Cross Currents: Water Scarcity and Sustainable CHI

Tad Hirsch
Intel Labs People and Practices Research
20270 NW Amberglen Ct
Beaverton OR 97006
tad.hirsch@intel.com

Ken Anderson
Intel Labs People and Practices Research
20270 NW Amberglen Ct
Beaverton OR 97006
ken.anderson@intel.com

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Abstract
Growing awareness of the threats posed by global freshwater shortages coupled with increased interest in environmental sustainability among CHI researchers make water management a ripe area for new CHI applications. This paper presents a qualitative study of practices and attitudes in a water-stressed region of the United States. We describe water conservation as a culturally-situated activity influenced by a variety of social factors, and show "sustainability" to be a complicated concept rife with competing, often incompatible interpretations and prescriptions. We discuss implications for designing interfaces that encourage personal conservation, and identify environmental policy making as an area ripe for new CHI activity. Finally, we suggest that sustainability has the potential to move from the periphery of CHI research and become a galvanizing force for the community at large.

Keywords
Water, conservation, sustainability, design

ACM Classification Keywords
H4.m Information Systems Applications: Miscellaneous.

General Terms
Design, Human Factors

Introduction

We report a qualitative study of water use in central New Mexico. We had several aims in undertaking this research. Water scarcity is a pressing global issue. Approximately 1 in 8 people currently lack access to safe water supplies [1], and it has been estimated that 2 out of 3 people could be living under conditions of "water stress" by 2025 [2]. We were interested in ways that new technologies, particularly personal consumption monitoring devices ("smart meters") could assist in water conservation.

We also hoped to understand how people in a water-stressed environment think about sustainability. Among CHI practitioners, sustainability is often presented as a normative value. Conservation is equated with "doing the right thing"[5]; technologies are intended to enable users to behave "in a more responsible manner"[6] and to "promote more sustainable behaviors" [3]. Bound up in these statements are implicit beliefs that conservation is always desirable, that environmentally responsible behavior is recognizable, and that the path to sustainability is clear. We certainly appreciate these sentiments – after all, who would argue against responsibility? However, we are concerned that using terms like "sustainability" in an uncritical manner elides serious and difficult questions about human relationships with nature, and implies consensus where none exists. As recent studies have begun to show (e.g. [12, 13, 15]) and as we will describe, looking closely at the real-world contexts in which environmental decision-making occurs defies such easy formulations and, we will argue, both complicates and suggests new opportunities for design.

Site: Central New Mexico

With a mere 20 inches annual rainfall and a rapidly growing and urbanizing population [7], New Mexico provides an early look at an emerging global phenomenon – some estimate as many as two-thirds of the world's population will face water shortages by 2025 [8].

Our study focused on an area bounded by three of the state's largest and fastest growing cities -- Albuquerque, Rio Rancho, and Santa Fe. The site provided easy access to a wide range of perspectives on water use, and an opportunity to examine intersection points between disparate kinds of stakeholders. Outside the cities, the region is largely agricultural, and is home to several Native American Pueblos. There are also several manufacturing facilities in the region, including a large semiconductor fabrication plant in Rio Rancho. The Rio Grande River bisects the research site, and is a significant source of water. Albuquerque and Rio Rancho operate municipal water systems; residents throughout the region also maintain private wells. In parallel, the area is served by an extensive traditional system of *acequias*, networks of irrigation ditches maintained at the grassroots level over the last 100 years or so through an evolved system of social relationships.

Participants

We conducted semi-structured interviews with government, industry, agriculture and community organization representatives. We also conducted unstructured interviews with area residents and observed local custom and infrastructure. Several of our participants had multiple areas of expertise: for example we interviewed a factory manager who also

raises horses and a lawyer who has represented environmentalists and Native Americans. All of our participants were central New Mexico residents.

Findings

Our interviews coalesced around two main themes: personal/institutional consumption practices and water allocation.

Contextualizing Consumption

Our interviews surfaced a variety of conservation activity, from low-flow toilets and efficient appliances to drip irrigation systems and extensive industrial management. While the specific techniques varied by context (home, farm, industry), there was a general sense across participants that conservation is a priority. All participants expressed familiarity with a variety of conservation tools and methods, including those currently in-use and those they had not yet chosen to employ. Most participants indicated that there were ways that they might do more, for example, by purchasing a more efficient dishwasher or upgrading water-processing equipment, but also had well-articulated justifications for the specific methods currently employed in their homes and workplaces.

MONEY AND MOTIVATION

When asked about motivations for conserving water, most participants couched their answers in terms of responsibility and ethical obligation. Statements like "it's the right thing to do," and "we live in a desert after all" were common. Cost was generally not presented as a motivating factor for either agricultural or domestic conservation, despite the widespread belief reported by Chetty et al [4] that conservation is primarily motivated by a desire to save money.

This is not to say that economics do not influence patterns of use. We discovered complex relationships between water and money that are shaped by broad institutional and policy frameworks. For example, in New Mexico as throughout the American West, water use is tied to water rights. Homeowners, farmers, factories, municipalities, indigenous tribes, and other stakeholders all have water allocation rights that entitle them to a certain amount of water per year. Failure to exercise one's rights for a period of five years leads to forfeiture – one's water will be allocated to another user whose need is deemed to be more pressing. Initially instituted to discourage speculation [9], the "use it or lose it" principle has had the unintended and unfortunate consequence of discouraging conservation.

An environmental lawyer working with local Pueblo communities provided a striking example. As Pueblo economies have shifted from their traditional basis in agriculture to a "modern economy" based on casinos and other development, water use has shifted from irrigation to new uses including, most notably, maintaining golf courses and soccer fields. According to our informant, "it's not that the Pueblo really love soccer. Soccer fields use a lot of water. They need to prove that they are using their water for future water rights adjudication."

PRIVACY AND SOCIAL NORMS

Water consumption throughout New Mexico occurs within an extremely contentious social and political climate. One outcome is that an individual's water use is considered a public matter. This theme was particularly highlighted in discussions of *acequia* use, where water withdrawals are highly visible and where users participate directly in governance and

maintenance. For *acequia* users, water management is an inherently public enterprise.

Regardless of which infrastructures they relied on, though, subjects frequently and critically alluded to others' actions, directing particular scorn towards flood irrigation, golf courses, and green lawns. Several described shame and peer pressure being employed to coerce compliance with social norms and punish outliers. One informant described a recent newspaper report naming Santa Fe's "10 Biggest Water Hogs." Another interviewee who lives south of Albuquerque reported spending $10,000 to dig her own well after "getting really pissed off" at a nearby golf course that continued to run its sprinkler system while water rationing prevented her from watering the flowers outside her home (wells are unregulated, and are therefore not subject to municipal water rationing). She subsequently had to put up a sign announcing her new well to ward off neighbors' complaints.

Allocation

While our participants were willing to discuss water conservation in great detail, they were far more interested in talking about allocation. That is to say, they were more concerned with how water is shared than how it is used. Several of our participants identified allocation is the single biggest challenge facing the region; as one put it "we don't have water problems, we have legal problems." This is perhaps unsurprising given that New Mexico is a water-scarce region undergoing rapid development and population growth. According to government officials, demand for water regularly outstrips supply, resulting in water use restrictions, droughts, and/or difficulties for the state to meet treaty obligations with its downstream neighbors. With population growth and urban expansion continuing to drive up demand for an already scarce resource, the sense among most of our participants is that key challenge isn't in increasing efficient use (although this is important), but rather in determining how water is apportioned – i.e. who gets it, and when.

SUSTAINABILITY AND JUSTICE

Currently, New Mexico's surface water is distributed according to a market-based system of transferable "rights," while groundwater is largely unregulated. None of our participants thought that this system is either sustainable or just. One informant said the lack of groundwater regulation incentivizes overdrafting (i.e. pumping water out of the ground faster than it can be reabsorbed), which in the short term causes wells to run dry and ultimately can lead to aquifer collapse. Another stated that extreme prices for water rights has discouraged farming and contributed to wintertime food shortages, and several said that New Mexico's "use it or lose it" policy encourages overuse. The current system is also seen as encouraging lawbreaking and cheating, with several respondents describing "double dipping" practices in which farmers sell their water rights to downstream developers but continue to irrigate their fields. As one respondent put it, "I can sell my rights and it doesn't affect my watering at all."

The system lacks transparency and is rife with mistrust. Descriptions of rights transfers being controlled by "old boy networks," and charges that "the state engineer is too friendly with developers" were common in our interviews. An environmental lawyer claimed historic records were intentionally "lost" during the State's transition to an electronic records system. Several participants charged that the State Engineer's office

intentionally hides its actions by publishing sales announcements in obscure, low-circulation newspapers ("the really important announcements don't make it to the website").

Several respondents described allocation reforms and alternatives that they saw as more equitable and/or more sustainable. These included limiting urban growth, eliminating water right transfers, and adjudicating existing indeterminate allocation issues. However, participants saw reforms as very difficult to achieve, as powerful forces are lined up to protect the status quo.

Decision Making in Contentious Climes

Several participants indicated that water allocation currently suffers from a lack of long-term planning. "We're definitely crisis-driven, not planning-driven," said one. A preference for planning-based approaches that privilege sustainable use and participatory processes that ensure equitable distribution was echoed by many participants, from state regulators who deal with whole watersheds to small neighborhood groups that share an *acequia*.

However, planning processes pose their own set of challenges. "Sustainability" remains an elusive term, which complicates the boundary conditions for planning exercises. To take one example, a representative of the State Engineer's office cited their 40-year planning horizon to consider environmental impacts as evidence of deep environmental commitment. From the perspective of government and industry, this represents long-term planning that extends across numerous election and business cycles. From the perspective of environmental scientists and activists, however, this time frame is laughably short. As one community activist put it, "40 years is less than a lifetime." To recognize the difference in these perspectives is to recognize a key challenge in environmental planning. What exactly is meant by "sustainable"? How far into the future must we project? What conditions should guide our thinking? Even for people who take a planning approach to water use, the question of how to think about complex environmental and social systems remains a problematic one.

Environmentalists, community activists, industry representatives, and regulators we spoke with all expressed a desire to for "good science" – particularly in the form of simulation and modeling – to play a more important role in planning decisions, although several acknowledged that science can also be a site of contention; models can and have been challenged – for example, farmers in a recent case who were unsatisfied with models produced by the State Engineer's office commissioned their own, competing models.

A reliance on scientific models is also seen as potentially exclusionary, tending to privilege expert scientists and engineers in discussions and leaving out residents and laypeople. "It gets pretty technical pretty quickly," said one resident.

Several respondents talked about the need for and challenges facing greater public participation in planning processes. While they valued consensus-based decision making, participants were quick to point out that planning processes are not free of conflict. A regulator with the State Engineer's office described the goal of participatory planning as "grudging consensus,"

indicating his belief was that the process is difficult and contentious, but also necessary and achievable.

A state regulator described public hearings as tending to be dominated by a relatively small number of "highly motivated" activists whose views may not reflect those of the community at large. More importantly, participatory planning requires trust, which several participants acknowledged can be difficult to achieve in a climate where, for example, community activists describe developers as "the new colonists." Several insisted that trust and cooperation are still possible, even in New Mexico's contentious climate.

Implications for design

Our findings suggest that "sustainability" is not an intrinsic value, nor that it is motivated by a single impulse. Rather, it appears that water use is a socially situated practice shaped by a host of political, cultural, and other factors. Further, it seems that sustainability is not simply a matter of using fewer resources, but instead is implicated in entire systems of consumption. There are particularly pressing issues in setting the policies that govern these systems and in resolving disputes.

We now turn to a consideration of what these findings mean for the design of personal consumption monitoring technologies and eco-technologies more generally, as well as for the CHI community at large.

Personal consumption monitoring

Our findings indicate several recommendations for individual efforts.

First, we encountered competing definitions of use that should challenge researchers to think carefully about exactly what it means to meter "consumption." For instance, is it enough to simply track the number of gallons that flow from a tap or a well, or would users be better served as several of our respondents indicated by systems that account for the rate and means through which water is returned to lakes, rivers, and aquifers (and in what condition)? For domestic users, could such systems be expanded to indicate effects of, say, chemical detergents on wastewater or the impacts of rainwater catchment on aquifers?

Second, we found substantial conservation activity even in the absence of financial incentives. This is a significant finding for proponents of smart-meters and real-time pricing schemes, who often place cost savings at the center of efforts to reduce domestic consumption. As Strengers [12] and Dillahunt et al [15] describe, money is not always the primary motivator for conservation practices. We found individual and institutional practices motivated by values like responsibility and citizenship and tempered by peer pressure and social norms. These findings raise questions for interface design. What is the "right" kind of information display? Is money the best indicator of value, or are there others we might choose to represent? The larger point is the normative values that many in the CHI community associate with conservation do not always correspond to facts on the ground. The motivations for using fewer resources (or not) are varied and complex, and cannot be taken as given. Instead, care must be taken to understand users' specific goals, fears, and aspirations and to design accordingly.

Third, we found that trust was a key factor in shaping behavior and perceptions of institutions, individuals and policies. We suggest that trust will be a similarly important factor in determining the adoption and use of any new water-monitoring scheme and that much will depend on how a new technology is implemented and by whom. For example, new schemes to monitor water withdrawals are likely to meet substantial resistance if they are perceived as first steps toward changing allocation or instituting new usage policies.

Finally, we found keen interest in policing others' water consumption and a sense that such external monitoring is in many cases both a responsibility and right. These observations contrast previous findings of a "natural reaction" that domestic resource consumption is a private matter [4], an assumption of privacy that echoes a guiding belief for interaction design work. Our findings suggest that no such assumption exists when private action has direct public impact, at least when local conditions create heightened awareness of these impacts. We also note in passing that challenging the assumption of privacy opens up all kinds of interesting design opportunities, including the development of what we might call "shameful computing": devices and interfaces that encourage behavior change by publicizing anti-social activities. While this may sound far-fetched, we suggest that shame is in fact an important if overlooked motivator. For example, one of our interviewees drew a strong connection between a company's environmental policies and an ongoing activist campaign.

From Consumption to Policy

A recurring theme in our interviews was that personal consumption is implicated in complex networks of people, institutions, and environments. "Sustainability," however one chooses to define it, is ultimately about aligning these various elements over the long term. While there was general agreement that sustainability requires systems-level solutions, we encountered multiple perspectives on what those solutions ultimately entail. We heard descriptions of free market approaches, of cap-and-trade systems, of tying growth to available water, and of grassroots management schemes. We spoke with regulators and industrialists concerned with maintaining growth and economic prosperity, and environmental and community activists who insist on the rights of wildlife and traditional cultures. Sorting through these various prescriptions, determining whose interests will ultimately prevail, and providing the necessary material support for distributing water is ultimately the realm of policy and planning. And, it is no easy task. Our respondents highlighted five distinct challenges associated with water sustainability planning:

1. The science is hard. Understanding interactions between human use and hydrologic cycles is an ongoing challenge for environmental scientists; educating laypersons in the basic workings of natural and man-made water systems an important and difficult task. Several respondents cited the need for "hydrology made simple" applications that can increase basic scientific literacy among stakeholders.

2. Modeling and simulation technologies are opaque and contentious. Several of our respondents see great promise in modeling and simulation to inform long-term planning. However, they also described the difficulties that policymakers and stakeholders have in understanding models and interpret results. We also

heard examples in which stakeholders challenged underlying assumptions, in one case going so far as to commission an entirely new, competing model. We also heard about the difficulties in representing hard-to-quantify cultural, spiritual, and aesthetic values. Ultimately, stakeholders need to understand and be able to challenge models' assumptions; model makers need to find ways to represent hard-to-quantify aspects of the natural world.

3. Policy implications are indeterminate. "Sustainability" remains an elusive concept with multiple, often competing definitions and a slew of policy recommendations. In addition, State regulators are interested in moving to "active management" water systems that enable more dynamic approaches to water distribution but also require new approaches to policy. As water allocation becomes ever more contentious and as policy requirements continue to shift and evolve, there is an abiding need for technologies and interfaces to support flexible, responsive decision making processes.

4. Public participation remains elusive. Several respondents cited the need for greater public participation in planning and policy making. They also described several barriers to participation including work and family obligations, inability to engage in technical discussions, and overt attempts by partisan interests to control agendas and exclude opposition. There is a need for tools for remote and asynchronous participation in planning activities, and to ensure fair representation and full involvement by all stakeholders.

5. Need for greater enforcement, transparency, and benchmarking. Ultimately, policy implementation requires enforcement and tracking progress against goals. These are ongoing challenges for regulators with limited staff and resources dispersed across multiple agencies to govern a large territory with varied infrastructure, geographically distant populations, and wildly heterogeneous population. Study participants also cited the need for greater transparency in decision-making and enforcement efforts to counter decades of mistrust and suspicion.

Grappling with complex assemblages of institutions, individuals, and policy may seem a departure from what Aoki et al describe as "classic CHI's" emphasis on personal behavior modification and consumer product design [13]. As Aoki [ibid] and Goodman [14] observe, designing for systemic change presents a fundamental challenge to traditional notions of human-centered design. However we wish to point out that the challenges outlined above speak to well-established parts of the CHI community. As researchers and developers, our community has developed deep expertise in educational technology, modeling and simulation, decision support tools, participatory planning, remote collaboration, process monitoring and remote sensing. All of these techniques and technologies have a central role to play in addressing the challenges outlined above. Echoing observations made by Williams [10] and Mainwaring et al [11], we see great promise for CHI in creating new infrastructures and enabling new approaches to policymaking.

Conclusions

Through our study of water-related practices and attitudes in New Mexico, we have shown that consumption and conservation are socially situated

practices influenced by a variety of cultural, economic, and political factors. We have also demonstrated that "sustainability" is an elusive concept with multiple interpretations and policy implications.

We caution designers not to think of conservation as an intrinsic good, or that cost savings and consumption are inextricably linked. Rather, we suggest that consumption activities are shaped by a variety of concerns including notions of identity, value, and social norms, and that these in turn influence the perception, adoption, use, and interpretation of conservation monitoring and other sustainability-oriented technologies.

These observations speak to the situatedness of environmental concern. Water is a central issue in New Mexicans' daily lives; it is unsurprising to find strong social and cultural connotations associated with its use. We would expect these factors to play out differently in other locales, where different values and motivations are at play. The implication is that "sustainability" – and by extension, sustainable CHI, is not a one-size-fits-all endeavor. It may in fact be well and good that "green tech" looks different in Santa Fe than it does in, say, Shanghai. Accordingly, we suggest that further research not overly concern itself with generalizable findings and "best known practices." While these considerations certainly have their place, we should also make sure that we make room in our work to acknowledge, indeed, to celebrate diversity and site-specificity.

We also observe that sustainability isn't just about consuming fewer resources; it is about entire systems of use that extend from individuals to institutions, from organizations to governments. We believe that there are key leverage points for CHI research to influence decision making about allocation, determining who gets access to what (and when). While allocations may be determined through the marketplace or through the courts, we call out participatory planning approaches as particularly ripe for intervention from the CHI community.

Ultimately, environmental resource decisions by both individual actors and policy makers turn on information, communication, and deliberation – all of which are familiar territory for the CHI community. In short, we see sustainability as more than a fringe activity within CHI, but rather as an opportunity to galvanize the community as a whole to take on the world's most pressing problems.

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