The evolution, and innovation, of an urban water trading system

Provisional summary report assessment*

A pilot demonstration project to establish a prototype online water savings marketplace

Grant funding support provided by the
California Water Foundation

Organized under the authority of the
Sonoma County Water Agency

Engaging the leadership and customers of the
Valley of the Moon Water District

Using customized software developed by
AquaShares Inc.
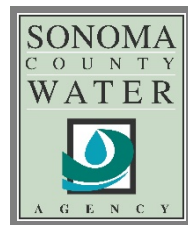
Prepared by James Workman

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*This internal summary completes the final deliverable of the grant allocation to AquaShares in the time allotted. But because the pilot will run through October 2017, AquaShares has committed to provide and present a further supplementary outside report when complete, at no additional expense to other entities.

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Executive Summary

Several years ago, a novel pilot demonstration project in Sonoma County set out to address what might seem a simple question, but one that has potentially large and complex repercussions: *who has incentives to save urban water, and what is that conservation effort worth*? The answer could alter the relationship between retail water providers, urban consumers, and the value of the resource they share. As water resources grew increasingly volatile – driven by escalating stress from pollution, population, prosperity and a changing climate – a clear price signal might offer a potent new stewardship tool to align diminishing supplies with rising demand, while securing the financial health and institutional stability of water utilities, districts and agencies.

The ambitious search for answers was unlocked by several institutions with overlapping motives. A bold and progressive water wholesaler, Sonoma County Water Agency, sought new ways to optimize systemic usage whether to reduce demand or mitigate threats to endangered aquatic species. An innovative and financially prudent public water retailer, Valley of the Moon Water District, wanted to empower its customers to see how much they want to conserve and be rewarded for doing so. Generous funds from the California Water Foundation, a philanthropic organization, hoped to find scalable solutions as the State entered a four year crippling drought. A $100,000 grant invested half of the funds into the acquisition and installation of new advanced metering hardware and software, linked, through the other half, to custom-developed software that combined the display of robust information about current demands and economic motivation to use less.

Not all aspects of the pilot were new. Others previously had provided online customer portals and dashboards to monitor consumption with advanced meters; some helped reduced demand 2-5% by comparing usage against peers. Previous extensive research efforts had also tried to give economic value to water through estimating a customer's "willingness to pay." And consultants routinely advise utilities on rate structures order to set the appropriate supply fees water utilities can charge customers, in order to balance out fixed and variable service costs with fixed and variable service revenues.

But the actual water itself remained, in these other cases, effectively priceless. It had neither relative nor scarcity value among competing users. So the Sonoma pilot sought to discover something rather different, and in many ways the opposite: the customer's "willingness to save" in order to set a price for water savings, sold to and paid by businesses, neighbors, governments, charities, or the utility itself. It offered the first online water savings marketplace, in which metered retail accounts could earn and trade 1,000 gallon conservation credits, known as AquaShares, with others sharing the system. In doing so, it opened up the possibility of "crowd sourcing" a new potable water supply source: not from new dams, desalination or groundwater drilling, but from within the existing water service district.

How to discover that price and quantity ratio proved an interesting challenge for the pilot to overcome. Initially it was suggested that the pilot base shares according to size of dwelling; or on number of occupants per structure; or pegged to average usage. Each of these approaches exposed drawbacks that would exclude participants, cause inequity, and/or discourage engagement by a majority (winning or losing regardless of future use). Ultimately, the pilot allocated each account an AquaMark, based on an algorithm of recent historical usage, adjusted to weather. Families and firms would earn AquaShares against their own average usage, encouraging best performance, allowing for 100% engagement, while putting a premium lesson on social equity (which could thrive in a true cap and trade, discussed later) than on generating maximum water savings over time.

The pilot, involving just over 300 participants, set a thin green line threshold (AquaMark) from several years of bimonthly data. It then introduced and displayed realtime tracking of daily feeds of current consumption to show users either how much they "earned" each day they kept below that threshold, or "lost" whenever they exceeded it. At the end of each month, if a client earned more AquaShares than it lost, the earnings could be owned and sold. At the client's request, monetary transactions for AquaShares could be delayed, while earnings could still accrue. When the price was introduced, at $0.91, participating accounts who earned shares were able to cash out for between $1 and $25 per month.

As the pilot unfolded, the water agencies statewide confronted and adapted to new discoveries, unforeseen delays, and forces beyond their control. Among these was Governor Brown's unprecedented imposition, and later lifting, of drought restrictions on every water utility in the State. The State legislature enacted the landmark Sustainable Groundwater Management Act, which set new priorities and institutions. The tiered rate structure used by 2/3rds of water agencies, including VOMWD, was put in limbo by Appellate Courts under Proposition 218, which prohibits collecting more for a service than it costs to provide it. This left California wrestling with how to comply with its constitutionally enshrined human right to water, raising fundamental legal, moral, and practical questions,: Should water be free? How much, or unlimited amounts? Of what quality? For which purposes? *Who is responsible for urban water, and what might it be worth?*

The AquaShares pilot has begun to tackle these questions, and has also gained traction and sparked strong interest from top universities (Harvard, Columbia, Oxford, Stanford, and UC Davis, UC Berkeley, UC Santa Barbara), by corporate multinationals in the beverage and mining industries, by coastal communities with as few as 161 metered accounts, and by major cities like Marrakesh, in Morocco which announced its urban adaptation of this approach while hosting the COP-22 as progressive ways both to mitigate emissions and adapt to climate change already underway.

Introduction

At first glance, California's urban thirst may seem an almost negligible concern. After all, total demand has been falling, even as the State's population rises. Per capita daily water use had declined from 232 gallons in 1995 to 178 gallons in 2010; in 2015, it fell to 130 gallons due to drought requirements, mostly through reduced landscape watering, which makes up roughly half of all urban water use. So why a new water district-level pilot to reduce demand?

Rationale

For starters, no one knows if or how much of these savings will persist beyond the drought. Also, cities do not exist in a natural, political, or temporal vacuum; they compete with rural, industrial and environmental demands. In dry years urban water use rises from 8% to 13% of California's water supply. That supply also accounts for the bulk of carbon-intensive energy, the nexus embedded in the process of lifting, moving, heating, and treating water to and from cities. Comparable regions, like Australia, use a third less urban water; so there is room to improve.

More fundamentally, California's urban challenge provides an intense microcosm of water problems globally: an undervalued resource leads to waste, scarcity, human conflicts, and freshwater extinctions. Conflict over inequitable access to California urban water has intensified, as past abundance has grown scarce. Today, many State and Federal mandates (ESA, CWA, SDWA, NEPA) govern the impacts of surface water diversion and use. These will soon be compounded by the 2014 Sustainable Groundwater Management Act (SGMA), forcing local basin stakeholders to ensure groundwater is used sustainably..

At the core are institutional threats. Service fees can no longer, legally, exceed costs of provision, as tiered rate structures have in some cases been ruled unconstitutional. Energy and labor costs for pumping keep rising. While California is among the leaders, its non-revenue water losses are estimated at 10% of all urban water use, bleeding an estimated $30-35 *per customer* each year in lost energy and carbon with each leaked drop. Such risks combine to test the resilient adaptive capacity of how cities can provide a precious shared resource. The limits force urban water managers in particular to confront a complex collective action issue, a 'wicked problem,' with three maddening water-related paradoxes.

First, the paradox of urban value means that water – while priceless in use – is worthless in exchange, a flaw that confounded even Adam Smith in his Wealth of Nations. Next, a paradox of efficiency ensures individuals who save water – via drip irrigation, high efficient toilets, drought tolerant landscaping – allow the whole system to demand more and more. Finally, in the paradox of monopoly, due to the high cost of capital investments and fixed costs saving water eats into utilities' income.

Even the most advanced and progressive urban water managers have been unable to manage these paradoxes through centralized restructuring, or top-down restrictions alone. The core obstacle has been revealed by behavioral economics. By natural instinct, humans neglect or abuse what we merely rent, yet we are stewards who protect and care for and invest in what we own. Right now, we all rent our municipal water; what we save belongs to everyone and no one, and in this tragedy of the commons (at the consumer level) there is no reason to plan for the future. What if people could, in fact, own their water savings? This would provide a strong incentive of rewarding 'carrots' to work in tandem with existing regulatory 'sticks.' That potential symbiosis is why we proposed a scalable, replicable, distributed, decentralized, bottom-up pilot, to test a solution: the first urban water savings marketplace.

Socio-ecological context

Families and firms in this pilot draw their water supply from two limited sources. The bulk comes from the Russian River, which empties into the Pacific; a smaller portion comes from groundwater linked to Sonoma Creek, which trickles into San Francisco Bay. Both sources, like coastal basins up and down California,


suffer from the classic 'wicked problem' known as the tragedy of the commons. Each day, tens of thousands of farmers, tourists, businesses, and residents divert, pump, degrade and withdraw water from their currents. All too often, they can't know the proportion of what they remove, the degree of seasonal risks they impose, or even exactly where their water comes from.

Even some water managers can be unaware of the precise extent of direct and indirect impacts on the natural integrity of the basin – how common actions put endangered steelhead, salmon, frogs, and other aquatic species at risk by lowering groundwater tables and fragmenting the continuous current into lethal isolated puddles. Worse, even if every individual was indeed

aware of his or her usage and impacts, each has no reason to reduce demands on this precious, natural aquatic resource out of self-interest.

Why? In Garret Hardin's famous parable of the open access public 'commons,' every producer is aware that natural resources – a grassy pasture, a coastal fishery, a freshwater stream like The Russian River or Sonoma Creek – are finite. But he is compelled by rational needs to take more and more, beyond the point of irreversible systemic collapse, until "therein lies the tragedy. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believe in the freedom of the commons. *Freedom in a commons brings ruin to all.*"

Against potential ruin, authorities had two standard enforcement options. Either police keep public resources from private theft through strictly regulated wild and scenic rivers or police guard natural property from public theft, through strict privatization of water. Californians tolerate neither. Yet as the late Nobel laureate Elinor Ostrom has argued, there is in fact a proven bottom-up solution to this wicked problem: community-based peer water negotiation. The water commons need not be tragic if measured and managed by a self-regulating local community, given the right tools and the ability to establish a transparent, accountable system. For modern water systems, this might include realtime metered usage within a basin, and then trading water savings within it. This pilot engages stakeholders to help restore the ecological health, structure, and integrity of the currents they share, and do so not out of guilt or fear of punishment from above, but rather through incentives that harness self-interest in a mutually reinforcing race to conserve.
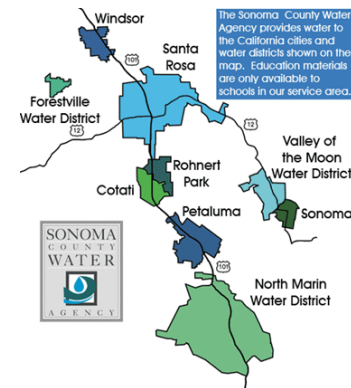
Background/History

In 2012, AquaShares Inc. (then known as SmartMarkets LLC) approached several leaders at the Sonoma County Water Agency with a proposal. To reward water efficient end users, customized software (then known as AquaJust) would capitalize on the convergence of three market drivers: ecommerce, social networks, and the green movement. The project would unlock new and democratic 'click' markets within a utility's natural 'brick' monopoly, through an online web/mobile platform that can be scaled, transferred, replicated and customized to all utilities. The project would not touch, redirect or divert physical water; nor would it tinker with staff, hardware, pipes, or canals. Infrastructure would remain as is, but software could transform how customers – who become vested through earned AquaShares (then known as EcoShares) -- value and use water in their consumption, reversing the supply/demand relationship.

"Save & Trade" software allows residential and commercial end users to own, save, accumulate and trade clearly defined water efficiency credits, and encourage meter adoption where none exist (groundwater pumping). It taps the self-interest of ratepayers to save water, money, and earn extra income through a transparent and accountable process.

Water markets are hardly new in the West. In California, prior appropriation law allows voluntary exchanges that reallocate water use among riparian parties who benefit from trade. Yet transaction costs are prohibitive due to geographic constraints, slow legal negotiations, and a small pool of buyers and sellers. This limits potential, creates economic distortions, and keeps market access exclusive to a few.

AquaShares technology could democratize the benefits and incentives of markets for all municipal users, by trading saved virtual credits within a closed water distribution system. It dramatically reduces transaction costs through a Web 2.0-based transaction platform. And it endows all metered accounts with an equitable way to earn water credits, ensuring that efficient gains are based on conservation merit.

While the pilot's initial volumes of water saved – and cash earnings generated – may seem minor, the scalable system has been designed for replication to all metered users throughout a district, across Sonoma County, and for hundreds of water utilities of California and the West. If scaled up to 600,000 people in Sonoma County alone, for example, a 29% reduction annually saves supplies 13,500 acre feet of water, water now available for dry seasons, other uses, kept in reservoir, or released for endangered aquatic species.

SCWA expressed a willingness to experiment, and included this as a pilot having engaged a client district (initially the City of Sonoma, which dropped interest when it changed management) in Valley of the Moon (VOMWD), led by General Manager Dan Muelrath, who engaged his Board under president Jon Foreman, to combine to VOMWD's new Badger/Itron meter hardware with a customer portal provided by AquaShares software.

Local water markets may be as old and universal as civilization itself, and are still practiced among Kalahari Bushmen (!*xaro*), Arabian villagers (*aflaj*) to Persian towns (*qanat*), Spanish irrigators (*huertas*) and Balinese rice growers (*subak*). But nothing remotely like this has been tried in US cities or suburbs. Given the potential for misunderstanding such a radically new approach, the software was developed and released in smaller and slower stages than initially envisioned. While this deliberate process set back the timetable for completion, it allowed for more careful and judicial analysis and adjustments along the way.

Comparable resource models

This sounds radical. But AquaShares' approach has been universally proven over millennia not only by every traditional culture, but also, more recently, by California's no-longer-at-risk fisheries. Indeed, the pilot offers the freshwater counterpart to the State's highly successful, self-managed cap-and-trade fishery model. After decades of decline under the old broken system, fishermen are now thriving as 'catch share' conservation markets have been proven to:

- slow, stop, and even reverse risks of depletion, pollution and waste;
- align private interests under public social and environmental goals;
- put more food on plates, profits in the bank, and wildness in nature;
- spur competitors to share data, collaborate on innovation; and

- dramatically increase compliance with scientific extraction limits.

Based on this model, how might the AquaShares pilot work in collaborative practice?

Step by step process

First, parties worked closely to clearly define and document short and long-term goals. These included: reducing demand, ensuring transparency, or avoiding leaks on both sides of the meter.

Then they developed a customized platform to reach these specific economic, social, and ecological outcomes, developing clear incentives that align private and public interests.

Drawing from data files documenting past usage, we assigned each account an AquaMark, or distinct threshold, based on the mean of their historic consumption. All accounts would be held to the same high standards, but each AquaMark is unique, and will represent a percentage of the whole, of all water withdrawn.

Significantly, one consumptive "user" beyond the existing accounts, was the VOMWD itself, as we have found that many districts can't account for losses of 10% or more of water withdrawn and treated even before distributed to your customer base. The system could turn this loss into an opportunity, with incentives to reward detection, fixing, and reduction of 'non-revenue water.'

The AquaMark ensures access to the same amount of clean water and, broken down by percentage, covers exactly the costs of service provision. There may no longer be a need for tiered rates, especially if a utility graduates to an approach described as a "variable-fixed" rate, where provision costs are kept distinct from water's value, giving utility financial security while letting customers negotiate water's value. This helps address Prop 218 liability concerns, as well as ensuring the human right to water. Revenues collected are more predictable, reliable, equitable, transparent, accountable, and secure. Users track and continue to consume amounts of their pattern of usage, with no surprises.

Outreach/Customer Discovery

One key early component of the pilot was to get a sense of what potential participants would prefer. Did a water savings marketplace make sense to them? Would they use it? Outreach has the dual advantage of preparing potential end users for what is to come, and managing or recalibrating the expectations and design by those shaping the pilot.

It was decided that rather than confuse, scare, or tip off future participants, and thus raise endless and perhaps needless concerns that could derail the pilot, outreach would be conducted among families and firms outside of VOMWD's service area, but in roughly comparable socioeconomic brackets. A similar

approach was taken to media and communications: until it began, all parties would describe the pilot only in the abstract, rather than in specific details. [See appendix]

Accordingly AquaShares employed two different college graduates to conduct phone and door-to-door surveys of a sampling of businesses in Sonoma and Marin Counties and residences in San Mateo County. The results were instructive.

Businesses, especially those that were the most 'water intensive' (spas, resorts, breweries, vineyards, coffee houses) were sensitive to brand reputation, and keen to find new ways to reduce or offset their water footprint. They felt concern about how much time and money would be required of them. They liked the fact that participation would, at least initially, be purely voluntary, allowing them to opt in or out at a price that was feasible to their own unique needs and desired outcomes. Interestingly, when we approached some of the largest of these industries, they expressed openness to the idea of offsetting their use through purchases of AquaShares earned by others. Yet several quickly made the leap to exploring how AquaShares could work as a market within the various units and branches of their own institutional corporate structure, turning water from being current cost items, or liabilities, into future earning centers, or assets.

Residences also liked the concept of voluntary, incentives-based conservation, as they felt mandates and regulations and rations most punished those who were already trying to save water. But many stated that they were less interested in the monetary gains (almost no one knew how much they paid per gallon or water, or how much water they actually used), than in understanding how they ranked within their local community. This reflects studies on peer pressure, but allowed the pilot to create a unique feature showing performance ranking not compared with an abstraction, but as measured against all participants in the pilot.

By far the most significant part of "customer discovery" and outreach was in better assessing and understanding the goals of the utility with which we were aligned. For example, while VOMWD was meeting its conservation targets, it became clear that reduced demand by customers ate into revenues, causing financial uncertainty. Nor did it feel pressed up against a wall of growing demand and shrinking supply. More important was optimizing customer service, client relationships, and showing itself as a socially conscious thought leader in the industry.

It also became clear that a utility supplier was also, in effect, a "consumer" of water, due to non-revenue water loss (NRW). VOMWD estimates of NRW were relatively low. And advanced meter installation could improve the location and measurement of leakage on both sides of the meter. But the pilot realized that an

online water savings market could make corrections far more economical to all, allowing utilities in particular to address water loss at a large scale with relatively small investments.

In outreach related to goals, we posed questions and sought answers that could apply beyond a single utility to meet the vexing challenges which undercut the integrity of 53,000 U.S. utilities, private or public, large or small. There was a deep perception in these interviews of an "us versus them" dichotomy when it came to water. Utilities charge what they want, while customers pay what they must. The system appeared arbitrary, with perverse incentives; many raised their frustrations at saving water, only to have the utility raise rates to make up the shortfall in income ("We get punished for doing the right thing, for doing what they tell us to do"). The resentment went beyond local retailers toward "the whole system" to include County and State and Federal levels, in which central authorities can and do fix a scientific 'cap' on water use, but find it difficult, in any democracy, to enforce stewardship and compliance by all, without "free riders." Top-down, unilaterally imposed rations, restrictions and rate hikes spark anger and protest from below. To meet private needs in a way that builds public trust and consensus, stakeholders urged the pilot to adapt a flexible approach of strong incentives: a self-managed conservation market that unlocks a competitive race to conserve.

Questions & Answers

How will people know their usage? Advanced Metering Infrastructure (AMI), collect real-time (every 15 minute) usage, and transmit this data to AquaShares. VOMWD may soon be able to alert users who develop leaks, and can detect and identify losses throughout the system. Accounts will be able to log in and see their usage, and ensure fidelity to their AquaMark.

What if people use less? AquaShares encourage investments (time, energy, thought, funds) into voluntary conservation measures, by rewarding all (including VOMWD) who go and stay below their AquaMark. Supply and demand for water – from within or outside the district – rewards (not punishes) those who reduce demand, fusing reliable information with strong motivation.

What if people use more? 'Waste' is in the eye of the beholder; some new or current accounts will want or need to use more water than they have in the past. Like a local online farmers market for water, clearly defined and locally transferable AquaShares resolves the tragedy of the commons, introduces a value for water, and sparks a widespread race to conserve, ensuring VOMWD becomes increasingly 'climate-proof.' It is a form of contained, secure, transparent, local, and creative capitalism.

Isn't this privatization or commodification of water? Others may object on ideological grounds, assuming water, as a right, should be free, and not traded in a marketplace. But any resource provided for free
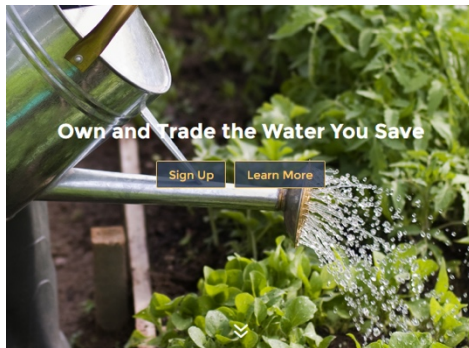
invariably tends to be devalued or wasted by the recipient. Those who imagine water as gift from god or nature ignore the costs of lifting, pumping, cleaning, conveying, heating, treating it; these service provision has costs. AquaShares equitably balances the costs of service provision, while giving scarcity value to water itself.

Software development

As a general rule of thumb, AquaShares' design and development of the online marketplace platform paralleled that maxim in architecture: "Form follows function."

The core function of the AquaShares pilot was to assign a unique allocation privilege, or "share" of water to each account, based on past usage. Initially this past included ten years, but, given the mandatory reductions imposed by the State, was adjusted to the three most recent years of historical data. From this baseline threshold, the pilot would calculate performance for status ranking, display usage, encourage earnings, and allow transactions of water for monetary or from donations (psychic income).

From these functions, the pilot broke down the software 'form' in two parts. First, a foundational "back-end" wireframe of code was developed by AquaShares to integrate, calculate, adapt and process all the raw data according to pre-defined logarithms. It would update records daily, and track performance and gains from the moment a participant enrolled in the system.

The 'front-end' surface display developed by AquaShares arranges that data in user-friendly features and format that allows for simplicity and ease of interaction.

Managing and clarifying the database

As a starting challenge, past historical data had to be 'cleaned' from the existing format in which they had been stored. The pilot had to make meaningful sense out of the past. To do so, we first cleaned the 9-year bi-monthly meter data for VOMWD's customers to detect errors and anomalies (n= 6,940 meters). We then ran analytics on the cleaned database including calculation of bi-monthly water use per customer per year (use per 2 months per customer) and average bi-monthly water use per customer, adjusted by weather, and calculated the percent use per customer as a portion of total use, annually. Finally, we created demand profiles per customer, based on high or low peaking and high or low demand. This effort delivered a report (see appendix) on the AquaMark, with demand profile results, a data dictionary, description of methods, a cleaned database containing all customer analytics, and a presentation communicating key results and methods.

## Integrating online software with meter hardware

A second logistical and functional challenge arose when VOMWD installed new meters. First, because the meter number changed, the new data was no longer aligned with the old codes; it took weeks to resolve the discrepancy and find a common denominator. Then, without warning, the meter identifications were
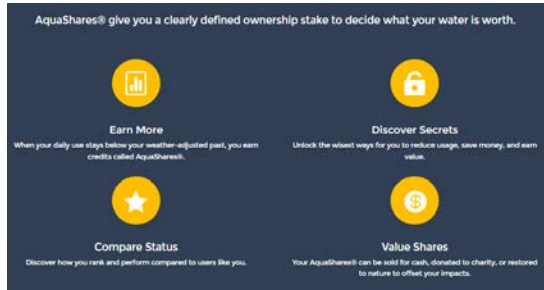
stripped and recalibrated, forcing a second adjustment. Ultimately, the utility, the meter company, and the software developers were able to get on the same page, and avoid similar disruptions in the future. We have developed a data formatting requirements document for current and future integration [see appendix].

Programming the initial allocation

The AquaMark (historic baseline) proved a surprisingly vexing issue, once it became clear how deeply the mandatory reductions had skewed usage patterns. Set too high, and certain end users would earn lots of
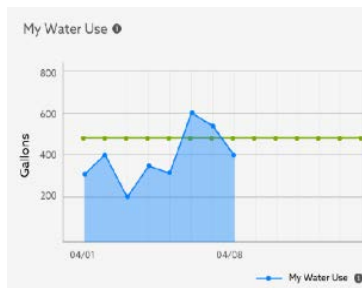

credits for very little investment in time, money and efforts toward savings, while others would have to work harder. Set too low, and the reverse might occur. And compared against a control group, neither might generate significant additional savings beyond the average 24% reduction that had taken place before the pilot began. To resolve this issue we worked through several different models, which algorithm would provide a fourth AquaMark closest to current usage, thus maximizing gains from future performance.

A second interesting challenge arose from the "save and trade" model: deciding how soon AquaShare credits could be 'banked.' If an account earned 25 gallons a day by keeping below its AquaMark for three days – or three weeks -- but then went 200 gallons over it on the fourth, that would constitute a net loss. The pilot couldn't reward a net loss, nor did it have the desire or power to financially punish negative performance. To encourage long term savings, AquaShares decided instead that the pilot would show net negative use as a monthly zero, and only allow 'banking' of AquaShares if, over the course of each month, performance resulted in net positive earnings.

A third challenge was whether AquaShares should expire at the end of each year, to align with allocations from the California Water Board, or whether, like a diamond, AquaShares would be "forever." Each had pros and cons. One of the lessons from catch shares, or fishing rights, was that the longer term the ownership tenure (i.e. advancing from 5 to 10 years, or even
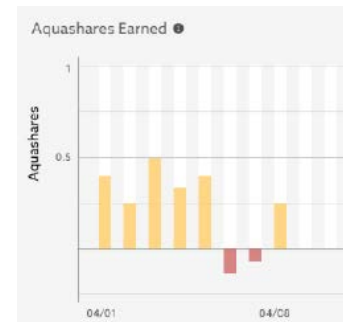
permanent), the higher the investments and performance from stewardship incentives. In these cases, where there was a real limit or cap on total allowable water supply, water savings could roll over into the next year. However, for the sake of the short term "save and trade" pilot, in which there was no cap, all banked shares, if not sold or donated, would simply expire at the end of a year. Earnings would resume again the next year.

User Experience Tests & Results

Before launching the site, the pilot devoted two months of time, money and effort into testing and learning from user experience in three ways. First, AquaShares engaged seven random users who had no knowledge or understanding of the project. The subsequent written questionnaire asked about their feelings, challenges and frustrations at every step, from the initial process of registration to relative understanding of what the dashboard revealed about: recent water usage, AquaMark, earnings, ranking and balance. AquaShares hired three individuals to video themselves, and their screenshot, as they clicked on and engaged with the website, speaking out loud as they tried and failed or succeeded at various tasks and metrics.

AquaShares identified several observations and lessons. Until there was an actual price for AquaShares, users couldn't appreciate what the platform was really for, or how they could donate or offset usage. The AquaMark needed clearer explanation. Some sought customized water saving recommendations. Most did not like being taken from the AquaShares site to the VOMWD for water saving tips, and the value of water as shown by AquaShares.
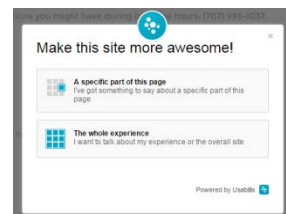
From these user experience efforts, AquaShares was better able to clarify assumptions and goals, with pop up questions. AquaShares streamlined a user feedback tab for customer suggestions to crowdsource

solutions. The firm also moved up the display of social performance, the feature relative to others in the study, for example, ranking 121 or 38th percentile.

AquaShares introduced a new page for water savings ideas, along with Frequently Asked Questions, and showed what the outcomes might be based on average usage, information that turned out to be more important once people saw water savings as an asset they could liquidate. An AquaShare was based on 1,000 gallons, not 100, and the platform recalibrated the calendar from what had been 12 day cycles, to show current week, month, year, lifetime, and synchronized each feature to rotate accordingly.

To set the stage for longer term goals, the platform included the paragraph: "During the summer of 2016, you will be able to take three actions with your AquaShares: sell, donate, or offset usage. You can sell your

AquaShares to earn cash, or donate your AquaShares to your local utility, or offset your usage to improve the environment and earn a designation from AquaShares. We will send you an email when we enable this functionality."

From these lessons, AquaShares drafted an outreach letter to try out with the VOMWD staff. The goal here was to incorporate a fourth round of user experience testing, and to ensure the utility would be able to handle internally any questions that might arise from its participating customers.

Several users in the tests expressed interest in optional, 'nice to have' future features. One as a customized goal setting and tracking component, that would allow each user to project weeks or months into his future,
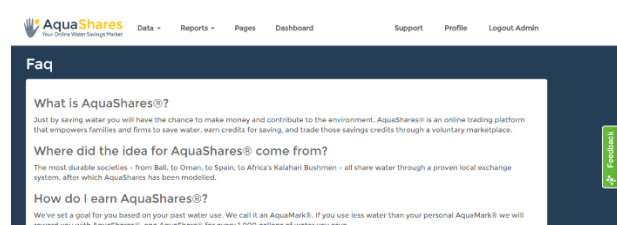

and be alerted if, when and how he or she was meeting performance targets. Another was a weather/climate/temperature feature that aligned with past and near future, which would attract more frequent visits and allow users to plan water use.

Legal requirements

Once established, but before going live, the pilot had to clear two important legal hurdles in order to ensure compliance with judicial norms and adapting boilerplate to reduce risks of litigation or misunderstanding.

First, AquaShares had to lay out the Privacy Policy for all participants signing up for the project. This included usage of sensitive information, jurisdictions, choices, access, third

party advertisers and services. To promote water conservation and reward users for their water-saving efforts, it describes our practices in connection with information that we collect through websites, through the software applications made available or mobile devices, as well as through HTML-formatted email messages. By providing Personal Information, parties agree to the terms and conditions.
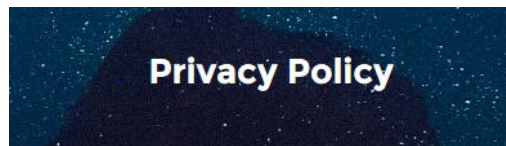
Next, AquaShares developed Terms of Service, which outline changes, information submissions, jurisdictional issues, rules of conduct, transactions, taxes, registration, profiles, license, monitoring, rights, proprietary data, third party links and materials, liability and indemnity, filtering, complaints, copyright infringement, export controls, etc.

Within these rules of engagement, for example, the pilot "may provide an electronic platform that allows you to monitor your water consumption based on information provided to us by you or your water utility. You may be able to earn virtual credits, which we call "AquaShares", based on the reduction in your water

consumption, or you may lose AquaShares based on excess water consumption (down to a zero balance). You may be able to sell or donate such AquaShares to other Site users that desire to obtain AquaShares. The rates and methodologies by which AquaShares are calculated and earned, and the prices at which such AquaShares may be purchased or sold, are subject to change."

What's more, "The availability of AquaShares does not imply our affiliation with the purchaser or seller of such AquaShares. Certain weights, measures and similar descriptions are approximate and are for convenience only. It is your responsibility to ascertain and obey all applicable local, state, federal and foreign laws (including minimum age requirements) regarding the purchase and sale of any AquaShares."

Going Live

At the end of August 2016, VOMWD sent out a jointly prepared invitation letter to ~300 customers who had been equipped with Badger/Itron advanced meters.

Letter

The letter informed each that he or she was among a small group chosen to take part in a free and voluntary water-saving rewards program, supported by the California Water Foundation, which opens a new opportunity to recognize, inform, empower and financially reward your efforts to save water. Once enrolled, the customers would gain access to a yearlong program of new benefits that lets them:

- ➢ Review and compare your daily use against your weather-adjusted past use;
- ➢ Discover how your water saving efforts compare to those of your neighbors;
- ➢ Start earning 1,000-gallon water saving credits, known as AquaShares, which you can (in the fall) sell for cash or restore to nature.
- ➢ Find the best ways you can reduce water use during California's water shortage.

To sign up and start earning AquaShares, they were directed to register at a VOMWD site, enter customer IDs and last name, check out how much water you're saving, how many AquaShares you're earning, and (soon) the latest AquaShare market prices and value of your savings.

Participation

The pilot had been warned that the normal sign up from outreach ranged from a 1-2%. A 3-4% response rate would be highly successful. In the first week, VOMWD received several calls from customers who asked for more details about the program, or sought help in signing up. Most of these enquired about the potential financial gains from transactions, but the pilot had decided not to introduce a price for the first two months after going live. Lack of a price may have been one deterrent; having to register through two websites instead of directly to just one might have raised a second obstacle, while at the same time providing more assurance and security that the program was legitimate.

In any case, AquaShares was gratified over the subsequent weeks as 11% enrolled in the AquaShares program, even before a price was introduced and transactions were allowed. We anticipate that 18-20% may enroll following the second mailing, which introduced a rising AquaShares price.

Setting the price

Introduction of the initial price involved much complexity, discussion, debate, and analysis. It was a core feature of the pilot. As part of the grant, funds had been set aside for purchase of AquaShares from customers, thus revealing a "willingness to sell" water that had been saved. But as the sole buyer, or 'market maker' this presented us with certain challenges, to put it mildly.

On the one hand, the price needed to be high enough to attract the most users to save the most water, especially as opposed to a control group without access to their social performance rank, daily water usage, or monthly earnings accrued by volume or value.

On the other hand, paying "too much" for water savings risked the viability and scalability of the program, and would fail in the long term to attract potential private, non-profit or public buyers of water savings credits, including future purchases by the utility itself.

We estimated that a certain degree of savings, up to 5%, could be generated by providing customers with realtime information about daily usage, and showing their social ranking, apart from a price signal.

In addition, based on reading one analysis (Mansur, Olmstead) of "willingness to pay" for water services throughout the state, adjusted by income, it was estimated (see appendix) that the pilot will need a price = $6.70 per AquaShare in VOMWD in order to drive an additional 10% savings. This estimate, while more than what the customer pays for the water delivery service, was based on several drivers:

- Price sensitivity research, with the two main parameters being income and % outdoor watering. We created estimates of these values for each of 410 water utilities in the state.
- Assumptions about what the average user would earn in VOMWD at $6.70, and whether someone would move for that amount, less, or more. This price would result in the average person earning $90 for reducing their usage 10% in Year 1 through a combined payment ($57) and reduced water bill ($33)...or more likely 20% of their outdoor water use for a region that uses 50% of water outside.
- Recognition that the price would encourage structural investments, resulting in a "levelized cost of conservation" that factors in future water savings over 10 or more years, bringing the value of this down in line with competing annual maintenance or behavioral change investments. That higher price, would thus appear sufficient to 'lock in' structural changes over time, resulting in an amortized or "levelized cost of conservation" of less than $1 per year.

17

However, the first two months after our going live suggested that customers were saving more water, and

AquaShare Price - Valley of the Moon
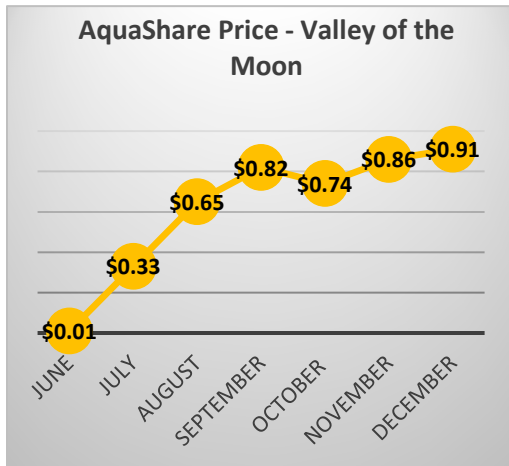
earning more AquaShares than anticipated. At such a price, the pilot would have to expend more funds than the entire amount that had been made available for the program.

Just as significantly, the pilot sought to demonstrate that conservation through a market that paid for outcomes could be driven at a lower cost than alternative supplies, or conventional 'rebate' programs that pay for 'inputs' like showerheads, HETs, cash for grass etc.

The result was a compromise. To manage expectations, but allow room for an increase if interest flags, we showed customers the price rising over several months to $0.91, a penny less than the average costs of pumping groundwater.

First trade: $98.73

The first AquaShare transaction just took place. On 19 January 2017, a VOMWD customer, Liz S., used the AquaShares platform and its marketplace incentives to troubleshoot a leak, and has as a result dramatically reduced her water usage, by 1,500 each day. This added up over time, and when she clicked on 'trade' a check was prepared to reward her with $98.73 in earnings.

This transaction followed the second letter, which shared the news that, based on our estimates, many participating "families have earned $15-65 a month, on top of their lower bill. AquaShares prices rise and fall, but are currently worth $0.91."

The supplementary outside review, which will be provided upon completion of the full pilot, will share the details of AquaShares price/earnings ratios. Meanwhile, the spark of this pilot has ignited curiosity and attention, spreading in several other directions.

Growing Interest

The AquaShares concept grew out of a chapter in a book about the resilience wrought by traditional water exchanges in water scarce cultures. As it grew closer to launch, the pilot continued to gain an increasingly prominent place in the water services literature and discussions. It was featured in a session at the WaterSmart Innovations, held annually in Las Vegas.

Davos/World Economic Forum

And the pilot filled two pages on financial solutions in the World Economic Forum book, Water Security:

"Because people want their newly acquired assets to increase in value, the AquaJust exchange system may lead to an unprecedented situation whereby a majority of end users actually encourage the district to raise rates… with more efficient use, conservation becomes both more challenging but also more rewarding; there are fewer EcoShares in circulation, but each is worth more. This project represents, albeit at a small scale, a classic example in which a public-private coalition formed a strategic alliance to increase efficiency, equity, and ecological benefits for all parties involved."

Nearby counties

Neighboring water districts in Napa and Marin County requested presentations by Muelrath and AquaShares, to consider as an option for building resilience within their own system. Richard Lou, in the finance department of the East Bay Municipal Utility District brought the pilot before his board, noting:

> The Valley of the Moon Water District in Sonoma County is starting a pilot program with AquaShares to assign water savings credits to customers who conserve water beyond their historic use. These water savings credits can then be saved, traded, sold, or donated through the AquaShares exchange. The AquaShares exchange pairs customers who have earned water savings credits with customers to offset their water use (similar to purchasing a greenhouse gas credit for an airline trip) or with organizations looking to encourage reduced water use.

ACWA editorial feature

This followed publication in the magazine of the Association of California Water Agencies (see appendix) of a 'solutions' article capturing the highlights of the pilot and relevance. It set the challenge as:

"Californians — including those served by the Valley of the Moon Water District in Sonoma County — have been practicing heroic water conservation for several years, letting lawns go dry and cars sit dirty. Those efforts may have pushed some water users into "drought fatigue" as they struggle to embrace water conservation for the long haul, even if they aren't being asked to conserve as intensely as they were during the height of the drought. This so-called "drought fatigue" has left some water managers asking how they can sustain water customers' commitment to water conservation moving forward.

This solution followed: "In August, Valley of the Moon WD will launch a pilot program of an innovative, voluntary conservation effort called AquaShares. Under the program, customers who choose to participate will be granted water savings credits, called AquaShares, if they use water beneath a threshold based on past usage. The AquaShares will then be deposited into an account and may be sold for cash on an online marketplace, donated to charity or restored to nature thereby offsetting a user's impacts."

Inside trading

Several of the world's leading beverage companies, agricultural companies and mining companies are exploring with AquaShares a variation on the platform that adapts the cap and trade marketplace for deployment within their corporate businesses operations. Each expressed interest in purchasing offsets earned by water utilities, but as the concept sank in, they sought to emulate British Petroleum's (BP) internal

trading of emissions, which reduced costs, minimized impacts, scaled back risk exposure, and boosted brand image.

BP pioneered a similar approach in 1992, when it committed to reduce the company's greenhouse gas emissions 10% below 1990 levels over the next twelve years. Three years after allocating permits, valued on average at $40 per ton, BP business units traded 4.5 million tons of emissions rights, and hit the company's target nine years early. That approach has since been emulated by Microsoft, among others.

Only with AquaShares, it would shrink the corporate water footprint, along with the energy and carbon nexus embedded within each 1,000 gallons saved. Said one multinational director general engaged in discussions with AquaShares "Our Company believes we can and must find ways to do much more with less. I am personally convinced that we can optimize our resources, by putting in place interactive systems—such as measuring and monitoring our water footprint, or an internal platform for water savings within our Group. We motivate teams to discover and reach these outcomes on their own"

Coastal CSDs

Scaling down, hundreds of thousands of California's residential and commercial water users fall outside the boundaries of the 410 established, well-run, centralized agencies. These community service districts are struggling to cope with a new raft of regulations about the human right to water, court challenges to rate structure, financial compliance, and meeting the needs of SGMA. One small CSD in Marin's coast, Muir Beach, has asked AquaShares to adapt the platform in ways that would help it automate the entire system, saving water, costs, labor, NRW losses, revenues, and time. The community may launch the first true online 'cap and trade' of water, bringing it into compliance while optimizing use.

Academic hunger

The combination of new rich and real-time data, combined with robust motivation from economic incentives, proved especially irresistible to professors at several universities and research institutes.

We have been approached by and met with Bob Hahn of Oxford, and Rob Metcalfe of University Chicago. Hahn helped design the first cap and trade for emissions under the 1990 Clean Air Act, while Metcalfe has pioneered the scientific rigor of randomized control trials, adapted from the medical world and applied them to improve environmental outcomes. These randomized control trials (RCTs) set up A/B testing controls to ensure that specific gains can be traced to specific drivers, rather than getting lost in the fog of data. A potential challenge is the desire for academic publication vs. proprietary data. But we are moving ahead with a second project where this risk could be mitigated.

Dr. Zachary Burt, of Colombia University, is seeking to compare our potential "willingness to sell" water savings against his extensive research in several countries that have demonstrated "willingness to pay" for new water, adjusted by income.

Scaling up, a Harvard University research team of scholars, led by Professor Peter Rogers, and joined by Susan Leal, former head of the San Francisco PUC, are deploying AquaShares as part of a pioneering project in Morocco. Backed by the Ministry of Water, the Ministry of Interior, and the National Office of Water and Energy, the parallel project will scale up from a core group of 100 users in Marrakesh to reward water savings throughout the utility. AquaShares is working with a Casablanca firm, Global Nexus, with a goal to replicate the approach throughout all urban water utilities in the country. Similar interest has been expressed from water managers in Kuwait, Saudi Arabia, and the United Arab Emirates, whose countries are sponsors of the Harvard research effort.

Tim Anderson of SCWA was asked to present on the AquaShares pilot at the Sustainable Water Markets Workshop at the UC Santa Barbara's Bren School of Environmental Science and Management. Meanwhile, Jay Lund of UC Davis had earlier highlighted our pilot as informing a discussion about "Let people pay what water is worth – sell your saved water." The water scarcity part of the bill, he argues, could be set using an internal water market:

> "Here, each customer could have a fixed share of the water available to the community or water utility, which could be sold or bought by each customer depending on their amount of water conservation. The share could be set by any of various methods.


This approach can provide equity, incentives for conservation, and flexibility to accommodate the many different types of households and customers in urban areas. You are paid if you use less than your share and pay more if you use more than your share. Allowing customers to "bank" some conserved water from month to month might be useful. Soliciting customers' selling prices for conserved water also is a challenge, perhaps with a default pricing policy set by the utility. There would be many implementation issues, but the idea seems worth considering and some (VOMWD) are already considering it."

Preliminary results

As noted, a richer analysis will inform a more complete report to be completed in late 2017, upon conclusion of full year of the pilot demonstration project. The data available will be more robust in duration and number of sample. That said, AquaShares, was able to draw some early and rough observations from the first two months of the project, based on engagement of participants who combined daily information, along with the long term motivation of economic incentives.

The challenge was not to simply consider participants in a vacuum, but to set the performance of those who

Average Water Usage
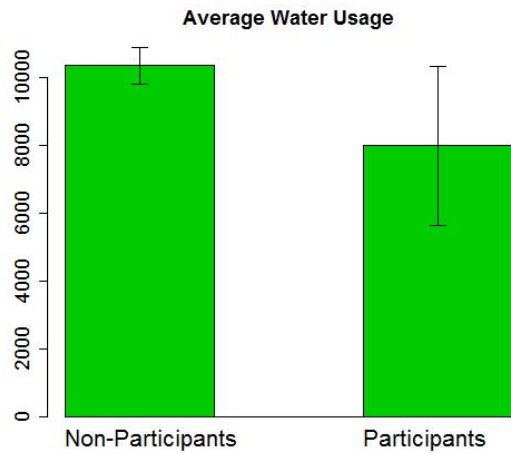
enrolled against a paired account with comparable use. A first analysis appears to show that AquaShares encouraged savings, but it does not account for the possible inherent differences between participants and non-participants, such as age, number of occupants, property size of yard, and value of home, and does not account for any time trends. A second analysis averages both groups for the months of Oct and Nov accounts for time trend by taking just a snap shot, but does not account for inherent differences between participants and non-participants. To best assess impact within these limitations, Dr. Burt tried a 'difference in difference' method to account for time trend and differences between participants and non-participants. Unfortunately, for this method it is important to start all "treatments" at the same time; but that didn't happen (participants were free to sign up at their own pace, if at all).

So he built models that estimates the impact of AquaShares, while controlling for inherent differences between the group of the participants and the group of non-participants, and also time trends. With those controls, only November shows a significant effect from AquaShares, but that is substantial.

Next steps

The AquaShares pilot is committed to following through on running tests with the core group of ~300 targeted participants, and drawing conclusions from the final performance results of savings at various prices/earnings.

In addition, the pilot is in discussions with VOMWD over the financial feasibility of potentially extending the market platform to 1,500 accounts equipped with advanced meters, toward an ultimate goal of allowing all users to participate in a program run by the utility, for its customers.

Additional features that could form a part of this expansion would include leak detection, as it appears, from our reading the early data, based on consecutive non-zero use during 24-hour-period, that 19% of customers may be losing water on the household side of the meter (perhaps, we assume, due to faulty plumbing or failed toilet stoppers). The alert would show that they have no point of zero use, and that this suggests a leak. It would further provide contacts to address the problem, leveraging advanced meters and economic motivations together.

We have also designed a "goal setting/tracking" feature that would allow each customer to determine their own customized targets, and follow their performance against past and current usage. This was requested in early outreach and user experience tests, and can be adapted to the dashboard at an affordable expense.

Equally useful, and economical, would be alignment of usage against weather records (past) and projections (current, future days) to better help users plan and meet their goals. More expensive and time consuming would be a mobile phone "App" that would simplify and store settings for each user on their cellular device, for easy access off and online.

From these features, and others that evolve, there is potential for how the utility itself could, over time, "dial in" a desirable level of water saving, crowdsourcing outcomes voluntarily from within its own service area. Based on emerging data about AquaShare price sensitivity, for example, VOMWD could, set the price (comparable to a time-consuming and costly rebate program), based on an optimal balance between its annual or future conservation budget capacity and the volume of water saving needed from the customer base. This could thus – rather like a company's buyback of shares from public and private investors -- bring certainty to financial planning, while ensuring targets are met in the most equitable, effective, deliberate and voluntary manner. It offers more certainty to what is often an unpredictable process.

Conclusion

With financial support from the California Water Foundation, and institutional oversight by the Sonoma County Water Agency, this pilot demonstration allowed the fusion of VOMWD hardware and AquaShares software to unlock a new approach to water, one that empowers end users to earn, own, and trade the water they save. The pilot was launched, data has been generated, and participants are engaging with the marketplace in increasing numbers, frequency, and activity.

The pilot suffered institutional, technical, political, financial, and operational setbacks, some causing months of delays that put the pilot more than a year behind schedule. But each time it overcame these challenges, learning lessons along the way. And in fact the delays allowed for more deliberative analysis, democratic consensus building, and judicious decisions at each stage, from data cleaning and integration (revealing anomalies), to setting the AquaMark allocation threshold (based on average of most recent three year history), to introducing an initial AquaShares price (of $0.91, less than the costs of pumping groundwater, of which there are thousands of wells in the VOMWD service area). The confusing brands of the early platform (SmartMarkets LLC, using AquaJust software, to trade EcoShare units) was simplified into one name, and even the AquaShare volume graduated from 100 to 1,000 gallons.

In other words, it was a learning process, but one which never deviated from the core goal of putting a meaningful price on water savings to financially and psychically reward conservation outcomes, and

revealing a first ever "willingness to sell." This core approach gained traction and momentum both within and outside the pilot. The critical but generally positive experience expressed by random members of the public, of staff members, and of the participants who enrolled suggested that the pilot will continue to yield lessons over the next nine months.

Building on the foundation provided by this pilot, the AquaShares market made its international debut in Marrakesh, as the government of Morocco announced at the COP-22 it would take this incentives-driven approach to reduce emissions (mitigation) and boost resilience (adaptation) to climate change.
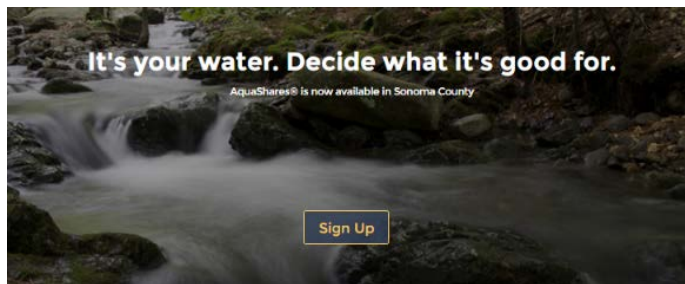
It was, in a sense, coming full circle from the ancient but now nearly extinct *khettara* through which tribal Moroccans would earn, own, and trade water within self-organized water management systems – the very kind of durable system that inspired this pilot.