff	Yes	No	Some	No
NE	No	No	Yes	No	Yes	Yes	Staff	Yes	Yes	Yes	No
NM	No	Yes	Yes	No	No	Yes	Mix	Yes	Yes	Yes	Yes
VT	Yes	Yes	Yes	No	Yes	Yes	Staff	Yes	Yes	Yes	Yes

The state case studies below highlight state-level agricultural water quality schemes based on our research and interviews.

Arizona

Arizona, and the western United States, has been in a long-term drought for 27 years. This impacts the availability of water throughout Arizona, which receives most water from Lake Mead from the Colorado River Basin. Lake Mead serves the lower Colorado river state users and is dropping at exponential levels. To combat drought, Arizona has attempted to maintain water quantity within the state. The Groundwater Management Act of 1980 allowed for limiting water use within Active Management Areas

Arizona, and the western United States, has been in a long-term drought for 27 years. This impacts the availability of water throughout Arizona, which receives most water from Lake Mead from the Colorado River Basin.

(AMAs) where agriculture was not permitted to expand past 1980. AMAs currently have programs to maintain water quality and quantity through regulation or voluntary practices implemented on the farm.

It is important to understand that with water quantity issues, there are bound to be water quality issues as well. Arizona does not currently have a nonpoint source (NPS) program within the Arizona Department of Environmental Quality (ADEQ), which is required by federal statute. This exemplifies Arizona's lack of attention to water quality problems within the state, especially relating to agriculture and NPS pollution. Although many say Arizona does not have water quality problems relating to NPS in the state, the Ambient Groundwater Monitoring Program proves this to be incorrect. In addition, there are a number of Arizona water quantity initiatives and some conservation programs and efforts throughout the state, but most do not have any mention of water quality.

AMA History

Arizona devised a long-term management plan for water conservation through the Groundwater Management Code, enacted in 1980. The Groundwater Management Code set up a management framework and established the Arizona Department of Water Resources (ADWR) to administer and enforce the Groundwater Management Code (ADWR, 2021). The goal was to eliminate severe groundwater overdraft in populous regions. There were six main provisions:

1. Establishment of a program of groundwater rights and permits
2. A provision prohibiting irrigation of new agricultural lands within AMAs
3. Preparation every 10 years of a water management plan for each AMA, designed to create a comprehensive system of conservation targets and other water management criteria
4. A framework for requiring developers and water providers to demonstrate a 100-year assured water supply for new growth
5. A requirement to meter/measure water pumped from all non-exempt wells.
6. A program for reporting annual water withdrawal and use

The Groundwater Management Code established AMAs. AMAs are areas within the state with heavy reliance on groundwater and have the highest degree of groundwater regulation within the State. Regulations include a prohibition on new irrigation acres, mandatory water conservation programs and annual water use reporting requirements. AMAs are responsible for administering the 1980 Groundwater Management Code and the enforcement of those requirements within AMAs and Irrigation Non-Expansion Areas (INAs). INAs were created in some rural farming areas to preserve existing irrigation of cultivated lands, but at a lower level of regulation than the AMAs. Management Plans are put forth for every AMA during each Management Period. Currently, all AMAs are in the third Management Period (3MP). Each AMA has a goal to reach, most having to do with reaching a safe yield (except for the Pinal AMA, which is focused on preserving the agricultural economy at present). 82% of Arizona's population is within these AMAs, so it is important to consider water management particularly within the AMAs. The main goals were to reach a safe yield of water within the AMAs by 2025. The safe yield is a long-term balance between groundwater withdrawals and recharge, but since this yield is not specifically quantified this definition leaves room for interpretation from different stakeholders.

The Arizona Water Settlements Act in 2004 established CAP cuts across the Pinal AMA. The issue remains that the DCP has reduced CAP water availability for agriculture, thus an expected increase in groundwater pumping is expected.

The main goals for each AMA can be found below, along with challenges and successes in each.

Table 2: Overview of AMAs and their unique attributes. Data sourced from ADWR, 2022c.

AMA	Management Goal	Challenges	Successes	Importance
Pinal	To allow development of non-irrigation use and to preserve existing agricultural economies for as long as possible, consistent with preserving future water supplies for non-irrigation use	Length of time to preserve agricultural economy not specified, nor are non-irrigation uses defined. 90% of water demand is agriculture based (tribal and non-tribal). Irrigation efficiency could be redundant if double cropping	Irrigation efficiency has been achieved	Second largest AMA by water use. The only unique AMA to preserve agricultural economies. The reduction in farms did not occur as planned or expected.

Santa Cruz	To maintain safe-yield and to prevent local water tables form long term declines (the double goal is due to the unique hydrology within the AMA, surface water and underground water are intertwined)	Aquifers are narrow and shallow, making them more sensitive to precipitation changes and streamflows. Another water demand lies in riparian habitat, providing important ecosystem services. Aquifer capacity is limited. Many general stream adjudications ongoing. No direct access to imported water supplies (natural recharge via Santa Cruz River).	Has reversed decline partially.	Southern border is the US-Mexico border (aquifer in Sonora impacts water conditions in AMA). Water from both sides of the border is treated and will eventually recharge the aquifer. The northern boundary is with Pima County. Groundwater flows out of Santa Cruz into the Tucson AMA (and eventually impacting all AMAs)
Tucson	To reach a safe-yield by 2025	If CO River supplies are cut, it would be difficult to maintain safe-yield in the long term.	Has made progress towards safe-yield, using imported CO River water to offset groundwater pumping.	TAMA is much larger than SCAMA, so it is likely SCAMA would be impacted by the underflow from the TAMA.
Prescott	To reach safe-yield by 2025	Heavily reliant on groundwater and surface water inconsistently available. No imported water		Practical and legal impediments to maintaining a safe yield and importation (i.e. infrastructure

		supplies. Many legal impediments (prior appropriations, adjudications, prior agreements, etc)		would take time and resources that are generally unavailable).
Phoenix	To reach safe-yield by 2025	20% of water supply comes from the CO River, so shortages impact the AMA greatly. Surface water variable depending on drought conditions		Largest AMA in terms of population, square mileage and total water use. ⅓ of annual water supply is in state surface water

No AMA besides the Tucson AMA is expected to reach a safe yield or management goals by 2025. Within the AMAs, there are areas designated as Irrigation Districts. Irrigation Districts are subdivisions that were established as a special taxing district for agricultural improvement or irrigation and conservation. The Irrigation Districts have a service area in which they can receive, pump and distribute water to irrigated land. Currently, there are 59 Irrigation Districts within the AMAs (ADWR, 2022c).

As of 2019, all AMAs were in a state of overdraft besides the Tucson AMA. The Tucson AMA has been in a long-term state of balance but faces many challenges to maintain that balance. Overdraft is a condition in which the volume of groundwater coming out of the aquifer is greater than the volume of recharge going in, over an annual or long-term period. Overdraft is a quantitative measure that is used to assess safe-yield within the AMAs, since safe-yield only relates to groundwater (and only those waters legally defined as groundwater, not underground Colorado River water). This quantitative legal concept is applied at an AMA wide scale, being one way to measure aquifer health, although it does not guarantee levels will remain stable. Continued overdraft can diminish future Assured Water Supply (AWS) determinations (explored in detail below). Deeper water can decrease in water quality, which can create treatment costs and the need to deepen wells. Subsidence can also be an issue if continuing overdraft occurs. This creates potential reduction in surface flows connected to groundwater sources, and possible issues with water availability for wild flora and fauna, or recreational purposes (ADWR, 2022c).

Water Quantity Trading in Arizona

The state of Arizona has four main water supplies and six water regulation regimes.
Four main supplies:

- Colorado River water
- Instate river water
- Ground water
- Recycled water

Colorado river water makes up 40% of Arizona water supply and is governed by the Colorado Compact, which is a multi-state compact and a whole body of federal statutes, national treaties, and other rules and regulations. To trade Colorado River water from one person to another requires approval of the Secretary of the Interior of the United States.

Groundwater, (pumped through wells in the ground) has two different legal regimes and five different designated AMAs: Phoenix, Pinal county, Santa Cruz river basin, Tucson, and Prescott basin. Within those active management areas, groundwater is subject to a cap and trade system, and it is heavily regulated. When Arizona passed the Water Management Act, by agreement there was a prohibition on the development of new irrigated agriculture because of concern for overdrafting groundwater at a huge rate (two and a half million acre feet per year). Arizona has a complex set of rules around the use of groundwater within these active management areas. In those areas, entities like farmers, cities, and irrigation districts can store water in the ground to get credits, and actively trade those credits. This is where Arizona has water markets, within the AMAs.

Outside of the AMAs there is no regulation around the use of groundwater.

Instate surface water rules dictate that the first entity that comes along and diverts water from the stream has the senior right to use that water, and the next person who comes along can get their share only after the first person uses their whole share. This is governed by the legal doctrine of prior appropriation. You cannot simply trade water. If you want to transfer legal rights, you have to follow a process that protects all of the other users in the systems. There is no market for trading under this regime.

Finally, recycled water is water that's treated by a city or an industrial user. It is Colorado River water, in-state river water or groundwater that gets used, and then the particular entity treats the used water for reuse. The rule for the reclaimed water is that the entity that treats the used water can do whatever it wants with it. Arizona does have a market for reclaimed water. For example, if the city of Tempe has reclaimed water, the city can sell it to a buyer or claim credits.

Active Management Plan Limitations

Management Plans are limited in their abilities to move AMAs towards their management goals because often they can be outside the plan's influence. For example, the management plans are limited by the statutory focus on groundwater for conservation. Although management plans only refer to groundwater, water is interconnected. With this in mind, a change in total water use, or in the use of another type of water source, can influence the utilization of groundwater. For example, an increase in surface water availability and use could offset groundwater use, or vice versa. In addition to the water source, transfers of water within the state have the potential to impact goals (ADWR, 2022c).

Another obstacle for AMAs to reach their goals is the allowable pumping under the Groundwater Management Code. A key assumption to the Groundwater Code was that less intensive uses of groundwater would gradually replace agricultural and other intensive uses of groundwater and that renewable supplies would be used to replace or offset groundwater demand. So, the Groundwater Code was created without a concrete plan to develop agricultural land into less water intensive uses (i.e. residential or industrial uses), and this did not allow significant reductions in groundwater withdrawals. Under this assumption, significant groundwater demand was allowed to continue, and certain new demands were also permitted. In many cases, non-irrigation development occurred without anticipated offset of reduced irrigated acreage (development leaned to occur on raw desert land instead of historically agricultural land). This resulted in overall increases in total water use and has allowed the same overall increase in groundwater use.

Interactions with implementation of other water conservation programs is also an obstacle in addressing AMA goals. These management goals can be used or referenced in other regulatory programs but can be interpreted or applied differently for different purposes. To receive an AWS designation, one must be consistent with the management goal within that AMA. The AWS Program operates within the AMAs to maintain the economic health of the area by preserving groundwater resources and promoting long term water supply planning. Even by meeting the criteria laid out in the management goals, overdraft may still occur in the AMA. This reduces physical availability and leads to more challenges for AWS applicants (Safe Yield Report, 2022).

According to the Safe-Yield Report, the last obstacle to overcome to achieve the management goals laid out is the scope of existing authorities under the management plan itself. Arizona is transitioning into a hotter and drier future, which will impact the availability of Colorado River supplies (comprising about 40% of AZ water supplies). In addition, regulations will be more impacted by economic considerations. Economic considerations are often outside the influence of management plans, like markets and incentives. For agriculture specifically, crop prices have a large impact on the amount of land irrigated and the crop type planted, since both impact water use. The conservation potential for the conservation programs already in place may be limited as well, due to the regulated community being unable to pay for those requirements. Since all water supplies are going to be more constrained in the future, management goals will only be met with a combination of augmenting supplies and managing/reducing demand in all sectors. Demand management seems unlikely with current regulatory tools in place, current provisions exist for allowable groundwater mining, increased non-irrigation development and concerns relating to economic viability of regulated communities (Safe Yield Report, 2022).

All AMAs are in the 3rd Management Period (3rd Management Plan implemented in 1999) and currently in process of formulating and adopting 4MP (period: 2010-2020)

- 4MP was delayed due to the 2008 recession
- The AMA Groundwater Users Advisory Council meetings are the forum for public comment
- The provisions of the 4MP will be in effect until the Fifth Management Plan is effective, for the period 2020-2025 (ADWR, n.d.a).

Arizona Agriculture

Arizona has very limited crop production but remains intense in some areas. Yuma, for example, is the leading supplier of winter vegetables across the country. This is due to the lack of frost and availability of sunlight and water throughout the year. Most pollutants from crop production are sediment, pesticides, total dissolved solids (TDS; specifically salinity), selenium, nitrogen and phosphorus. Excess applications of nutrients can result in eutrophication of shallow lakes used for irrigation, as well as wind carrying soil particles from a field to surface waters.

Irrigation is often used to protect against freezing/wilting and supplement natural rainfall. If this is done inefficiently, it can cause water quality problems. Rainwater in wetter states can carry residues from applied chemicals deep into the soil. Excess irrigation can concentrate those residues in the top of the soil. So, irrigation return flows can also contain these concentrated residues. Canals used on farms usually provide water for irrigated crops and a channel for polluted runoff being returned to surface waters.

Ranching in Arizona is common, and grazing can cause water quality problems within the state. More than 1,000 grazing allotments are present on public and tribal land. Livestock are drawn to water and the surrounding riparian habitat in such a hot and dry environment, sometimes a perennial stream is the only source of water nearby. Grazing can create water quality problems by contributing sediment and animal wastes containing nutrients and disease-causing organisms to surface waters. Soil disruption and natural vegetative cover reduction can increase erosion and destabilize stream channels, which can be done by grazing. Currently, the US Forest Service adopted an Adaptive Management Approach, requiring a change in number of grazing animals on the land or BMP implementation before the permit is renewed for grazing. This has been improving some conditions in Arizona (ADEQ, 2014).

In addition to grazing, timber harvesting has impacted water quality. Arizona has harvestable forests all the way from the Colorado Plateau to the Mogollon Plateau. Most of the water quality issues arise from habitat destruction. This can also impact wildfire occurrence and pollution.

The Office of Border Environmental Protection (OBEP) is a branch of the ADEQ Director's Office that focuses on the border region of Arizona and Sonora, Mexico. This is located in Tucson's Southern Regional Office. This area is defined as a 100km buffer zone on either side of the international boundary. The 1983 La Paz Agreement details this border treaty. It is important to consider water quality and regulation will impact not only Arizona within state borders, but surrounding areas within the shared watershed. The Santa Cruz AMA specifically will need international consideration for water management (ADEQ, 2014).

Arizona's Primary Water Quality Problems and Ambient Groundwater Monitoring Program

According to a 20-year study on Water Quality in Arizona by the ADEQ Ambient Groundwater Monitoring program, arsenic was the most common exceedance under the Primary Maximum Contaminant Levels (Primary MCLs) having been found in exceedance in 22% of the 1766 sites tested for water quality. Arsenic occurs when natural geochemical conditions allow for dissolution of arsenic from aquifer materials. Specific to agriculture, irrigation can increase arsenic levels by recharging aquifers and those aquifers encountering sediments present with arsenic. In addition, low rates of natural recharge can increase arsenic levels in groundwater, thus tying together the impacts of water quantity and quality. This occurs from long groundwater residence times, which allows for increased interaction with aquifer sediments and a higher pH. High pH levels promote detachment of arsenic from sediments and, therefore, increase its concentration in groundwater (Towne & Jones, 2016).

Arsenic was the most common exceedance under the Primary Maximum Contaminant Levels, having been found in exceedance in 22% of the 1766 sites tested for water quality.

Most Primary MCL exceedances were found in the Southwestern part of the state, with a frequency of over 50%. This poor groundwater quality is impacted by shallow aquifers, irrigated farming, and older groundwater that tends to have a high pH and sodium chemistry (producing higher levels of arsenic and fluoride present). Yuma is an exception to this pattern because Colorado River water is a source of irrigation. The fresh water flushes the aquifers and groundwater moves out of the basin, with the assistance of drainage wells.

Along with arsenic, nitrate contamination can also occur from agricultural production (specifically the use of fertilizer). Another nonpoint source is from wastewater discharges from failing septic systems. Irrigated farmland is the largest source of nitrate exceedances. There were five tested basins that had nitrate exceedance frequencies higher than 20%: Gila Bend, Harquahala, McMullen Valley, the Rangeras Plain and the Pinal AMA. All of these locations have significant amounts of irrigated cropland. In addition, shallow, domestic wells that are located among these irrigated fields are likely to have high nitrate concentrations. For example, nitrate concentrations are significantly higher in the shallow perched aquifer, which is recharged via irrigation, than six other aquifers tested in the McMullen Valley. In the Gila Bend basin, nitrate is much higher in younger groundwater that was recently recharged than that of older groundwater (Towne & Jones, 2016).

These contaminants exemplify the need for water quality management in Arizona, specifically in areas with agricultural development. Groundwater in Arizona accounts for 43% of annual water use in the state, according to the ADEQ Ambient Groundwater Monitoring program. The Ambient Groundwater Monitoring program is essential to address the gap of characterizing groundwater quality, but this program does not look at tribal lands. ADEQ is not responsible for nonpoint source monitoring and does not regulate agricultural and septic wastewater disposal systems, which tend to be major nonpoint sources of pollution in Arizona's waters. In addition, Arizona uses the CWA as its primary tool to protect and regulate surface waters. The ADEQ Ambient Groundwater Monitoring Program is mostly done by one person over 20 years within a single department, so the data is standardized and can be compared state-wide. The monitoring program fills that data gap and characterizes water quality conditions in the state's groundwater (Towne & Jones, 2016).

The vast majority of the groundwater is used to irrigate crops, as well as for public water supply. Groundwater quality is important to consider because the groundwater discharge creates the base flow for streams, wetlands and lakes in the state. This directly impacts the water quality of surface waters. In particular, agricultural activities have increased the amount of TDS in many waters. TDS will usually refer to salts dissolved in the water. TDS is important to address potable water in the state, considered a Secondary Maximum Contaminant Levels (Secondary MCLs). TDS concentrations occur from a number of natural processes, like mineral dissolution. As groundwater moves downgradient—into low-lying areas—the water chemistry shifts to higher concentrations of sodium, chloride, and sulfate. This results in higher levels of arsenic and fluoride moving downgradient as well. In closed basins, evaporative concentration can cause significant TDS accumulations over time. The use of fertilizers and treated wastewater for irrigation increased concentration of TDS in shallow groundwater. The highest exceedances for TDS are present in Southwestern basins, which are surrounded by extensive irrigated agricultural production. In every sample tested in Gila Bend and Yuma basins, the exceedances of TDS remained above 75%. The lowest TDS levels were found in the Southeastern part of the state.

In Arizona, it is estimated that over 330,000 residents, 5% of the state, use private wells for drinking water. One third of these wells produce water that is contaminated and are often unregulated. Private wells are not subject to EPA's SDWA and are not required to be tested, which is rarely done throughout the state. Analysis is a prohibitive cost for most private well owners, testing for the main constituents (arsenic, fluoride, uranium, gross alpha, nitrates) can cost upwards of $300, while bacteria testing (E. coli) can cost up to $570. Water quality should be considered in all parts of the state, and private well testing should be conducted regularly to maintain healthy communities.

What follows is a list of current government entities dealing with water quality and quantity.

Arizona Water Protection Fund

The Arizona Water Protection Fund (AWPF), along with the Arizona Water Protection Fund Commission, was created in 1994 to provide an annual source of funds for the development and implementation of water quality and water quantity measures, and to maintain, enhance and restore bodies of waters throughout the state, all while being consistent with current water rights and laws. The AWPF Commission is responsible for administering the fund, along with assistance from ADWR (Arizona Water Protection Fund, n.d.).

The AWPF Commission consists of 13 members and is the main policymaking body for the fund. This includes nine voting members that must be residents of Arizona and represent a variety of different stakeholders (i.e. variety of land and water use, as well as socioeconomic perspectives). In addition, there are two non-voting members: the director of ADWR and the commissioner of the Arizona State Land Department. There are also two non-voting advisory members: one from the House of Representatives and another from the Arizona State Senate. The AWPF administration provides technical, legal, and administrative staff to the AWPF Commission, and is managed by its Executive Director. Staff includes ADWR legal counsel and support from ADWR legal division (ADWR, 2021).

To date, 12 AWPF grant projects are being implemented in Arizona. In addition, AWPF has supported 243 projects, awarding close to $48 million toward restoration, protection and enhancement of water and riparian resources in Arizona.

These are the current AWPF grant projects for FY22, including six that have been funded in this grant cycle:

Table 3: Current Arizona Water Protection Fund grants. Data source: ADWR, 2021.

Project	**Purpose**	**Funding Amount**	**Accomplishments**
Gila Valley Irrigation District System Optimization Phase I	To improve Gila Valley Irrigation District's efficiency and available flow at turnouts for on-farm deliveries, increase efficiency of individual irrigators and conserve water downstream	$623,702	
Winkelman Natural Resource Conservation	Create a Tamarisk Management Plan, as well as remove tamarisk from the Gila River and	$205,844	

District Riparian restoration	revegetate the riparian corridor		
Upper, Middle, and Lower Fossil Creek Invasive Plant Removal	Eliminate Russian olive and giant reed and manage tamarisk and Tree of Heaven to 10% of the riparian corridor	$98,662	
Harrenburg Wash Enhancement	Implement stream channel improvements, remove invasive weeds, revegetate area with native species, clean up and removed of debris from the site (previous channel excavations that created head cuts lead to areas of excess flood fill), and the construction of a parking area boundary	$129,190	Work to address the headcuts was completed November 2021, and in December placed wetland plant seed and fabric over the headcuts. In February 2022, seeded some of the upland areas and laid down straw fabric to prevent erosion. In April 2022, wetland seeding completed and cottonwood/willow planted/fenced. This July, there are two weed pull volunteer events at the site
Paria Beach Riparian Restoration	Tamarisk control and native species revegetation along the Colorado River, the purpose is to further inform riparian vegetation in other SW states involving tamarisk removal (impacted by the tamarisk beetle)	$187,699	Prescribed fires took place for tamarisk removal
Fort McDowell Yavapai Nation Lower Verde	To control invasive plant species along the Verde	$237,246	

River Riparian Restoration	River and restoring native vegetation		
Verde River Riparian Restoration (Highway 89A to Bignotti Picnic Site)	To control invasive plants and create landowner outreach to educate and engage people on the threats of invasive riparian plants	$247,350	
Little Green Valley Fen Restoration Feasibility Study	Create a restoration plan for the wet meadow function of the Little Green Valley Fen, and propose a budget for those restoration activities	$77,003	
The Path to Protection at Oak Creek: Social Trail Rehabilitation for Watershed Health	Increased visitation caused soil and erosion and transporters sediment/E.coli into Oak Creek, the project will accomplish a high priority project approved in the Oak Creek Watershed Restoration Action Plan and aims to improve riparian habitat for wildlife and stream water quality	$238,980	
Dye Ranch Erosion Control and Wetland Improvement	To improve habitats along the ephemeral stream and meadow on Dye Ranch, the project aims to reduce erosion, improve water quality and aid in floodplain development (by	$76,945	

	allowing floodwaters to spread out)		
Habitat Restoration in the Gila River Riparian Corridor	To promote nativeplant establishment and survival despite tamarisk decline, shifting focus towards active management of previously treated sites	$97,455	
Ravenna and Pampas Grass Control along the Colorado River from Glen Canyon Dam to Diamond Creek	Mapping and manually removing Ravenna grass and pampas grass from the area	$43,178	

Almost all of these projects are related to habitat restoration of native species. Although the AWPF aims to restore water quality *and* quantity, the quality aspect is not relevant or measured in these projects. Out of 12 projects, only three mention water quality specifically: Gila Valley Irrigation District System Optimization Phase I, The Path to Protection at Oak Creek: Social Trail Rehabilitation for Watershed Health, and the Dye Ranch Control and Wetland Improvement. In addition, the only farm specific project is the Gila Valley Irrigation District System Optimization Phase I Project. Most grants fund invasive species removal, specifically tamarisk (ADWR, 2021).

Tamarisk concentrates salt in its leaves, making the soil saltier and less favorable for native plants. It also grows quickly and in dense stands, overcrowding the area. Tamarisk has a deep tap root, which means it can often outcompete native plants in drought conditions. In addition, tamarisk can change water flow patterns, its stems trap sediment and cause shallower channels and increased flooding. The Brazos River in central Texas is an example of how detrimental tamarisk can be, becoming 8ft shallower and 300ft narrower in about 38 years (1941-1979). It can also create a hurdle for livestock to reach water. Tamarisk is depleting the groundwater supplies, specifically in areas with farm irrigation. Even if the tamarisk removal is successful, the soil remains salty and it can be harder to reestablish native plants. Since tamarisk changes water patterns, quality can be impacted greatly. It is important to consider water quality with quantity projects, especially with dwindling groundwater supplies being impacted by

Crop irrigation is so efficient today that it leaves a lot of salts behind that build up in the root zone.

invasive species (Beitler, 2007). Salinity of the soil is a major problem in Arizona, an example of impacts on water quality and quantity. Some crops can leach salts from the ground, while others actually add to the salt present. When speaking about vegetable production in Yuma, several interviewees mentioned that crop irrigation is so efficient today that it leaves a lot of salts behind that build up in the root zone. This shows how important crop type and irrigation is to reducing water overdraft, in addition to keeping the water quality (Allen, 2019).

Arizona Reconsultation Committee

The Arizona Lower Basin Drought Contingency Plan Steering Committee, known as the 2007 guidelines, was recreated to form the Arizona Reconsultation Committee (ARC). ADWR, along with the Central Arizona Project (CAP) will develop an Arizona consensus on the reconsultation of the Colorado River 2007 Guidelines, which will be renegotiated in 2026. The Drought Contingency Plan (DCP) is being used as a template for ARC. This committee met for the first time in June 2020. The process is expected to take several years to complete (Central Arizona Project, 2022).

As of 2021, Arizona still maintains tier zero status, contributing 192,000 acre-feet of Arizona's 2.8 million acre-foot annual entitlement to Lake Mead. This contribution is solely through the CAP. Recently, shortages for tier 1 reductions were announced. (ADWR, 2021).

Arizona Department of Water Resources

The Arizona Department of Water Resources (ADWR) administers the Arizona water laws, except those that are related to water quality. ADWR also explores augmenting water supplies to meet water demand, as well as develop and implement policies to promote water conservation. ADWR is responsible for jurisdictional dams and reservoirs in the State to protect the public. The primary task of ADWR is to implement and manage the 1980 Groundwater Management Code. This legislation requires ADWR to create a series of five management plans, each unique to that particular AMA. The assumed result of these management plans is to complete each requirement by the end of the management period year. These plans include mandatory conservation requirements for all industries. ADWR is *not* responsible for water quality management, but rather ADEQ enforces these regulations. ADWR supervises and controls jurisdictional dams/reservoirs in Arizona, to protect life and property. The department monitors Colorado River water entitlements in the mainstream region, and water deliveries through the CAP to irrigation districts, agricultural producers, and cities. The Colorado River water is contributed solely through CAP (ADWR, 2021).

The DCP in Arizona is a set of agreements to protect the Colorado River resources through voluntary reductions and increased conservation. These agreements included Mexico, along with multiple states within the US. The ADWR and CAP were participants from Arizona. Within the DCP, there is an Upper Basin DCP (including CO, NM, UT, WY) and the Lower Basin DCP (including AZ, CA, NV). A companion agreement connects these programs and connects to Mexico through a US-Mexico Agreement. The purpose of the agreements are to share risks and opportunities relating to water in the Colorado River basin. For Arizona specifically, the DCP provides greater certainty for reliable and secure water supplies. The current predicted risk of Lake Mead going below 1025' by 2026 with DCP implementation is about 8%. It is assumed that without DCP, there is a 43% chance of Lake Mead going below that level. The DCP Authorization Act was signed in 2019, starting Arizona Colorado River basin reductions in 2020. These agreements will also be renegotiated in 2026.

DCP continues to be implemented across the state with new agreements underway, such as the Colorado River Indian Tribes System Conservation Agreement and the Groundwater and Irrigation Efficiency Fund Agreement. Grants from the Groundwater and Irrigation Efficiency Fund sets the framework for ADWR funding projects, by qualified irrigation districts to construct/rehab wells and related infrastructure for the efficient use of groundwater. The assumption is that these projects are to facilitate the transition from surface water to groundwater. In FY21, ADWR gave over $4 million to four irrigation districts. Without the DCP and other Arizona efforts, Lake Mead would be almost 50ft lower.

Arizona and the CAP have the most to lose from DCP agreements because Arizona has junior priority to the Colorado River supplies. This means its supply will be cut first when reductions occur. The most important aspect of the DCP is that it does not prevent a Colorado River shortage, which is an increasingly prevalent issue in Arizona (with Lake Mead being the Lower Basin's primary reservoir). The goal is to address changing hydrology within the Colorado River.

ADWR is also responsible for representing Arizona in adjudications of surface water rights with tribal nations. These adjudications occur in two main portions of Arizona, the Gila River System and the Little Colorado River System. These adjudications determine the nature, extent and priority of water rights.

Specific to the Colorado River, there is a Colorado River Basin Salinity Control Program that is focused on improving water quality by attempting to reduce salinity levels in the Colorado River. Within the Program, there is a Salinity Control Program Forum and an ADWR representative, appointed by the Governor, represents Arizona in the Forum (along with two other Arizona representatives). The purpose of this interstate program is to provide technical expertise and policy guidance to future and current Salinity Control Programs in order to reduce costs of salinity, specifically from TDS in the Colorado River Basin. This is especially important for main-stem users at the end of the Colorado River, where salts often collect from the head of the River.

Current Arizona Initiatives

The current Arizona water initiative, as determined by Governor Ducey, is the creation of the Governor's Water Augmentation, Innovation and Conservation Council for discussing water problems in the state. Forty-three members were appointed to the council, including a collection of diverse stakeholders and members of the legislature. The goal of the council is to identify and recommend opportunities for water augmentation, innovation or conservation. The most recent conversations were focused around the Desalination Committee that summarized the legal and regulatory limitations to brackish groundwater. In addition, the Non-AMAs Groundwater Committee proposed the establishment of Rural Management Areas (Arizona Governor's Water Augmentation, Innovation, and Conservation Council, 2021).

Within the council there are several programs to note the importance of water conservation and quality:

The **Drought Program** provides resources to the public and committees within the program include the Drought Monitoring Technical Committee, the Interagency Coordinating Group, and the Local Drought Impact Groups. These were all developed through the Arizona Drought Preparedness Plan that was adopted in 2004. Since 1999, a Drought Emergency Declaration has been in effect in the state of Arizona.

The **Conservation Program** offers conservation assistance, outreach and education on conservation resources and regulations. It encourages the efficient use of water through conservation practices. The Program provides water conservation assistance in collaboration with regional and national conservation partners. The most recent publication of the Conservation Program is the Pinal and Santa Cruz AMA Low-Water-Use/Drought Tolerant Plant Lists for the Fourth Management Plans (ADWR, n.d.a).

For rural communities outside of the AMAs, the **Rural Planning Program** provides resources to those communities. The 1999 Rural Watershed Initiative provides technical information, administrative support and advice on water issues. The Rural Planning section carries on this work. The Program collects data and technical studies of specific rural areas in the state. The studies are conducted in collaboration between ADWR and USGS (through contractual agreements). Since 2000, the Arizona Legislature has provided annual funds to ADWR for Rural Water Studies. These funds are generally used to monitor hydrogeologic changes in rural areas.

As mentioned previously, the 1980 Groundwater Management Act may be the single most important piece of legislation to conserve water within AMAs. The AMA section is responsible for administering and enforcing the Groundwater Management Act. Within AMAs, strict regulations were imposed through the Act. These include prohibition on irrigating new acres, mandatory water conservation programs and reporting requirements on water use. Irrigation Non-Expansion Areas (INAs) were established in some rural farming areas to be regulated at a lesser degree than AMAs. In November 2020, Governor Ducey signed an executive order to continue the Agricultural Water Conservation BMP Advisory Committee (which is chaired by a Pinal AMA farmer). This order will allow better stakeholder discussions and development of the Agricultural BMP Program. In early 2019, the State General Fund appropriated $2 million to ADWR through DCP provided grants, known as the Groundwater Conservation grants, to support groundwater conservation and reduce withdrawals within the AMAs. The most money was awarded to the Phoenix AMA ($1,245,000). Tribal water users are not subject to Groundwater Management Act requirements, as well as management plan requirements. They are also not required to submit annual water use reports to ADWR (Governor's Water Augmentation, Innovation, and Conservation Council Annual Report, 2021).

The **Surface Water Program** is through ADWR as well. This Program provides permits, certificates and claims for the use of surface water in Arizona. This is for waters other than mainstem Colorado River basin users.

Governor Ducey recently signed Senate Bill 1740, giving the Water Infrastructure Fund Authority more funding and authority to "empower the state to be proactive in bringing in new water sources" (Hill, 2022; State of Arizona Senate, 2022). Although this is aimed to conserve water, it seems limited to finding new sources rather than conserving present sources of water. The goal is to conserve water for all aspects of the state, including agriculture, but it does not state if the price of water will go up or if there will be additional conservation requirements placed on farmers. Farmers are impacted most dramatically by these shortages in the center of the state, since farmers near the Yuma area have more water availability from the CO River basin.

In addition, ADWR has six main priorities to accomplish:

- Protect the Colorado river system: by implementing AZ Reconsultation Process and by executing DCP implementation plan
- Support general streams adjudication: by completing multiple major technical reports
- Protect life and property of AZ: by helping dam owners address their safety deficiencies, auditing floodplain management plans and responding to requests for flood assistance
- Improve accessibility and accuracy of AZ water data: by advancing data quality initiative by publishing new dashboards online
- Advance water planning priorities: by completing and publishing drafts of 5th Management plans in the AMAs
- Recruit, retain and develop highly skilled personnel: by implementing post-COVID telework, reducing reliance on employee-owned equipment and reclassifying Hydrologist and Water Resources positions
- Support ongoing drought mitigation measures: by collaborating with Drought Mitigation Board to establish policy detailing ADWR's responsibility in supporting the newly formed committee (established 2021)

It is important to note that none of these priorities speak about water quality and the protection of water quality in AMAs (Buschatzke et al., 2022).

According to Arizona Revised Statute (ARS) 45-465, "only land associated with a certificate of Irrigation Grandfathered Right (IGFR) can be legally irrigated with groundwater within an AMA" (ADWR, 2022a). IGFRs are issued by ADWR based on irrigated acreage during 1975-1980. This statute includes calculations for water use. ADWR is also required to develop and administer an Agricultural Conservation Program in each AMA for all management periods. There are three programs in which IGFRs are enrolled (ADWR, 2022a).

Base Program: Each IGFR owner, along with any entitled groundwater user, is regulated under the Base Program. IGFRs are assigned water duties and allotments based on crops grown during the 1975-1980 period. A water duty is the total volume of water needed throughout the season to grow that crop to maturity. ADWR allows for flexibility credit accounts for each IGFR in the Base Program, which allows IGFRs to borrow or bank groundwater in varying climates and market conditions. These credits can be used at any time in the future on the same farm, or it can be used to offset debts. Under specific conditions, IGFRs can transfer, convey or acquire credits to or from other IGFR owners (ADWR, 2022a).

Best Management Practices Program (BMP): The BMP Program is an alternative conservation program to be as effective at water conservation as the Base Program, with more flexibility in achieving these goals. This is a voluntary program that has IGFR owners implement conservation practices that involve irrigation improvements and better water management. Farms that are enrolled do not have their annual conservation allotment and flex credit accounts are frozen. So, instead of a maximum groundwater allotment the IGFR owner will voluntarily commit to implementing said practices. ADWR worked with the agricultural community to develop a list of BMPs within the management plans for each AMA. In doing so, farms can choose which practices to implement to have the best efficiency and water savings. To maintain enrollment in the program, the farm must meet minimum requirements. Once the farm is enrolled, the farm is committed to the BMP program for the remainder of the management plan period (some exceptions may exist, which can be found in each management plan). The BMP program assigns a point value to practices within categories, the farm practices have to add to a total of 12 points across categories to be considered for the program. Practices implemented prior to the application do not count into the point system (ADWR, 2022b).

Historic Cropping Program: This another alternative conservation program and was developed by ADWR. Within the program, accrued flex account credits are limited to 75% of the farm’s annual allotment. A negative balance that exceeds 25% of the annual allotment means a violation of the requirement. Credits gained through the program can be used in the future and to offset debts, but cannot be conveyed, sold or transferred (ADWR, 2022a)

Around 35% of statewide water is under mandatory conservation program requirements in the agricultural sector (ADWR, 2022a).

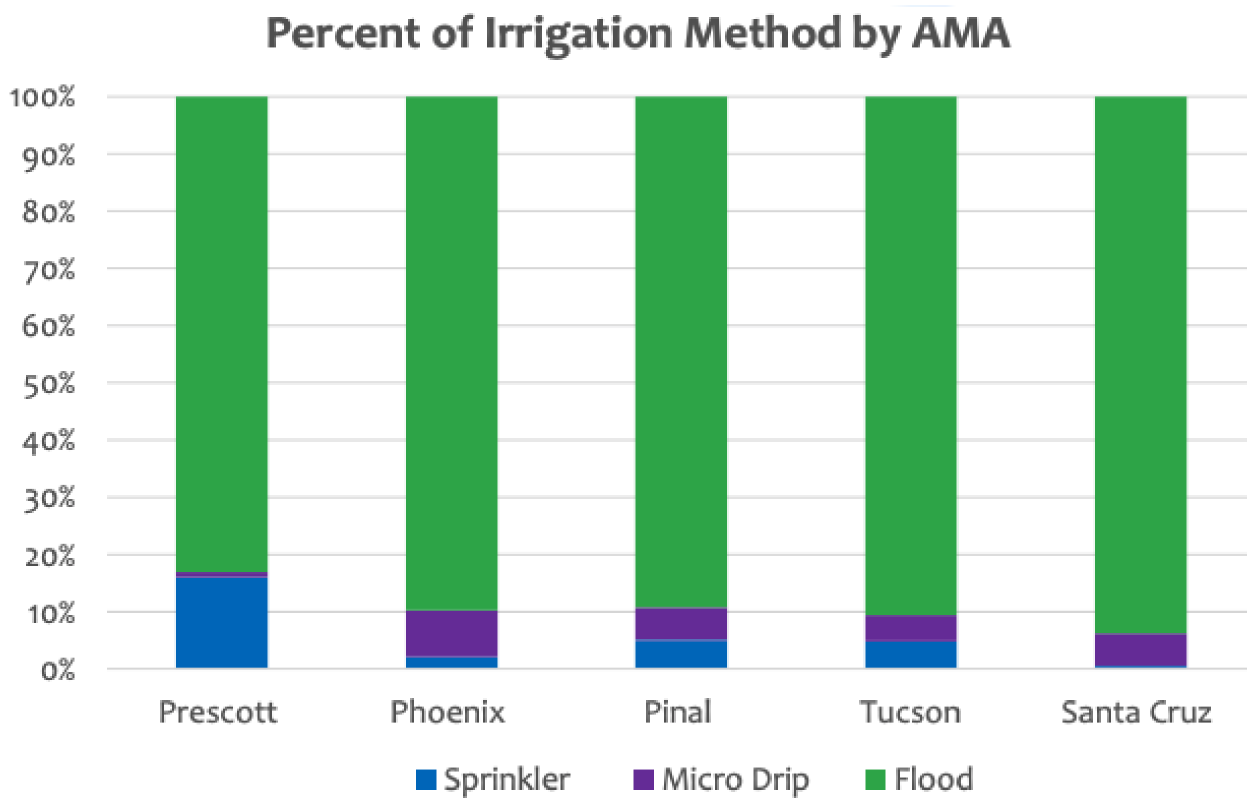


Figure 4: Percent of Irrigation Methods by AMA. Image Source: ADWR, 2020.

In Central Arizona, which includes the Phoenix, Pinal and Tucson AMAs, there are three main water authorities.

Arizona Water Banking Authority (AWBA): Established 1996 to increase the utilization of Colorado River water entitlements and develop long term storage credits for the state. Essentially, AWBA stores water from the Colorado River water for future use in times of shortages (ADWR, 2016b).

Central Arizona Project (CAP): Construction for CAP began in 1973 and was completed in 1993, it is managed and operated by the Central Arizona Water Conservation District (CAWCD). The Colorado River Basin Project Act, implemented in 1968, gave way to the construction of CAP, a 336 mile long system that brings Colorado River water to Central and Southern Arizona. CAP delivers an average of 1.5 million acre feet of Colorado River water per year to Maricopa, Pima and Pinal counties. This is the single largest resource of renewable water supplies in the state (ADWR, 2016b).

Central Arizona Groundwater Replenishment District (CAGRD): Established in 1993 to provide a method of meeting the Assured Water Supply (AWS) requirements for Maricopa, Pima and Pinal counties. Water is stored underground, which will replenish groundwater that is being pumped out. The CAGRD is governed by CAWCD (ADWR, 2016b).

Arizona Department of Environmental Quality

ADEQ manages nonpoint source pollution by creating a management plan every 5 years through the Water Quality Division. The State's Nonpoint Source Management Program was originally developed under the CWA. The research and plan is done through a Performance Partnership Grant with the US EPA. The goal is to identify and prioritize nonpoint source threats and impairments. This is done through the implementation and planning of actions to reduce nonpoint source pollution discharges. In addition, the program will assess state programs, rules and authorities to protect and restore water quality.

Nonpoint sources create most water quality impairments from pollutant loadings present in the water. The most common nonpoint sources in Arizona are:

- Soil erosion caused by stormwater
- Runoff from abandoned mines
- Wastes from pets and livestock
- Road crossings
- Poorly maintained septic systems
- Runoff from impervious surfaces

The current program (2020-2025 period) had changes made to improve water quality in the state. This includes, enhancing technical assistance, direct funding of high priority projects, seeking additional funding for future projects, implementation of a new prioritization strategy, focused monitoring to identify sources, and shifting focus from a watershed scale to specific projects to improve water quality. The ultimate goal is always to delist impaired waters. As projects are identified, they are ranked and prioritized based on their perceived impacts on water quality. These projects can then be implemented in watersheds with an approved 9-Element Watershed Plan by ADEQ capable watershed groups, state agencies and Native American Tribes. The CWA 319 funding is limited in scope and quantity, so staff will seek out more funding, but these will then be identified by internal and external customers. The highest priority projects were focused on metal contamination, followed by E. coli. E. coli is associated with watershed wide activities, like grazing. Metals are much more discrete and can be found in waters from tailing pipes in abandoned mine sites. Due to this, ADEQ approaches E. coli impairments on a watershed-scale to realize delists of waters over the long term. The approach to metal contamination is much more driven by priority project implementation for more short term delists. The overall mission of the NPS Program is to, “To achieve and maintain water quality standards through the reduction of nonpoint source pollutant contributions to Arizona’s surface and groundwater” (ADEQ, 2014). ADEQ does not currently have an active NPS Program, which is required by CWA section 319. In order to receive funds, Arizona will need an NPS Program.

Within the Water Quality Division, there are several programs pertaining to NPS. Standards Development creates standards for water quality and proposes standards to maintain water quality in designated areas. Water quality monitoring programs for both surface water and groundwater exist, as required by ARS 49-225 in the state legislature. These programs include studies completed with other programs, if possible, as well as measuring macroinvertebrates in surface water (which will show impact over a longer period). The water quality monitoring programs also monitor the effectiveness of BMPs. A water quality assessment is done every two years to explain the status of Arizona’s waters (both surface water and groundwater). The Water Quality Division also creates TMDLs for each surface water listed as impaired and watershed planning. There is a water quality improvement grant program to allow watershed partnerships (in addition to landowners, state agencies, local governments, universities, etc) to use resources on projects to quantify a reduction in NPS pollution in Arizona waters. This is funded through CWA section 319. Through this federal legislation, nine-element watershed-based plans (WBPs) are required to be developed prior to funding future projects through CWA 319. In addition, states must provide a 40 percent non-federal match in order to receive federal NPS funds. Since a significant portion of the grantees are individual landowners, nonprofits or federal agencies, this proved extremely difficult. This resulted in a lack of funding for some high priority projects. Previously, the projects aimed at water quality improvement have not been successful. To combat this, ADEQ has shifted to a direct funding of high priority projects, which have a quantifiable reduction proposed before implementation.

ADEQ also issues Aquifer Protection Permits (APPs). APPs are required for anyone owning or operating a facility that discharges a pollutant directly to an aquifer (or the surrounding area) in such a way that the pollutant will likely reach the aquifer. This is mostly found in farming areas (from CAFOs, Nitrogen fertilizer, grazing, wastewater discharges or lagoons).

Within ADEQ, there is a Pesticide Groundwater Quality Protection Program that protects groundwater from NPS pollution. This is done by preventing/eliminating pollution of groundwater aquifers from routine pesticide use. This program evaluates groundwater data and determines pollutants. It also generates the Groundwater Protection List.

ADEQ also serves as the Biosolids/Sewage Sludge Management Program and enforcement authority, which the EPA oversees. This Program implements section 503 of CWA, requiring registration with the department of any person applying, generating or transporting biosolids/sewage sludge within the state.

ADEQ has the authority to establish a Nitrogen Management Area if conditions in nitrogen loading contribute to an exceedance of aquifer water quality standards for nitrate. If surface water becomes impaired by nutrients, ADEQ can investigate whether the standards are being met and if the establishment of a Nitrogen Management Area is necessary.

The Clean Water Act is currently the primary tool for protecting and regulating surface water within Arizona. 89% of surface waters in Arizona are ephemeral streams, meaning they only flow in response to runoff events. Many lakes often dry out and become meadows or mudflats. Due to this, Arizona had to create their own Surface Water Protection Act 2021 to protect the water within the state that may not be included in WOTUS. This is one of the most important surface water protection legislations in the state, with only CWA to protect waters in general. Most of these lakes were created as reservoirs for irrigation purposes, only a handful of these lakes are natural. Many of these lakes are eutrophic, due to being shallow and near farm operations. Ephemeral streams also tend to have more sediment transport, this can occur from human disruption in the environment that increases erosion. In addition, monsoon rains can carry large amounts of sediment and pollutants across the landscape. While surface water may be more available in some areas, groundwater is naturally replenished at slow rates in most places in the state. This can be from lack of rainfall, high evaporation losses and the depth the water needs to travel to actually recharge deep aquifers. Clearly the landscape of the state needs to be considered when implementing a water quality plan. Arizona extends over 114,000 square miles, with mountain ranges that often absorb rainfall before it hits flatlands, and elevation differences across the state (changing the types of plants, animals, and soil present). All of these factors make a single restoration plan difficult (ADEQ, 2014).

Arizona is also home to 21 federally-recognized Native American Nations and tribal reservations. This occupies 28% of the land in the state. Water Quality statutes do not apply to tribal land, but EPA collaboration allows for a development by tribes of their own plan. Currently, most have not integrated with ADEQ programs (Arizona Department of Environmental Quality, 2022).

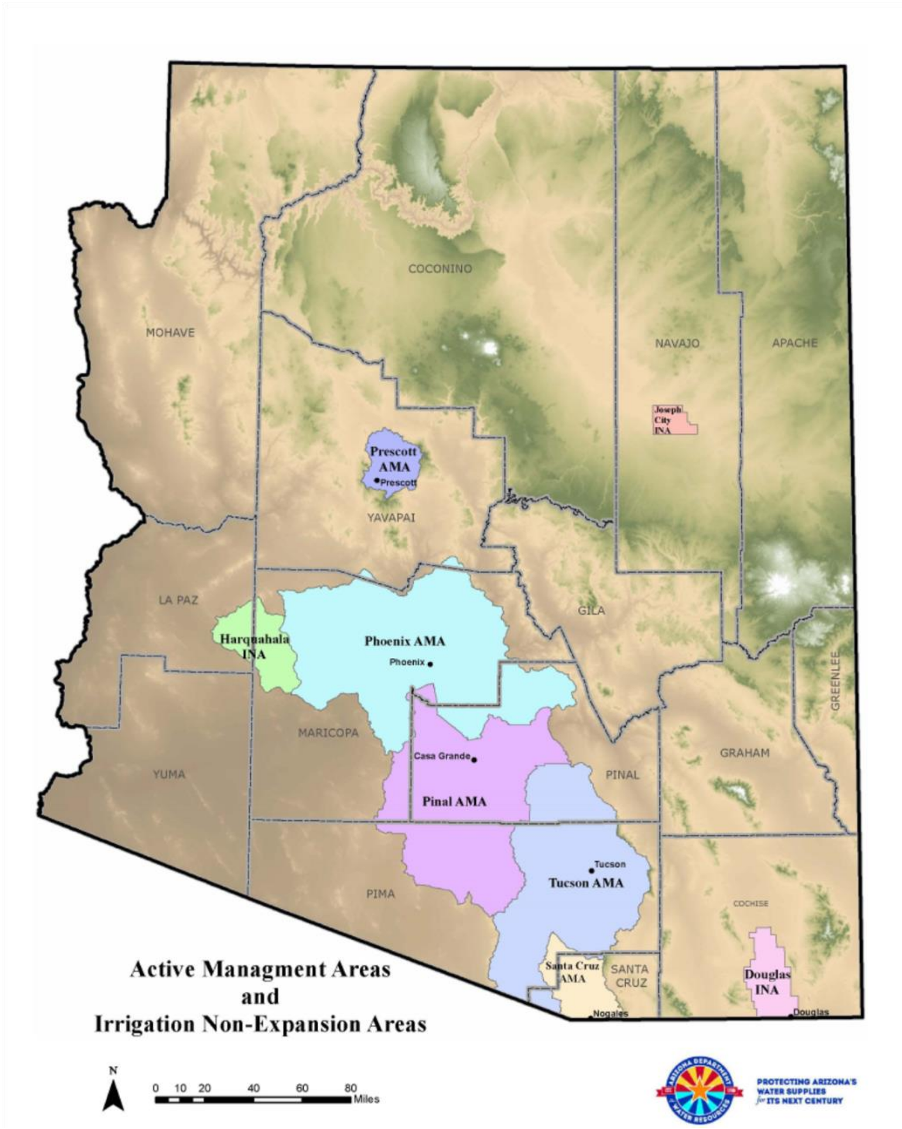


Figure 5: Active Management Areas and Irrigation Non-Expansion Areas

Minnesota

The state of Minnesota has created innovative, extensive, and coordinated water quality programs related to agriculture. This section will give an overview of water quality issues in Minnesota and discuss how the statewide policies and program aim to address current challenges and opportunities for agricultural land to improve water quality.

Minnesota is known for its abundance of surface water - lakes, wetlands, streams, and rivers - and today the state takes great pride in protecting and promoting these assets for recreation, environmental justice, and health. The state has a long history of working to protect its water, using legislation and regulations to address both contamination and conservation. In the late 1800s and early 1900s, it was routine for sewage, garbage, and industrial waste to be dumped directly into rivers and lakes as a means of disposal. In 1885, Minnesota passed its first legislation to prevent pollution in rivers and drinking water. In 1897, the state law first adopted the term public waters and established state authority over these lakes, rivers, and streams that had a use or benefit to people. In the 1930s, severe droughts pushed the state to step up protection of both surface and groundwater, and the state began exercising more permitting authority to protect the amount of water available for public use. In 1945, the Legislature created the Water Pollution Control Commission to encourage communities to build wastewater treatment plants to address unsafe drinking water from raw sewage dumped in lakes and rivers. In 1962, Minnesota experienced two catastrophic oil spills from a pipeline breaking on the Mississippi River and a soy oil storage tank bursting on the Minnesota River. These two oil spills were catastrophic for wildlife and water quality and led to the creation of the Minnesota Pollution Control Agency (MPCA) in 1967, which replaced the Water Pollution Control Commission with increased authority over air pollution and solid waste disposal (Minnesota Pollution Control Agency, 2017b).

As water quality and quantity challenges shifted over time, so did the state's approach to addressing the issues. Over the last 50 years, Minnesota has enacted many programs and policies, relying on strong cooperation among state and local agencies, public and private organizations, as well as individuals, to address the quality of Minnesota's groundwater and surface waters. One of the most important pieces of legislation in recent years is the Clean Water, Land and Legacy Amendment, known as the Legacy Amendment, which was passed by Minnesota voters in 2008. The Legacy Amendment to the Minnesota Constitution increases the state sales tax by three-eighths of one percent to protect drinking water sources, restore natural ecosystems, enhance wildlife habitat, preserve arts and cultural heritage, and support parks and trails. The sales tax began in 2009 and will continue until 2034, with the revenue divided into four funds: 33 percent to the clean water fund, 33 percent to the outdoor heritage fund, 19.75 to the arts and culture fund, and 14.25 percent to the parks and trails fund (Minnesota Legislative Coordinating Commission, n.d.). In particular, the Clean Water Fund is of interest to this research project because it is the primary source of funding for many of the agricultural water quality programs and policies in Minnesota. This dedicated, long-term source of funding has allowed for strategic investment in innovative program design and staffing to support new initiatives.

Minnesota agricultural water quality issues

Minnesota's agricultural industry covers 25.4 million acres, right around 50 percent of the state's land (NASS 2021 State Agriculture Overview, Minnesota). Like most Midwestern states, agriculture is the source of high levels of nutrients from fertilizers and animal waste in Minnesota's waters. Phosphorus is a leading contaminant, along with nitrogen, sediment, and chloride (Water Pollutants and Stressors, MPCA). As agricultural practices have altered the natural landscape through tillage and tile installation, the amount of water moving from fields into streams, rivers, and lakes has increased significantly. Combined with increasing usage of fertilizers, pesticides, herbicides and the concentration of livestock into feeding operations, the negative impact of agriculture on water quality has become extremely difficult to manage.

In Minnesota, there is strong public investment and interest in improving water quality. The public seems to understand that clean water means protecting human health, animal well-being, thriving ecosystems, recreational opportunities, and Minnesota's economy. There is also recognition that, as a headwater state, the burden Minnesota places on surface water sources flows downstream (Why you should care about water quality, MPCA).

Below is a snapshot summary of Minnesota's state agencies, programs, and partners that are involved with agricultural water quality and conservation.

Board of Water and Soil Resources (BWSR) is a 20-member board that acts as the state's administrative agency for 90 Soil and Water Conservation Districts (SWCD), 46 watershed districts, 23 metropolitan watershed management organizations, and 80 county water managers. Board members serve four-year terms and are appointed by the governor to set a policy agenda. Related to agriculture, BWSR's staff administer grants for the Clean Water Fund and other grants, oversee planning and conservation programs, and provide training and technical resources *(*Minnesota Board of Water and Soil Resources, n.d.).

The Buffer Law was a controversial regulatory action passed in 2016 requiring perennial vegetative buffers of up to 50 feet along lakes, rivers and streams, as well as buffers of 16.5 feet along ditches. The purpose of this law is to protect state water resources from erosion and runoff pollution, stabilize soils, shores, and banks, and protect or provide riparian corridors by filtering out phosphorus, nitrogen, and sediment (Minnesota Legislature, 2022). The deadline for implementation for buffers along public waters was November 1, 2017, and for public ditches was November 1, 2018. BWSR, in collaboration with Soil and Water Conservation Districts across the state, oversees compliance with the Buffer Law. As of July 2019, they reported that 98 percent of parcels adjacent to public waterways were in compliance with the law (Minnesota Board of Water and Soil Resources, 2019).

Many stakeholders that we interviewed in Minnesota noted the political challenges and economic impact to farmers of implementing mandatory regulations to address water quality issues. At the same time, additional technical support and financial resources were available to help producers comply with the law. Five years later, it is clear that regulatory strategies continue to be unpopular and unlikely to be used again in the state, however the law has been effective in achieving targeted protections adjacent to water bodies.

Clean Water Council was created through the 2006 Clean Water Legacy Act and is a 28-member council directed to advise the Legislature and the Governor on the administration and implementation of the Clean Water Fund. Members are appointed by the Governor or another appointing authority and serve until another appointment replaces them (Clean Water Council, 2009).

Clean Water & Land Legacy Amendment was passed by voters in 2008 to increase the statewide sales and use tax rate by three-eighths of one percent for 25 years, from 2009 through 2034. Each year, Legacy Amendment dollars are dedicated to four funds: Outdoor Heritage Fund, Clean Water Fund, Parks and Trails Fund, and Arts and Cultural Heritage Fund. Several stakeholders mentioned in interviews the importance of the coalition building across different interest groups that came together to pass the Legacy Amendment.

The Clean Water Fund has been appropriated $256.792 million during fiscal year 2022-2023, divided between seven agencies working on water resources. The largest share goes to BWSR (55 percent), followed by MPCA (16 percent) and MDA (8 percent), among others. These funds support the agencies and partner organizations to address water quality with a wide variety of programs and strategies, including grants to farmers to implement BMPs, technical assistance and training, compliance with regulations, permanent conservation easements, and more (Minnesota Department of Agriculture, 2022). This voter-approved funding source has created ample opportunities for collaborative and innovative approaches towards clean water in Minnesota. We heard from several stakeholders that the visible nature of this taxpayer supported fund creates some additional pressure to communicate the impact of the investments, especially as it gets closer to time to vote on the amendment again in 2034.

Forever Green Initiative (FGI) is run by University of Minnesota's College of Food, Agricultural and Natural Resource Sciences research platform within the Department of Agronomy and Plant Genetics. FGI is working to develop and improve perennial crops and winter-hardy cover crops for Minnesota's climate, that allow soil and water health to be protected through all seasons, while simultaneously creating new economic opportunities (Forever Green Initiative **|** Forever Green, n.d.). Several stakeholders discussed cover crops as integral to their programs or as best practices on their farms and pointed to FGI as an important effort.

Healthy Soils Bill passed the Minnesota Legislature in March of 2022 establishing goals to improve soil health, appropriating money to support improved agricultural practices for soil health and creating a soil health action plan.

Minnesota Department of Agriculture (MDA) administers the Minnesota Agriculture Water Quality Certification Program (MAWQCP), a voluntary certification program for farmers to lead the way in adopting conservation practices on their farm to protect water quality. MAWQCP producers receive regulatory certainty to be deemed in compliance with any new water quality regulations for ten years after certification. MDA works closely with SWCDs to implement the program throughout the state (Minnesota Department of Agriculture, n.d.).

Minnesota Pollution Control Agency (MPCA) is responsible for permitting point source pollution and has been the primary agency working on water quality trading between point source and nonpoint source actors (Minnesota Pollution Control Agency, 2017b).

One Watershed, One Plan is a Minnesota statute passed in 2015, requiring a coordinated and comprehensive management plan for each watershed. BWSR oversees One Watershed, One Plan, and offers grants each year to support planning efforts (Minnesota Board of Water and Soil Resources, 2022).

Soil and Water Conservation Districts exist throughout the country, often operating at the county-level in support of healthy soil, clean water, and natural resource conservation. SWCDs were founded in the 1930s and 40s in response to the Dust Bowl and exist today under a variety of names and structures (National Association of Conservation Districts, 2023).

Tribal nations are important to consider when discussing water quality in Minnesota. There are eleven federally recognized tribes in Minnesota, each with sovereign tribal governments that are responsible for the water quality on tribal land. This research does not include discussion of water quality programs or policies on tribal land due to IRB restrictions.

Additionally, it is important to note that there are many nonprofit organizations working on these issues as well. There are state affiliates of national organizations working on the local level in Minnesota or in the region, as well as local organizations.

Minnesota Agriculture Water Quality Certification Program

The Minnesota Department of Agriculture took a leadership role in developing and implementing a voluntary water quality certification program that incentivizes farmers and agricultural landowners to implement conservation practices to protect water quality. The program began with a Memorandum of Understanding between Minnesota's previous Governor, Mark Dayton, USDA Secretary, Tom Vilsack, and then EPA Administrator, Lisa Jackson, during the Obama Administration. The MOU directed the state of Minnesota to tackle ongoing agricultural water quality issues in a new way, using the tool of regulatory certainty as an incentive for farmers to adopt water quality BMPs and adjust management practices to reduce water quality impairments. Regulatory certainty is a relatively new model that uses the certification process to give farmers and ranchers who voluntarily adopt approved practices a guarantee that their operation will be deemed in compliance with any new water quality regulations that come down during the ten years following certification.

Regulatory certainty is a relatively new model that uses the certification process to give farmers and ranchers who voluntarily adopt approved practices a guarantee that their operation will be deemed in compliance with any new water quality regulations that come down during the ten years following certification.

Brad Jordahl Redlin joined MDA in 2012 to design and launch the program, and he remains the program manager of MAWQCP to this day. From the beginning, stakeholder stakeholder engagement was an important part of the MOU. MDA formed an advisory committee as part of the program to ensure the voices of farmers were at the table as the program was developed. In June of 2014, MDA issued their first certification and in June of 2022, 1,234 producers had been certified representing 890,581 acres enrolled in the certification program (Jordahl Redlin, 2022). While this is a large number of producers and acres, it still only represents about 3.5 percent of agricultural acres in the state.

The MAWCQP is primarily funded through the Clean Water Fund with an annual appropriation of three million dollars. This funds five full-time staff at MDA to operate the program, as well as pass through dollars to SWCD regions. Each region covers 10-12 counties and has funds to hire at least one full-time employee to implement MAWQCP on the ground in their area. Certifiers are trained and housed within SWCDs and are key to working directly with farmers to complete a risk assessment using specialized software to identify land and operations management changes to most significantly reduce the impact of the farm on water quality. The assessment software and process is designed to work for all types of agricultural production, from small specialty crop farmers to large commodity crops to livestock operations. Once a farmer or landowner completes the changes, they can become certified under the program. The program also offers an internal grant of up to $5,000 with a quick application and turnaround to help farmers with the initial cost of new practices to complete their certification process.

MAWCQP uses models to estimate the impact of the BMPs used on certified farmland, and as of June 24, 2022, Brad Jordahl Redlin shared the following numbers. 2,474 new practices adopted to obtain certification, resulting in:

- 42,974 tons of sediment prevented per year
- 124,621 tons of soil loss prevented per year
- 54,061 lbs of Phosphorus loss prevented per year
- Up to 49% reduction in Nitrogen loss per year
- 47,947 (COMET C02-e metric tons per year)

According to surveys of certified farmers, regulatory certainty ranks third in their motivations to participate in the MAWQCP, behind “Demonstrate to others my water ethic” and “Review of my farm management practices.” The vast majority of producers hear about the program from their local Soil & Water Conservation District or NRCS staff (71 percent), followed by a referral from neighbors, family, or friends (16 percent), and media (14 percent). (MAWQCP 1,000 Certified Producers Survey, 2021). Additionally, a study by Minnesota State Agricultural Centers of Excellence shows that MAWQCP certified farms show a 6 percent higher profitability than farms that are not certified under the program. This marks the third year in a row that the study found improved financial outcomes from the practices implemented through this program

(Annual Study Again Confirms Higher Profits for Ag Water Quality Certified Farms, 2022).

An additional component of the certification process is for farmers to add endorsements or additional certification levels based on the impact of specific practices they implement. As of June 2022, the following endorsements had been added to certified farms:

- 69 Soil Health Endorsements
- 56 Integrated Pest Management Endorsements
- 40 Wildlife Endorsements
- 42 Climate Smart Endorsements (recently secured new with grant funding from McKnight Foundation to include a $1,000 grant for 5 consecutive years to support implementing conservation practices and technical assistance to identify best practices for carbon markets in the future under this endorsement)
- 4 Irrigation Endorsements

The endorsements model acts to further give credit and incentive to farmers and landowners who go above the minimum criteria for water quality certification.

Research indicates that this program would be replicable in other states and that the risk assessment framework could be applied to different types of agricultural water issues - water quality, quantity, or other management challenges. The software that has been developed for this program is a critical component and could be adapted to meet the needs of another state. Another important component to replicating this program is the boots on the ground partnerships with trusted relationships in the agricultural field. In Minnesota, the SWCDs fill this role, but this partnership might look different in other states. Additionally, the MAWQCP includes federal, state and local partnerships collaborating to make the program possible, including: Clean Water Land & Legacy Amendment, Minnesota Board of Water and Soil Resource, Minnesota Department of Natural Resources, Minnesota Pollution Control Agency, and the USDA Natural Resources Conservation Service (Minnesota Department of Agriculture, 2022). The final component for replicability is a sufficient and reliable funding source. In Minnesota this comes through the statewide sales tax in the Clean Water, Land & Legacy Amendment, but other states have used federal funds or leveraged private partnerships to address agricultural water quality.

Minnesota water quality trading program

Trading is a permitting exercise, so demand for purchasing credits must be driven by growth. For example, an entity may need to offset part of its pollutant load due to expansion or new regulations on a pollutant. In some cases, it may be more cost effective for the entity to pay a farm to implement practices to reduce their pollution to offset continued pollution from the facility, essentially trading water quality credits within the same watershed to lower overall pollution-control costs.

The Minnesota Pollution Control Agency (MPCA) has led efforts in the state to create pilot programs and systems for water quality trading. Most notably, in 2021 the MPCA worked with MDA and BWSR on a water quality trading pilot project in the North Fork Crow River Watershed (Minnesota Department of Agriculture, Minnesota Pollution Control Agency, and Minnesota Board of Soil and Water Resources, 2021). The group of collaborators released an informative report and recommendations following stakeholder meetings, which includes the need for more clarity on key logistical aspects of water quality trading, more examples of collaborative partnerships coming together and what role each entity plays in the effort, and dedicated resources of staff and tools to manage this and future water quality trading projects (Minnesota Department of Agriculture, 2021). Water quality trading is a flexible tool, so the first step to initiating a trade in Minnesota is to contact the MPCA to discuss the details and possibilities of a trade (Minnesota Pollution Control Agency, 2017a).

Colorado

Every river in Colorado originates within the state. The water is clean coming from the melted snowpack in the mountains, flowing through the major metropolitan areas before reaching rural areas which are impacted by water quality issues. Like other states in the region, 319 funding from EPA has been channeled toward mitigation from mining activities for the past 30 years or so. But in the last 15 years, more funding has gone toward mitigation from agricultural activities with increasing interest in irrigation management practices which saves fertilizer, pesticides, and water. For better or worse, the regional drought has necessitated some of these and other conservation practices, which ultimately impact water quality. Producers who can afford to convert their irrigation methods are doing so now.

The Agricultural Chemical and Groundwater Protection Act was passed in 1990 to create the Groundwater Protection Program. “The goal is to prevent groundwater contamination before it occurs by improving agricultural chemical management” (CDA, 2013). The plan includes three primary functions: regulation, groundwater monitoring, and education and training. The Colorado Department of Agriculture leads the program in collaboration with the Colorado Department of Public Health and Environment (CDPHE) and Colorado State Extension. In addition, CDPHE houses the Colorado Water Quality Control Commission and the Water Quality Control Division which protect ground and surface waters of the state. Regulation 85 was passed in 2012 to support voluntary actions from farmers and ranchers to control nutrients such as nitrogen and phosphorus, ahead of potential regulation in 2022. With the help of extension, Colorado has spent a lot of effort to engage agricultural producers and ranchers around water quality initiatives in the state.

Colorado is currently in an open public comment period to update the Colorado Water Plan for 2023. It is created and managed by the Colorado Water Conservation Board (CWCB) located within the Department of Natural Resources. CWCB funds the program and provides technical assistance for its implementation. This plan builds off the original 2015 framework and is "a grassroots effort, and relies on the Colorado water community to identify and implement basin-specific and/or statewide water projects that provide multiple benefits to the state's diverse water users." (CWCB, 2023) The plan encourages collaboration among stakeholders including 100 specific examples of actions for citizen partners and state agencies, as well as four major action areas including vibrant communities, thriving watersheds, robust agriculture, and resilient planning. It also includes five water plan grant categories that complement existing water quality funding opportunities: conservation and land use, water storage and supply, engagement and innovation, agriculture, watershed health and recreation.

In addition to the state plan, there are eight Basin Implementation Plans (BIPs), tailored for every major river basin in the state: Arkansas, Colorado, North Platte, Rio Grande, Gunnison, Yamp-White-Green, South Platte, and Southwest. These plans were developed in collaboration with a wide range of citizen stakeholders via "basin roundtables" first established in 2005 by the Colorado Water for the 21st Century Act, and reconvened in 2015 to create updated BIPs for 2022.

Kansas

Kansas is an interesting case study because it is divided between humid and arid regions. The Eastern part of the state is humid and primarily cropland, whereas the Western side of the state is arid and more ranchland, which gives rise to very different water challenges throughout the state. In response to severe flooding followed by years of drought, in 1955, Kansas established the Kansas Water Resources Board (KWRB) to address water issues in the state. Their work led to the State Water Plan Act of 1963 which gave statutory authority and guidance for the KWRB to cooperate with other state agencies to create the Kansas Water Plan. In 1989, the State Water Plan Fund was created to fund programs and practices recommended in the State Water Plan (Kansas Water Office). In 2021, nearly 19 million dollars was appropriated to the Kansas Department of Agriculture (KDA), Kansas Water Office (KWO), and Kansas Department of Health and Environment (KDHE) from the Kansas State Water Plan Fund. Each agency plays a distinct role in addressing water issues, and it is evident that the Kansas Water Plan and designated funding creates opportunity for agency collaboration, innovation, and opportunities to leverage additional funding (Kansas State Water Fund Appropriations).

The Kansas Department of Agriculture is home to the Division of Water Resources, which administers 30 laws and responsibilities including the Kansas Water Appropriation Act; regulates the construction of dams, levees and other changes to streams; oversees four interstate river compacts; and coordinates the national flood insurance program. One tool that KDA uses is the designation of a Local Enhanced Management Area (LEMAs) within a Groundwater Management District (GMDs). LEMAs are approved by the chief engineer at KDA to give GMDs the authority to set specific goals and measures to improve water conservation. Another tool at KDA is Water Conservation Areas (WCAs), which create a framework for individual or groups of water right owners to develop plans to reduce water withdrawals, with the aim of extending the life of the Ogallala-High Plains Aquifer. Both of these tools give agricultural producers and landowners a flexible structure to conserve water use over a five-year timeframe without losing their water rights.

The Kansas Department of Health and Environment oversees the Kansas Watershed Restoration Protection Strategy (WRAPS), which offers a comprehensive framework for citizens, farmers, and landowners to engage with watershed management. The WRAPS process involves key stakeholders working together to identify key restoration needs within the watershed, setting goals for protection and restoration, creating an action plan to achieve the goals, and implementing the plans. This program is funded through EPA Section 319 funding and the Kansas Water Plan Fund. Each project is implemented in partnership with a facilitating organization on the ground in the community - some are nonprofit organizations, some are Extension, others are conservation districts - because the state agencies recognize that trusted relationships in agricultural communities are a key to effecting change among farmers and ranchers, who are the largest users of water and contributors to water quality issues. Today, there are 36 WRAPS projects that have completed at least three steps of the process. WRAPS' citizen-led approach creates a sense of ownership over the plans. The plans often take a holistic look at farm management, for instance a plan may start with one practice such as educating and incentivizing farmers to use cover crops on their field, but that one change makes an impact on many aspects of the farm ecosystem and economic resilience.

Finally, the Kansas Water Office (KWO) oversees the Kansas Water Plan and is primarily responsible for water planning, policy, coordination, and marketing. Founded in 1981, KWO is directed by Kansas Statute 74-2608 to collect data and information about

Tensions are high between agricultural practitioners who hold water rights and don't want to lose them, and those who are thinking about the future of the region's water supply.

climate, water, and soil; develop a state plan to manage water resources; develop guidelines for water conservation plans and practices; and establish guidelines for drought conditions. It appears that the KWO is dedicated to strong partnerships throughout the state, hosting regular meetings with 14 Regional Advisory Committees and listing 60 organizations and agencies on the "Our Partners" page of their website. The level of opportunity for citizen engagement is encouraging. In addition to the Kansas Water Plan that gets updated every five years, in 2013 Governor Brownback called for the development of a 50-Year Vision for the Future of Water in Kansas, stating, "Water and the Kansas economy are directly linked. Water is a finite resource and without further planning and action we will no longer be able to meet our state's current needs, let alone growth" (Water Vision, Kansas Water Office). The Water Vision Team, composed of representatives from KWO, KDA, and KWA, worked together to engage stakeholders throughout the state and create a comprehensive and regionally-specific vision and plan. This lofty goal to create a 50-year vision and the coordinated effort to achieve it is an important step in the process towards creating a more sustainable water future.

The Natural Resource Conservation Service and Soil and Water Conservation Districts are key partners for on the ground implementation of best practices and coordinate closely with state agencies to leverage technical expertise and funding from different sources. The NRCS and state agencies shared similar messages in interviews, including that addressing water quality and quantity challenges is directly linked to holistic management for soil health.

While efforts around managing water are well coordinated in Kansas, the Western part of the state still faces serious challenges with the rapid depletion of the Ogallala Aquifer. Tensions are high between agricultural practitioners who hold water rights and don't want to lose them, and those who are thinking about the future of the region's water supply. In an article published in Kansas Reflector in May of 2022, Representative Ron Highland reported from a visit to Garden City, KS, saying, "Several of the farmers that irrigate said, 'I'm going to pump it dry, and then move away.' But … the other side of the coin is those that want to keep something for their grandchildren and great grandchildren" (Kite et al., 2022). In the face of scarcity, this division and resistance to adopting new agricultural practices is similar to Arizona's culture around water.

Michigan

Michigan's Agricultural Environmental Assurance Program (MAEAP) is a voluntary certification program run through the Michigan Department of Agriculture and Rural Department (MDARD). MEAEP was established in 1998, "by a coalition of agricultural, environmental and conservation groups to assist farmers in taking a voluntary, proactive approach to reducing agricultural pollution while keeping their business operations sustainable (MAEAP 2022)." MAEAP was codified into Michigan law by legislation in March of 2011. It receives a combination of state and federal funds. MAEAP originally established three different types of verification programs, for Livestock, Farmstead, and Cropping enterprises, and later added a fourth recognition for Forest, Wetlands & Habitat.

MAEAP verification requires three main components. First, farmers are required to attend a MAEAP educational session. Then, farm operations are evaluated through an on-farm risk assessment, wherein a local technician tours the farm and assesses needs to address the farm's specific environmental impacts, with the recognition that each farm system is unique. After the recommendations from the risk assessment have been implemented, there is a third-party verification into the program, which lasts for five years until a farm must be reverified. The program is free for farmers to participate, and MAEAP verification can lead to access to grants and additional funding opportunities. (MAEAP, 2022)

MAEAP addresses several environmental components, besides water resource use (quantity and quality). It also includes pesticide and fertilizer use, fuel storage, well safety, soil erosion control, and general compliance with environmental laws. While the state of Michigan touts the success of the MAEAP program in several aspects, including reducing phosphorus and nitrate runoff into drinking water, one academic research study disagreed. Stuart, Benveniste, & Harris interviewed Michigan corn farmers regarding their participation in MAEAP and reduction of nutrient runoff. They found that most farmers opted to participate to avoid additional regulation and enforcement, and made few environmental changes. Their study showed little benefit both to Michigan's environmental standards and to the farmers who participated in the program. They cautioned that:

> While proponents of neoliberal approaches claim that MAEAP represents a more cost-effective program that enhances flexibility in achieving environmental goals, replacing government conservation programs with such programs would represent a significant step backwards. Despite pressure to identify low-cost approaches to environmental governance, those involved in efforts to address farm pollution from cropping systems should be aware of the limitations of

> environmental assurance programs like MAEAP. A combination of policy tools, including government incentive programs and regulation, is more likely to result in positive environmental outcomes. (Stuart et al., 2014).

In this study, they found that more regulatory tools were needed, over a simple environmental certification program.

According to one expert interviewed, MAEAP has been successful in recruiting farmers both due to the social recognition aspect and the grants available. Some farmers see the MAEAP certification as a way to show their neighbors that they're taking care of their land and water resources and doing things the right way. This is especially apparent in Southeast Michigan, where high phosphorus loads into Lake Erie have caused high-profile destructive algal blooms. MAEAP has focused on reaching farmers in this Western Lake Erie Priority Area (MAEAP, 2014), with some success. According to a respondent, while the MAEAP standards aren't written explicitly for phosphorus runoff as it would be cost-prohibitive to monitor, the focus has been on reducing tolerable soil loss, according to a model. This approach really focuses on overall soil health as being a predictor of runoff, as the respondent said that "good soil health solves 95% of our problems" including nutrient runoff, erosion, groundwater infiltration, and better rates of aquifer recharge. The MAEAP program remains a model of a statewide environmental certification that has had some successes, particularly compared to the smaller amount of funding.

Missouri

Missouri faces similar water quality challenges to other Midwestern states, where nutrient runoff and soil erosion top the list of water-related challenges in the state. In fact, in the 1980s, Missouri faced some of the worst soil erosion in the country, and the legislature decided to take action. In 1982, Rep. Jerry Burch introduced a bill to divert half of the 1/8 cent sales tax funds for conservation to support soil erosion. After failed attempts to pass this in the Legislature, a Citizens Committee for Soil, Water and State Parks formed to work on passing a new one-tenth-of-one percent sales tax to address soil erosion, water quality, and protect state parks. By bringing together farmers, parks supporters, conservation groups, and concerned citizens, the coalition was able to pass the statewide sales tax as a Constitutional amendment on the ballot in 1984. The tax must be reapproved by voters every ten years, which it has been with overwhelming support for the last 38 years (Missouri Department of Natural Resources, n.d.).

The Parks, Water, and Soil tax is administered by Missouri's Department of Natural Resources, which oversees the Missouri Soil and Water Conservation Program with guidance from the Soil and Water Districts Commission. The Soil and Water

Conservation Program provides administrative support and oversight of Missouri's local Soil and Water Conservation Districts in each county throughout the state. The program primarily uses funds from the sales tax to offer cost-share funding to Missouri farmers to voluntarily implement conservation practices. The Soil and Water Conservation Cost-Share Practices includes 55 different practices and addresses seven resource concerns: Sheet, Rill and Gully Erosion; Grazing Management; Irrigation Management; Animal Waste Management; Nutrient Pest Management; Sensitive Areas; and Woodland Erosion. The most popular practices include adding terraces to sloped land and using cover crops (Soil and Water Conservation Cost-Share Practices | Missouri Department of Natural Resources, n.d.).

Each year the cost-share program matches about $40 million in conservation practices at 75 percent of the standard cost for the area, using a reimbursement model. Soil and Water Conservation District staff are responsible for implementing the cost-share program in each county of the state. Most cost-share practices are only eligible to pay to the landowner, although the use of cover crops, improved pest management, and strategic nutrient management may be implemented and reimbursed to the lessee of cropland.

Missouri clearly has strong public support for soil and water conservation practices and has invested heavily in creating a model to implement conservation practices in support of soil health and water quality on agricultural land. As with most states, Missouri uses modeling to estimate the impact of this investment on the environment and community. Missouri's measurements focus on soil savings, estimating the soil saved over five to ten years depending on the practice, because that was the motivating force behind the sales tax. It is estimated that more than 177 million tons of soil have been saved since the start of the sales tax (Casper, 2016).

It is notable that there are many shared characteristics between Missouri's soil conservation and water quality efforts and the Minnesota Agricultural Water Quality Certification Program. It seems that Missouri farmers and ranchers could benefit from a certification program to earn more public recognition for the soil and water health practices they implement, and it wouldn't be a significant stretch to create from the cost-share program that is already in place.

Nebraska

Nebraska has some of the best water resources in the nation and the world. Groundwater (located beneath the state's surface in porous regions known as aquifers) could cover the state with nearly 40 feet of water if it were all pumped to the surface.

Because groundwater is so plentiful and reliable, 85% of the state's population uses groundwater as drinking water.

The Nebraska Department of Environment and Energy (NDEE) develops water quality standards that designate the beneficial uses to be made of surface waters and the water quality criteria to protect the assigned uses. Title 117 - Nebraska Surface Water Quality Standards form the basis of water quality protection for all surface water quality programs conducted by the department. These standards were revised and approved in 2012. In addition to developing the standards, the Planning Unit develops and implements procedures for applying the standards to surface water quality programs.

Many challenges face Nebraskans when trying to protect this valuable resource. Like many states, runoff from rain and irrigation can carry chemicals and topsoil into streams in both urban and rural areas, causing surface water contamination. More than 50 years of crop production has allowed fertilizers and ag chemicals to reach groundwater in parts of the state, causing contamination.

The following programs are addressed in the Water Quality Division:

Groundwater: The Groundwater programs include the Groundwater Management area Program, Underground Injection Control, Mineral Exploration and Wellhead Protection. The program also issues an annual report to the Legislature concerning groundwater quality in Nebraska and is responsible for hydrogeologic review of various Department programs.

Petroleum Remediation: The Petroleum Remediation Program involves two inter-related program areas: overseeing the investigation and cleanup of petroleum contamination resulting from leaking above-ground and underground storage tanks; and administering financial assistance for persons responsible for investigation and cleanup costs due to petroleum releases from tanks.

Surface Water: The Surface Water Monitoring and Assessment programs collect physical, chemical, and biological water quality samples from streams and lakes, implement surface water improvement projects, and prepare surface water quality reports.

Planning: The Water Quality Planning Unit is involved with multiple programs, including:

- Impaired Waters and Total Maximum Daily Loads
- Nonpoint Source Management Program

- Nonpoint Source Water Quality Grants
- Section 401 Certification
- Source Water Protection Grants

The following are programs in the Water Permits Division:

Agriculture: The Agriculture Section's programs consist of the Livestock Waste Control Program, the Chemigation Program and the Agricultural Chemical Containment Program.

State Revolving Fund (SRF) Section: NDEE, in coordination with the Nebraska Department of Health and Human Services Division of Public Health, distributes funds from two major revolving loan fund programs. These two programs – the Clean Water State Revolving Loan Fund (for wastewater treatment facilities) and the Drinking Water State Revolving Loan Fund. (Nebraska Department of Environment and Energy, 2019)

Wastewater: The Wastewater Section administers the construction permit program for new and modified wastewater treatment facilities and collection systems built in the state.

Permitting: All persons discharging or proposing to discharge pollutants from a point source into any waters of the state are required to apply for and have a permit under the National Pollutant Discharge Elimination System (NPDES) to discharge including all significant industrial users discharging to a publicly owned treatment works. (Nebraska Department of Environment and Energy, n.d.)

New Mexico

The New Mexico Water Quality Act of 1967 gives authority to the state's Water Quality Control Commission (WQCC), whose charge is to adopt standards for the state and direct programs that align with the Clean Water Act. It consists of diverse stakeholders across state government including the Environment Department, Department of Game and Fish, Office of the State Engineer, State Parks Division, Department of Agriculture, Soil and Water Conservation, Health Department, as well as local government agents and citizens, appointed by the governor (Utton Transboundary Resources Center, 2015). The programs are enacted through the New Mexico Environment Department, broken into several subdivisions responsible for varying water quality issues: drinking water, surface water, ground water. In addition to the role of the state government, tribes may have differing standards in New Mexico since they are treated as sovereign nations and operate their own water quality programs when and where they have capacity to do so. Each agency is responsible for having a tribal communications policy to ensure as effective communication as possible with tribal liaisons as water quality and monitoring issues arise that impact sovereign nations.

The New Mexico Surface Water Quality Bureau alone has individual staff positions to do monitoring and assessment against the water quality standards, implement water regulations and permits for point source pollution, and oversee watershed improvement projects (New Mexico Environment Department, 2022). New Mexico is one of two states whose surface water discharge permits go through EPA in the neighboring state of Texas. This is especially applicable for their state dairies along the Rio Grande, which is impaired with E. coli. Their programming is federally funded through 319, and does not have additional state funding to support the work. One of the biggest challenges they face is resource shortage as the fifth largest state, many remote areas to monitor, and not enough staff capacity. Despite this, they are regularly praised for their public outreach and engagement, and the robustness of their program given these constraints. New Mexico's water quality standards for surface water include a section on "Outstanding National Resource Waters" where anyone can nominate a state surface water for designation. The agencies also utilize a public newsletter to communicate about RFAs and project progress across their programming.

Vermont

The state of Vermont has a wet climate with high levels of precipitation - both rain and snow - and fresh water. Vermont's agricultural water quality initiatives have predominantly focused on nutrient runoff, particularly phosphorus and nitrates, into the major waters of Lake Champlain, Lake Memphremagog, and the Connecticut River. (Dickerson & Richter, 2021)

Vermont Clean Water Fund

In 2015, the Vermont legislature passed the Clean Water Act, which created a Clean Water Board and the Clean Water Fund (CWF). The Clean Water Fund, together with substantial federal monies, make up most of the funding for state programs. The Clean Water Fund was initially funded through a 0.2% tax as part of the Vermont Property Transfer Tax on property sales. In 2020, additional tax sources were allocated to the CWF in the form of 6% of the Meals and Rooms Tax revenue, as well as unclaimed beverage container deposits (when cans aren't returned for the deposit). In 2021, the Clean Water Fund had a total of $22 million. Federal funds for clean water initiatives (through USDA, EPA and Federal Highway Administration) totaled around $61 million in

2021. In addition, nearly $225 million in federal American Recovery Plan Act funding will go toward clean water over a three-year period. (Dickerson & Richter, 2021).

Nearly $225 million in federal American Recovery Plan Act funding will go toward clean water over a three-year period.

Agricultural Clean Water Initiative Program (AgCWIP)

One way that Vermont state funds for clean water are distributed to help with agricultural non-point source pollution is through the Agriculture Clean Water Initiative Program (AgCWIP). Individuals and organizations can submit proposals that help both "regulatory compliance and agricultural non-point source pollution reduction" and "economic and environmental viability on Vermont farms". Areas of focus include organizational capacity development, education & outreach, technical assistance, and conservation practice surveys. In 2022, there was a total of $3 million available in grant funding (Vermont Agency of Agriculture, 2021).

Required Agricultural Practices (RAPs)

Also in 2015, the Vermont legislature passed the Required Agricultural Practices Rule for the Agricultural Nonpoint Source Pollution Control Program. This ruling classifies all farms with over $2,000 of income or over 4 acres into one of four categories: Small Farming Operation, Certified Small Farm Operation, Medium Farm Operation, and Large Farm Operation. All farms must be certified annually, and the size of the farm indicates the level of regulation. Aspects of the RAP include required water quality training, nutrient management planning, discharges, soil health, manure and nutrient storage, manure and nutrient application, buffers, mortalities, livestock exclusions, ground water, and farm structures. Financial and technical assistance is available to help farms comply with the RAPs. (Vermont Agency of Agriculture, 2016).

Vermont Environmental Stewardship Program (VESP)

The Vermont Environmental Stewardship Program (VESP) was a pilot program aimed at encouraging a variety of environmentally sound practices amongst different farms. According to one expert we interviewed, the VESP program was conceptualized in 2013 to provide a holistic farm assessment. One motivating factor was that farmer working groups said they wanted a program like this, to provide a farm assessment and social recognition for good environmental practices. Goals included water quality improvements, as well as issues of soil erosion, soil organic matter, air quality, nitrogen loss to air, habitat health, terrestrial and aquatic species protection, and carbon sequestration. An NRCS model for assessing farms was tested to fit Vermont farms and practices. According to the interviewed expert, there were no financial incentives, but interest in the program was still very strong amongst farmers. A dozen farms participated in the pilot program. The program was put on hold and not continued after the initial pilot.

Payment for Ecosystem Services and Soil Health Working Group

In 2019, the Vermont legislature passed an act directing the Agency of Agriculture, Food and Markets to create the Payment for Ecosystem Services and Soil Health Working Group. The group meets twice a month in a public forum (or virtually). The group's purpose is to "implement agricultural practices that improve soil health, enhance crop resilience, increase carbon storage and stormwater storage capacity, and reduce agricultural runoff to waters" (Vermont State Legislature, 2019). They look to find ways to create financial incentives and financial compensation programs so that both farmers and the environment can benefit. The Vermont Pay for Phosphorus Program is related to discussions from this working group.

Vermont Pay for Phosphorus Program (VPFP)

One major concern has been that Vermont's Lake Champlain's phosphorus TMDL was disapproved in 2011, leading to several initiatives focused on Lake Champlain (Dickerson & Richter, 2021). Vermont has historically had a problem with phosphorus runoff, particularly from dairy farms into Lake Champlain, which is surrounded by fertile agricultural land. This has led to toxic algae blooms in Lake Champlain, and widespread water quality issues throughout the region. In 2021, Vermont introduced a new program, the Vermont Pay for Phosphorus Program (VPFP) to address the issue. The program is funded by a $7 million grant from the USDA Natural Resources Conservation Service through the Regional Conservation Partnership Program Alternative Funding Arrangement. The program enrolls farmers that meet the state's required Nutrient Management Plan, and farmers are eligible for $15 per acre enrolled in the program, up to a total of $4,000 per farm. Then, the VPFP measures the farm's base phosphorus load and provides technical assistance for field management practices that can lower phosphorus levels. Upon verifying the data on the farm's phosphorus reductions, farmers are paid $100 per pound of eligible phosphorus reductions per year, up to $50,000. The program aims to provide enough financial incentive to induce farmers to participate. Because the program is in its infancy, there are no reports yet on the success of the program in reducing Vermont phosphorus runoffs. (Vermont Agency of Agriculture, 2022)

Discussion and Recommendations

Coded Responses from Interviews

Table 4 below summarizes the population of the interviewees. Each person interviewed fell into one or two of the listed working categories (government, non-profit, academia, farmer or a private business), **thus the total people is less than the sum of the categories of actors**. These are totaled per state and per working group. Most responses were from governmental employees and came from Arizona or Minnesota.

Table 4: Coded Responses from Interviews

State	Government	Non-Profit	Academia	Farmer	Private Business	Total
Arizona	7	3	3	1	2	16
Colorado			1			1
Kansas	2					2
Michigan	1	2				3
Minnesota	9	3		2		12
Missouri	1					1
New Mexico	3					3
Pennsylvania			1			1
Utah	1	2			1	2
Vermont	3					3
Total	27	10	5	3	3	44

When respondents were asked about the main problems with current water quality programs, most relayed that funding was an issue and most of these programs were state initiatives. Interviewees were asked about changes they may make to current water quality programs. One suggestion that came up many times was the lack of funding sources. There are several federal initiatives, like the CWA 319 funds, that can cover some costs depending on what is implemented, but there is not enough funding to

For a water quality program to be successful, the farmers' needs must be met and maintained. This could be in the form of a single program for water quality, in order to reduce paperwork, or more funding opportunities to reward implementation of water quality enhancing practices.

follow up after these practices are implemented or outreach for the program does not exist. For example, there is no funding for promotion staff within AZDA. In addition, lack of staffing can create delays in labs and testing in the field. Most funding for these water quality programs comes from federal CWA funds, which can limit the amount and type of work done.

In almost all the interviews, respondents had changes they wanted to make to current programs. Some water quality programs have motivated farmers to have discussions about soil health and water quality; in Arizona, most do not concern themselves with water quality, but rather with water quantity. Soil health factors can contribute to poor water quality and improving the soil can be a step forward to improve water quality, as well as quantity. A significant number of responses had to do with nutrient impairment programs, like preventing nitrogen and phosphorus runoff from creating eutrophic waters. These respondents tended to be from midwestern states, especially those in Minnesota. Arizona respondents tended to speak more about salinity than nutrient impairment in waters and soil.

One issue that came up many times was efficiency with time and money, while also being equitable to farmers. This is a complicated issue that needs to be addressed through state programs. For a water quality program to be successful, the farmers' needs must be met and maintained. This could be in the form of a single program for water quality, in order to reduce paperwork, or more funding opportunities to reward implementation of water quality enhancing practices.

Local solutions are key to understanding issues present in each area within Arizona, especially considering cultural and hydrologic differences across the state. It was mentioned by several people that programs could be more successful if driven by a single issue, like sediment or salinity, but not by addressing both in the same program. Minnesota's program uses a risk assessment that differs per field, allowing for this localized approach, which could be useful in Arizona.

Difficulty in measuring outcomes is a major hurdle for water quality programs. The programs discussed with interviewees showed modeling is the most dominant way to advise policy forward on quality issues. In Arizona, barely any monitoring or testing is done, but there is software used to evaluate impaired waters. Overall, there is a need for more communication with the public, educating not only on water quality issues, but also how government policies are created and implemented.

Discussions about key stakeholders also came up in interviews. Most responded with universities, agricultural departments in the state, and nonprofits. Some mentioned the need for farmers' presence in these conversations. There is a lack of communication across government agencies, especially in Arizona. Many interviewees confirmed this and suggested this change in order to combat water quality issues better.

Questions about best practices for desert agriculture were asked to those relating to this work. Several practices are currently used by Arizona farmers that result in better soil health and, in turn, hopefully cleaner water. Flood irrigation is the dominant type of irrigation used in Arizona, specifically in Yuma. This is done to alleviate salts found in the top layer of the soil, by forcing them lower into the ground. Since Yuma laser cuts fields for a flatter landscape, this is more efficient than flood irrigation in other areas by allowing an even distribution of water across the entire field. In addition, farmers have a focus on soil health, to improve moisture in the soil and therefore yields. Due to the continued water shortage, universities and research labs will be forced to consider better technology for agriculture. In addition, it is important to consider Yuma farms differently than central Arizona. In Yuma, specialty crops are grown that are sold for a significant amount of money (especially compared to cotton or dairy). This allows farmers to experiment more with different technologies that may be expensive. For example, farmers in Yuma often use furrow packing wheeled tractors to increase efficiency of water to crops on the field, as water cannot readily infiltrate within the furrow from soil compaction. In addition, since agriculture has been so successful and productive in Yuma, it is unlikely agriculture will cease to exist with water shortages. Yuma has available labor, water and a frost-free growing season.

When speaking about equity in water quality programs, funding was a common theme that came up. Almost all interviewees admitted that equity is not really accounted for in these programs, although some conversations among government employees have come up. It is important to understand what the issue is and who it is impacting the most. Overall, more needs to be done to include unheard voices in these conversations, especially with the dramatic impact climate change is having on these communities. More access to funding and outreach could improve the equity conversation in Arizona.

In research interviews, respondents' suggestions for improving state water quality were categorized into three main topics: improve, reinvent, and end. Improvements included recommendations for changing specific farming practices, policies, regulations, and programs to improve agricultural water quality. Improvements will be discussed below in the framework of a proposed voluntary water quality initiative as the best option. Respondents' calls to reinvent and innovate new farming practices called into question the current agricultural system and seek to change the landscape of Arizona farming as we know it. Finally, some respondents called for the need to end specific agricultural practices or crops in areas of Arizona, as being entirely unsustainable. Each of these three categories of recommendations is discussed below.

Improve Agricultural Water Quality

Several specific recommendations are provided below for improving agricultural water quality within the existing agricultural system. In particular, a program must be developed with public engagement within the relevant cultural context. Government agency involvement must be coordinated to expand existing capacities and funding mechanisms. A program must take into account tribal representation and interagency coordination. Practices must be encouraged that build overall soil health as both a water quantity and quality strategy. A holistic approach is necessary that takes into account technical assistance and cultural shifts. And finally, programs must be developed in a manner that supports specific targeted outcomes.

1. Public engagement and awareness building

A recurring theme in the development of successful water quality initiatives in several states was public engagement, both of the general public and of farmers specifically. This can be either grassroots engagement or via specific government entities. In Arizona, the lack of general public engagement around agricultural water will require targeted outreach and peer-to-peer learning at watershed levels.

Public awareness around water quality was cited by several respondents as an important motivator behind the development of government programs. General public engagement was the driving force behind the Minnesota Clean Water, Land, and Legacy Amendment, a constitutional amendment that created a sales tax specifically for clean water, which then led to agriculture-specific initiatives. In Minnesota, respondents described a coalition of hunters, fishers, hikers, farmers, local governments, and metropolitan communities that worked together to pass the amendment. In Michigan, respondents described environmentalists, tourist business owners, and lakefront property owners coming together to increase the visibility of water quality issues, such as lake algal blooms. In Vermont, public awareness was spread through news articles around the environmental damage of phosphorus overload of Lake Champlain. In Missouri, the impact of soil erosion on water quality drove citizens to take collective action on the issue of water quality and soil health. In Utah, environmentalists have expressly educated the public on issues of water contamination from tar sands. In each of these cases, pre-existing public awareness is helping to spur water quality initiatives.

In Arizona, there is a lack of public engagement around non-point source pollution in general and a lack of public knowledge around agricultural water specifically. None of our Arizona interviewees referenced widespread public knowledge, but instead more specific issues relevant to them as a water stakeholder. For example, Yuma farmers are very concerned about E. coli levels in incoming irrigation water. Environmentalists expressed concern about the effects of salinity in drought conditions, where evaporation in reservoirs like Lake Mead and Lake Powell increase the water's salt content. Anglers are concerned about water contamination of previous upstream uranium mining. However, none of these issues currently has widespread public traction to build a political base for encouraging government action around water quality.

Public awareness can also be encouraged by specific government entities or nonprofit organizations through public groups or forums, several of which were described by interviewees and discovered through our research. For example, the Babbitt Center for Land and Water Policy serves as a boundary-spanning organization that coordinates Colorado River stakeholder meetings. The Moab Area Watershed Partnership in Utah is another successful group that has brought together different actors into ongoing water discussions and set policy priorities. The Georgia State Water Plan created Regional Water Planning Councils, watershed-level management groups which convenes a diverse group of stakeholders and voices to recommend watershed management practices. In states such as Kansas, the local NRCS coordinates water stakeholder meetings. In Minnesota, the Clean Water Council brings together a group of different stakeholders. In Vermont, the Payment for Ecosystem Services and Soil Health Working Group brings together voices around encouraging and supporting positive environmental practices through payment programs. In Colorado, individual groups representing citizens living in and around the nine river basins convene in Colorado Basin Roundtable events to develop a plan to preserve and protect their specific watershed. Each of these initiatives helps foster public engagement and awareness of water issues and programs.

For farmer-specific water quality engagement, respondents recommended building relationships through established trusted networks and peer-to-peer learning. The Vermont Agency of Agriculture funds self-organized farmer watershed groups that meet monthly to discuss issues. Where these are not self-organized, awareness and engagement is best through existing networks. In Michigan, it was described how participating farmers in the Michigan Agricultural Environmental Assurance Program

(MAEAP) program put out signs and started talking and encouraging their neighbors to join, to show the public that farmers were responsible land stewards working towards clean water. One farmer participating in the Minnesota Agricultural Water Quality Certification Program described how before participating, he learned about the program through a variety of farmer groups and trade organizations before deciding to participate. In Colorado, CSU Extension played a key role in doing outreach to farmers within their existing network to build awareness of the government water quality programming, collaborating closely with the Department of Agriculture and the Department of Public Health and Environment. Repeated targeted outreach through trusted networks is therefore very important. Arizona lacks promotion staff within AZDA, which is important to establishing public awareness and outreach within the department. Funding for a promotion section in AZDA seems crucial in creating a water quality program within the AZDA structure.

For Arizona, we would recommend that any proposed program be first built with farmers' input, and that repeated outreach be done through trusted farmer partners. Farmer water quality working groups could be convened at a regional level through conservation districts and the partnerships described below. From interviewees' responses, farmer trade organizations and cooperatives from a diverse array of sectors should be included in such discussions, such as the Arizona Cattlemen's Association, United Dairymen of Arizona, Agribusiness and Water Council of Arizona, Arizona Association of Conservation Districts, Yuma Fresh Vegetable Association, grain cooperatives, and the Organic Farmers Association. These organizations have more capacity than individual farmers to engage with new initiatives, and a broad range of experience and knowledge. If they have buy-in and support the initiatives, they have the network to reach their farm members through existing relationships and communication channels. These water quality working groups would include a variety of agricultural stakeholders and seek to both learn from farmers to inform the programs, as well as disseminate information and encourage participation.

2. Voluntary Initiatives

Our research has led us to recommend a voluntary initiative when crafting new water quality initiatives for Arizona. One interviewee described how regulations are necessary to keep everyone above a certain very low threshold. But above that, voluntary participation can often be more meaningful and effective. This is particularly true given that basic regulations already exist that prevent or address the most egregious water quality violations, particularly for point source pollution. For example, programs already exist to certify Arizona CAFOs and regulate manure storage, disposal, and runoff. Programs exist to test for E. coli in surface water irrigation. The Pesticide Safety Trainer

Program prevents farmers from introducing pesticides into water. While pesticide runoff in water is not currently adequately tested, current results show that the regulations are working. What is needed is less a one-size fits all regulatory approach, and instead a more nuanced, whole systems approach for encouraging farming practices that improve water quality through a focus on soil health, as discussed in the upcoming section.

The other main reason for a voluntary initiative is a lack of current political willpower in Arizona to pass regulatory changes. In 2021, Governor Doug Ducey signed the Arizona Surface Water Protection Program, to regulate surface water that does not fall under federal jurisdiction. While this is a very important step in giving Arizona DEQ the authority for regulating surface water quality, one respondent worried whether DEQ would be given the funding, testing capacity and the political will to adequately follow through. In addition, the current hands-off approach of Arizona's legislature to environmental concerns makes it unlikely that stricter regulations will follow. For example, one interviewee referenced that as long as Arizona Representative Gail Griffin remains Chair of the House Natural Resources, Energy, and Water Committee, she has expressed that she will not allow any legislation increasing state regulation of groundwater, or allowing municipalities increased control over groundwater quality, out of the committee. Politically, it is always difficult to target farmers with additional regulation since farmers are recognized for their necessity in feeding the population. With minimal profit margins in many agricultural sectors nationwide, it becomes difficult for farmers to comply with costly state regulations.

3. Government agency coordination

In developing a voluntary state water initiative, the question arises of agency control and interagency coordination. In other states, such agricultural water quality programs are generally under the state Department of Agriculture or similar state agricultural division, even while water is generally regulated through a Department of Environment and Natural Resources, or similar division. A few interviewees mentioned farmers have a more trusted, existing relationship with the Department of Agriculture, which is an important reason why successful programs originate with that department. However, the Arizona Department of Agriculture (AZDA) does not have a history of working with farmers around water issues, beyond a few specific programs. While AZDA officials expressed a willingness to partner with other agencies around water initiatives, there was not a desire to create agriculture-focused water quality initiatives through the department, and participants expressed that water was beyond the scope of the department's purview. Therefore, we recommend that a voluntary water certification program be housed in the Arizona Department of Environmental Quality, which already works around agricultural water usage and water quality.

For a strong and successful program, it would be necessary for ADEQ to build strong interagency partnerships with other government agencies and trusted resources. Representatives from the Department of Agriculture should be included on a steering committee, as should NRCS and conservation districts. In states with established agricultural water quality programs, interviewees talked about having worked cross-agency for decades and having long-established interagency relationships. In Arizona interviews, there were few references to existing interagency cooperation. While some officials have a passing knowledge of other state employees, there were large gaps in knowing what agricultural water issues organizations and agencies were currently working on. Therefore, there is a long way to go in establishing those interagency relationships, but no better time than the present. The program should include regular, monthly meetings with different departments to coordinate programing, in addition to regular monthly meetings with farmers and farm organizations for feedback and outreach.

It is worth noting that any new state program would not directly apply to tribal lands, but could benefit from consultation with tribal representatives to determine partnerships and joint capacity building. Tribal water regulations and programs lay outside the scope of our research, and are a notable gap in this research that should be further explored.

4. Soil health as a water quantity and quality strategy

Throughout interviews across several states, as well as in our literature review, there were many references to a strong relationship between soil health, water conservation, and water quality. Many BMPs for water management are rooted in improving the soil's organic matter, structure, and biological activity. As soil health improves through the adoption of practices such as no-till farming, year-round cover through cover crop use, and others, the resilience of a farm and surrounding ecosystem improves. When asked about best practices for water quality, seven interviewees highlighted soil health as a key aspect of improving the relationship between agriculture and water.

One interviewee relayed that while their agricultural water quality programs may start with supporting producers to change a few practices, they often lead to changing a whole farm management system to better protect soil health and water quality. For instance, a farmer may implement cover crop use, which enables them to move towards rotational grazing of livestock and pull cattle out of riparian areas. Another example was planting a fall cover crop, which leads to longer forage availability through the season, which allows a farmer to keep cattle off of a feedlot for a few more months reducing concentrated waste concerns. The short-term investment in cover crops and portable fencing through a water quality program pays off in a long-term farm management strategy that supports healthy soil and in turn, improves water quality and ecosystem health.

In Arizona, improved soil health can reduce the quantity of water needed to sufficiently irrigate crops by building soil structure that more effectively retains water, whether from minimal rain or from irrigation. While soil health strategies will look different in Arizona than they do in Minnesota and other humid states, the same principles apply. Keeping soil covered as much as possible, minimizing disturbance of the soil, maximizing biodiversity, and enhancing the presence of living roots will be a critical strategy for Arizona's farm and ranchland to persist in a changing climate (NRCS Soil Health) with less water available. The goal of water conservation certainly outweighs concern over water quality in Arizona, but focusing on soil health would allow one program to address both issues.

5. Holistic approach including cost share, TA, culture shift

Several stakeholders discussed that solely providing cost-share funding to implement BMPs for agricultural water quality concerns is not sufficient to encourage widespread adoption. The most successful programs outlined in this report take a holistic approach including risk assessment, cost-share funding to implement practices, technical assistance and training to understand why and how to implement BMPs, and coaching or mentoring from trusted sources. The financial incentive is critical to encourage adoption of practices that may impact the bottom line of a farm business initially. However, stakeholders from many states talked about training and technical support as equally important to help farmers transition to new ways of managing their land.

Another theme across many states is that farmers and ranchers are most likely to adopt new practices or technologies if it is recommended to them by a neighbor, relative, or respected resource in their community. They are unlikely to make changes based on a government agency telling them they should or must do something differently. At this time, very few states have the political will to regulate changes in agricultural practices, so the power of strong local relationships is critical to the success of voluntary programs.

As Arizona works with farmers and ranchers to address water concerns, the right partners must be in place on the ground to help deliver messages and support implementation. In many states, conservation districts or extension fills this role, often in close collaboration with state agencies. Over Arizona's diverse agricultural landscape, different types of partners may be more effective at achieving a culture shift towards adopting water quality practices. Whether the partner is a Natural Resource Conservation District, an extension office, an agricultural association, or other type of organization, a program must provide adequate funding for the partner to hire local staff to implement the program. These staff should be able to provide comprehensive risk assessment, technical assistance, facilitate education and networking opportunities, and distribute cost-share funding to farmers to implement approved practices.

6. Ensure that funding supports targeted outcomes

Even within existing agricultural water quality initiatives, both the literature review and interviews revealed that the measurable environmental impacts of these programs were unclear. While farmer engagement has been critical in adjusting production practices to implement more BMPs, some interviewees spoke to the tension between measuring short term indicators like these versus the ultimate desirable outcomes of improved environmental quality within the watersheds. In Arizona, one interviewee stated that measuring BMPs has not resulted in an improvement in water quality to date. The structure of many voluntary programs prevents innovation and farm-level cost effectiveness, therefore many producers are incentivized to perpetuate the same practices with unclear or nominal results, instead of focusing on continuous improvement over time tied to measurable outcomes. In addition, extensive state and federal resources have been spent on clean water initiatives across the country in the past several decades. Even with this investment, by many accounts there is not enough funding - from any source - to effectively mitigate all known pollutants in American waterways.

All this points to the recommendation of targeting funding where it can have the most impact. Namely, toward the watersheds identified as critical source zones or particularly environmentally sensitive regions. By applying the Pareto principle, also known as the 80/20 rule, in any state, there are certain watershed areas producing the most pollution. The key is to identify these areas and allocate funds toward achieving specific, pre-identified goals that quantify the changes where it can have the most impact. In addition, build rewards and incentives toward the achievement of those goals.

7. Funding

In interviews and research conducted across ten states, the funding mechanisms for agricultural water quality programs varied widely. Minnesota and Missouri passed a statewide sales tax with a portion of the money dedicated to funding water quality initiatives. Several states use CWA Section 319 Grant funding to implement agricultural water quality programs. According to the 319 Grant website, the grant money “supports a wide variety of activities including technical assistance, financial assistance, education, training, technology transfer, demonstration projects and monitoring to assess the success of specific nonpoint source implementation project" (US EPA, 2015). The flexibility of this funding has enabled some states to create innovative programs and partnerships to support farmers and producers in adopting better management practices for water quality. ADEQ already uses 319 funding for water quality programs, so a new program may need to consider alternative sources, or at least matching funds to leverage 319 funding. Nebraska uses a portion of fees levied by the Nebraska Department of Agriculture for pesticide registration and applicator licenses to fund their Natural Resource Districts through the Natural Resources Water Quality Fund (Nebraska Natural Resources Commission, n.d.).

One of the key findings throughout this research is that water quality and quantity should not be separate conversations in Arizona.

In June of 2022, The Center for the Future of Arizona (CFA) published new data as part of the Arizona Voters Agenda, which included water as an important political issue in the state. The report noted, "Very few things in politics achieve unanimous support, but in Arizona, the issues of addressing Arizona's water future and tackling drought come very close" (Center for the Future of Arizona, n.d.). Polling data shows that 90-96% of Arizona voters support four different water-related policy items from securing the state's water future to preserving and protecting Arizona's rivers, natural areas, and wildlife. Given this context, it may be an opportune time for a citizen-driven initiative to put a sales tax to fund innovative water conservation and water quality initiatives on the ballot (Center for the Future of Arizona, n.d.)

8. Integrate Additional Water Quality and Quantity Policies where Applicable

One of the key findings throughout this research is that water quality and quantity should not be separate conversations in Arizona. It isn't uncommon for agricultural issues to siloed, whereas the evidence that we have uncovered points to the need for systems thinking in managing the overall water challenges Arizona faces. Soil health is the most pertinent of these approaches to deal with both ends of the quality/quantity spectrum, but there are additional specific quantity tactics that could be implemented in the spirit of the aforementioned state quality plans. Under the purview of this same potential water quality plan, it could make sense to have additional incentives for improving water quantity through techniques such as laser field leveling, improved concrete sluice lining and conversion to lower water usage forms of agriculture. Rather than further compartmentalizing these challenges in a state where increased collaboration has been identified as an ideal to strive for, putting together these two issues would be a way to address that concern with this plan.

Reinvent Current Structures, Systems, and Ways of Thinking

An overarching theme from many of our interviews was a need for culture shift in how Arizona approaches water quality as a whole, and questions of political will to enact the funding and programming necessary to make the big changes needed in the coming decade. One culture shift related to economics is how Arizona approaches water pricing. This idea was not the focus of our research, but one interviewee mentioned this as the most important takeaway for long term water protection in a desert climate as a result of simple economics of supply and demand. When a resource is free - or farmers are incentivized to utilize their water resources at risk of losing them - there's an inherent tension in the value we claim it holds and how it is being expended. This is especially true in the dynamics playing out in Arizona between rapidly developing urban areas and water-intensive agricultural usage. Yet another perspective on this topic cautioned against the strategy of pricing water since it would leave rural and farming communities without water. Any potential pricing strategy for Arizona water must hold the needs of all communities to work together toward a sustainable future.

Several interviewees raised the idea of markets paying a premium price for crops that are certified for water quality. Similar to the USDA's Organic Certification, could there be a national certification model for agricultural production that reduces water pollution and improves water conservation practices? A culture shift in consumers would be necessary to demonstrate a willingness to pay more for this food to fill in the funding that is currently coming from state and federal tax dollars.

Alternatively, change the model so that agricultural polluters must pay for the damage they do to water quality, and use those fees to replace current public funding to support better management practices. While it is clear regulatory measures on agriculture are extremely unpopular politically, perhaps a market-driven disincentive to negatively impact water quality and scarcity would drive voluntary adoption of BMPs and create new funding sources to support the efforts.

Another consideration for Arizona is capital investment as a major component and incentive for voluntary water quality initiatives. Given the "land-rich, cash-poor" nature of many Arizona farmers and their operations, promising large amounts of capital for climate-smart and water-minded investments could incentivize and prompt producers to enact changes in Arizona's agricultural production. The precedent for large amounts of capital investment earmarked for climate innovations already exists in Arizona through solar panels on residential roofs, which have been subsidized by numerous programs throughout the years. Why not apply similar incentives to farmers looking to make water and climate-smart changes to their farm? Two emerging forms of sustainable agriculture deserve consideration: agrivoltaic farming and vertical farms. Both utilize unconventional techniques to increase land and water use efficiency.

Agrivoltaic farming entails the use of solar panels placed over crops to capture sunlight as renewable energy and fuel for plants. While there are drawbacks to this approach - namely a decrease in crop yield due to decreased direct sunlight - there are considerable benefits, especially in the arid Arizona desert. According to studies on AV from 2018 and 2019, respectively:

> Model simulations have been able to reproduce the expected benefits from agrivoltaic installations, for example showing that it is possible to improve land use efficiency and water productivity at once, by reducing irrigation amounts by 20%, when tolerating a decrease of 10% in yield or, alternatively, a slight extension of the cropping cycle […] (1) crop cultivation underneath APV can lead to declining crop yields as solar radiation is expected to be reduced by about one third underneath the panels. However, microclimatic heterogeneities and their impact on crop yields are missing reference and thus, remain uncertain. (2) Through combined energy and crop production, APV can increase land productivity by up to 70%. (3) Given the impacts of climate change and conditions in arid climates, potential benefits are likely for crop production through additional shading and observed improvements of water productivity. (4) In addition, APV enhances the economic value of farming and can contribute to decentralized, off-grid electrification in developing and rural areas, thus further improving agricultural productivity (Cheviron et al., 2018)

While the loss of crop yield efficiency may lead some to dismiss AV farming, the aspects of increased water efficiency and overall increased land efficiency should give detractors pause. While there are challenges that exist, such as those surrounding ideal crop selection, water runoff management, and potentially expensive infrastructure, the benefits seem well suited for the challenges that the Arizonan climate presents. Due to the increased retention of moisture, microclimate conditions and soil health would both improve. By tapping into more abundant yet underutilized sunlight resources, the disproportionate savings in water of twice the supply for the amount of crop yield lost would serve to remind us of one simple, yet key, principle: shade helps prevent evaporation. In an agricultural climate in which fallowed fields are becoming more and more the norm, a willing loss in production in the name of increased water and economic efficiency could offer a way to transition into climate-adapted agricultural systems, enhancing both quantity and quality.

Similar in terms of increased efficiency, vertical farming is a burgeoning, albeit capital intensive, form of agriculture. Vertical farming is a style of plant production that forgoes soil in favor of producing either hydroponically or with limited beds of soil stacked vertically. While the challenges of this style of growing are daunting (initial capital, cleanliness and a relative limit on what types of plants can be grown), one of the key benefits is too valuable for Arizona to ignore: water usage reduction rates of 90-95% can be expected due to the highly controlled indoor environment and limited evaporation. It also avoids runoff, preventing inadvertent downstream contamination. Additionally, the increased electrical demands with this avenue of growth are well-suited to be sustainably supplied by solar panels in the scorching desert, turning the at-times oppressive heat into an advantage rather than a disadvantage.

Due to this potential to save water and protect quality, vertical farming has fans in the state of Arizona. If vertical farms are to replace field-grown greens, this could free up currently utilized cropland for purposes or plants more suited to our desert environment. Choosing to grow VF crops indoors, in conjunction with choosing native perennials best suited to flourish in a desert environment in the former crop space, could allow farms to remain financially successful and have more options in terms of good stewardship of the land. Whether it be crops chosen for the production of food, the sequestration of carbon, the improvement of soil health, or some combination thereof, the improved space and water efficiency afforded by vertical set-ups could enable a less demanding, and more desert adapted direction for conventional Arizona agriculture to take, thanks to the space, water and financial benefits freed up by growing indoors.

Furthermore, vertical farming would not be brand-new to the Valley. Vertical farms like True Garden in Mesa and Citifarms in Central Phoenix are already up and running, and OnePointOne, an agtech startup from Silicon Valley, invested in a 50,000 sq ft vertical farm in Avondale in 2021. These companies have shown the feasibility of vertical farming in the Valley, while hinting at the potential it could attain in the future. Universities have also been active players on the VF front, with both ASU and the University of Arizona having vertical farms on their campuses. Additionally, the vertical farm at ASU utilizes the energy production and fertilizer generated by a food waste breakdown tank. The potential for generating this methane and humus is especially high in Arizona, as we unfortunately rank amongst the worst states in the nation for food waste:

> Arizona is the No. 1 state that wastes the most food for a cornucopia of reasons. Among the 50 states, the Grand Canyon State registered the highest share of food wasted and the lowest share recycled. It also ranked No. 3 for the lowest share of food donated to people in need. (Ardoin, 2021)

Widespread implementation of systems like this could have a great impact upon how Arizona grows and conserves food, and the underlying connection with conserving water. The organic matter generated by this process would be especially beneficial in aiding soil health initiatives that could improve state water quality and quantity. Methane could be an additional energy resource that would free up farmers' funds for future farm improvements, or manage increased overhead costs elsewhere, especially if the future price of water becomes exorbitantly high. Mitigating some of the food waste (and water waste) would represent a way for farmers to recoup some value from this resource being wasted.

Another area where universities could have an impact on state water quality and quantity is in the potential to set up scholarship funds and create curated curriculum to guide students looking to contribute their career efforts to combating these and other challenges connected to farming amid climate change. The potential to guide the process and then connect students with prospective employers, or ways to become agricultural entrepreneurs, could help fill a very valuable and in-demand niche. This was a need that was vocalized at Arizona's Conservation Districts Annual Conference in August, 2022. The demand for a workforce to help manage water quality and quantity efforts in the fields is outpacing the supply of college educated individuals equipped to lead on these issues - either as policymakers or as producers - to evolve the conversation in Arizona.

Another area discussed is the relative disrespect cast on agriculture as a form of high-level study. At this same conference it was pointed out by several attendees that agriculture should be considered an integral part of STEM, as the scientific, technological, engineering and mathematical challenges of figuring out better water plans, infrastructure and agricultural policies are no less valid or important than the industries more commonly associated with STEM study. Introducing students to these concepts early could be a way to incentivize them into farming and solving the state's most pressing challenges. The skillset of an individual schooled in a 4-year program on water efficiency and environmental quality could become highly desirable given the ongoing water crisis that is reshaping Arizonan agriculture and demanding the development of such pools of talent.

Ending Unsustainable Farming

The most drastic recommendation we heard in a few interviews was that to protect Arizona water, agriculture should be phased out entirely in specific agricultural activities and sectors in specific geographic areas of the state. The issue boils down to whether, as Arizona continues to experience a drier climate, it can support and continue to sustain both the current level of water-intensive agriculture and a growing population. One interviewee strongly believed that there is no future at all in farming in Central Arizona due to its reliance on groundwater. Due to the lack of surface water supply, they posited that farming should end before continuing to use groundwater and deplete aquifers. The problem of land subsidence, including sinkholes, has resulted from aquifer collapses due to historic agriculture de-watering aquifers well below the natural recharge rate. With the finite amount of groundwater, it should not be used to grow crops such as cotton and alfalfa which are not direct food sources. And in fact, as farming has begun to decrease in central Arizona due to urban sprawl, urban home water use has replaced agricultural uses. Another interviewee noted that farmers' water rights in the prior appropriation legal framework have become their retirement package, as they sell off those rights and the water is pumped from one aquifer to another to support new subdivisions, which are required to have a 100-year supply of water. As one respondent put it, "We don't really have a water shortage problem, we have a planning and zoning problem." Another interviewee noted that the orange groves they had planted decades earlier in Maricopa County had since been ripped out by backhoes to build condos. While a few respondents mentioned long-distance pipeline projects and aquifer pumping as a solution to water shortage, other respondents decried these measures for not addressing the lack of sustainable water use.

Realistically, of course, farmers are not going to simply walk away from their business and way of life. As one Arizona respondent said, some farmers who have farmed for years, or even generations, now use less water than ever before as increased populations in urban areas use more and more water. There are not a lot of ways to keep decreasing the quantity of water used. Decreasing rural and agricultural allotments for the needs of urban communities becomes an equity issue when rural farmers are disadvantaged to use water or priced out compared to wealthy urban areas. The respondent pointed out that farming is not a thing of the past, and we will always need to grow food - an obvious statement, but nevertheless often overlooked by urban policymakers. According to another Arizona respondent, the increasing global population necessitates increasing global food supply, so decreasing agricultural production is not a solution.

Decreasing rural and agricultural allotments for the needs of urban communities becomes an equity issue when rural farmers are disadvantaged to use water or priced out compared to wealthy urban areas.

Given the complexities around the controversial idea of ending farming, a targeted program should be recommended to help compensate central Arizona farmers for desisting from agriculture that is reliant on groundwater. This program could be through payments for water rights, or for technical assistance programs that help farmers transition to agricultural production methods informed by Native American farming techniques and early historical methods that grow drought-resilient food without requiring groundwater. Colorado state's program, Colorado River Drought Contingency Plan, which paid farmers to stop farming amidst drought, could be modified in which the state pays Arizona farmers to permanently stop farming. The state of Arizona would effectively buy those farmers' water rights and could then hold onto those rights to decrease overall pumping from aquifers in danger of failing.

Conclusion

Summary of Findings

This report looks to shine a light on issues of Arizona agricultural water quality, which are consistently overshadowed by conversations around water quantity. However, with a limited quantity of water, maintaining water of high quality for farmers, cities, and ecosystems becomes that much more important. Through research of other state water quality programs, the scientific literature, and interviews with 44 water experts throughout Arizona and across the United States, this report has gathered insights and recommendations for future Arizona policies and programs at the state level. Notably, many of the recommendations for mitigating nonpoint source agricultural pollution center around soil health, which is also frequently cited as a method for decreasing water usage.

The recommendations discussed in this report center around measures to improve water quality, innovate new technical solutions, and eliminate groundwater irrigation. To improve water quality, a program is laid out for a voluntary state certification program for producers, which can provide technical assistance and grant funds to help farmers in meeting water goals on their farm. Recommendations for new technology and research to truly reinvent the current structure of Arizona agriculture is laid out. And finally, a recommendation is made for a program to assist in eliminating groundwater withdrawals for irrigation in areas with depleted aquifers.

With surface water, such as Lake Powell and Lake Mead, at record low levels and ongoing groundwater depletion, Arizona needs farmers to come to the forefront and participate in discussions to find long term water solutions, and not simply protect the status quo. These programs can be a solid steppingstone to engage farmers and to create a learning network for continuing to adapt in the coming decades. Real coalitions and coordinated action take years to build, but there is no better time to start than now. It is not yet too late to act.

Concluding Thoughts

The wind whips through the canyons of the American Southwest, and there is no one to hear it but us - a reminder of the 40,000 generations of thinking men and women who preceded us, about whom we know almost nothing, upon whom our civilization is based. - Carl Sagan

It is often said that history repeats itself. In the end, Mother Nature always outlasts humanity, and no matter our best intentions, the desert and current drought conditions threaten to undo the water safety and security of the state of Arizona. Mega-drought conditions undermine the long-term development of an otherwise ideal space for expansion and growth, and as climate change demands adaptations from us all, agriculture in Arizona, too, must answer that call. If the lessons of the past, other states and even those examples from within, can be synthesized and utilized by the state of Arizona to overcome these daunting water challenges, the state could not only prosper, but set a precedent for other states and communities to follow. The Hohokam irrigation system helped birth the early agricultural attempts of settlers, and their latticework lines the landscape to this day, like wrinkles in time reminding us that in the desert water is life. This is a sentiment that modern-day residents would be wise to heed.

The Arizona agricultural paradigm has always been to take advantage of the natural resources Arizona has in abundance, land and sun, and to bring in when needed that which it lacks, chiefly, water. However, the changing climates, both literal and societal, are putting more pressure than ever on this production paradigm, demanding compromise and change to keep the careful balance of Arizonan agriculture and non-agricultural development afloat. The time has come to question the paradigm in order to determine the most logical steps moving forward. Throughout the course of our research and dozens of interviews, the wide variety of opinions and recommendations for how Arizona can protect its agricultural water quality and quantity have left us with three general categories: calls to improve, reinvent or eliminate the agricultural scene in Arizona all have their own merits, and a comprehensive Arizona plan will likely need to integrate elements of all three.

Reinventing the agricultural industry in Arizona might prove to be the most costly, yet most beneficial of the three avenues of approach. Long-term thinking demands long-term investment, and the upfront costs of subsidizing agrivoltaic farming, vertical farming, scholarship funds for future farmers and other innovative techniques might yield astounding long-term yields for the economic conditions of water in our state. Leading the way through both desire and necessity, Arizona could become a hotbed of agricultural innovation.

For crops that can’t be grown hydroponically, why not take advantage of the intensity of the sun and save some water while you’re at it? Agrivoltaics might not have quite the same yield, but what good is matching the yield of a system that needs to change? The tradeoff of increased moisture and free solar power might be enough to make some farmers sign up to make the change.

If water, your scarce, expensive, and life-giving resource is so valuable, why use it outside and exposed to some of the harshest elements in the country if it can be avoided? Vertical farming could be an answer here. Transitioning to indoor, clean-room style vertical farms would be a way to safeguard against evaporation, runoff and the myriad of problems that comes with in-ground agriculture. It would make more sense to grow produce in a way that maximizes water in a state desperate to find more sources.

Innovation and state of the art technology are areas in which Arizona has experience, from the history of industries like computer chips to the groundbreaking contributions of the state universities in a variety of fields. Training the agricultural workforce of the future through scholarships and creating cutting-edge curriculum plans could ensure the continued role of agriculture industries in Arizona for years to come.

Ending the agricultural industry in Arizona is the most drastic approach. More than anything, hopefully this dire suggestion serves as a reminder of the need to implement improvements and innovation to avoid such an end. Ending Arizonan agriculture entirely would do more than cripple an industry and end the livelihood of thousands, it would also spell the end of an important tenet of Arizonan culture. However, that is not to say that selective retirement of land for neither agricultural or developmental purposes wouldn’t have its merits.

The political climate in the state of Arizona has proven to be a factor needing consideration as well. Due to political pressure, plans should incentivize improvement rather than force legislation that put producers into a box in which they have no options but to comply with mandates from above. Decisions should be made on the level where the decision will be felt, so initiatives that allow farmers to voluntarily improve their operations are ideal. This has been one of the key lessons that Kathleen Merrigan, the Executive Director of the Swette Center, has emphasized in our program curriculum: the need to understand what farmers themselves desire as a key component of any policy-making decision. The decision-making process should include input from the people whom the decision will impact, and if the voluntary plan operates with this approach, the odds of acceptance and adoption by Arizona farmers would likely be far greater than a plan bereft of collaboration.

At a time when political contention is more intense in Arizona than in years past, it has become clear that water action is a key area where conservatives and liberals are able to potentially see eye to eye. The issue of water in Arizona has a unifying effect amongst many people of the state that might be otherwise politically divided. From research, interviews and conferences such as the Arizona Association of Conservation

Districts, the impression gained is that people in Arizona who may not be able to agree on much else, agree that taking action on water is a top priority. Working together on initiatives, starting ballot measures and collecting signatures for petitions could be ways in which the political divide is bridged over the common cause of water protection. An increase in public awareness and outreach through the establishment of these recommendations could help do just that.

Further Research Needed

Due to the IRB approval procedure as Arizona State University students, which requires extensive review of any research involving tribes, there were no interviews conducted with members representing Native or tribal nations. Therefore, the research team was not able to learn and understand perspectives and needs of this population. More research is needed to understand the unique context and regulatory considerations of sovereign nations.

In the literature review, there were no studies on regulatory certainty as an incentive for farmers and ranchers, which is a key component of the Minnesota Agriculture Water Quality Certification Program, so this is another recommended topic for future research.

Many stakeholder interviews discussed the challenges of measuring the actual impact of BMPs on water quality and conservation. The measurements and outcomes of implementing these practices are based on models, which are difficult to follow downstream. Future research could address how to better quantify the impact of implementing different practices on agricultural land, particularly as practices are stacked.

Lastly, a few interviewees mentioned the importance of leveraging the deep knowledge and innovative solutions that can be developed through extension research and land grant universities. More research is needed around new ways of growing crops in desert climate including improved genetics for drought tolerant crops. One example from Minnesota was the Forever Green Initiative which has developed new genetic seeds and new markets for farms to make it financially feasible for farmers to implement year-round cover cropping that protects soil and reduces the need for nitrogen applications. More research is needed to adapt this type of model for Arizona.

References

ADEQ. (2014). *Nonpoint Source Management Plan*. Arizona Department of Environmental Quality. https://static.azdeq.gov/wqd/nps/5yp_14-19.pdf

ADWR. (n.d.a). *Changes from 4MP to 5MP*. Retrieved July 11, 2022, from https://new.azwater.gov/sites/default/files/media/5MPOverviewofChanges.pdf

ADWR. (n.d.b). *Water Quality | Arizona Department of Water Resources*. (n.d.). Retrieved July 26, 2022, from https://new.azwater.gov/permitting-wells/water-quality

ADWR. (2016a, March). *AMA Fact Sheet 2016*. Retrieved July 11, 2022, from https://new.azwater.gov/sites/default/files/media/AMAFACTSHEET2016%20%281%29_0.pdf

ADWR. (2016b, November 18). *AZ's Groundwater Management Act Of 1980*. Arizona Department of Water Resources. https://new.azwater.gov/news/articles/2016-18-11

ADWR. (2020). *5th Management Plans Work Group: Safe-Yield Technical Subgroup Meeting*. Arizona Department of Water Resources. https://new.azwater.gov/sites/default/files/media/2020-07-07_SY_Presentation.pdf

ADWR (2021). *ADWR Annual Report*. Retrieved July 10, 2022, from https://new.azwater.gov/sites/default/files/media/7-1_ANNUALREPORT2021_Final.pdf

ADWR. (2022a). *Agriculture Program | Arizona Department of Water Resources*. Retrieved July 11, 2022, from https://new.azwater.gov/ama/agriculture-program

ADWR. (2022b). *BMP Approved Best Practices example form*. Retrieved July 11, 2022, from https://infoshare.azwater.gov/docushare/dsweb/Get/Document-24467/BMPWorksheet-ContinuingReg3MP4MP.pdf

ADWR. (2022c). *Overdraft, Safe-Yield, and the Management Goals of Arizona's Active Management Areas*. Arizona Department of Water Resources. https://new.azwater.gov/sites/default/files/media/2022_SYReport_0.pdf

Aleshire, P. (2022, April 8). Water shortage forces new Pine moratorium. *Payson Roundup*. https://www.paysonroundup.com/water-shortage-forces-new-pine-moratorium/article_eb99d421-1b4a-5cc9-b1ba-36fc25f930f4.html

Allen, L. (2019). *Yuma researchers track soil salt, crop water use.* Western Farm Press. https://www.farmprogress.com/water/yuma-researchers-track-soil-salt-crop-water-use

Ardoin, J. (2021, November 23). *2022's States That Waste the Most Food*. Lawnstarter.Org. https://www.lawnstarter.com/blog/studies/states-that-waste-most-food/

Arizona Water Protection Fund Commission. (n.d.). *AZ Water Protection Fund Annual Report 2022*. Retrieved July 10, 2022, from https://www.azwpf.gov/sites/default/files/FY2022AWPFAnnualReport.pdf

Beck, H. E., Zimmermann, N. E., McVicar, T. R., Vergopolan, N., Berg, A., & Wood, E. F. (2018). Present and future Köppen-Geiger climate classification maps at 1-km resolution. *Scientific Data*, *5*(1), 180214. https://doi.org/10.1038/sdata.2018.214

Beedell, Jason. (2000). Using social-psychology models to understand farmers' conservation behaviour. *Journal of Rural Studies*, *16* (1), 117–127. https://doi.org/10.1016/S0743-0167(99)00043-1

Beitler, J. *Pinpointing an Invasive Plant's Next Move | Earthdata*. (n.d.). Retrieved July 10, 2022, from https://www.earthdata.nasa.gov/learn/sensing-our-planet/pinpointing-an-invasive-plant-s-next-move

Bodin, Ö. (2017). Collaborative environmental governance: Achieving collective action in social-ecological systems. *Science*, *357*(6352). https://doi.org/10.1126/science.aan1114

Bouwer, H. (2000). Integrated water management: emerging issues and challenges. *Agricultural Water Management*, *45*(3), 217–228. https://doi.org/10.1016/S0378-3774(00)00092-5

Boyle, K. J., Kotchen, M. J., & Smith, V. K. (2017). Deciphering dueling analyses of clean water regulations. *Science*, *358*(6359), 49–50. https://doi.org/10.1126/science.aap8023

Britannica. (2012). *Great Drought*. Britannica. https://www.britannica.com/event/Great-Drought.

Brown, T. C., & Froemke, P. (2012). Nationwide Assessment of Nonpoint Source Threats to Water Quality. *BioScience*, *62*(2), 136–146. https://doi.org/10.1525/bio.2012.62.2.7

Bureau of Reclamation. (2006). *Central Arizona Salinity Study: Phase II – Salinity Control in Waste Water Treatment Plants*. U.S. Bureau of Reclamation. https://www.usbr.gov/lc/phoenix/programs/cass/pdf/Phase2/3SalinityControlWWTP.pdf

Buschatzke, T., & Selin, S. (2022). *AZ Department of Water Resources Fiscal year 2022 Strategic Plan*. 2.

Carlowicz, M. (2022). *Lake Mead Keeps Dropping*. NASA Earth Observatory. https://earthobservatory.nasa.gov/images/150111/lake-mead-keeps-dropping

Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N., & Smith, V. H. (1998). Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen. *Ecological Applications*, *8*(3), 559–568. https://doi.org/10.1890/1051-0761(1998)008[0559:NPOSWW]2.0.CO;2

Casper, D. (2016, October 14). *SWCD History* [Text]. Missouri Soil and Water. https://mosoilandwater.land/internal/swcd-history

CDA. (2013). *Agricultural Chemicals & Groundwater Protection in Colorado*. Colorado Water Institute. Special Report No. 23. http://waterquality.colostate.edu/documents/sr-16_agchemicals.pdf

Center for the Future of Arizona. (n.d.). *Arizona Voters' Agenda: Water.* Retrieved August 12, 2022, from https://www.arizonafuture.org/news-events/news/2022/6/arizona-voters-agenda-voters-care-deeply-about-water-and-arizona-s-long-term-drought/

Central Arizona Project. (2022, February). *Drought Contingency Plan CAP*. Retrieved July 10, 2022, from https://library.cap-az.com/documents/departments/planning/colorado-river-programs/CAP-FactSheet-DCP.pdf

Cheviron, B. (2018). *Water budget and crop modelling for agrivoltaic systems: Application to irrigated lettuces*. Abstract. https://doi.org/http://dx.doi.org/10.1016/j.agwat.2018.07.001

Christian-Smith, J., & Allen, L. (2012). Legal and Institutional Framework of Water Management. In *A Twenty-First Century US Water Policy*. Oxford University Press.

Claassen, R., Breneman, V., Bucholtz, S., Cattaneo, A., Johansson, R., & Morehart, M. (n.d.). *Environmental Compliance in U.S. Agricultural Policy: Past Performance and Future Potential*. 55.

Clean Water Council. (2009, November 16). Minnesota Pollution Control Agency. https://www.pca.state.mn.us/about-mpca/clean-water-council

Copeland, C. (2010). *Clean Water Act: A Summary of the Law*. Congressional Research Service. https://congressional.proquest.com/congressional

CWCB. (2023). *Colorado Water Plan*. Colorado Water Conservation Board. https://cwcb.colorado.gov/colorado-water-plan

Delozier, J. L., & Burbach, M. E. (2021). Boundary spanning: Its role in trust development between stakeholders in integrated water resource management. *Current Research in Environmental Sustainability*, *3*, 100027. https://doi.org/10.1016/j.crsust.2021.100027

Dery, J. L., Rock, C. M., Goldstein, R. R., Onumajuru, C., Brassill, N., Zozaya, S., & Suri, M. R. (2019). Understanding grower perceptions and attitudes on the use of nontraditional water sources, including reclaimed or recycled water, in the semi-arid Southwest United States. *Environmental Research*, *170*, 500–509. https://doi.org/10.1016/j.envres.2018.12.039

Dickerson, D., & Richter, J. (2021). *Funding Clean Water Initiatives in Vermont* (VT LEG #358910 v.1; Issue Brief). Vermont Legislative Joint Fiscal Office. https://ljfo.vermont.gov/assets/Publications/Issue-Briefs/a93794cd98/Clean-Water-Initiatives-Issue-Brief-December-2021.pdf

Foster, S., Pulido-Bosch, A., Vallejos, Á., Molina, L., Llop, A., & MacDonald, A. M. (2018). Impact of irrigated agriculture on groundwater-recharge salinity: a major sustainability concern in semi-arid regions, *26*(8), 2781–2791. https://doi.org/10.1007/s10040-018-1830-2

Governor's Water Augmentation, Innovation & Conservation Council (2021). *2021 GWAICC Annual Report*. Retrieved June 28, 2022, from https://new.azwater.gov/sites/default/files/2021_GWAICC_AnnualReport_062121_Final.pdf

Hilal, N., Kim, G. J., & Somerfield, C. (2011). Boron removal from saline water: A comprehensive review. *Desalination*, *273*(1), 23–35. https://doi.org/10.1016/j.desal.2010.05.012

Hill, T. (2022, July 6). $1 billion investment to acquire, conserve water is signed by Ducey. *Cronkite News | Arizona PBS*. https://cronkitenews.azpbs.org/2022/07/06/arizona-water-conservation-bill-1-billion-doug-ducey/

Homburg, J. A., & Sandor, J. A. (2011). Anthropogenic effects on soil quality of ancient agricultural systems of the American Southwest. *CATENA*, *85*(2), 144–154. https://doi.org/10.1016/j.catena.2010.08.005

Hooda, P. S., Edwards, A. C., Anderson, H. A., & Miller, A. (2000). A review of water quality concerns in livestock farming areas. *The Science of the Total Environment*, *250*(1–3), 143–167. https://www.proquest.com/docview/71108342?parentSessionId=5pl4mz5puZincJnxrqIiVSdASUL1lih96YIBEfuXQ60%3D&pq-origsite=primo&

Kauffman, J. B., Beschta, R. L., Lacy, P. M., & Liverman, M. (2022). Livestock Use on Public Lands in the Western USA Exacerbates Climate Change: Implications for Climate Change Mitigation and Adaptation. *Environmental Management*, *69*(6), 1137–1152. https://doi.org/10.1007/s00267-022-01633-8

Kite, A. (2022, May 16). Why an ambitious effort to overhaul Kansas water management fell short. *Kansas Reflector*. https://kansasreflector.com/2022/05/16/why-an-ambitious-effort-to-overhaul-kansas-water-management-fell-short/

Kling, C. L. (2011)*. Economic Incentives to Improve Water Quality in Agricultural Landscapes: Some New Variations on Old Ideas.* American Journal of Agricultural Economics, 3 (2), 297-309. http://dx.doi.org/10.1093/ajae/aaq190

Köppen Climate Types of Arizona. (n.d.). [Map]. PRISM Climate Group, Oregon State University. https://commons.wikimedia.org/wiki/File:Arizona_K%C3%B6ppen.svg

Lakhani, N., Uteuova, A., & Chang, A. (n.d.). *Revealed: the true extent of America's food monopolies, and who pays the price*. The Guardian. https://www.theguardian.com/environment/ng-interactive/2021/jul/14/food-monopoly-meals-profits-data-investigation

Lemly, D. (1197). *Environmental Implications of Excessive Selenium: A Review*. 21. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=b20e28f6a05e0f676e847538bd71e7ea7ae6b3d9

MAEAP. (n.d.). *Michigan Agriculture Environmental Assurance Program (MAEAP)*. https://maeap.org/

MAEAP. (2014, February 25). *Michigan Agriculture Environmental Assurance Program*. Michigan House Ag Appropriations Subcommittee, Agriculture & Rural Development. https://www.house.mi.gov/hfa/Archives/PDF/Agriculture/ARD_SC_Feb_25_2014_MAEAP_History_Testimony.pdf

Matous, P., & Wang, P. (2019). External exposure, boundary-spanning, and opinion leadership in remote communities: A network experiment. *Social Networks*, *56*, 10–22. https://doi.org/10.1016/j.socnet.2018.08.002

Michigan. Gov Agricultural & Rural Development. Retrieved August 13, 2022, from https://www.michigan.gov/mdard/environment/maeap/content/michigan-agriculture-environmental-assurance-program-maeap

Minnesota Board of Water and Soil Resources. (n.d.). *What We Do | MN Board of Water, Soil Resources*. Retrieved July 25, 2022, from https://bwsr.state.mn.us/what-we-do

Minnesota Board of Water and Soil Resources. (2019). *Minnesota Buffer Law | MN Board of Water, Soil Resources*. Retrieved August 4, 2022, from https://bwsr.state.mn.us/minnesota-buffer-law

Minnesota Board of Water and Soil Resources. (2022). *One Watershed, One Plan | MN Board of Water, Soil Resources*. Retrieved August 12, 2022, from https://bwsr.state.mn.us/one-watershed-one-plan

Minnesota Department of Agriculture. (n.d.). *Minnesota Agricultural Water Quality Certification Program*. (n.d.). Retrieved May 19, 2022, from https://www.mda.state.mn.us/environment-sustainability/minnesota-agricultural-water-quality-certification-program

Minnesota Department of Agriculture, Minnesota Pollution Control Agency, and Minnesota Board of Soil and Water Resources. *Water Quality Trading Pilot Project - North Fork Crow River Watershed Final Report*. (2021). 67. https://www.pca.state.mn.us/sites/default/files/wq-wwprm1-37.pdf

Minnesota Department of Agriculture. (2022) *FY 2022-23 Clean Water Funds Appropriated for Minnesota's Water Agencies*. https://www.mda.state.mn.us/environment-sustainability/clean-water-fund

Minnesota Legislative Coordinating Commission. (n.d.) *Tracking Minnesota's Legacy and Trust Funds*. Minnesota's Legacy. Retrieved August 12, 2022, from https://www.legacy.mn.gov/tracking-minnesotas-legacy-and-trust-funds

Minnesota Legislator. (2022). *Sec. 103F.48 MN Statutes*. Retrieved August 4, 2022, from https://www.revisor.mn.gov/statutes/cite/103F.48

Minnesota Pollution Control Agency. (2017a, June 27). *Water quality trading*. Minnesota Pollution Control Agency. https://www.pca.state.mn.us/water/water-quality-trading

Minnesota Pollution Control Agency. (2017b, October 4). *What we're doing to improve water quality.* Minnesota Pollution Control Agency. https://www.pca.state.mn.us/water/what-were-doing-improve-water-quality

Missouri Department of Natural Resources. (n.d.). *History of the Parks, Soils and Water Sales Tax.* Retrieved May 23, 2022, from https://dnr.mo.gov/land-geology/soil-water-conservation/parks-soils-water-sales-tax

Morris, C. & Potter, C. (1995). Recruiting the New Conservationist: Farmers' Adoption of Agri-environmetal Schemes in the U.K. Journal of Rural Studies, 11, 51-63. http://dx.doi.org/10.1016/0743-0167(94)00037-A

Muñoz-Erickson, T. A., Cutts, B. B., Larson, E. K., Darby, K. J., Neff, M., Wutich, A., & Bolin, B. (2010). Spanning Boundaries in an Arizona Watershed Partnership: Information Networks as Tools for Entrenchment or Ties for Collaboration? *Ecology and Society*, *15*(3), art22. https://doi.org/10.5751/ES-03390-150322

Nabhan, G. P., Richter, B. D., Riordan, E. C., & Tornbom, C. (2023). *Toward Water-Resilient Agriculture in Arizona: Future Scenarios Addresssing Water Scarcity in the Lower Colorado River Basin*. The University of Arizona College of Social and Behavioral Sciences Southwest Center. https://swc.arizona.edu/sites/swc.arizona.edu/files/Toward%20Water-Resilient%20Agriculture%20in%20Arizona%20Report_FINAL.pdf

National Association of Conservation Districts. (2023). *About Districts*. NACD. Retrieved August 12, 2022, from https://www.nacdnet.org/about-nacd/about-districts/

National Weather Service. (2023). *Phoenix Rainfall Index*. National Weather Service | National Oceanic and Atmospheric Administration. https://www.weather.gov/psr/PRI

Natural Resources Commission. (n.d.). *Natural Resources Water Quality Fund* | Retrieved August 12, 2022, from https://nrc.nebraska.gov/natural-resources-water-quality-fund

Nebraska Department of Environment and Energy. (n.d.) *NDEE Water Quality*. Retrieved August 14, 2022, from http://www.deq.state.ne.us/NDEQProg.nsf/WaterHome.xsp

Nebraska Department of Environment and Energy. *Nebraska DEE*. (2019). Retrieved August 14, 2022, from http://dee.ne.gov/NDEQProg.nsf/OnWeb/SWQS

New Mexico Environment Department. (2022). Monitoring, Assessment and Standards. https://www.env.nm.gov/surface-water-quality/monitoring-assessment-and-standards-section/

NWS. (2021). *2021 Climate Year in Review for Phoenix, Yuma, and El Centro*. National Weather Service. https://www.weather.gov/psr/yearinreview2021

Page, G., & Bellotti, B. (2015). Farmers value on-farm ecosystem services as important, but what are the impediments to participation in PES schemes? *Science of The*

Total Environment, *515–516*, 12–19. https://doi.org/10.1016/j.scitotenv.2015.02.029

Perry, L. A. (2021). *Arizona Department of Environmental Quality: Water Quality Protection Responsibilities Performance Audit* (Report 21-116; A Report to the Arizona Legislature). Arizona Auditor General. https://www.azauditor.gov/sites/default/files/21-116_Report.pdf

Ribaudo, M.O., Horan, R.D., & Smith, M.E. (1999). *Economics of Water Quality Protection from Non-point Source: Theory and Practice.* U.S. Department of Agriculture, Economic Research Service, 33-59. https://wayback.archive-it.org/5923/20110914042704/http://www.ers.usda.gov/publications/aer782/aer782d.pdf

Rock, K. (2019, January 25). *What is a Market-Based Approach to Water Quality?* Center for Rural Affairs. https://www.cfra.org/blog/what-market-based-approach-water-quality

Ruto, E., & Garrod, G. (2009). Investigating farmers' preferences for the design of agri-environment schemes: a choice experiment approach. *Journal of Environmental Planning and Management*, *52*(5), 631–647. https://doi.org/10.1080/09640560902958172

Scanlon, B. R., Jolly, I., Sophocleous, M., & Zhang, L. (2007). Global impacts of conversions from natural to agricultural ecosystems on water resources: Quantity versus quality. *Water Resources Research*, *43*(3). https://doi.org/10.1029/2006WR005486

Segerson, K. (1988). Uncertainty and incentives for nonpoint pollution control. *Journal of Environmental Economics and Management*, *15*(1), 87–98. https://doi.org/10.1016/0095-0696(88)90030-7

Shortle, J. (2013). Economics and Environmental Markets: Lessons from Water-Quality Trading. *Agricultural and Resource Economics Review*, *42*(1), 57–74. https://doi.org/10.1017/S1068280500007619

Shortle, J. (2017). Economic Incentives for Water Quality Protection. Water Economics and Policy, 3. https://doi.org/10.1142/S2382624X17710047

Shortle, J., Ribaudo, M., Horan, R., & Blandford, D. (2012). Reforming Agricultural Nonpoint Pollution Policy in an Increasingly Budget-Constrained Environment. Environmental Science and Technology, 46 (3), 1316-1325. https://doi-org.ezproxy1.lib.asu.edu/10.1021/es2020499

State of Arizona Senate. (2022). *Senate Bill 740*. State of Arizona Senate. https://www.azleg.gov/legtext/55Leg/2R/laws/0366.pdf

Stuart, D., Benveniste, E., & Harris, L. M. (2014). Evaluating the use of an environmental assurance program to address pollution from United States cropland. *Land Use Policy*, *39*, 34–43. https://doi.org/10.1016/j.landusepol.2014.03.009

Towne, D., & Jones, J. (2016). *20 year overview of water quality ADEQ (ambient groundwater monitoring program)*. Arizona Department of Environmental Quality. Retrieved July 12, 2022, from https://static.azdeq.gov/wqd/gw/fs/16-02_20year_final_ofr.pdf

Tscharntke, T., Clough, Y., Wanger, T. C., Jackson, L., Motzke, I., Perfecto, I., Vandermeer, J., & Whitbread, A. (2012). Global food security, biodiversity conservation and the future of agricultural intensification. *Biological Conservation*, *151*(1), 53–59. https://doi.org/10.1016/j.biocon.2012.01.068

US Census. (2022, May 26). *Fastest-Growing Cities Are Still in the West and South*. Census.Gov. https://www.census.gov/newsroom/press-releases/2022/fastest-growing-cities-population-estimates.html#:~:text=San%20Antonio%2C%20Texas%2C%20had%20the,experienced%20relatively%20small%20population%20growth

US EPA. (2015, September 9). *319 Grant Program for States and Territories* [Overviews and Factsheets]. https://www.epa.gov/nps/319-grant-program-states-and-territories

US EPA. (2018). *Current Implementation of Waters of the United States [Other Policies and Guidance]*. US EPA. https://www.epa.gov/wotus/current-implementation-waters-united-states

US EPA. (2022). *Water Quality Trading* | *US EPA*. (n.d.). Retrieved August 13, 2022, from https://www.epa.gov/npdes/water-quality-trading

USGS. (2015). *Agricultural Lands in Arizona* [Map]. United States Geological Ser. https://www.usgs.gov/media/images/agricultural-lands-arizona

Utton Transboundary Resources Center. (2015). *Water Matters!* Utton Center | The University of New Mexico. https://uttoncenter.unm.edu/resources/research-resources/water-matters-.html

van Schilfgaarde, J. (1994). Irrigation — a blessing or a curse. *Agricultural Water Management*, *25*(3), 203–219. https://doi.org/10.1016/0378-3774(94)90061-2

Vermont Agency of Agriculture, Food and Markets. (2016). *A Summary of the Required Agricultural Practices*. Vermont Agency of Agriculture, Food and Markets. https://agriculture.vermont.gov/sites/agriculture/files/documents/Water_Quality/RAPsummaryPDF.pdf

Vermont Agency of Agriculture, Food and Markets. (2021). *FY2022 Agricultural Clean Water Initiative Program Grants*. Vermont Agency of Agriculture, Food & Markets. https://agriculture.vermont.gov/sites/agriculture/files/documents/Water_Quality/AgCWIP_FY22_RFP.pdf

Vermont Agency of Agriculture Food and Markets. (2022, January 7). *VAAFM Announces Vermont 'Pay-For-Performance' Agricultural Phosphorus Reduction Program Now Taking Applications | Agency of Agriculture, Food and Markets*. https://agriculture.vermont.gov/agency-agriculture-food-markets-news/vaafm-announces-vermont-%E2%80%98pay-performance%E2%80%99-agricultural

Vermont State Legislature. (2019). An act relating to agricultural development, Vermont Code No. 83 (2019). https://legislature.vermont.gov/Documents/2020/Docs/ACTS/ACT083/ACT083%20As%20Enacted.pdf

Weyers, S. L., Gesch, R. W., Forcella, F., Eberle, C. A., Thom, M. D., Matthees, H. L., Ott, M., Feyereisen, G. W., & Strock, J. S. (2021). Surface runoff and nutrient dynamics in cover crop–soybean systems in the Upper Midwest. *Journal of Environmental Quality*, *50*(1), 158–171. https://doi.org/10.1002/jeq2.20135

Wichelns, D., & Oster, J. D. (2006). Sustainable irrigation is necessary and achievable, but direct costs and environmental impacts can be substantial. *Agricultural Water Management*, *86*(1), 114–127. https://doi.org/10.1016/j.agwat.2006.07.014

Willamette Partnership, Forest Trends, & the National Network on Water Quality Trading, (2018). Breaking Down Barriers: Priority Actions for Advancing Water Quality Trading. www.willamettepartnership.org/breaking-downbarriers-priority-actions-for-advancing-water-qualitytrading

Willamette Partnership, World Resources Institute, and the National Network on Water Quality Trading. (2015). *Building a Water Quality Trading Program: Options and Considerations*. National Network on Water Quality Trading. http://willamettepartnership.org/wp-content/uploads/2015/06/BuildingaWQTProgram-NNWQT.pdf

Zarkin, M. (2017). Policy Learning Mechanisms and the Regulation of US Drinking Water. *Public Organization Review*, *17*(2), 275–291. https://doi.org/10.1007/s11115-015-0341-z

Appendix

Appendix 1: Interview Questions

Questions for state water quality experts, non-profit organizations, and other stakeholders:

- Describe your participation/involvement with your state's water quality program.
- What are the key issues with current water quality programs and policies in your state, particularly as related to agriculture?
- What are some examples of water quality programs or policies seeking to address these issues? (e.g. regulatory vs. voluntary, impacts on farmers' ability or interest to participate?)
- What has been the impact resulting from these water quality programs or policies? (e.g. water quality improvement, water conservation, etc.)
- How is the impact of the water quality programs or policies tracked or measured? (e.g. data, communication, etc.)
- What are current "best in class" practices associated with water quality programs? And how can other states like Arizona replicate them?
- What changes in programs or policies could positively impact future water quality and quantity?
- Who are the key stakeholders in water quality decisions?
- What are the risks/costs associated with treating contaminated well water for drinking?
- What best practices are recommended for desert style agriculture?
- How is equity accounted for in water quality schemes? (e.g. farmer access, Indigenous water rights, community impact, etc.)

Questions for farmers participating in state water quality programs:

- Describe your participation/involvement with your state's water quality program:
    - When did you start?
    - How did you learn about the program?
    - What water quality practices are you using?
    - What does the process look like from a farmer's perspective?
- If the program is voluntary, why did you choose to participate?
- What impacts have you seen from participating in the program?
- What do you like best about the program/policy?
- What would you change about the program/policy?
- What resources would make it easier for you to better address water quality on your farm?
- Are there any other farmers or people working in agricultural water quality that we should talk to for this research project?

Appendix 2: Glossary of Abbreviations and Acronyms

3MP	Third Management Period
AMA	Active Management Areas
ADEQ	Arizona Department of Environmental Quality (ADEQ)
ADWR	Arizona Department of Water Resources
AgCWIP	Agricultural Clean Water Initiative Program
APP	Aquifer Protection Permits
ARC	Arizona Reconsultation Committee
ARS	Arizona Revised Statute
AWPF	Arizona Water Protection Fund
AWS	Assured Water Supply
AZDA	Arizona Department of Agriculture
BIP	Basin Implementation Plans
BMP	Best Management Practices
CAFO	Concentrated Animal Feeding Operations
CAGRD	Central Arizona Groundwater Replenishment District
CAP	Central Arizona Project
CDPHE	Colorado Department of Public Health and Environment
CNCEP	Connecticut Nitrogen Credit Exchange Program
CRP	Conservation Reserve Program

CSP	Conservation Security Program
CWA	Clean Water Act
CWCB	Colorado Water Conservation Board
CWF	Clean Water Fund
DCP	Drought Contingency Plan
EPA	Environmental Protection Agency
EQIP	Environmental Quality Improvement Program
GMD	Groundwater Management District
IGFR	Irrigation Grandfathered Right
INA	Irrigation Non-Expansion Areas
KDA	Kansas Department of Agriculture
KDHE	Kansas Department of Health and Environment
KWO	Kansas Water Office
LEMA	Local Enhanced Management Area
MAEAP	Michigan Agricultural Environmental Assurance Program
MCL	Maximum Contaminant Levels
MDARD	Michigan Department of Agriculture and Rural Department
MPCA	Minnesota Pollution Control Agency
NCAB	Nutrient Credit Advisory Board
NDEE	Nebraska Department of Environment and Energy

NGO	Non-Governmental Organizations
NOAA	National Oceanic and Atmospheric
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
OBEP	Office of Border Environmental Protection
RAP	Required Agricultural Practices
RIA	Regulatory Impact Analysis
SDWA	Safe Drinking Water Act
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Loads
USGS	US Geological Survey
VESP	Vermont Environmental Stewardship Program
VPFP	Vermont Pay for Phosphorus Program
VRBP	Verde River Basin Partnership
WBP	Watershed-Based Plans
WCA	Water Conservation Areas
WOTUS	Waters of the United States
WQCC	Water Quality Control Commission
WQT	Water Quality Trading (WQT
WRAPS	Watershed Restoration Protection Strategy (WRAPS)

About the Authors

Zac DeJovine

Zac is a local graduate of ASU, having studied Political Science during his time there as an undergraduate. In addition to this conventional university education, Zac was also diagnosed as diabetic his freshman year at school. In some ways this personal health experience was as educational as his classroom experience, and helped to lead him down the path he is now currently interested in, that of the connection between politics, sustainable economics and the impact of food and housing on these systems. He believes that in a system where people inadvertently vote with their dollar for their own environmental destruction, economic choices that are truly sustainable must give people a way out of contributing to climate change. He currently works as a math and Spanish tutor, y está completando su certificación para ser maestro de español. When not reading about dirt, he enjoys running in his EarthRunner sandals and befriending every dog he meets.

Jillian Dy

Jillian is a former vegetable farmer and sustainable food advocate working to reorient the food system toward transparency and equity. As Policy Specialist at FoodCorps, Jillian supports partners and leads projects to build the case for federal policy reform that will strengthen local and regional food systems, support farm to school procurement, and create more equity in child nutrition programs. Prior to FoodCorps, Jillian was Deputy Director at The Common Market Mid-Atlantic, a nonprofit food hub that creates wholesale market opportunities for sustainable family farms while increasing healthy food access through institutional procurement. Her efforts leading the Mid-Atlantic outreach team resulted in $15.5 million of local food sales from over 100 small and mid-scale farms. Jillian is a Senior Fellow of the Environmental Leadership Program, and was a 2020 finalist for NYC Food Policy's 40 under 40.

Ami Freeberg

Ami Freeberg works for Cultivate Kansas City, a nonprofit working to grow food, farms, and community in support of a sustainable and healthy local food system for all. She began her career with Cultivate Kansas City in 2010, working for seven years in communications, outreach, and community engagement. After four years away, Ami rejoined the team as the Program Manager for Metro Farms & Food Systems, working with Kansas City's urban farmers through technical assistance, networking, grantmaking, and collaborative advocacy. She serves on the steering committee of the Greater Kansas City Food Policy Coalition. Ami has also worked in community development and environmental nonprofit organizations. As a passion project, Ami founded and runs Longfellow Farm, an urban farm where neighbors work together to grow food and build community. Ami graduated from Grinnell College with a degree in Sociology and Global Development Studies.

Shelby Kaplan

Shelby recently graduated from the University of Wisconsin Madison with a degree in plant pathology and a minor in food systems. She is originally from New York, but did not have a background in agriculture. Wisconsin introduced her to organic agriculture and its importance. Shelby's interest continued as she worked in research labs focusing on plant diseases in major crops. In her classes she kept coming back to agricultural policy issues. To her, this is how to make the largest difference. After graduating she was able to support the Organic Farming Research Foundation as an intern and hopes to continue working to improve our food systems.

Deborah Sadler

Deborah is the Operations Manager at the Food Connects Food Hub in Brattleboro, Vermont, where she has coordinated the distribution of local food throughout New England throughout a period of high growth. She is excited about providing real-world practical solutions to deliver food from producers to consumers and leveling the playing field to provide access for smaller producers and customers. She wants to help build strong local networks that help the profits stay with the producers. While studying anthropology and international relations at Eckerd College, she became passionate about the culture of food. She went on to research the effects of government policies on farmers' ability to adapt to drought. She previously worked at farms and creameries in Massachusetts, Vermont, and Washington state, including managing a goat dairy and farmstead creamery.

Nithesh Wazenn

Wazenn, Nithesh is a US liaison to the research wing of a multinational company, who turned to be homeless, lived in the streets of New Jersey, was kidnapped, lost immigration status, became illegal, got debarred from entering the United States for ten years, and lost footing in society. Eventually challenged his difficulties and established life in the United States.

Wazenn worked with the Labor Racketeering Division in a fraud investigation that helped over 146 immigrant students regain their valid immigration status and back wages from a fraudulent employer. He is also the first individual to be granted a direct permanent residency in the USA by the Labor Racketeering Division, Voorhees, NJ for helping end IT sweatshop trafficking. He has operational expertise across discrete manufacturing, oil & gas, and telecommunication companies in United States, Europe, and Asia-Pacific regions and practiced as a paralegal specializing in business laws and Immigration. Wazenn's entrepreneurship journey started as a climate change entrepreneur and failed due to governmental regulations. The lessons learned from failure eventually led to an interest in food policy & governance and sustainable food systems.

Contact for more information:

Swette Center for Sustainable Food Systems
Email foodsystems@asu.edu | Website foodsystems.asu.edu

Swette Center for Sustainable Food Systems is a unit of ASU School of Sustainability